Renewable Energy in the California Desert
Mechanisms for Evaluating Solar Development on Public Lands

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ACC	Air Cooled Condenser
ACEC	Area of Critical Environmental Concern
AFC	Application for Certification
APD	Application for Permit to Drill
ARRA	American Recovery and Reinvestment Act
a-Si	Amorphous Silicon
ATV	All-Terrain Vehicle
BLM	Bureau of Land Management
BMPs	Best Management Practices
CalISO	California Independent System Operator
CDCA	California Desert Conservation Area
CDD	California Desert District
CdTe	Cadmium Telluride
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CFR	Code of Federal Regulations
CIS	Copper Indium Diselenide
CNDDB	California Natural Diversity Database
CNPS	California Native Plant Society
CPUC	California Public Utilities Commission
CPV	Concentrating Photovoltaic
CSI	California Solar Initiative
CSP	Concentrating Solar Power
DEM	Digital Elevation Model
DFG	Department of Fish & Game
DNA	Documentation of NEPA Adequacy
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DRECP	Desert Renewable Energy Conservation Plan
DWMA	Desert Wildlife Management Area
EA	Environmental Assessment
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ERP	Emerging Renewables Program
ESA	Endangered Species Act
FIT	Feed-in Tariff
FLPMA	Federal Land Policy and Management Act
FWS	U.S. Fish & Wildlife Service
GIS	Geographic Information Systems
GRank	NatureServe Global Rank
HCE	Heat Collection Element
HCPV	High Concentrating Photovoltaic
HTF	Heat Transfer Fluid

IOU	Investor-Owned Utility
IUCN	International Union for Conservation of Nature
LCOE	Levelized Cost of Energy
LCRS	Leachate Collection and Removal System
LORS	Laws, Ordinances, Regulations, and Standards
LTVA	Long Term Visitor Area
MOU	Memorandum of Understanding
MPR	Market Price Referent
MW	Megawatt
MWh	Megawatt-hours
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NPS	National Park Service
NREL	National Renewable Energy Laboratory
O&M	Operation and Maintenance
OHP	Office of Historic Preservation
OHV	Off-Highway Vehicle
ORV	Off-Road Vehicle
PACT	Planning Alternative Corridors for Transmission
PEIS	Programmatic Environmental Impact Statement
PM10	Particulate Matter less than 10µm in diameter
PMPD	Presiding Members Proposed Decision
POD	Plan of Development
PPA	Power Purchase Agreement
PURPA	Public Utilities Regulatory Policies Act
PV	Photovolatic
REAT	Renewable Energy Action Team
REC	Renewable Energy Certificates and Credits
REPG	Renewable Energy Policy Group
RETI	Renewable Energy Transmission Initiative
RMP	Resource Management Plan
ROD	Record of Decision
ROW	Right-of-Way
RPS	Renewable Portfolio Standard
SCA	Solar Collector Assembly
SEGS	Solar Energy Generating Systems
SES	Stirling Energy Systems
SESA	Solar Energy Study Area
SETP	Solar Energy Technologies Program
SGIP	Self-Generating Incentive Program
SHPO	State Historic Preservation Officer
SIS	System Impact Study
SRank	NatureServe State Rank
TWS	The Wilderness Society
USFS	U.S. Forest Service
WREZ	Western Renewable Energy Zone
WSA	Wilderness Study Area
WSR	Wild and Scenic River

EXECUTIVE SUMMARY

Solar energy development is experiencing significant growth today due to a variety of reasons, including national interest in increasing energy efficiency, reducing dependence on fossil fuels, increasing domestic energy production, and curbing greenhouse gas emissions. This national interest and the availability of high quality solar resources in the California desert have led to proposals for 54 utility-scale solar facilities on public lands. These proposals have forced conservation organizations to consider the tradeoffs between renewable energy generation as a means of combating climate change, and the preservation of the desert's wildlands and biodiversity.

This study analyzes the political, economic, and technological drivers for utility-scale solar development on public lands, as well as the potential impacts to local residents and desert ecology. The goals of this report are to provide a series of qualitative and quantitative analyses of the potential impacts, describe a series of tools for evaluating proposed utility-scale solar energy projects, and develop a series of recommendations for the Bureau of Land Management (BLM) permitting process.

Methodology

We used several methods of analysis:

- We reviewed government policies and programs to identify the key drivers of growth in the solar industry.
- We conducted interviews with desert ecology specialists, conducted extensive literature reviews, and performed Geographic Information Systems (GIS) spatial analyses to evaluate potential impacts to the desert's natural resources.
- We examined developer applications to calculate land and water use efficiency for different types of solar technology.
- We conducted a case study of an operational solar facility in Nevada, a mail survey of residents from three communities in the California desert, and GIS models to analyze impacts to desert residents.
- We surveyed stakeholders and BLM staff to analyze the solar project siting process.

Key Findings

Proposed Solar Technologies

- Project developers choose a type of solar technology for a project using three considerations: technological maturity, solar resource, and cost of installation.
- The majority of applications to the BLM propose the use of concentrated solar power technology with photovoltaic (PV) systems being the second choice of developers.
- As of 2009, according to California Energy Commission (CEC) guidance, new projects are restricted from using "wet" cooling systems. While "dry" cooling systems consume 95 percent less water than "Wet" cooling systems, they also have a five to 20 percent performance penalty.

Political and Economic Drivers

- Policy-based economic incentives are driving development of utility-scale solar development in the California desert and the recent rise in the number of utility-scale projects in development is attributable to two key factors:
    - The longer-term extension of production and investment tax credits to match the development timeline, which can take several years, and
    - The implementation of aggressive Renewable Energy Portfolio Standards (RPS) in California.

- Distributed generation will complement, but not replace, utility-scale solar development and several barriers must be overcome in order to ensure continued growth and adoption of distributed generation.
    - Incentive programs must be streamlined and improved in order to reduce administration costs.
    - Behavioral preferences must be changed in order to increase the number of rooftop solar installations.
- The current federal administration and existing federal policies promote the use of public lands for renewable energy development.

Site-Level Solar Development and Ecological Impacts

Site Engineering

- Once the location of a solar energy facility has been determined, a variety of site engineering processes will need to be performed to prepare a project site for construction. These processes include grading, vegetation removal, the installation of perimeter fencing, and the construction of roads and transmission lines.

Grading and Vegetation Removal

- The amount of grading being proposed for most projects is substantial. Six of the projects we analyzed were planning to move anywhere from 1.7 million to 8.3 million cubic yards of soil. As a comparison, if 8.3 million cubic yards of soil were placed on a football field, the mound of soil would be over one mile in height.
- Grading and vegetation removal procedures have the potential to impact soil stability, dust emissions, fragile biological soil crusts, nutrient cycling, and water infiltration. The impacts to these processes, in turn, are likely to negatively affect plant and animal populations on and near the project site.

Perimeter Fencing

- All the projects include the installation of perimeter fencing, which will act both as security for the site and as an environmental barrier to keep wildlife out of the project site.
- The construction of fencing may disrupt habitat connectivity. Not only does fencing remove habitat within its boundaries, it can also act as a barrier, restricting or completely blocking movement of species. Even if a population will not be affected by loss of habitat within a facility's fenced area, the fencing itself may be difficult to navigate around. If migration corridors are blocked, the viability of a population may be compromised due to gene-flow restriction.

Roads and Transmission Lines

- The new roads constructed for these projects will serve an array of functions including general mobility, access for panel cleaning, and repairs. In some locations, primary roads such as highways already exist, nonetheless, every applicant will need to at least improve existing roads and construct new maintenance roads through the solar panel fields. Additionally, given the relatively remote locations of many of these proposed projects and the limited amount of available capacity on the existing transmission grid, utility-scale solar facilities will also require new sections of transmission to be built.
- Roads and vehicle travel provides an opportunity for the spread of invasive plant species throughout the desert, and invasive plant species can increase the intensity and frequency of wildfires in the desert. Additionally, these roads present a substantial threat to the maintenance and protection of biological soil crusts.

Facility Location and Placement

- The location and placement of the infrastructure on the project site will directly determine the type and intensity of the site-level ecological impacts discussed above. Developers generally look for three key characteristics when selecting a project site: distance to transmission, slope of the land, and the availability of water.

- Solar facilities that are built on top of dry water channels, washes, or playas, or that are constructed on or near alluvial fans (also called bajadas), may interfere with the sediment deposition that sustains desert sand dune systems.
- Solar development may affect species migration if facilities are sited in pre-existing or potential migration corridors, including corridors utilized by both limited-range species (such as desert tortoises) and wide-range species (like bighorn sheep).

Landscape-Level Solar Development and Ecological Impacts

Water Use Efficiency and Impact

- Parabolic trough with “wet” cooling systems consume the most water per MW of generation capacity installed while thin film PV systems consume the most water per MWh electricity produced.
- Based on the projects we analyzed, many of the developers propose at least some use of ground and surface water. Groundwater withdrawal or surface water diversion could negatively affect groundwater dependent vegetation, riparian vegetation, springs, and aquatic habitat. The main alternative to groundwater and surface water would be having water trucked in from an outside source.

Land Use Efficiency and Disturbance

- Dish/engine systems have the highest land use efficiency while thin film PV systems have the lowest land use efficiency. A high land use efficiency indicates that a project can generate a relatively larger amount of electricity per acre of disturbed land.
- Land disturbance can release large amounts of dust, depending on facility placement. Management of dust emissions on facility sites will influence the contribution of solar development to PM10 pollution concentrations in the California desert region with implications for human health.
- Disturbance of biological soil crusts across the California desert landscape could negatively affect the carbon sequestration capabilities of the desert soil and affect regional albedo.

Species Case Studies

- Development of utility-scale solar facilities across the California desert landscape will have negative consequences for the federally threatened desert tortoise (*Gopherus agassizii*), including habitat loss, habitat fragmentation from new roads and other linear corridors, direct mortality from roads, increased prevalence of predators, increased human access, and increased invasive plants and wildfires.
- Solar development could negatively affect wide-ranging species like the desert bighorn sheep (*Ovis canadensis nelsoni*) by depleting water sources on which they depend, and reducing habitat connectivity and obstructing migration corridors, thereby preventing access to vital resources and habitat.
- Cumulative impacts of solar development will likely include the loss and fragmentation of large areas of low-elevation vegetation like the creosote bush (*Larrea tridentata*), with negative implications for desert pollinators. In conjunction with climate change, impacts to pollinators could severely disrupt processes and services that are essential to the desert ecosystem.

Spatial Impacts

- Using three development scenarios to develop a spatial understanding of the ecological and visual impacts of solar development: only “Fast Track” facilities are built (10 facilities), only “Solar Energy Study Area (SESA) Facilities” are built (21 facilities), and “All Proposed Facilities” are built (54 facilities) we found that the SESA development scenario minimized ecological and visual impacts to the California desert landscape.

- Of BLM land not excluded from solar development, the Fast Track scenario would develop 1.15 percent of potentially available acres, the SESA scenario would develop 4.26 percent, and the All Proposed scenario would develop 10.74 percent.
- Using an ecological classification scoring system, analyses for individual facilities and the three development scenarios showed that 34 of the 52 facilities would have “low impact” to sensitive habitat, 12 would have “medium impact,” and 6 would have “high impact”. Of the three scenarios, the All Proposed scenario had the largest impact to sensitive habitat, followed by the Fast Track scenario, and last was the SESA scenario.
- Distance of a proposed facility to existing transmission lines and slope of the proposed facility site were used as proxies for the amount of disturbance that a facility might have on the landscape. Under the three development scenarios, the All Proposed scenario had the highest minimum distance to transmission, followed by the Fast Track, then SESA scenario. Similarly, the All Proposed scenario had the highest average slope, second was the Fast Track scenario, and the SESA scenario had the lowest average slope.
- A visual impact analysis identified the extent to which visual resources might be affected by solar development across the California desert landscape. Using the three scenarios, a ratio compared the amount of land developed in each scenario with the size of the scenario’s visual footprint. The Fast Track scenario had the highest visual footprint to developed acres ratio at 17.64, followed by the All Proposed scenario at 7.79, and the SESA scenario was last at 4.87.

Socioeconomic Impacts

- Utility-scale solar facilities in the California desert will have few long-term socioeconomic impacts on nearby communities. Our case study of Nevada Solar One shows that the nearby community, Boulder City, experienced no impacts to traffic, housing, or public services during the construction of the facility. The most positive impact was the annual lease payment the developers made to the town.
- Unlike Boulder City, which benefits greatly from solar facility Nevada Solar One’s annual lease payments, communities in the California desert will not receive rent payments; this is because facilities sited on BLM land will make lease payments directly to the U.S. Treasury.
- Though hundreds of temporary workers will be needed for construction, once in operation each facility will require relatively few full-time employees. Therefore, these facilities are unlikely to result in a significant increase to long-term employment in local communities.
- Demographic data and proposed facility location may be analyzed to help predict a facility's socioeconomic impacts. We utilized this information to predict that the socioeconomic impacts to two towns in the California desert, Lucerne Valley and El Centro.

Community Attitudes

- Of the 625 survey respondents from three communities, the majority, 64 percent, supported utility-scale solar development near their communities. Primary reasons for support included an increase in jobs, more energy for the community, and additional business activity.
- Those who opposed solar development, 17 percent, cited potential water shortages, damage to the natural habitats, and poorer air quality as reasons for concern.
- The distribution of support and opposition did not vary by age or town. Education was correlated to support: our analysis revealed that the more educated respondents were, the less they supported solar.
- The overwhelming majority, 83 percent, have not participated in any of the BLM’s public comment opportunities, predominately due to a lack of awareness of these opportunities. Yet, our analyses did not indicate that there was a connection between participation and support, suggesting that the BLM may be missing an opportunity to inform opinion.
- Respondents ranked water as their greatest concern. Our analysis has indicated that the communities’ concerns as well as their uncertainty about water are reasonable. Utility-scale solar energy facilities, similar to other industrial operations, have substantial water needs. In an effort to combat the potentially irreversible draw down of desert aquifers, the CEC has issued guidance to developers that dry cooled systems should be utilized and that wet cooled

systems are extremely unlikely to be allowed by the agency. It would be useful to communicate this measure to desert residents to address concerns about impacts to water.

- The survey results also indicate that respondents believe decreased air quality is a relatively unlikely impact of solar development (1.89 on a 5-point scale). This public perception may represent an underestimation of this potential impact since the site engineering associated with development, especially grading and vegetation removal, has a high potential for releasing large dust emissions.
- Survey respondents ranked increased employment opportunities during facility construction and operation as both highly likely and quite valuable. Unfortunately, this optimistic outlook may prove to be unfounded. Although facility construction will create hundreds of temporary jobs, the labor pool in the California desert includes thousands of individuals and residents will face stiff competition for these positions.

Decision-Making Process

- The BLM and CEC have created a joint process for assessing proposed solar facilities which includes joint environmental analysis and public participation opportunities.
- The current BLM process for siting solar facilities was evaluated based on a set of criteria that are found to be key to effective policy/regulation. Based on this set of criteria, the current process was determined to be insufficient in achieving the following: efficiency, clarity, and adequate levels of environmental protection. Additionally, it was found that the current BLM process does not include the consideration of a robust set of alternative options nor does it consider the potential cumulative impacts of multiple projects. Finally, as was confirmed by the results of our stakeholder survey, the process does not include adequate levels of public involvement.
- There are multiple ways the current solar right-of-way (ROW) process could be improved using some components from existing processes for oil and gas leasing and wind ROW grants such as developer guidance documents, BLM processing instructions, identification of areas open for potential development, and the standardization of land leasing rates.

Conclusions and Recommendations

Our research and analysis reveals the many complexities, controversies, and uncertainties that exist within the issue of solar development in the California desert. Despite these challenges, state and federal administrations, solar developers, and renewable energy advocates are exerting pressure on regulatory agencies to finalize the processes necessary to move development forward. Given the unknown impacts of solar development, an adaptive management approach, which includes Best Management Practices (BMPs) and mitigation requirements, should be carefully and thoughtfully developed. An adaptive management approach might require a slower pace of development with a high level of monitoring of constructed facilities in order to measure the true efficacy of BMPs and mitigation measures. If BMPs and mitigation measures are found to be ineffective, the management plan should then be adapted to address these deficiencies.

We have developed recommendations based on our findings, which can be used to establish a siting, development and implementation process that can proceed deliberately and adaptively. Our recommendations aim to improve the solar facility approval process, address potential ecological impacts, and support continued growth of the distributed generation market. We have also identified areas in need of future research.

- The BLM should establish a more transparent and efficient solar siting process that designates areas that are closed or potentially available for solar development. The process should also incorporate a land rental rate, establish minimum land use and water use efficiency standards, and increase public involvement.

- The BLM should define effective environmental mitigation measures, develop alternatives to traditional acquisition-based mitigation, such as opportunities for developers to fund desert research, expand educational opportunities, and finance restoration.
- The BLM should develop and require the use of its own set of BMPs specific to the desert environment. Currently, solar developers are proposing the use of BMPs that may be inappropriate for the region and may result in unanticipated ecological consequences or may be ineffective at reducing impacts.
- Environmental organizations and elected officials should support the expansion and extension of tax credits and other investment incentives for distributed generation in order to support this growing market and help meet the California RPS goal.
- Future research should be conducted in the areas of natural history of the California desert, regional-level impacts, ecological restoration techniques, climate change and the California desert, ecosystem services and the non-market value of the desert, and transmission.

Outlook

In order to meet the California RPS goal of 33 percent renewable energy by 2020, a total of 48 terawatt-hours of new renewable energy must be generated, some of which is likely to come from utility-scale solar energy facilities. As the BLM completes a Programmatic Environmental Impact Statement for solar development, the opportunity exists to incorporate measures that simultaneously improve the overall permitting process, maximize the benefit of renewable electricity generation, and minimize the ecological and socioeconomic impacts of development. Given the current political climate, in which both federal and state governments are prioritizing renewable energy, measures should be identified and implemented swiftly to reduce the likelihood of rapid development without appropriate consideration of negative impacts.

CHAPTER 1 | INTRODUCTION AND METHODOLOGY

BACKGROUND

Renewable energy projects in the United States are on the rise. Technologies that received limited attention in the 1970s, such as solar and wind power, are experiencing significant growth today due to the perception of national interest to increase energy efficiency, reduce dependence on fossil fuels, increase domestic energy production, and curb greenhouse gas emissions. This perception of national interest has been made evident by the range of new policies and incentives that spur renewable energy research and development. Policies aimed at increasing the use of renewable energy include the Renewable Energy Production Tax Credit, adoption of a renewable energy portfolio standard (RPS) by many states, and creation of markets for Renewable Energy Certificates and Credits (RECs).

In 2002, the State of California adopted its own RPS and now depends on the development of new, utility-scale solar energy installations to help reach its goal of 20 percent of electricity generation from renewable sources by the end of 2010.[1] Utility-scale solar development began in California with the construction of Solar Electric Generating Station I, called SEGS I, which was built in the town of Daggett in 1985.[2] Between 1985 and 1991, eight additional SEGS facilities were constructed in California's Mojave Desert.[3] Although these nine solar energy power plants totaled over 353 megawatts (MW) capacity, they only represented 0.8 percent of California's overall electricity generation capacity. Since these were facilities constructed by the U.S. Department of Energy (DOE), their primary purpose was for scientific testing rather than commercial electricity production and they have since been decommissioned.

California has received national attention for solar energy development for two reasons. First, the state has some of the best solar resources in the world and contains several major cities, or load centers. Second, California has sufficient amounts of available land needed to make these projects viable. The Bureau of Land Management (BLM) and the U.S. Forest Service (USFS) are in the process of evaluating more than 150 applications for wind and solar projects on federal lands in California, covering more than 1.3 million acres.[4] In particular, the BLM has 54 applications for solar projects in the California desert.[5] In order to judge the cumulative impacts of so many projects, the BLM and the DOE began developing a nationwide Solar Energy Development Programmatic Environmental Impact Statement (PEIS) in early 2008 to guide future application decisions.

"Green" Versus "Green"

The impending development of utility-scale solar power facilities on public land in the California desert is creating a conflict between conservation and industry groups and elected officials. For example, in

December 2009, Senator Diane Feinstein (D-CA), introduced legislation to establish nearly 1.1 million acres of the California desert as two national monuments, thereby conserving these areas while prohibiting solar or wind development.[6] Conflict also exists among conservation groups, who are struggling to define the value of desert conservation when compared to the value of developing new renewable energy facilities, in essence creating a “green” versus “green” conflict. The sense of urgency surrounding development has caused some conservation organizations to raise questions concerning the most appropriate use of land desired for solar development and to question whether the tradeoff between conservation and development is understood well enough to make siting decisions.

Some environmental groups, such as The Wilderness Society (TWS), are supportive of renewable energy development and want to be involved in decisions about permitting solar projects in order to ensure that they minimize ecological impacts and maximize energy gains. As Pam Eaton, deputy vice president of the TWS Public Lands Campaign, states, “You’ve got the short-term impact of a project versus a long-term problem, which is climate change.”

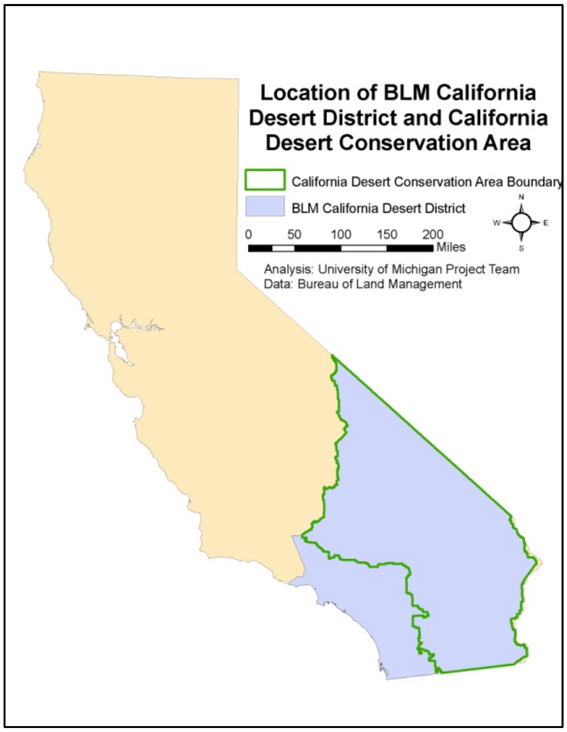
In the face of growing electricity demand, the relative scarcity of renewable energy development in the California desert provides public land managers with an important opportunity to solicit comment from stakeholders about appropriate locations for new solar facilities as they develop the PEIS and process existing solar applications. The rapid progression of energy policy decisions and pressing need to meet aggressive RPS standards requires a method to quickly and effectively identify and evaluate trade-offs inherent in many existing permit applications. Environmental groups, including our client, TWS, struggle with ways to support renewable energy development while protecting fragile desert lands. This may ultimately lead them to support some individual facilities and to oppose others.

Purpose and Scope of the Study

The rapid rise of interest in solar development in California has made it imperative that the technological, social, political, and environmental costs and benefits of solar development be analyzed. Decisions with long-term effects are currently being made, at a relatively fast pace, and with an incomplete understanding of the full range of potential impacts. The goal of this report is to present a series of qualitative and quantitative analyses that together provide a framework for evaluating proposed utility-scale solar energy projects in California. We also present recommendations and guidelines that will enable stakeholders to evaluate potential impacts of these utility-scale solar developments. The analysis and recommendations ultimately provides guidance for the selection of the best proposals for utility-scale solar facilities in desert locations that allow for both solar energy generation and conservation of ecosystems.

This study focuses on *utility-scale* solar development on public lands in the California desert. Utility-scale solar facilities generally have a nameplate capacity of over 50 MW and produce electricity, which is bought by an electric utility provider to be fed into the electric grid. To generate this electricity, solar modules are placed directly on the ground and aligned to catch sunlight.

The geographic boundary of the study area is the California Desert Conservation Area (CDCA), a 25 million acre area in southern California that encompasses the Colorado desert and the portion of the Mojave desert that lies within the state (Map 1.1). The study examines the policy and economic drivers, ecological and socioeconomic impacts, and decision-making processes of utility-scale solar facility development on public lands in the CDCA.



Map 1.1 Location of the BLM California Desert District and California Desert Conservation Area.

In addition to land requirements, proposed solar facilities will require infrastructure to connect to the electrical grid. Though we recognize the critical role transmission plays in siting decisions, an analysis of transmission was beyond the scope of the study. The processes, regulatory agencies, and decision-making structures are different from facility siting, and they represent added layers of complexity in the larger issue of utility-scale renewable energy generation. In addition, relevant transmission data were unavailable for a variety of reasons, including those related to concerns over national security. Also, transmission is being adequately researched by other groups. Two professional working groups are developing models and assessments of transmission development: the Renewable Energy Transmission Initiative (RETI) model and the Planning Alternative Corridors for Transmission (PACT) model (see Chapter 11 for further details).

RESEARCH QUESTIONS

To guide our research, we developed the following questions related to utility-scale solar development on public lands in the California desert:

What are the policies and incentives driving utility-scale solar in the California desert?

- How are policy decisions and incentives driving the development of the solar industry and how do they favor either distributed generation or utility-scale solar?

- How do the policy and management incentives and disincentives at the federal, state, and local levels affect siting solar projects on public lands?

How will the different forms of solar energy development affect the ecology of the California desert?

- What are the resource and infrastructure needs of various proposed technologies?
- What are the relative land use efficiencies of each of the “fast-track” solar-energy facility proposals?
- What current stressors should be considered in order to understand the impact that utility-scale solar development might have on California desert ecosystems?
- What direct and indirect impacts of utility-scale solar development on key species, natural communities, and landscape-level ecological processes should be taken into consideration by decision makers?

Can landscape suitability and desert-wide impacts be identified and analyzed spatially?

- What areas may be in high conflict with solar development in the California desert due to land management designation?
- What areas of the desert present a high degree of conflict for building solar facilities due to known occurrences of species habitats?
- What areas of the desert would be visually affected by solar development?
- How can solar facility impacts and needs be analyzed spatially given alternative development scenarios?

How will solar development affect desert residents, and are their opinions and information gaps being addressed?

- What are the socioeconomic impacts of utility-scale solar facilities?
- How can demographic data and facility location be used to predict socioeconomic impacts?
- What are the socioeconomic impacts of existing utility-scale solar facilities and how might the impacts of future facilities be similar and/or different?
- How do existing communities view proposed solar developments?
- What are the knowledge gaps for local stakeholders?
- What sources of information do stakeholders use?
- What are the perceived types and likelihoods of a range of impacts?

How are decisions being made in the solar energy siting process?

- What is the current process for siting solar facilities on public lands?

- What are the strengths and weaknesses of the process?
- Are local stakeholders aware of and using BLM public commenting opportunities?
- What aspects of existing alternative processes would be beneficial for the solar siting process?

What changes and improvements can be adopted to more effectively site solar facilities with minimal ecological impact?

- How should the current solar siting process be changed and improved?
- What mitigation and design measures can developers take to reduce the ecological impacts of utility-scale solar development on the California desert?

METHODOLOGY

We utilized the following methods to collect and analyze data. Methods are organized by research question:

What are the policies and incentives driving utility-scale solar in the California desert?

How are policy decisions and incentives driving the development of the solar industry and how are they driving development of utility-scale solar?

We reviewed historical and current federal and state policies affecting investment and development decisions within the solar industry. Further insights were gained by attending the Greentech Media Solar Summit conference held in Phoenix, Arizona, on March 30 and 31, 2010.

How do the policy and management incentives and disincentives at the federal, state, and local levels affect siting solar projects on public lands?

We performed a literature review of existing federal, state, and local policies that affect siting solar projects on public lands. Additionally, policies were identified through interviews with BLM staff and environmental organizations.

How will the different forms of solar energy development affect the ecology of the California desert?

What are the resource and infrastructure needs of various proposed technologies?

We performed a literature review of sources such as peer-reviewed journal articles, news articles, and policies and memos from the CEC and interviewed nine developers and other industry professionals working in this field by phone and in person.

What are the relative land use efficiencies of each of the “fast-track” solar energy facility proposals?

Our analysis began by summing the total area of the site that is to be developed either with roads, transmission lines, solar panel systems, main building complexes, or other planned infrastructure. This total then is referred to as the “direct disturbance area”. We calculated the “actual annual electricity production” that will be generated by the facility by multiplying the nameplate capacity in total MW by the capacity factor. The capacity factor is the average percentage of time that the solar facility is expected to operate at full capacity.[7] In order to quantify the relative impact of the facility footprint size and the actual amount of energy produced by the facility, the analysis then used two metrics:

1. The amount of “direct disturbance area” required per megawatt-hour (MWh) produced as the “actual annual electricity production”.
2. The amount of energy produced in MWh per amount of land area used as “direct disturbance area”. These two metrics are the inverse of one another, but provide two different perspectives on how efficiently the proposed facility will utilize the landscape.

All of the data compiled into this analysis tool were taken directly from the documentation submitted by the applicant as part of the Application For Certification (AFC). The reader should note that the AFC documents for photovoltaic (PV) projects were not readily accessible online and we were unable to obtain copies of the applications from the BLM. Therefore, in order to estimate the land-use efficiency of PV projects, we relied on two assumptions: first, that the ratio of disturbed area to total site area of PV projects was similar to Concentrating Solar Power (CSP) projects, and second, that the estimated capacity factor for PV projects was 11 percent. For the first assumption, we calculated the average ratio of disturbed land to total site area for the 10 other projects listed below and converted this to a percentage (in this case, on average 53 percent of the site area was disturbed), which we then applied to the PV projects to estimate disturbance area. As PV systems are similar to parabolic trough systems, they have to be constructed in long, contiguous rows and are therefore likely to have similar footprints. For the second assumption, we calculated an estimated thin-film PV capacity factor of 11 percent.[8] This estimated capacity factor is based on the operating capacity factors of PV facilities that were built in Germany in the past three years.

What current stressors should be considered in order to understand the impact that utility-scale solar development might have on California desert ecosystems? What direct and indirect impacts of utility-scale solar development on key species, natural communities, and landscape-level ecological processes should be taken into consideration by decision makers?

We performed a literature review of desert ecology and conducted in-person and telephone interviews of 20 scientists with expertise in California desert ecology from universities, federal and state agencies, and environmental organizations to obtain qualitative data on the potential impacts of solar development and how these impacts may exacerbate current stressors in the California desert. We asked experts about their primary concerns, predicted impacts to key species, natural communities, and ecological processes, potential cumulative impacts, mitigation of potential impacts, policy barriers, and areas where research is lacking. These interviews helped us identify the ecological processes that are both essential for ecosystem functioning as well as those most at risk to impact. We also identified the types of impacts species are likely to face as a result of development. We combined the knowledge from interviews and the literature review with our research on technology-specific site engineering, landscape modifications, and facility parameters to extrapolate the likely impacts of utility-scale development in the CDCA.

Can landscape suitability and desert-wide impacts be identified and analyzed spatially?

What areas may be in high conflict with solar development in the California desert due to land management designations? What areas of the desert present a high degree of conflict for building solar facilities due to known occurrences of species habitats? What areas of the desert would be visually affected by solar development? How can solar facility impacts and needs be analyzed spatially given certain development scenarios?

We used Geographic Information Systems (GIS) and gathered publicly available data from the BLM, U.S. Fish and Wildlife Service (FWS), and U.S. Geological Survey National Map Seamless Server, as well as an academic subscription to the California Natural Diversity Database (CNDDB). We developed and assigned quantitative ranking and classification systems to spatial data using ESRI ArcGIS and analyzed results in Excel. We analyzed spatial categories that included land management designation, rare and endangered species occurrences, visual resources, percent slope, and distance to transmission. The context for our analyses was three potential development scenarios:

1. Only proposed solar facilities labeled as “fast track” applications are built (10 projects total).
2. Only proposed solar facilities located in Solar Energy Study Areas (SESAs) are built (22 projects total).
3. All currently proposed solar facilities (as of March 2010) are built (54 projects total).

How will solar development affect desert residents, and are their opinions and information gaps being addressed?

What are the socioeconomic impacts of utility-scale solar facilities?

We conducted a literature review of academic, government, and industry studies on the socioeconomic effects of solar energy development. Several studies used models to predict solar development job creation; these job predictions were compared to job creation projections for several proposed facilities in the California desert. A review of academic literature on the socioeconomic effects of oil, gas, and wind energy development was completed. From these results, inferences were made about solar development's likely effects on nearby communities.

How can demographic data and facility location be used to predict socioeconomic impacts?

Using two California desert communities as examples, demographic data were analyzed to predict the effects that solar development might have on the local workforce and housing market. Drawing on observations from a solar facility in operation in Nevada, inferences were made on how a community's distance from a facility, the project site's previous land use, and the site's owner (a public or private entity), will influence the facility's community effects.

What are the socioeconomic impacts of existing utility-scale solar facilities and how might the impacts of future facilities be similar and/or different?

We completed an in-depth case study of Nevada Solar One, a solar facility in Nevada. Our research goal was to infer the socioeconomic effects of utility-scale solar facilities proposed for the California desert by researching the impacts of facilities already in existence. Because many of the proposed facilities have nameplate capacities of at least 50 MW, we limited our research to facilities with comparable output. We assumed it would be difficult to locate individuals knowledgeable of older facilities. We therefore limited our research to facilities built within the past 10 years.

Data collection was mostly comprised of interviews. Our questionnaire, designed to be administered over the phone, covered a variety of topics, including general impressions of the facility and surrounding areas. The questionnaire also asked the interviewees to give their opinion on how the facility may have affected the local area, in such areas as traffic, public roads, employment, municipal revenue, and local stores. Questions covered impacts both during facility construction and operation. Over the course of the project, eight individuals were interviewed. We identified individuals to interview through internet searches and from recommendations made by other interviewees. All interviews took place from July to November 2009. Interviewees included a Boulder City elected official, a community development planner, a representative from Acciona Solar Power (the facility developer), a representative from NV Energy (the utility purchasing Nevada Solar One's power), and an individual from a local business development organization.

How do existing communities view proposed solar developments? What are the information gaps for local stakeholders and what sources of information do they use? What are the perceived types and likelihoods of impacts?

A stakeholder survey was conducted on residents in these communities in the California desert. Prior to this study, little research had been done to assess local communities' attitudes about utility-scale solar energy development. Basic methodology is provided below. Further information on the survey, including more detailed methodology, can be found in Appendix A.

Target Respondents

Three communities in the California Desert region were selected to receive the stakeholder survey: El Centro, Lucerne Valley, and Newberry Springs. Three criteria were used to select these communities.

1. Current stage of the proposed project: To capture the most informed opinions possible, we selected communities that had already held at least one public meeting regarding the proposed solar project.
2. Proximity to a proposed solar project: To ensure that those surveyed were representative of true community stakeholders, we only considered locations within 25 miles of a proposed solar energy project. This proximity requirement was designed to maximize the likelihood that the individuals surveyed in fact had a vested interest in the construction of these projects.

3. Population size: For statistical reasons, we chose to only survey communities that were 1,500 residents or more. The community of Newberry Springs did require a partial exception to this rule. Though Newberry Springs included land parcels that were owned by over 1,500 unique persons, many of these were “absentee owners”, meaning that they owned the land and title, but did not permanently reside in the community.

Survey Instrument Development

Prior to identifying locations and developing survey questions, we developed research objectives to guide our work and to form the basis of the survey instrument. The objectives, designed as a set of questions, were in part derived from what we identified as underexplored or altogether missing information from academic literature and current discourse. These questions were pre-tested by representatives from environmental organizations and desert communities. The questions developed in the stakeholder survey addressed these questions and captured demographic information to allow us to perform statistical analyses that explored the relationship between each community’s perceptions and the respondents’ age, education, and length of residence in the California desert region. Overall, there were 14 questions asked, three of which were demographic in nature. Of the 14, two were open response: “What do you think are the positive impacts of these facilities?” and, “What do you think are the negative impacts of these facilities?” The remaining 12 questions required respondents to either choose one of a set of ranked options, or to check all that applied, most of which offered the option to fill-in a response.

Survey Instrument and Dissemination

The survey instrument was distributed by mail and included both a paper copy of the survey with a stamped and addressed return envelope, and a website link that respondents could use if they preferred. A total of 5,079 surveys were mailed; households received two copies of the survey, one in English and one in Spanish, as census figures indicated a high level of Hispanic populations in these communities. 624 response were received, between early December 2009 and the end of January 2010.

Survey Response Analysis

We analyzed the results of our survey in three primary ways: first, we calculated the mean response for each question as an aggregate number from the sample and by four demographic categories using a contingency table; second, we placed those in favor of and those opposed to solar into two groups, and calculated the means and variances of each question using two-sample t-test to identify divergence of opinion and statistical significance; third, we read each open-response question and assigned a numerical value to individual words or phrases as they appeared, such as “jobs” or “green,” which we then coupled with a qualitative analysis to identify issue gaps in our close ended questions. Where we spotted patterns in the data, we conducted chi-squared tests and regression analyses to ensure statistical significance and dependence or correlation. See Appendix A for additional detail.

How are decisions being made in the solar energy siting process?

What is the current process for siting solar facilities on public lands?

In order to determine the current process for siting solar facilities on public lands, 22 in-person and telephone interviews were conducted with BLM staff involved in solar facility siting at the state office, California Desert District (CDD) office, and all field offices within the CDD, as well as with staff members of the California Public Utilities Commission (CPUC), California Energy Commission (CEC), Department Of Defense (DOD), National Park Service (NPS), and FWS involved in the solar facility siting process or with management jurisdiction within the CDCA. All interviewees were asked to explain their roles in the current siting process.

What are the strengths and weaknesses of the process?

A critical evaluation of the BLM's right-of-way process as it is being applied to solar facilities was conducted using a set of normative criteria. These criteria included: efficiency of the process, clarity of process, consideration of a robust set of options, level of environmental protection, consideration of spatial and temporal scale, and public engagement. The evaluation of the process was supplemented by interviews with staff from the BLM, CEC, CPUC, DOD, NPS, and FWS. Interviewees provided their opinions on the strengths and weaknesses of the current solar siting process. Additionally, a targeted internet-based survey of desert-region city and county governments, citizens groups, chambers of commerce, environmental organizations, recreation organizations, and tribes was conducted. This organizational survey was designed to determine the level of participation in the BLM process by organizations and what these organizations considered strengths and weaknesses of the BLM’s process as well as the most important aspects of the process. Two hundred and sixty five surveys were sent and 41 responses were received. Additionally, the stakeholder survey was used to determine the level of public engagement by individual residents.

What aspects of existing alternative processes would be beneficial for the solar siting process?

We conducted a literature review of two processes used for energy generation, the wind energy right-of-way process. This knowledge informed a comparative analysis of these two processes, using the set of normative criteria identified for the solar right-of-way process analysis. The comparative analysis looked at which parts of the processes can be or are already used for solar and if they would work with the CEC process.

What changes and improvements can be adopted to more effectively site solar facilities with minimal ecological impact?

How should the current solar siting process be changed and improved?

Recommendations were formulated following analysis of data collected to answer our research questions on how decisions are being made in the solar energy siting process. These recommendations stemmed from the strengths and weaknesses identified through the evaluation of the current process, as well as from our analysis of alternative processes used for siting energy development on public lands.

What mitigation and design measures can developers take to reduce the ecological impacts of utility-scale solar development in the California desert?

Six proposed solar facility applications were selected for an analysis of Biological Resources Best Management Practices (BMPs) and mitigation measures. In our analysis, we differentiate between the terms “best management practice” (BMP) and “mitigation”: BMPs are used on site to reduce the impacts of development on biological resources, while mitigation is used off site. The same six facilities were used in both the BMP and mitigation analysis. BMPs were not attributed to specific solar facilities, though some language from the applications was used to describe the BMPs. Our ecological analysis and interviews with scientists provided the background information necessary to construct informed recommendations for BMPs and mitigation measures.

REPORT OUTLINE

The economic and policy drivers, proposed technologies, and ecological impacts and implications of utility-scale development in the California desert are described in the following chapters (Figure 1.1).

- Chapter 2 provides geographic, jurisdictional and ecological context for our research. Also included is an overview of the ecology of the California desert, including the ecological processes that may be sensitive to development and play an import role in ecosystem functioning. This chapter concludes with a discussion of the current anthropogenic stressors to desert ecology to which solar development may contribute.

- Chapter 3 describes the various solar technology options and key considerations that guide project developers when determining which technology is best suited for their utility-scale solar project.

- Chapter 4 describes economic drivers for utility-scale development and the policies affecting siting on public lands in California. This chapter also dicusses the role of distributed generation in meeting California's RPS goals.

- Chapters 5 and 6 discuss the ecological impacts of solar development at the site-level and landscape-level respectively. These chapters include the types of site engineering that are performed by developers and the associated ecological effects of these at the project site and the larger landscape scale.

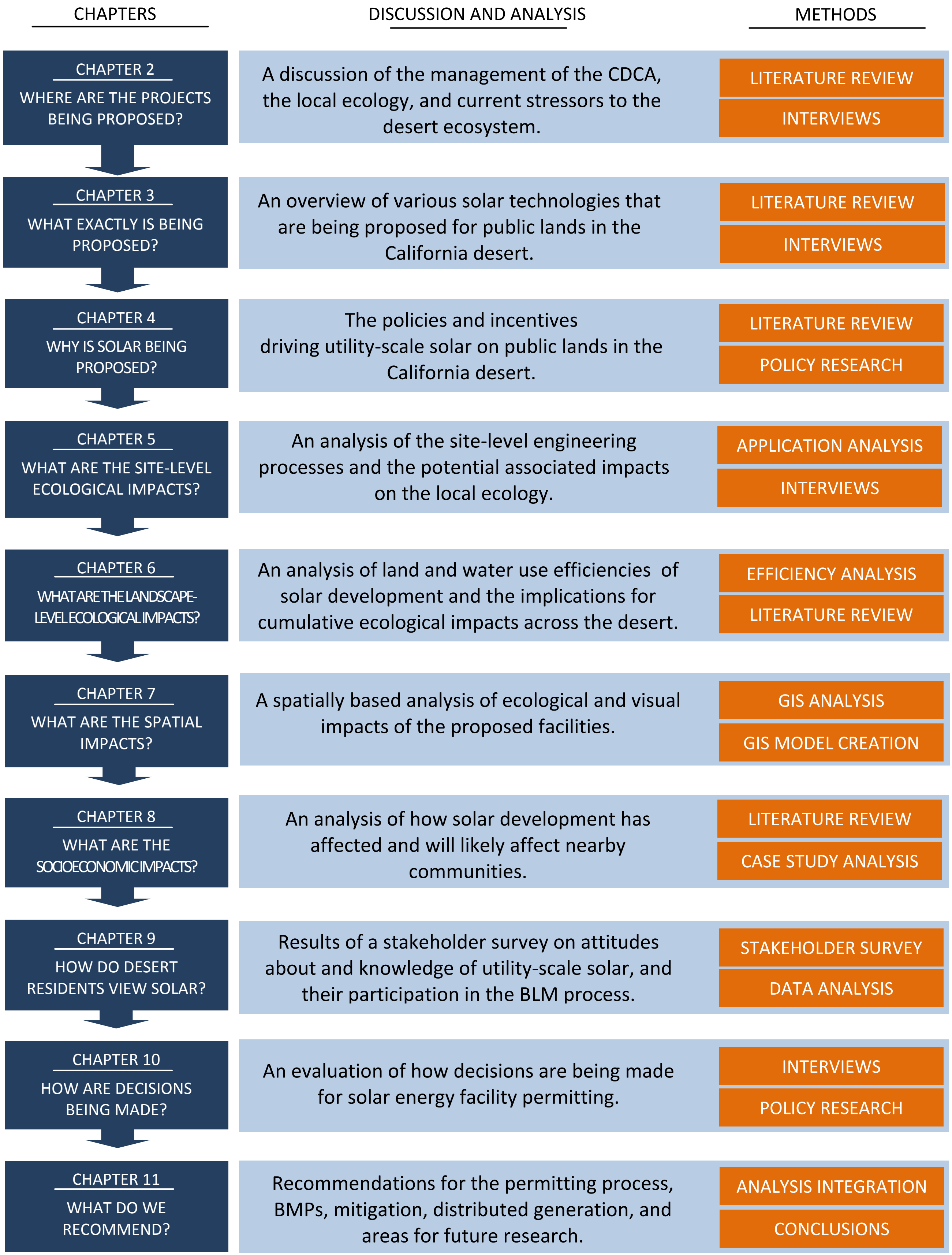
- Chapter 7 examines potential ecological and visual impacts using spatial analyses. This chapter includes an analysis of individual facilities and using three different development scenarios: only Fast Track facilities are built; only SESA facilities are built; and All Proposed facilities are built. These analyses were used to draw conclusions on landscape level impacts for multiple facilities.

- Chapter 8 couples a case study of an existing solar facility with academic and industry research to predict the socioeconomic impacts of proposed projects.

- Chapter 9 analyzes the results of a stakeholder survey conducted in three California desert communities with close proximity to utility-scale solar facilities. Differences in attitude were explored between those who support and oppose solar. Respondents were asked about the likelihood of possible outcomes, concern for negative consequences, value they place on potential positive impacts, their level of participation in the BLM process, and use of a variety of information sources.

- Chapter 10 examines the decision-making processes of the BLM and CEC, evaluates the BLM permitting process, and analyzes the oil and gas leasing and wind right-of-way processes for solutions to weaknesses of the solar permitting process.

- Chapter 11 highlights our key findings and makes recommendations on ways to improve the solar permitting process, mitigate the impacts of utility-scale solar development on habitat and wildlife, and promote expanding the use of distributed generation.



CHAPTERS	DISCUSSION AND ANALYSIS	METHODS
CHAPTER 2 WHERE ARE THE PROJECTS BEING PROPOSED?	A discussion of the management of the CDCA, the local ecology, and current stressors to the desert ecosystem.	LITERATURE REVIEW INTERVIEWS
CHAPTER 3 WHAT EXACTLY IS BEING PROPOSED?	An overview of various solar technologies that are being proposed for public lands in the California desert.	LITERATURE REVIEW INTERVIEWS
CHAPTER 4 WHY IS SOLAR BEING PROPOSED?	The policies and incentives driving utility-scale solar on public lands in the California desert.	LITERATURE REVIEW POLICY RESEARCH
CHAPTER 5 WHAT ARE THE SITE-LEVEL ECOLOGICAL IMPACTS?	An analysis of the site-level engineering processes and the potential associated impacts on the local ecology.	APPLICATION ANALYSIS INTERVIEWS
CHAPTER 6 WHAT ARE THE LANDSCAPE-LEVEL ECOLOGICAL IMPACTS?	An analysis of land and water use efficiencies of solar development and the implications for cumulative ecological impacts across the desert.	EFFICIENCY ANALYSIS LITERATURE REVIEW
CHAPTER 7 WHAT ARE THE SPATIAL IMPACTS?	A spatially based analysis of ecological and visual impacts of the proposed facilities.	GIS ANALYSIS GIS MODEL CREATION
CHAPTER 8 WHAT ARE THE SOCIOECONOMIC IMPACTS?	An analysis of how solar development has affected and will likely affect nearby communities.	LITERATURE REVIEW CASE STUDY ANALYSIS
CHAPTER 9 HOW DO DESERT RESIDENTS VIEW SOLAR?	Results of a stakeholder survey on attitudes about and knowledge of utility-scale solar, and their participation in the BLM process.	STAKEHOLDER SURVEY DATA ANALYSIS
CHAPTER 10 HOW ARE DECISIONS BEING MADE?	An evaluation of how decisions are being made for solar energy facility permitting.	INTERVIEWS POLICY RESEARCH
CHAPTER 11 WHAT DO WE RECOMMEND?	Recommendations for the permitting process, BMPs, mitigation, distributed generation, and areas for future research.	ANALYSIS INTEGRATION CONCLUSIONS

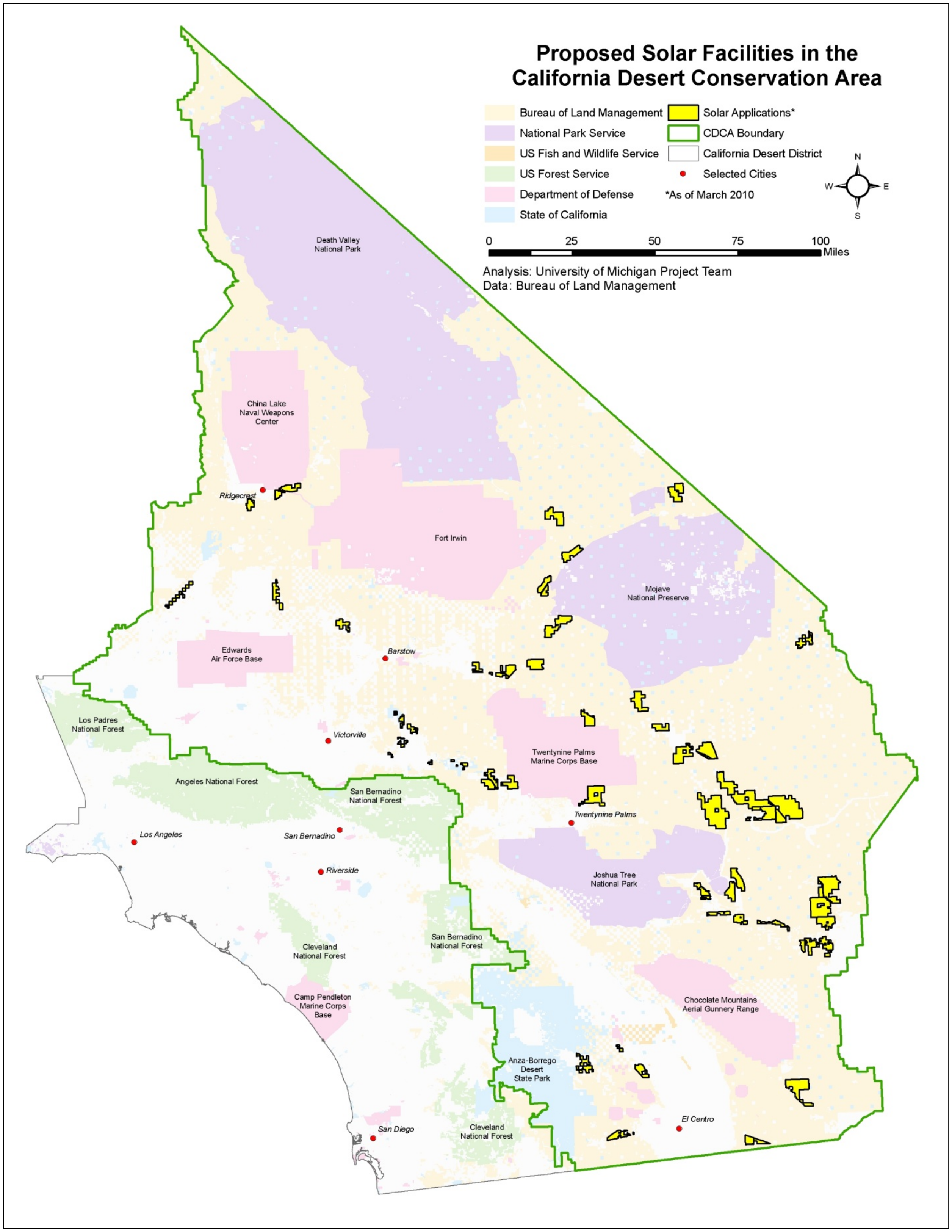
Figure 1.1. Flow Diagram of Full Study

CHAPTER 2 | MANAGEMENT AND ECOLOGY OF THE CALIFORNIA DESERT

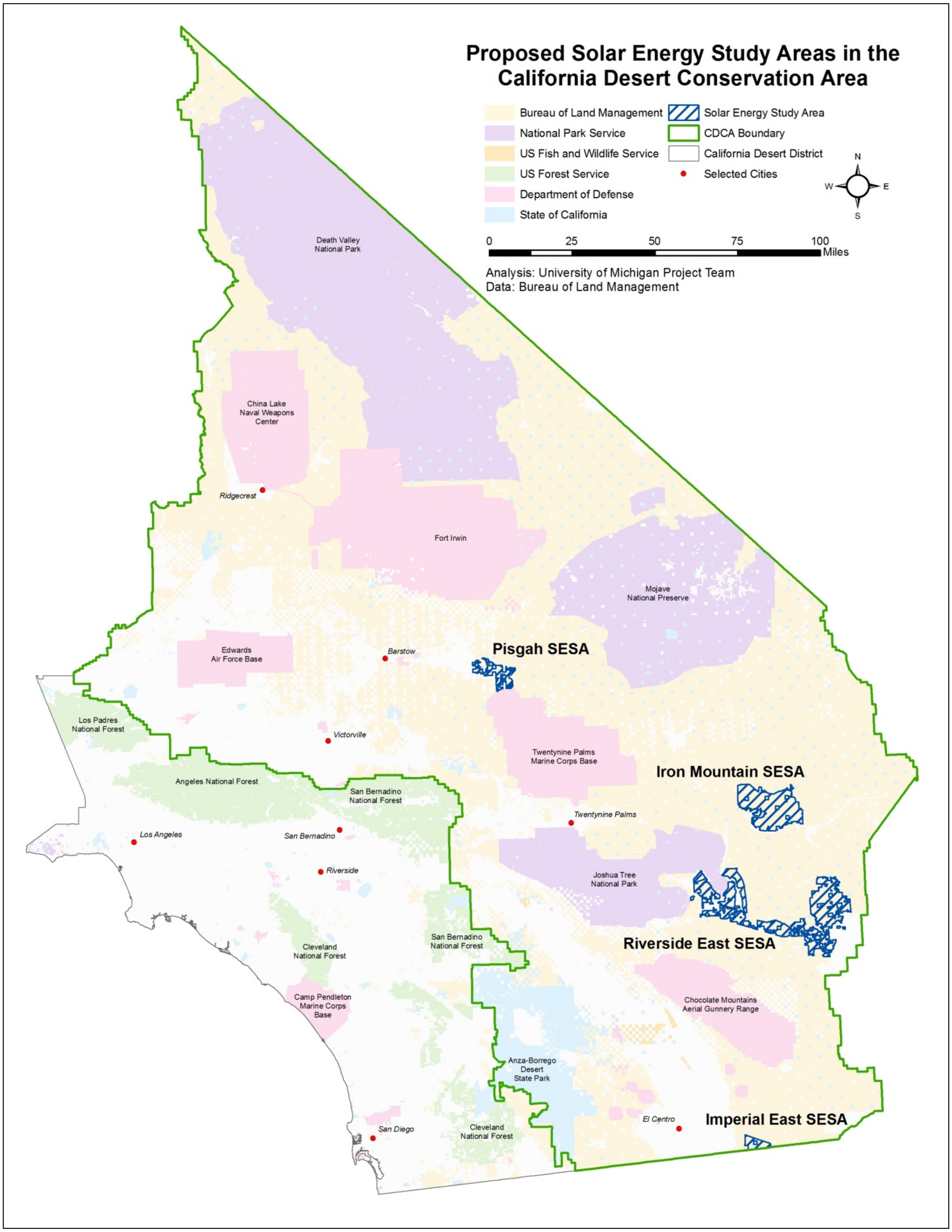
Public lands in southwestern states show particular promise for utility-scale solar installations, often having the levels of solar radiation and available tracts of land required to make these projects viable. As of March 2010, the BLM has 54 right-of-way applications for solar projects in the CDCA covering just over half a million acres (Map 2.1).[9]

The CDCA consists of the Mojave and Colorado deserts within California and covers approximately 25 million acres of arid land in the southeast corner of the state. The area is bounded by Nevada and Arizona to the east and Mexico to the south. The area is known for its complex ecosystems, which provide diverse habitats for many rare, threatened, and endangered species. While approximately 10 million acres are public lands managed by the BLM, the remaining land is owned or managed by a multitude of federal and state agencies, local government, and private landholders (Map 2.1). The CDCA includes portions of Imperial, Inyo, Kern, Los Angeles, Mono, Riverside, San Bernardino, and San Diego Counties. Notable cities and communities include Victorville (population 108,586), Palm Springs (42,350), El Centro (39,979), Ridgecrest (27,613), Barstow (24,957), and Twentynine Palms (24,389).[10] Additionally, the Department of Defense (DOD) operates several major military installations and the National Park Service (NPS) manages two National Parks — Death Valley and Joshua Tree — and Mojave National Preserve in the region. The U.S. Fish and Wildlife Service (FWS) manages four National Wildlife Refuges that lie within the CDCA: Coachella Valley, Sonny Bono Salton Sea, Havasu, and Imperial. The State of California also has landholdings throughout the region. Several state parks and state recreation areas are managed by the California Department of Parks and Recreation. State wildlife areas, state ecological reserves, and various other lands are managed by the California Department of Fish and Game (DFG), and an array of state trust lands, found in a checkerboard pattern throughout the desert, are managed by the State Lands Commission.

Given the complexity of the study area, decisions regarding siting solar facilities on public lands must be made with consideration of existing management of these lands and the sensitivity of the desert ecosystems. This chapter provides a discussion of the current status of solar development in the CDCA, how desert public lands are being managed, and the relationship of solar development to existing management designations. It also provides an overview of desert species, ecological processes, and existing ecological stressors that will be considered in evaluating suitability of solar development sites in later chapters.



Map 2.1 Proposed Solar Facilities in the CDCA.



Map 2.2 Proposed Solar Energy Study Areas in the CDCA.

CURRENT STATUS OF DEVELOPMENT

In response to the overwhelming interest in solar development on public lands, the BLM and the DOE began developing a nationwide Solar PEIS in May 2008 to guide future application decisions, judge the cumulative impacts of multiple projects, and identify and prioritize locations best suited for utility-scale solar development.[11] During this effort, 24 SESAs were identified. These areas have high solar resources, suitable slope, proximity to roads and transmission, contain at least 2,000 acres of public lands, and avoid sensitive and wilderness lands.[12] The four SESAs in California, which total 351,049 acres (Map 2.2), contain 22 proposed solar facilities. These areas will undergo an in-depth Environmental Impact Statement (EIS) conducted through a National Environmental Policy Act (NEPA) process during the PEIS to determine their suitability for solar development. The PEIS public scoping period ended in September 2009 and the BLM and the DOE are currently drafting the PEIS. In the meantime, 10 of the proposed projects have elected to take advantage of stimulus money under the American Recovery and Reinvestment Act of 2009 (ARRA). In order to be eligible for federal funding the projects need to be ready for development by December 2010.[13] While no solar projects have been approved as of March 2010, the BLM has pledged to complete an individual EIS for each of these “fast track” projects by the expiration date, despite the fact the PEIS has not been completed.

In addition to the nationwide Solar PEIS, in November 2008 the DFG, the California Energy Commission (CEC), the BLM, and the FWS signed a Memorandum of Understanding (MOU) to establish the California Renewable Energy Permit Team. This team is responsible for creating a Desert Renewable Energy Conservation Plan (DRECP), which will be a conservation strategy to facilitate and streamline compliance with all applicable state and federal laws and identify renewable energy zones in the California desert.

MANAGEMENT OF THE CDCA

The BLM, an agency in the U.S. Department of Interior, holds management authority over the National System of Public Lands, which is the collective term for BLM’s land holdings nationwide. These lands include the public lands in the California desert on which multiple utility-scale solar facilities have been proposed. The Federal Land Policy and Management Act of 1976 (FLPMA) established the BLM's multiple use mandate to manage the land for resource extraction, recreation, cultural value, and conservation.[14] This multiple use mandate creates conflict in that the BLM is called to manage public lands in a manner that will protect ecological and environmental quality, but also allows resource use in a way "that takes into account the long-term needs of future generations for renewable and non-renewable resources," among other considerations.[15] While not always mutually exclusive, these provisions present a challenge to the BLM as it considers processing and approving permits for utility-scale installations that will harvest a renewable resource and cause ecological impacts at site and landscape levels. Additionally, in many cases, these facilities conflict with existing uses of the land.

The CDCA has a complex history of statutes, regulations, and management plan designations and prescriptions guiding the management of the various federally owned lands within the desert. Within the BLM, the California state office oversees the CDD office, which is itself responsible for the five field offices that fall within the CDD and the management of the CDCA.

The 1980 California Desert Conservation Area Plan (CDCA Plan) guides management of the CDCA, though more detailed resource management plans exist for specific regions within the CDCA. These include the West Mojave, Northern and Eastern Mojave, Northern and Eastern Colorado, Western Colorado Desert, Coachella Valley, and Imperial Sand Dunes Plans.

CDCA Multiple-Use Classes

The CDCA Plan divides BLM lands into four multiple-use classes:[16]

1. Class C (Controlled Use) lands include Wilderness Areas and areas "preliminarily recommended" for wilderness by Congress, such as Wilderness Study Areas (WSAs).[17] There are approximately four million acres of Class C lands.[18]
2. Class L (Limited Use) lands protect "natural, scenic, ecological, and cultural resource values."[19] The lands are "managed to provide for generally lower-intensity, carefully controlled multiple use of resources, while ensuring that sensitive values are not significantly diminished."[20] There are approximately four million acres of Class L lands.[21]
3. Class M (Moderate Use) lands provide a "controlled balance between higher intensity use and protection of public lands."[22] They allow for energy and utility development, among other uses. There are approximately 1.5 million acres of Class M lands.[23]
4. Class I (Intensive Use) lands "provide concentrated use of lands and resources to meet human needs."[24] There are approximately 500,000 acres of Class I lands.[25]

Scattered parcels of land that do not fall into one of these four categories are designated "unclassified" and are managed on a case-by-case basis.

The CDCA Plan stipulates that solar energy development is not allowed on Class C lands, but may be allowed on Class L, M, or I lands after NEPA requirements are met.[26] While the CDCA Plan allows for solar development, this allowance did not consider the impacts of current technologies and acreage necessary for utility-scale solar today.[27] As Class L lands are designated for “lower-intensity, carefully controlled multiple use of resources,” an argument can be made for interpretation of the plan to prohibit utility-scale solar development on Class L lands. While it is an issue being discussed, one BLM field office manager noted, "The initial indication from the [California Desert] District was that solar energy would be in conformance with both the M and the L classes. It could be done, and an amendment [to the CDCA Plan] may not or should not be necessary. These things can all be looked at on a case by case basis."[28]

BLM Management Areas and Other Designations

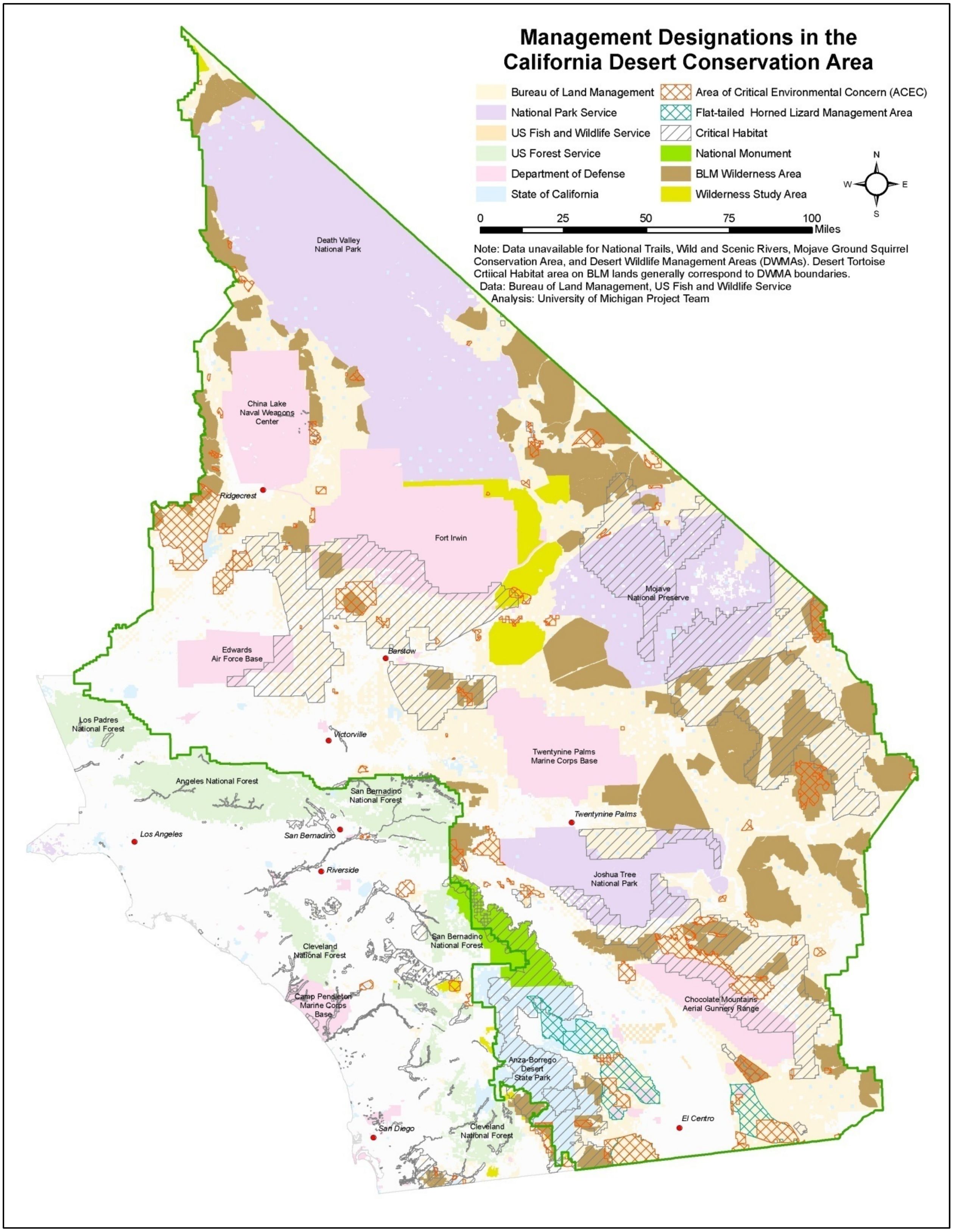
On BLM lands within the CDCA, many special management areas and other designations have been established through statue, regulation, and management plan amendments (Map 2.3). These include Wilderness Areas, Wilderness Study Areas (WSA), Wild and Scenic Rivers (WSR), Areas of Critical Environmental Concern (ACECs), Desert Wildlife Management Areas (DWMAs), critical habitat, Long-term Visitor Areas (LTVAs), and designated routes and areas for off-highway vehicle (OHV) use, among others. Many of these areas prohibit or limit development and are discussed in more detail below.

Wilderness Areas, as set forth by the Wilderness Act, prohibit commercial enterprise, permanent roads and, except as necessary to administer the areas, temporary roads, use of motor vehicles and other forms of mechanized transport, and structures and installations.[29] While wilderness areas are not compatible with solar development, indirect impacts from the development of solar facilities on the Federal Reserved Water Rights, air quality protected under the Clean Air Act and additional State standards, and visual resources of wilderness areas will need to be analyzed in a facility's EIS.[30]

Wilderness Study Areas (WSA) are areas "under study" by Congress as potential wilderness, and, until Congress designates them wilderness or releases them from study, are managed in a manner that does not impair the suitability of such areas to be designated wilderness.[31] Current WSAs are therefore excluded from solar development unless released by Congress. Similar considerations for wilderness areas apply to WSAs.

Wild and Scenic Rivers (WSR) are whole rivers or segments of rivers that “possess outstanding remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values” and are designated to be “preserved in free-flowing condition” and “protected for the benefit and enjoyment of present and future generations.”[32] There are two WSRs in the CDCA administered by the BLM, the Amargosa River (26.3 miles) and Cottonwood Creek (4.1 miles).[33]

National Monuments, as defined in the Antiquities Act, are “historic landmarks, historic and prehistoric structures, and other objects of historic or scientific interest.”[34] They can be established either by Executive Order or by an Act of Congress, and are withdrawn from development. Santa Rosa and San Jacinto Mountains National Monument is the only National Monument in the CDCA.



Management Designations in the California Desert Conservation Area

Note: Data unavailable for National Trails, Wild and Scenic Rivers, Mojave Ground Squirrel Conservation Area, and Desert Wildlife Management Areas (DWMAs). Desert Tortoise Crtiical Habitat area on BLM lands generally correspond to DWMA boundaries.
Data: Bureau of Land Management, US Fish and Wildlife Service
Analysis: University of Michigan Project Team

Map 2.3 BLM Management Areas and Other Designations in the CDCA.

National Trails are designated to allow for travel close to original trails or routes of historical significance, outdoor recreation uses through nationally significant scenic, historic, natural, or cultural areas, or outdoor recreation uses near urban areas.[35] The BLM manages three such trails in the CDCA: the Pacific Crest National Scenic Trail, Juan Bautista de Anza National Historic Trail, and the Old Spanish National Historic Trail.

Areas of Critical Environmental Concern (ACEC) are defined in FLPMA as areas "within the public lands where special management attention is required to protect and prevent irreparable damage to important historical, cultural, or scenic values, fish and wildlife resources, or other natural systems or processes, or to protect life and safety from natural hazards."[36] ACECs have special site-specific management prescriptions in order to protect the specific natural or cultural resource for which the ACEC was designated. Development on ACECs may be allowed if such development does not impact the resource for which the ACEC was designated.[37]

Desert Wildlife Management Areas (DWMA) have been established to protect high quality habitat for the threatened desert tortoise.[38] Most DWMAs overlap with critical habitat for the desert tortoise. Individual DWMAs have a one percent surface disturbance limit to protect the desert tortoise.[39]

Critical habitat areas, as designated under the Endangered Species Act, are protected from "destruction" or "adverse modification" of the habitat.[40] In many areas, critical habitat areas overlap with DWMAs. While they may not statutorily prohibit solar development, the amount of disturbance created by a solar facility essentially excludes critical habitat from development.

Special Management Areas, including the Mohave Ground Squirrel Conservation Area and Flat-tailed Horned Lizard Management Areas, are designated for the management of specific species that are considered at risk of being listed under the Endangered Species Act (ESA). These areas have special management prescriptions that may limit surface disturbance within the designated area.

Cultural and Historical Resources listed on the National Register of Historic Places, and other such resources not listed on the National Register that would be impacted by a solar facility will be analyzed in the EIS for each facility.

Long Term Visitor Areas (LTVA) are recreation areas where visitors may camp for several months at a time. There are five LTVAs totaling 3,470 acres in the CDCA.[41] Solar energy development within LTVAs would prohibit public use of the areas for recreation.

Off-highway Vehicle (OHV) Use Areas and Routes are the primary recreational use of BLM-managed public lands in the desert. Throughout the CDD, there are 500,000 acres of open areas and an additional 6.7 million acres of routes.[42] The BLM has indicated that it has steered developers away from OHV recreation areas, and that solar facilities that block OHV access routes should provide alternate access to those routes.[43]

ECOLOGY OF THE CALIFORNIA DESERT

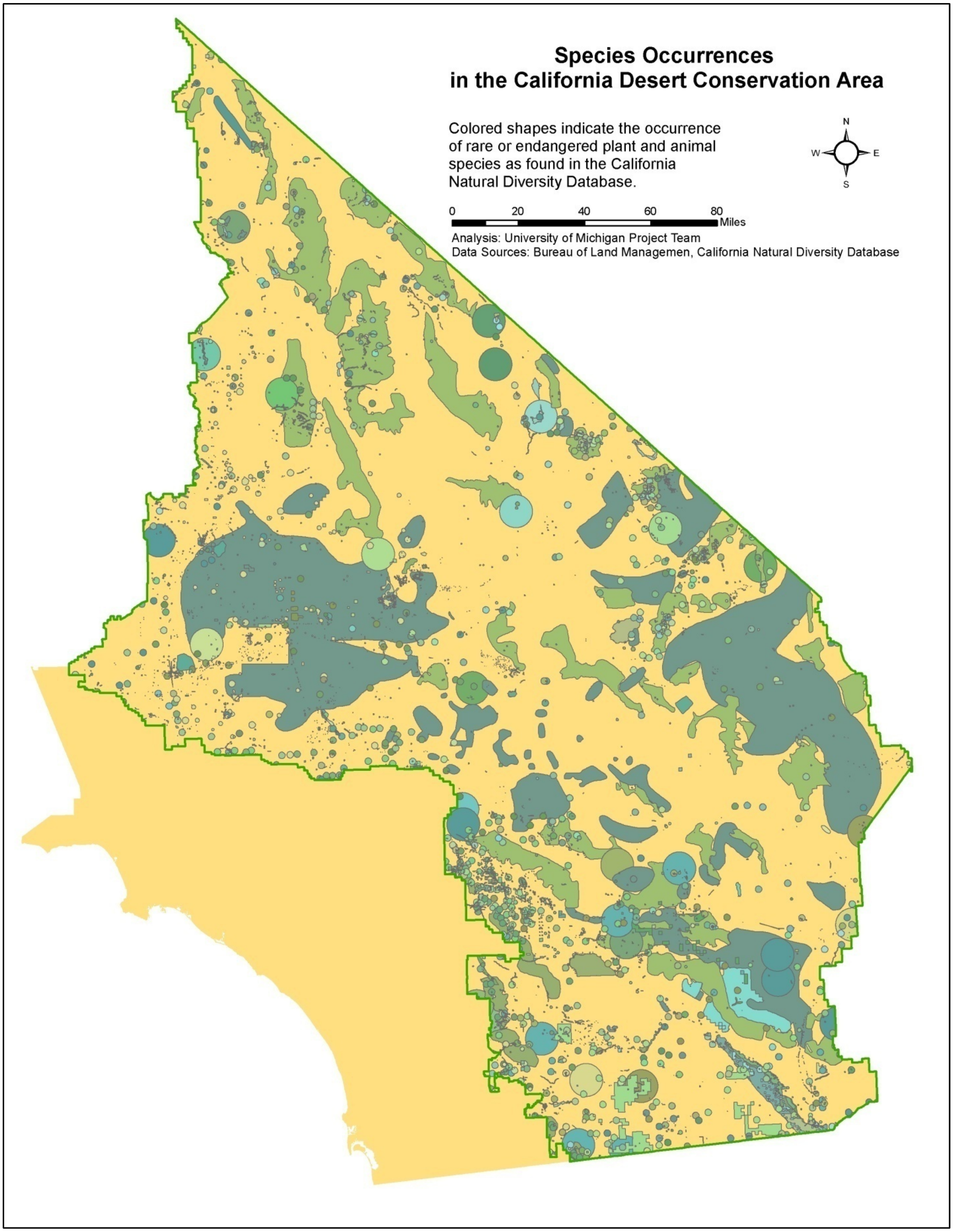
As can be seen from the land management designations described above, there are several ecologically important habitats and species found throughout the CDCA. Severe aridity, extreme temperatures, intense sunlight, and high winds create a harsh environment for life in the California desert. Biological diversity can persist due, in part, to complex and interconnected ecological processes that sustain these ecosystems. Climate drives regional and local weather patterns, determines seasonal temperatures, frequency and size of precipitation events, and wind patterns. These processes in turn drive plant productivity and nutrient cycling. Geomorphology and desert landforms (e.g., mountains, alluvial fans, ephemeral streams, sand dunes) directly affect water infiltration, run-off, erosion, storage, and salt accumulation, as well as soils and nutrients.[44] Wind, water, and biota interact with soil through processes of erosion, deposition, bioturbation, and compaction, making it more or less suitable for desert life.[45] Wind patterns, wind erosion, rainfall, water erosion, and water distribution are critical processes that shape the structure and dynamics of desert ecosystems. The sum of these processes determine if, where, and what biodiversity can persist. Impacts to these processes can result in fundamental changes to the ecology and biology of the California desert.

Rare and Endangered Species

Many of the species in the California desert are endemic, either due to evolution or isolation, and are adapted specifically for this type of bioregion.[46] It would be a misconception to consider deserts devoid of life; in fact the bioregion's extreme landscape and climatic characteristics prove to be important drivers of species evolution. There are over 2,400 native plant and animal species in the California desert, and no less than 72 species are endemic to the California desert, 40 of them specifically to the California expanse of the Mojave.[47] Many of the species in this region are considered rare or at risk (Map 2.4).

Sand Dune Systems

Sand dune systems are microcenters for biodiversity (Figure 2.1).[48] The dynamic nature of sand dune systems forces evolution of unique adaptations that allow them to survive in sand dune habitat; consequently, dune species are ill adapted for survival outside of dune habitat.[49] For example,



Map 2.4 Rare and Endangered Species Occurrences in the CDCA. Different colors represent different species.

Figure 2.1 Tracks in a Sand Dune System. Image Credit: Sarah Tomsky.

psammophiles (plants restricted to active dunes) produce large seeds with larger food reserves than non-psammophiles, allowing psammophile seedlings to emerge even when deeply buried by sand.[50] However, the production of large seeds restricts the number of seeds that a plant can produce, making it more difficult for large-seeded psammophiles to compete in non-dune habitat where the production of smaller, more numerous seeds may be advantageous. Cameron Barrows, a researcher for the Desert Studies Initiative, notes:

> "Sand dunes are incredibly difficult places to live if you're a plant or an animal because the surface of the sand is constantly moving, almost on a daily basis – certainly on a weekly basis. So if you're a plant you're always in danger of having your habitat being eroded out from underneath you or being dumped on top of you, and if you're a small mammal or a small animal of any kind the same thing is true. If you burrow into the sand you're going to get buried, if you burrow in the sand you might get eroded away – so they have to be able to deal with a high level of dynamics. All of the adaptations that enable them to do that (there is a fascinating array of adaptations that both the animals and plants have) don't function at all off of the sand dunes, so they are less competitive when they get off the sand dunes. As a result, most of the species that evolve on sand dunes are unable to move very far distances in between sand dunes. There's not a huge list, but virtually every sand dune system in the warm desert areas of the desert southwest there is at least one endemic plant, at least one endemic beetle, usually another endemic species of arthropod, and often an endemic lizard, and very often the list is much longer than that. In larger dune systems you can have a dozen or more species that are only found on that dune system, and in some cases only one or two of them have been identified so far."

The evolution of unique dune adaptations is evident in the array of dune-endemic or dune-restricted species, such as the flat-tailed horned lizard (*Phrynosoma mcallii*), desert kangaroo rat (*Dipodomys deserti*), Peirson's milk-vetch (*Astragalus magdalenae* var. *peirsonii*), and Hardy's dune beetle (*Anomala hardyorum*). These species and many others are dependent on wind to transport sediment to and from these habitats. The loss of these transport processes could result in the extirpation of dune endemic species and the habitat on which they depend, as well as jeopardize the continued existence of critical habitat for threatened and endangered species, such as the Coachella Valley fringe-toed lizard (*Uma inornata*).[51]

One of the greatest threats to the persistence of sand dune systems is the interruption of the sand transport processes. Because sand dune systems rely on sources of sediment and the availability of wind to transport that sediment, interrupting either of those processes can modify the influx of sediment to an area and therefore alter the balance between sediment deposition to the dunes and sediment transport away from the dunes. Sand transport processes can be interrupted by urbanization and housing development, agriculture, wind breaks, and other structures that prevent sediment deposition or create barriers to natural wind movement.[52,53]

Watercourse modifications can also interrupt aeolian processes. One study found that modification of river channels within the Coachella Valley reduced the amount of sediment deposited in the valley during flood events, which reduced the amount of sediment available for transport by winds to replenish dune sediments.[54] The reduction in deposited sediment resulted in the accelerated reduction, degradation, and stabilization of the major active dune habitat in the Coachella Valley.[55]

Dust Emission

Though often overlooked, the storage, release, and transport of dust play significant roles in ecosystem processes, at scales that range from site up to global scales.[56] Some dust particles are small enough to travel long distances (even up to hundreds of kilometers in one wind event), carrying soil nutrients and organic matter to areas of deposition.[57,58] Dust from the Mojave Desert has been documented in areas as far west as California's Channel Islands, and as far east as the Colorado Plateau.[59] The soil fertility of source and sink areas can therefore be impacted by wind erosion that serves to deplete source areas of nutrients, while delivering it to deposition sites.[60] Wind erosion and dust emission therefore play a role in nutrient cycling across landscapes and ecosystems (both terrestrial and aquatic).

Several biotic and abiotic factors control both the sequestration and the emission of dust. The accumulation and sequestration (or storage) of dust at a particular site depends on the rate of supply from the origin, vegetative cover at the end point, wind speed, air turbulence, and rainout during transport.[61] Dust emission is a function of wind turbulence (which fluctuates with meteorological conditions), the ability of surface materials to resist erosion (controlled by particle size, soil moisture, and soil crusting), and the amount and type of vegetation at the point source.[62]

In addition to influencing ecosystems, dust emission can negatively impact human health through particulate matter (PM10) pollution (particulate matter that is less than 10 microns in diameter). The U.S. Environmental Protection Agency (EPA) lists the major concerns for human health from exposure to PM10 air pollution as effects on breathing and respiratory systems, damage to lung tissue, cancer, and premature death.[63] The EPA warns that the elderly, children, and people with chronic lung disease, influenza, or asthma, are especially sensitive to the effects of particulate matter.[64] In the Coachella Valley, PM10 pollution has been linked with death from cardiorespiratory complications and mortality in individuals older than 50.[65]

The contribution of windblown dust to PM10 air pollution has been well-studied in relation to Owen's (dry) Lake, California. Windblown dust erosion off of the dry lake bed can cause 24-hour average PM10 concentrations to exceed 12,000 μg m^{-3}; federal air quality standards require the PM10 concentration to be below 150 μg m^{-3}.[66]

Three Controls of Dust Emission in the Desert

1. Soil moisture binds soil particles together, making the surface more resistant to erosion. [67] Arid regions, therefore, are more prone to dust emission, and climate change-induced temperature increases (leading to increased evaporation), compounded by expected decreased precipitation, may boost dust emission from California's desert regions.

2. Soil crusts help buffer the effects of wind erosion; studies indicate that lichen/moss biological soil crusts are the most resistant of desert soil types to wind erosion (on par with desert pavements).[68] However, the ability of soil crusts to withstand erosion is drastically decreased when disturbed; they are particularly susceptible to disturbance in dry conditions, becoming easier to crush when trampled.[69] Several studies have shown that sediment loss increases dramatically as these surfaces are disturbed, and more severe types of disturbance (especially those that have higher downward compressional force – such as impaction of heavy vehicles driving over them) can also increase dust emission.[70, 71]

3. The presence of vegetation across a potential dust source area can also act as a control for emissions. Plants act as a protective cover, decreasing the ability of wind to reach the desert surface and therefore inhibiting wind erosion. As cover decreases, and unvegetated gaps increase in size, the surface becomes more vulnerable to erosion and sediment loss.[72] Plant type may also play a role in the level of protection provided by vegetation; in a 2009 study of sites in the Mojave Desert, Urban et al. showed a negative correlation between dust emission and the presence of annual plants, which offer dense cover and may continue to act as protection even after death.[73] In addition to decreased soil moisture and increased soil crust vulnerability, climate change threatens the role of vegetation in the California desert as a dust control as well, since dryer and hotter conditions may reduce plant cover and therefore erosion resistance.

Biological Soil Crusts

The name "biological soil crust" is derived from the fact that living organisms, primarily cyanobacteria, bind the surface of the soil together, forming a cohesive crust.[74] Biological soil crusts are common in ecosystems with high light input on the surface of the soil, including arid ecosystems like the California desert; up to 70 percent of soil surface may be covered by biological soil crusts in desert regions (Figure 2.2).[75, 76] In recent decades, the importance of these crusts to ecosystem functioning has been increasingly understood and highlighted in scientific journals. In arid ecosystems, biological soil crusts enhance soil stability, fertility, and erosion resistance, in addition to controlling water infiltration, surface albedo, and carbon sequestration.

Hydrology


Figure 2.2 Soil Crusts, Mojave National Preserve. Image Credit: Sarah Tomsky.

Water infiltration is an essential process that enables desert plants, especially plants whose roots do not reach the water table, to capitalize on rare and variable precipitation events.[77] By physically slowing down vertical and horizontal water movement, plants can improve water infiltration in arid ecosystems and create microhabitats more suitable for their own survival.[78] Plant stems and foliage break up raindrops, with water both flowing down the stems and into live root channels into the soil, and dripping more slowly off of foliage.[79] By slowing down precipitation, plants increase water infiltration into the soil. Vegetation patches can also slow the horizontal movement of water by obstructing runoff and storing that water as runon.[80] In a 2005 study by Ludwig et al., the authors found that by trapping water runoff, vegetation patches enhanced plant growth.[81] Increased plant growth could lead to increased seed and biomass production, creating greater plant densities within a vegetation patch, and a greater ability of the vegetation patch to trap water, resulting in a positive feedback cycle.[82] Ludwig et al. found that vegetation patches also encouraged more active soil macroinvertebrates (e.g. termites, ants, and earthworms).[83] Macroinvertebrates and plant roots move and mix the soil through burrowing and excavating, root penetration and decay, in a process called "bioturbation."[84] The spaces, or macropores, generated by bioturbation can improve water movement and infiltration through the soil.[85, 86]

In addition to altering the movement of water across the landscape, plants affect soil moisture by modifying the microclimate beneath and around them. In a 1998 study by Breshears et al., the authors found that during the summer season in a semiarid ecosystem, soil beneath the canopies of woody plants had temperatures that were as much as 10 degrees C lower than soils that were not beneath their canopies.[87] These lower soil temperatures substantially reduced soil evaporation rates and loss of soil moisture.[88]

Figure 2.3 49 Palms Oasis, Joshua Tree National Park. Image Credit: Sarah Tomsky.

Aquatic habitats in deserts include pools, rivers, springs, and seeps (Figure 2.3). Fed by subterranean freshwater aquifers, they support a variety of sensitive and rare species due to their relatively low occurrences in arid regions. Desert springs are just one example of a rare aquatic habitat; they are seldom encountered in arid ecosystems and their distribution is scattered.[89]

Habitat Connectivity

Habitat connectivity is considered to be one of the most important factors in maintaining biological diversity.[90] Maintaining gene flow is essential for genetic fitness, allowing for evolutionary adaptation to environmental changes or pressures. Many conservation initiatives are focused on maintaining connectivity, particularly when increased urbanization threatens to fragment habitats. For some species with limited range, especially reptiles and small mammals, the loss of habitat itself threatens population viability, particularly if species cannot migrate to suitable replacement habitat.[91] Maintaining connectivity allows limited-range species to make small spatial shifts in habitat to adjacent patches if populations experience loss of home-range habitat. For larger species, particularly those with a wide range like bighorn sheep, connectivity is required across a much larger swath of the landscape.[92] Resources are dispersed across a broader geographic scope, and gene flow often occurs between smaller populations within a metapopulation. This gene flow is important to avoid inbreeding depression.

In 2000, several conservation and research organizations participated in a workshop for the purpose of identifying "linkages" between important core habitat areas across the State of California.[93] Maintaining or reestablishing connectivity between these core areas is seen as critical for protecting the state's biodiversity. Within the Mojave Desert ecoregion, the group identified 37 linkages, utilizing information on several species (including mammals, birds, amphibians, and reptiles).[94] Importantly, the group also identified primary barriers to migration, with highways and major roads accounting for nearly 70 percent of the existing barriers.[95] As urbanization increases in the California desert, maintaining connectivity and mitigating existing barriers to migration are considered a conservation priority. In the face of climate change, which may require species to move in response to habitat range shifts, connectivity to potential future habitats will be essential for adaptation.

CURRENT ECOLOGICAL STRESSORS

Solar development would not represent the only stress on California desert ecosystems; the region has seen significant stresses from human activity, both historic and current. The California desert has histroically served as major trade and migration routes, and was exploited by early settlers, miners, and cattlemen.[96] Today the desert is surrounded by some of the most populous counties in California whose residents place increasing demands on its natural resources. The following provides an overview of the major current stressors, including urban and suburban development, grazing and agriculture, water demand, linear corridors, OHV recreation, invasive species, military operations, and mining.

Urban and Suburban Development

Dramatic population growth in the California desert since the 1980s is correlated with suburban expansion.[97] This growth has continued; San Bernardino County alone showed a population increase of 17.9 percent between 2000 and 2008 according to the U.S. Census Bureau.[98] Population increase typically results in expansion of developed land; as an example, the town of Victorville (in San Bernardino County) experienced a population increase from 8,100 in 1962 to 60,650 in 1995, which was accompanied by an increase of developed area from 25 km^2 to 175 km^2 over the same time period.[99] This sustained growth paired with limited resources in the California desert means people rely on importing necessities such as food, water, and energy. Resource importation results in higher demand on fossil fuel-based transportation as well.[100] Urban and suburban development and population growth lead to additional linear corridors as well as increased groundwater withdrawal and surface water diversion. These developments also contribute to habitat fragmentation, which can have negative impacts on wildlife and plants.

Grazing and Agriculture

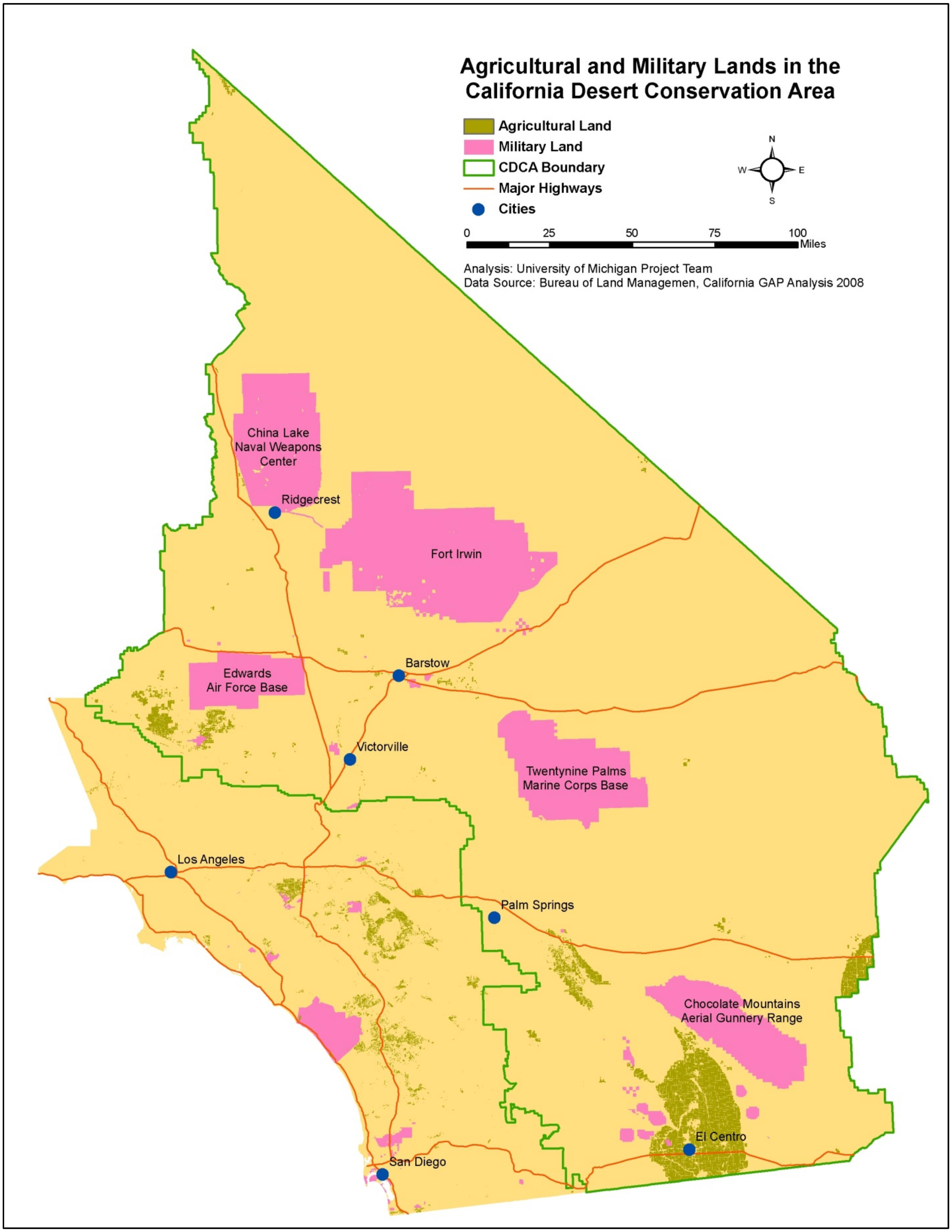
Figure 2.4 Grazing Allotment, Mojave National Preserve. Image Credit: Nerissa Rujanavech.

The 1980 CDCA Plan states that: "Currently and historically, livestock grazing has been and continues to be a significant use of renewable resources on public land in the California desert."[101] Under the CDCA Plan, the BLM leases 4.5 million acres (36 percent of public lands in the CDCA) to graze cattle and sheep. While livestock production provides benefits in the form of food and fiber, negative ecological impacts are incurred. Negative impacts of livestock grazing in desert ecosystems include decreased plant cover and biomass, shifts in the vegetation community, soil disturbance, soil compaction, and increased spatial and temporal heterogeneity of water and soil nutrients.[102] Overgrazing may trigger the decline of arid rangeland through a positive feedback cycle of damage to vegetation and soil structure, and reduced capacity of the soil to capture and retain water, which leads to slowed recovery of vegetation (Figure 2.4).[103] Livestock can also damage soil crusts, which has serious implications for desert ecosystems. The impact that livestock has on soil structure and plants may negatively affect wildlife that depend on desert vegetation for shelter or food.

Agriculture occupies several hundred thousand acres of land in the California desert (Map 2.5). While agricultural production occurs on private land, ecological impacts can be felt beyond land ownership boundaries. For example, Imperial Valley has been heralded as one of the most productive agricultural areas in the world. In 2008, combined field crop and livestock production in Imperial County grossed almost $1.7 million on approximately 600,000 acres of land.[104] In order to sustain such high productivity in an extremely arid region, the Imperial Valley diverts roughly 2.8 to 3.0 million acre-feet of surface water from the Colorado River per year, water that historically replenished aquifers and sustained natural plant and animal communities.[105] Irrigation practices combined with heavy use of pesticides are responsible for the degradation of river water quality and aquatic ecosystems in the New and Alamo Rivers.[106] In addition, poor water management on agricultural land can increase soil salinity and alkalinity while livestock feed and farming practices can facilitate the spread of invasive plant species.[107,108]

Water Demand

The California desert is relatively lacking in surface water. Reliance on groundwater, therefore, is resulting in overdraft conditions in many groundwater basins that are tapped to support agriculture and municipal uses. In fact, communities in the California desert rely on sources outside of the ecosystem (such as Northern California and the Colorado River) for much of their water use, as many regional sources are depleted or nearly depleted.[109] Surface water diversions up-river may lead to heavier dependence on groundwater basins, and overdraft occurs when water extraction exceeds groundwater recharge. When groundwater levels are low, particularly in valleys characterized by fine-grained sediment, there is a greater risk for land subsidence.[110] Subsidence, or a drop in land-surface elevations, can disrupt surface drainage, reduce aquifer-system storage capacity, form earth fissures, and damage wells, buildings, roads, and utility infrastructure.[111] For example, historical ground water pumping in Antelope Valley, which mainly supported agriculture, contributed to more than six feet of land subsidence by the late 20th century.[112] Agriculture has been replaced by population growth as the major stress on the water source, but efforts have been made to import surface water to the area.[113] While subsidence may have been halted in Antelope Valley, the current surface water resource is also limited; periods of drought could lead to increased ground water withdrawal and potentially renewed subsidence.[114]



Map 2.5 Agricultural and Military Lands in the CDCA.

Linear Corridors

Figure 2.5 Linear Corridor, Mojave National Preserve. Image Credit: Sarah Tomsky.

Linear corridors such as roads and vehicular routes, railways, pipelines, and powerlines create long, narrow corridors of disturbance that can impact land far beyond the actual area of the infrastructure (Figure 2.5). For example, 8,000 km of overhead power transmission lines present in the California desert in 1980 were found to impact more than 69,000 acres of land.[115] In a 2006 study by Boarman and Sazaki, the authors found that desert tortoise (*Gopherus agassizii*) populations were reduced in a zone at least 400 meters from roadways.[116] Direct impacts include destruction of soil and plant cover during construction, and prevention of recovery and revegetation of an area due to infrastructure operation and maintenance.[117]

The California desert contains a wide variety and abundance of vehicular routes, including OHV trails, unimproved and improved local roads, arterial roads, and limited-access highways.[118] In a 2009 study, Brooks and Lair refer to vehicular routes as "one of the most intense and pervasive forms of anthropogenic disturbance in the Mojave Desert."[119] Vehicular routes can impact soils by disturbing soil crusts, changing water runoff patterns, and accelerating soil erosion rates, which impacts plant productivity and composition through an alteration of water and nutrient flow across the landscape.[120,121] These routes can also facilitate human access to natural areas, which can amplify other human-related disturbances such as illegal collection and vandalism of plants and animals.[122,123] In addition, routes can increase air pollution, increase accumulation of pollutants (e.g. heavy metals) in soils and plants, facilitate non-native species invasion, and lead to wildlife mortality.[124]

Potential Major Corridor: The DesertXpress

The DesertXpress, a high-speed passenger train proposed to run between Victorville, California and Las Vegas, Nevada, represents a potentially major new linear corridor running through the California desert. Meant to offer an alternative transportation option for Californians to access Las Vegas, project proponents highlight the need for reduced automobile congestion along Interstate 15. To that end, the rail would generally run alongside I-15, mainly utilizing public Right-of-Way over BLM managed lands.[125] In the Draft EIS Report, prepared by the U.S. Department of Transportation's Federal Railroad Administration in March of 2009, several potential impacts to biological resources were identified if the project proceeds. The impacts of this proposed linear corridor could include (but are not limited to) permanent removal of some special-status plants, loss of suitable desert tortoise (*Gopherus agassizii*) and Mohave ground squirrel (*Spermophilus mohavensis*) habitat, increased habitat fragmentation as a result of added barriers to wildlife movement, and mortality of wildlife during construction phase.[126]

OHV Recreation

OHV use is a popular recreational activity in the California desert. OHVs, also known as ORVs (off-road vehicles), include four-wheel drive trucks and sport-utility vehicles, all-terrain vehicles (ATVs), and dirt bikes. The creation of new, illegal OHV routes is a serious problem on BLM land. A single pass by a vehicle will leave a track, and repeated use of the track can create a visible trail.[127] The inadvertent or intentional creation of new trail networks in desert areas is particularly problematic because the lack of dense vegetation makes it easy for OHVs to drive off-route. Equally challenging for the BLM are closing illegal routes, restoring past damage, and preventing the creation of illegal routes in the first place. OHV use in fragile desert ecosystems destroys soil crusts and soil stabilizers, increases wind and water erosion, contributes to soil compaction, decreases water infiltration into the soil, crushes plant stems, foliage, and roots, and increases noise and air pollution that negatively impacts wildlife.[128] Compacted soils reduce plant and seedling survival by impeding root growth. OHV use in legal recreation areas can also have negative ecological impacts. For example, the Imperial Sand Dunes Recreation Area is an intensively used OHV area that receives over 1.4 million OHV visitors per year.[129] OHV use has been found to negatively impact the survival of an Algodones Dunes endemic plant, the Peirson's milk-vetch (*A. m.* var. *peirsonii*), a threatened species under the Endangered Species Act, causing both short- and long-term damage.[130] OHV use in the Mojave Desert has also been shown to produce noise levels loud enough to cause hearing loss in kangaroo rats (*Dipodomys* spp.), desert iguanas (*Dipsosaurusdorsalis* spp.), and fringe-toed lizards (*Uma* spp.), which may affect species survival.[131] Engine emissions from OHVs are not regulated in the same way as on-road vehicles, and are significant contributors to air pollution, affecting humans and wildlife.[132]

Invasive Species

Invasive plants have a significant impact on native species throughout California. The colonization of natural areas by non-native plants has been facilitated by transportation corridors and habitat disturbances such as OHV recreation, livestock grazing and agriculture.[133] In the California desert, invasive plants compete for resources, such as water and soil nutrients, and can use allelopathic chemicals to inhibit native plant growth.[134] Invasive plants also disrupt natural fire regimes. In riparian areas invasive plants, such as saltcedar (*Tamarix* spp.), pose serious threats to native vegetation and wildlife species.

Military Operations

The military has a large historic and current presence in the California desert. During World War II, the U.S. Army established several temporary camps and training grounds in the Mojave Desert and over a million soldiers have passed through these training facilities.[135] Today active military bases include the National Training Center at Fort Irwin, the Marine Corps Air Ground Combat Center at Twentynine

Palms, China Lake Naval Air Weapons Station, and the Chocolate Mountain Aerial Gunnery Range (Map 2.4).[136] Military bases can provide protection from disturbances by limiting public access to large areas, but military training exercises and infrastructure can also be detrimental to the desert ecosystem. Tent sites, roads, tanks, and vehicles can compact soil, alter soil texture, remove topsoil, alter drainage, and decrease plant density and cover (Figure 2.6).[137]

Figure 2.6 Marine Corps Air Ground Combat Center, Twentynine Palms, CA. Image Credit: Sarah Tomsky.

Mining

In 2008, the State of California supported 717 active non-fuel mines.[138] Mining has occurred in the California desert since the late 1880s and continues to the present day. The CDCA produces a variety of mineral commodities and has “excellent potential” for future production, according to the CDCA Plan.[139,140] Impacts of mining include the construction of pits, ore dumps, and mine tailings, the evaporation of compounds from dry lake mine operations, and exposure of wildlife to radioactive materials.[141] Rare-earth metals, for example, are currently being mined near the town of Mountain Pass in San Bernardino County (Figure 2.7). These rare-earth minerals have many uses; of particular interest is the importance of some of these minerals in the manufacturing of “green” technologies such as hybrid cars, wind turbines and compact fluorescent lightbulbs.[142] In the case of Mountain Pass Mine, impacts have included radioactive wastewater leaks.[143] The mining operation was shut down for several years due to environmental impacts, though it was recently permitted to reopen, following statements from the mining company that these impacts have been resolved.[144] While the mined rare-earth materials are needed for environmentally friendlier energy and transportation alternatives, the resulting environmental impact to produce these technologies is difficult to ignore.

Figure 2.7 Mountain Pass Mine, San Bernardino County. Image Credit: Greg Vojtko

Climate Change

All of the above impacts must also be considered in the context of climate change and its biological and ecological implications. Climate models show a slow warming of the Mojave and Sonoran Desert regions, especially at night.[145] This warming is likely to alter precipitation regimes and weather patterns, which could alter plant cover and productivity, and affect ecosystem functions, species distribution, and community composition.[146,147] Desert ecosystems are particularly sensitive to changes in atmospheric carbon dioxide. Future rises in atmospheric carbon dioxide will affect rates of plant photosynthesis and water loss, and are predicted to increase efficiency and productivity in desert plants.[148,149] Increased plant productivity, especially the productivity of invasive grasses, could increase the incidence of wildfire in the desert.[150,151] Increased variability, more episodic climate events, and more severe and persistent droughts are predicted for desert ecosystems worldwide.[152] Therefore, climate change has implications for plants and their pollinators, wildlife species, and ecosystem processes, and may exacerbate impacts from current stressors.

Addressing climate change may include a transition from fossil fuel-based energy generation to renewable energy sources. Given this, utility-scale solar facilities may be one way for California to meet its growing energy needs while also reducing greenhouse gas emissions. However, the sensitivity of desert ecology must be considered in the decision-making process, especially given the existing stressors on the ecosystems. In order to understand how solar development may affect desert ecology, it is necessary to know how these ecological processes function and why they are important. Having provided this information above, our ecological impact analyses in Chapters 5 and 6 can be understood in the context of this broader ecosystem functioning.

CHAPTER 3 | UTILITY-SCALE SOLAR TECHNOLOGIES

The type of technology chosen for a utility-scale solar project influences a project's efficiency as well as its ecological impacts. This chapter describes in detail the various technologies currently proposed in right-of-way applications as well as several that are currently in development. Also included is a discussion of the key considerations project developers take into account when selecting the type of technology to be used for a utility-scale solar project. Subsequent chapters will focus on the ecological impact implications of these utility-scale facilities.

SOLAR TECHNOLOGIES

Of the 54 right-of-way applications the BLM is currently reviewing for approval, roughly 60 percent call for the use of concentrated solar power (CSP), also referred to as solar thermal power, and the other 40 percent propose the use of PV technology.[153] There are three main types of CSP technologies (parabolic trough, power tower, and dish/engine), and three main types of PV technologies (flat plate, thin film, and concentrating PV) developers consider when scoping a utility-scale solar project. These systems are ideal for bulk electricity generation because they are designed to produce power on a utility scale, which is orders of magnitude greater than distributed generation or rooftop systems. While there is currently no set definition of utility-scale solar, these facilities generally have a nameplate capacity of over 50 MW and produce electricity that is fed back into the electric grid. In order to generate this amount of power, utility-scale solar power plants require large parcels of land along with access to either surface or groundwater, especially if the facility has an associated cooling system. A value called the capacity factor is used to describe the overall efficiency of a power generation facility. The capacity factor is defined as the ratio between the actual output of a power plant and the maximum rated output, or nameplate capacity. It is calculated by measuring the total energy produced over a period of time and dividing by the amount of energy the plant would have produced over the same period of time at full capacity. For CSP and PV plants, the capacity factor is dependent primarily on the availability of the sun's energy over a given period.

What follows are detailed descriptions of the various solar technologies mentioned above, including a discussion of various cooling system types developers are considering for use in utility-scale facilities. A complete list of utility-scale solar projects in operation or development for the region is included in Appendix B.

Concentrated Solar Power (CSP)

Parabolic Trough

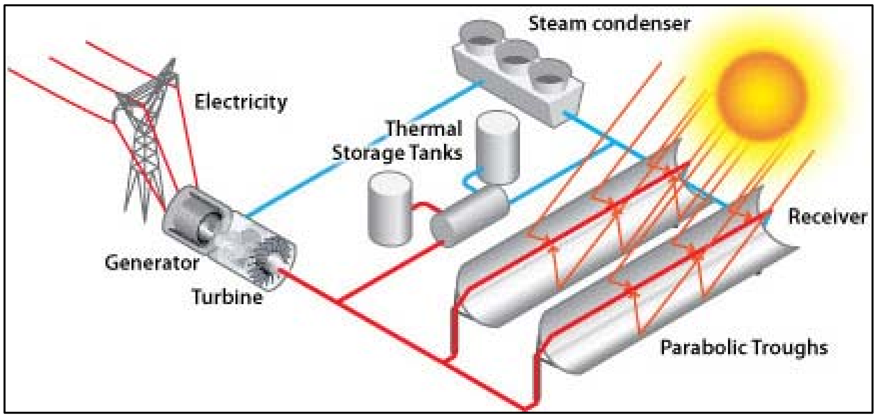


Figure 3.1 Linear Concentrator Power Plant Using Parabolic Trough Collectors. Source: U.S. Department of Energy. http://www1.eere.energy.gov/solar/linear_concentrators.html.

As was mentioned earlier, roughly 60 percent of the applications under review by the BLM call for the use of a parabolic trough system (Figure 3.1). These systems are composed of long parabolic shaped mirrors, a receiver tube that runs the length of the mirrors, a tracking support structure and drive components that control the movement of the collector throughout the day in relationship to the position of the sun. Altogether these components are called a solar collector assembly (SCA). The SCA's can sit approximately 25 to 30 feet above ground. The parabolic mirrors are made of 4-millimeter thick glass with high transmittance properties and include a reflective silver layer on the backside of the glass.[154] The mirrors are shaped in a parabola such that the sun's light is directed to a focal point where the energy is concentrated onto to the linear receiver, or heat collection element (HCE). The HCE is a stainless steel tube with a specific diameter and is coated with a special solar-selective absorber surface to maximize efficient transfer of heat from the sun's energy to the heat transfer fluid (HTF) traveling inside the tube. The HTF is usually comprised of a either a high-temperature oil or a mixture of water and ethylene glycol.[155] The heated transfer fluid is supplied to the power plant where it passes through a series of heat exchangers, turning water into high-pressure steam that drives a Rankine steam turbine. The HTF is then returned to the solar collector field to be heated once again, creating a closed loop system. Parabolic trough plants achieve at least a 25 percent[156] capacity factor, which means about a quarter of the sun's energy that is captured by the system is converted to usable electricity.

Power Tower

There are also several applications in with the BLM that call for the use of Power tower systems (Figure 3.2). These systems use a large field of mirrors called heliostats that track the sun and concentrate the light onto a central receiver on top of tower. Tower heights range from approximately 300 to 650 feet. Tower height and field size vary depending on individual project economics. An economic optimization analysis takes into consideration the capacity factor and capital costs. The amount of solar energy collected is a function of the number of heliostats installed. However, as the number of installed mirrors increases, the height of the tower must also increase. Determining the optimal tower height

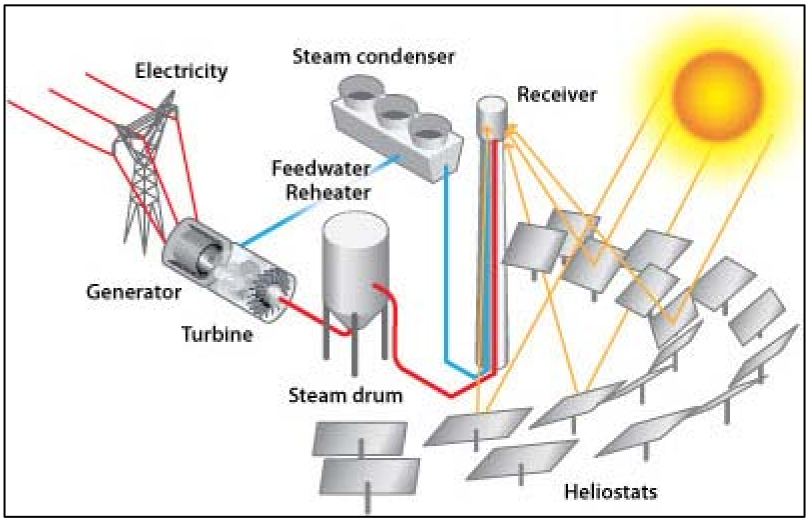


Figure 3.2 Power Tower Power Plant. Source: U.S. Department of Energy. http://www1.eere.energy.gov/solar/linear_concentrators.html.

and field size is driven by economies of scale. It is relatively inexpensive to increase equipment size once a project has incurred its initial fixed costs of installation. Larger plants, therefore, tend to be more economical. Additionally, the heliostats can be mounted in ground with up to five percent slope because they do not rely on a linear collector to heat the HTF. Like the parabolic trough systems, HTF is an integral part of the power tower system. The HTF is composed of either water or molten nitrate salt and as it moves through the receiver it is heated to temperatures over 500 °C. The heated HTF is then sent to a heat exchanger where water is turned into steam, which then drives a turbine generator. More advanced systems that use molten salt as the HTF can take advantage of the higher heat capacity of the fluid and can store the heat energy, which allows the system to continue to generate electricity during cloudy weather or at night. Thermal storage allows systems to continue to generate electricity for several hours longer compared to those without, which effectively increases a power tower's capacity factor from 34 to over 40 percent.[157] Additionally, power tower systems typically employ dry cooling as opposed to wet cooling technology, requiring less water to operate the plant.

Dish/engine

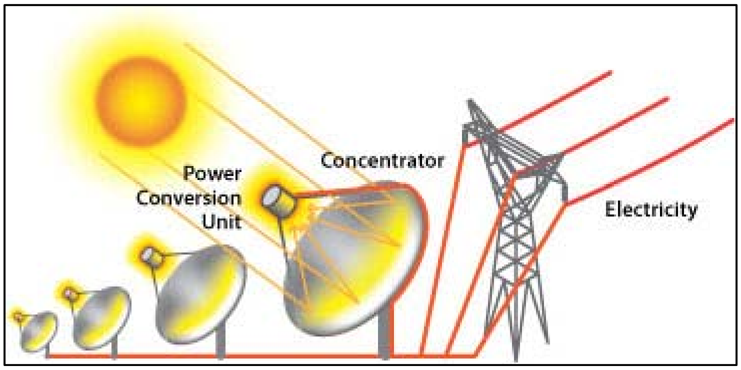


Figure 3.3 Dish Engine Power Plant. Source: U.S. Department of Energy. http://www1.eere.energy.gov/solar/linear_concentrators.html.

There are also a few applications in with the BLM that call for the use of dish/engine systems (Figure 3.3). These systems consist of a large mirrored dish (also known as a solar collector), a receiver, and a small engine. The dish is mounted on a tracking system that follows the sun throughout the day and focuses sunlight onto the receiver. The receiver consists of a series of tubes that are filled with a heat transfer medium. The medium is usually either hydrogen or helium. Concentrated sunlight heats the fluid in the receiver and transfers energy to the engine. A Sterling engine is the most common type of heat engine used in dish/engine systems. These systems use the heated fluid to move pistons and create mechanical power. The mechanical power is then used to run a generator to produce electricity.[158] The waste heat from the engine is dissipated by a radiator system similar to one found in a car. The cooled medium is then recycled to the engine and the process repeats. To date there are no large installations of dish/engine systems in operation and therefore a capacity factor figure is not available. However, a leading Sterling engine system manufacturer has achieved a dish/engine system efficiency of about 31 percent.[159] Using this value as a proxy, a comparison of capacity factors of the various concentrated solar power technologies is summarized in Table 3.1.

Table 3.1 Concentrated Solar Power Technology Efficiency Comparison.

Technology Type	Capacity factor (%)
Parabolic Trough	25
Power Tower	34
Dish/Engine	31

Linear Fresnel lens

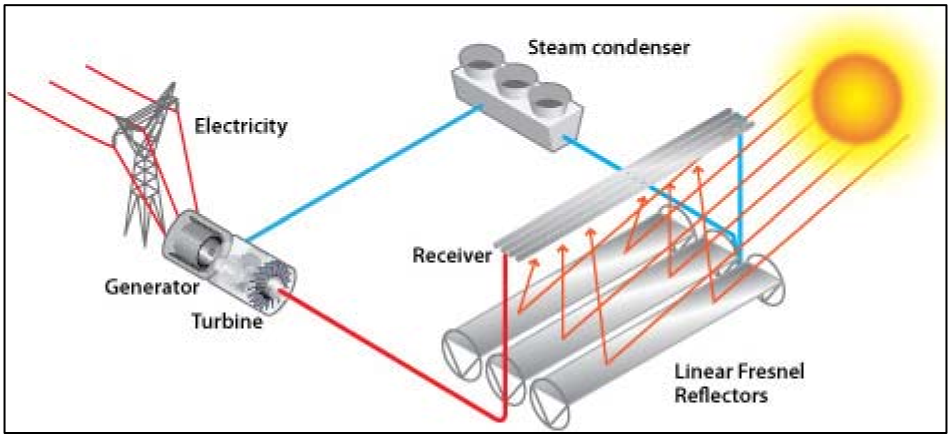


Figure 3.4 Linear Fresnel Reflector Power Plant. Source: U.S. Department of Energy. http://www1.eere.energy.gov/solar/linear_concentrators.html.

One technology that should be monitored, but does not yet appear in any applications, is a Linear Fresnel reflector systems (Figure 3.4). These systems are similar to parabolic trough systems in that a set of mirrors reflects the sun's energy onto a linear receiver. The major difference is that with a Fresnel system the mirrors are either flat or slightly curved and are mounted on a tracker that focuses the sun light onto a fixed receiver tube system that sits above the mirrors. A central receiver, the tallest component in this system, rises approximately 50 feet above the ground. Few power plants using this technology have been installed and therefore little data is available related to plant efficiency and operational reliability. However, with efficiency improvements on the horizon, more attention is being given to this technology.[160] Linear Fresnel systems have lower production costs due to the use of flat mirrors compared to the curved mirrors used in parabolic trough systems. Another major difference is that water can be converted directly into steam in the long receiver tubes, negating the need to install additional heat exchange equipment. If the plant economics are found to be favorable or if linear Fresnel plant efficiencies can be increased to a point where it is comparable to parabolic systems, then these systems may become the dominant technology type found in utility-scale solar plant facilities.

Photovoltaic (PV)

Roughly 40 percent of the applications submitted to the BLM call for the use of photovoltaic technology. Photovoltaic power generation is one of the cleanest and environmentally benign methods of generating electricity. During operation, it does not produce emissions or hazardous waste and does not consume water. These types of systems are attractive to utility power providers because they are generally easier to construct and install compared to conventional fossil or nuclear power plants. They can also be more easily expanded as demand increases. The two main types of PV technologies that are being considered for utility-scale solar power generation today are flat plate and thin film PV.

Flat Plate Photovoltaics (PV)

According to the DOE, the most common solar array designs use flat plate PV modules (Figure 3.5).[161] Flat plate PV modules are used in fixed systems or integrated into more sophisticated designs that include tracking systems that follow the sun's trajectory across the horizon throughout the day. Flat plate PV devices can be made of various types of semiconductor materials, the most common of which is silicon. Silicon can be single (or mono)-crystalline, multicrystalline or amorphous. Crystallinity is a measure of how perfectly ordered the atoms are in the crystal structure. Most flat plate PV modules use solar cells that are made from either single-crystalline or amorphous silicon. Single-crystalline silicon is composed of a very uniform crystal structure and is ideal for conducting electrons through the material. Solar cells made from this type of silicon are usually more efficient but also tend to be the most expensive because of the purity of silicon material. Solar panels that utilize amorphous silicon solar cells are currently the most common and are usually cheaper; however, they yield lower energy conversion efficiency. To date, crystalline silicon-based flat plate PV technology is able to achieve module conversion efficiencies between 15 and 20 percent.[162] Module conversion efficiency is a measure of how effectively the sun's energy is converted directly to electricity by the collection of solar cells that make up a single modular unit. At these performance levels, some solar companies have determined that there is a business case for developing large utility-scale solar facilities using flat plate PV technology.

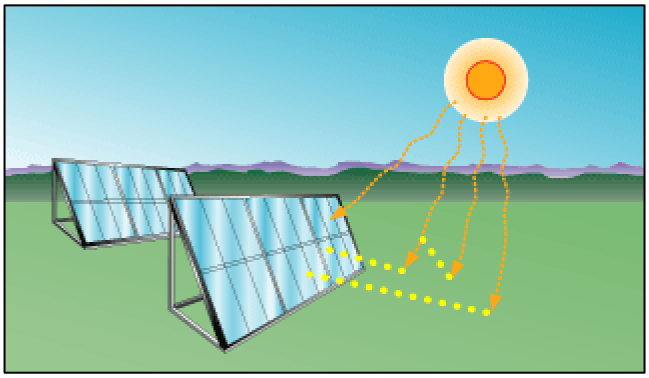


Figure 3.5 Flat Plate Photovoltaic Modules. Source: U.S. Department of Energy. http://www1.eere.energy.gov/solar/linear_concentrators.html

Thin Film PV

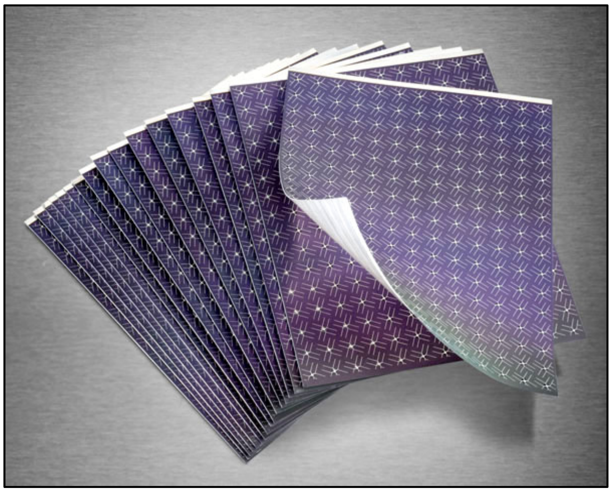


Figure 3.6 Nanasolar Thin Film Solar Cells. Source: Nanosolar http://www.nanosolar.com/technology/technology-platforml.

Thin film photovoltaic cells (Figure 3.6) are usually made of a certain type of polycrystalline material. The three most common thin film materials are amorphous silicon (a-Si), copper indium diselenide (CIS) and its alloys, or cadmium telluride (CdTe).[163] Thin film solar cells are produced by depositing very thin consecutive layers of atoms on a flexible substrate. Substrate material can be either glass, stainless steel or various types polymers. Thin films use much less material during production compared to silicon-based solar cells and can be manufactured in large-area automated continuous-process equipment. One method of production employs roll-to-roll printing technology which further reduces the cost of manufacturing. Thin film production costs approximately half that of silicon-wafer based solar cell production.[164] The trade off is that thin film PV cells are significantly less efficient compared to single or amorphous-crystalline silicon solar cells. CdTe based thin film solar cell module efficiency is currently around 13 percent[165], the highest of the three material types. CIS produce modules with an efficiency around 10 percent and a-Si around 8 percent.[166] However, research and development in this area is constantly pushing the efficiency of thin film solar cells closer to that of conventional silicon based PV.

Concentrating Photovoltaic (CPV)

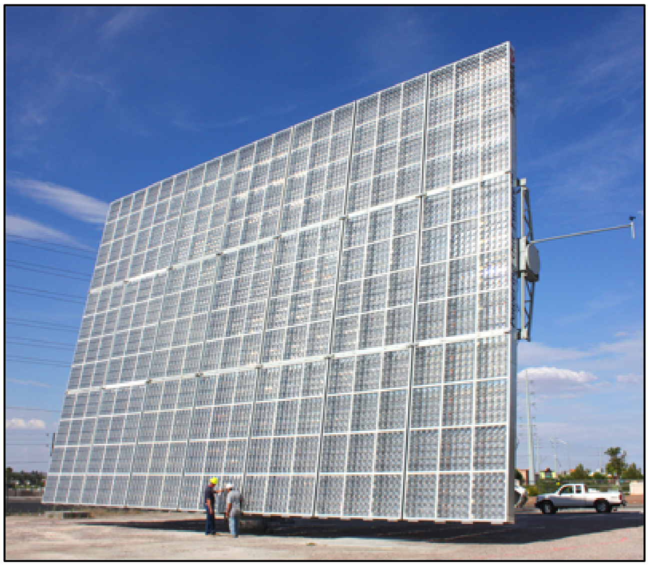


Figure 3.7 Amonix Solar Concentrating PV Module. Source: Amonix Solar http://www.amonix.com/products/index.html.

Several concentrating photovoltaic system companies are developing technology that can also be used for utility-scale solar electricity generation, however, none of the applications currently proposed for BLM land call for this technology. CPV systems (Figure 3.7) employ either a large dish of reflective mirrors or concentrating lenses that direct sunlight onto a photovoltaic surface which produces electricity directly from the sun's energy. Either module is installed on a high-precision dual-axis tracking system which ensures optimal operation throughout the day. These systems can be configured to concentrate the sun's energy between two to 500 times. High concentration PV (HCPV) systems favor the use of high efficiency, multi-junction solar cell technology because efficiency of these cells rises faster with concentration than do conventional silicon based solar cells. CPV systems have only recently been installed in utility-scale facilities, and therefore system reliability and lifetime performance data is sparse. However, commercially available CPV systems have demonstrated energy conversion efficiencies of approximately 29 percent.[167] A comparison of module efficiencies of the various photovoltaic technologies is summarized in Table 3.2.

Table 3.2 Photovoltaic Solar Technology Efficiency Comparison.

Technology Type	Module efficiency (%)
Flat Plate PV	15
Concentrating PV	29
Thin Film	
CdTe	13
CIS	10
a-Si	8

COOLING SYSTEMS

Solar power plant operation relies on water for a number of functions, but none is as intensive as the cooling system. The amount of water consumed largely depends on the type of cooling system technology employed: wet, dry, or hybrid. Of the eight applications currently under review by the BLM that propose the use either parabolic trough or power tower technology, three plan to install "wet" cooling systems while the other five remaining plan to install "dry" cooling systems. Parabolic trough and power tower technologies use the power of the sun to drive steam turbine generators which necessitate the use of a cooling system to complete the power generation cycle. Dish/engine and photovoltaic systems, on the other hand, generate electricity directly from the sun's energy and therefore do not require the use of a cooling system during operation. The main source of water consumption for these systems is related to mirror washing.

Wet Cooling

Wet cooling tower (also called "Evaporative cooling" or "Wet re-circulating")

Wet cooling systems (Figure 3.8) are the most common technology in new power plants.[168] Waste heat is dissipated to air via evaporation of cooling water. The difference between the wet bulb temperature of the liquid and the dry bulb temperature of the surrounding air determines the potential for evaporative cooling. Consequently, a greater difference between these two temperatures results in greater evaporative cooling effect. This thermodynamic property is the reason why wet cooling systems perform better in areas with high ambient temperatures greater than 110 °F, compared to air cooled systems. These systems withdraw between 300 and 700 gallons per MWh, but all of the water withdrawn is consumed.[169] The water treatment chemicals and minerals found in the cooling water become more concentrated as the re-circulated liquid evaporates over time. In order to remove particulates and reduce the concentration of salt in the water found in the catch basin, part of the water is discharged (called "blowdown") and replenished (called "makeup water") from either surface or ground water supplies. The blowdown is collected in evaporation ponds, which are double-lined to reduce the risk of contaminated water leakage. Some applications include pond designs that do not require the removal of residual solids over the life of the power generation plant. Others account for periodic removal and land-fill disposal of the solids. Several applications call out more specific design requirements that are in accordance with the local Water Quality Control Board. Details include:

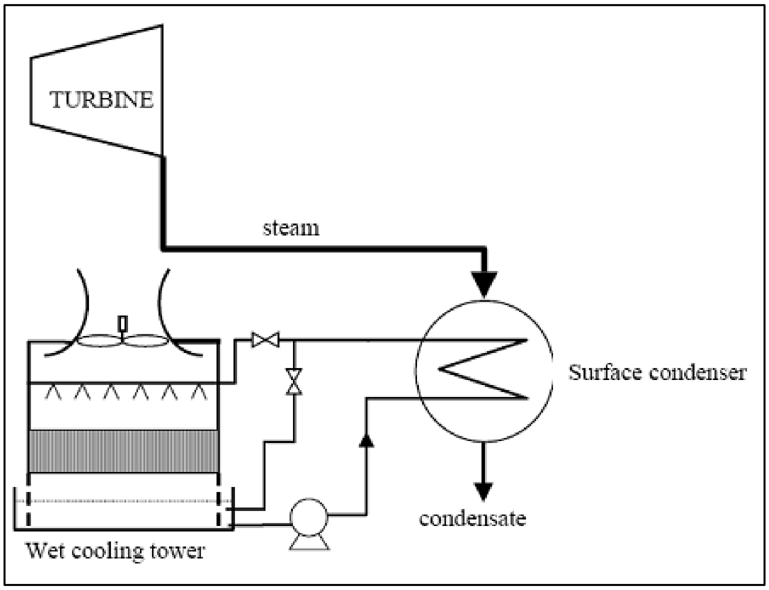


Figure 3.8 Schematic of Wet Cooling System. Source: U.S. Department of Energy.

- 60 millimeter thickness liner
- High density polyethylene material
- Synthetic drainage net between double lining as part of the leachate collection and removal system (LCRS)

Monitoring of these ponds to detect the presence of liquid and/or constituents of concern is also required according to the CEC. Some applications call out monitoring of the LCRS along with sampling from existing onsite wells. Constituents of concern that are to be monitored include chloride, sodium, sulfate, TDS, biphenyl, diphenyl oxide, potassium, selenium and phosphate.

Once-through

Clean Water Act regulations prohibit the use of once-through cooling for new power plants due to environmental concerns[170] and are not relevant for this context of new solar development in California, and therefore, are not discussed in detail in this report.

Dry Cooling

Air cooled condenser (ACC)

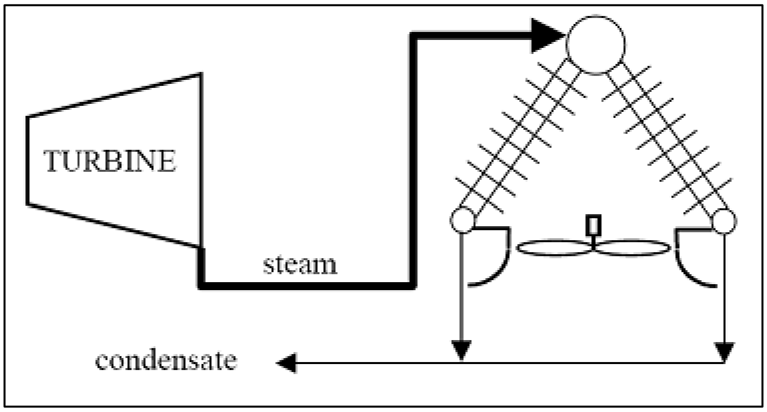


Figure 3.9 Schematic of Dry Cooling System. Source: U.S. Department of Energy.

Dry cooling systems (Figure 3.9) can be categorized as either direct or indirect. Air cooled condensers (ACC) are an example of a direct dry cooling system. For ACC systems, steam from the turbine is routed directly to an array of A-framed tubes and a fan blows air directly across the array, convectively condensing the steam.[171] Dry cooling systems use approximately 95 percent less water than wet systems[172], and are becoming more common in thermal power plants. But they require higher capital costs, higher auxiliary operating power, and result in lower overall power plant performance, especially on hot days when peak power is needed most.[173] According to one study by the National Renewable Energy Laboratory, dry cooling systems impose a seven to nine percent penalty on the levelized cost of energy.[174]

Indirect dry cooling (Heller System)

Indirect cooling, or Heller systems use air as a secondary cooling medium. The primary cooling medium is still water, but the cooling water flows in a closed system and is never in contact with the cooling air. The heat transfer between air and cooling water is achieved with convection rather than evaporation as in wet cooling systems. An additional advantage is that Heller Systems do not require makeup water and have been found to consume roughly 97 percent less water than wet cooling systems with minimal impact on plant performance - roughly one percent increase in levelized cost of electricity.[175] The tradeoffs are a higher initial investment cost and higher long term operating costs.

Hybrid Cooling

Though largely not used in the United States, hybrid systems (Figure 3.10) involve both wet and dry units that run in parallel or use water to cool air going to the air-cooled condenser. In a parallel cooling system, the dry unit is the primary heat rejection system and is used exclusively for the majority of the time during operation.[176] When the ambient air temperature reaches higher temperatures typical of a summer day in the desert Southwest, part of the steam leaving the turbine generator is routed to a wet cooling unit. By reducing the load on the air-cooled condenser, the dry unit can bring the condenser steam temperature closer to the design condenser temperature on hotter days.[177] Hybrid systems have been found to reduce water consumption by 50 percent with only a one percent drop in annual electricity output.[178] Hybrid systems that reduce water consumption compared to wet cooled systems and provide enhanced performance in warmer climates compared to dry cooled systems are of great interest for CSP applications. Hybrid cooling systems aimed at plume abatement involve the reduction of the water vapor plume from a cooling tower to eliminate the appearance of the plume or to avoid winter icing on nearby roads.[179] This is less of a concern for CSP systems in the arid climate of the Southwestern United States.

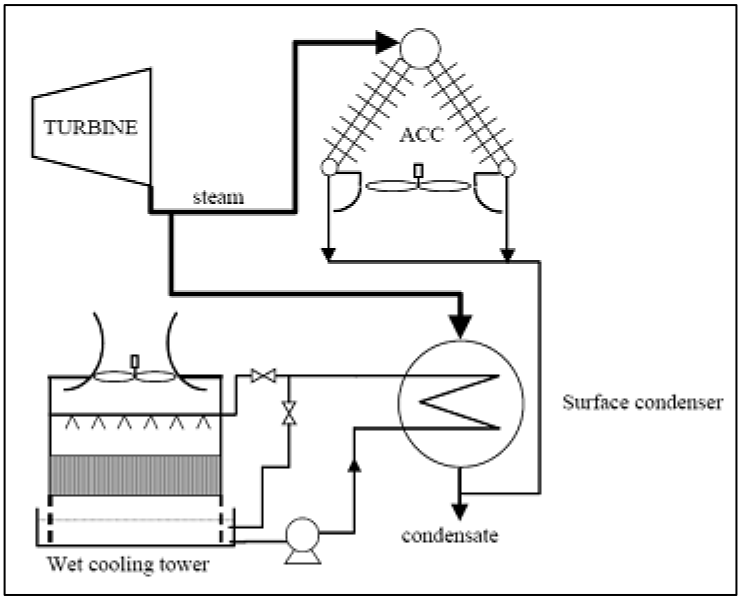


Figure 3.10 Schematic of Hybrid Cooling System. Source: U.S. Department of Energy.

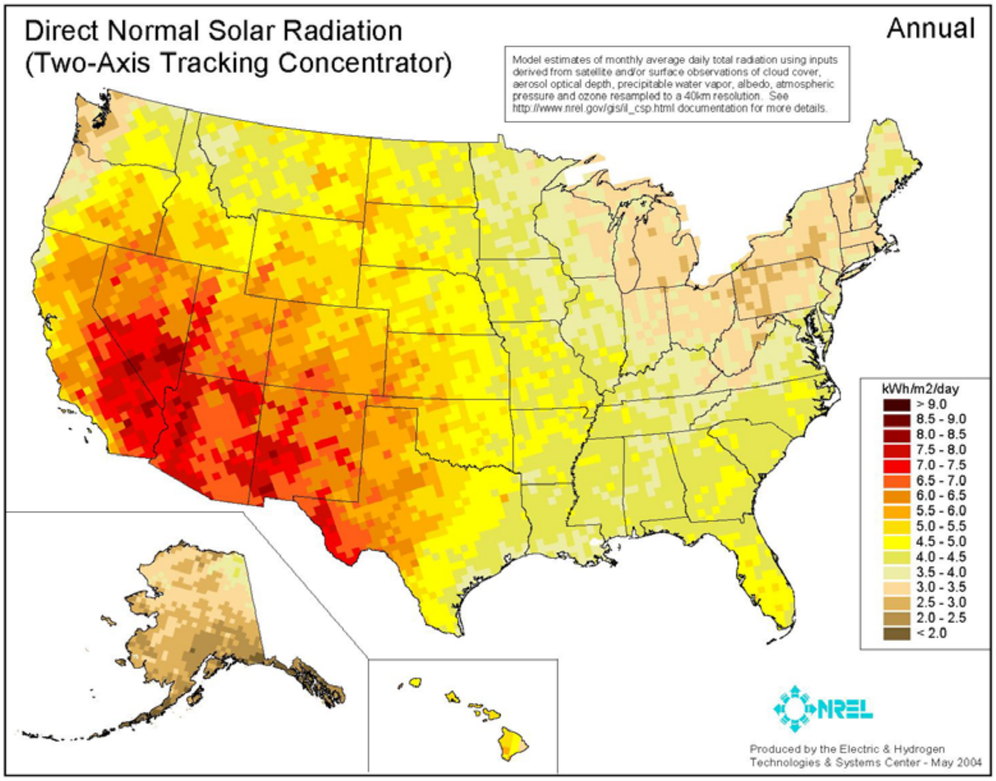
KEY CONSIDERATIONS OF DEVELOPERS

Over the course of nine interviews we conducted with industry experts and solar developers, we determined three key items developers consider when selecting a technology: technological maturity, solar resource at the location of the proposed facility, and cost of installation.

1. Technology maturity: The level of technological maturity was brought up as a key consideration. The relatively long operational history associated with parabolic trough technology was mentioned by one solar developer as the primary reason why their company has chosen CSP technology over all others.[180] Starting with the SEGS I demonstration project back in 1984 through the 1990s with SEGS II through IX, parabolic trough technology has been generating electricity in the California desert for over 25 years. In contrast, while the original concept of the Stirling engine was conceived in the 1800s, this technology has only been applied to solar power production since Stirling Energy Systems, a Scottsdale, Arizona-based systems and integration management company, began serious development in 1996. Additionally, to date, only a 1.5 MW demonstration Stirling Engine facility has been installed. Similarly, photovoltaic technology has experienced only marginal penetration into the utility-scale power generation market, despite being used for various power generation applications since the 1960s, primarily because solar cell manufacturing costs have been too high. However, with increased utility rates and bolstered manufacturing capability, the photovoltaic industry has experienced tremendous growth over the past 15 years[181], which also provides an

indication why roughly 40 percent of the applications submitted to the BLM for review use photovoltaic technology.

2. Solar resource: The solar resource at a given location has a direct impact on the power generating capability of any solar technology system. As discussed earlier, the California desert hosts some of the best solar resource in the world; however, it is not evenly distributed across all regions (Map 3.1). Even within the broader context of the desert region, a 10 percent change in solar resource can occur within a few miles of two different locations.[182] Therefore, in order to produce the same amount of electricity, a 10 percent decline in solar resource translates to a 10 percent increase in facility size, which can lead to cost and other impact implications.



Map 3.1 United States Solar Radiation Resource Map. Source: U.S. Department of Energy.

3. Cost of installation: And finally, the last key consideration for developers is cost. Table 3.1 summarizes installed costs for the various technology options currently available for utility-scale solar facilities. Most technologies included in this list cost the same to install; however, dish/engine systems have a noticeably wider cost range and flat plate PV systems have a minimum cost three times higher most other technologies. Using the 13 Applications for Certification (AFC) that are publicly available for viewing as an indicator of developer preference, two projects each call out the use of power tower, dish/engine and thin film PV technology, while the remaining seven use parabolic trough technology (Table 3.3).

Table 3.3 Installed Cost of Various Utility-Scale Solar Technologies.

Technology Type	# of proposed projects	Installed cost ($/W)
Parabolic Trough	7	3 - 6[183]
Power Tower	2	2 - 5[184]
Dish/Engine	2	2 - 50[185]
Flat plate PV	0	6 - 10[186]
Thin Film PV	2	3 - 5[187]

One factor that is no longer much of a consideration for developers is cooling system type. In September of 2009, the California Energy Commission passed down guidance restricting the use of “wet” cooled systems and mandating the use of “dry” cooled systems for new power generation facilities built in California. However, because applications were submitted prior to the publication of the CEC report, some projects still include plans for the installation of a “wet” cooled system. Therefore, a brief discussion of the tradeoffs related to various cooling system types is warranted. The CEC commissioned an external consultant to research economic, environmental and other tradeoffs. Some of the key findings are summarized in the Table 3.4.

Table 3.4 Tradeoffs of Various Cooling System Technologies.[188]

Tradeoff	“Wet”	“Dry”	Hybrid - Plume abating	Hybrid - Water conserving
Water Consumption	600 to 900 Gal/MWh	~5 percent of “Wet”	Equal to “Wet”	20 to 80 percent of “Wet”
Capital Cost	BASE	1.5x to 3x Base	1.1x to 1.5x Base	3x to 5x Base
Performance Penalty	BASE	5 to 20 percent capacity loss	Equal to Base	Highly variable

CHAPTER 4 | POLICIES PROMOTING UTILITY-SCALE SOLAR DEVELOPMENT ON PUBLIC LANDS

The high level of interest in solar development of the California desert and the urgent need to determine appropriate siting criteria and land use policies necessitates an understanding of what is driving solar developers to choose this area and which political and economic factors can lead to success or failure of project development. Utility-scale solar projects are eligible for multiple economic incentives from both the state and federal governments. Additionally, state and federal laws and policies have incentivized the use of public lands for renewable energy development.

ECONOMIC DRIVERS OF UTILITY SCALE SOLAR DEVELOPMENT

Solar development benefits economic development while providing an alternative to fossil-fuel based energy sources, and the industry has been growing steadily over the last several years. Yet, solar electricity is still more expensive than traditional energy sources due to the material costs of an installation. Policy measures intended to accelerate solar development and lower costs through economies of scale and advanced technologies have created an industry dependent on and driven by subsidies and incentives. In order to better understand the interactions between policy decisions, siting decisions, economic incentives and market development, we will outline a brief history of key federal and state political milestones and track them against growth of the solar market. Through this lens we will discuss the barriers and drivers of utility-scale solar development.

Early Stages of Utility-Scale Solar Development: A History of SEGS

During the late 1980s and early 1990s, a series of solar thermal generation facilities located in San Bernardino County, California, known as Solar Energy Generating Facilities, or SEGS, I-XII dominated utility-scale solar development in California. Other CSP projects at the time included the 10 MW Solar One central tower research facility, completed in 1981 and operational from 1982 to 1986; Solar Two, which added additional mirrors to Solar One and operated from 1995 to 1999; a 3.19 MW PV system built by the Sacramento Municipal Utility that went on line in August 1984; and the 110 MW Solar 100 project certified by the CEC in 1982 that was never built due to land use issues.[189] The completed projects accounted for about 0.8 percent of California's energy generation capacity in 1991[190] and the SEGS projects alone accounted for 95 percent of the world's solar electricity generation.[191] Although the proposed SEGS projects totaled 594 MW in capacity, only 354 MW of capacity came on line before the developer filed for bankruptcy in 1991. The developer, Luz International Limited, cites a number of policies that contributed to the failure:[192]

- The Public Utilities Regulatory Policies Act (PURPA), passed by Congress 1978, required local utilities to grant grid interconnection access to independent power generators, which stimulated utility-scale solar development. However, PURPA capped the amount of energy that a generating facility could sell at 30 MW. Although this cap was raised to 80 MW in 1989, Luz was forced to build a series of facilities that were less efficient and more expensive per MW than the optimal 200 MW capacity.
- PURPA also required utilities to purchase energy produced by non-utility-owned generating facilities. The California Energy Pricing Policy for solar energy was based on the avoided cost of producing electricity from oil or natural gas, whichever was lower. Although improved technology brought the solar electricity cost down to $0.08 per kWh, gas prices dropped 80 percent between 1981 and 1989 and oil prices fell to $18 a barrel. The avoided cost pricing policy brought the purchase price down to $0.05 per kWh, making more expensive solar projects economically infeasible.
- Annual energy tax credit cycles severely limited the company's ability to secure long-term funding from investors. Each calendar year Luz had to race to obtain site approval, secure financing and complete a facility. In 1989, the tax credit period was cut to nine months and, as a result, Luz endured a cost overrun that consumed two-thirds of their remaining capital.

The failure to complete all of the Luz SEGS projects was due to an unrealistic timeline for tax credit cycles and an electric purchase pricing policy tied to volatile commodity market prices. Conditions remained unfavorable for utility-scale solar development until the 2005 Energy Policy Act increased and extended renewable energy tax credits.

Changing Federal Incentives

Between 1981 and 1989, The Reagan Administration cut funding for renewable energy research and development by nearly 90 percent (Figure 4.1) which left the solar industry unable to continue development of technologies that could compete with lower cost, fossil fuel based sources of energy. For the next decade, while the United States experienced rapid economic development and enjoyed relatively low oil and natural gas costs (Figure 4.2), utility-scale solar developers were on hiatus. The shift in the willingness to invest in renewable energy generation came about in the late 1990s as scientists continued to issue dire warnings about climate change and energy analysts forecasted rapidly rising oil costs tied to peak oil predictions. The September 11, 2001 terrorist attacks further encouraged politicians to renew their efforts to improve energy security and protect against geopolitical risks and rapidly rising oil prices by introducing bills to address climate change and promote renewable energy development.

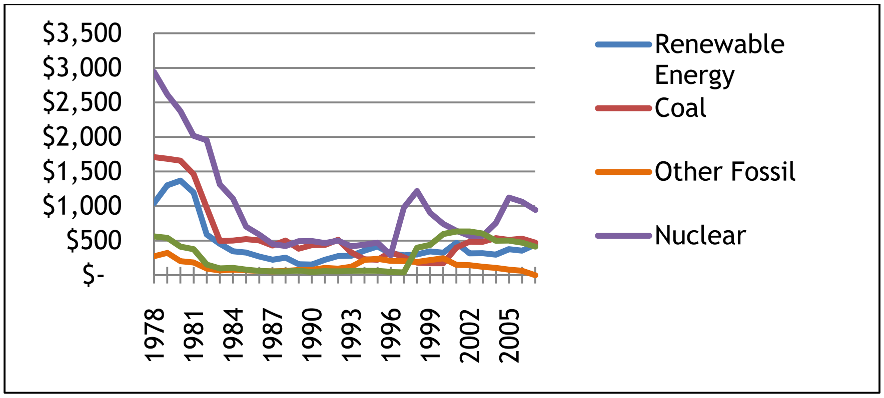


Figure 4.1 Department of Energy Research and Development Expenditures, 1978-2007 (million 2007 dollars). Federal energy research and development expenditures (along with tax incentives and direct subsidies) are intended to accelerate development of cost-effective technologies and bring them to market sooner than if R&D is funded by the private sector alone. President Reagan cut energy research and development budgets by nearly 90 percent and eliminated renewable energy production tax incentives when he took office in 1981. Data Source: Energy Information Administration.[193]

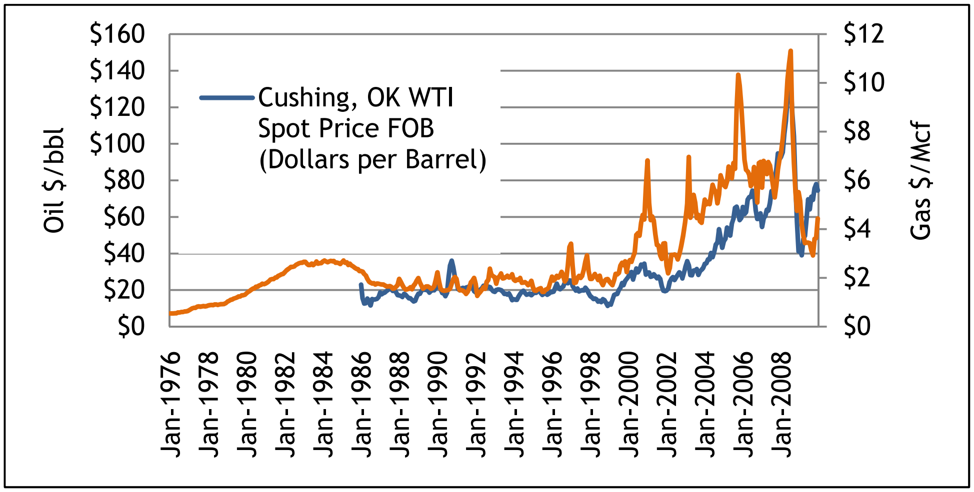


Figure 4.2 Oil and Natural Gas Prices, 1976-2009. With the passage of the Public Utilities Regulatory Policies Act, the California Energy Pricing Policy tied prices for utility-scale solar energy generation to natural gas and oil prices for energy generation. When prices remained low throughout the 1990s, solar developers could not compete with the low cost of fossil fuel-based energy generation until federal and state tax incentives and subsidies improved the marketability of solar energy for both utility-scale and distributed generation. Data Source: Energy Information Administration.[194, 195]

Several acts passed by Congress in the following years significantly increased funding and incentives available to state governments and developers for renewable energy programs and projects (Table 4.1). The Energy Policy Act of 2005 gave a short term boost to the developers and investors waiting for better economic incentives to build utility-scale solar facilities by increasing tax incentives available to commercial developers from 10 to 30 percent for a period of two years and by extending the production tax credit through 2007. Although this helped stimulate the market, the timeframe for the

Table 4.1 Federal Policies Impacting Solar Development. [196, 197, 198, 199]

	Investment Tax Credits	Production Tax Credits	Renewable Energy Grants	Loan Guarantees	Clean Renewable Energy Bonds	Direct Spending Measures
2005 Energy Policy Act	Increased the commercial solar investment tax credit from 10 percent to 30 percent for 2 years	Extended renewable energy production tax credit of $.019/kWh for first ten years of operation through 2007			Allocated a total of $1.2 billion over 2 years for non-taxable entities that could not use ITC or other tax benefits ($84 million for solar in 2007)	
2008 Energy Improvement and Extension Act	Extended commercial 30 percent investment tax credit for solar energy through 2016. Allowed using ITCs to offset alternative minimum tax	Extended the placed-in service date for production tax credit for solar facilities through December 31, 2010			Authorized an additional $2.4 billion for a period of 3 years ($839 for solar)	
2009 American Recovery and Reinvestment Act	Established 30 percent advanced energy manufacturing credits for manufacturing facility retrofits; Repealed subsidized energy financing limitation on investment tax credit		Established 30 percent grant program in lieu of investment tax credit for facility construction beginning in 2009 or 2010.	Established renewable energy loan guarantee program for generation and transmission projects underway by September 30, 2011		Appropriates direct spending for renewable energy projects, grid development, research and development

incentives was not long enough to provide certainty to developers since projects could take many years to complete and come on line. Without certainty about tax incentives and their impacts on the project development costs, utility-scale solar development remained sluggish.

Between 2002 and 2007, tax expenditures for renewable energy increased from $238 million to $790 million.[200] For example, tax expenditures for Clean Renewable Energy Bonds (CREBS) were appropriated as part of the Energy Policy Act and the American Recovery and Reinvestment Act. CREBS are one tax mechanism whereby tax exempt entities may issue interest-free bonds. The government or public utility issuing the bond pays back only the principal while the bond holder receives a tax credit in lieu of interest payments. Although direct spending for renewable energy research and development declined slightly between 2002 and 2006, 2007 appropriations grew by 23 percent over 2002 amounts, including an increase from $99 million for solar energy in 2006 to $203 million in 2007 (Figure 4.1).[201] Returns associated with solar stock investments grew through the fall of 2008, reflecting optimism among investors until the collapse of the banking industry caused sources of private capital necessary for a new solar industry to dry up practically overnight (Figure 4.3).[202] The Energy Improvement and Extension Act of 2008, passed on October 3, created some certainty about access to financing by extending production and investment tax incentives, which eventually helped lure investors back to utility-scale solar energy projects. By 2009, with the passage of the American Recovery and Reinvestment Act, federal investment programs such DOE’s Solar Energy Technologies Program (SETP) also provided significant support for renewable energy implementation by focusing on market transformation, systems integration, CSP deployment, and PV development (Table 4.2, Figure 4.4). The SETP is partnering with the BLM to develop the Solar PEIS in order to promote successful project development.

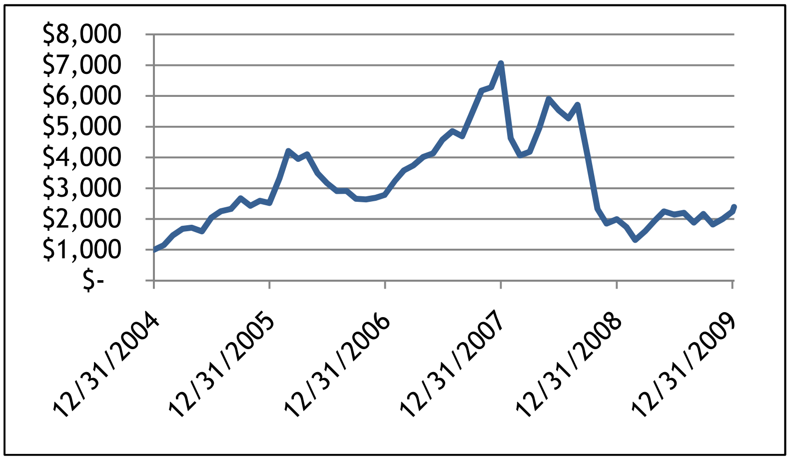


Figure 4.3 Ardour Global Solar Energy Index Total Returns in $US. Returns for investors in solar energy dropped following the credit crisis of 2008 and developers suffered from the loss of private capital for project development.

Table 4.2 Subprograms of the DOE’s Solar Energy Technologies Program.[203]

Market Transformation	•Address non-R&D barriers to solar energy adoption •Partner with various organizations to develop codes and standards, coordinate decision-makers, promote workforce development, provide technical assistance and support the Solar America Cities program
Systems Integration	•Address economic bariers to solar energy grid integration •Develop technologies and strategies in partnership with utilities and solar industry
Concentrating Solar Power	•Leverage industry partners and national laboratories to increase R&D and deployment efforts •Achieve market competitiveness by 2015 and baseload competitiveness by 2020 •Work with the BLM to develop Programatic Environmental Impact Assessment and other activities necessary for utility-scale solar development in the southwest United States
Photovoltaics	•Invest in technologies across the development pipeline •Minimize cost of solar energy through new devices and processes, prototype design and pilot production, systems development and manufacturing

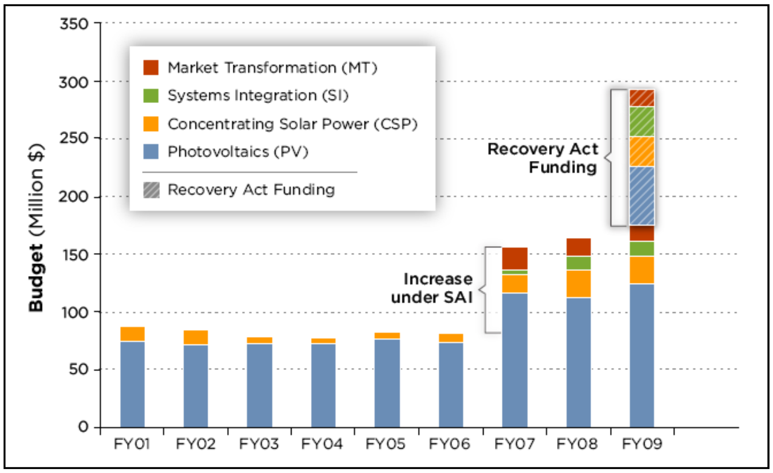


Figure 4.4 Department of Energy Solar Energy Technologies Program Investment. Renewed federal investment in solar industry technologies improved after 2006 with the Department of Energy’s Solar Energy Technologies Program (SETP). The Solar America Initiative (SAI) accounted for most of the $75 million budget increase from FY 2006 to FY 2007. The American Recovery and Reinvestment Act added nearly $118 million to the SETP budget, including $26 million for CSP.[204]

Private financing for solar industry development is often directed towards entrepreneurial entrants and early actors in market development. The financing may be different forms of equity or debt, carrying different levels of risk and attracting different kinds of investors. The infusion of private capital is critical for moving technologies developed through federal research and development dollars to the market. In 2008, the solar industry in the United States experienced an increase of venture capital and private equity investment from $61 million in 2004 to $2.3 billion in 2008, corresponding to a four-year capitalized annual growth rate of 148 percent.[205] Today, the risk for solar investors remains high as the market develops and public funding in the form of tax credits, special bonds, or loan guarantees are important incentives for investment in projects and businesses along the solar value chain. Without both private and public sector financial support, utility-scale solar projects cannot be developed.

The path to widespread adoption of solar energy technologies is currently dependent on incentives that create price parity between solar electricity and electricity generated from non-renewable sources. As the market expands, technical improvement and innovation will lower the cost of solar electricity generation. Increased deployment will allow the solar industry to reach economies of scale, reducing the need for subsidies. But whether the goal should be to phase out solar subsidies is questionable. At a recent solar industry conference, one panelist noted: "Other [subsidized energy] industries don't say 'how do we get rid of our subsidy.' Are we picking the wrong battle? We should be working on a level playing field."[206] The solar industry has fought a long battle to bring both utility-scale and distributed solar energy technology into the mainstream. Renewable energy policies and subsidies are necessary for maintaining the industry and bringing solar energy on line.

Utility-Scale Solar Development in California

In 2002, the State of California recognized the economic, social and environmental benefits of renewable energy and adopted one of the country's first RPS. The RPS required Investor Owned Utilities (IOU) to increase sales of energy generated from renewable resources by at least 1 percent each year to reach a total of at least 20 percent by 2017. The RPS legislation modified the pricing policies for renewable energy by directing the CPUC to establish market price referent (MPR) to represent the avoided costs of non-renewable power purchases. The MPR is used to calculate the net present value of the levelized cost of energy (LCOE) for a long term contract. Unlike previous pricing policies, the MPR is calculated based on installed capital costs, fixed and variable operations and maintenance costs, natural gas fuel costs, cost of capital, and environmental permitting and compliance costs. If an IOU enters a contract with pricing below the MPR, the cost can be recovered in retail sales. Contracts for long term purchases above the MPR may qualify for above-MPR funds from the state's RPS program.[207] However, these funds are limited. The modified pricing policies help utilities control the costs of meeting RPS goals and the contracts help to make utility-scale projects feasible once again from a developer's perspective.

The recent rise in the number of utility-scale projects in development is attributable to two key factors: the longer-term extension of production and investment tax credits to match the development timeline, which can take several years, and the implementation of aggressive RPS goals in California. Longer-term tax credits provide some certainty for investors and RPS goals create market demand among utilities seeking renewable energy power purchase agreements.

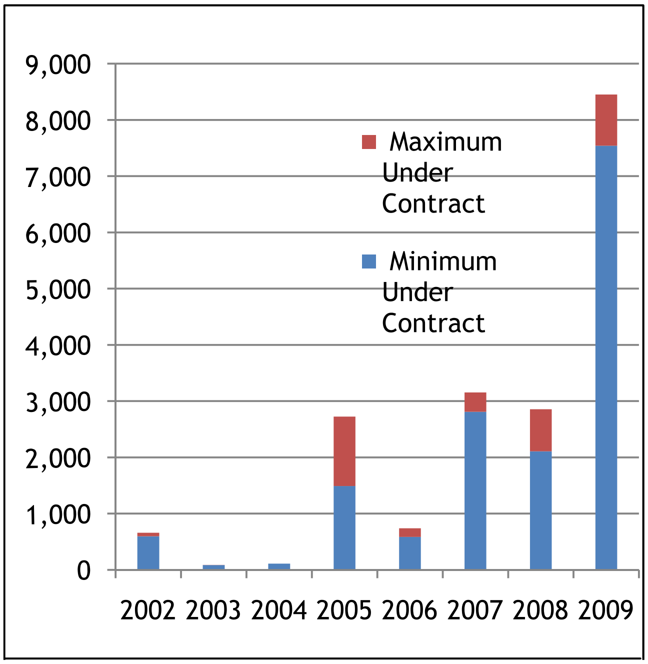


Figure 4.5 Total Renewable Energy Capacity Under Contract by Year for Pacific Gas and Electric, Southern California Edison, and San Diego Gas and Electric (Capacity in MW). The RPS was amended in 2009 to 33 percent of peak load capacity by 2020 and the number of contracts increased significantly. Base cases used in implementation studies indicate that 7,200 MW of solar thermal and 3,200 MW of utility-scale PV resources can realistically be developed by 2020.

By the end of 2009, utility-scale development was expected to grow significantly[208] and the state of California once again amended the RPS by adding a secondary target of 33 percent by 2030. This new target covers IOUs as well as publicly owned utilities and is truly a statewide goal, leaving many utilities wondering how much utility-scale generation would be needed to meet the targets (Figure 4.5). Once again, pricing may be an issue as “nearly half of the projects submitted for CPUC approval have been above the MPR” since 2007.[209] This is an indication that the cost of producing electricity from solar energy is still more expensive than other resources but the number of renewable energy contracts available to utilities is limited. Transmission issues will also have an impact on utility-scale development because new or upgraded transmission infrastructure will be required in order to bring a large number of projects online.

The potential for utility-scale solar energy development in the California desert is clear in terms of the available solar resource and improved financial incentives. However, utility-scale developers also desire an expedited process for accessing large tracts of public land as they moved forward with siting decisions development plans. In 2008, the BLM announced it would soon revise land use plans to incorporate renewable energy development. The market incentives combined with a potentially easier permitting process catalyzed a public land grab among developers eager to secure inexpensive land, attract recovering investors, and build the expansive facilities that could meet the IOU’s pressing need for renewable energy created by the more aggressive RPS targets. In order to meet the California RPS goal of 33 percent renewable energy by 2020, 48 terawatt hours of new renewable energy need to be brought online.[210] In response to utilities' requests for proposals for renewable energy generation capacity needed to meet RPS goals, solar developers began to submit their bids and in 2007 four contracts for utility-scale PV installations were filed with the CPUC (Figures 4.6[211] and 4.7[212]). The CPUC predicted increases in development activity in its 2008 first-quarter RPS procurement status report:

> "Solar energy has historically been a high-cost resource due to supply chain production constraints and other factors. However, its on-peak energy production and relatively consistent capacity are valuable, and increased developer activity is expected to drive prices downward. As prime wind resources are developed, leaving resources with lower capacity factors and higher prices, the price gap between wind and solar energy may narrow, making solar facilities more attractive and further boosting solar development."[213]

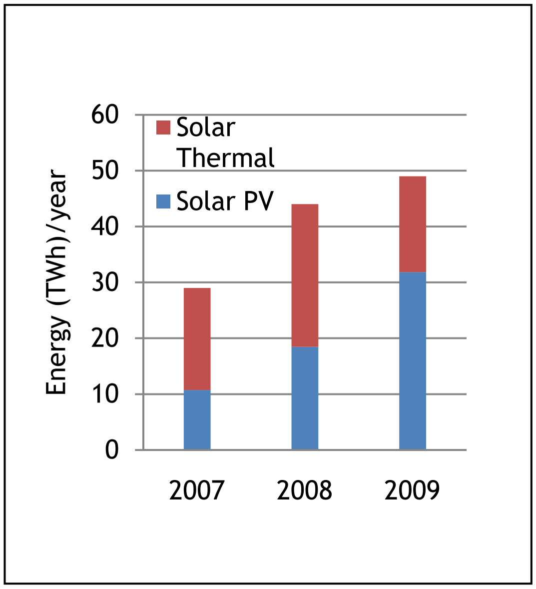


Figure 4.6 Large IOU RPS Solicitation- Solar Bids by Technology. The number of solar PV applications increased significantly in recent years and is expected to increase over the next decade.

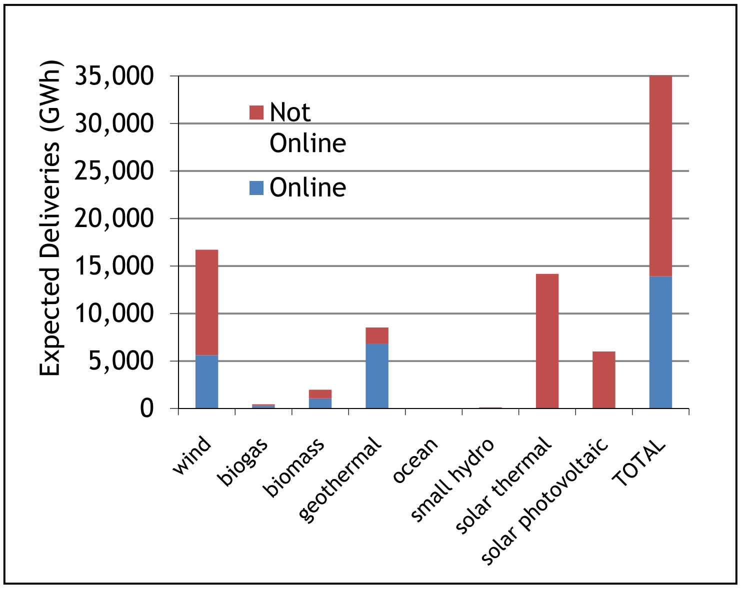


Figure 4.7 Total Expected Renewable Deliveries from Contracts Signed Since 2002, by Operational Status (minimum GWh). The majority of RPS contracts online are from wind and geothermal sources. As optimal locations for these resources are developed, the price gap for solar is expected to narrow and result in an increase in solar contracts.

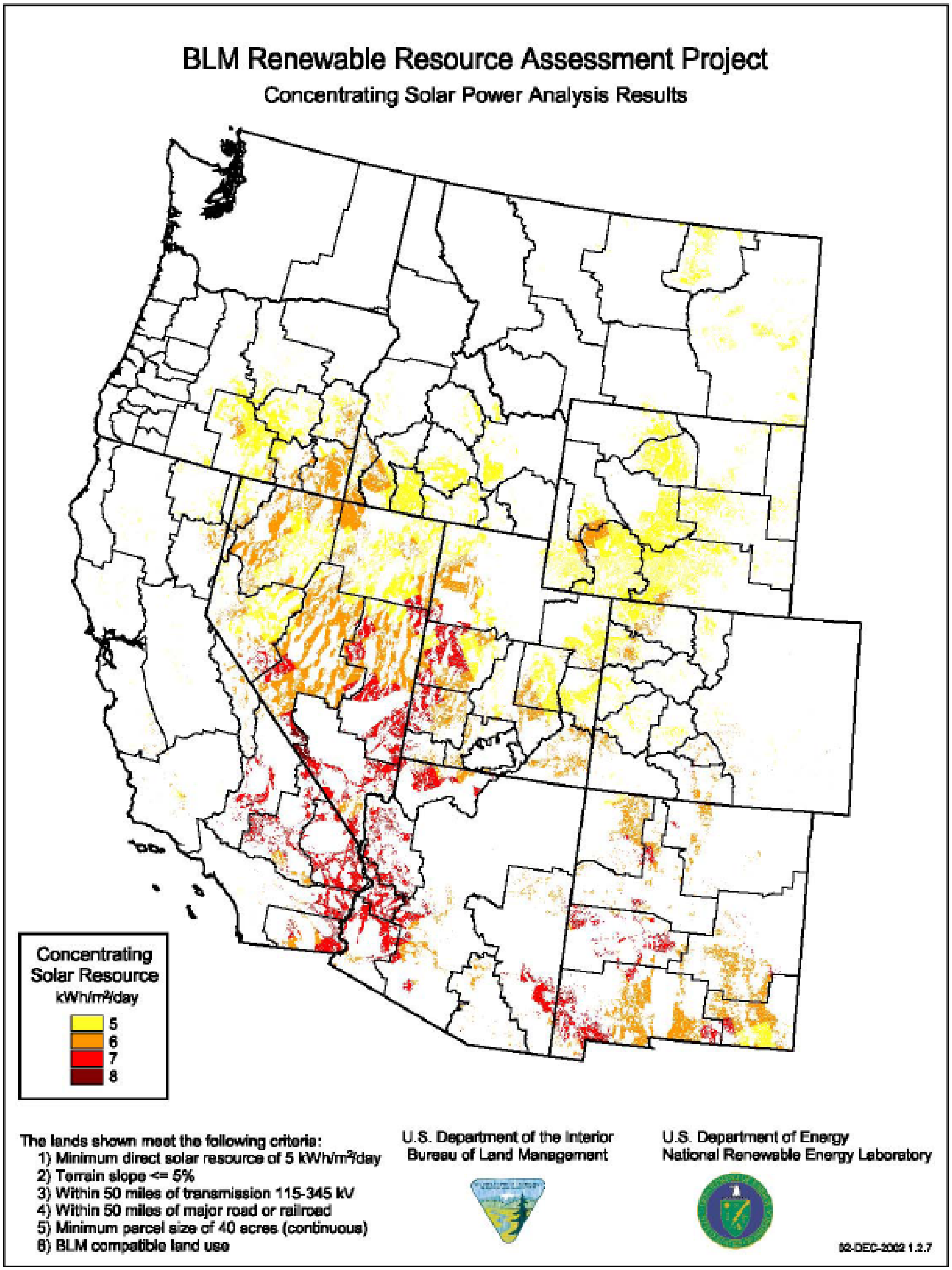
POLICIES AFFECTING SITING OF UTILITY-SCALE SOLAR DEVELOPMENT ON PUBLIC LAND

Besides economic drivers for utility-scale solar development there are state and federal policies that incentivize the use of public lands for renewable energy generation. In 2003 the US Department of the Interior (DOI) and the DOE released "Assessing the Potential for Renewable Energy on Public Lands." This report identified areas with the best solar energy potential in terms of sun, slope, transmission access, road availability, size, and are located where federal, state, and local policies are supportive.[214] This information generated a map identifying areas with the best potential for solar energy development, most of which are concentrated in southern California and portions of Nevada and Arizona (Map 4.1).

Both the DOI/DOE report and the California RPS encouraged solar developers to study public lands in Southern California for utility-scale development. Knowledge of the primary policy drivers of utility-scale solar development on public lands is necessary to understand the current situation in the California desert (Table 4.3).

Table 4.3 Policy Incentives and Disincentives for Solar Development on Public and Private Lands.

Policy	Incentive or Disincentive	Level	Land Affected	Details
Energy Policy Act of 2005	Incentive	Federal	Public	• Mandated 10,000 MW on public lands by 2015
2008 BLM Energy and Mineral Policy	Incentive	Federal	Public	• Land use plans must incorporate renewable energy potential • Encourages private industry to develop energy sources on public lands
Obama Administration Policy	Incentive	Federal	Public	• 25 percent renewable energy by 2025 • DOI to increase renewable energy capacity on public lands by 9,000 MW by 2011
California Land Conservation Act of 1965 (Williamson Act)	Disincentive	State	Private	• Prevents development on 16 million acres of farmland protected statewide
California Desert Protection Act of 2010 (Proposed)	Disincentive	Federal	Public	• Would prohibit renewable energy development on 1.2 million acres of BLM land



The lands shown meet the following criteria:

1) Minimum direct solar resource of 5 kWh/m^2/day
2) Terrain slope <= 5%
3) Within 50 miles of transmission 115-345 kV
4) Within 50 miles of major road or railroad
5) Minimum parcel size of 40 acres (continuous)
6) BLM compatible land use

Map 4.1 Results of BLM & DOE's Assessment of CSP Solar Resources on Public Lands. Lands shown have solar resource of 5 kW per m^2 per day, less than 5 percent slope, are within 50 miles of 115 to 345 KV transmission lines and a major road or railroad, have at least 40 acres, and are BLM lands compatible with solar development. Source: BLM, DOE. 2003. Assessing Renewable Energy Potential on Public Lands.

Public vs. Private Land

While BLM land in the desert is very much a checkerboard of public and private land, it is thought by BLM employees that solar developers have found the BLM ROW process easier than trying to purchase or lease multiple tracks of land from multiple private landowners. As one BLM employee stated in regards to why developers are choosing public over private land, "There are a number of reasons for it. How feasible is it if you're looking at an area that's as large as areas that they're trying to develop? If there's a large number of landowners for a 4,000 acre project, that's 20 or 30 landowners, it's much harder to deal with and reach agreements and pull a project together with that many landowners than with one federal landowner."[215] Solar developers choosing BLM land also have the benefit of returning the land to the BLM should the project no longer be viable at the end of the lease agreement. If developers chose to purchase land, they would have to find a buyer for degraded desert lands after the solar project's life span ended, for which there is a small market base.

Policies Affecting Siting

Energy Policy Act of 2005

The United States does not currently have a national RPS. However, the Energy Policy Act of 2005 states, "It is the sense of the Congress that the Secretary of the Interior should, before the end of the 10-year period beginning on the date of enactment of this Act, seek to have approved non-hydropower renewable energy projects located on the public lands with a generation capacity of at least 10,000 megawatts of electricity."[216] This stipulation has incentivized solar development on public lands in California by requiring DOI to meet this quota. However, one setback is that the law does not mandate which agency is responsible for fulfilling the renewable energy requirement or which technology should be used. A BLM employee stated, "We have a national goal of 10,000 MW, but where are they coming from? From BLM? From Forest Service? Which agency is responsible for responding to those goals? Which portion does each of us play in those goals? We have 260 million acres in the West. Does that mean we should bear the burden of all that when our lands are used by so many other people?"[217]

2008 BLM Energy and Mineral Policy

In 2008, the BLM revised their Energy and Mineral Policy to provide principles to guide BLM management of energy and mineral resources on public lands. The new policy stipulates that land use plans must incorporate and consider energy assessments and potential on public lands, including renewable energy.[218] The policy also endorses that BLM "actively encourages private industry development of public land energy and mineral resources."[219] This policy has incentivized solar development in California by changing the agency outlook on renewable energy and making it more acceptable for the agency to approve permits for solar development.

Obama Administration Policy

The Obama Administration and the Secretary of the Interior have chosen renewable energy development to be a top priority. The Administration has set a goal of generating 25 percent of the Nation's energy from renewable sources by 2025.[220] To realize this goal, Secretary Salazar introduced the "New Energy Frontier" in DOI's Fiscal Year 2010 budget. This program allocated $16.1 million for the BLM to support four Renewable Energy Coordination Offices, including one in California, to expedite authorization of renewable energy projects on public lands.[221] Secretarial Order 3285 was also issued in 2009 by Secretary Salazar to create an Energy and Climate Change Task Force to develop a strategy to increase development and transmission of renewable energy on public lands.[222] Secretary Salazar has declared an additional DOI goal to increase approved capacity of renewable energy sources on DOI lands by at least 9,000 MW by 2011.[223] Both the administration and departmental goals have incentivized solar development in California on public lands by providing set targets with deadlines and infrastructure to BLM employees in processing applications.

California Land Conservation Act of 1965 (The Williamson Act)

The California Land Conservation Act of 1965, commonly referred to as the Williamson Act, is a state law that enables local governments in California to enter into contracts with private landowners to preserve private land as agricultural land or other related open space.[224] In return for limiting development on their land, landowners receive lower property tax assessments. Contracts must be no shorter than 10 years, and they automatically extend each year beyond the end of the contract unless a notice of cancellation or nonrenewal is given.[225] The act is a disincentive for utility-scale solar development on private lands in the state, as the approximately 16 million acres of lands protected under the act cannot be sold or leased for development while under contract.[226]

California Desert Protection Act of 2010

Senator Diane Feinstein, D-Calif., introduced the proposed California Desert Protection Act of 2010, S. 2921, in December 2009. If enacted, the act would alter solar development in the California desert through new restrictive land designations and changes to the renewable energy permitting process. Approximately 1.2 million acres of land would be closed to solar energy development through two national monument designations, one special management area designation, and land transfers to the NPS. Even though the bill has not been enacted, its announcement has already caused developers of proposed facilities within the proposed national monument boundaries to postpone or abandon their plans.[227]

CAN DISTRIBUTED GENERATION ELIMINATE THE NEED FOR UTILITY-SCALE SOLAR DEVELOPMENT?

Meeting renewable energy goals in California will require both utility-scale and distributed generation approaches to solar development. The complementary approaches to electricity generation and delivery enable utilities, developers, and consumers to cooperatively invest in solar energy development in a number of market sectors and take advantage of a variety of investment incentives that economize investment at all scales. California's preliminary analysis of the implementation scenarios for meeting the 33 percent RPS goal explored the potential for a high level of distributed solar electricity generation capacity[228] based on three screens: ease of interconnection, site suitability, and customer's willingness to install the technology (Figure 4.8). GIS mapping of available rooftop area and analysis of peak load service were used to construct the screens and the statewide potential for PV applications totaled 17,300 MW,[229] or about 30 TWh (assuming a 20 percent capacity factor). California will require approximately 75 TWh of new renewable electricity generation capacity by 2020 in order to meet the RPS goal.[230]

Distributed generation has the potential to contribute significantly to the state's energy portfolio but will not replace utility-scale development. While distributed generation offers many benefits, such as rapid deployment and use of rooftops or disturbed land in developed areas, several barriers exist, including behavioral preferences, higher costs and questions about ownership of Renewable Energy Credits (RECs).

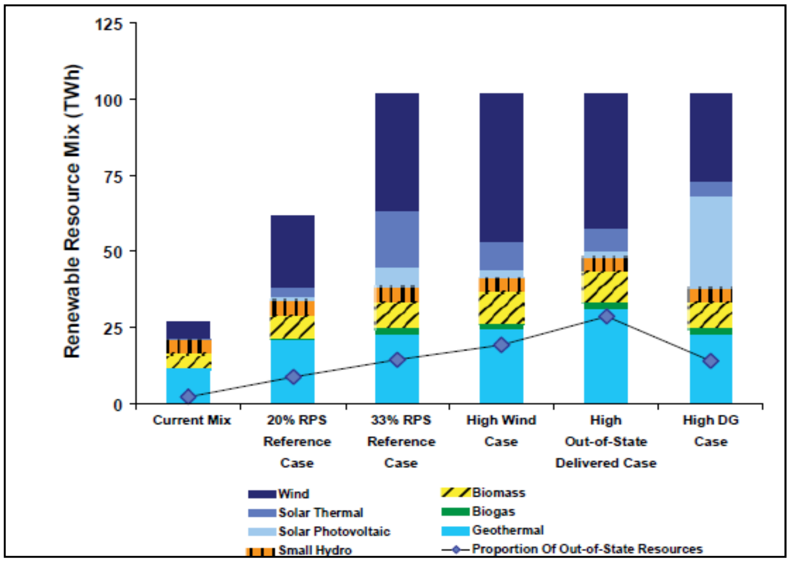
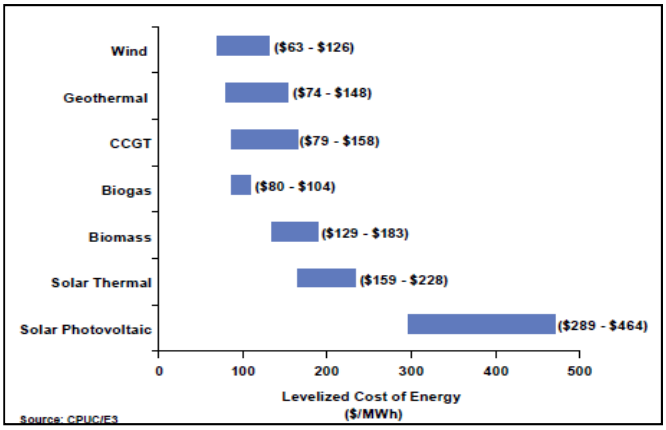


Figure 4.8 Renewable Resource Mixes in 2020 under Different Cases. The 33 percent RPS Implementation Analysis Preliminary Results produced by the CPUC includes a scenario for high distributed generation capacity using solar photovoltaic technology.

The most common technology used for distributed generation is combined heat and power for industrial processes (i.e. using waste heat to generate energy), but policy-based incentives are fueling the growth of the PV market for commercial and residential distributed generation. The modular nature of PV panels is appropriate for rooftop applications or ground-level arrays sized according to the energy demand of the site or the space available. Utility customers can take advantage of many of the same economic incentives as a developer of a large solar facility but have the advantage of streamlined interconnection rules and regulations, which cuts overall project costs. Because a distributed generation solar electric system reduces demand for electricity from the grid during peak periods of demand, customers with time-of-use rate pricing can take advantage favorable net metering rates. Pacific Gas and Electric, for example, offers residential customers with PV installations up to 1 MW a time-of-use net metering rate that values solar energy produced during peak periods at a rate three times higher than during non peak periods.[231] Utilities support distributed generation because projects can come on line quickly, reduce peak load demand, and contribute to RPS goals. However, PV remains more expensive per MWh[232] (Figure 4.9), which is a major barrier to widespread adoption despite numerous economic incentives.



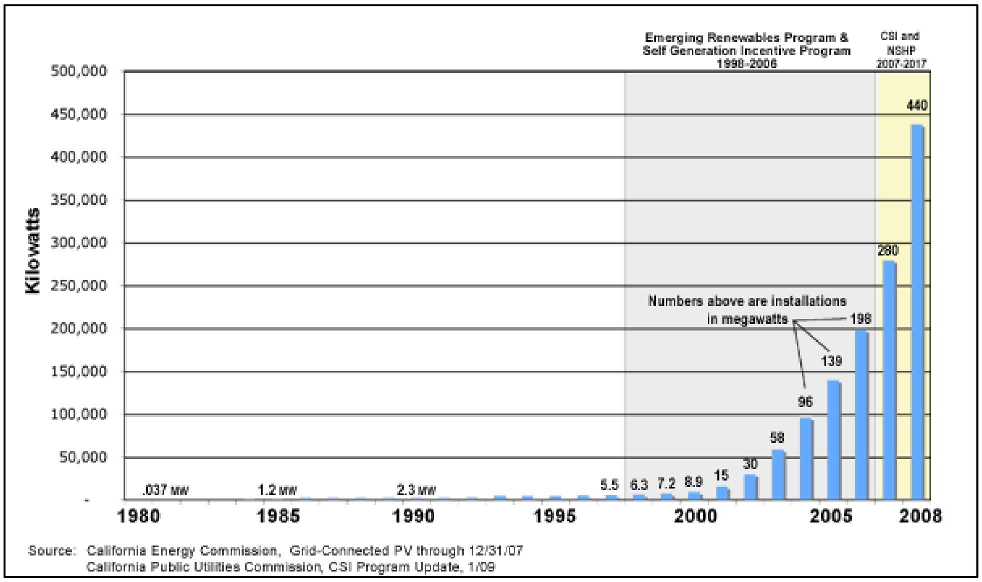
Source: CPUC/E3

Figure 4.9 Developer Levelized Cost of Generation by Technology Type. The cost of PV for distributed generation per MWh of electricity produced is currently significantly higher than for other renewable energy resource technologies, including solar thermal used in utility-scale applications.

California's Incentives for Distributed Generation

During the period from 1990 through 1999, overall electricity demand in California increased by 11.3 percent while electric generating capacity decreased by 1.7 percent over the same period.[233] The imbalance between electricity supply and demand came to a head during California's energy crisis of 2000 to 2001, when the state endured rolling blackouts during the summer peak demand periods. Skyrocketing wholesale electricity costs forced utilities to limit supply to customers who enjoyed artificially low, regulated electricity billing rates. Wholesale electricity market prices exhibited "significant departures from competitive pricing during the high-demand summer months and near-competitive pricing during the lower-demand months" between 1998 and 1999 and increased significantly in 2000.[234] This increase was likely due to rent-seeking behaviors and inequitable market power among generators in the recently restructured market rather than to rising fuel costs or environmental costs. While an in-depth discussion of California's energy market restructure and consequences is outside the scope of this review, it is worth noting for its contribution to the energy crisis and the subsequent policies created to address market failures and increase alternative, competitively priced distributed electric generation capacity. Today, not only is distributed generation important for California's energy security, it is a boon to the state's economic development and plays a significant role in meeting renewable energy goals.

As policy measures are introduced and extended to reduce uncertainties and enable widespread adoption of solar technologies, opportunities for improvements and investment in the distributed generation solar market arise. As with utility-scale projects, the PV market creates a value chain starting with research and development, followed by investment, material supply and manufacturing, project development, labor and installation, legal, financial and environmental consulting, and ultimately, the consumer. Rapid evolution of the industry over the past decade coupled with uncertainty of policy incentives and market externalities over the extended economic life cycle of product creates points throughout the value chain that are dependent on favorable policy and incentives. The market for PV is growing rapidly in California (Figure 4.10) with the support of progressive and ambitious renewable energy goals. California's incentive programs (Table 4.4) and pricing policies (Table 4.5) for distributed generation resulted in over 24,000 distributed PV installations with a combined capacity of 459 MW between 1998 and 2008.[235] California's innovative programs targeted specifically at adoption of residential solar power also support a growing workforce of specialized distributers and installers.



Source: California Energy Commission, Grid-Connected PV through 12/31/07
California Public Utilities Commission, CSI Program Update, 1/09

Figure 4.10 Grid-Connected Solar Photovoltaic Installed Capacity in California-Cumulative by Year, 1981to 2008. Market penetration of PV systems is rapidly accelerating. California's goal is to reach 3,000 MW of installed capacity by 2020.

Emerging Renewables Program

In 1998, the California Legislature created the Emerging Renewables Program (ERP), which established an incentive fund managed by the CEC to support installation of household-sized (less than 30 kW) photovoltaic systems, among other technologies. The program required California's major utilities to contribute a total of $540 million collected from ratepayers to an Emerging Renewable Resources Account between 1998 and 2001. The goal was to stimulate the near-term market for PV systems and "encourage manufacturers, sellers, and installers to expand their operations and reduce their costs per unit."[236] While the ERP was expanded to $135 million per year through 2011, other programs came online to support the growing market for distributed generation.

Table 4.4 California Programs Incentivizing Distributed Photovoltaic Systems.[237,238]

Emerging Renewables and Self-Generation Incentive Programs 1998 to 2006	•Provided rebates for residential installations •The CEC offered rebates for PV systems <30kW •The CPUC offered rebates for renewable energy systems >30 kW •192,792 kW of grid connected PV by 2006
California Solar Initiative 2006 to Today	•Provides an up-front Expected Performance-Based Buydown payment for smaller systems OR Performance-Based Incentive payments for larger systems •Payment values decrease over time as installed capacity increases •Includes New Solar Homes Partnership Program to incentivize installation of PV on new construction •Available to customers of IOUs •299.2 MW of grid connected PV as of February, 2010
Property Assessed Clean Energy Financing 2008 to Today	•The state adopted AB811 in 2008, which allows municipalities to sell bonds to finance a renewable energy and energy efficiency loan fund •Property Assessed Clean Energy financing allows property owners living in participating municipalities to obtain low-interest loans and repay them through a special assessment on the property •Repayment obligation stays with the property in the event of a sale

Table 4.5 Economic Incentives for Distributed PV Installation .

Net Metering	•Beginning in 1996, customers with small systems (less than 1MW) are allowed to feed excess generation back to the grid and earn credit against electricity used on site •Credit from one billing cycle is rolled into the next and the customer has the option to cash out credit balance after a 12-month period
Feed-In Tariff	•Production incentive established in 2006 for customer-generators •Currently allows owners of small systems (up to three MW) to enter into 10-, 15-, or 20-year contracts for sale of electricity to utility •Price paid is based on CPUC MPR and is adjusted for time-of-use to reflect value of electricity during peak demand periods
Residential Financing	•Lowers up-front costs and likely reduces utility bills in the future •Property Assessed Clean Energy financing enabling legislation was passed in California in 2008 and is a model for many other states •Several additional options with improved or streamlined structures are coming to market for residential PV financing

Self Generation Incentive Program

The rolling blackouts of the early 1990s occurred during the summer months, when peak demand exceeded supply. As a response, and in addition to establishing a RPS, the CPUC established the Self Generation Incentive Program (SGIP) in 2001 to bring new distributed generation capacity online. The program continues to provide up-front capital costs for ratepayer-owned, grid-connected distributed generation projects. Utilities benefit from an offset to peak demand wholesale market pricing impacts and, as a result, ratepayers benefit because utilities have less need to build new utility-scale generation capacity that would likely result in a rate increase. The SGIP complimented the ERP by providing incentives for qualifying solar PV systems with up to one MW capacity between 2001 and 2006. Although the program continues to offer incentive payments to other generation technologies, PV projects no longer qualified when California Solar Initiative was established in 2006. By 2008, completed PV projects accounted for 133 MW (40 percent) of SGIP capacity, contributed 197,178 MWh to California's statewide energy use, resulted in 65 percent of the SGIP's greenhouse gas emission reductions, and developers received a total of $454 million in incentive funding (76 percent of total).[239]

California Solar Initiative

The annual statewide production capacity for solar energy reached 1,868 MW by 2006. At this point, incentives for residential and commercial customer-owned solar PV were relocated to the new California Solar Initiative (CSI) program, established by the CPUC and the CEC, in order to better serve the needs of the market. The goal for the CSI is to install an additional 3,000 MW of distributed generation capacity and include solar PV on 50 percent of new homes built by 2020. The 10-year program was allocated $2.17 billion (2007 to 2016) to enable utilities to provide direct incentives to consumers for PV and non-PV technologies, fund low-income solar programs, pilot a solar water heating program, and stimulate research, development and deployment.[240] The diversity of rebate, grant and loan programs included in the CSI encourages growth of the solar industry in a number of market sectors and technologies for residential and commercial applications. The CSI framework encourages manufacturers to improve performance because the incentives are based on performance (kWh produced) rather than nameplate capacity. This framework benefits the industry as a whole by rewarding manufacturers that can deliver the least cost, highest performing products that are essential for creating a self-sustaining industry. In addition, the incentive payments are scaled to favor early adopters since payments decrease as the total number of MW installed increases.

Net Metering

Net metering (or co-energy metering for publicly owned utilities) laws passed in 1996 in California allow IOU and public utility customers with small PV systems (less than 1 MW) to put any excess energy generated on the electric grid and carry the net generation forward to their next energy bill. Since there are no interconnection, standby or other charges to the customer, this significantly lowers the payback period for residential and commercial PV installation and encourages property owners to install PV. The safety and manageability concerns often cited by utilities concerned about the impacts of cumulative inputs to the grid are addressed through an aggregate capacity limit of the utility's peak demand. Originally, the cap was set at 2.5 percent of a utility's peak demand and some utilities were close to reaching the cap in 2009. Solar advocacy groups lobbied the state to increase the cap to 10 percent and avoid the roadblock to reaching the 3,000 MW of new solar capacity goal set by the CSI. When a bill to raise the cap was introduced to the state assembly, Assemblyman Skinner stated "according to recent estimates by the PUC, each IOU share of the 3,000 megawatt goal represents between 4.5 to five percent of the utility's aggregate peak load. Even with the grant program created under the CSI and federal tax credits, distributed generation solar is not economical for the customer generator unless the utility participates in some form of a buy-back program such as net-metering."[241] Although Skinner's bill sought to increase the cap to 10 percent, the legislature passed a revised cap of five percent in February 2010.

Utilities and some customers resisted more significant increases to the net metering cap because, some believe, it creates a disparity among electricity customers when those who do not have renewable energy installed for net metering are effectively subsidizing the electricity use of those who do.[242] While Pacific Gas and Electric and Southern California Edison supported increasing the cap to five percent through 2010, they called for additional studies of not only the economic impacts of the program but also the impacts on grid stability, which might be impacted by voltage spikes created by multiple residential systems. Matching the feed-in-tariff caps to the desired distributed generation installed capacity is important for avoiding boom-bust cycles in the solar PV industry. Property owners are heavily incentivized by the net-metering program which drives the market for residential PV installation.

Feed-In Tariffs

Feed-in tariffs (FIT) are used around the world to incentivize and streamline incorporation of renewable energy in existing electricity grid networks. In the United States, the basic requirements include a requirement for a utility to purchase electricity from renewable energy generators, payment guarantees and assurance of access to the grid.[243] California adopted FIT legislation in 2006 and starting in 2010 it will include all IOUs and publicly-owned utilities serving more than 75,000 customers. Customers with solar thermal electric or photovoltaic systems (among other eligible renewable technologies) may enter into 10-, 15-, or 20-year contracts to sell the electricity and associated Renewable Energy Credits to the utility. The 2009 amendments to the 2006 legislation increased the maximum generation capacity of the customer-owned systems from 1.5 MW to three MW and also allows for the system to be located off-site from the customer's property as long as the system is within the service area of the contracted utility. The tariff rate is based on market prices with time-of-use adjustments which provide a higher rate during peak demand periods. The mechanism is specifically directed towards assisting utilities with meeting RPS goals and will be available until the statewide cumulative capacity installed equals 750 MW.[244]

The provisions of California's amended FIT expand solar market opportunities by increasing the number of potential projects and, because of the certainty afforded by a sales contract, provide leverage for capital by developers. The FIT compliments California's RPS goal by offering alternatives to utility-scale developments that face project financing uncertainty, high contract failure rates, permitting delays, and market concentration. In addition, RPS policy alone limits the potential for renewable energy development because utilities employ a competitive bidding process for projects that "increase the return on investment requirement, which ultimately increases the required payment price. These high transaction costs also make it difficult for smaller investors to participate."[245] However, the payment structure in California may not be sufficient for attaining the desired market results. California's FIT payment structure is based on the utility's avoided cost rather than the actual cost of the project. As a result, the returns are based on market electricity prices and the variability increases the uncertainty for investors.

Residential financing programs

The California legislature AB 811 in 2008 and gave local municipalities the authority to establish Property Assessed Clean Energy financing districts. This innovative financing mechanism allows municipalities to sell bonds and create a lending fund for property owners who wish to install energy efficiency measures or renewable energy technologies. The money borrowed from the local government is paid back through a special tax assessment and the loan is senior to any other debts, including the mortgage. One advantage of this kind of lending is that the 20-year payback obligation can be transferred to a new owner in the event of a property sale, which incentivizes investment in systems with a long payback period such as PV and solar hot water heaters. The financing also helps property owners overcome the high up-front costs associated with installing PV systems.

Private sector start-ups are beginning to enter the market for residential financing and will offer homeowners additional options and structures for obtaining low-cost capital for PV systems. One alternative recently offered by SunRun, Inc. in California is third-party ownership of the solar PV system. The structure involves establishing a power purchase agreement whereby the homeowner provides a down payment and agrees to purchase electricity produced by the system at a locked-in rate over 18 years.[246] SunRun installs, owns, and maintains the system, thus reducing overall costs for the homeowner. This approach may prove to be an attractive complement or alternative to PACE financing. Additional financing structures are summarized in Table 4.6.

Table 4.6 Advantages and Disadvantages of Residential PV Financing Structures.[247]

Residential PV Matrix from Homeowners' Perspective	Purchase with Cash	Home Equity Loan	Solar Lease	Residential PPA- SunRun Power Plan	Property Tax Model- PACE	PSE&G Solar REC Loan Program
Up-front cost to homeowner	36-70%	None/Low	0-20%	5-25%	None/Low	36%
Homeowner has maintenance responsibilities	Yes	Yes	Depends on program	No	Yes	Yes
Homeowner Pays for Inverter Replacement	Yes	Yes	Depends on program	No	Yes	Yes
Likely impact on future utility bills*	Lower	Lower	Lower	Lower**	Lower	Lower
Required cash payments (above utility bills)	No	Yes- loan payment	Yes- lease payment	Yes- electricity payment	Yes- property tax payment	No- although annual true-ups possible
Ownership of PV system in Year 1	Yes	Yes	No	No	Yes	Yes
Take residential federal tax credit	Yes	Yes	No	No	Yes***	Yes***

*** Compared to buying 100% of the electricity from the local utility. This does not mean that other costs, such as a loan or lease payment will be 100% offset by retail utility bill savings.**
**** The third-party PPA ownership model assumes that retail electricity prices will exceed the PPA price. While likely unless structured as a fixed discount to retail prices, it is not guaranteed.**
***** Based on the proposed changes to the subsidized energy financing concept in the stimulus bill.**

THE FUTURE OF UTILITY-SCALE SOLAR DEVELOPMENT IN CALIFORNIA

After a promising year in 2008, developers have been stalled by delays over permits and siting decisions by the BLM, which has created uncertainty in project timelines for developers and investors. Pressure has grown as developers try to bring power on line in time to take advantage of the December 31, 2010 deadline for production tax credits. Pressure also grew among IOUs to secure their target RPS, which led to a record number of new power purchase agreements, some of which had contract prices above the MPR, with facilities located on public lands throughout the desert. Once the policies regarding permitting of solar project development on public lands are established, it is likely that a secondary push for utility-scale development on public land will ensue if conditions are favorable and result in a lower LCOE compared to private land development. Key factors in determining project costs, and by extension the LCOE, include reaching economies of scale, the technology efficiency, optimization of the solar resource, availability of and access to capital, land use costs, and access to transmission.

A lower LCOE is a competitive advantage for securing a PPA since the MPR rate will be lower for the utility. Currently, some developers are choosing to avoid BLM lands in order to avoid the uncertainty and delays facing projects proposed for public lands. One panel discussion among utility-scale project developers at the Greentech Media Solar Summit on utility scale solar development strategies highlighted the differences in location and technology choices for two projects in development.[248] Developers of Mojave Sun Power's 340 MW solar trough project in Arizona purposely avoided public land in favor of a suitable parcel that was aggregated for a residential development project deal that failed. The representative from Mojave Sun Power explained that the technology choice was secondary to other factors such as available subsidies and financing options that would lower the project cost and expedite development. Although other technologies are considered more efficient than solar trough, they are not proven in the market and, therefore, face financing barriers which limits their market entry potential. Tessera Solar's three dish/engine projects (2,150 total MW) on public lands are facing delays and project cost uncertainties due to undefined land use and mitigation costs. The choice of dish/engine technology is based on the higher efficiency of the installed project and the economies of scale achieved for the purpose of lowering the LCOE.

Solar trough technology currently dominates CSP development in California with 4,606 MW of the total 7,647 MW of potential generation capacity.[249] A study conducted by the National Renewable Energy Laboratory (NREL) found that the LCOE for the first CSP plants installed in 2009 was $148 per MWh, which is competitive with the simple cycle combustion turbine LCOE of $168 per MWh, assuming that the temporary 30 percent Investment Tax Credit is extended, although still higher than the $104 per MWH for a combined cycle combustion turbine plant.[250] A number of CSP technologies, including concentrating PV, dish engine and power towers, are beginning to enter the market (Appendix B). While some technologies pose a higher risk for investors, the ability to generate more power per acre and the possibility of lower land use costs makes the project attractive. As more efficient technologies are proven in the market, LCOE and land use impacts per MW produced will be reduced for future projects. For example, concentrating PV requires two acres to produce 1 GWh per year while thin film requires 2.3 acres to produce the same amount of electricity.[251] The land use impacts varies based on technology type used and the fact that some, less efficient technologies are more easily financed presents a dilemma to BLM staff who review permit applications on a first-come, first-served basis. At this point, the permit review process does not prioritize proposals that have a more efficient land use footprint, reduced need for water, or do not require extensive land grading. If the process can be modified to give priority to technologies that have a reduced impact on the environment, this will incentivize investment in CSP technologies that are in the early stages of market deployment.

While there are some smaller utility-scale solar facilities in development, typically economies of scale are not achieved unless facilities are located on large parcels of land and in close proximity to one another. For example, two NREL reports on the preferred plant size and siting arrangements for a parabolic trough facility found that the levelized cost of electricity decreased by about $0.02 per kWh when the plant size was increased from 88 MW to 220MW[252] and that siting multiple plants in close proximity to one another decreased levelized electricity costs by an additional 10 to 12 percent.[253] However, the permitting process and limited availability of large, contiguous parcels of suitable land can delay projects and create a barrier to developing utility-scale systems. As an alternative, many developers are exploring smaller, decentralized facility projects on private land. This approach incorporates medium-sized generation facilities (five to 300 MW) located near load centers to satisfy peak load demands. While optimal economies of scale might not be achieved with smaller plants, the proximity to load reduces the impact a project may have on the landscape and environment because smaller parcels of disturbed land are located nearer to loads than are remote tracts of public lands. Load centers are also locations where peak demand can cause stress on the delivery system and decentralized facilities help power providers manage and maintain electric reliability, thus adding value to the project.

CHAPTER 5 | SITE-LEVEL SOLAR DEVELOPMENT AND ECOLOGICAL IMPACTS

There is an inextricable link between the built landscape and the natural landscape. Within the context of utility-scale solar energy development, that link specifically connects the development and construction of the project to the effects the project will have on the surrounding desert ecosystem. By providing both landscape constraints and opportunities, local ecological conditions dictate the type of development that is suitable for an area. In turn, technological development alters the natural landscape, thereby affecting the resident wildlife and plant populations as well as inorganic aspects of the ecosystem, such as soil stability and drainage patterns. The type and severity of the potential impacts that solar development may have on an ecosystem are also influenced by technology type, and therefore certain design variables also play a key role in determining the ecological impacts of a project.

Given the potential that utility-scale solar development will disturb large areas of the California desert landscape, an understanding of the ecological footprint, resource requirements, and additional necessary infrastructure for these projects is essential to determine the impacts these facilities will have on the local ecology. These potential ecological impacts should be considered when making siting decisions, especially if development will occur on relatively undisturbed portions of the California desert. To assess the impacts of utility-scale facilities on desert ecology, our research was based on the understanding that the type, intensity, and scope of impact will depend on technology type, geographic location, and the biological resources associated with the site.

This chapter includes a discussion of site engineering processes and landscape modifications required for development, plus an analysis of the implications these requirements have for the ecological processes and species of the California desert. This chapter also summarizes some of the mitigation measures that developers are currently proposing to minimize ecological impacts; however, an in-depth analysis of mitigation measures and biological resource Best Management Practices (BMPs) is included in Chapter 11.

SITE DEVELOPMENT AND ECOLOGICAL IMPACTS

Since a wide range of technological needs and ecological impacts will be discussed in this chapter, we have prepared Table 5.1, which visually displays the relationship between these two subjects. When a technological need may result in an ecological impact, the corresponding box in the below table is marked with the likely intensity of that impact. In cases where the intensity of the impact is dependent on multiple factors, a footnote has been added for explanation. This table provides an at-aglance summary of which site engineering processes are the most likely to have potentially serious effects to the surrounding ecosystems as well as which site engineering processes appear to be less problematic. The needs of different solar technology types, the associated land manipulation practices required to meet these needs, and the ultimate impacts of these factors on the environment are discussed in more detail below.

Table 5.1 Site Development and Ecological Impacts.

	Sand Dune Systems	Biological Soil Crusts	Invasive Plants and Fire	Habitat Connectivity	Hydrology
Grading, Hydrological Modification, and Vegetation Removal	□	■ * (1)	■	□	▓ * (1)
Fencing	□	□	□	■ * (2)	□
Roads	□	▓	■	■	░
Transmission	□	▓	▓	■	░
Facility Location	▓	□	□	■	□

■	High Impact
▓	Medium Impact
░	Low Impact
□	No Impact

(1) The amount of impact will be dependent on technology type and the amount of grading that is necessay. Technologies such as parabolic trough and thin-film PV will require more grading and will therefore result in greater destruction of biological soil crusts and changes to local hydrology, i.e., movement of water across land surface.

(2) The amount of impact is dependent on the total size of the facility since fencing is typically placed along the perimeter of the site; i.e., larger facilities will require more fencing than smaller facilities.

GRADING, HYDROLOGICAL MODIFICATION, AND VEGETATION REMOVAL

Most development requires that a certain amount of site engineering be performed on site in order to accommodate the proposed project. At the very minimum, this usually includes grading, road construction, and fencing. Because certain solar technology types, such as parabolic troughs and PV, require panels that are level and extend hundreds of feet, the desert floor upon which these systems sit must be manipulated to accommodate these systems (Figure 5.1). While parabolic trough technology can only be accommodated on land with a slope of approximately three

Figure 5.1 Existing Amonix CPV System in Arizona. Source: Arizona Public Service Commission.

percent or less, dish/engine and power tower systems can easily tolerate a grade of up to six percent.[254] The higher slope tolerance of dish/engine systems is likely due to the fact that the mirrors are anchored to the ground independently of one another and therefore require less uniform land conditions. Although this may seem like a minor difference, a slight change in the pitch of the land can result in the need to grade a considerably larger portion of the project site.

Other types of site engineering necessary to prepare a project site include erosion control measures, placement of infill, and the redesign of hydrologic features on site such as ephemeral streams and low-lying basins. The redesign of hydrologic features, such as streams, is designed to keep water from pooling next to large pieces of infrastructure and to prevent any flooding from occurring on site during rain events. Most developers only propose the re-routing of hydrologic features that overlap proposed infrastructure. Streams that run along the edges of the project site, or away from the buildings and solar array field are often left unaltered. Each of these processes may need to be performed to a varying degree, depending on the technology type that will be placed on the site. Grading and slope adjustment are the most common types of landscape alteration for solar facility development. This is due to the relatively inflexible range of slope tolerance for the different solar technologies as mentioned above.

All of the proposed projects that have submitted an AFC to the CEC include a grading plan and often other detailed site engineering descriptions and drawings. This information usually includes estimates of the amount of soil being moved.

Figure 5.2 demonstrates the substantial amount of earthwork planned for the construction of solar facilities. For a comparison of the volume of soil that is being removed, if all the soil being moved by the Solar Millennium Blythe project were placed onto a football field, the mound of soil would be over a mile in height. The grading process for each project will vary based on the size and layout of the project, the slope of the land, and the type of solar technology that will be utilized. Before discussing the ecological implications of such large-scale earthwork, a review of site engineering processes used when grading land is important to better understand the intensity of these activities.

Although each of the project developers address grading in the supporting documents for their project application (such as the AFC), some applications include more detailed information regarding the grading process than others. For example, the AFC for the Tessera Calico project (formerly called Solar One) simply stated that the site topography was “sloping gently to the south” and that only “minor cut and fill will be required” in order to prepare the site for construction.[255] Cut and fill is a process where

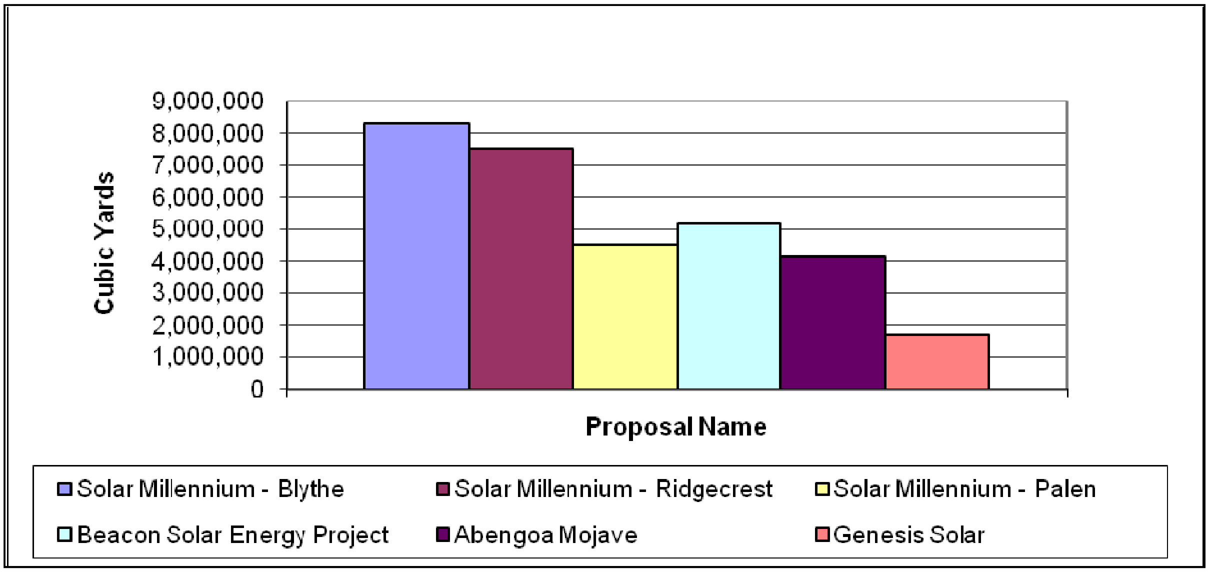


Figure 5.2 Grading Estimates for Select Solar Projects in CA. All estimates are taken from the AFC materials.

material is cut away from one area of a landscape, such as a slope or hill, and used to fill in another part of the same landscape, such as a low-lying depression. This earthwork process is commonly used alongside grading, since it can assist in the overall leveling of an area.

Additionally, many developers will be utilizing infill to prepare the site for construction. The term infill refers to the general concept of filling in a given area of land with additional materials, such as soil, brick, or concrete. For the purposes of this research, this term is used to describe the process of adding additional soil to an uneven desert surface in order to make either a level or low-grade (less than five percent) plane. Though some of the solar applications indicate that there will be a net import of soil materials on site to be used as infill, others indicate that they will implement a “balanced” grading plan, which means no soil would be imported or exported from the site for general earthwork. However, it is expected that some materials, such as engineering fill, will be imported to the site in order to provide adequate structural support for building foundations, even for those projects that are relying on a predominately balanced grading plan. Engineering fill is different from regular soil since it has specific properties, such as grain size and moisture content, which can make compaction easier.

A final earthwork process associated with grading a project site is soil compaction. Industrial-level soil compaction will be performed to stabilize the land and sufficiently reinforce it so that it can support the construction of buildings, solar arrays, roads, and fencing. This soil compaction will likely be performed using industrial equipment such as single-drum rollers, reversible plate compactors, or tire rollers depending on the size of the area that requires compaction. Additionally, the movement of heavy equipment around the project site will also cause soil compaction. Clearly, these processes will have a range of types and intensity of effects on the surrounding ecology, which will be discussed in detail in the following section.

In addition to these grading practices, most developers also propose to clear vegetated undergrowth from the project site. Vegetation removal is often a requirement for development in order to meet California's high standards for fire prevention. This requirement is not likely to vary based on technology type, which means that the ecological implications of this activity cannot be circumvented by utilizing a different type of system. This vegetation removal will primarily be focused within the solar array field and around the buildings, as these areas represent the greatest threat for wildfires.[256,257] For example, the AFC for the Genesis Solar states that,

> "Access routes will also be graded between the parabolic troughs to permit washing of the mirrors with a pick-up truck mounted tanker and the occasional cutting of vegetation to reduce the risk of fire due to plant regrowth."[258]

Ecological Impacts

These extensive grading practices as well as the removal of vegetation from the project site are likely to have critical implications for the surrounding flora and fauna populations.

Biological Soil Crusts: Soil Structure and Stability

Grading and erosion control measures associated with the installation of solar infrastructure, in addition to the movement of workers and vehicles during the construction and operation of a facility, will result in substantial disturbances to soil crusts. Biological soil crusts play a significant role in stabilizing soil in a water limited and consequently erosion prone environment. Unfortunately, their importance is not matched by their durability, as biological soil crusts are incredibly fragile. The drier the environment, the easier they are to crush, so crusts in the hot and dry California desert are particularly vulnerable to anthropogenic stressors, including the relatively low compressional force of human footsteps as well as grading-related disturbances.[259] When crusts are crushed, the aggregate crust structure is destroyed and soil stabilizing, as well as dust-trapping, capabilities will be significantly compromised.[260]

Biological Soil Crusts: Dust Emission

The scraping and grading of sites, particularly during construction phase of development, will likely have immediate and foreseeable impacts on dust emission. While the removal of vegetation as a result of scraping increases soil surface vulnerability to wind erosion, perhaps the most dramatic increase in dust emission would result from development activities that disturb biological soil crusts. As these crusts are quite fragile and highly vulnerable to anthropogenic stressors, disturbances can range from trampling by foot and vehicle to complete removal by scraping in preparation for facility installations.

Sites that have expanses of soil crusts may be particularly large sources of dust emission during construction, in that crusts are good at sequestering dust, often trapping dust for decades or longer (Figure 5.3).[261] In some areas, dust layers can be several meters thick, and trapped just below the desert surface.[262] Rich Reynolds, a research geologist for the US Geological Survey (USGS), expressed this concern in an interview:

Figure 5.3 Soil Crusts, Mojave National Preserve. Image Credit: Sarah Tomsky.

> "It turns out that these kinds of desert surfaces, in the Mojave, the Great Basin, and almost all deserts, *sequester* dust… They're not only areas where dust is emitted, but they're areas where dust is deposited… And there's a process in desert geomorphology whereby the dust that falls in these rough areas where there are plants and perhaps gravels or coarse grains at the surfaces – these rough surfaces protect the fallen dust from going back up into the atmosphere… And this dust, over hundreds of years, thousands of years, and even, in some cases, hundreds of thousands of years works its way down (through wetting and drying), gets down into the cracks in the soils, moves through the soils in various ways, and accumulates in these desert soils…
>
> Now this dust that has been deposited over hundreds of years to thousands of years, to even a hundred thousand years, is now buried – but not far below the surface – so that if one were to scrape and take off the surface, even on the order of a few centimeters or even tens of centimeters, one then uncovers these very thick deposits of fallen dust… If one then were to scrape for any reason, and one can do this just by pulling cobbles off the surface, one gets down to a dust layer, and now that layer is exposed… Some of these dust deposits are quite thick – on the order of a few meters thick, if they're old and harbored by surfaces that have been exposed to the atmosphere for a few hundreds of thousands of years. So there's a potential in certain places to expose old dust, especially during construction. Such places, when disturbed, have high potential for emission of large amounts of dust."[263]

One major consideration for siting decisions is the fact that neither dust sequestration nor biological soil crusts have been mapped in the California desert. Therefore, without doing a survey on site, it may be difficult to predict an area's potential for dust emission prior to construction.

Biological Soil Crusts: Nutrient Cycling

Solar development that directly destroys biological soil crusts could alter nutrient cycles by eliminating the main source of nitrogen and carbon fixation, as well as decreasing soil fertility by releasing fine soil particles from their aggregate. In the California desert, where vascular plants are sparse, biological soil crusts are the main source of nitrogen and carbon fixation — in many cases they are "the only show in town" for this important ecosystem function.[264] When crusts are wet, such as following a rain event, they release the stored carbon and nitrogen for use of nearby organisms.[265] In addition to storage and release of nutrients by the crusts directly, the fine soil particles trapped by biological soil crusts also bind plant-essential nutrients, increasing soil fertility.[266] The capture of these nutrients by the rough

Figure 5.4 Soil Crust Detail, Mojave National Preserve. Image Credit: Nerissa Rujanavech.

soil surface therefore acts as the main control for nutrient availability in nutrient-limited ecosystems like the California desert. The rough surface in Figure 5.4 is created by a black soil crust (a dime is used for scale). Plants that do establish in soil crusts tend to have greater biomass and a higher concentration of nutrients than those growing in soil without crusts.[267] If crusts are destroyed as a result of solar development, nutrient availability will be drastically reduced and the re-establishment and/or growth of vegetation may be limited.

Biological Soil Crusts: Water Infiltration

The destruction of soil crusts as a result of solar development may also affect on-site water infiltration. Infiltration rates can be influenced by soil moisture retention, soil surface permeability, and residence time of water. Biological soil crusts act as one control on the distribution of water that falls on the soil surface by modifying water infiltration, and therefore disturbance of crusts can have impacts on the ecosystem. However, as the permeability and roughness of biological soil crusts are variable, it can be difficult to determine whether soil crusts in a given location limit or increase infiltration.[268] Water availability drives most microbial processes in arid ecosystems, determining the location and density of vegetation. Solar development that destroys soil crusts can alter water runoff patterns, changing the path of this important driver.[269] Additionally, disturbance of crusts that have been enhancing water infiltration on site may lead to increased runoff. This runoff can also erode the soil, transporting nutrients away from the project area and delivering it elsewhere, changing the nutrient balance of the surrounding ecosystem. In a nutrient-limited desert, fluctuations in the nutrient balance may be difficult for the ecosystem to tolerate. Conversely, disturbance of soil crusts that normally *encourage* runoff can lead to death of plants downslope if their water source has been eliminated by increased infiltration upslope.[270]

Biological Soil Crusts: Recovery and Long-term Consequences

Solar development, with the necessary grading, vegetation removal, movement of soil, and soil compaction, will likely cause severe disturbances to biological soil crusts. Siting decisions should be made in light of the potential long-term consequences that a solar facility might have on the recovery of biological soil crusts. While recovery of soil crusts after solar development has not been studied specifically, there has been extensive research on the recovery of crusts after other disturbances, including military camps, pipeline corridors, roads, heavy livestock grazing, and OHV areas. The following discussion is based on those studies, but the true recovery potential for soil crusts on solar facility sites remains largely unknown due to the sheer number of acres that could be disturbed.

Estimates for soil crust recovery time depend on the model used for estimation and the definition of the word “recovery.” In a 2002 study, authors Belnap and Warren estimate that full recovery of soil crusts from General Patton’s World War II military training exercises in the Mojave Desert will require almost two millennia, with full recovery defined as the recovery of the most sensitive crust species.[271] A 2003 article by Belnap states that total recovery of soil crusts will take over 1,000 years in deserts with high potential evapotranspiration (the California desert falls into this category).[272] Estimates of recovery time become more nuanced when distinguishing between different soil crust functions and species. A 2010 study by Bowker et al. estimates that natural post-disturbance recovery of ecosystem nitrogen-fixation capabilities might take several decades.[273] In a 2009 study by Webb et al., the authors estimate that for soil crusts in the Mojave Desert, cyanobacteria may take 20 to 50 years to recover, while lichens and mosses may take 100 to over 1,000 years to recover.[274]

Factors affecting recovery rates of biological soil crusts include climate regimes (e.g., precipitation), soil moisture, soil fertility, the condition of adjacent soils, presence and type of plant structure, recovery of nitrogen and carbon fixation (which is dependent on different soil crust species), surface albedo and soil temperature, and lastly the frequency, severity, size, and type of disturbance.[275] Therefore, the recovery rate and recovery potential of soil crusts are extremely dependent on the characteristics of a particular site. For example, the rate of lichen recovery is much slower for disturbed areas that have a higher internal surface area to perimeter area ratio.[276] In some cases, full recovery of species diversity or full physiological function may not be possible.[277] Cyanobacteria (e.g., *Microcoleus* spp., *Collema* spp.) are usually the first crust organisms to recolonize an area after disturbance, but in the lower elevation areas of the Mojave Desert, limited soil moisture restricts the ability of lichen and moss species to recolonize.[278,279,280] Sometimes it may not be possible to regain species diversity of biological crust organisms after a disturbance because conditions that allowed the establishment of a particular species in the past may no longer be present.[281]

Invasive Plants: Soil Disturbance

The land disturbed within the solar project site boundaries could become a source of propagules and allow for the establishment of invasive plants because habitat disturbances can facilitate the colonization of natural areas by invasive plants.[282] Construction machinery and other earth-moving equipment could carry invasive plant material and seeds to the solar facility site from other construction sites. The disturbed soils created by grading and vehicle traffic could create sites that facilitate the growth of invasive plants. Invasive plants will also likely benefit from water used to suppress dust during facility construction.

Invasive Plants: Alterations to Fire Regimes

Disturbances from solar development that facilitate the spread of invasive grasses, such as *Bromus* spp. and *Schismus* spp., can increase the frequency of fire events in the California desert. Because decomposition of organic matter occurs slowly in arid regions, thick layers of plant litter can accumulate when invasive annual plant species die off each year.[283] The accumulation of litter can lead to increased size and intensity of fires, and can shorten the amount of time between fire events.[284] In a 1999 study, Brooks found that *Bromus* spp. fuel intense, hot fires that destroy perennial shrubs while *Schismus* spp. can facilitate the spread of fire between patches of *Bromus* spp.[285] Invasive annual grasses increase the frequency of fire by providing a more persistent and uniformly distributed fuel than is normally supplied by native plants.[286] Fires were historically uncommon in the California desert due to limited and sparsely distributed vegetative fuel; consequently native perennial shrubs are poorly adapted to the increasing frequency of natural and anthropogenic fires.[287]

The shift from a natural fire regime characterized by small, infrequent fires to a new fire regime characterized by large, frequent fires would be detrimental to native plants, and would also allow invasive species to gain an even greater competitive advantage. In the California desert, invasive plants compete for resources, such as water and soil nutrients, and can use allelopathic chemicals to inhibit native plant growth.[288] Frequent fires not only eliminate competition from native plants, but they create an environment that is much more conducive to invasive plant growth.[289] Invasive plants are better able to exploit the increased availability of soil nutrients and light after a fire than native plants due to their relatively high growth rates and ability to disperse quickly into burned areas.[290] Recovery of native plants is made more difficult if a high proportion of the seedbank is destroyed during a fire.[291] A shift in the natural fire regime around multiple solar facilities could result in regional changes to the natural fire regime, giving invasive plants an advantage over native plants on a much larger scale. This positive feedback cycle may become difficult to stop. Once a fire regime that favors invasive plants over natives is established, restoration of preinvasion conditions is challenging.[292] Solar development could further contribute to this cycle if the potential for fires from power generation or transmission are not adequately dealt with. Shifts in the natural fire regime could result in fundamental changes in native plant community structure and plant and animal food web dynamics.[293]

Hydrology: Soil Compaction

Soil compaction is detrimental to desert ecosystems because it crushes soil pores, decreases soil permeability and impedes water infiltration into the soil, thereby increasing runoff.[294] In addition to increasing the volume of runoff, soil compaction can also alter the flow of runoff over the landscape. Moving heavy construction equipment and vehicles over the facility site, industrial-scale soil compaction, as well as foot traffic on the site will likely result in soil compaction and alter water flow across the project area. Soil compaction can result from trampling by people or passage of a vehicle over the soil. In a 2009 study, author Lei found that soils became significantly compacted after 10 passes on a foot trail, so it is likely that construction and maintenance workers will contribute to soil compaction as well.[295]

Hydrology: Re-routing Stream Channels

Solar developers plan to redesign hydrologic features on site in order to accommodate the construction of the facility, such as re-routing desert washes that fall within a project area. In general, ephemeral stream flow will be diverted to artificial channels that go around the site and return to the approximate location of the existing wash. Changing water movement across the landscape may divert water away from important water capturing features such as ephemeral stream channels and playas. The diversion of ephemeral stream flow could affect water infiltration and groundwater recharge depending on the length and acreage of stream channel that is covered up by the project site. Ephemeral stream channels are characterized by exceedingly high infiltration rates, caused by the sand and gravel sediments within these channels.[296] The infiltration that occurs in stream channels during precipitation events is the primary source of groundwater recharge in desert ecosystems.[297] Playas are desert basins that become shallow lakes during periods of water flow, often after precipitation events. Playas provide a sink for water, sediments, and salt; water entering a playa can either evaporate or percolate downward, possibly providing another source for groundwater recharge.[298] Therefore, diverting water flow away from these natural channels or playas could reduce or eliminate a much-needed source of recharge for an already overdrawn aquifer system.

Hydrology: Vegetation Removal

Removal of vegetation for facility construction and fire prevention, especially perennial vegetation (e.g., shrubs like creosote bush, *Larrea tridentata*), could result in reduced water infiltration and decreased soil moisture. The removal of all or a large proportion of the vegetation on a several thousand acre solar facility site could increase soil evaporation rates, as well as significantly speed up the flow of water over the land surface, increasing the potential for water erosion of the soil and decreasing the potential for water infiltration into the soil.[299, 300] Over time, reduced water infiltration and increased evaporation may lead to decreased soil moisture, thereby increasing the likelihood of wind erosion of drier soils and also making recolonization of the site by plants more difficult should vegetation be allowed to return.

Current Mitigation Measures for Development

Given the range and intensity of earthwork processes that will be performed and the potential ecological effects, it is important to consider what developers are doing to minimize the impacts. As with most development in California, the applicant is required to utilize BMPs in order to mitigate the ecological impact of any activity. An in-depth analysis of mitigation measures and biological resource

BMPs, including a rating of these practices and a discussion of the potential unintended consequences of their implementation can be found in Chapter 11.

Many of the solar project applications have indicated that after grading is performed, extensive BMPs will be utilized. For example, in the application for the Solar Millennium Blythe project, the applicant states:

> "[t]he site will be graded as part of construction. With the implementation of best management practices (BMPs), such as soil compaction, dust suppression, straw bales, and silt fences, as well as limiting exposed areas, impacts during construction would be less than significant. Likewise, BMPs and dust control measures will be implemented to minimize water and wind erosion impacts during Project operation."[301]

As is evidenced by this quote, there are a multitude of possible BMPs that a developer can rely upon to reduce the intensity of grading effects. A second example can be seen in the AFC submitted by Stirling Energy Systems (SES)-Tessera for the Calico (formerly named Solar One) facility, which included a large range of measures that aim to reduce the ecological impact to soils under the guidelines of the California Environmental Quality Act (CEQA). A sample list of some of these measures includes wetting active construction areas to minimize wind erosion, stabilization of exposed areas by compression or application of polymeric soil stabilizers, application of a native seed mix to encourage revegetation, segregation and stockpiling of removed topsoil for potential reuse, and the implementation of drainage control measures.[302]

Due to a high fire risk in portions of this region, fire protection measures are non-negotiable for developers and must be implemented. Yet developers are not required to mitigate any indirect effects that may result from these fire protection measures. For example, typically developers have to remove vegetation from within the field of solar arrays and around buildings to prevent fires, however, any subsequent impacts that result from the removal of this vegetation, such as increased wind or water erosion, are not required to be addressed. Despite this, there are a few special circumstances in which developers are including some BMPs. For example, when special-status plant species must be removed in order to reduce the risk of fire on site, then developers often include some mitigation measures to offset this impact. The Ivanpah project states:

> "Mitigation for the loss of special-status plants… may consist of the following approaches (or a combination thereof): (1) permanent protection of an existing offsite native population; (2) translocation of existing plants to an offsite location; (3) salvage of the plants to the botanical institutions and native plant nurseries; (4) salvage of the plants to the general public; (5) mitigation banking; and (6) a fee in lieu of mitigation."[303]

PERIMETER FENCING

Most utility-scale solar facilities will also require the placement of perimeter fencing. The fencing will serve two primary functions: as security for the infrastructure, and as an environmental barrier to keep wildlife out of the project site (Figure 5.5). But before discussing the ecological ramifications of fencing and the measures being proposed by developers to reduce the associated impacts, it is important to clarify the scale of the fencing that is being proposed. Table 5.2 provides the estimates that were supplied by the project developers in each of their project applications.

Figure 5.5 Example of Fencing in Desert Regions. Source: Bureau of Land Management, Essex.

Table 5.2 Fencing Estimates for Select Solar Facility Proposals in California.

Proposal Name	Nameplate Capacity (MW)	Fencing Estimate (in acres)
City of Palmdale - Hybrid Gas-Solar	62	377
San Joaquin Solar 1 & 2	106.8	640
Rice Solar Energy Project	150	1,410
Solar Millennium - Ridgecrest	250	1,440
Beacon Solar Energy Project	250	2,012
Abengoa Mojave	250	1,765
Genesis Solar	250	1,800
Ivanpah	400	3,400
Solar Millennium - Palen	484	2,974
Imperial Valley (formerly Solar Two)	750	6,500
Calico (formerly Solar One)	850	8,230
Solar Millennium - Blythe	1,000	5,952
AVERAGE	*400.2*	*3,042*

There is a wide range in the amount of area that each project proposal plans to fence, with the average being 3,042 acres, which is nearly five square miles (Table 5.2). In order to understand the causes of this range, we looked at three variables; technology type, nameplate capacity, and how much infrastructure is going to be fenced. Figure 5.6 displays the relationship between these three variables. Our results indicate that range of fencing estimates is partly due to the fact that the nameplate capacity (total MW) varies for each project proposal. Facilities with larger nameplate capacities show a tendency to have higher amounts of proposed fencing. This is likely due to the fact that a larger nameplate capacity generally means a larger facility footprint. This range is also partly due to the fact that each project proposal plans to fence a different portion of their generating infrastructure. Some of the project proposals include fencing around the solar generating panels, the

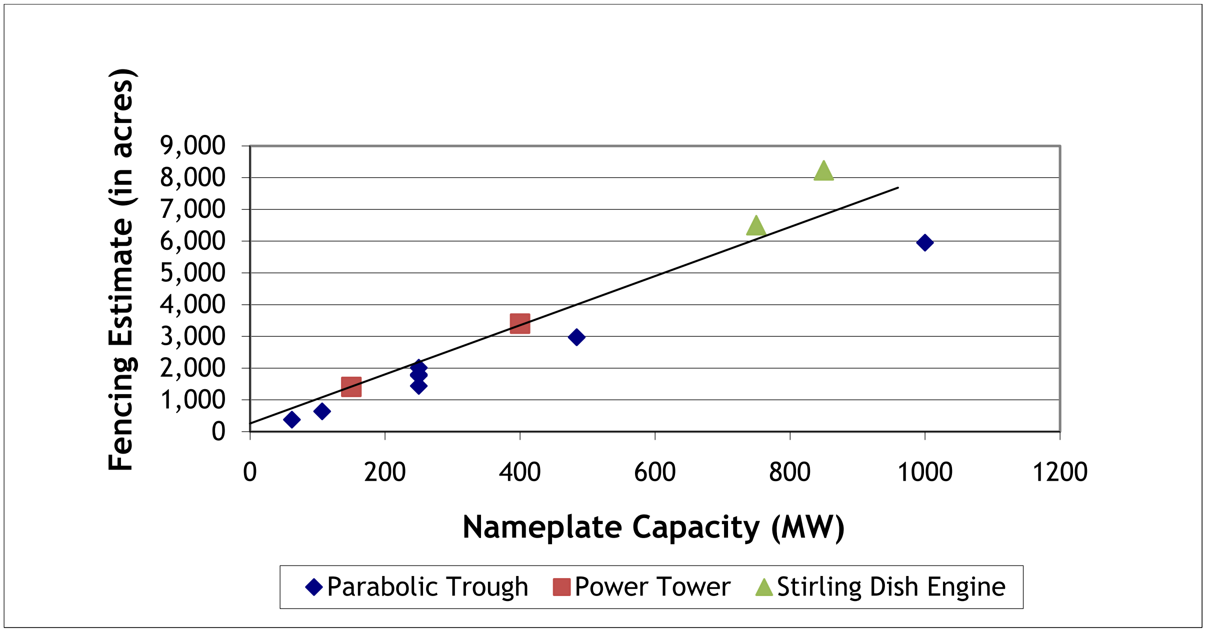


Figure 5.6 Fencing Estimates and Technology Type of Solar Facilities in California.

power block and associated buildings, and the permanent parking areas, while other project proposals include plans to fence the entire "disturbance" area, comprising all of the above areas in addition to the access roads and some of the transmission infrastructure. However, the results of the graph also indicate that there *does not* appear to be a significant relationship between the amount of area to be fenced and the technology type. As can be seen, the technology types appear to be somewhat interspersed throughout the fencing estimates, suggesting that there is not a strong correlation. Additionally, since there are not any project proposals that are the same nameplate capacity but have different technology types, we are not able to infer whether there is a strong relationship between these two variables.

Ecological Impacts

Habitat Connectivity

Larger landscapes can be described as habitat mosaics, with patches of habitats dispersed across an ecosystem.[304] Regardless of whether habitat remains intact within the interior of a fence surrounding a solar facility, this barrier essentially removes the habitat for species that cannot penetrate the fencing. For species with limited range, loss of habitat can directly affect species survival; if suitable habitat does not exist outside facility fencing, or is not substantial enough to support a population, limited resources such as forage or cover may result in direct mortality.

Species with higher mobility often rely on habitat patches to meet resource needs as they move throughout their range.[305] While these species may be able to survive by traveling farther distances to access forage, fencing that directly removes a vital habitat patch could severely limit their ability to survive. A solar facility that restricts access to some or all of a habitat patch may therefore inhibit species movement if suitable replacement cannot be found and a large enough gap exists between other patches to prohibit migration. Wildlife species most vulnerable to habitat loss from solar development are those reliant on plant assemblages found only in flat, lower elevation areas of the California desert, since these areas are most preferable for developers.

Not only does fencing remove habitat within its boundaries, it can also act as a barrier, restricting or completely blocking movement of species. Even if a population will not be affected by loss of habitat within a facility's fenced area, the fencing itself may be difficult to navigate around. If migration corridors are blocked, the viability of a species' population may be compromised as a result of gene-flow restriction.

Current Mitigation Measures for Development

Each of the applications that have been submitted to the BLM and the CEC include a variety of mitigation measures that aim to minimize the effects of perimeter fencing on regional wildlife movement. These measures include the use of low-to-the-ground rolling gates at the entrances and exits to the site to prevent wildlife entering the facility and becoming trapped, reduced speed limits on access roads to avoid car strikes of wildlife, the placement of clear and prominent markers to ensure all vehicles remain on the designated roads, and long-term equipment storage and space for parking will occur in fenced areas to exclude the possibility that wildlife may be drawn to these spots for shelter.[306] Many of the applications also indicate that the disturbance associated with fencing will not be limited to the period during construction, thus requiring that any adopted mitigation measures be kept in place throughout the lifetime of the project.

Furthermore, projects that encompass habitat of the federally threatened desert tortoise also include the construction of tortoise exclusion fencing (also sometimes called tortoise-proof fencing), designed specifically to prevent tortoises from entering the facility area, which may prevent unintended fatal vehicle strikes of the tortoises. In general, this type of fencing is comprised of vertical galvanized mesh fencing at least two feet high and buried at least one foot deep to prevent tortoise access through burrowing.[307,308] In some areas, burial of a portion of the fence will not be possible and in these cases the galvanized mesh fencing will be bent at a right angle directed toward the outside of the fenced area and covered with soil.[309] Some applications also include tortoise-proof gates, which are especially low-to-the-ground rolling gates to prevent tortoises from being able to crawl underneath.[310] This fencing is considered a mitigation measure, despite the fact that it will result in some loss of habitat, because it serves to minimize the potential for vehicle strike mortality within the facility, among many other potential on-site threats to the tortoise.

ROADS AND TRANSMISSION LINES

Every utility-scale solar energy facility application includes the construction of roads. These roads may be paved or unpaved with varying levels of improvement and will serve an array of functions including general mobility, access for panel cleaning, and repairs (Figure 5.7). In some locations, primary roads such as highways already exist, nonetheless, every applicant will need to at least improve existing roads and construct new maintenance roads through the solar panel fields. Additionally, given the relatively remote locations of many of these proposed projects and the limited amount of available capacity on the existing transmission grid, utility-scale solar facilities will also require new sections of transmission to be built. Due to the size of many of the proposed solar facilities, the total area that will be developed with road and transmission infrastructure will represent a considerable amount of land disturbance.

Although each project proposes some road construction, there is a sizable amount of variation regarding road disturbance area. Table 5.3 below shows the estimated amount of land that will be permanently disturbed due to road construction for four of the solar energy facility applications currently under review. Although we reviewed all 11 of the solar applications currently on file with the CEC, many of them did not contain sufficient information to calculate total acreage of the permanent disturbance area. In order to maintain data quality and accuracy, only those applications that presented sufficient and consistent data on access infrastructure development are included. However, a summary table that also includes the applications that contained minimal data can be found in Appendix C.

Figure 5.7 An Unpaved Road in the California Desert. Source: Bureau of Land Management.

Table 5.3 Road Construction Estimates for Select Solar Facility Proposals in California.

Proposal Name	Permanent Disturbance Area (acres)	Nameplate Capacity (MW)
Genesis Solar	154	250
Calico (formerly Solar One)	1,132	850
Imperial Valley (Solar Two)	550	750
San Joaquin Solar 1 and 2	18	106.8
AVERAGE	*464*	*489.2*
**All estimates are taken from the Application for Certification materials*		

The variation in area of road construction can be substantial (Table 5.3). This variation results from numerous contributing factors, including:

- Surrounding Development: Some of the solar energy facilities are proposed for very remote locations, which currently have minimal or no existing access routes. Other projects are proposed for locations near agricultural or industrial development, where construction or improvement of access routes in the area has already occurred. The prevalence of existing access infrastructure will have a significant influence on how much new access infrastructure will need to be built.
- Previous Uses on Site: Although the majority of solar energy facilities are proposed on completely or largely undisturbed land, some have chosen locations that have recently hosted other types of development, such as agriculture or recreation. In these cases, even though the previous use has been abandoned, some of the road infrastructure may still remain in place. This would reduce the need for new roads to be constructed.
- Size and Layout of Proposed Solar Energy Facility: Design characteristics also play a role in determining the land area that will be required for road construction. Applications vary by technology type, nameplate capacity (total megawatts of the facility), and layout of the development, all of which can result in differences in the number and size of roads that must be built to serve the proposed facility. Some of the variation may be explained by the nameplate capacity of the facility. However, four data points is not a large enough sample to draw a firm statistical conclusion of the relationship.

Unfortunately, we were not able to perform a detailed analysis on the needs and impacts of transmission construction for two primary reasons. First and foremost, the highly sensitive and secure nature of transmission data makes it difficult to obtain unless formally working with a government agency. Second, information that was available was often times incomplete, insufficiently labeled, or outdated, and never included information on the specifics of proposed transmission. Due to this unexpected constraint, we chose to focus our research on the impacts associated with roads.

Ecological Impacts

Biological Soil Crusts

Similar to grading, the construction of new roads and transmission lines pose a threat to biological soil crusts. As previously discussed, soil crusts are extremely fragile and can be easily crushed by grading, road construction activities, and the movement of workers and vehicles across the project site. This type of disturbance to soil crusts can disrupt soil structure, which can lead to dust emissions and impede new vegetation growth. This disturbance can also alter the nutrient cycle, and may change the level and pattern of water infiltration on site.

Invasive Plants

Roads, both dirt and paved, can serve as primary pathways for nonnative plant invasions into arid ecosystems.[311] Vehicles serve as major transporters of nonnative plant seeds while runoff from roads can elevate the supply of water at the edges of roads, facilitating the establishment and productivity of nonnative plants along roadsides.[312] Once invasive plants become established, they more easily spread away from roadsides and into natural areas.[313] Each solar facility will also require at least one transmission line to connect the facility to a new or existing substation. Maintenance roads along power lines are also a concern.[314] Similarly to roads, the disturbed areas created by utility corridors are more susceptible to invasion by non-native plants.[315]

The construction of new roads and utility corridors will also increase human access to previously inaccessible areas, exacerbating other human-mediated disturbances.[316] For example, OHV use tends to be concentrated around dirt roads and can further the spread of nonnative plant seeds into the surrounding ecosystem.[317] The tracks created by a single OHV pass can create microsites that enhance the abundance of nonnative plant species.[318] When road densities are high in an area, the biomass and number of nonnative plant species may increase from the combined effects of high nonnative plant biomass near roads, increased seed dispersal along and away from roads by vehicles, and decreased distance from roads to other areas of the landscape.[319]

Agricultural regions serve as major sources of invasive plant propagules, where farming practices and livestock feed introduce nonnative plant species into a landscape.[320] Roads and highways connect the desert ecosystem with large agricultural areas such as the Imperial Valley and the Central Valley.[321] The use of new solar facility roads by vehicles transporting agricultural products may inadvertently facilitate the spread of invasive species. For example, hay straw and seed can become dislodged from bales and disperse off trucks onto roadsides.[322] This problem could be compounded if developers choose to use hay bales or other straw-based materials to control erosion during the construction phase as it would provide invasive plants with multiple entry points into the ecosystem (i.e. all roads used to transport straw-based materials and the facility site where the materials are used).

Habitat Connectivity

Linear corridors such as roads, transmission lines, pipelines, and OHV trails, can serve as barriers to migration. Species like the bighorn sheep may avoid crossing large or heavily trafficked roads. Therefore, solar development that requires any substantial new roads or results in increased traffic on existing roads may further fragment habitats.[323] In addition to this potential restriction of gene flow, an added risk to species includes increased vehicle-strike mortality.

Hydrology

Because soil can become significantly compacted after a single pass by a vehicle,[324] it is likely that dirt roads to and within a solar facility site may suffer from severe soil compaction. Soil compaction from new roads specifically could redirect water flow and concentrate runoff streams, accelerating erosion.[325] Additionally, the formation of pools of water along the roads could result in damage to the roads, which might force the developer to repave or regrade the roads more frequently, which would in turn augment the ecological impact of roads on the project site.

Current Mitigation Measures for Development

The construction of roads can incur a variety of ecological impacts, ranging from habitat fragmentation to direct strikes of wildlife by vehicles. Additionally, since the roads will be used throughout the lifetime of the project, this type of development is considered to be permanent land disturbance, therefore requiring that the proposed mitigation and remediation measures be sufficient for ameliorating long-term impacts. However, the BMPs proposed by developers to minimize these ecological impacts are fairly limited. Most of these BMPs focus on either keeping vehicles on designated roads, reducing run-off and water pooling around roadways, and limiting the areas where toxic substances can be used such as gasoline and road sealant.

FACILITY LOCATION AND PLACEMENT

The selection of the facility location and placement on the project site are arguably the most important decisions that a developer makes during the planning process. The location and placement of the infrastructure on the project site will directly determine the type and intensity of the site-level ecological impacts discussed above. Over the course of nine interviews, we established that developers generally look for three key characteristics when selecting a project site: distance to transmission, slope of the land, and the availability of water.

1. Distance to Transmission: Distance to transmission is one of the most important considerations for obvious reasons. Without transmission infrastructure, the developer has no way to get the electricity from the facility to the nearby towns and cities. Furthermore, transmission infrastructure is extremely costly to construct, making locations with nearby transmission lines extremely desirable to developers as it keeps the construction costs down.
2. Slope of the Land: As was mentioned earlier, each technology type has its own range of slopes that it can tolerate and therefore developers that are proposing parabolic trough systems may look for the areas with the lowest natural grade. Additionally, developers prefer level areas since it reduces the overall amount of grading that will need to be performed, and therefore can reduce the construction cost.

3. Water Availability: And finally, a consideration that was frequently mentioned by developers was the availability of water. Of course, water availability is a greater concern for CSP systems than for PV systems, but nonetheless PV systems do still need water for panel washing. Developers indicated that the wastewater could be piped in from a local municipality, assuming they could provide enough wastewater to meet the facilities needs, or could be pumped from underground wells. However, if neither of these options are available, then a developer will be forced to have water trucked in and stored on site. This process ultimately is more costly since it requires additional water storage infrastructure to be built, contractual agreements with a delivery company, and potentially hiring additional employees. Moreover, the trucking in of water requires the use of more energy in the form of gas or diesel and also includes the associated carbon dioxide emissions. This is an unfortunate side effect, especially for a renewable energy facility that aims to reduce greenhouse gas emissions.

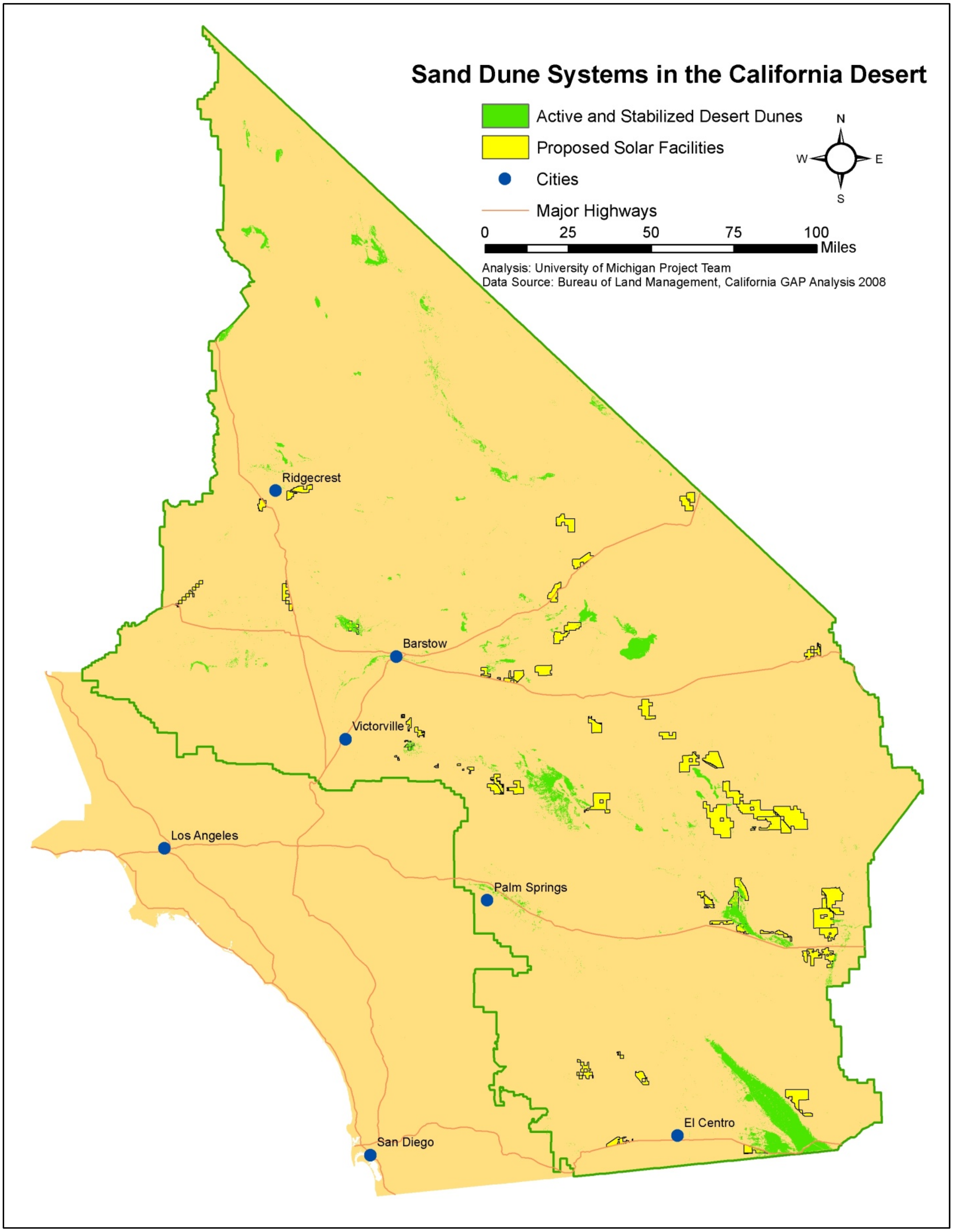
Many developers select the facility location based on these three criteria, and the potential ecological implications of facility siting may not necessarily play a significant role in the initial siting decision. However, the location and layout of the facility will have considerable implications for the overall ecological impacts of the facility. These effects will range in type and intensity based on the specific ecological conditions of the projects site. These impacts are discussed further below, and a spatial analysis of ecological impacts using GIS modeling can be found in Chapter 7.

Ecological Impacts

Aeolian Wind Processes: Sand Dune Systems

Solar facilities that are built on top of dry water channels, washes, or playas, or that are constructed on or near alluvial fans (also called bajadas), may interfere with the sediment deposition that sustains desert sand dune systems. Solar facilities constructed in wind corridors risk interrupting or blocking the transport of sediment to these dune systems. A solar facility site that has hundreds to thousands of acres of infrastructure, potentially with energy-capturing structures up to 40 feet tall, such as dish/engines, may be large enough to create wind barriers.

The placement of solar facilities in the proximity of sand dune systems may negatively affect dune endemic biodiversity (Map 5.1), resulting in impacts similar to suburban development. For example, suburban development encroachment on aeolian sand dune habitat in the Coachella Valley has been found to negatively impact flat-tailed horned lizards (*Phrynosoma mcallii*) up to 150 m from the edge of the habitat boundary.[326] Anthropogenic habitat fragmentation due to roads and suburban development in the Coachella Valley has rendered some sand dune habitat areas too small to sustain populations of the threatened Coachella Valley fringe-toed lizard (*Uma inornata*).[327] Roads could also



Map 5.1 Sand Dune Systems in the California Desert.

be a source of mortality, while perimeter fencing and buildings on-site could provide hunting perches for avian predators. The cumulative effect of new utility-scale solar facilities and current impacts to sand dune systems (e.g., OHV recreation, urban and suburban development, and invasive species) may exert even greater pressure on these already threatened systems.

Habitat Connectivity

Solar development may affect species migration if facilities are sited in pre-existing or potential migration corridors, including corridors utilized by both limited-range species (such as desert tortoises) and wide-range species (like bighorn sheep). Inability to access food and water could have immediate impacts on population viability, leading to mortality; in small populations, decreases in population size due to mortality can lead to long-term impacts by shrinking the gene pool.[328] Similarly, sustained migration corridor blockage can decrease evolutionary fitness of a population or metapopulation by placing long-term restrictions on gene-flow.[329]

The placement of solar facilities in key migration corridors may limit a species' ability to adapt to future changes in climate. Changes in temperature and precipitation may result in the spatial shift of suitable microclimates or habitats, and it may be necessary for some species to adjust ranges to reflect this shift. Inability by individuals or populations to access suitable microclimates or resources could lead to species decline.

Disturbed vs. Undisturbed Land

Whether a facility is placed on undisturbed natural areas or land that has already been disturbed, influences the magnitude of impact caused by solar development. There is greater potential for disturbed areas to have already undergone land modifications like grading, vegetation removal, and soil compaction. Facility placement on undisturbed lands may result in a significant departure from existing natural conditions than if the facility was placed on disturbed lands. If facilities are placed on disturbed lands (e.g. abandoned agriculture), there is a higher likelihood that crusts have already been destroyed and have not returned. Conversely, if facilities are sited on undisturbed lands, there is a higher likelihood of crusts being present on-site. Facilities placed in disturbed areas may have a relatively smaller contribution to the establishment and spread of invasive plants in the area than facilities placed in undisturbed areas. Invasive plants may already be established on disturbed lands and the development of a solar facility may not result in a significant departure from existing conditions. Conversely, the placement of a facility on undisturbed lands may result in the establishment of invasive plants on and around the site, resulting in a significant departure from existing natural conditions.

Current Mitigation Measures for Development

The identification of a potential project site is the responsibility of the developer. Their first choice is related to the general location of the facility within the areas open for development on BLM-managed lands. The second choice is regarding the facility size and location within the selected site. The developer frequently performs initial studies to determine the best design and layout to maximize energy generation, and may fund ecological surveys to determine the location and distribution of sensitive resources on site. The size and layout can be influenced and changed during the permitting approval process, although most developers make these decisions before submitting their application to the BLM, having already spent significant financial resources on their design.

Once an application has been submitted, developers typically will consult with the BLM about different options for design and layout. While the BLM may suggest changes in layout or location to reduce the amount of ecological impacts on the site based on known resources, the initial financial investment may leave developers reluctant to make large changes or move the proposed placement of key infrastructure. Some developers consult early with the BLM in order to incorporate the agency's recommendations before committing too many resources to a design that may require changes. While this may be preferable, it is currently not the typical progression of facility design and placement. Given the current decision-making process for facility location and placement, mitigation measures are therefore limited. An analysis of the BLM's process for approving proposed facilities is included in Chapter 11.

CHAPTER 6 | LANDSCAPE-LEVEL SOLAR DEVELOPMENT AND ECOLOGICAL IMPACTS

Although there are many ecological impacts that can occur at the site-level, there is also the potential for even greater landscape-level impacts, especially when considering the cumulative effects of multiple facilities across the California desert. These impacts have implications for the functioning of ecological processes and the status of species well beyond the boundaries of the facility site, and can result in fundamental changes to the ecology and biology of the region. Landscape-level impacts could result from disruptions of or alterations to ecological processes including habitat connectivity, sand transport systems, carbon sequestration, and surface albedo. The extent and type of impacts are dependent on the geographic placement of the facilities within the context of the CDCA, the total amount of land and water consumed, and the nature or intensity of the impact. To the extent that these landscape-level impacts may disrupt ecological functions and species interactions, the sum of these impacts may determine if, where, and what biodiversity can persist in the face of utility-scale solar development. Therefore, an analysis of the likely landscape-level ecological impacts is a critical component in understanding the potential cumulative environmental effects of these projects.

In addition to ample amounts of sunlight, the most important resource needs of a solar energy facility are land and water. Given this, we developed a method of analysis that can be used to quantify the relationship between the benefit of the renewable electricity generated by these projects and their relative impacts on the surrounding land and water resources. We refer to these analyses as land and water use efficiencies. The quantity of land and water consumed, as well as the facility locations, will determine the type, intensity, and extent of ecological impact. The following section includes our land use efficiency analysis and an examination of how facility size combined with geographic location may affect surrounding wildlife populations and ecological processes. Next we include our water use efficiency analysis and a discussion of the landscape-level impacts of groundwater use and surface water diversion. Finally, using species as indicators of larger-scale ecosystem health, we illustrate how solar development may affect population-level dynamics in three important desert species: the desert tortoise, the desert bighorn sheep, and native pollinators.

LAND USE EFFICIENCY

A land use efficiency analysis was performed by calculating the amount of renewable electricity a facility expected to produce in a year and dividing this number by the total acreage that the facility expected to disturb. This served as our metric for the land use efficiency of a given project. Table 6.1 summarizes the results. By using this analysis tool to quantify the relationship between the technology type, size of facility footprint, and the amount of energy being produced, we are able to compare the

Table 6.1 Analysis of Land Use Efficiency by Project Size (in MW) and Technology Type.

Proposal Name	Nameplate Capacity	MWh Produced Per Acre Disturbed	CSP or PV	Technology Type
Solar Millennium - Blythe	1,000	352.11	CSP	Parabolic Trough
Solar Millennium - Ridgecrest	250	283.90	CSP	Parabolic Trough
Solar Millennium - Palen	484	336.50	CSP	Parabolic Trough
Beacon Solar Energy Project	250	455.95	CSP	Parabolic Trough
Abengoa Mojave	250	409.60	CSP	Parabolic Trough
Genesis Solar	250	407.00	CSP	Parabolic Trough
City of Palmdale - Hybrid Gas-Solar	62	356.46	CSP	Parabolic Trough
Parabolic Trough Average	*364*	*371.65*		
Calico (formerly Solar One)	850	1,000.20	CSP	Dish/Engine
Imperial Valley (formerly Solar Two)	750	845.20	CSP	Dish/Engine
Dish/Engine Average	*800*	*922.70*		
Chevron Lucerne Valley	60	211.55	PV	Thin-Film
FirstSolar's Desert Sunlight	550	226.90	PV	Thin-Film
PV Average	*305*	*219.23*		
Ivanpah	400	991.70	CSP	Power Tower

relative land use efficiencies of the proposals on both a project-by-project basis as well as on a technology-versus-technology basis. In a project-by-project comparison, this analysis shows which proposed facility is making relatively better use of the land by producing a greater quantity of energy per unit of area. In short, the project with the best ratio, in this case the *highest* amount of megawatt-hours of electricity produced per acre of land disturbed, could be viewed as the most efficient project in terms of land use. This is a simplified way of determining which project will have a relatively “smaller” environmental footprint while still maximizing the amount of electricity that is produced by the facility.

As can be seen in Table 6.1, there is a substantial range of land use efficiencies, with the Solar Millennium Ridgecrest project having the lowest efficiency at 284 MWh of electricity produced per acre of land disturbed, and the Tessera Calico project having the highest efficiency at 1,000 MWh of electricity produced per acre of land disturbed.

An analysis across technology types was also performed. Although the majority of applications are for parabolic trough systems, there are also other types of solar technologies being proposed, including power tower, dish/engine, and thin film PV. Each of these technologies has its own distinct set of advantages and disadvantages, including relative operating efficiencies, land requirements, and cooling system needs. By calculating the average land use efficiency for each technology type, we are able to see which technologies appear to have higher land use needs, and thus a greater ecological impact. A breakdown of the average land use efficiencies by technology type, as well as an average across technology types and the maximum and minimum values, is shown below in Figure 6.1.

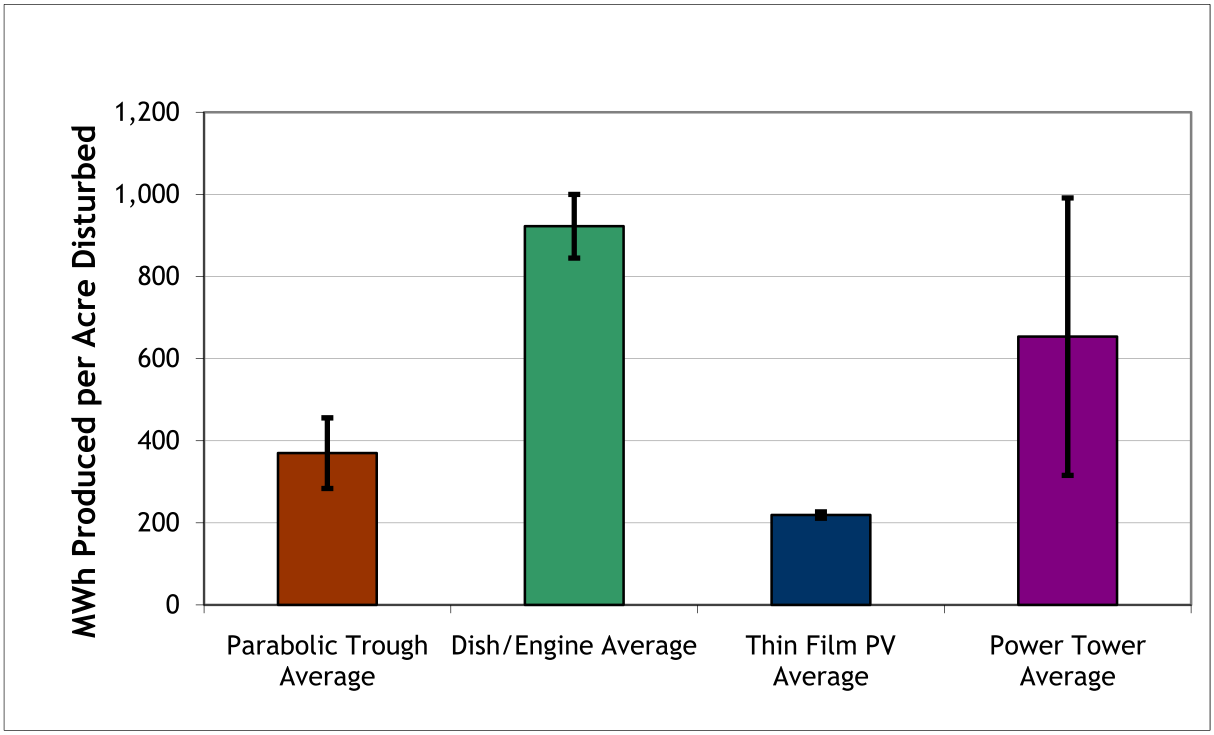


Figure 6.1 Average, Maximum, and Minimum Land Use Efficiencies for Four Solar Technologies.

This analysis shows the effect that technology type has on the overall facility footprint. The above results indicate that thin film PV and parabolic trough systems have the lowest average land use efficiency of these four technologies. For parabolic trough and thin film PV systems, this is likely due to the fact that these systems require long, contiguous rows of panels or mirrors to be constructed on a three percent grade or less. This requirement means that a greater portion of the site must be graded to accommodate the technology. In contrast, technology types that have fewer land constraints have higher land use efficiencies. An example is the dish/engine system, which can be placed in non-contiguous configurations and can tolerate slopes up to six percent. Since dish/engines can be anchored to the ground independently of one another, this eliminates the need to grade the entire solar field to a consistent level, which results in a lower overall grading requirement. In turn, this means there will be fewer disturbances to soil crusts, native vegetation, and wildlife species, which may contribute to the high average land use efficiency of this technology type.

This analysis can serve as a preliminary dataset for stakeholders to determine which technologies appear to be maximizing energy production while keeping facility footprint and related ecological impacts relatively low. Yet, it is important to keep in mind that these averages are currently based on only 13 projects, with some technology types only having two projects to draw data from.

Ecological Impacts Dependent on Size of Facility Footprint

The land use efficiencies for proposed projects are directly related to the size of the facility footprint. The total amount of land disturbed has implications for dust emissions related to aeolian wind processes, carbon sequestration by biological soil crust, and regional albedo.

Aeolian Wind Processes: Dust Emission

Solar development may release large amounts of dust if a facility is particularly large, if it is constructed in a location where a large quantity of dust is currently sequestered, or if multiple facilities are constructed in relative proximity to one another. Dust release could have indirect impacts to both the facility site as well as off-site areas downwind. Dust plays a role in nutrient cycling; since much of the plant-essential nutrients are stored in the top few millimeters of soil, excess dust release may significantly deplete nutrients on site.[330] This may limit availability in an already nutrient-starved ecosystem, deliver excess nutrients to the deposition area, and alter the overall nutrient balance of the system. Additionally, dust storms may result in a “sandblast” effect downwind of a solar development-induced dust release, causing increased wind erosion and disturbance in adjacent areas, and triggering larger dust emissions in the dust storm’s path.[331] Large dust depositions could also bury landscapes in a layer of dust, halting photosynthetic activity and reducing fertility if plants and soil crusts are covered.[332] Finally, at a global scale, far reaching dust could increase snowmelt (by decreasing snow albedo), alter nutrient load in aquatic ecosystems, or have other impacts to distant ecosystems.[333]

Aeolian Wind Processes: Human Health

Any process or activity, whether it is natural wind movement or vehicles driving on unpaved roads, can resuspend dust particles and contribute to PM10 pollution. For example, in the Mojave Desert and Salton Sea Air Basins, dust emissions from paved and unpaved roads and construction contribute to PM10 pollution concentrations.[334] Therefore the construction of solar facilities is likely to contribute to PM10 pollution, but the potential relative contribution of facilities to the overall PM10 concentrations in the California desert region remains unknown. How dust emissions are managed on site, such as the application of water to suppress construction dust, will also influence the contribution of a facility to overall PM10 pollution concentrations. Addressing potential increases in PM10 pollution is crucial to the health and well-being of residents in desert communities.

Biological Soil Crusts: Carbon Sequestration

Solar development could affect the carbon sequestration potential of the California desert; the extent of this impact may be dependent on total size of disturbed area (in other words, the facility footprint), in addition to the carbon sequestration potential at the specific facility location. In the 2004 article “Carbon Sequestration in Dryland Ecosystems,” author Lal states that the worlds arid land ecosystems have a large potential to sequester carbon, and that degradation of these lands often results in emission of carbon dioxide, CO_2, into the atmosphere.[335] In a two-year study of the Mojave Desert published in 2008, Wohlfahrt et al. found the ecosystem to be a significant net sink for CO_2. The authors attribute a significant portion of the desert soil’s carbon sequestration capabilities to the expansion and growth of cryptobiotic soil crust organisms.[336] In a 2008 review of the Wohlfahrt et al. paper, author Stone wrote:

> “The effect could be huge: About 35 percent of Earth’s land surface, or 5.2 billion hectares, is desert and semiarid ecosystems. If the Mojave readings represent an average CO_2 uptake, then deserts and semiarid regions may be absorbing up to 5.2 billion tons of carbon a year – roughly half the amount emitted globally by burning fossil fuels, says John ‘Jay’Arnone…a co-author of the Mojave paper.”[337]

However, assertions about desert soils as carbon sinks have been met with skepticism by some scientists. In Stone’s 2008 article in *Science*, Jayne Belnap, an ecologist for the USGS and world renowned authority on soil crusts, says: “There is no way that all the CO_2 absorption observed in these studies is due to biological crusts, as there are not enough of them active long enough to account for such a large sink.”[338]

Despite the controversy, the potential for desert soils to act as long-term carbon sinks has important implications for solar development in the California desert. The grading of land necessary for facility construction could eliminate the ability of the soil to sequester carbon and might result in the release of large amounts of carbon into the atmosphere. Whether developing large swaths of desert for solar energy production or leaving the desert soil intact has greater potential for reducing carbon emissions warrants further study.

Biological Soil Crusts: Carbon Uptake and Avoided Carbon Emissions

Because of the potential for biological soil crusts to fix carbon across the California desert landscape, we examine potential carbon uptake by desert soils compared with the range of potential avoided carbon emissions that would result from the construction of solar facilities in the California desert. Our calculations indicate that potential carbon taken up by biological soil crusts is far less than the amount of carbon offset by the production of solar energy. This calculation does not take into account the amount of carbon emitted by the solar panel manufacturing process, which can be a significant portion of the life-cycle carbon emitted by this product, and is only intended to provide a rough comparison of whether desert soils or solar energy production are more effective at reducing overall carbon emission. Our results must be understood within the context of our assumptions and parameters, which are as follows:

- Rates of carbon uptake determined by the 2008 Wohlfahrt et al. paper are average for the California desert and that rates can be applied to the entire California desert.
- If these utility-scale solar facilities were not built, the carbon that would have been produced by conventional energy sources can be estimated by using CO_2 emitted per MWh of electricity produced, using a statewide average coefficient of 0.138 metric tons CO_2 per MWh for California's grid.[339]
- Average nameplate capacity of proposed solar facilities in California = 427 MW
- Average number of acres for proposed solar facilities in California = 3,797 acres
- Highest average operating efficiency for proposed solar technologies = 39.9 percent (dish/engines)
- Lowest average operating efficiency for proposed solar technologies = 11 percent (Thin Film PV)

Wohlfahrt et al. found that their study sites in the Mojave Desert took up 102 and 110 g C m^{-2} during 2005 and 2006, respectively. We used the average of the two years to calculate the annual rate of carbon uptake per acre of undisturbed desert at 428,967 g C/acre/yr.[a] Operating efficiencies for Thin Film PV at 11 percent efficiency and dish/engine at 39.9 percent efficiency were used to calculate a lower and upper range of avoided emissions: 4,081,211 to 14,803,667 g C/acre/yr.[b, c] A comparison of carbon uptake to avoided emissions is shown in Figure 6.2.

The estimated range of avoided carbon emissions from use of solar energy is 4 to 14.8 million grams carbon per acre per year, depending on the operating efficiency of the solar technology, while the amount of annual carbon uptake is much smaller at approximately 429,000 grams carbon per acre per year. Under these assumptions and parameters, solar facilities are much more effective at reducing overall atmospheric carbon than desert soils.

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[a] Calculating the amount of carbon uptake by desert soils:
$(106 \text{ g C} / \text{m}^2) * (1 \text{ m}^2 / 0.000247105 \text{ acre}) = 428{,}967.443 \text{ g C/acre/yr}$

[b] Calculation for Thin Film PV:
$(427 \text{ MW}) * (0.138 \text{ t } CO_2/\text{MWh}) * (0.11) * (8{,}766 \text{ hr/yr}) = 56{,}819.98 \text{ mt } CO_2/\text{yr}$
$(56{,}819.98 \text{ mt } CO_2/\text{yr}) * (10^6 \text{ g / mt}) * (12\text{g C} / 44\text{g } CO_2) = 1.55 * 10^{10} \text{ g C/yr}$
$(1.55 * 10^{10} \text{ g C/yr}) \div (3{,}797 \text{ acres}) = 4{,}081{,}211 \text{ g C/acre/yr}$

[c] Calculation of Dish/Engine
$(427 \text{ MW}) * (0.138 \text{ t } CO_2/\text{MWh}) * (0.399) * (8{,}766 \text{ hr/yr}) = 206{,}101.58 \text{ mt } CO_2/\text{yr}$
$(206{,}101.58 \text{ mt } CO_2/\text{yr}) * (10^6 \text{ g / mt}) * (12\text{g C} / 44\text{g } CO_2) = 5.62 * 10^{10} \text{ g C/yr}$
$(5.62 * 10^{10} \text{ g C/yr}) \div (3{,}797 \text{ acres}) = 14{,}803{,}666.6 \text{ g C/acre/yr}$

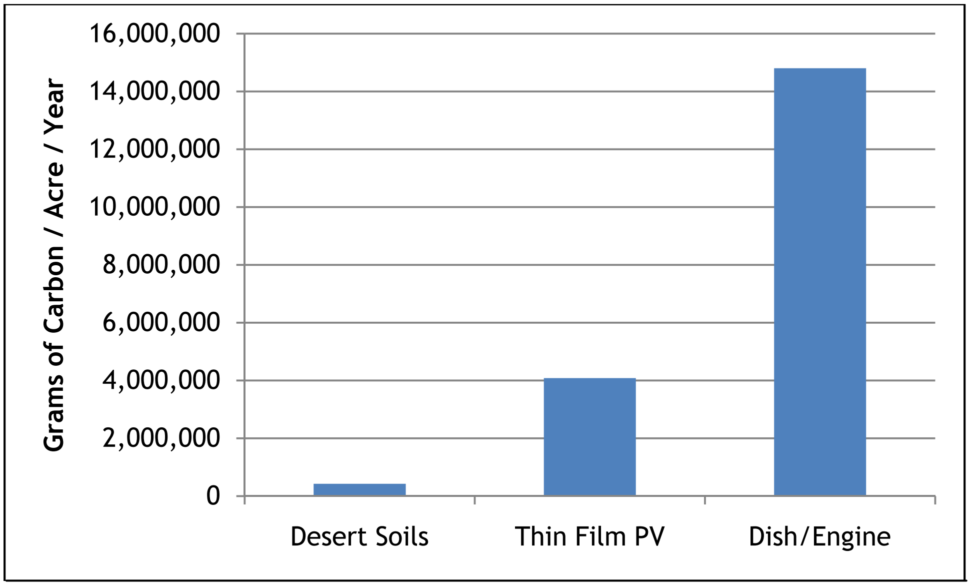


Figure 6.2. Comparison of Carbon Uptake by California Desert Soils and Avoided Carbon Emissions by Solar Energy Production.

Biological Soil Crusts: Albedo

Another unanticipated consequence of solar development might be its effect on regional climate through alteration of soil albedo. Albedo is a measure of how reflective a surface is to the sun's radiation.[340] A surface that is more reflective to this radiation (e.g. a light-colored surface) would have a higher albedo than a surface that absorbs more of the sun's radiation (e.g. a dark-colored surface). In a 2003 paper by Belnap and Eldridge, the authors state that the trampling of dark-colored biological soil crusts exposes lighter soils and can increase albedo; they also caution that *large-scale* changes in surface color may lead to changes in regional climate patterns.[341] There is concern that eliminating the soil crusts, which are dark in color, over several thousand acres of desert and replacing those dark surfaces with reflective panels and mirrors, could also affect regional climate. Jayne Belnap of the USGS said:

> "You've now taken a pretty dark surface and made it reflective. And so you've vastly changed the albedo of that surface. Probably not a big deal in terms of a small solar installation, but in terms of a large one, there are studies that indicate that you can change the regional climate by having large reflective surfaces. And 250,000 acres is a large reflective surface. It could end up decreasing rainfall in the region where the reflective surface is."[342]

The effect that modifying several thousand acres of surface albedo will have on the regional climate of the California desert warrants further study.

WATER USE EFFICIENCY

The impacts to groundwater and surface water availability from solar development will vary by project, and will depend on amount of water used as well as water source. Water obtained by surface water diversion and groundwater pumping can have implications for desert ecosystems. However, hydrology in the California desert is a complex system, and impacts to water levels are sometimes difficult to predict. After having analyzed the relative land use efficiencies of individual projects as well as averages by technology type, it was determined that a similar analysis for water would be a useful step in understanding the implications that solar development may have for desert water resources. Due to the limited amount of water resources in the California desert, the issue of water use by utility-scale solar energy facilities is highly contentious in the views of environmentalists, communities, developers, politicians, and land managers. In order to investigate the impact of the various projects on water resources, an analysis was conducted based on information gathered from the publicly available AFC for each project (Table 6.2). On a project-by-project basis, a clear comparison can be made based on absolute water consumption among the various technology types (Table 6.2 and Figure 6.3).

Table 6.2 Annual Average Water Consumption per Project.[343]

Proposal Name	Technology Type	Cooling System Type	Annual Water Usage (AFY)
Solar Millennium - Blythe	Parabolic Trough	Dry	600
Solar Millennium - Ridgecrest	Parabolic Trough	Dry	150
Solar Millennium - Palen	Parabolic Trough	Dry	300
Parabolic Trough Average			350
Beacon Solar Energy Project	Parabolic Trough	Wet	1,600
Abengoa Mojave	Parabolic Trough	Wet	1,077
Genesis Solar	Parabolic Trough	Wet	1,644
Parabolic Trough Average			1,440
Ivanpah	Power Tower	Dry	100
Rice Solar Energy Project	Power Tower	Dry	150
Power Tower Average			125
Calico (formerly Solar One)	Dish/Engine	N/A	36
Imperial Valley (formerly Solar Two)	Dish/Engine	N/A	33
Dish/Engine Average			35
Chevron Lucerne Valley	Thin-Film PV	N/A	0.14[344]
Notes: "N/A" stands for not applicable in this table.			

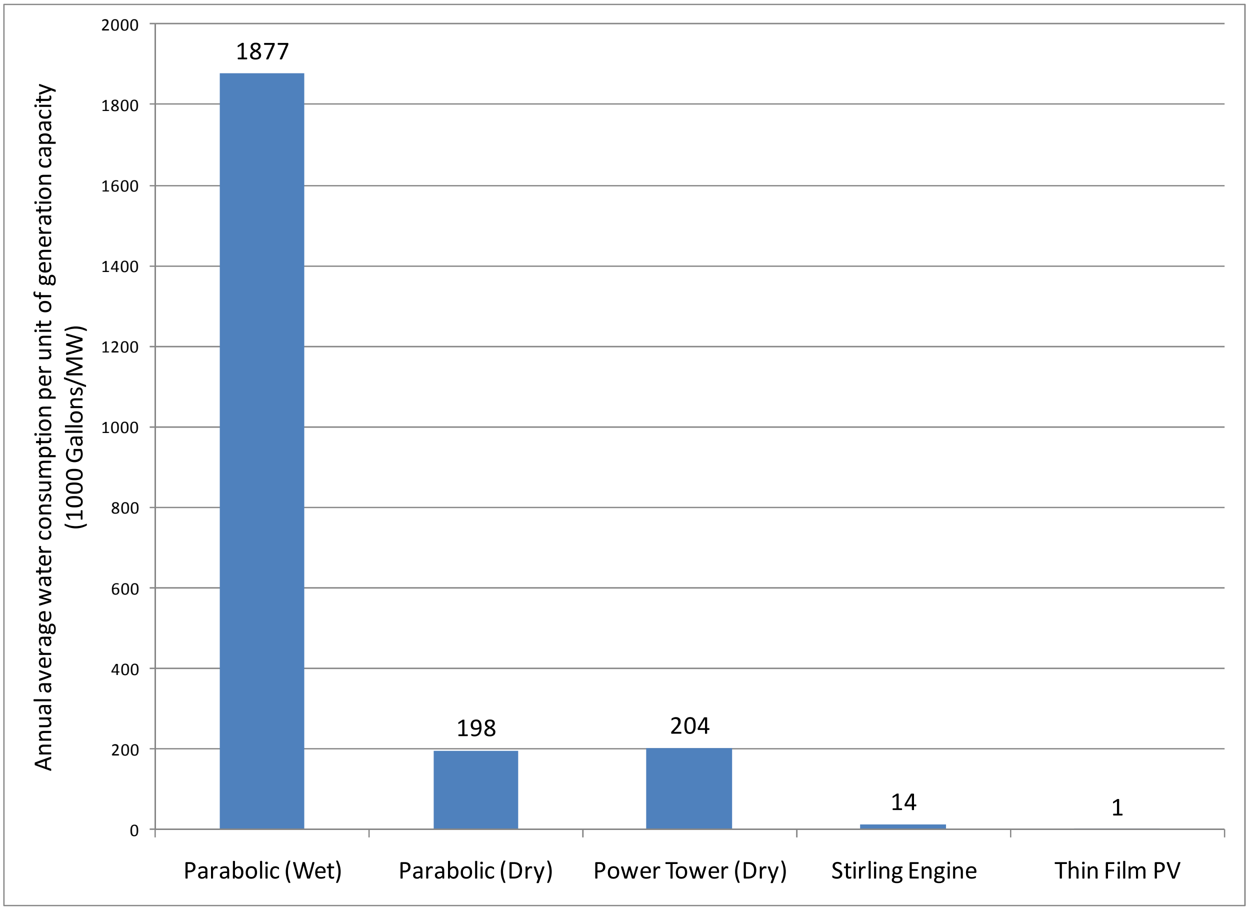


Figure 6.3 Average Annual Water Consumption of Solar Technology Types with Wet and Dry Cooling Systems.

On an absolute scale, thin film photovoltaic facilities appear to consume much less water than other solar thermal based technologies. This is mainly because the water that is used during operation of these types of facilities is only for washing the modules and is not needed as part of the electricity generation process. It should be noted, however, that the water use value for thin film PV technology in this study is based on only one project and the size of the facility is approximately one fifth the size of an average parabolic trough system. Therefore, for a more accurate comparison, the amount of water used by the thin film PV facility would need to be increased by five times. Yet, even with a five-fold increase, the absolute consumption of water by thin film PV systems is still the lowest of all the technologies analyzed. In contrast, in terms of total annual water consumption, wet-cooled parabolic trough systems are clearly the most water-intensive technology type, consuming an average of close to 1.9 million gallons of water per mega-watt of installed capacity.

Total water consumption is often used as a metric to measure impact on water resources; however, these values do not accurately represent how *efficiently* the various technology types use water. In order to quantify this efficiency, a separate analysis was conducted using the water consumption values in conjunction with each project's electricity generation capability, similar to the land use efficiency analysis above. The analysis was based on average annual water consumption rates and average annual electricity production of each facility. The total electricity production value (in MWh) was chosen over the nameplate capacity (in MW) of the facility because it inherently takes into consideration the operating efficiencies of various solar technology types and is a more accurate representation of the facilities' power producing capabilities.

Based on this analysis, it was determined that on a per MWh basis, thin film PV facilities actually appear to be the least water efficient technology with an average efficiency of 6,912 gallons of water used per MWh of electricity produced (Table 6.3). In contrast, dish/engine systems appear to be the most water efficient technology type, requiring only an average of four gallons of water consumed per MWh of electricity produced. In other words, a thin film PV facility would use approximately 1,700 times more water than a dish/engine facility to produce the same megawatt of electricity. This was a surprising result since PV facilities have the lowest overall water consumption due to the fact that they do not utilize cooling systems and the only water used during operation is attributed to washing the modules. Upon further investigation, it was determined that the reason why thin film PV facilities appear so unfavorable in this analysis is because of the low module efficiency of this type of technology. This leads to two important consequences that affect the analysis. First, the low module efficiency effectively lowers the overall operating efficiency of the facility, thereby reducing the total

Table 6.3 Water Efficiency Analysis Based on Annual Water Consumption per Project.

Proposal Name	Technology Type	Cooling System Type	Water Consumption per Unit of Electricity Produced (Gal/MWh)
Solar Millennium - Blythe	Parabolic Trough	Dry	93
Solar Millennium - Ridgecrest	Parabolic Trough	Dry	98
Solar Millennium - Palen	Parabolic Trough	Dry	98
Parabolic Trough Average			96
Beacon Solar Energy Project	Parabolic Trough	Wet	869
Abengoa Mojave	Parabolic Trough	Wet	557
Genesis Solar	Parabolic Trough	Wet	1,786
Parabolic Trough Average			1,071
Ivanpah	Power Tower	Dry	34
Rice Solar Energy Project	Power Tower	Dry	109
Power Tower Average			71.52
Calico (formerly Solar One)	Dish/Engine	N/A	3.94
Imperial Valley (formerly Solar Two)	Dish/Engine	N/A	4.10
Dish/Engine Average			4.02
Chevron Lucerne Valley	Thin Film PV	N/A	6,912[345]

amount of electricity produced. Second, because less power is produced per unit area, installation of more solar modules would be necessary to produce a fixed amount of electricity. As a result of this increase of installed units, more water would be necessary to clean these additional modules. For comparison, water efficiency rates among various solar and conventional power plant types such as coal, natural gas or nuclear is shown in Figure 6.4.

It should be noted that PV technology companies are continuously working on improving water capture and reuse methods as well as developing systems that would not require module washing. Advances in this area would greatly improve the water use efficiency values of these systems and should be monitored and analyzed on an ongoing basis.

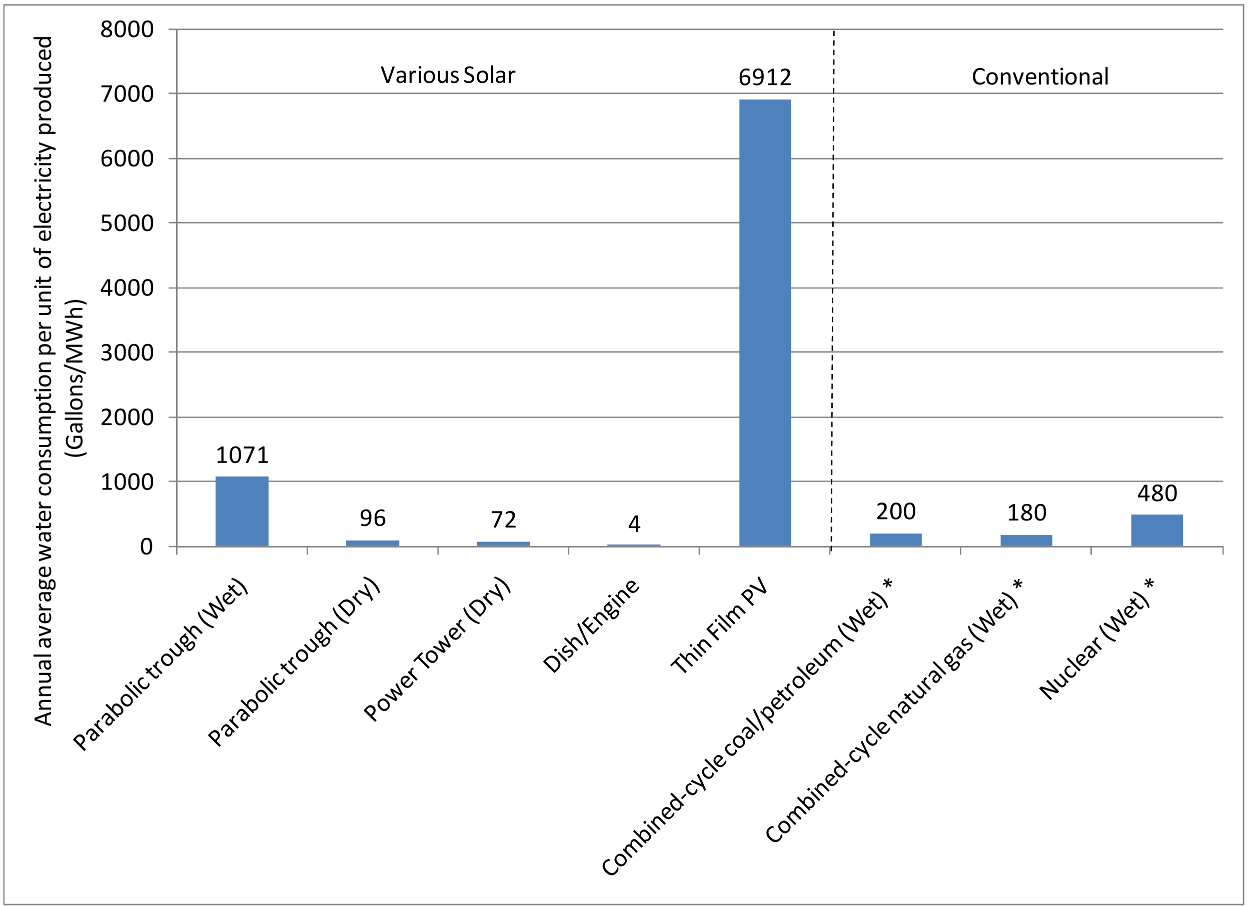


Figure 6.4 Comparison of water consumption efficiency rates. Source: Water & Sustainability (Volume 3).[346]

Ecological Impacts from Groundwater Withdrawal or Surface Water Diversion

The total amount of water used by solar facilities across the landscape, how efficiently that water is used, and the source of the water has consequences for the hydrology of the California desert. Terrestrial, riparian, and aquatic habitats are likely to be affected. The desert pupfish (*Cyprinodon macularius*) and the Owens Valley are used as examples to demonstrate potential impacts.

Hydrology: Impacts to Terrestrial Habitats

Long-term sustainability of groundwater-dependent ecosystems in arid regions is particularly sensitive to anthropogenic alterations of subterranean water systems.[347] Groundwater withdrawals for solar development that lower an already shallow water table may lead to reduction or even elimination of spring discharge. Some plant species in arid regions are more dependent on groundwater resources than precipitation because groundwater is less subject to annual variability than precipitation.[348] If pumping water for solar development reduces groundwater to a level below the root zones, these groundwater-dependent plants could be adversely affected.[349] The result may include reduced plant species richness, reduction of plant cover, or shift in vegetation type.[350] Vegetation response to groundwater pumping is dependent on several factors, including but not limited to the magnitude of change in spring discharge, amount of groundwater decline, spring size, soil characteristics that affect salt percolation, and distance from extraction site.[351] Additionally, water obtained for solar development could alter the ratio of surface water and groundwater availability, which could induce changes to vegetation community composition.[352] Alteration in plant communities can, in turn, affect animal species through habitat loss or decreased habitat connectivity. Similar impacts to desert species may occur if solar development requires surface water diversions that decrease water supply to riverine systems and riparian corridors.[353] In addition to habitat loss, decreased vegetation resulting from water extraction or diversion may result in increased erosion and sediment production since plant assemblages protect against wind and water scraping.[354] Reduced soil moisture that may result from vegetation removal has the potential to cause localized and long-term increases in dust emission.

Habitat Connectivity: Impacts to Riparian Corridors

Riparian habitats, which are assemblages of plant communities characterized by their associations with surface or subsurface water, often function as migration corridors.[355] Both the water and the plants associated with these corridors provide important resources for the species that rely on these riparian habitats. In the Mojave in particular, many bird species are supported by these riparian habitats.[356] These habitats can be patchy, but they provide connectivity for species as they move across the landscape. If gaps between patches become too wide along the corridor, they may no longer be useful for migration. Solar development that limits water supply to these corridors, through either channel diversion or withdrawal, may impact the health of these habitats. Riparian habitats that suffer a loss of water may not be able to support as many plant communities, or water availability for animals may be depleted.

Hydrology: Impacts to Aquatic Habitats

Aquatic habitats, while relatively limited in arid regions, are susceptible to impacts from solar development in the California desert if groundwater and surface water sources are affected. Desert springs are just one example of a rare aquatic habitat; they are seldom encountered in arid ecosystems and their distribution is scattered.[357] Though they may occur as single springs or a cluster of springs, distances between spring habitats are often too far to allow migration between them.[358] If the vitality of a spring is compromised by groundwater extraction for solar development, species dependent on the spring may suffer loss of habitat that cannot be mitigated.[359]

However, impacts to water supply as the result of groundwater extraction (for solar development or otherwise) can be difficult to predict both spatially and temporally; aquifers in the California desert are structurally complex, impacts may occur at great distances from extraction sites, and there may be a lag time between extraction and identifiable impacts.[360] This complexity also makes cumulative effects difficult to predict. An agency hydrologist notes:

> "It's not enough to just monitor withdrawal effects, since even if you stop pumping, effects may be slow to reach the site… Every time you start pumping an aquifer, something's got to give. Either there is going to be a decline in spring discharge or water levels down gradient; it could increase recharge from up-gradient areas - but something's got to give. The aquifer is in equilibrium with natural conditions as far as recharge rates and discharge rates, and when you start sticking more straws in the glass, each one of these actions - not the individual actions but the cumulative effects of these incremental increases in water withdrawals from that aquifer – are going to result in decreased water levels, aquifer levels and decreased spring discharge."[361]

While impacts to groundwater- and surface water-dependent species and habitats from solar development may be difficult to predict or monitor, water extraction that exceeds groundwater recharge or replenishment from precipitation has potential long-term consequences. Additionally, impacts may be difficult to assign to specific projects, as they often occur at great distances from the extraction source and/or after significant time has passed.

Case Study: The Desert Pupfish

The desert pupfish (*Cyprinodon macularius*) serves as one example of a sensitive aquatic species that may be affected by reduction in water availability, as their habitat includes warm pools, marshes, springs, seeps. The species is listed as federally endangered, and NatureServe Explorer gives the species a global status of G1 (Critically Imperiled).[362] Populations have been drastically reduced as a result of several threats, including habitat loss from water extraction and encroachment by invasive plant species, introduction of predator and competitor species, and water contamination by pesticides.[363] Though not widely distributed, they are considered an indicator species for water availability and stability in some areas of the California desert.[364] Generally considered a fairly hearty species, the desert pupfish can tolerate wide ranges of salinity and temperature.[365] However, they have an upper limit for temperature tolerance, and like many other species in the California desert, the desert pupfish is already living at its upper limits of these tolerances.[366] Groundwater pumping that limits water supply to pupfish habitat can increase water temperatures and put a physiological stress on the species.[367] Specifically, when the upper temperature limit is crossed, either egg-hatching success dwindles close to zero or survival of newly hatched larvae is limited.[368] Paired with climate change predictions for decreased precipitation and increased temperatures, these changes could have a devastating effect on the species.

The desert pupfish, therefore, is an illustration of aquatic species sensitivity to reductions in water availability. Climate change will likely continue to put stress on aquatic species, with increased water temperatures, intensified pollutant toxicity, and a reduction in dissolved oxygen levels.[369] In 2006, Carveth et al. showed that increasing water temperatures may provide more suitable habitat for introduced fish species, adding another potential threat to native fish in the form of competition.[370] Consideration of these species interactions should be given to hydrologically connected aquatic habitats if groundwater is pumped for solar development needs.

Case Study: Water Extraction and Diversion in Owens Valley, CA

The depletion of surface and groundwater by solar development may have unexpected consequences, as illustrated by the impacts of both surface water diversion and groundwater pumping in Owens Valley, California. The Owens Valley, located in the Great Basin Desert in California's Inyo County, provides a good example of terrestrial impacts that can result from reduced flows of surface and groundwater. In 1913, Los Angeles opened an aqueduct that diverted surface water from the Owens River, which runs through the Owens Valley, down to the city. Los Angeles began pumping groundwater in 1918, and opened a parallel aqueduct that pumped additional groundwater out of the valley in 1970.[371] Surface water diversion and groundwater pumping have induced measurable changes in vegetation composition and cover of the Owens Valley, including increased shrub cover replacing grass cover.[372] Preliminary evaluations of vegetation change found that from 1906 to 1968, major vegetation cover declined by 38 percent, and from 1968 to 1981, major vegetation cover declined by 67 percent.[373] It has been estimated that approximately 25,000 acres of groundwater-dependent vegetation in the valley have been negatively affected by groundwater pumping.[374]

The water table served as a buffer for vegetation to adjust to annual fluctuations in precipitation, but diversion and pumping have resulted in fluctuations in the water supply that negatively affects native plants such as willow (*Salix* spp.), saltgrass (*Distichlis spicata*), greasewood (*Sarcobatus vermiculatus*), and favors weed species such as Russian thistle (*Salsola* spp.) and bassia (*Bassia hysopifolia*).[375] Saltcedar (*Tamarix ramosissima*) has colonized riparian habitats below the aqueduct intake because intermittent surface water flow creates disturbance that harms native vegetation and favors saltcedar.[376] Nevada saltbush scrub (*Atriplex torreyi*), saltgrass meadow, and alkali marsh communities around the Little Black Rock Spring have declined because of groundwater pumping.[377]

Conclusion

The information on site engineering processes (such as grading and fire prevention) combined with the results of the subsequent land and water use analyses, indicate that technology type and facility footprint have a number of implications for the effect of a project on the surrounding ecosystem. This analysis has yielded a variety of interesting results that help us to better understand how and to what degree these two variables act on the local environment. The analyses have demonstrated that certain technology types, such as dish/engine systems, show the promise of having both high land and water use efficiencies, which could make this technology type one of the most productive forms of solar development while also suggesting that it may incur a relatively lower amount of ecological impact. Likewise, these analyses demonstrated that one of the most effective design changes a facility can make to reduce its environmental impact is to utilize a dry-cooled system rather than a wet-cooled system.

However, it is important to note that the land use analysis also has some limitations. First, it constructs the disturbance ratio based on the amount of area that will be covered completely by various forms of infrastructure, such as roads, buildings, and the solar field. It does not include other types of disturbance or environmental disruption that may arise from other forms of infrastructure, which may still result in ecological impacts on the surrounding area and wildlife. Second, this form of analysis utilizes the area of disturbance as the key variable in assessing the relative land use efficiency of a project proposal. Caution should be applied with this approach as these project proposals are still in the permitting process and are therefore subject to design change. Should certain design changes occur, the relative land use efficiency ratio of a project might change as well. Third, although this tool primarily focuses on the relationship between the facility footprint and the amount of electricity generated by the facility, users should keep in mind that the size of the facility footprint also contains its own set of ecological and efficiency trade-offs. For example, solar energy facilities that utilize a dry-cooling system will inherently operate at a lower efficiency, and therefore developers will frequently expand the footprint accordingly to generate the same amount of energy as a smaller wet-cooled facility. For some users of this tool, the consideration of the amount of water use may be of greater concern than area of land use, in which case, they may weigh the results of the water use efficiency analysis more heavily. And finally, users of this tool should refrain from extrapolating the total environmental impact of a project from these ratios. Although land use efficiencies are undoubtedly helpful for comparisons among different projects and even various technologies, they remain a snapshot of the proposed development and are certainly not comprehensive in their scope of environmental assessment.

Regardless of a technology type's relative land-use and water-use efficiency, the geographic location of facilities, as well as the biological resources associated with sites, will directly determine the type, intensity, and extent of landscape-level impacts from development. Case studies of potential impacts to desert wildlife offer an illustration of how landscape-level impacts resulting from the construction of multiple facilities may affect species at the population level; to that end, we developed case studies of potential impacts to three desert species, discussed below.

SOLAR DEVELOPMENT IMPACTS: SPECIES CASE STUDIES

In addition to our analysis on the potential impacts of solar development on ecological processes, many of the sensitive species found in the California desert are also at risk. Individual species as well as populations may be affected by site-level and/or landscape-level impacts. To illustrate this, we discuss the potential impacts that solar development may have on: the desert tortoise (*Gopherus agassizii)*, the desert bighorn sheep (*Ovis canadensis nelsoni*), and pollinators in the California desert. Though we chose to focus on just three examples to illustrate the potential impacts utility-scale solar development may have on desert species, similar concerns could be relevant for any species that may suffer from habitat loss, habitat fragmentation, water depletion, migration corridor blockage, or the indirect impacts associated with increased human presence in the region. Species that are most at risk include species with limited ranges, in particular those species with primary habitat in the flat, low-lying desert areas where solar development is most likely to occur.

Desert Tortoise (Gopherus agassizii)

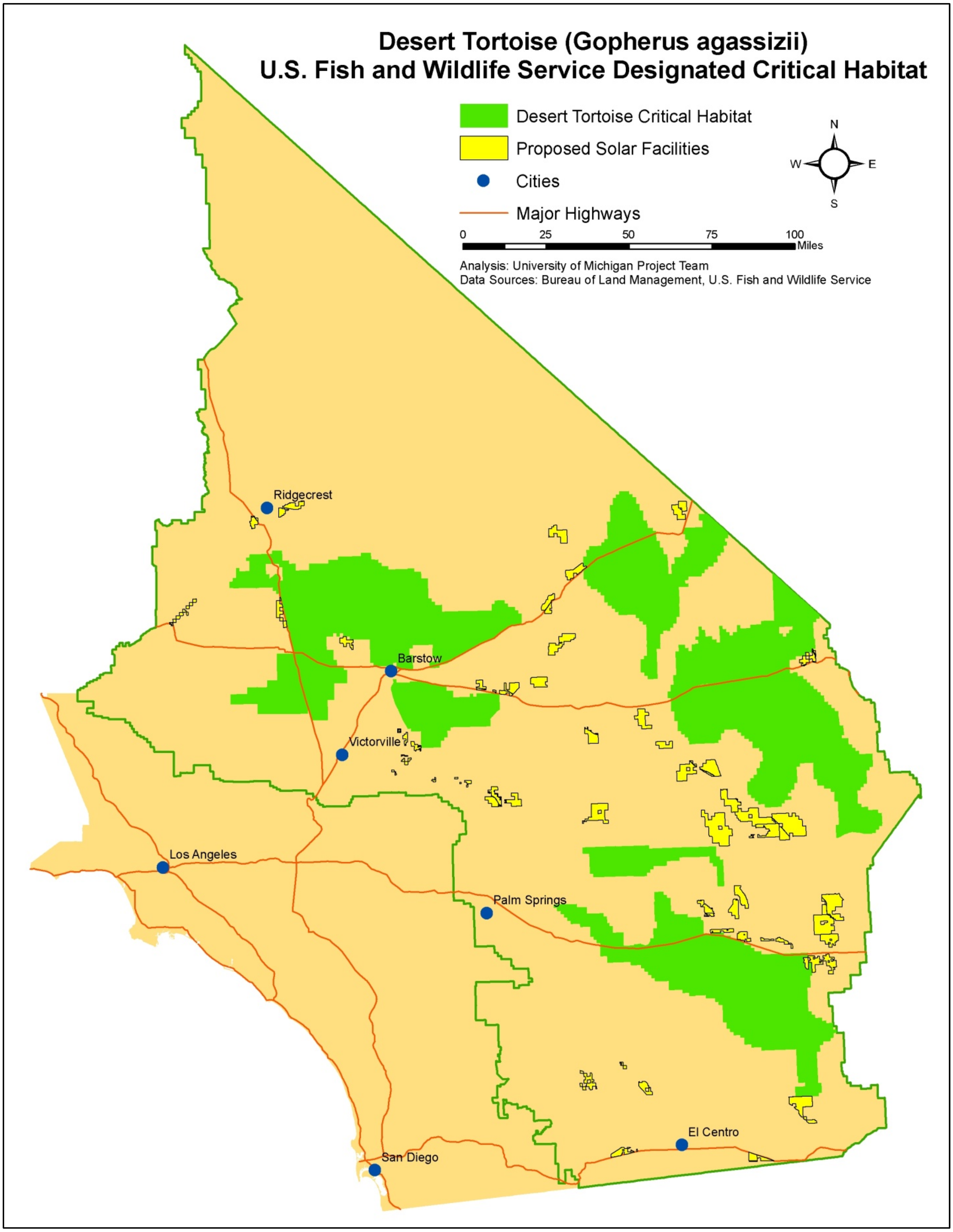
Status/Listing

Figure 6.5 Desert Tortoise. Image Credit: Beth Jackson/FWS.

The desert tortoise, a flagship species in the California desert, has been listed as threatened under the California Endangered Species Act since 1989 and the Mojave population has been listed under the Federal Endangered Species Act since 1990 (Figure 6.5).[378] The Sonoran population of tortoises is currently under review for listing by the FWS.[379] NatureServe Explorer gives the tortoise a global status of G4 (apparently secure) and a state status of S2 (imperiled) for California.[380] The International Union for Conservation of Nature lists the desert tortoise as Vulnerable.[381] Despite the listing and attention the species receives for recovery and conservation efforts, populations continue to experience dramatic decline.[382]

Habitat Loss

Many solar facilities have proposed siting in or near desert tortoise habitat (Map 6.1). Development of the these facilities will result in a direct loss of habitat for the desert tortoise because proposed solar facilities plan to use fencing specifically designed to exclude desert tortoises from a project site.



Map 6.1 Desert Tortoise Critical Habitat and Proposed Facilities.

Tortoises will be excluded from project sites in order to prevent them from being accidentally killed by machinery during construction, killed by vehicles during operation, or otherwise trapped within the facility. While fencing the entire disturbance area of a facility may prevent the direct mortality of individual tortoises, the total area of habitat that is lost could have negative impacts on tortoise populations, depending on habitat quality within proposed sites.

Surveys of one proposed (2,012 acre) solar facility found zero desert tortoise within the project disturbance area, and five tortoises about 600 feet outside of the proposed disturbance area.[383] The low numbers of tortoises found at this site may be due in part to past agricultural activities that left the site heavily disturbed and low in native vegetation. However, surveys of another proposed (1,760 acre) solar facility found 40 desert tortoise within the project disturbance area, and 10 tortoises within the one-mile buffer zone.[384] Surveys of the project site and buffer zone also found over 200 tortoise burrows, where 36 active burrows were within the disturbance area and 12 were in the one-mile buffer zone.[385] Though the project is not located in designated desert tortoise critical habitat or in a designated desert tortoise Desert Wildlife Management Area (DWMA), the estimated density of adult tortoises within the disturbance area was greater than that of a nearby DWMA: 9.8 desert tortoise per km^2 within the proposed solar site, compared with 5.3 to 7.6 desert tortoise per km^2 within the nearby DWMA.[386] Projects that are built in areas of high desert tortoise density will permanently eliminate large swaths of high quality habitat.

Habitat Fragmentation and Connectivity

Increased habitat fragmentation caused by new facilities, roads, ground disturbance under transmission lines, and other linear corridors (e.g., pipelines), will create barriers to movement that could negatively affect population dynamics. Roads and other linear corridors subdivide contiguous habitat, creating smaller and more isolated tortoise populations. These smaller, isolated populations are more susceptible to decline or local extinction due to drought or other stochastic events, as well as the negative effects of inbreeding. Recovery by small, isolated populations may rely heavily on immigration of new individuals from adjacent habitat, but these inter-population movements are often prevented by the very things that fragmented the habitat in the first place (i.e. roads, development).[387]

The development of barriers between desert tortoise critical habitats is especially problematic. In a 2009 study, Bare et al. found that solar development in the West Mojave could inhibit movement between certain desert tortoise critical habitats.[388] Conserving habitats that allow movement of individuals between critical habitat units is essential to the long-term viability of the Mojave population of the desert tortoise.[389, 390] Solar development, in addition to eliminating several thousands of acres of occupied and potential desert tortoise habitat per project, may also eliminate or fragment habitats that serve as crucial habitat corridors between conservation areas, which may compromise recovery of the species.

Linear Corridors

New roads constructed to service solar facilities and/or an increase in traffic on existing roads will increase mortality of desert tortoises. Desert tortoises are vulnerable to being run over by automobiles, and the proliferation of new roads through tortoise habitat will likely increase the risk of roadkill mortality.[391] Increased OHV access to previously undisturbed natural areas via these new roads could also increase the chances of tortoises being run over by OHVs. In addition to increased OHV access, an increase in human access to tortoise habitat has several other negative implications.

Increased human access to and presence in the California desert due to new solar facilities could benefit the common raven (*Corvus corax*), considered to be a “subsidized predator” of juvenile desert tortoise.[392] Ravens are able to travel long distances to take advantage of human-provided food and water sources at a solar facility, such as trash generated on-site, roadkill created by increased vehicle traffic, and standing water created by dust suppression techniques.[393] Raven populations, elevated by human-provided food supplies, venture far beyond developments and into natural areas where they prey on juvenile desert tortoises.[394] Says Jody Fraser, a biologist with the FWS:

> “Ravens may travel more than 40 kilometers to forage and will take advantage of subsidies, such as food, water, and perch and nest substrates provided, often inadvertently, by humans. Large solar facilities in remote areas of the desert will likely attract ravens to these sites, and the transmission infrastructure will provide a corridor along which they can travel.”[395]

Solar facility infrastructure, such as fencing, buildings, or transmission lines, could create elevated perches that could be used by ravens to hunt tortoises more effectively. Predation by ravens is a serious threat to desert tortoise populations. In a 2003 study by Kristan and Boarman, the authors state that “anthropogenic resources for ravens could indirectly lead to the suppression, decline, or even extinction of desert tortoise populations.”[396] More recently, coyote (*Canis latrans*) predation on desert tortoise has become a problem especially in light of the prolonged drought being experienced in the region and a decline in prey species, such as jack rabbits and ground squirrels.[397] A proliferation of solar development in desert tortoise habitat could supplement existing human-provided resources for ravens and coyotes, and lead to further decline of tortoise populations.

The proliferation of new roads in or near tortoise habitat has the potential to negatively affect tortoise populations via increased trash or litter, collection, disease, and vandalism. For example, one proposed solar facility would be sited about seven miles from a desert tortoise DWMA. Increased human access to desert areas in the proximity of tortoise habitat could lead to an increase in the amount of trash or litter in tortoise habitat. Tortoises have been known to eat balloons, plastic, and other pieces trash, which can become lodged in the digestive tract, eventually causing death.[398] Other human activities that endanger tortoise populations are collection of tortoises (i.e. for pets), release of previously-collected tortoises from captivity that can spread diseases to wild tortoises, and vandalism.[399, 400] Disease in wild desert tortoise populations is responsible for increased stress and mortality in tortoises, likely contributing to population declines.[401,402] Acts of vandalism include shooting, beheading, severing of body parts, and overturning (which immobilizes the tortoises).[403] In 1996, Berry found a higher percentage of desert tortoise gunshot deaths in the Western Mojave, compared to the Eastern Mojave or Colorado Deserts, and attributed this to a higher number of human visitors and greater vehicular access in the Western Mojave.[404]

Invasive Plants

Roads and other transportation corridors necessary for solar development could facilitate the colonization of natural areas by invasive plants.[405] The spread of invasive plants is problematic for the desert tortoise because of its effect on the frequency of fire. Invasive grasses increase the frequency of fire by increasing the amount of vegetative fuel and by reducing the space between plants, allowing fire to spread to a larger area.[406] Wildfires have both direct and indirect effects on tortoises. The slow-moving tortoises might not be able to escape a fast-moving wildfire, and could therefore suffer direct mortality in a fire.[407] If a tortoise does survive a fire, the loss of vegetation from the fire could leave large areas devoid of food for the tortoise and lead to starvation. In addition, loss of vegetative cover leads to loss of protection from predators (i.e. places to hide) and temperature extremes (i.e. loss of shade).[408]

The effect that non-native grasses have on tortoise diet is less clear. Non-native annual grasses compete with native annual plants in the Mojave Desert, potentially reducing the amount of acceptable/useable food plants for the tortoise.[409] However, desert tortoise may include non-native plants in their diet.[410] Despite a possible increase in the availability of tortoise forage, positive effects from non-native plant species are far outweighed by the serious negative effects from higher fire potential and subsequent habitat destruction.[411]

Implications for the Ecosystem

To escape from harsh environmental conditions, tortoises will utilize a wide variety and number of burrows that they have either excavated on their own or modified from another animal.[412] Excavation and construction of burrows by tortoises can provide habitat for several other species, including, but not limited to: antelope ground squirrel (*Ammospermophilus lecurus*), blacktailed jackrabbit (*Lepus californicus*), kangaroo rat (*Dipodomys* spp.), kit fox (*Vulpes macrotis*), burrowing owl (*Athene cunicularia*), Gambel's quail (*Callipepla gambelii*), roadrunner (*Geococcyx californianus*), desert spiny lizard (*Sceloporus magister*), western rattlesnake (*Crotalus viridis*), ground beetle (*Tenbrionidae*), and tarantula (*Aphonopelma* spp.).[413] Because the tortoise creates microhabitats for numerous other species, it could be considered a keystone species of the California desert.[414] Extirpation or continued decline of the desert tortoise in the California desert from the impacts discussed above may have implications for species that currently benefit from tortoise burrows.

Ecological Implications for Facility Location and Design

The magnitude of impact that the development of a single solar facility or multiple facilities will have on the desert tortoise is dependent on the facility design variables and location as discussed in Table 6.4. These variables will influence the magnitude of the cumulative impact of solar development on the desert tortoise populations in the California desert.

Table 6.4 Solar Facility Design Variables Affecting Desert Tortoise.

Facility Design Variable	Implications for the Desert Tortoise
Location of Facility	Determines the quality of desert tortoise habitat that is eliminated (some areas are better quality tortoise habitat than others). Determines magnitude of habitat fragmentation (some areas are more heavily used by tortoises for movement and migration).
Size of facility	Larger facility has a greater probability of eliminating desert tortoise habitat.
Proximity to other development	The closer a facility is to developed areas, the more likely it is that desert tortoise habitat is already degraded and populations are depressed from predation and other human impacts.
New and existing roads to access the facility	More roads increase the probability of roadkill mortality.
Number of construction and operation personnel	More vehicles increase the probability of roadkill mortality.
Speed limits	Lower speed limits reduce the probability of roadkill mortality.
Length of new transmission line(s)	Longer transmission lines create a larger disturbance area and increased habitat fragmentation.
On-site Raven Management Plan	An effective raven management plan might prevent the establishment of ravens at the facility site and could reduce predation of ravens on desert tortoise.
On-site trash and standing water BMPs	Secured trash and minimization of standing water on-site reduces attractiveness of the facility to predators (e.g. ravens, coyotes) and reduces predation on desert tortoise.
Invasive plant and fire management plans	Plans that minimize the establishment and spread of invasive plants and contain fires reduce direct and indirect mortality of tortoises from fire.

Nelson's (or Desert) Bighorn Sheep (Ovis canadensis nelsoni)

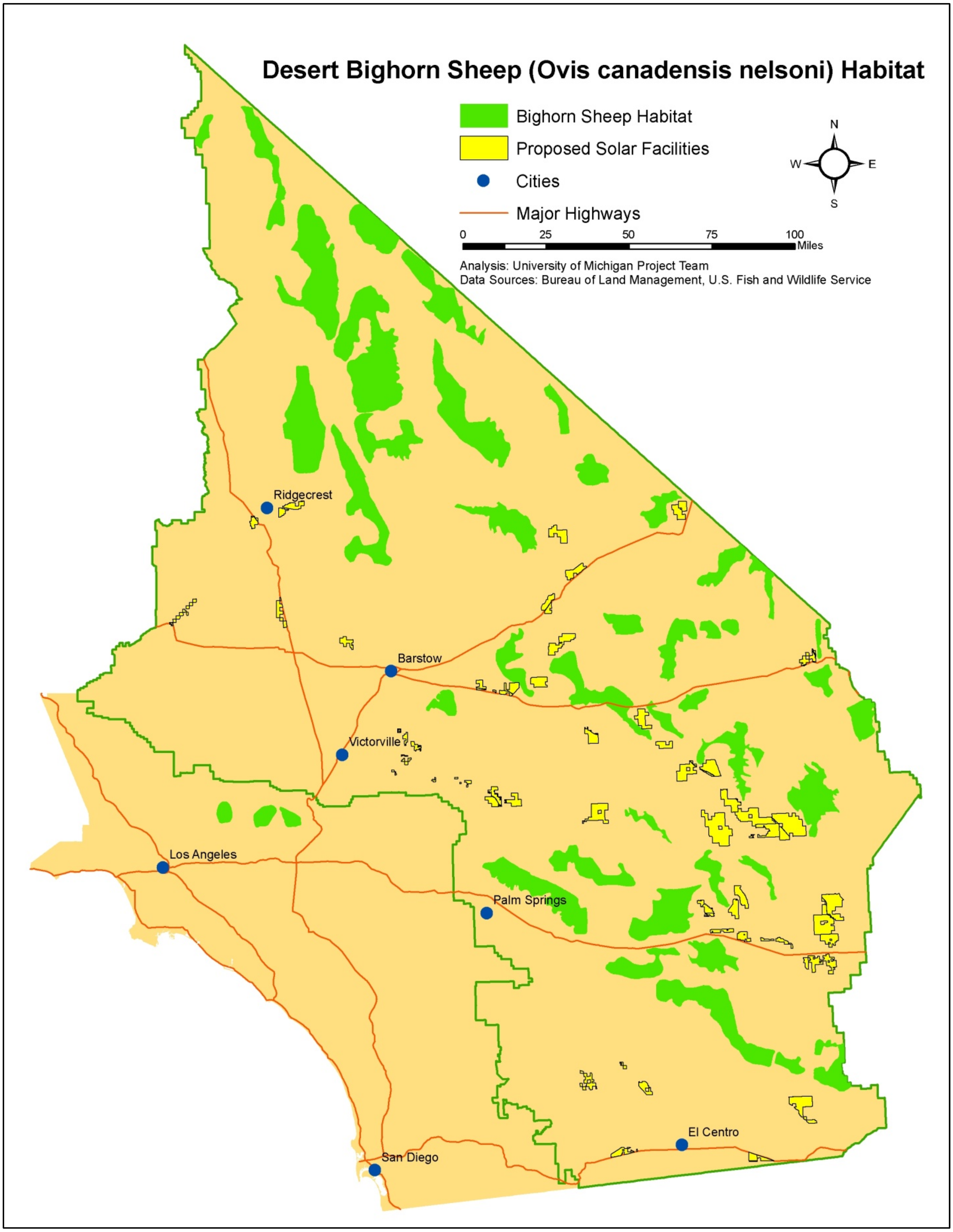
Status/Listing

Figure 6.6 Desert Bighorn Sheep. Image Credit: Lynn B. Starnes/USFWS

There are three subspecies of bighorn sheep (*Ovis canadensis*) within or in proximity to the California desert: Nelson's bighorn sheep (*O. c. nelsoni*), peninsular bighorn sheep (*O. c. nelsoni DPS*), and Sierra Nevada bighorn sheep (*O. c. sierrae*).[415] Historical population and distribution data shows a substantial decline in California's bighorn sheep populations over the last 60 years due to human pressures that include habitat degradation and disease introduction from domestic livestock.[416] Nelson's bighorn sheep (or desert bighorn sheep) is the only subspecies of the three that thrives in the California desert, and is the largest native vertebrate in the bioregion (Figure 6.6).[417] The desert bighorn sheep is not federally listed; the BLM and the USFS, however, both list the subspecies as Sensitive.[418] NatureServe Explorer gives the desert bighorn sheep subspecies a global status of G4T4 (apparently secure), and a California state status of S3 (vulnerable).[419] The International Union for Conservation of Nature (IUCN) lists *Ovis canadensis* as Least Concern, but NatureServe indicates the IUCN's historic listing for the desert bighorn sheep subspecies as Conservation Dependent.[420,421]

Habitat Fragmentation: Loss of Connectivity and Barriers to Migration

Habitat loss and fragmentation are major contributors to the declining bighorn sheep population in the California desert.[422] Metapopulations need to be able to move between mountain ranges and come in contact with one another, in order to maintain genetic diversity through breeding.[423] These intermountain movements also allow for new colonization of available habitat. As connectivity between mountain ranges is essential for the persistence of the population, the addition of solar facilities on the desert floor may have consequences for these mountain-dwelling bighorn sheep (Map 6.2). Fencing and roads associated with these facilities could act as barriers to migration. In a 2005 study of the rapid decline of genetic diversity for the subspecies, Epps et al. found an apparent elimination of gene flow due to anthropogenic barriers that include highways and developed areas. Their results indicate these barriers represent a "severe threat" to the persistence of the populations.[424] Though solar development may not necessitate new highways, even some two-lane roads may deter movement of desert bighorn sheep; heavy traffic and/or sustained human presence may inhibit migration across new or existing roads associated with solar facilities, particularly during construction phase.[425] Paired with the potential impacts of climate change, which could include loss of habitat (as sheep are pushed into higher elevations), and decreased water availability, this added pressure could be detrimental to the metapopulation. As evidenced by the 2005 Epps et al. study:



Map 6.2 Bighorn Sheep Habitat and Proposed Facilities.

> "Our analyses point to the conclusion that human-made barriers may greatly reduce stability of the system as a whole…Extinction risk for many desert bighorn sheep populations in California is high, and may sharply increase in the coming century because of climate warming… if barriers disrupt gene flow and recolonization, genetic diversity may be lost very rapidly from the system as a whole (given that the total number of populations in this instance is not large."[426]

Dr. Clinton Epps, the lead author of that study, offered a follow-up perspective of the desert bighorn sheep metapopulation in the California desert in light of potential solar development. In a personal interview, he expressed concern about maintaining habitat connectivity:

> "When I found out about the solar projects it was pretty shocking frankly. One of the conclusions from my years of working down there is that probably the most critical thing we can do to preserve bighorn over the larger landscape is maintain connectivity between those populations... Well we've seen some of them get recolonized, and so the analysis is, I think, correct in that extinction is more likely in some of those low-lying areas but if you look at it from a metapopulation perspective, the system as a whole will be more stable and more genetically diverse the more those patches are occupied, and the way to keep those patches occupied is to maintain the ability for these animals to move back and forth between those patches.
>
> The developments are mostly slated for the flats – people still regard flats between those mountain ranges as wastelands, but we've got very clear evidence (genetically, directly, radiotelemetry, etc.) that they do move back and forth between these areas and that it's not just a question of inbreeding and genetic diversity although that's part of it; it's also just a simple extinction and recolonization dynamics, and my guess is that's actually more important than the genetic diversity worries."[427]

In 2009, Bare et al. modeled the connectivity of 69 bighorn sheep populations in West Mojave that depend on gene flow between populations facilitated by migration. This study analyzed the potential of utility-scale renewable energy development to obstruct these pathways. Results indicate that extensive development could have serious consequences for desert bighorn sheep, by obstructing movement and gene flow.[428] The authors also caution against siting facilities in areas that are currently unoccupied suitable habitats for bighorn sheep as these areas may be needed for future recolonization.[429]

Water Availability: Groundwater Pumping and Invasive Plants

While severe drought compromises water availability, solar facilities have the potential to affectdesert bighorn sheep populations if groundwater pumping or surface water diversions occur as a direct or indirect consequence of development. Aquifer drawdown that results in the reduction or elimination of surface water used by desert bighorn sheep could negatively affect their ability to survive in the already water-limited desert. Additionally, studies indicate that sustained human presence deters bighorn sheep from accessing relied-upon water sources — this could be problematic during the construction phase when more workers are present on site.[430] Introduced species from new or increased road access during construction and operation phases can also have an indirect impact on water availability. For example, the well-established non-native shrub tamarisk (*Tamarix* spp.), also known as saltcedar, has already had detrimental effects on water availability; introduction of new invasive plant species could compound this problem, consuming more groundwater and therefore limiting surface water availability for the bighorn sheep.[431]

Ecological Implications for Facility Location and Design

The magnitude of impact that the development of a single solar facility or multiple facilities will have on the desert bighorn sheep is dependent on the facility design variables and location as discussed in Table 6.5. These variables will influence the magnitude of the cumulative impact of solar development on the bighorn sheep metapopulations in the California desert.

Table 6.5 Solar Facility Design Variables Affecting Bighorn Sheep.

Facility Design Variable	Implications for the Desert Bighorn Sheep
Location of Facility	Determines whether facility blocks a migration corridor or impedes bighorn sheep movement. Also determines if resources for sheep are lost due to habitat removal by perimeter fencing.
Size of facility	Larger facility (i.e. greater fenced area) increases probability of blocking migration corridor or impeding bighorn sheep movement, increases amount of habitat loss if sheep relies on fenced area for resources.
Proximity to other development	Determines magnitude of habitat fragmentation or migration corridor blockage.
New and existing roads to access the facility	Determines magnitude of habitat fragmentation or migration corridor blockage. More roads increase probability of impact.
Number of construction and operation personnel	Greater human presence increases probability of impeding species movement (sheep often avoid areas of high human presence).
Water Source and Quantity	Water source (groundwater pumping or surface water diversion) for facility use determines whether a water source has been compromised for the sheep. Greater quantity of water diverted increases likelihood of affecting habitat connectivity for sheep that rely on affected surface water resource for migration.

Pollinators

Despite the importance of pollinators, pollination appears to have been overlooked in the solar debate thus far.[432] Pollinators provide an essential ecosystem service – pollination – to wild plants and crops worldwide. In addition to valuable crops, pollinators sustain plants that are important to natural resource-based tourism. The Mojave National Preserve, Death Valley National Park, and Joshua Tree National Park are popular tourist destination for colorful springtime wildflower blooms (Figure 6.7). Both Joshua Tree National Park and Mojave National Preserve attract visitors from around the world who come to see the distinctive Joshua tree (*Yucca brevifolia*). The loss of pollination services to natural ecosystems is difficult to predict. One potential impact from the loss or disruption of this service could be severe limitation of flowering plant reproduction, which could have cascading effects throughout an ecosystem.[433]

Figure 6.7 Pollinator in Mojave National Preserve. Image Credit: Sarah Tomsky.

Cumulative Effects from Solar Development

Utility-scale solar development could significantly contribute to habitat loss and fragmentation for pollinators in the California desert. A 2009 study by Brown and Paxton cites habitat loss as the "most universal and high impact factor driving bee declines"; second on their list is habitat fragmentation.[434] Without the services of reliable pollinators, flowering plant populations in habitat fragments may experience reduced seed production and lower genetic diversity.[435] Solar development, at the scale that it has been proposed, would likely result in habitat loss and fragmentation for pollinators. Because most solar technologies require a zero to six percent rise in slope (a few can tolerate seven to 11 percent), much of the habitat loss will occur in lower elevation areas. The creosote bush (*Larrea tridentata*) that dominates these lowland areas attracts over 120 species of bees, one of the richest bee faunas of any plant in North America.[436] Additionally, areas of the California desert along the Colorado River contain a high number of endemic bee species that specialize on the creosote bush.[437] The loss and fragmentation of several thousands of acres of a relatively common plant species could seriously affect a much wider array of pollinator biodiversity.

Habitat loss and fragmentation are not the only threats to pollinators; climate change and the invasion of non-native honeybees (*Apis mellifera*) that compete with native bees for pollen resources also threaten native desert pollinators.[438] Even if pollinators could survive a single threat relatively unscathed, the cumulative effect of these threats compounded by solar development, could result in a decline in pollinator populations and biodiversity, with unknown effects for the rest of the California desert ecosystem.

Climate Change and Pollinators

Pollination mutualisms exist between pollinators and the plants that provide them with food or other services. For example, several moth species have co-evolved a mutualistic relationship with the plant genus *Yucca* (family Agavaceae), including the distinctive Joshua tree (*Yucca brevifolia*) (Figure 6.8).[439] Moths simultaneously pollinate yucca flowers and lay eggs within them and the yucca seeds nourish the moth larvae once they hatch. In the Sonoran Desert, the senita cactus (*Lophocereus schottii*) and senita moth

Figure 6.8 Joshua Trees (*Yucca brevifolia*). Image Credit: Sarah Tomsky.

(*Upiga virescens*) have also evolved a mutualistic relationship.[440,441]

Global climate change could affect pollination mutualisms by disrupting the synchrony between flowering plants and pollinators.[442] Shifts in phenology (i.e. flowering time) induced by climate change could reduce or eventually eliminate the temporal overlap between pollinator activity and plant flowering, potentially causing local extinction of pollinators whose activity periods no longer overlap with any of their food plants.[443] Climate change could also disrupt pollination mutualisms by altering desert plant communities. Climate models show a slow warming of the Mojave and Sonoran Desert regions, and climate change is also likely to alter precipitation regimes.[444,445] Changes in temperature and precipitation patterns could result in a greater production of invasive grasses and/or increased mortality of native plants; elevated fire frequencies and shifts in the distribution of plant communities are also concerns.[446] Pollinator species with narrow habitat requirements and/or specialized diets may decline if certain plant species or communities become locally extinct.[447]

Ecological Implications for Facility Location and Design

The magnitude of impact that the development of a single solar facility or multiple facilities will have on the desert pollinators is dependent on the facility design variables and location as discussed in Table 6.6. These variables will influence the magnitude of the cumulative impact of solar development on the important but not well-understood role of these pollinators.

Table 6.6 Solar Facility Design Variables Affecting Desert Pollinators.

Facility Design Variable	Implications for Desert Pollinators
Location of Facility	Determines the quality of pollinator habitat that is eliminated (some areas are better quality habitat than others).
Size of facility	Larger facility increases probability of eliminating pollinator habitat.
Proximity to other development (solar and other)	Determines magnitude of habitat fragmentation.
Land-Use Efficiency	Determines facility’s contribution to off-setting net carbon emissions and reducing the impacts of climate change on pollinators while minimizing impacts to pollinators from habitat loss and fragmentation.

CHAPTER 7 | SPATIAL IMPACTS

OVERVIEW

Many of the potential conflicts and benefits of the proposed solar facilities are spatial in nature. The location of a facility determines whether the benefits outweigh the costs, or vice versa. GIS can be used to understand the issues of siting solar facilities in the California desert. The spatial analyses we conducted allows for a visual and quantitative comparison across different variables, such as sensitive habitat and visual footprint, providing information and perspective that cannot be supplied by our other analyses.

Purpose of Spatial Analyses

We used spatial analyses to examine three potential development scenarios and the effects that these scenarios have on ecological and visual resources. The three potential development scenarios are:

1. Only proposed solar facilities labeled as "Fast Track" applications are built (10 projects total);
2. Only proposed solar facilities located in Solar Energy Study Areas (SESAs) are built (22 projects total);
3. All currently proposed solar facilities (as of March 2010) are built (54 projects total).

While it is unlikely that any of these three scenarios will manifest exactly as we analyzed them, they represent a wide range of possibilities that can be illustrative of likely impacts should any combination of facilities be built throughout the California desert landscape. The "Fast Track" application scenario was chosen because these applications are those that are most likely to be approved first, and may represent a first wave of development. The "SESA" application scenario was chosen because, pending adoption of the Solar PEIS, development will likely be actively promoted in these areas. The third scenario of full build-out of "All Proposed" facilities was chosen as a proxy for the maximum extent of development in the near future. In this analysis, facilities are identified using the serial number provided by the BLM because project names change fairly frequently whereas serial numbers do not. While results varied across individual facilities and the three scenarios, the SESA scenario and many individual SESA facilities were found to have the lowest ecological and visual impacts. A discussion of the analyses and results follow.

Ecological Impact Analyses

As discussed in Chapters 5 and 6, site engineering requirements, technological needs, and associated infrastructure could have significant impacts on site- and landscape-level ecology. To measure ecological impact, we conducted spatial analyses that would allow us to quantify the effects of solar development on California desert ecology and biodiversity:

- We utilized land management designations to identify and eliminate areas from our analysis that are legally incompatible or otherwise likely to conflict with solar development.
- We identified sensitive habitat using the presence of rare or endangered species.
- We used the distance of facilities to existing transmission lines and the slope of the proposed facility site as proxies for the amount of disturbance that a facility might have on the landscape.

These three ecological impacts were analyzed separately because, for example, a score based on distance of a proposed facility to the nearest transmission line cannot be objectively compared to a score based on ecological impact. Therefore, layers were not added together to form a single analysis map. For the ecological impact analysis we analyzed 52 of the 54 proposed facilities. Two facilities, CACA 049490 and CACA 048728, are proposed for the same area and were only counted once. One facility, CACA 050379, is proposed for land that was excluded from our analysis by land management designation and so had no habitat calculations. In addition, facilities CACA 049490/048728 and CACA 050379 are all SESA facilities, so 20 out of 22 SESA facilities were analyzed for ecological impacts.

Visual Impact Analysis

The visual impact analysis sought to quantify how the construction of utility-scale solar facilities could affect the visual character of the California desert. The construction of multiple, utility-scale solar facilities, which can occupy several thousand acres and reach heights of 40 to over 600 feet, could have a significant impact on what the California desert landscape looks like. This is important because visual or scenic value is a defining characteristic of the desert and is important to residents and visitors alike. Significant changes to viewshed may be met by opposition from local residents. For example, attempts to install utility-scale wind power turbines off the coast of Cape Cod met strong resistance from local residents who were concerned about impacts that turbines would have on the view and indirectly on property values and quality of life.[448] Underscoring the importance of visual resources, the BLM is required to consider impacts to visual resources through an EIS under NEPA. We compared impacts to visual resources in the California desert under the three different development scenarios discussed above. For the visual impact analysis we analyzed 53 of the 54 proposed facilities. CACA 049490 and CACA 048728 are proposed for the same area and were only counted once. CACA 050379 is analyzed for visual impacts even though it was not analyzed in the ecological impact analysis. So, 21 out of 22 SESA facilities were analyzed for visual impacts.

Processing steps for all analyses can be found in Appendix E.

Study Area

Map 7.1 Spatial Analysis Study Area.

We used two different geographic boundaries for these analyses: the CDD and the CDCA (Map 7.1). The CDD is a BLM administrative area and is the functional unit for the management of the California desert ecosystem. It encompasses approximately the lower third of the State of California. The CDCA is the ecological boundary of the California desert landscape and represents the area where impacts from solar development could occur. Most data files were clipped to either the CDD or the CDCA depending on the type of data; because the CDD covers such a large area, data were sometimes clipped to the CDCA to reduce their file size. Both CDD and CDCA files were downloaded from the California State BLM GIS website (http://www.blm.gov/ca/gis). We used the North American Datum 1983 and Universal Transverse Mercator 11N projection for all data files.

ECOLOGICAL IMPACT ANALYSES: DEFINING THE SCOPE

We utilized land management designations to narrow the scope of our ecological impact analysis. By identifying areas that would conflict with solar development due to land management designations, we were able to define areas that are or should be excluded from solar development.

Data Sources

Publicly available data files were downloaded from the California State BLM GIS webpage (http://www.blm.gov/ca/gis/). These included wilderness areas, WSAs, national monuments, ACECs, and land ownership by agency, which was used to identify NPS, FWS, and DOD lands. Flat-tailed Horned Lizard Management Areas data were obtained directly from the El Centro Field Office. Critical habitat data files were obtained from the FWS critical habitat webpage. WSR data, which available on the California State BLM GIS website, were not used because all WSRs in the CDCA were designated after the last update of the data file, and are thus not included in the file. We were unable to obtain data files for Desert Wildlife Management Areas (DWMAs). Critical habitat for the desert tortoise was used instead, as DWMA boundaries generally correspond to desert tortoise critical habitat on BLM land in the CDCA. We were also unable to obtain data files for national trails, the Mohave Ground Squirrel Conservation Area, and areas with cultural or historic resources, so they are not included in this analysis. Data were gathered over the course of several months in late 2009 and early 2010. Any updates that occurred to the data after a file was downloaded to represent a new or changed designation or a correction in the data file is not captured in the data we use in our analyses.

Excluding High Conflict Areas

We define "high conflict" areas as those areas that are or should be excluded from solar development. These include:

- Areas that are legally incompatible with solar energy development based on statute, regulation, or administrative designation.
- Areas that may be legally compatible, but where development of one or more solar facilities within such areas may hinder the ability for the BLM to manage the areas for their designated use.

These high conflict areas include wilderness areas, WSAs, WSRs, national monuments, national trails, ACECs, DWMAs, critical habitat, special management areas, areas with cultural or historic resources, LTVAs, and OHV use areas (Table 7.1). Additionally, lands managed by the NPS, FWS, and DOD were included, as these lands are withdrawn from energy development (Map 7.2).[a] All other areas of BLM land in the California desert would thus be "potentially available", and these areas were chosen as the scope of our ecological impact analyses.

Table 7.1 BLM Land Management Designations with Conflict Ratings.

Designation	Conflict Level
Area of Critical Environmental Concern (ACEC)	++
Cultural and Historical Resources	++
Critical Habitat	++
Desert Wildlife Management Area (DWMA)	++
Long Term Visitor Area (LTVA)	+
National Monument	+++
National Trail	+
Off Highway Vehicle (OHV) Use Area	+
Solar Energy Study Area (SESA) (Under Solar PEIS)	-
Special Management Area	++
Wild and Scenic River (WSR)	+
Wilderness Area	+++
Wilderness Study Area (WSA)	+++

+++ designations of areas that are withdrawn from energy development or otherwise legally prohibit it. ++ areas of high conflict that may technically allow some level of surface disturbance, but where a solar facility may fill or breach any such cap or otherwise limit the ability of the BLM to manage the land for its designated purpose. + areas that may not have a limit on development or legal exclusion of energy development, but where energy development may preclude BLM from managing the area for its designated purpose. - areas specifically designated to be compatible with utility-scale solar development, though some site-level conflicts may still exist.

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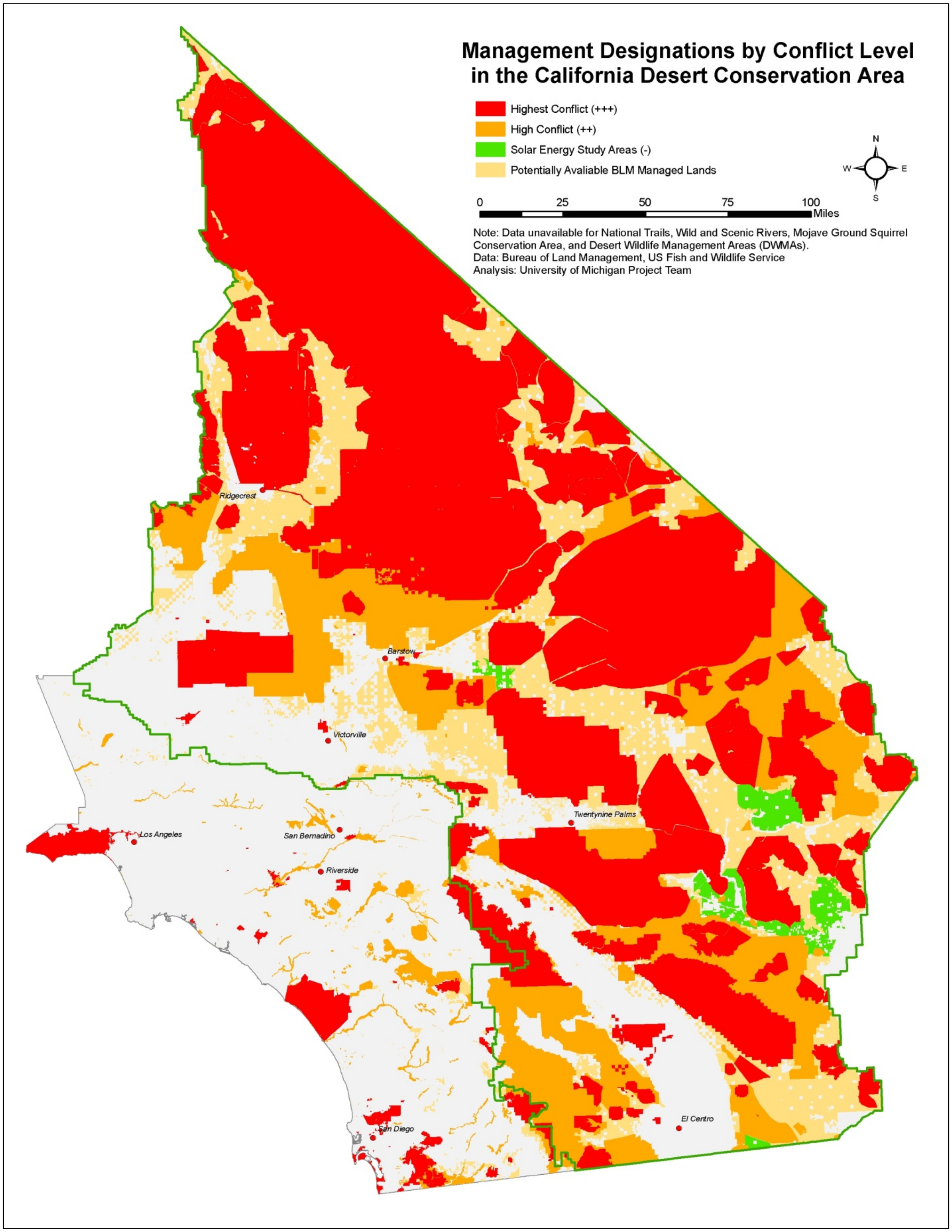
[a] Note: DOD may allow energy development on their lands if all the energy produced is used on DOD land. It has yet to be determined if energy development for sale to the grid is considered an authorized military use on BLM lands withdrawn for military purposes, which constitute many of the DOD lands in the California Desert.



Note: Data unavailable for National Trails, Wild and Scenic Rivers, Mojave Ground Squirrel Conservation Area, and Desert Wildlife Management Areas (DWMAs).
Data: Bureau of Land Management, US Fish and Wildlife Service
Analysis: University of Michigan Project Team

Map 7.2 Management Areas by Conflict Level in the CDCA.

Results

After removing wilderness areas, WSAs, National Monuments, ACECs, critical habitat, and Flat-tailed Horned Lizard Management Areas, we determined that there are 4,299,064 acres of BLM land that are potentially available for solar development. Had we been able to access appropriate data for WSRs, National Trails, and Mohave Ground Squirrel Conservation Areas, this number would be smaller. We then determined the percent of potentially available BLM land that would be developed under the three development scenarios (Table 7.2). Under the Fast Track scenario, 1.15 percent of potentially available BLM lands would be developed. Under the SESA scenario, 4.26 percent would be developed, and 10.74 percent would be developed under the All Proposed scenario.

Table 7.2 Percent of Potentially Available BLM Acres Developed Under Three Development Scenarios.

Scenario	Acres of BLM Land Developed for Solar Production	Percentage of Potentially Available BLM Acres
Fast Track Facilities	49,441	1.15
SESA Facilities	183,251	4.26
All Proposed Facilities	461,890	10.74
Total Potentially Available BLM Land = 4,299,064 acres		

ECOLOGICAL IMPACT ANALYSES: SENSITIVE HABITAT

We sought to devise a method that would allow us to quantify the effects of solar development on California desert ecology and biodiversity. Because quantifying all potential ecological impacts, such as impacts to all landscape-level ecological processes or impacts to individual species, was neither practical nor feasible, the replacement of rare or endangered species habitat by solar development was used as an indicator for other potential ecological impacts. The effect of solar development on these habitats is just one of the possible ecological impacts. By developing a numerical scoring system that corresponds with established classification systems, we were able to quantify the ecological impact of individual facilities and each development scenario on rare or endangered species habitat.

Data Sources

We utilized the California Natural Diversity Database (CNDDB), a database managed by the DFG. The CNDDB compiles the status and locations of rare plants and animals for the entire state of California.[449] Rare or endangered species and communities in the CNDDB are referred to as "elements," and an "element occurrence" is a site which contains a population of an "element."[450] The data are not systematic surveys of the state, but instead are provided to the CNDDB by independent researchers, federal land management agency biologists (e.g. BLM, USFS), other agency biologists, biological consultants, and others.[451] Therefore, the CNDDB (and consequently our analysis) cannot be considered comprehensive because it is subject to a number of inherent limitations. Note that while the CNDDB contains species data for the entire State of California, our analysis was limited to species within the CDCA.

Potential general limitations:

- Charismatic megafauna might be more heavily surveyed.
- Data availability is weighted heavily towards areas that are of particular interest to researchers (e.g. national parks and certain ecosystem types).
- Data availability is dependent on researchers knowing about the CNDDB and choosing to share their survey data.
- Private land might not be well surveyed due to issues of access to land for research.

Potential desert-related limitations[452]:

- Most botanical surveys are conducted in the spring in favored wildflower areas. Plants that grow or flower at other times of year are not well-surveyed.
- Old collection data might need to be re-surveyed to determine if species are still present.
- Surveys tend to occur on lands scheduled for some type of land use change, leaving many natural areas under-represented in the CNDDB.
- Once areas are developed or an area is degraded, usually no follow-up survey is conducted. Species may no longer be present in areas that have been developed, but have not been removed from the database.
- Survey data may be concentrated around roads since those areas are easier to access.
- Large areas have not been surveyed.

We acknowledge that the data used to create this tool is far from complete. It has been impressed upon us by several interviewees[453] that the desert is not well-studied relative to other ecosystems and that current and/or complete data is sorely lacking. Nevertheless, we believe that the overall results are useful even with these data issues and hope that users will take the following ideas and associated techniques, and expand on them to improve the accuracy and completeness of analysis.

Classification Systems

We utilized established classification systems to determine the sensitivity of habitat to development. Established classifications systems have proved useful in determining conservation priorities. Of the attributes provided with each CNDDB element occurrence, we decided that Global Rank, State Rank, listing under the Endangered Species Act (ESA), listing under the California State Endangered Species Act (CESA), and listing under the California Native Plant Society (CNPS) List would best capture how sensitive a species would be to anthropogenic disturbance. These scores were used as proxies for sensitive habitat, under the assumption that the more rare or endangered the species, the more likely it is that the species would be sensitive to habitat disturbance from solar development.

Global Rank and State Rank

Global Rank and State Rank are classifications used by NatureServe, a non-profit conservation organization that works with its network of natural heritage programs to provide information about rare and endangered species and threatened ecosystems.[454] Both Global Rank (GRank) and State Rank (SRank) are conservation status ranks that are assessed and determined by NatureServe scientists and its collaborators.[455] GRank uses a numbered status rank, 1 to 5, to reflect a species' risk of extinction. These numbered ranks include:

1 = critically imperiled
2 = imperiled
3 = vulnerable
4 = apparently secure
5 = secure

GRank refers to a species "global" status, while SRank refers to a species' status within a particular state or province.[456] These different geographic focuses can result in different GRank and SRank for a particular species. For example, the desert tortoise (*Gopherus agassizii*) has a GRank of G4, but in California it has a SRank of S2.

State Ranks in California are comprised of two parts. The number directly following the "S" indicates the number of element occurrences, individuals, or habitat; the number after the decimal is a threat designation. The first numbers indicate the following:

S1 = Less than 6 element occurrences OR less than 1,000 individuals OR less than 2,000 acres
S2 = 6 to 20 element occurrences OR 1,000 to 3,000 individuals OR 2,000 to 10,000 acres
S3 = 21 to 100 element occurrences OR 3,000 to 10,000 individuals OR 10,000 to 50,000 acres
S4 = Apparently secure within California, but there is some threat or somewhat narrow habitat
S5 = Demonstrably secure to ineradicable in California

The threat designations are the following:

0.1 = very threatened
0.2 = threatened
0.3 = no current threats known

The ranks S4 and S5 do not have a threat ranks associated with them. For the purposes of this study, we will refer to "element occurrences" of a species as "sensitive habitat" of a species from here onward.

Federal Endangered Species Act

The ESA is the primary species protection law in the nation. The stated purpose of the act is the "protect and recover imperiled species and the ecosystems on which they depend."[457] Under the ESA, which lists both plants and animals, species may be listed as "Endangered" (the species is in danger of extinction throughout all or a significant portion of its range) or "Threatened" (the species is likely to become endangered within the foreseeable future).[458] The following categories are used in the CNDDB:

1. Federally listed as Endangered
2. Federally listed as Threatened
3. Proposed for federal listing as Endangered
4. Proposed for federal listing as Threatened
5. Candidate for federal listing
6. Species of Concern
7. None – no federal status
8. Delisted – previously listed

California State Endangered Species Act

The CESA generally follows the main provisions of the Federal ESA.[459] Under the CESA, which lists native plants and animals, a species can be listed as "Endangered" (a species or subspecies in serious danger of becoming extinct throughout all or a significant portion of its range),[460] "Threatened" (a species or subspecies not presently threatened with extinction but is likely to become an endangered species in the foreseeable future in the absence of special protection and management),[461] "Rare" (a species or subspecies not presently threatened with extinction, but is in such small numbers throughout its range that it may become endangered if its present environment worsens),[462] "Candidate" (a species or subspecies that is under review by the California Department of Fish and Game for listing).[463] The following categories are used in the CNDDB:

1. State listed as Endangered
2. State listed as Threatened
3. State listed as Rare
4. Candidate for state listing
5. None – no state status
6. Delisted – previously listed

Listing under the ESA is not a prerequisite for listing under the CESA, and vise-versa. A species may have a different listing category under each Act.

California Native Plant Society

The CNPS is a statewide non-profit organization that seeks to increase understanding of and preserve California's native flora for future generations.[464] The CNPS tracks the conservation status of hundreds of rare and endangered plant species in California and shares this information with the CNDDB.[465] Species undergo a rigorous, science-based review process before being placed on the CNPS *Inventory of Rare and Endangered Plants of California*; the *Inventory* is widely regarded as the standard for information on the rarity and endangerment status of plants in California.[466] List categories include:

- 1A = Plants presumed extinct in California
- 1B = Plants rare, threatened, or endangered in California and elsewhere; AND
    - 1B.1 = …seriously threatened in California
    - 1B.2 = …fairly threatened in California
    - 1B.3 = …not very threatened in California
- 2 = Plants rare, threatened, or endangered in California, but more common elsewhere; AND
    - 2.1 = …seriously threatened in California
    - 2.2 = …fairly threatened in California
    - 2.3 = …not very threatened in California
- 3 = Plants about which we need more information
    - 3.1 = …seriously threatened in California
    - 3.2 = …fairly threatened in California
    - 3.3 = …not very threatened in California
- 4 = Plants of limited distribution
    - 4.1 = …seriously threatened in California
    - 4.2 = …fairly threatened in California
    - 4.3 = …not very threatened in California

Limitations of Established Classification Systems

Despite the fact that all five of these classification systems are well-established, relied upon methods for assessing a species' level of rarity or endangerment, they still face some limitations. Population estimates and trends for many species remain unstudied or have not been updated in many years, resulting in an inaccurate or unspecified assessment of rarity or endangerment. The ESA or CESA lists may be disproportionately weighted towards charismatic megafauna or inherently biased towards species that have social and cultural value, not necessarily biological value.[467] This is not to say that these classification systems should not be used, but that users need to be aware of the potential limitations of this tool.

Creating a Scoring System

Each classification system (GRank, SRank, ESA, CESA, CNPS) was assigned a numerical scoring system on a scale of 0-60, with a score of 0 reflecting low sensitivity and a score of 60 reflecting high sensitivity. For example, a GRank of "G1" was given a score of 60 while a GRank of "G5" was given a score of 20. For GRank and SRank, species were occasionally given two ranks (such as "G3G4") in which case the average numerical score was taken. For a full list of all the numerical scores given to each classification system see Appendix E3.

Species in the CNDDB were given scores under each of the five classification systems. For example, the Coachella Valley fringe-toed lizard (*Uma inornata*) is rated at G1 (critically imperiled globally) under the GRank classification system and was given a score of 60. The lizard also was given scores under the SRank, ESA, and CESA classification systems: 30, 50, and 60 respectively. Since only plants are scored under the CNPS system, the lizard was given a score of zero. In the map created for the GRank classification system, the lizard's habitat was given its score of 60. In the SRank map, those same areas of land were given its SRank score of 30. The same method was used for the ESA, CESA, and CNPS maps.

A map of numerical scores was created for each individual classification system: GRank (Map 7.3), SRank (Map 7.4), ESA (Map 7.5), CESA (Map 7.6), CNPS (Map 7.7). Where habitat of multiple species overlapped, the numerical scores were added together. Natural breaks in the resulting scores were used to categorize sensitive habitat into different colors on the maps. Areas with a high concentration of overlapping sensitive habitat had higher numerical scores. An example of overlapping habitat is provided by Figure 7.1.

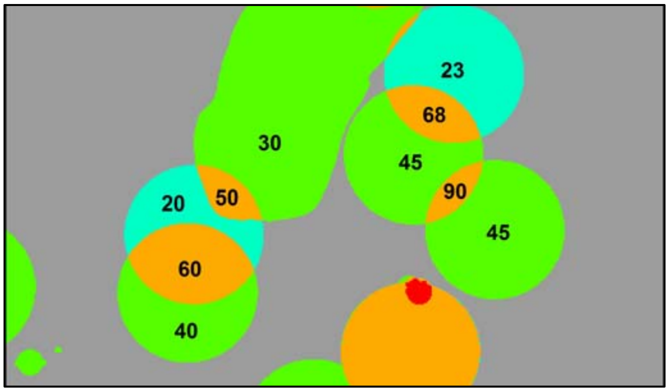
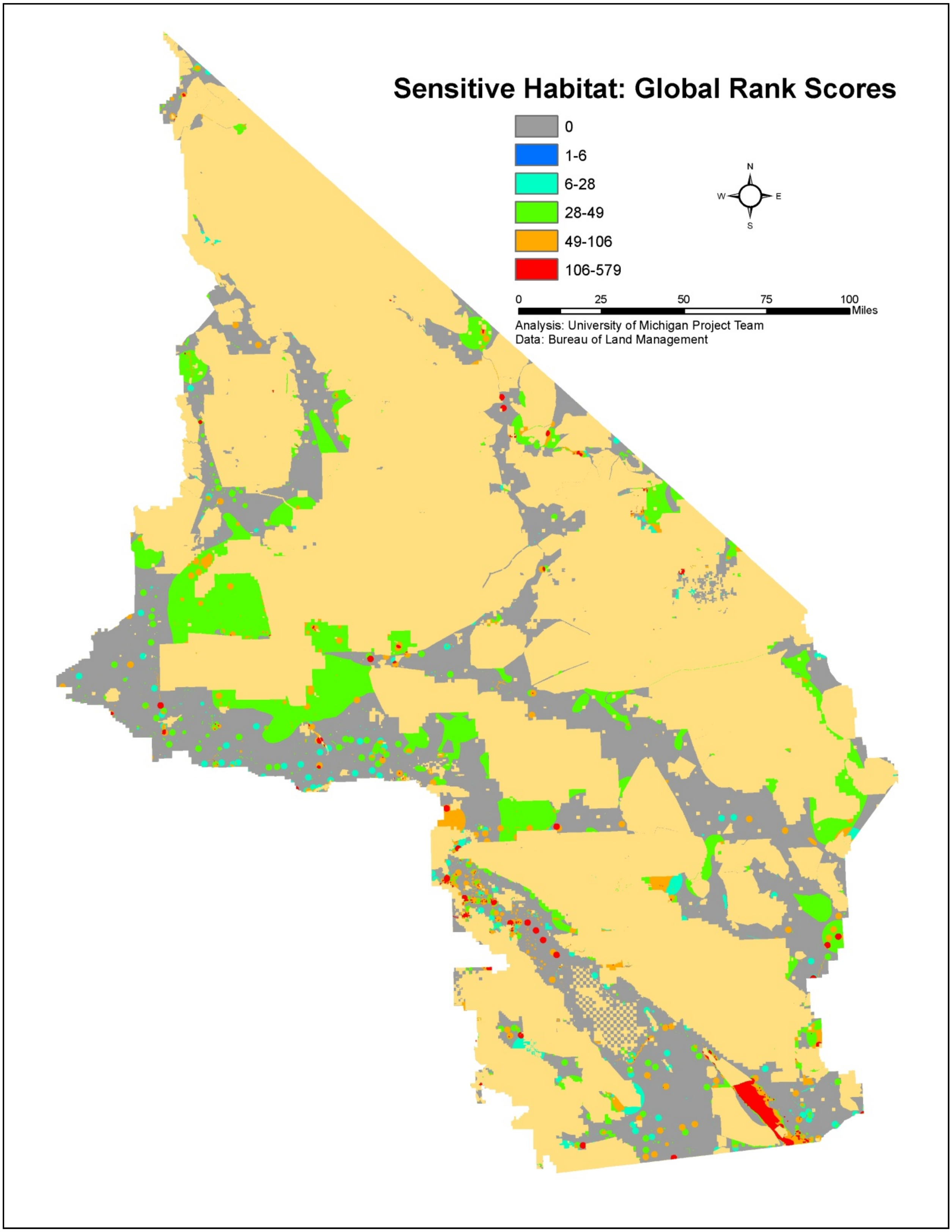
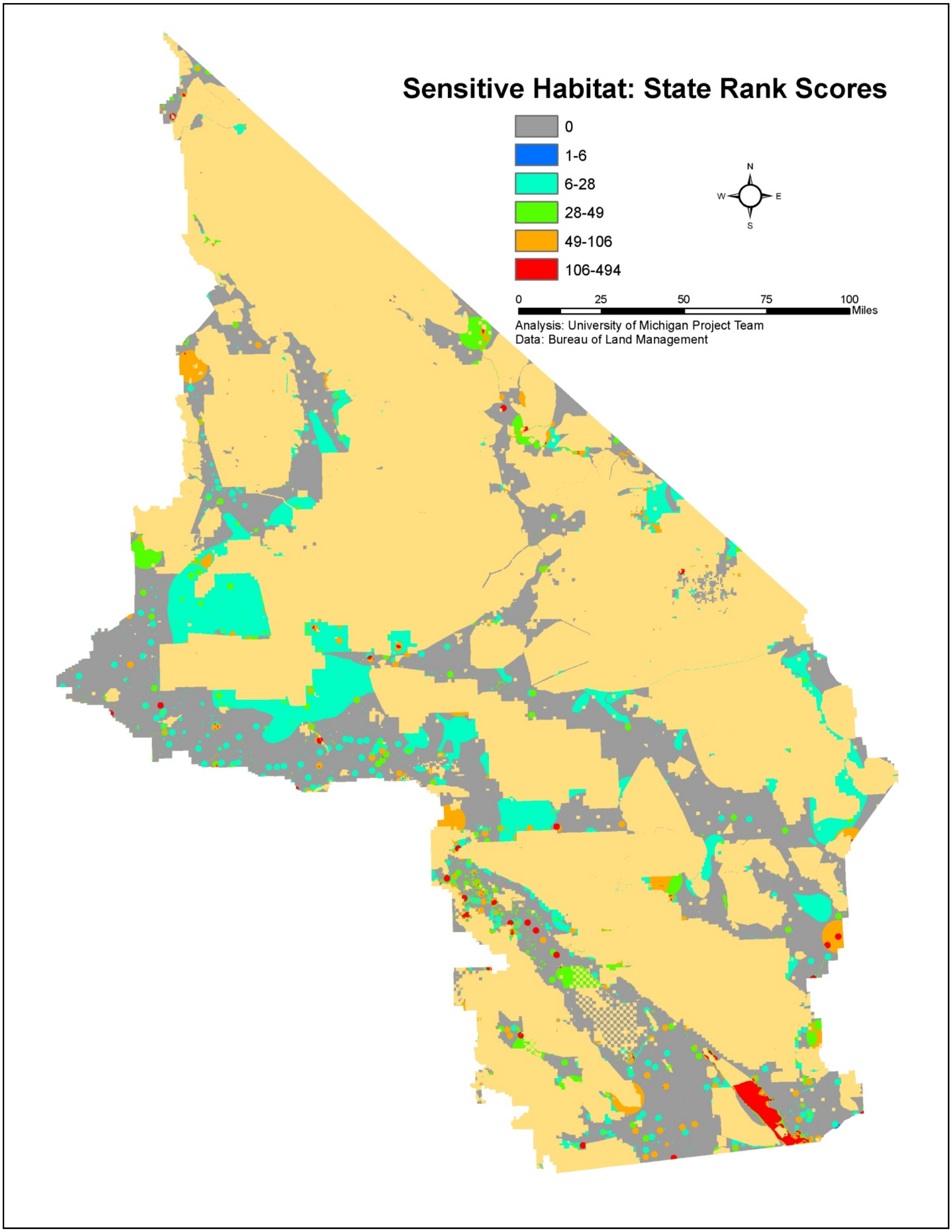


Figure 7.1 Close-Up of the GRank Map with Labeled Habitat Scores.

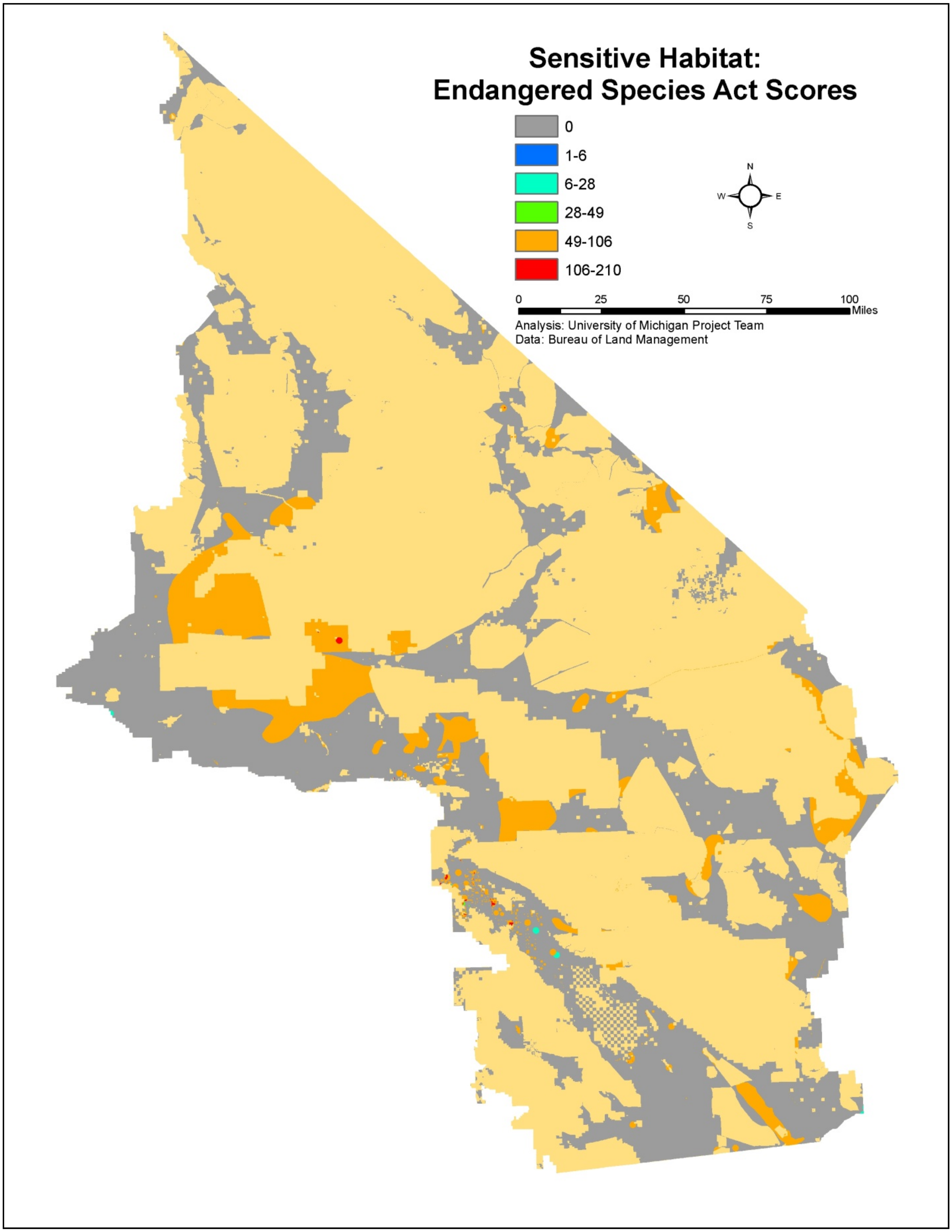
The circles and large, irregular green shape in Figure 7.1 indicate the habitat of several different species. In this figure, the gray areas have a score of zero, dark blue areas have scores of 1 to 6, light blue areas have scores of 6 to 28, green areas have scores of 28 to 49, orange areas have scores of 49 to 106, and red areas have scores higher than 106. Where two green circles, each with scores of 45, overlap the resulting score is the sum, 90. Overlapping species habitats are prevalent throughout our study area, as seen in Maps 7.3 to 7.7.



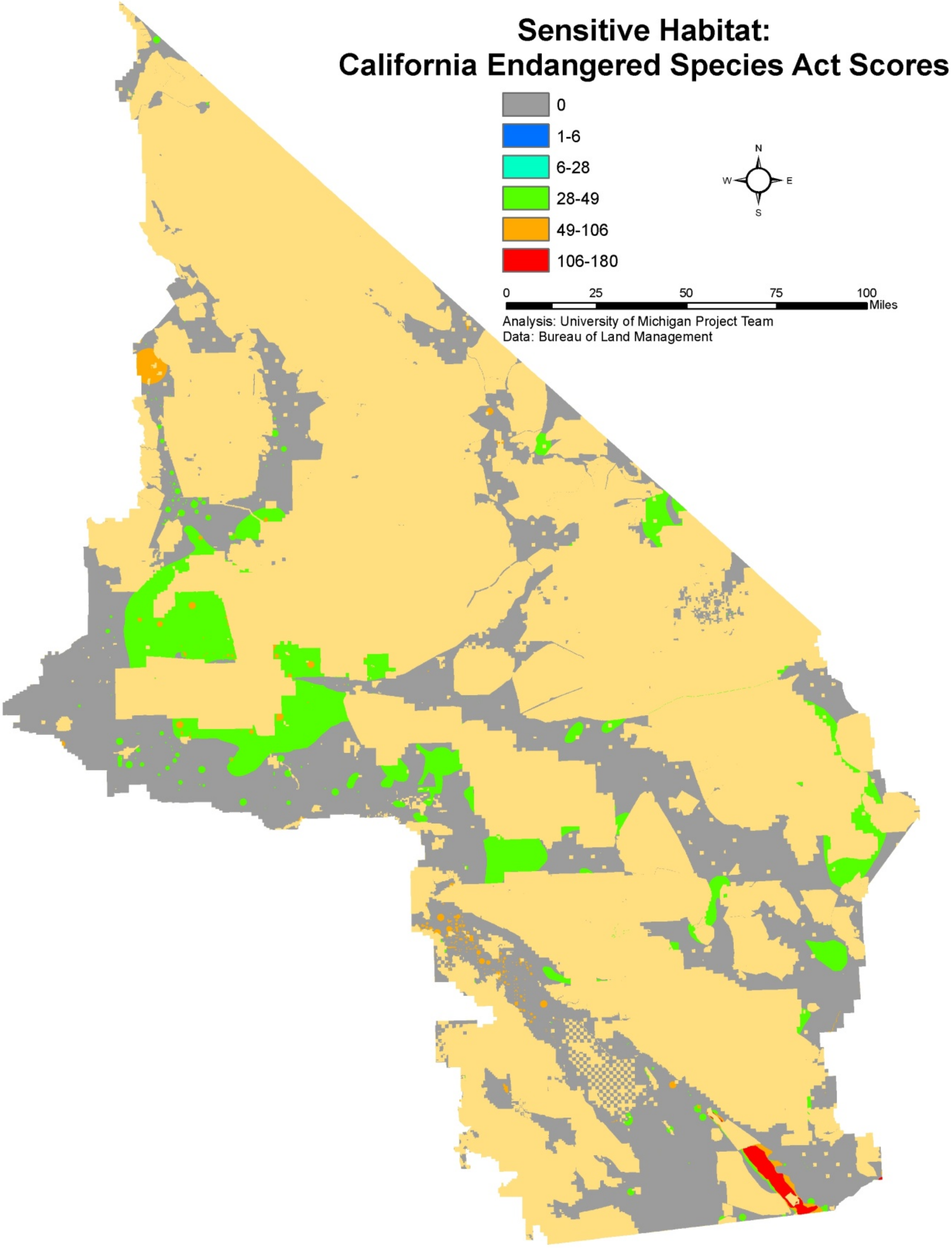
Map 7.3 Sensitive Habitat: Global Rank Scores. Tan areas represent excluded land.



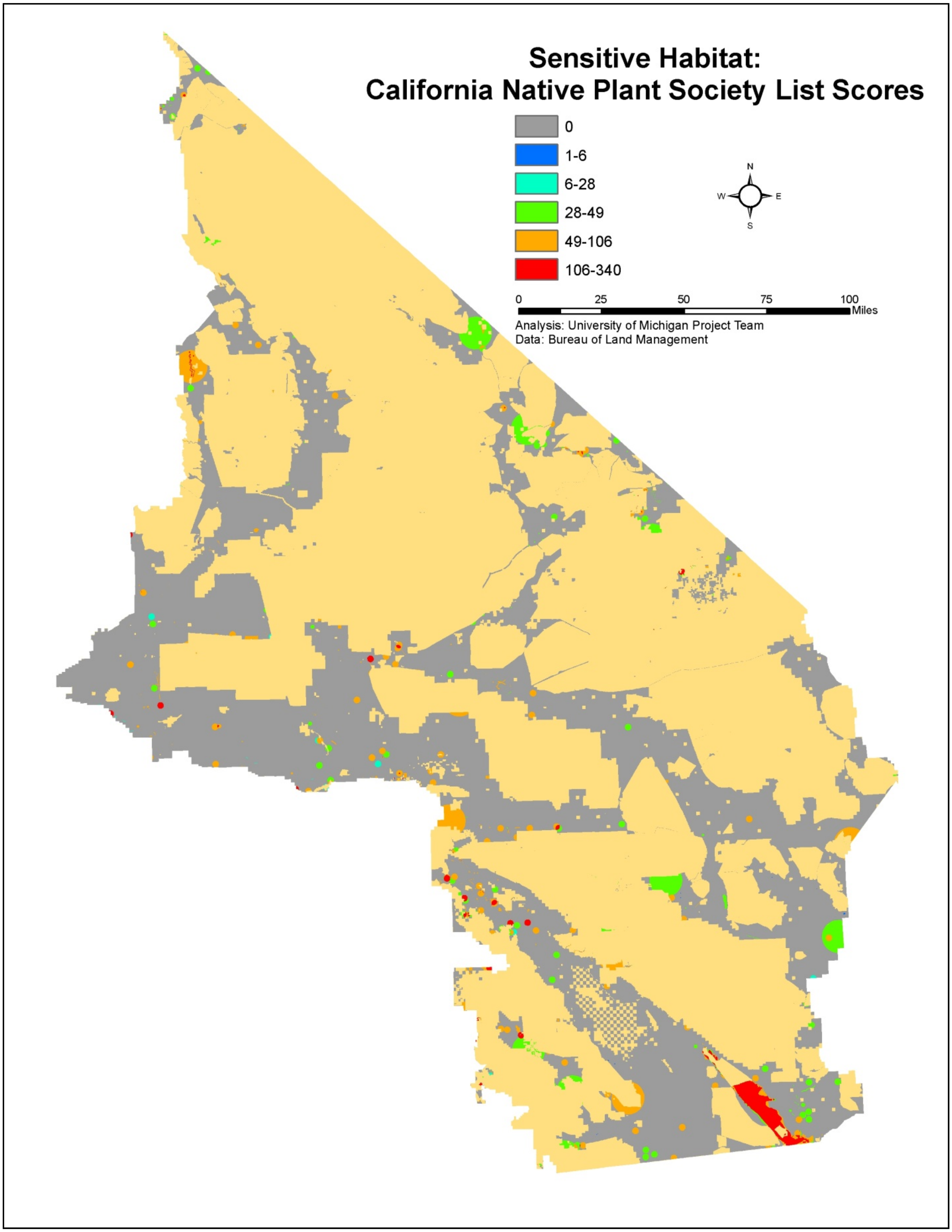
Map 7.4 Sensitive Habitat: State Rank Scores. Tan areas represent excluded land.



Map 7.5 Sensitive Habitat: Federal Endangered Species Act Scores. Tan areas represent excluded land.



Map 7.6 Sensitive Habitat: California Endangered Species Act Scores. Tan areas represent excluded land.



Map 7.7 Sensitive Habitat: California Native Plant Society List Scores. Tan areas represent excluded land.

Results

General Habitat Impacts

With our first analysis, we were interested in the number of facilities that would have an effect on sensitive habitat and how much sensitive habitat would be affected by individual facilities. We compared the area of land within a facility that had a score of zero (indicating the absence of sensitive habitat) to the area within a facility that had a score greater than zero (indicating the presence of rare or endangered species habitat). If all of the land within a facility had a score of zero, the facility would not affect sensitive habitat, while scores other than zero within the facility boundary indicated that the facility would affect sensitive habitat. Of the 52 proposed facilities, we found that 31 of the facilities affected sensitive habitat, while 21 of the facilities had no effect on sensitive habitat (Table 7.3). The amount of sensitive habitat for each facility ranged from zero percent of the facility (no sensitive habitat was contained by that facility) to 100 percent (the entire facility area contained sensitive habitat). Table 7.3 lists the percent of sensitive habitat within a facility and the number of facilities that contain that proportion of habitat.

Table 7.3 Percent of Sensitive Habitat within a Facility.

Percent of Sensitive Habitat	Number of Facilities
0	21
>0 to 10	12
>10 to 20	5
>20 to 30	4
>30 to 40	3
>40 to 60	0
>60 to 80	2
>80 to 100	5

Of the 52 facilities, 21 of the facilities contained no sensitive habitat. For 12 facilities, 10 percent or less of the facility area contained sensitive habitat. For 12 facilities, 11 to 40 percent of the facility area contained sensitive habitat. For 7 facilities, over 60 percent of the facility area contained sensitive habitat.

We also examined the amount of sensitive habitat that would be affected by each of the three solar development scenarios relative to the total number of acres that would be developed in each scenario. Acres of sensitive habitat were added up for each scenario to give a total number of sensitive habitat acres affected (Table 7.4). Acres of sensitive habitat were divided by the total number of developed acres to determine percent of sensitive habitat affected by each scenario.

Table 7.4 Percent of Habitat Affected by Three Development Scenarios.

	Acres of Sensitive Habitat	Total Facility Acres	Percent of Sensitive Habitat
Fast Track	9,338	49,442	18.89
SESA	20,303	187,025	10.86
All Proposed	56,871	461,990	12.31

Of the three scenarios, the Fast Track scenario had the largest relative impact, with sensitive habitat occupying 18.89 percent of land in the scenario. The All Proposed scenario had the second largest relative impact with sensitive habitat occupying 12.31 percent of land in the scenario, and the SESA scenario had the smallest relative impact with sensitive habitat occupying 10.86 percent of land in the scenario (Table 7.4). However, it is important to note that the amount of sensitive habitat found within a facility site may depend on whether or not the proposed site has been surveyed for biological resources, when the site was surveyed, and for what species. Our results must be understood in the context of the data limitations we discussed earlier in this chapter.

Individual Facilities: Average Impacts

Next we compared the average impact of individual facilities. We calculated the weighted average of the scores within each proposed facility using the score and the number of acres occupied by that score. This resulted in five weighted averages for each facility. As an example, weighted averages for one facility are shown in Table 7.5

Table 7.5 Weighted Averages for Proposed Solar Facility CACA 049431.

Classification System	Score	Number of acres	Weighted Average
GRank	0	8290.48	5.31
	30	1760.44	
	33	20.68	
SRank	0	8290.48	4.41
	20	20.68	
	25	1760.44	
ESA	0	8311.16	8.74
	50	1760.44	
CESA	0	8311.16	7.87
	45	1760.44	
CNPS	0	45780	0
TOTAL Facility Impact (Sum of Weighted Averages)	--	--	26.33

The five weighted averages were added together to arrive at a total impact score for each facility. In Table 7.5, the total impact of facility CACA 049431 on sensitive habitat was calculated to be 26.33. We used the sum of the five weighted averages for each classification system to reach a total facility impact score as the five classification systems provide different information on the rarity or endangerment of a particular species, and thus how sensitive the species would be to habitat disturbance. The total impact score was calculated for all proposed solar facilities and each facility was placed into one of three categories (Table 7.6). Facilities with total facility impact scores of zero to 10 were categorized as "low impact" facilities, facilities with scores of greater than 10 to 60 were categorized as "medium impact" facilities, and facilities with scores greater than 60 were categorized as "high impact" facilities. The scores 10 and 60 were chosen as cutoff points because 10 is the value at which a species reaches some level of rarity or endangerment in four of the five classifications systems, and 60 is the highest value that an individual species can receive.

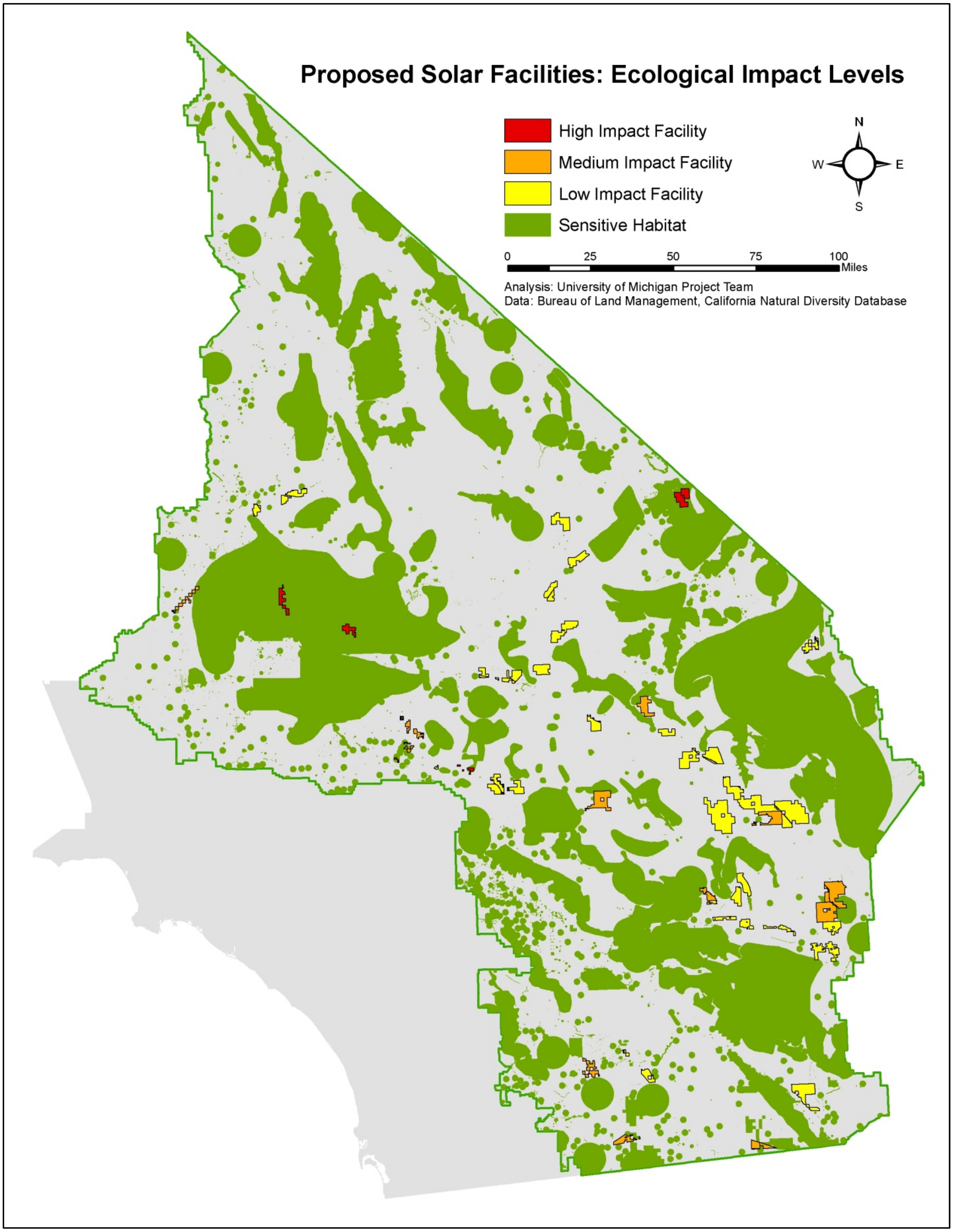
Table 7.6 Impact Categories and Number of Facilities in Each Category.

Category	Score Range	# of Facilities	# of Fast Track	# of Fast Track / SESA	# of SESA	Other
Low	0 to 10	34	2	5	9	18
Medium	>10 to 60	12	1	1	5	5
High	>60	6	1	0	0	5

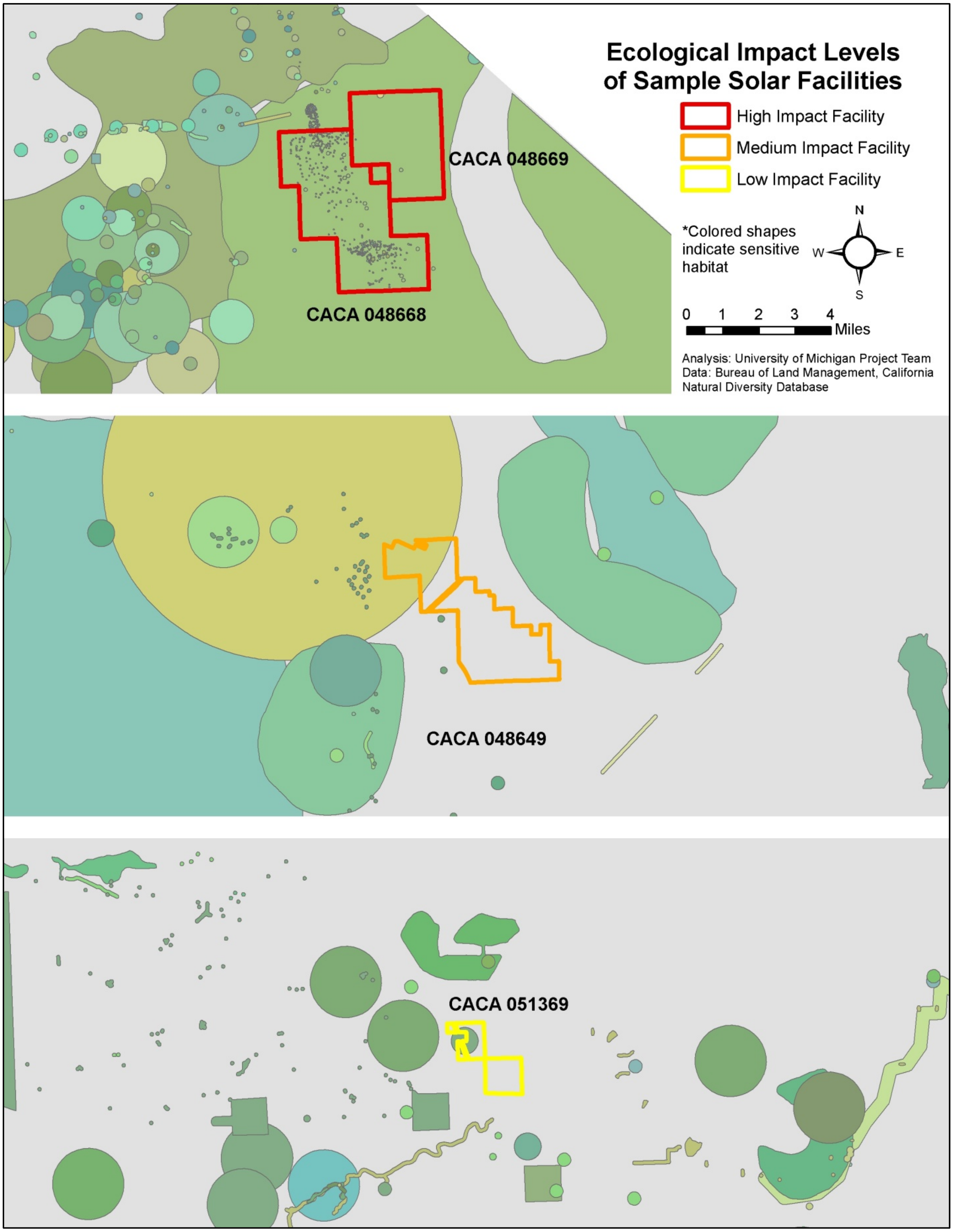
Note: some facilities are in both the Fast Track and SESA scenarios and are labeled as "Fast Track/SESA" in this table.

Of the 52 facilities, 34 were categorized as low impact facilities, 12 were categorized as medium impact facilities, and 6 were categorized as high impact facilities. Most facilities in either the Fast Track or SESA scenario fall into the low impact category, though one Fast Track facility (CACA 048668) falls into the high impact category. A complete list of facility total impact scores can be found in Appendix E7. The spatial arrangement of these facilities across the California desert landscape is shown in Map 7.8.

Map 7.9 zooms in on facilities in each of the impact categories to provide a better sense of why facilities received certain scores. For the two high impact facilities at the top of the map, high scores resulted from complete overlap with one species' habitat. In addition, facility CACA 048668 is situated over numerous smaller species occurrences. In the middle and bottom frame, less than half of the medium and low impact facilities overlap with species habitat, and so these facilities received lower scores. New off-site roads and transmission lines were not factored into the sensitive habitat analysis, but would also have an impact on the habitat surrounding the facilities. The high impact facility, and to some extent the medium impact facility, in Map 7.9 are surrounded by sensitive habitat, and construction of new roads or transmission lines would likely have negative effects on those habitats as well.



Map 7.8 Proposed Solar Facilities: Ecological Impact Levels.



Map 7.9 Ecological Impact Levels of Sample Solar Facilities.

Individual Facilities: A Closer Look at High Impact Facilities

A few facilities stood out as having higher impacts to sensitive habitat in both the analysis of the percent of sensitive habitat within a facility and in the analysis of average facility impacts. To better understand the negative ecological impacts of high impact facilities, the three facilities with the highest total impact scores were chosen. Relative to facilities in the All Proposed or Fast Track scenarios, the SESA facilities had lower total impact scores and lower percentages of sensitive habitat within the facilities. The SESA facility in Table 7.7 is used to highlight the contrast between the highest impact Fast Track and non-Fast Track/non-SESA facilities. The SESA facility was selected as an example because it had the highest percentage of sensitive habitat within the proposed facility site and one of the highest total impact scores of all the SESA facilities.

Table 7.7 Sample High Ecological Impact Facility.

Identification Number	Facility Status	Percent of the Facility that is Sensitive Habitat	Facility Total Impact Score
CACA 050528	None	92	179
CACA 048668	Fast Track	100	155
CACA 050103	None	100	153
CACA 050174	SESA	62	41

Of all the proposed facilities, CACA 050528 had the highest total impact score, with a score of 179, followed by CACA 048668 (score of 155), and CACA 050103 (score of 153). These scores were significantly higher than the scores of the majority of facilities, as six facilities have total impact scores above 90 (CACA 050528, 048668, 050103, 049017, 048669, 050150), with the next highest impact score falling to 52 (CACA 048728, CACA 049490) (Appendix E7). Sensitive habitat that could be affected by these four facilities is shown in Table 7.8.

The four facilities either completely overlap sensitive habitat (CACA 048668, CACA 050103), or almost completely overlap sensitive habitat (CACA 050528, CACA 050174) of rare and endangered species. The facility with the highest total impact score, CACA 050528, almost completely overlaps both purple-nerve cymopterus (*Cymopterus multinervatus*) and prairie falcon (*Falco mexicanus*) habitat. The Fast Track facility, CACA 048668, completely overlaps desert tortoise (*Gopherus agassizii*) habitat, as well as sensitive habitat for six different rare plant species. CACA 050103 completely overlaps desert tortoise (*G. agassizii*) habitat, and partially overlaps the habitat of the other two species. The SESA facility, CACA 050174, partially overlaps flat-tailed horned lizard (*Phrynosoma mcallii*) habitat and only slightly overlaps Yuma clapper rail (*Rallus longirostris yumanensis*) habitat.

Due to the effect that CACA 050528, CACA 048668, and CACA 050103 are likely to have on sensitive habitat, we encourage the BLM to fully analyze the possible ecological impacts of these and other high impact facilities. We are especially concerned about CACA 048668 because it is a Fast Track facility

Table 7.8 High Ecological Impact Facilities and Affected Sensitive Habitat Listed by Species.

Identification Number	Affected Sensitive Habitat (By Species)
CACA 050528	• Purple-Nerve Cymopterus (*Cymopterus multinervatus*) • Prairie Falcon (*Falco mexicanus*)
CACA 048668*	• Desert Pincushion (*Coryphantha chlorantha*) • Desert Tortoise (*Gopherus agassizii*) • Mojave Milkweed (*Asclepias nyctaginifolia*) • Nine-Awned Pappus Grass (*Ennaepogon desvauxii*) • Parish's Club-Cholla (*Grusonia parishii*) • Rusby's Desert Mallow (*Sphaeralcea rusbyi* var. *eremicola*) • Small-Flowered Androstephium (*Androstephium breviflorum*)
CACA 050103	• Burrowing Owl (*Athene cunicularia*) • Desert Tortoise (*Gopherus agassizii*) • Western Snowy Plover (*Charadrius alexandrinus nivosus*)
CACA 050174**	• Flat-tailed Horned Lizard (*Phrynosoma mcallii*) • Yuma Clapper Rail (*Rallus longirostris yumanensis*)

* = Fast Track Facility
** = SESA Facility

slated to be permitted and break ground before December 31, 2010 and we encourage the BLM to reconsider this proposed facility.

Development Scenarios: Average Impacts

Next we compared the average impact of each development scenario. Initially, we examined each classification system separately. Using the Fast Track scenario as an example, we took the mean of GRank weighted averages for all the Fast Track facilities by treating each facility as one unit (Table 7.9). The overall GRank score for the Fast Track facilities is 4.61.

Table 7.9 GRank Weighted Averages for Fast Track Facilities.

Fast Track	Weighted Average
CACA 047740	8.27
CACA 049539	1.67
CACA 048668	31.58
CACA 049537	0.28
CACA 049561	0
CACA 048810	0
CACA 048880	0
CACA 048811	0
CACA 048649	4.02
CACA 049016	0.31
Mean of Weighted Averages	4.61

Using this method, we calculated overall GRank, SRank, ESA, CESA, and CNPS scores for all three development scenarios. We then added the overall GRank, SRank, ESA, CESA, and CNPS scores for each scenario to achieve an average impact score for each scenario (Table 7.10). Since we used the mean of the weighted averages to determine impact scores for each classification system, average impact scores can be compared even though there are an unequal number of facilities in the three scenarios.

Table 7.10 Average and Total Impact Scores for Each Scenario and Classification System.

	GRank	SRank	ESA	CESA	CNPS	AVERAGE Impact of a Facility within each Scenario	TOTAL Scenario Score (Sum of Facility Scores)
Fast Track	4.61	4.08	5.12	4.61	1.05	19.47	195
SESA	3.74	2.84	1.90	1.69	0.85	11.02	220
All Proposed	6.02	5.35	5.96	5.36	1.93	24.62	1,280

Facilities in the All Proposed scenario have the greatest impact to rare and endangered species with an average facility score of 24.62, the Fast Track scenario has the second greatest impact with an average facility score of 19.47, and the SESA scenario has the least impact with an average facility score of 11.02. The sum of all facilities scores was also taken, resulting in a total score for each scenario. The Fast Track scenario had the lowest total scenario score, with a score of 195, followed by the SESA scenario (220), and the All Proposed scenario (1,280). It is understandable that the Fast Track scenario has the lowest score because it has the fewest number of facilities while the All Proposed scenario has the highest score because it has most number of facilities. However, considering that the SESA scenario has twice as many facilities as the Fast Track scenario, there is surprisingly little difference between the total scenario scores. The small difference between the Fast Track and SESA total scenario scores is supported by the average impact scores, because the average impact score of a SESA facility is lower than the average impact score of a Fast Track facility.

ECOLOGICAL IMPACT ANALYSES: TRANSMISSION AND GRADING DISTURBANCE

The installation of multiple utility-scale solar facilities across the California desert will have ecological impacts beyond sensitive habitat, such as impacts to landscape-scale ecological processes. We chose two variables as proxies for the amount of disturbance that a facility might have on the landscape:

- Distance to transmission was chosen because the farther away a facility is from existing transmission lines, more land will need to be disturbed when building new transmission lines and associated infrastructure to connect the facility to the grid. New transmission lines could interrupt ecological processes like migration by disrupting habitat connectivity.
- Slope of the proposed facility site was chosen as the second variable. Solar facilities require a relatively low slope, zero to six percent slope for most facilities, and therefore a higher slope

at the facility site will require more grading and site engineering to make the land flat. Changes to the slope over large areas could impact ecological processes like the movement of water across the landscape.

Other infrastructure-based disturbances are inherent in the installation of utility-scale solar facilities and addition of other variables would strengthen this analysis.

Data Sources

Transmission data in GIS form is protected for national security reasons. Thus, we were unable to obtain adequate data for this analysis. However, we were able to obtain one publicly available data file, downloaded from the California State BLM GIS webpage (http://www.blm.gov/ca/gis/). While this file does not contain complete transmission line data, it is used here as a proxy. Data for the slope analysis came from a digital elevation model (DEM) with 30 square meter resolution, obtained from the USGS National Map Seamless Server (http://seamless.usgs.gov).

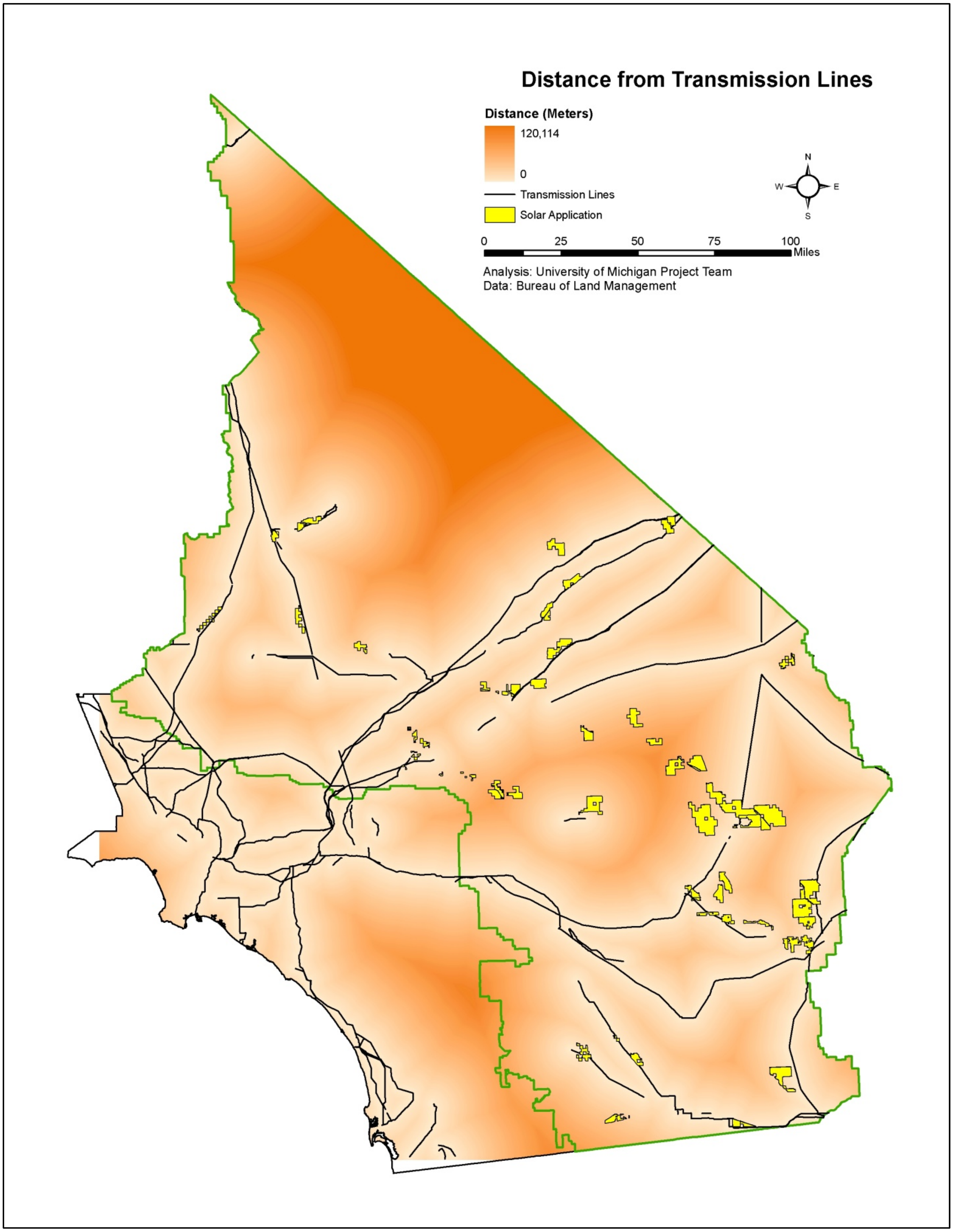
Creating a Scoring System

The transmission line data layer was used to create a raster data layer with each cell assigned a value of the straight line distance to the nearest transmission line. We used this data to calculate the minimum distance from each facility to the nearest transmission line. We calculated the average slope for each facility to compare the amount of grading and site engineering required relative to other facilities. We use the average slope as a method for comparing slopes across sites, though we recognize that average slope is not an accurate indicator of the amount of grading that will be performed on-site.

Results

Distance to Transmission

The minimum distance of a facility to the nearest transmission line ranges from zero meters (indicating that the facility is proposed to overlap an existing line) to 36,707 meters, or about 23 miles (Map 7.10). Looking at the average minimum distance to transmission for each scenario, the SESA scenario has the smallest average minimum distance at 1,558 meters, while the All Proposed scenario has the largest at 5,496 meters (Table 7.11). Table 7.11 also lists the minimum and maximum distances in our minimum distance to transmission calculation. The Fast Track scenario falls in the middle at 2,694 meters. Because some existing transmission lines are absent from the data used for this analysis, it is possible that some proposed facilities may be closer to transmission lines than our results suggest.



Map 7.10 Distance of Proposed Solar Facilities to Existing Transmission Lines.

Table 7.11 Results of the Minimum Distance to Transmission Analysis.

	Average Minimum Distance	Minimum Minimum Distance	Maximum Minimum Distance
Fast Track	2,694	0	12,098
SESA	1,558	0	6,936
All Proposed	5,966	0	36,707

Because one of the criteria for SESA locations was proximity to transmission, it makes sense that the SESA scenario has the lowest average distance to existing transmission lines. To understand how individual facilities contribute to the overall scenario, we placed individual facilities into four categories based on the minimum distance to transmission (Table 7.12).

Table 7.12 Distance to Transmission Categories and Number of Facilities in Each Category.

Minimum Distance to Transmission (in meters)	Total Number of Facilities	Fast Track	Fast Track and SESA	SESA	Other
0	24	2	4	8	10
1 to 5,000	11	0	2	4	5
5,000 to 10,000	7	1	0	2	4
10,000 to 20,000	6	1	0	0	5
Greater than 20,000	4	0	0	0	4

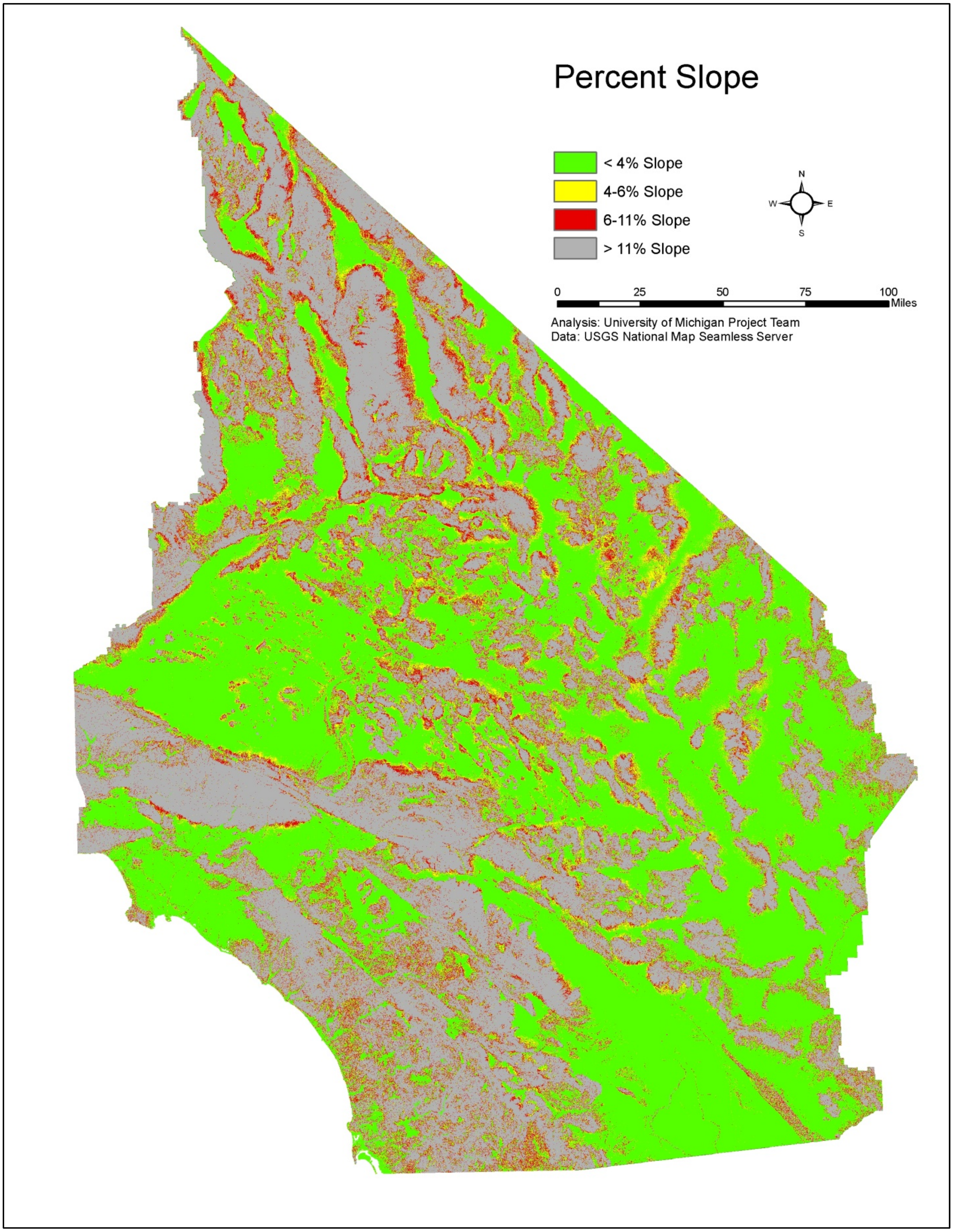
While one of the Fast Track facilities and nine of the All Proposed scenario facilities are over 10,000 meters from existing transmission lines, all SESA facilities are within 10,000 meters of existing transmission lines. Twelve of the 20 SESA facilities are directly on existing transmission lines.

Percent Slope

The California desert contains a range of percent slope (Map 7.11). The average percent slope of a facility ranges from one percent to 51 percent. Looking at the mean of the average percent slope for each scenario, the SESA scenario has the smallest mean average percent slope at 13.75 percent, while the All Proposed scenario has the largest at 17.68 percent (Table 7.13). The Fast Track scenario falls in the middle at 14.75 percent.

Table 7.13 Results of the Average Percent Slope Analysis.

	Average	Lowest	Highest
Fast Track	14.75	2	44
SESA	13.75	1	51
All Proposed	17.68	1	51



Map 7.11 Percent Slope of the California Desert.

Because one of the selection criteria for SESA locations was relatively low slope, it makes sense that the SESA scenario has the lowest average slope. To understand how individual facilities contribute to the overall scenario, we placed individual facilities into four categories based on average percent slope (Table 7.14).

Table 7.14 Average Percent Slope Categories and Number of Facilities in Each Category.

Average Percent Slope	Total Number of Facilities	Fast Track	Fast Track and SESA	SESA	Other
1 to 6	18	1	3	7	7
6 to 11	9	1	2	2	4
12 to 40	18	2	1	2	13
Greater than 40	7	0	0	3	4

Over half of the Fast Track facilities (seven of the 10) and SESA facilities (14 of the 20) have an average slope below 11 percent. However, of all 52 facilities, about half have an average slope below 11 percent and about half have a slope above 11 percent, contributing to the higher mean average percent slope for the All Proposed scenario.

VISUAL IMPACT ANALYSIS

The visual impact analysis sought to identify the extent to which visual resources will be affected by solar development across the California desert landscape. For each of the three scenarios, we wanted to determine the number of visually-affected acres and the percentage of the CDCA these affected acres comprise. To get a sense of the magnitude of impact, we were interested in determining how many solar facilities could be seen from a particular place in the landscape. We also sought to compare scenarios to determine which scenario had a larger overall impact and which had a proportionately larger impact relative to the number of acres developed. Finally, we conducted a visual impact analysis of a viewshed from Mojave National Preserve as an example to demonstrate how solar development may affect areas valued for scenic views.

Data Sources

We obtained and downloaded proposed solar facility shapefiles from the California State BLM GIS webpage (http://www.blm.gov/ca/gis/). Data used by ArcGIS for the viewshed analysis came from a digital elevation model (DEM) obtained from the USGS National Map Seamless Server (http://seamless.usgs.gov).

Building Scenarios

A viewshed analysis was conducted for each of the 53 proposed solar facilities. There were 53 facilities in the All Proposed scenario, 21 facilities in the SESA scenario, and 10 facilities in the Fast Track scenario. Each analysis was conducted using the solar facility as the observation point, under the assumption that the landscape visible from the facility would be the same as the locations on the landscape from which the facility was visible. The observation point was placed on the ground in the center of the facility. The Viewshed Analysis tool in ArcGIS outputs a single raster for each facility, indicating the land that is visible from the facility (i.e., the facility's visual footprint), and the land that is not visible from the facility. We overlayed the facilities included in each scenario to determine the overall visual footprint of the scenario.

The following assumptions are inherent in our analysis. We utilized a single observation point in the center of solar facilities ranging from several hundred to thousands of acres, which could underestimate a facility's visual footprint. Second, the observation point was placed on the ground even though some facility infrastructure may reach much greater heights. This could also result in underestimates. For example, dish/engines are about 40 feet tall, while the three proposed facilities that plan to utilize power tower technology provide tower, the tallest element of the facility, heights of 312, 459, and 653 feet tall. Last, the DEM under the facility was not modified in any way, even though developers are likely to make modifications to the landscape, such as grading to reduce the slope of the land. Whether this assumption over- or underestimates a facility's visual footprint is likely dependent on individual facility sites. Overall, our analysis most likely significantly underestimates the visual impact of the individual facilities and the three scenarios.

Results and Analysis

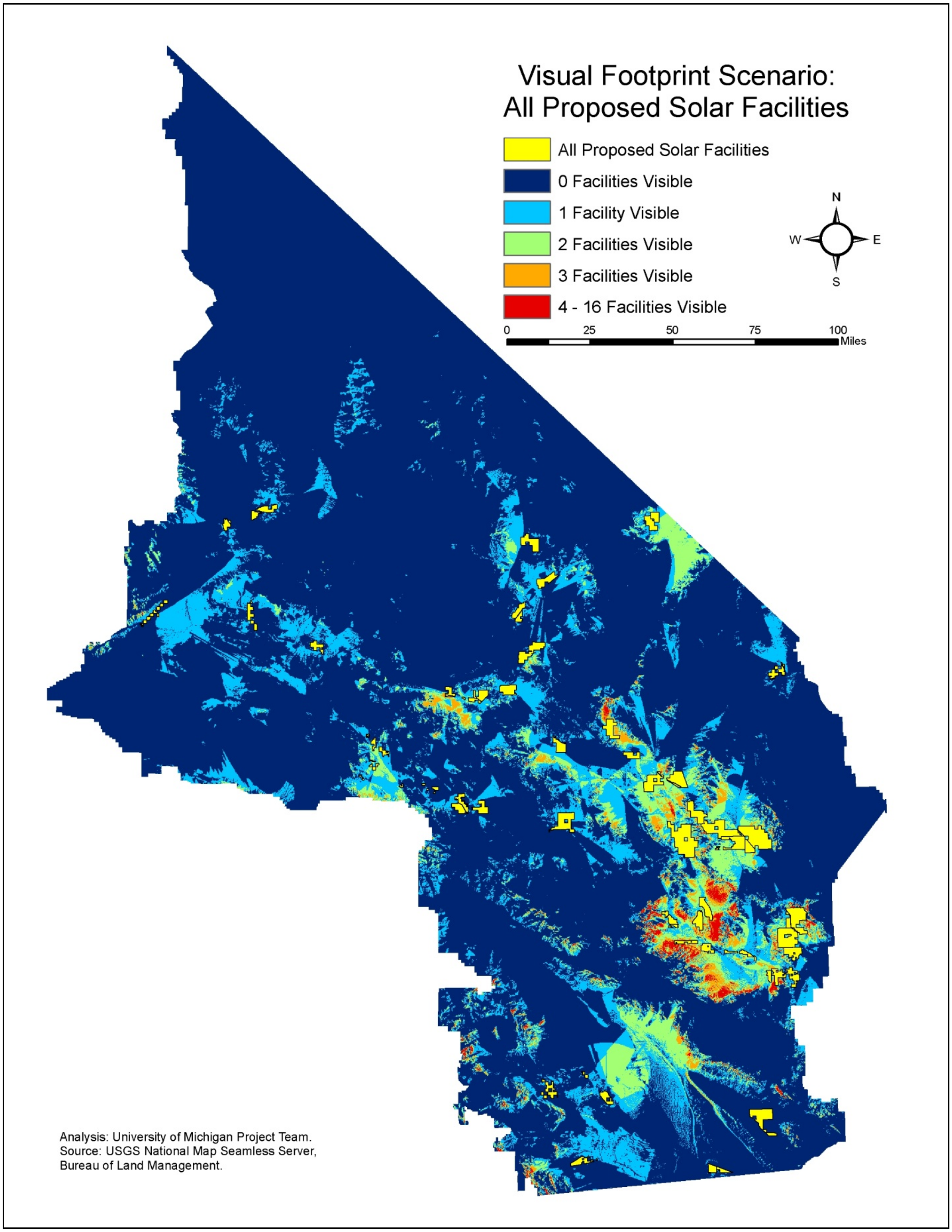
Table 7.15 displays the results of the viewshed analysis for each scenario. In the Fast Track scenario, almost 900,000 acres of land have a view of at least one solar facility while four facilities is the greatest number of facilities that can be seen at one time; in the SESA scenario, just over 1 million acres of land have a view of at least one solar facility while 13 facilities is the greatest number of facilities that can be seen at one time; in the All Proposed scenario, about 3.6 million acres of land have a view of at least one solar facility, while 16 facilities is the greatest number of facilities that can be seen at one time. To put the number of affected acres into perspective, we provided the percent of the CDCA for each visual footprint, with the CDCA being about 25.6 million acres of land.

Of the three scenarios, the All Proposed scenario has the largest visual impact (Map 7.12), with at least one solar facility visible to about 15 percent of the CDCA. The SESA scenario has the second largest impact, with at least one solar facility visible to about 4 percent of the CDCA (Map 7.13). The Fast Track scenario has the smallest impact, with only about 3.5 percent of the CDCA visually affected by solar facilities (Map 7.14).

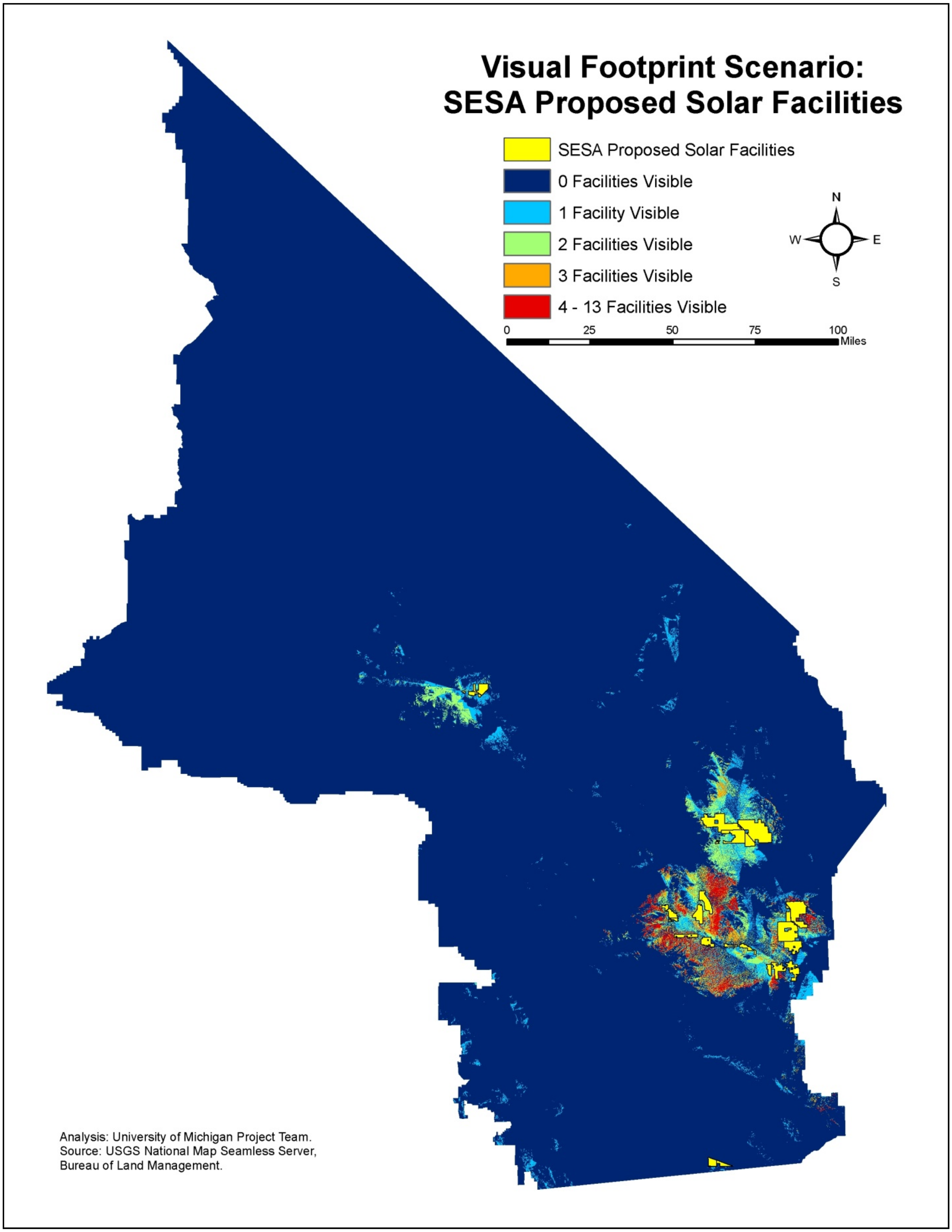
Table 7.15 Viewshed Analysis for Fast Track, SESA, and All Proposed Build-out Scenarios.

	Fast Track		SESA		All Proposed	
Number of Visible Facilities	# of Acres	% of CDCA	# of Acres	% of CDCA	# of Acres	% of CDCA
1	**802,985**	**3.133**	**475,052**	**1.854**	**2,473,928**	**9.654**
2	**79,335**	**0.310**	**311,426**	**1.215**	**884,328**	**3.451**
3	**3,963**	**0.015**	**127,346**	**0.497**	**292,271**	**1.141**
4	**40**	**0.000**	**65,105**	**0.254**	**109,831**	**0.429**
5			**36,722**	**0.143**	**47,493**	**0.185**
6			**12,103**	**0.047**	**15,824**	**0.062**
7			**4,031**	**0.016**	**4,898**	**0.019**
8			**2,006**	**0.008**	**2,422**	**0.009**
9			**1,148**	**0.004**	**1,342**	**0.005**
10			**744**	**0.003**	**847**	**0.003**
11			**173**	**0.001**	**283**	**0.001**
12			**3**	**0**	**22**	**0**
13			**0.220**	**0**	**9**	**0**
14					**8**	**0**
15					**4**	**0**
16					**3**	**0**
At Least 1	886,323	3.459	1,035,859	4.042	3,833,512	14.959

The numbers of acres in the table correspond to the number of facilities that are visible from those acres. The total number of visually affected acres for each scenario is calculated by adding up acres for each of the number of visible facility values, seen here as the numbers in the "At Least 1" row.

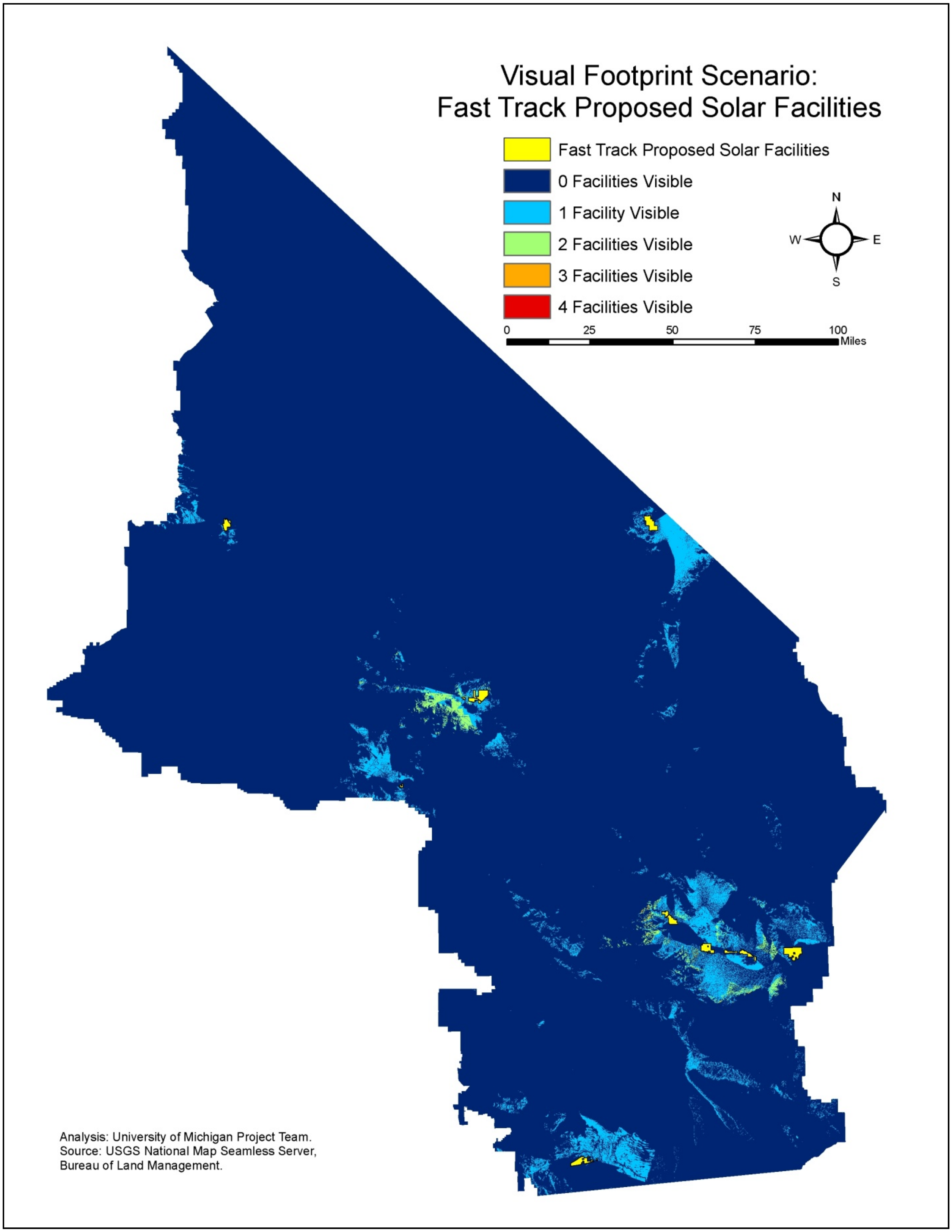


Map 7.12 Visual Footprint Scenario: All Proposed Solar Facilities.



Analysis: University of Michigan Project Team.
Source: USGS National Map Seamless Server,
Bureau of Land Management.

Map 7.13 Visual Footprint Scenario: SESA Proposed Solar Facilities.



Map 7.14 Visual Footprint Scenario: Fast Track Proposed Solar Facilities.

Since the total number of acres of solar facilities differs across the scenarios, we compared the amount of land developed in each scenario with the size of the scenario's visual footprint. The total developed acres were calculated for each scenario by adding up the acreage for each proposed facility within that scenario (Table 7.15). The amount of land where at least one solar facility was visible was considered to be the scenario's visual footprint. The ratio of visual footprint acres to developed acres was calculated by dividing Visual Footprint acres by Total Developed Acres.

Table 7.15 Visual Footprint to Developed Acres Ratio.

	Total Developed Acres	Visual Footprint	Ratio
Fast Track	50,252	886,323	17.64
SESA	212,901	1,035,859	4.87
All Proposed	491,828	3,833,512	7.79

The Fast Track scenario has the largest visual footprint ratio, while the SESA scenario has the smallest. There are about 18 acres of visual footprint for every 1 acre of solar development in the Fast Track scenario, about 5 acres of visual footprint for every 1 acre of solar development in the SESA scenario, and about 8 acres of visual footprint for every 1 acre of solar development in the All Proposed scenario.

To understand how individual facilities contribute to the overall scenario footprint ratio, we placed individual facilities into four categories based on the size of the facility's visual footprint (Table 7.16).

Table 7.16 Visual Footprint Categories for Individual Solar Facilities and Number of Facilities in Each Category.

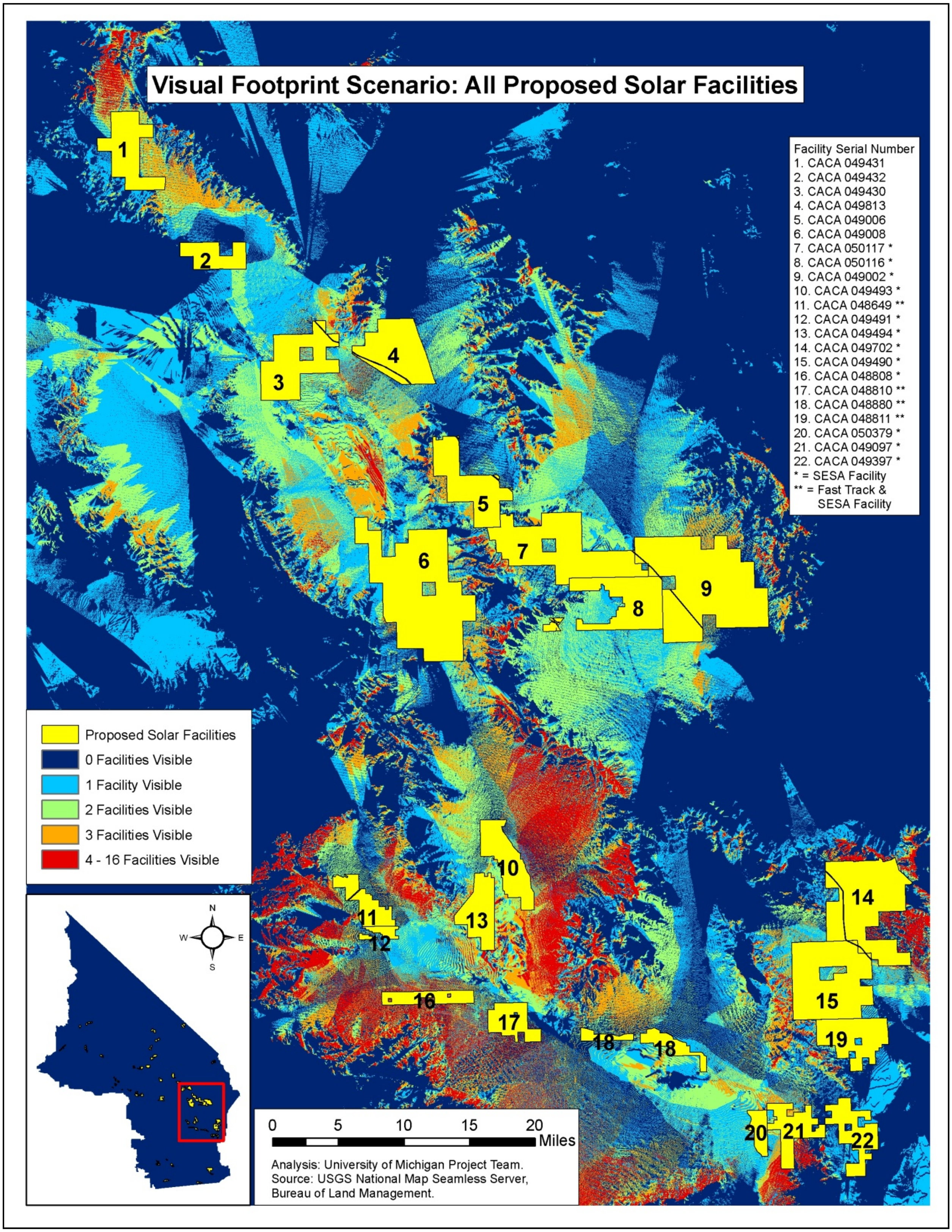
Visible Acres (in 1,000s)	Total Number of Facilities	Fast Track	Fast Track and SESA	SESA	Other
Less than 50	10	1	1	2	6
50 to 100	18	1	3	5	9
100 to 150	13	1	0	7	5
150 to 600	12	1	2	1	8

The majority of individual facilities, 43, affect fewer than 150,000 acres. Surprisingly, many SESA facilities were present in the higher impact categories: three facilities in the 150,000 to 600,000 acre category, seven facilities in the 100,000 to 150,000 acre category, and eight facilities in the 50,000 to 100,000 acre category. However, if visual footprints for multiple facilities overlap within a scenario, the number of acres that are visually affected by at least one facility will remain constant. Overlapping visual footprints likely contributes to the low visual footprint to developed acres ratio in the SESA scenario. It makes sense that the SESA scenario has the smallest visual footprint ratio because SESAs are meant to cluster facilities, which reduces the overall area by which they can be seen.

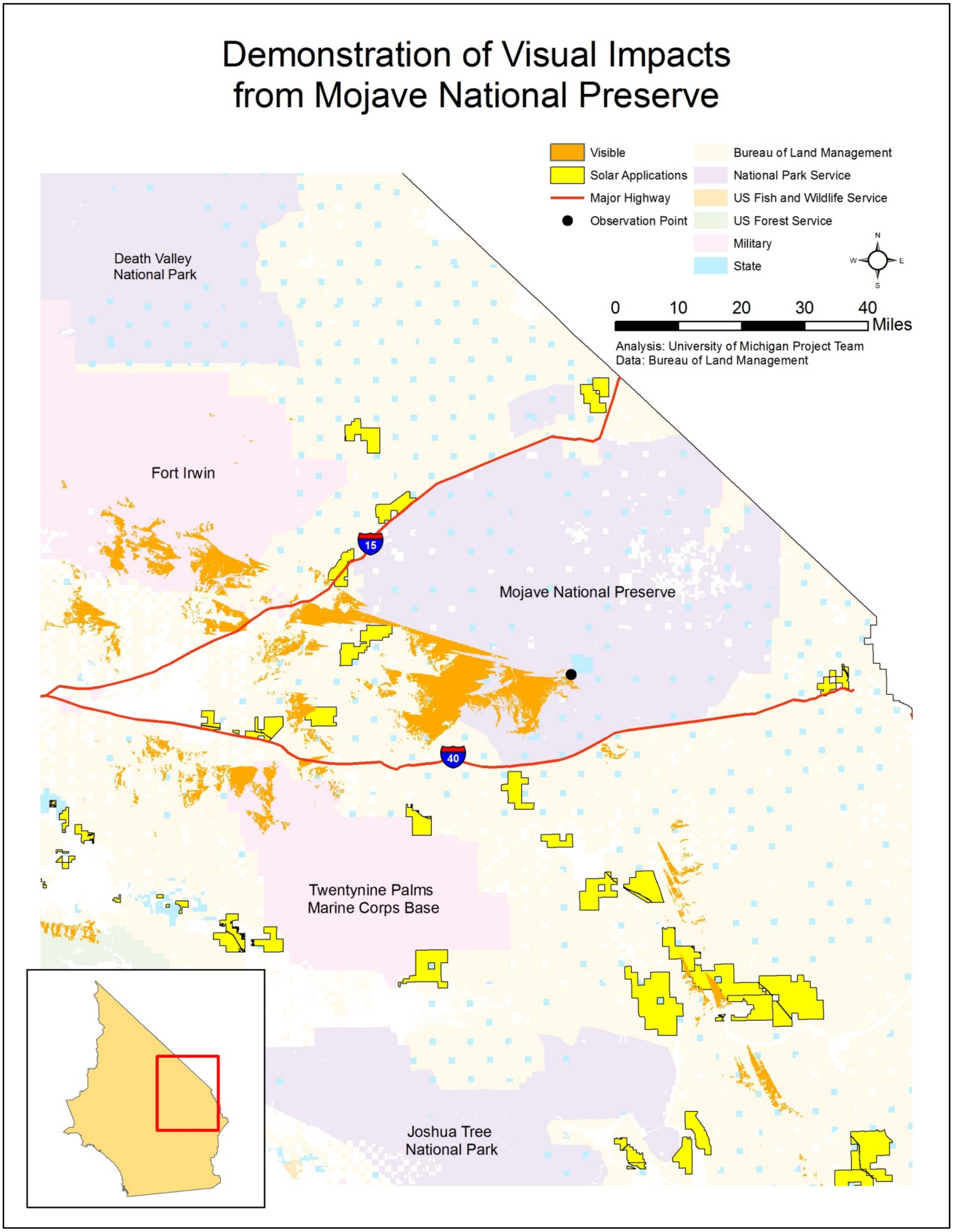
If we examine the viewshed of several solar facilities more closely, we see how factors like clustering play a role in determining the magnitude and extent of impact to visual resources (Map 7.15). Impacts to visual resources are high in and around clusters of facilities and then dissipate as distance from the cluster of facilities increases (Map 7.13). Elevation plays a major role in determining the extent of facility visibility. A greater number of facilities are visible to higher elevation areas, such as mountaintops, and therefore views of the desert landscape from those areas are more heavily affected. However, higher elevation areas may also play a role in containing the visual impact of a facility because facilities are usually situated in low slope and low elevation areas. For example, facilities labeled 10 to 13, 16, and 17 in Map 7.15 are surrounded by higher elevations. The mountaintops surrounding these facilities sustain high impacts to visual resources and are denoted in red, indicating that four to 16 facilities may be seen from those areas. However, beyond these higher elevation areas (such as the northeast), the facilities are no longer visible. Facilities that are not bordered by higher elevation areas, including facilities one to nine, have a much wider area of impact. The extent of visual impacts in the SESA scenario are smaller and more concentrated (Map 7.13) than visual impacts in the Fast Track scenario (Map 7.14), despite a higher number of facilities in the SESA scenario. Thus, if land managers were interested in minimizing the visual impact of utility-scale solar development across the California desert landscape, siting facilities in SESAs or similarly clustered developments might be the most effective way to accomplish such a goal. Restricting visual impacts to a smaller area may also be accomplished by siting developments in lower elevation areas surrounded by mountains or other high-elevation landscape features.

Demonstration of Impacts from Mojave National Preserve

While mountain tops and high-elevation landscape features may sustain heavy impacts to visual resources, impacts to views experienced by desert residents and visitors could be better assessed by determining visual impacts from road corridors and highly trafficked areas. Stakeholder groups (e.g., local municipalities, private landowners, land management agencies, and environmental groups) interested in specific visual resources could select a series of points from which to conduct viewshed analyses of individual facilities or facility development scenarios. We were interested in seeing how solar development might affect views from national parks and other areas valued for their scenic qualities. We selected one observation point from a visitor use area in the Mojave National Preserve from which a few solar facilities are visible, to serve as an example of further analyses that can be conducted from towns, roads, trails, and visitor use areas throughout the desert to predict impacts of proposed solar facilities to visual resources (Map 7.16).



Map 7.15 Visual Footprint Scenario: A Closer Look at the All Proposed Solar Facilities Scenario.



Map 7.16 Demonstration of Visual Impacts from Mojave National Preserve.

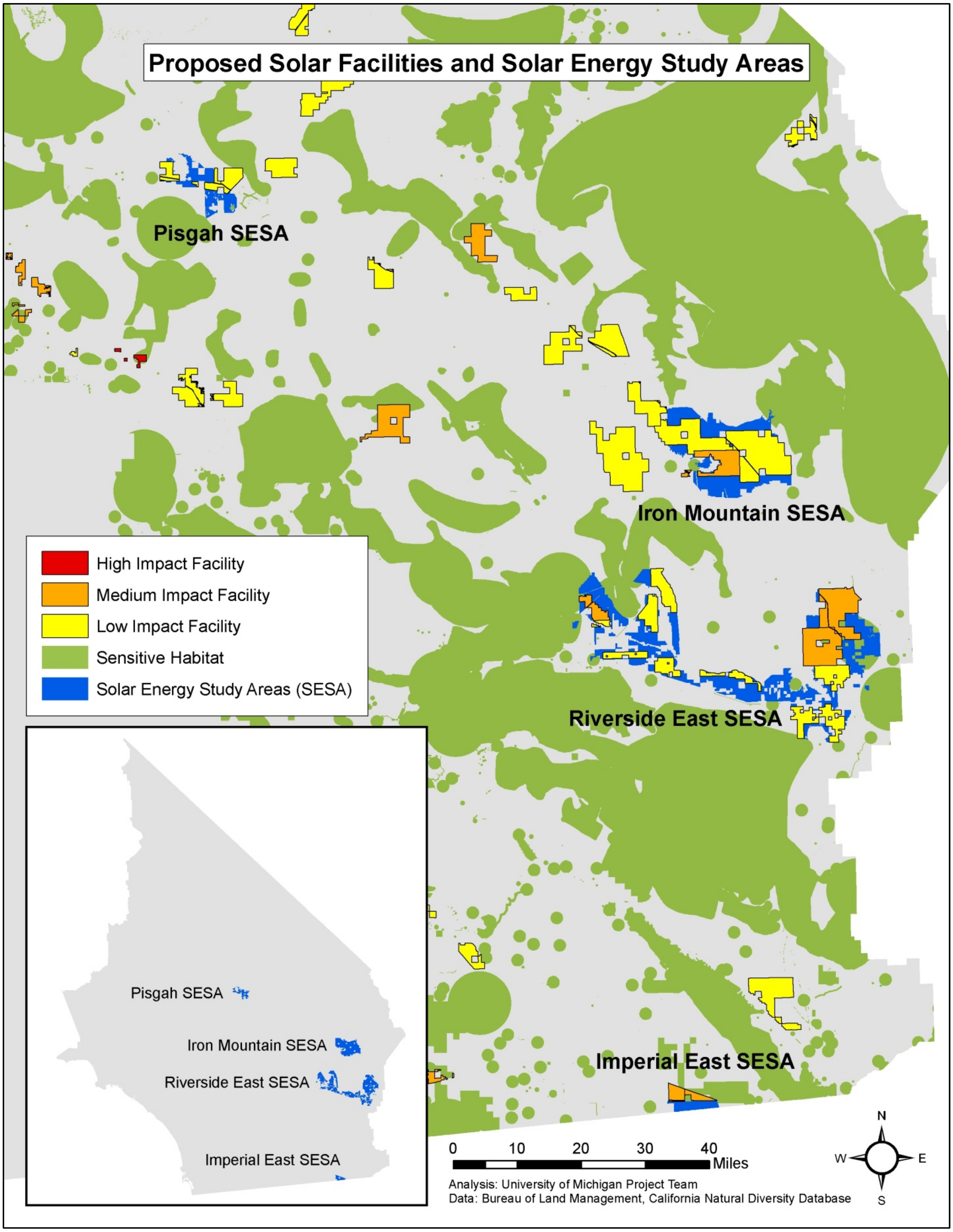
CONCLUSIONS

The four SESAs in the California desert were chosen under the Solar PEIS process for their high solar resources, suitable slope, proximity to roads and transmission, avoidance of areas with important visual resources, and avoidance of sensitive and wilderness lands, including threatened and endangered species designated critical habitat, ACECs, and wildlife movement corridors.[468,469] Based on the results of our spatial analyses, these selection criteria were effective in choosing areas for development that would minimize impacts to both ecological and visual resources.

Compared with the Fast Track and All Proposed scenarios, the SESA scenario has the lowest overall ecological impact, with the lowest amount of sensitive habitat within the scenario, the lowest total sensitive habitat impact score, and fewer individual high and medium impact facilities, based on the data used and the assumptions noted. Only 10.86 percent of land proposed for development in the SESA scenario contains sensitive habitat, compared to 12.31 percent for the All Proposed and 18.89 percent for the Fast Track scenarios. In addition, the SESA scenario has the lowest average facility impact score at 11.02, while the Fast Track (19.47) and All Proposed (24.62) scenarios have much higher average facility impact scores. Examining total impact scores for individual facilities, 14 of the SESA facilities are low impact, six are medium impact, and none are high impact. All four of the SESAs avoid major swaths of sensitive habitat and most of the facilities within SESAs are low impact facilities (Map 7.17).

Based on the data available to us, the SESA scenario will also require the least amount of disturbance to surrounding habitat because its facilities are, in general, closer to existing transmission lines and have lower slope. Concentrating facilities into limited areas like SESAs, may allow facilities to share new or existing transmission lines and reduce the amount of land that would need to be disturbed to connect new facilities to the grid. In our visual impact analysis for the three scenarios, we found that clustering facilities in low elevation areas surrounded by mountains or other high elevation landscape features helped to minimize the extent of impacts to visual resources. The SESA scenario was found to have the lowest visual impact compared to the amount of land actually developed, with a ratio of only 4.87 acres of land that are visually affected for every one acre of land developed, compared to the All Proposed (7.79) and the Fast Track (17.64) scenarios. Clustering of facilities may be crucial to reducing visual impacts of solar development across the landscape.

Based on our ecological and visual impact analyses and associated assumptions, we conclude that the SESA development scenario would have the least impact of the three scenarios. However, further analysis would be needed to determine whether SESAs are the optimal locations for solar development in the California desert. This scenario-based approach would be useful in future evaluations of landscape-level impacts from solar development.



Analysis: University of Michigan Project Team
Data: Bureau of Land Management, California Natural Diversity Database

Map 7.17 Ecological Impact Levels of Proposed Solar Facilities and SESA Locations.

CHAPTER 8 | SOCIOECONOMIC IMPACT ANALYSIS

In today's society, proposed industrial facilities are scrutinized for their impacts on the environment. Local residents, elected officials, and environmental groups ask how a new facility will affect the air, water, and wildlife. NEPA and CEQA require environmental assessments, which typically include an assessment of the local social and economic implications of such facilities.

This chapter investigates the socioeconomic effects of utility-scale solar facilities proposed for the California desert. Limited research has been conducted on this topic;[470] thus, we used several other methods and data sources to predict the social and economic impacts of solar development:

- A literature review of the socioeconomic impacts of other energy developments- oil and gas and wind energy- and an analysis of how these observations may inform predictions for the impacts of solar development.
- A case study of the socioeconomic impacts of the utility-scale solar facility Nevada Solar One, a 64 MW solar thermal facility located approximately 15 miles from downtown Boulder City, Nevada. The facility, which came online in 2007, uses solar trough technology and covers approximately 400 acres. Data collection for the case study consisted of eight interviews with individuals familiar with the facility.
- A summary of government, industry, and non-profit predictions for solar development and job creation.
- An analysis of demographic data to predict how two California desert communities, Lucerne Valley and El Centro, will be affected by solar development.
- An analysis of how project location can help influence a facility's socioeconomic effects.

Based on these analyses, it appears likely that utility-scale solar development in the California desert will have limited long-term socioeconomic impacts. Unlike Boulder City, which benefits greatly from solar facility Nevada Solar One's annual lease payments, communities in the California desert will not receive rent payments; this is because facilities sited on BLM land will make lease payments directly to the U.S. Treasury. Solar development will also have little effect on employment, as each facility will require relatively few full-time employees once in operation. Construction impacts may be greater in the California desert than they were in Boulder City, though the relative distance from facilities to population centers helps to mitigate impacts on traffic levels and public services. Nevertheless, there may be impacts from some projects and a full range of potential social impacts (considering the categories of impacts described in this chapter) should be analyzed during the project-level siting process.

THE SOCIOECONOMIC IMPACTS OF OIL AND GAS AND WIND ENERGY DEVELOPMENT

Although research on the socioeconomic impacts of utility-scale solar is scarce, an abundance of research exists on the impacts of oil and gas and wind energy development. By considering the effects and similarities that oil, gas, and wind energy share with the solar industry, we can make predictions about the socioeconomic effects of solar facilities proposed for the California desert (Table 8.1).

Table 8.1 Socioeconomic Effects in the Oil and Gas, Wind Energy, and Solar Energy Industries.

Community Effects	Oil and Gas	Wind Energy	Solar on Public Lands
Job Creation	+ +	Negligible	Negligible
Population Growth	– –	Negligible	Negligible
Lease Payments	+	+	None
Property Taxes	+	+ +	Negligible
Tourism	NA	+/–	+/–
Recreation	NA	+/–	+/–
Quality of Life	NA	+/–	+/–
Social Cohesion	NA	+/–	+/–

A "+" indicates a benefit while a "–" indicates a cost. A "+/–" indicates the effect could be a cost or benefit and a double symbol indicates a significant effect.

The Oil and Gas Industry

The social and economic effects of energy-producing facilities have been studied extensively. Extractive industries, such as mining and oil and gas drilling, have historically occurred in rural areas with few nearby towns. In cases where the facility or site was far from existing settlements, the organizations heading the effort (either a private company or a government agency) would build a new town to house the workers. Since our study focuses on the effects of utility-scale solar facilities upon existing population centers, this literature review will exclude information on towns built purely for a new facility.

Literature review suggests that traditional resource development facilities, such as those based on petroleum, affect existing rural areas in a variety of ways. Effects vary greatly among different industries and facility locations; thus, quantitative data on impacts is hard to come by. However, studies often focus on three broad areas:

- Job creation
- Population growth
- Local fiscal impacts

Job Creation

Proponents of resource development often extol the positive effects these facilities will have on local employment. However, job creation is often dependent on several facility characteristics, including project scale and technology. While the local labor pool may be qualified for less-skilled jobs, often local hiring will not satisfy the demand in professional, technical, and supervisory areas.[471] While local laborers may be hired, local unemployment levels may not necessarily decrease, especially when the unemployed do not have the skills required for the new positions. Just as the quality of local labor plays a part in employment impacts, so does the quantity of available labor. A town will likely experience greater employment effects if its job applicants do not have to compete with the job applicants in other nearby towns.

Similarly, oil and gas facilities may also generate secondary employment effects. Secondary employment refers to jobs created indirectly by the facility. For example, if a new facility attracts workers to the area, local stores will likely see an increase in business, which may lead to new jobs at the stores. The magnitude of indirect employment effects are largely determined by the new project and are dependent on factors such as employee wages and the company's likelihood of purchasing local goods.

Population Growth

Rapid population growth is a common experience in rural towns near new resource extraction facilities. Examples of small towns experiencing rapid population growth because of energy development can be seen as early as the 1800s and up through modern times. In the late 19th century, an oil boom in Scio, Ohio, caused the town's population to skyrocket from 900 to approximately 12,000.[472] More recently, Uinta County, Wyoming's population grew from 7,100 to 13,021 residents between 1970 and 1980 as a result of oil and gas development and the construction of gas processing plants.[473] Similar trends are evident in towns experiencing other types of energy development, including coal mining and power plant construction.[474]

When an area's labor pool is inadequate for an energy project, outside labor will likely move to the area to fill the gap. Like a facility's impact on employment, in-migration is also dependent on several facets of the project, including the facility's scale. Towns with larger populations (greater than 1,000 individuals) and with developed services will likely experience greater rates of population growth than areas without developed services.[475] Generally, such towns may see their population grow as much as 10-15 percent annually.[476] With the influx of new individuals, secondary industries in the town may also begin to grow; more individuals will move to the area to fill these secondary positions.[477]

Rapid population increase often corresponds with decreased availability of public services. Demand for education, water and sewer, health care facilities, fire and police protection, and transportation systems may increase as a result of population growth.[478] The term "boomtown" is used to describe towns where "rapid population growth associated with energy and other resource development creates social disruptions, cultural conflicts, and pathological behaviors."[479] Increased rates of mental illness, school dropout rates, child abuse and drunkenness have all been observed, though other research suggests that the social deviancy associated with new resource extractive facilities may be overblown.[480,481,482,483] Decades of research suggest boomtowns are the result of inadequate services, because they are either antiquated and/or unable to absorb the increased demand.[484] Eventually, increased tax revenue may cover the costs of expanded services.[485]

Sweetwater County, Wyoming, exemplifies the boomtown phenomenon.[486] In the early 1970s, mineral extraction and processing ramped up significantly. Population and employment nearly doubled in four years, to 36,900 and 15,225 respectively. Also during that time, the number of mental health clinic caseloads increased eight-fold and there was a drastic shortage of schoolrooms. Furthermore, growth in municipal water and sewage services, as well as roads and electric service, could not keep up with demand. During the boom, crime rates increased by 60 percent.

Local Fiscal Impacts

It is difficult to generalize the fiscal impacts of extractive facilities because taxation systems vary by state.[487] However, most states impose a severance tax, which taxes a facility by the amount of a resource extracted. A portion of severance tax revenue may be funneled to an "impact fund" for affected communities.[488] States may also levy a corporation income tax. Facilities on federal land may pay lease fees and production royalties. However, taxes and fees collected at both the state and federal level may not specifically benefit local municipalities affected by the extractive facility.

In addition to funds that come from state or federal government, local municipalities may benefit from a facility's indirect and induced effects. Local workers hired by the facility will likely live in town, thereby increasing the demand for housing and possibly spurring construction of new housing stock. Local workers will spend their earnings in town, boosting the economy. An influx of new workers will create a demand for more stores and restaurants, which will in turn hire workers who will spend their incomes locally.

The Wind Energy Industry

The above review suggests that many of the negative effects experienced by local towns are caused by extreme population growth spurred by job opportunities at energy facilities. However, utility-scale wind facilities employ relatively few individuals post-construction; for this reason, wind farms may not have the same socioeconomic effects as oil and gas facilities, though perhaps may be more similar to the effects from solar facilities. Wind farms also differ in their local fiscal impacts. This literature review focuses on wind energy development's affect on:

- Job creation
- Population growth
- Fiscal impacts
- Tourism
- Recreation
- Quality of life
- Social cohesion

Job Creation

Wind farms may produce between 0.4 and 1.4 jobs per MW of facility nameplate capacity during construction and 0.06 to 0.2 jobs per MW for operation and maintenance (O&M).[489] Wind farms can vary greatly in nameplate capacity, so it is difficult to say how many jobs the "average" wind farm will create. However, a 50 MW wind farm might create 20 to 70 jobs during construction and three to 10 jobs during O&M. A 2006 NREL study found that while wind farms do generate jobs, local labor must have specific skills if they are to be hired.[490] If local residents are unqualified for the jobs, labor will be brought in. Since wind farms create relatively few jobs, and the bulk of these jobs are temporary, wind energy development has little effect on population growth.

Fiscal Impacts

Private citizens often benefit financially from a wind farm. Individuals may benefit from lease payments of $2,000 to $5,000 per turbine per year when turbines are sited on their land.[491] In terms of facility nameplate capacity, landowners may receive lease payments of $2,500 to $4,000 per MW per year.[492] Due to their small footprints, wind turbines may not decrease the land available for agricultural purposes;[493] therefore, landowners can benefit financially both from lease payments and agriculture. Property taxes may be assessed at the county level, and typically run from one to three percent of the wind farm's assessed value.[494]

Wind farms may benefit the local rural economy especially when the economy was previously supported by one industry, such as agriculture. Wind farms create another industry and contribute greatly to the local tax base.[495] Wind farms may also be community owned. In this case, the facility's owners, which may be a group of landowners or a municipality, would benefit directly from the sale of electricity to the local utility.

Because wind turbines may be several hundred feet tall, and are sited in open areas such as plains and ridgelines, they are often highly visible to the nearby population. Compared to oil and gas, concerns over negative impacts to the view have been particularly prevalent in the wind industry. Property devaluation is a common concern among residents who live within view of the wind farm, an area often referred to as the viewshed. However, two separate studies have found that this concern may be unfounded. A 2009 study conducted by the Lawrence Berkeley National Lab found that view of and distance to a wind energy facility had no statistically significant impact on home sale prices.[496] A 2003 study of 10 wind farms found that “for the great majority of projects the property values actually rose more quickly in the view shed [sic] than they did in the comparable community.”[497]

Tourism

Views of the turbines may negatively affect local tourism, particularly in areas where tourism is dependent on rural views. For example, a town in France saw a coalition of winegrowers and tourism industry representatives form in response to a proposed wind farm. The coalition worried that the turbines would ruin the view’s “authenticity,” and result in fewer visitors and wine sales.[498] An economic impact study of a wind farm in Australia assumed there would be reductions in local tourism, particularly for farms within sight of the wind farm that provide lodging during holidays.[499]

In contrast, a wind farm may serve as a tourist attraction, drawing tourism dollars to the local economy, as tours may be organized to visit the wind farm. Although some believe wind turbines negatively affect the view, others find the structures to be beautiful. Wind farm proponents may find wind turbines are “sleek, futuristic and a handsome symbol of an environmentally healthier future.”[500]

Recreation

Similarly to the way a wind farm may impact local tourism, area recreation may also be affected. On one hand, a wind farm may be detrimental to the ability of an area to be used for recreation. For example, impacts to the view or noise generated from the turbines may negatively affect a community’s ability to hike and camp in the area.[501] In contrast, turbines may boost a recreational area’s appeal if individuals are drawn to the site because of the turbines.

Turbines may negatively affect residents living in the viewshed. Though noise is generally not an issue, there are several examples of wind farms in which area residents have been disturbed by the noise generated by nearby turbines.[502,503,504] Shadow flicker, which occurs when the rotating blades create a moving shadow, may also disrupt neighboring residences. However, because the amount of time a turbine will create shadow flicker can be calculated, turbines can be sited so as to minimize or negate this issue.[505]

Quality of Life

Wind farms may also be detrimental or beneficial to local quality of life. Residents who live within the viewshed may experience a decrease in their quality of life due to the change in view. An economic analysis of a wind farm in Australia found that concern over view fell into two categories: 1. Impacts to the landscape, and 2. Impacts on the community's visual amenity.[506] The first category refers to sentiments expressed by several residents that wind turbines would disturb the pristine natural setting. The second category captures residents' opinions that the wind turbines would alter the area's character, making the area seem less rural. In contrast, proponents of wind energy may experience an increase in quality of life once a wind farm is built.

Social Cohesion

Tension may form in communities where the economic benefits of a wind farm are not shared equally among the residents. Such may be the case when the wind farm is sited on private property; the property owner may receive lease payments while the neighbors do not. This conflict may be localized such that only properties that are in close proximity or direct view of the turbines are involved.[507] Tension may also form between wind farm supporters and opponents. One economic analysis noted, "the greatest tensions have occurred between the landholders who would have turbines on their properties and community members campaigning to stop the project."[508]

Implications for Solar Development

Oil and gas and wind energy development have a multitude of socioeconomic effects on nearby communities. Since oil and gas and wind, like solar, are all forms of energy development, it is possible that the socioeconomic impacts of these industries can inform the future impacts of solar development (Table 8.1).

From the Oil and Gas Industries

An analysis of the effects of the oil and gas industries can provide insight into the effects of solar development. If the local workforce cannot satisfy the solar facility's demand for labor, the area may experience an influx of new residents who may move to the area looking for job opportunities. Employment at oil and gas facilities, compared to solar, fluctuates differently; while employment at oil and gas facilities fluctuates continuously with production, employment at a solar facility peaks during construction, and significantly declines during operation. Since solar facilities need relatively few workers while in operation, solar facilities will not create long-term boomtowns. Though there may be an influx of workers during construction, these workers are largely temporary.

Lastly, in contrast to the oil and gas industries, local municipalities will not benefit from lease payments or property taxes paid by facilities on public lands. All lease payments for facilities on BLM land will go directly to the federal government. Federal land is exempt from local property tax assessment, thus solar development on public lands will have no effect on local property tax rolls. Solar development will also have no effect on Payments in Lieu of Taxes, which the BLM pays to local communities to help offset losses to property taxes because federal land is non-taxable.

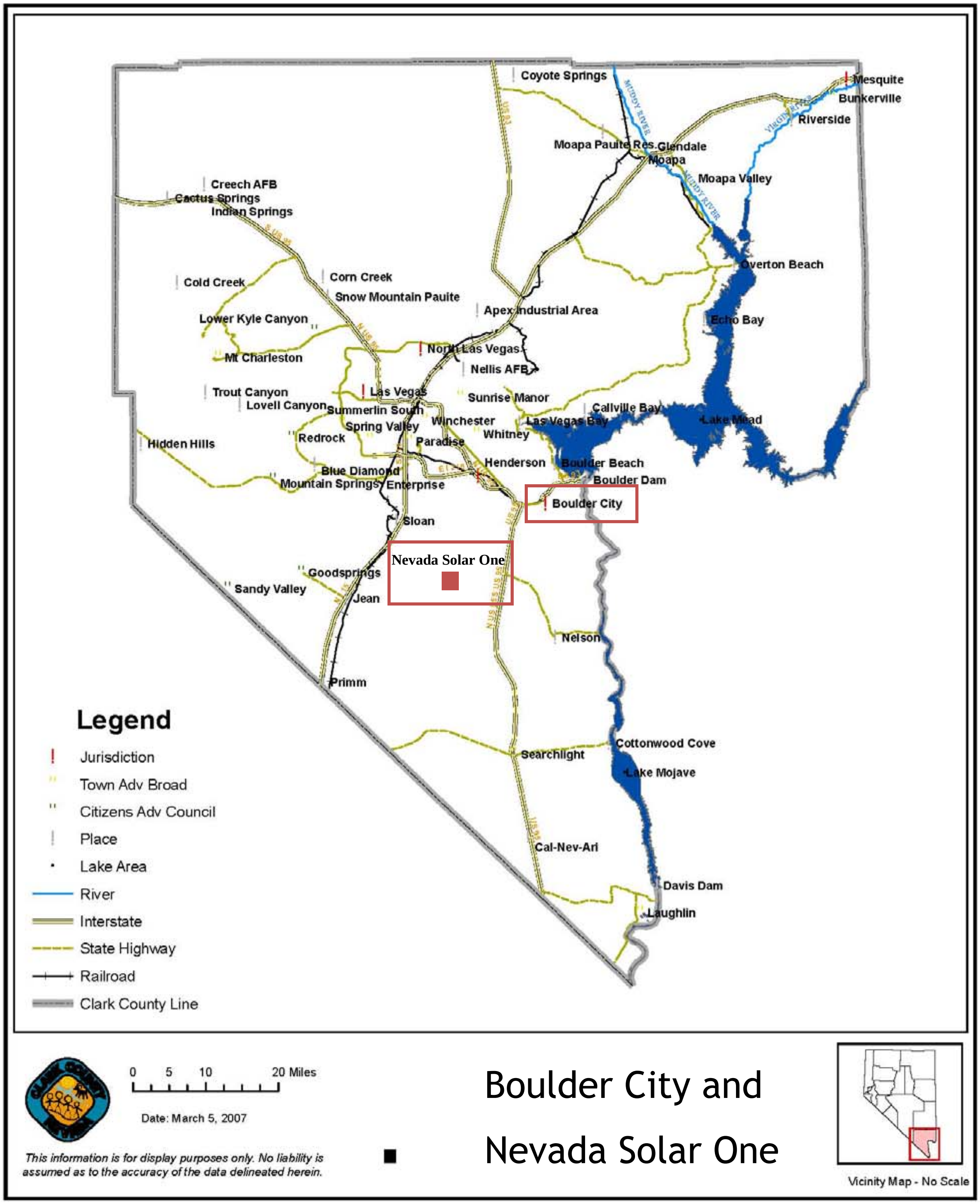
From the Wind Energy Industry

Utility-scale solar facilities will likely share impacts similar to wind farms. Like wind farms, solar facilities will create several permanent O&M positions. Solar and wind facilities may also negatively affect the viewshed, possibly decreasing residents' quality of life and negatively affecting tourism. Like wind farms, solar facilities may also be detrimental to area recreation, particularly if they are sited in areas popular for outdoor activity. Similarly to the way a politically contentious wind farm may spur community members to organize, area residents may also organize in support of or opposition to a proposed solar facility.

THE SOCIOECONOMIC IMPACTS OF NEVADA SOLAR ONE ON BOULDER CITY: A CASE STUDY

In an effort to further understand the socioeconomic impacts of future utility-scale solar facilities on California desert communities, we researched the impacts of existing solar facilities. Our research focused on Nevada Solar One, a 64 MW solar thermal facility located approximately 15 miles from downtown Boulder City, Clark County, Nevada (Map 8.1). The facility, which came online in 2007, uses solar trough technology and covers approximately 400 acres.

Overall, Nevada Solar One's socioeconomic impacts on Boulder City have been minimal (Table 8.2). During construction, impacts on local traffic, stores, and public services were minor. Though the facility required over 1,000 construction workers, it is likely that few workers came from Boulder City and that few workers utilized the city's short-term rental housing. Post-construction impacts on local industry, employment, and public services have also been minimal. Although Nevada Solar One has helped to increase local tourism, the biggest impact has been the facility's lease revenue, which helps to keep Boulder City's taxes low. Boulder City also receives a portion of the facility's annual property taxes, which the project developer pays to Clark County. Except for the lease revenue, Nevada Solar One has not greatly changed Boulder City or affected the town's character.



Map 8.1 Locations of Nevada Solar One and Boulder City. Boulder City is approximately 25 miles east of Las Vegas and 15 miles northeast of Nevada Solar One. The facility's location is represented by the square (square not to scale). Base map source: Clark County GIS Management Office.

Table 8.2 Summary of Nevada Solar One's Socioeconomic Impacts.

Community Effects	Magnitude of Effect
During Construction	
Job Creation	Negligible
Rental Housing	Negligible
Local Restaurants and Stores	Negligible
Transit	Negligible
Public Services	Negligible
During Operation	
Job Creation	Negligible
Lease Payments	++
Property Taxes	+
Local Tourism	+
Local Industry	Negligible
Public Services	Negligible

A "+" indicates a benefit, while "++" indicates a benefit with a significant effect.

Boulder City and Solar Development

Our research focused on Nevada Solar One's socioeconomic impacts on Boulder City, Nevada, to the exclusion of other urban areas in proximity to the facility. Initial research efforts identified two urban centers in Clark County close to Nevada Solar One: Boulder City, the jurisdiction in which the facility is located, and the nearby city of Henderson, Nevada. We assumed these cities had experienced the greatest impacts because they are located closest to the facility. However, early interviews with two Henderson urban planners revealed that the city had likely experienced few if any effects from the facility, and that our research should focus on Boulder City.

Located approximately 20 miles from Las Vegas, Boulder City, Nevada is a small town of about 16,000 people. Originally built to house the workers who built the Hoover Dam, today Boulder City encompasses over 200 square miles, making it Nevada's largest city by land area. Despite its sprawling size, Boulder City is known for its "small town feel." A local planner described Boulder City as a "typical Midwestern small town except in the west and in the desert." One individual said that city residents "like to keep their community somewhat small and quaint." The community is slow growth by ordinance, meaning that city laws discourage increases to the population. A city official noted the residents' strong sense of community and that many actively volunteer in the area.

Boulder City has several dominant employers and industries. The Bureau of Reclamation and Clark County school district employ many individuals, as do the Hoover Dam, Boulder City government, and the local hospital. Tourism is also an important part of the city’s economy; nearby tourist attractions include the Hoover Dam and Las Vegas.

Boulder City began planning for solar development in the mid-1990s. In 1995, the City amended its city charter to reserve 3.5 square miles of undeveloped land specifically for future solar development. Since then, Boulder City has set aside a total of about 14 square miles for solar development.

In 2003, Boulder City released a request for proposal to build a solar energy facility. Residents were generally supportive of the solar facility. As one interviewee put it, residents’ primary question was, “‘What’s in it for me?’” The interviewee added that once residents began to realize the positive impacts a solar facility would have on the city, such as the lease payments, they were all “very supportive.” Approximately four years later, in June 2007, Nevada Solar One began producing power. At that time, the developer, Acciona Solar Power, billed the facility, which has a nameplate capacity of 64 MW, as the largest solar electric project in 14 years, as well as the third largest in the world.[509] Nevada Solar One is approximately 15 miles from downtown Boulder City.

Impacts of Facility Construction

Conversations with individuals familiar with Nevada Solar One indicate that the facility’s construction had minimal impacts on Boulder City. Though it is unclear how many individuals may have moved to Boulder City to work on the facility’s construction, the information gathered from the interviews suggests that workers who did move to the city had little impact on the rental housing market. Construction also had little impact on Boulder City’s stores, transit, and public services.

Job Creation

During the 13 months of construction, there were between 800 and 1,300 workers onsite at any one time. Most of these jobs were temporary full-time. Tradesmen needed onsite included electricians, plumbers, pipefitters, and general laborers. Lauren Engineers and Constructors served as Acciona’s main contractor, and subcontracted firms from throughout the Las Vegas metropolitan area to construct the facility.

It is unclear how many workers hired during construction were already living locally and how many came from out-of-state. During the construction period, union organizations in the state complained that Acciona was not hiring enough Nevada residents given the lucrative state tax incentives the $250 million project had received.[510] Two interviewees alluded to this controversy, one noting that hiring practices were “a bone of contention” and that he believed that Acciona had hired “a considerable amount” of imported labor. Another interviewee said she thought Acciona’s employment practices were one of the negative aspects of the project; to her knowledge, not many of the workers were local.

Regardless of who filled Nevada Solar One's construction jobs, these positions likely had little impact on Boulder City due to the size and demographics of the city's workforce. Given that over a third of the city's 16,000 residents are retired, Boulder City's workforce is relatively small in comparison to the Las Vegas metropolitan area's workforce;[511] as one interviewee noted, "We're right next to a large metropolitan area, with two million people, and quite a few people looking for work…. [Acciona] had a large employment base to choose from in the region as a whole." Furthermore, Boulder City's residents are generally highly educated and white collar;[512] the city's workforce likely did not have the skills or desire to hire into the facility's construction jobs.

Rental Housing

During facility construction, interviewees reported there was little effect on Boulder City's rental housing market. Though it is unclear how many workers were already living in the Las Vegas Metropolitan area when construction commenced, no interviewees observed a large influx of new residents to the area. Hence, it is unlikely that construction stimulated demand for rental property in Boulder City.

Additionally, workers that moved to the area for facility construction probably did not move to Boulder City because the city's rental property is relatively expensive and scarce in comparison to rental stock available throughout the Las Vegas metropolitan area.[513] One respondent noted that, "Being a slow growth community… [Boulder City has] a very low vacancy rate and … high rents." Individuals that did move to the area for construction jobs likely did not live in Boulder City. Of workers that moved to Boulder City, one individual noted that several senior employees from Lauren Engineers and Constructors "actually lived in Boulder [City] because they could afford the rent." However, this group likely included "maybe only a dozen people all together."

Local Restaurants and Stores

Interviewees gave mixed responses as to whether Nevada Solar One construction had an impact on Boulder City's local stores and restaurants. A representative from Acciona said the construction crews "absolutely" had an impact. Though he qualified his response as an "assumption," he believed, "People ate lunch in the restaurants. For purposes of hardware stores and other businesses, there was a need for materials that weren't ordered in large scale." A Boulder City elected official also noted a "flurry of activity" during the construction period.

However, other individuals were more skeptical of impacts the facility's construction may have had on downtown businesses. Some interviewees said stores saw little change in demand because they believed few individuals moved to Boulder City because of construction. Workers that did move to Boulder City likely shopped where the local residents shopped- in Las Vegas. As one interviewee noted, "Even people in Boulder [City] go over the hill to Las Vegas and Henderson to do their shopping." As for the construction workers that commuted to Boulder City, a city planner said, "I wish I could say it affected us a lot, but because it literally is out in the middle of nowhere" workers generally could not drive to Boulder City for lunch because the commute would consume most of their break. Instead, he believed most workers packed their lunch: "They would come to the job site for work, do their thing, and then go home."

Transit

Interviewees generally thought Nevada Solar One's construction had very little impact on local traffic and public roads. One respondent said no "city-maintained roads" were affected by facility construction. With regards to increased traffic, individuals cited the facility's location, approximately fifteen miles away from downtown, as the reason why construction vehicles were not much of a presence in town. One individual also noted that US 95, the highway near the site of Nevada Solar One, is a main corridor for freight trucks; in his words, the facility's construction vehicles were "not even statistically relevant" compared to the amount of traffic normally on the highway.

In terms of wear and tear, the facility also had little impact on public roads. No additional public roads were built for the project and, as stated previously, the main road to the facility was designed for heavy truck traffic.

Public Services

Facility construction had little to no impacts on Boulder City or Clark County's ability to provide social services. Given that construction only lasted 13 months and that construction workers lived throughout the Las Vegas metropolitan area, impacts on Boulder City schools and other services were minimal.

Impacts During Facility Operation

While in operation, Nevada Solar One's socioeconomic effects have been more substantial. Twenty-eight full-time positions were created for facility operation and lease payments and property taxes will provide a steady stream of revenue for many years to come. Post-construction, the facility has had minimal affect on local tourism, industry, and public services.

Job Creation

A representative from Acciona said that there are between 28 and 32 full-time equivalent individuals that work at Nevada Solar One. There is always a minimum of 28 staff, but this number fluctuates as contractors are brought in for short-term work. The facility is staffed 24 hours a day, 7 days a week. Individuals that work at the facility year-round serve a variety of functions. Field workers are required for general maintenance and to wash the mirrors while others are needed to work inside of the power block and control room. A business development professional said every full time employee is a Nevada resident and is paid equal to or above the Nevada state average wage, which in 2007 translated to wages of $18 per hour or more. A representative from Acciona said “more than half the people” now working at Nevada Solar One come from the Las Vegas metropolitan area.

Local Fiscal Effects

Local governments, including Boulder City and Clark County, benefit from the long-term revenue stream created by Nevada Solar One. Acciona’s lease payments add an additional $700,000 annually to Boulder City’s general fund. These lease payments will increase over the project’s 40-year lease period in step with increases to the Consumer Price Index. A city planner noted that Acciona’s lease payments, which in 2007 accounted for approximately 2.3 percent of the city’s budget, allow Boulder City to decrease the tax burden on individual residents while still maintaining a high level of services. Clark County and municipalities within the county benefit from Nevada Solar One’s property tax payments, which total approximately $400,000 annually.

Local Tourism

When asked how Nevada Solar One may have affected local tourism, interviewees gave mixed responses. A community development planner noted that Nevada Solar One had “put us on the map internationally.” He added, “The solar facility has indirectly helped our tourism by bringing us to the attention of people who normally wouldn’t have paid attention to Boulder City.” He explained that the city gets “quite a few requests” for tours of the facility, noting an upcoming tour with a group of Australian solar developers. Furthermore, a portion of a popular television show was filmed in Boulder City, likely as a result of the publicity the city received because of Nevada Solar One. He added that international tourists are attracted to Boulder City because of recognition the city has received from the solar facility, but come to enjoy the city’s other tourist attractions. An employee at NV Energy was less optimistic; in reference to the millions of tourists drawn to the Las Vegas area, he did not think that Nevada Solar One “moved the needle at all.”

Impacts to outdoor recreation at the facility site have not been an issue. Prior to facility construction, the project site area was unpopular for outdoor activities. Thus, one interviewee believed that Nevada Solar One did not negatively affect recreation in the area.

Local Industry

In general, interviewees did not believe that Nevada Solar One has had lasting impacts on the area's industry. One interviewee noted that Nevada Solar One was "small in comparison to other things going on" in the metropolitan Las Vegas economy. Since Nevada Solar One came online, solar development has progressed rapidly in Boulder City; as of fall 2009, several solar developers had expressed interest in leasing land within the city. Given this continued interest to build utility-scale solar in Boulder City, one area planner speculated that the trend is more likely a result of the city's prime location than a result of Nevada Solar One: "We have three major transmission corridors that go through town" as well as a substation that transmits power to Los Angeles. He added, "Nevada Solar One may not have been *the* reason [for increased solar development], but I think it may have been a contributing reason." In contrast, another interviewee believed Nevada Solar One has helped draw other solar developers to the area.

Public Services

It is unlikely that Nevada Solar One will be a burden on city and county public services, such as the fire and police departments. Interviews with solar developers suggest that utility-scale solar facilities similar to Nevada Solar One pose a minimal fire hazard at worst. Additionally, none of the interviewees were familiar with any vandalism, theft, or safety problems related to the solar facility.

Electricity rates in Boulder City were unaffected by Nevada Solar One. NV Energy, a large electric utility that serves parts of Nevada and California, purchases Nevada Solar One's power; however, this entity does not serve Boulder City electric customers.

Conclusion

Nevada Solar One's socioeconomic impacts on Boulder City have been minimal. Facility construction had few to no impacts on local traffic, stores, and public services. Construction also had little impact on Boulder City's workforce and rental housing market. Post-construction impacts, with the exception of the lease payments, and to a lesser extent property taxes, were also minimal. Nevada Solar One has not greatly affected Boulder City or changed the town's character.

When asked if they thought, considering everything, Nevada Solar One had been good or bad for Boulder City, interviewees overwhelmingly replied that Nevada Solar One had either positive effects or no effect on Boulder City. Several interviewees cited the lease revenue as a positive long-term project impact. Of Nevada Solar One, a local business development professional said, "I think it's been a positive attribute for Boulder City" because it has created some positive awareness of the solar industry. He also cited the lease revenue. Similarly, when asked if they thought the town's character had changed as a result of the facility, interviewees believed that it had remained intact. On the topic of future solar development in the area, one respondent noted that residents “literally” ask, “‘Where’s the next one?’”

UTILITY-SCALE SOLAR DEVELOPMENT AND JOB CREATION

Although little research exists on the broad community impacts of utility-scale solar development, several recent studies have sought to understand the employment impacts of such facilities. NREL, the Large-scale Solar Association, and the Vote Solar Initiative have all funded research that predicts how many construction and O&M jobs a solar facility will create. Many solar developers with proposed projects in the California desert have also predicted the number of jobs their facilities will create upon construction and operation. The following analysis compares the results of these research studies with several developer job projections and the actual employment effects of Nevada Solar One. This analysis focuses on the employment impacts of CSP facilities because most facilities proposed for the California desert utilize CSP technology.

A Review of Past Research

A utility-scale solar facility will generate job opportunities during facility construction and O&M. Facility construction requires expertise from ironworkers, carpenters, pipefitters, electricians, construction equipment operators, construction managers, boilermakers, millwrights, and skilled and unskilled laborers.[514] Developer interviews have indicated a “strong preference” for local labor if the local individuals have the requisite skill sets.[515] Most facility workers are employed during the construction phase, with comparatively few full-time workers required during facility operation. CSP technology is generally more labor-intensive than PV technology; hence, CSP facilities generally employ more people during construction and operation.

Government, industry, and non-profit entities have all researched the employment impacts of utility-scale CSP facilities. In the past six years, NREL has contracted at least two studies on the subject.[516,517] The Large-scale Solar Association, a solar advocacy association, and the non-profit group the Vote Solar Initiative have also funded studies to investigate the issue.[518,519] Table 8.3 summarizes the results of these four studies. Unfortunately, a difference in units among the various studies makes it difficult to generalize construction job creation. However, during O&M, a CSP facility can be expected to create anywhere from 0.25 to 0.6 jobs per MW of nameplate capacity.

Table 8.3 Summary of Four Studies on CSP Facilities and Job Creation.

Study Author	Facility Nameplate Capacity (MW)	Construction Duration (years)	Estimated Job Creation			
			During construction	**Per MW**	**During O&M**	**O&M Jobs/MW**
Schwer and Riddel (Contracted by NREL)	100	3	817 jobs/year	8.17 jobs/year	45 jobs	0.45
Applied Analysis (Contracted by Large-scale Solar Association)	100	2	800 job-years	8 job-years	25-45 jobs	0.25-0.45
Stoddard et al. (Contracted by NREL)	100	2	455 job-years	4.55 job-years	38 jobs	0.38
The Vote Solar Initiative	2,000 (in 8, 250 MW facilities)	6	5,900 jobs/year	2.95 jobs/year	1,200 jobs	0.6

Please note the two different units, jobs/year and job-years, used to describe construction job creation. Construction jobs are often measured in the unit job-year, which refers to one person who is employed full-time (at least 40 hours worked per week) for one year. Without detailed information on each job, such as job duration, it is impossible to convert from jobs/year to job-years.

Developer Projections for Proposed Facilities

Solar developers are also predicting the employment impacts of their proposed facilities. Employment projections are available from a variety of sources, including developer web sites, facility Applications for Certification (AFCs), Environmental Impact Statements, and California Energy Commission Final Staff Assessments. Table 8.4 summarizes the findings for 14 proposed facilities, including three PV facilities.

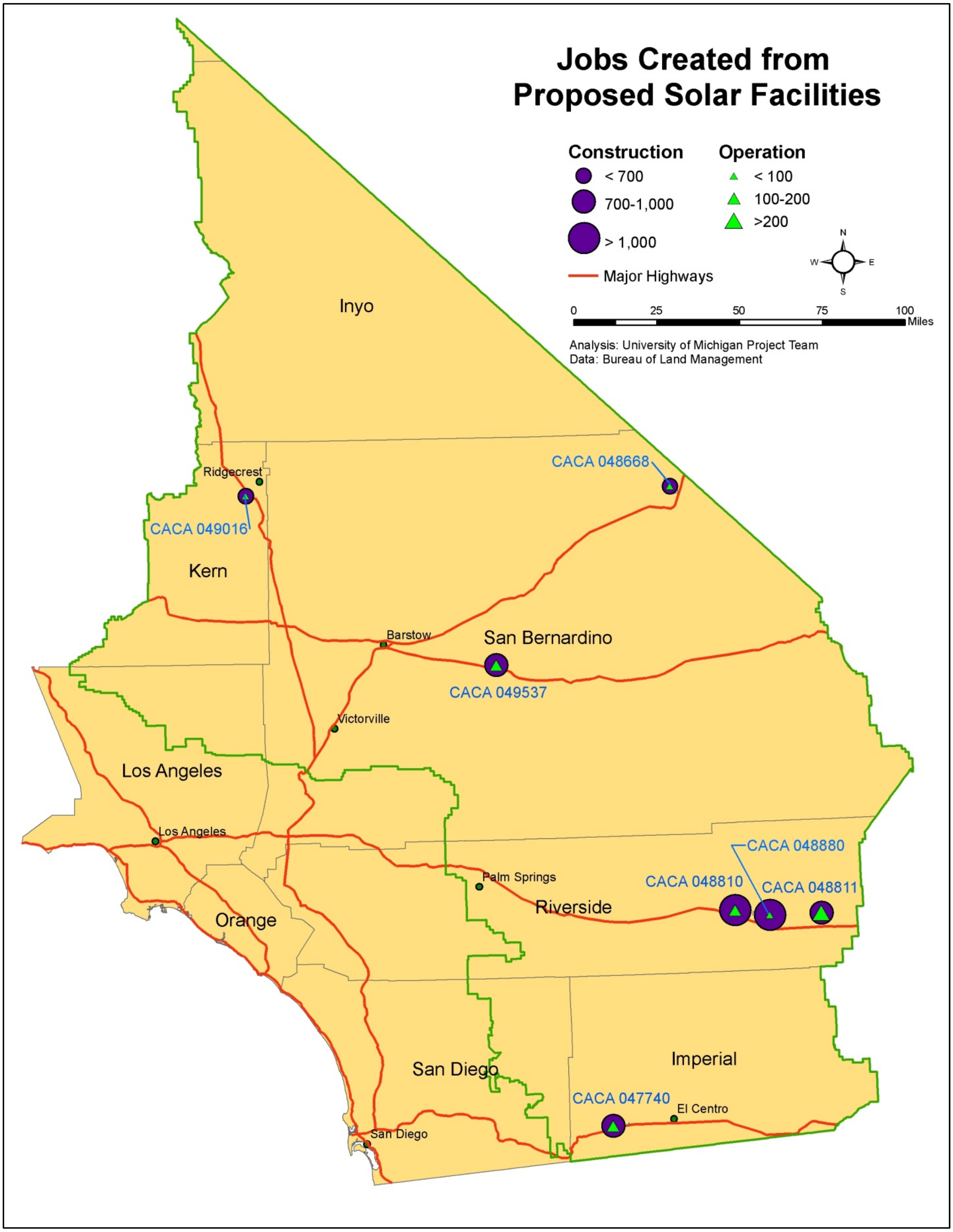
The CSP facilities reviewed for this study expect to create 0.83 to 4.65 peak construction jobs per MW. Generally, this figure declines as facility nameplate capacity increases. CSP facilities are expected to create 0.18 to 0.34 O&M jobs per MW. Nevada Solar One had greater employment impacts during both construction and operation than are predicted for any of these facilities. PV facilities are expected to create 0.91 to 1.3 peak construction jobs per MW and 0.05 to 0.09 O&M jobs per MW.

It is interesting to compare the results of the funded research studies with the developer predictions. Unfortunately, differences in units prevent a comparison of construction job creation. Considering O&M jobs, the four research studies reviewed for this analysis generally predict more job creation per MW of nameplate capacity than do the solar developers. Study estimates are in line with the actual number of

O&M jobs created by Nevada Solar One. Map 8.2 shows predicted job impacts for five proposed CSP facilities.

Table 8.4 Comparison of projected employment impacts for 14 proposed facilities.

Project Name	Technology	MW	Construction jobs (peak)	Construction jobs/MW	O&M jobs	O&M jobs/MW
Rice Solar Energy Project	CSP	150	438	2.92	47	0.31
Beacon Solar Energy Project	CSP	250	836	3.34	66	0.26
Abengoa Mojave Solar Project	CSP	250	1,162	4.65	68	0.27
Solar Millennium Ridgecrest	CSP	250	633	2.53	84	0.34
Genesis Solar	CSP	250	1,085	4.34	45	0.18
Agua Caliente (if built with CSP)	CSP	280	1,000	3.57	50	0.18
Solar Partners Ivanpah SEGS	CSP	400	637	1.59	90	0.23
Solar Millennium Palen	CSP	484	1,141	2.36	134	0.28
Imperial Valley Solar Project (Formerly SES Solar Two Project)	CSP	750	731	0.97	164	0.22
Calico Solar Project (Formerly SES Solar One Project)	CSP	850	703	0.83	180	0.21
Solar Millennium Blythe	CSP	1000	1,000	1.00	221	0.22
Agua Caliente (if built with PV)	PV	330	300-400	0.91-1.21	15-20	0.05-0.06
Lucerne Valley Solar Project	PV	45	45	1	3	0.07
Solar Ranch One	PV	230	300	1.3	20	0.09
Nevada Solar One	CSP	64	800-1,300	12.5-20.31	28-32	0.44-0.5



Map 8.2 Predicted Job Creation for Five Proposed CSP Facilities.

PREDICTING THE IMPACTS OF FUTURE SOLAR FACILITIES

Lessons learned from the Nevada Solar One case study and job creation estimates, coupled with demographic data, may be used to predict how proposed utility-scale solar development will impact nearby communities. The Nevada Solar One case study is helpful in understanding the role facility location plays in effects on community. Demographic data helps us to infer what costs and benefits the community's labor market and rental housing market will likely experience. This analysis also includes a review of why Nevada Solar One's greatest socioeconomic benefits, lease payments and property tax revenue, may not be factors for California desert communities.

This analysis uses two California desert communities, Lucerne Valley and El Centro, as examples for how to use demographic data to project socioeconomic impacts. As discussed below, we surveyed these same two communities, as well as an area known as Newberry Springs, in an effort to understand the local public opinion of utility-scale solar. The following socioeconomic analysis builds on the results of this survey. Due to a lack of available demographic data, Newberry Springs is excluded from this analysis.

Located in the Mojave Desert, Lucerne Valley is an unincorporated community in southwest San Bernardino County. El Centro is located in the southern part of Imperial County, near the border with Mexico. These residents were chosen for the survey because utility-scale solar facilities are proposed for public land nearby both communities. Chevron Energy Solutions has proposed a 45 MW PV power plant approximately eight miles from Lucerne Valley to be called "Lucerne Valley Solar Project."[520] Tessera proposed a 750 MW CSP facility "Imperial Valley Solar" about 14 miles west of El Centro.[521]

Using Demographic Data to Predict Socioeconomic Impacts

Using demographic and economic data, it is possible to hypothesize how future utility-scale solar facilities may affect Lucerne Valley and El Centro. For example, using information about population, median income, age, and education is useful for understanding how a community may benefit from construction jobs at a solar facility. Furthermore, statistics describing the area's housing market could indicate if a community is able to provide a suitable housing stock for the hundreds of workers needed to construct a utility-scale solar facility.

Much of the data used in this document, including all of the housing data, comes from the U.S. Census 2000, and hence is somewhat dated. Regardless of how these statistics have changed over the last decade, this information is still helpful in comparing localities to one another and for demonstrating how this data may be used to predict future impacts (Table 8.5).

Table 8.5 Comparison of Demographic Data for Boulder City, Lucerne Valley, and El Centro.

	Boulder City, NV (Clark County)	Lucerne Valley, CA (San Bernardino County)	El Centro, CA (Imperial County)
Population	16,000	7,500	44,000
Median Annual Household Income (1999)	$50,523	$24,969	$33,161
Percent of population 25 years or older with at least one year of college education	48	33	36
Percent of population 60 years of age or older	30	30	13
Percent of housing units renter occupied (vs. owner occupied)	24	34	52
Number of renter occupied housing units (1999)	1,522	456	6,986
Median rent asked (1999)	$605	$377	$450
Cities/towns greater than 10,000 residents, in a ~25-mile radius	Henderson City (243,000) Las Vegas (560,000)	Victorville (109,000) Apple Valley (69,000) Hesperia (88,000)	Imperial (13,000) Calexico (39,000) Brawley (27,000)

This table uses a variety of data sources: the U.S. Census 2000, the 2006-2008 American Community Survey, the "Draft Environmental Impact Statement and California Desert Conservation Area Plan Amendment for the Proposed Chevron Energy Solutions Lucerne Valley Solar Project: Volume 1"[522], and the "E-4 Population Estimates for Cities, Counties and the State, 2001-2009, with 2000 Benchmark."[523]

Effects on the Local Labor Pool and Rental Housing Market

By comparing population, income, education, and age demographics among Boulder City, Lucerne Valley, and El Centro, we can gauge what costs and benefits the latter two communities may experience with regards to the local labor pool and rental housing market if a utility-scale solar facility was built nearby. A community will obviously benefit if its workers are hired at the facility. However, the area may incur costs if the labor pool cannot satisfy the workforce demand and the area's rental housing market cannot accommodate workers who move to the area.

Generally, Boulder City's workers did not benefit from Nevada Solar One, the primary reason being that Boulder City residents must compete for jobs with metro Las Vegas' extensive workforce. It is also possible to infer why by interpreting the city's demographic data. Boulder City's high median annual income and high percentage of educated individuals may reflect a population uninterested in construction work and/or lacking the skills needed to fill such positions.

An interpretation of demographic data may also explain why Boulder City's rental housing market was largely unaffected by Nevada Solar One's construction. For instance, Boulder City has a small percentage of rental housing stock. A conversation with a Boulder City community development planner suggests the city's rental market is tight and expensive in comparison to rental housing stock in the nearby Las Vegas metropolitan region. Individuals who moved to the area to build Nevada Solar One found a greater variety of housing with cheaper rent outside Boulder City.

Lucerne Valley

Demographic information from Lucerne Valley sheds light on what costs and benefits the area might experience if a solar facility is constructed nearby. Lucerne Valley's workforce may benefit from unskilled labor jobs created during facility construction. This hypothesis is based on the community's low levels of education; Lucerne Valley's percentage of adults 25 years of age or older with at least one year of college (33 percent) lags behind both the state (50 percent) and national (45 percent) averages, which suggests the community workforce may be interested in unskilled work.[524]

However, the possibility that Lucerne Valley residents would benefit from solar facility jobs diminishes when considering the competing labor pools in the area and the number of jobs the facility is predicted to create. Lucerne Valley residents will have to compete with workers in three nearby population centers: Victorville, Apple Valley, and Hesperia. Furthermore, Chevron's facility is expected to create 45 construction jobs and up to three O&M jobs, hardly a job creation boon for the area.[525] Though Lucerne Valley's workforce will not greatly benefit from the small number of jobs, this minimal job creation also means that the community's rental housing market will not be unduly stressed. Even if all 45 of Chevron's construction workers were to move to Lucerne Valley, there would not be a significant impact on short-term housing in the community.

Despite this, it is helpful to use Lucerne Valley's housing data to predict how similar communities may be affected by a large influx of temporary workers. If hundreds of workers were to move to a community like Lucerne Valley, the demand for rental housing would quickly and vastly exceed the available supply. Victorville, Apple Valley, and Hesperia, which together have thousands of rental units, would likely accommodate the excess demand. With median rent asked around $450 to $500 in the three neighboring communities, Lucerne Valley's rental stock (median rent asked $377) would remain economically competitive. This situation sharply contrasts with the situation in Boulder City, where comparatively high rents helped to push rental-housing demand into the surrounding metro Las Vegas area.

El Centro

Based on the city's large population and relatively small percentage of retirees, El Centro has a sizable workforce. El Centro's education data also suggests that residents might benefit from the creation of unskilled labor positions. However, it is unlikely the city's workforce will benefit from Imperial Valley Solar since the city's labor pool must compete with workers in nearby Imperial, Calexico, and Brawley. Considering that Imperial Valley Solar is projected to create 731 jobs during peak construction and 164 operation positions, and that the populations of the four urban centers sum to over 120,000 people, the number of new jobs is largely insignificant.[526]

Similar to Lucerne Valley, El Centro's rental housing market will be largely unaffected by the new solar facility. The number of construction workers needed for Imperial Valley Solar is largely insignificant in comparison to the considerable population of the area. However, if all 731 workers added to the demand for temporary housing, El Centro's nearly 7,000 rental units may not be enough to accommodate the increase. In that situation, temporary workers may also choose to rent less expensive units in one of the three nearby cities, where median rent asked ranges from $186 to $406 per month.

Using a Facility's Location to Mitigate Socioeconomic Impacts

Depending on where a utility-scale solar facility is sited, the project will have different socioeconomic impacts on nearby urban areas. Several aspects of Nevada Solar One's siting, such as distance to downtown and how the community utilized the site prior to facility construction, influenced how the project affected Boulder City. Drawing on these observations, one can infer how a proposed utility-scale solar facility would affect neighboring communities. These inferences suggest changes be made to the siting process so that facility impacts are mitigated.

Increase Community Distance from Facility

Several individuals interviewed for the Nevada Solar One Case Study noted that the solar facility's construction likely had so few impacts on Boulder City because it was sited over 15 miles from the downtown area. As one community planner put it, the facility "is out in the middle of nowhere." An employee of the utility purchasing Nevada Solar One's power said, "If the project were closer it would have definitely had a greater impact on the town."

Had the facility been closer, the socioeconomic impacts to Boulder City could have been very different. The hundreds of construction workers on site every day would have been able to go downtown for lunch, thereby stimulating demand at the local restaurants and stores. Public infrastructure could have been damaged, particularly if heavy construction vehicles had to drive local public roads to get to the facility. If the facility had been built closer to residents, there may have been negative impacts to the view. Workers driving to and from the facility might have caused traffic problems at certain times of the day.

Increasing the distance between the community and the facility may be a way to mitigate some of a facility's negative impacts. However, as was the case for Boulder City, siting a facility farther from downtown may also decrease some of the facility's positive effects. Ultimately, communities may find that avoiding negative effects outweighs the forgone benefits.

Consider Previous Land Use

Solar facilities may be sited to avoid affecting areas that are popular for recreation. According to a local planner, Nevada Solar One was built on land unpopular for outdoor activities, such as driving off-highway vehicles (OHV's) and hiking. In contrast, a facility sited in an area popular with outdoor enthusiasts could draw backlash and be detrimental to the community's quality of life.

For example, the facility near Lucerne Valley is proposed on land that BLM has not designated for recreation, though areas in the vicinity are used for hiking and off-highway vehicle use.[527] If these recreational areas are in the facility's viewshed, they could be negatively affected. Imperial Solar Valley could also negatively affect recreation, as off-highway vehicle use is popular on the project site.[528]

Consider Implications of Landownership

In broad terms, Nevada Solar One's lease payments, which add $700,000 each year to the city's General Fund, have had a very positive fiscal impact on Boulder City. Specifically, the extra revenue has allowed the city to maintain a high level of services while keeping the tax burden low. Boulder City also benefits in small part from the property taxes Nevada Solar One pays to Clark County, a portion of which goes to Boulder City.

Generally, a solar facility sited on both public and private land will have greater direct fiscal benefits to the community than will a facility sited solely on federal public lands. It is unlikely that many municipalities and private landowners will benefit from lease payments or property taxes paid by new solar facilities sited solely on public lands. Although developers who build utility-scale solar facilities on BLM land will owe lease payments, this money will go into the general US treasury, as opposed to directly benefitting the local community. However, a developer whose site covers both public and private land will owe lease payments to the private landowner(s) as well. For example, the Imperial Solar Valley project site covers approximately 360 acres of private land.[529]

California and Nevada also have different laws for assessing solar infrastructure for property taxes, which has repercussions for how California municipalities may benefit economically from future solar facilities. Under Section 73 of the California Revenue and Taxation Code, developers who build utility-scale solar facilities in California are not assessed property taxes on their solar infrastructure.[530] Since federal land is exempt from local property tax assessment, the code does not affect facilities sited solely on public lands. However, this law has implications for projects that span both public and private land. Solar developers with projects on private land will owe property taxes on buildings and other infrastructure not directly related to energy production, although the project's assessed value drops dramatically when the solar infrastructure is excluded. This property tax exclusion does not carry over if a facility is sold; if the original project developer sells the facility to another entity, the facility's solar infrastructure will no longer be protected from property tax assessment. In this case, the new entity will be assessed property taxes on the entire facility, which could translate into a significant amount of revenue for the county. Solar infrastructure could also become assessable if the tax exemption, which is set to sunset January 1, 2017, is not renewed.

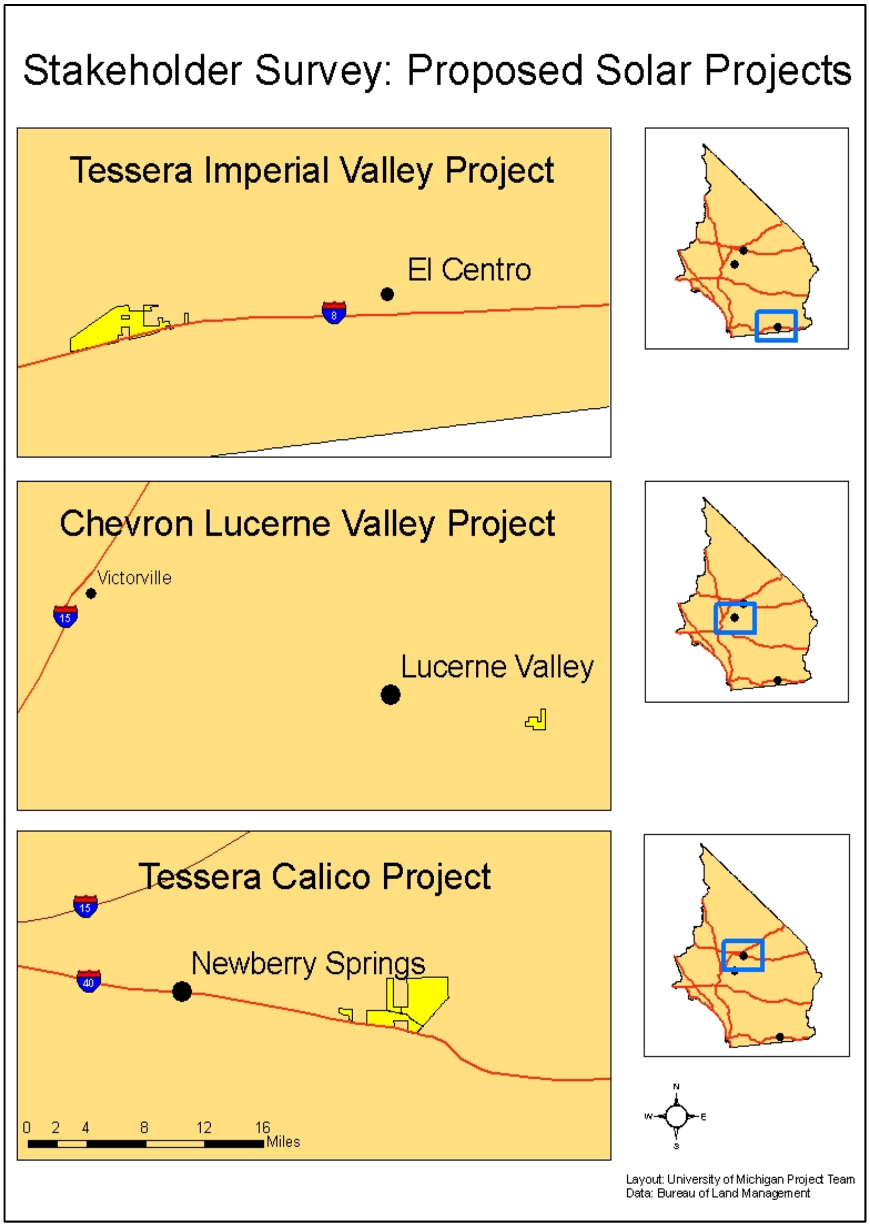
CONCLUSION

Although there is a lack of academic research on the socioeconomic impacts of utility-scale solar development, there are many other sources of data with which to infer the impacts facilities will have in the California desert. A review of wind energy development suggests that solar development may have comparable socioeconomic effects. For example, like wind energy development, solar development will have minimal impact on job creation and population growth. An in-depth look at Nevada Solar One revealed that the facility had few long-term socioeconomic impacts, with the exception of annual lease payments. However, communities in the California desert will not benefit directly from lease payments paid by facilities sited on public lands. Housing and demographic data can help predict the effects of temporary construction jobs. Lastly, facilities should be sited in recognition of the role that location plays in mitigating facility impacts.

Given the range of potential impacts, the BLM does a good job taking into account the socioeconomic impacts utility-scale solar facilities may have. Among the developer AFCs and EISs reviewed for this study, socioeconomic impacts were thoroughly addressed. The BLM should continue to support a NEPA process in which such impacts are adequately addressed.

CHAPTER 9 | COMMUNITY ATTITUDES

Prior to this study, little research had been done to assess local communities' attitudes regarding utility-scale solar energy development. Yet, the interests, opinions, and concerns of desert residents are both important and highly relevant because these individuals and communities will be directly affected by the development of multiple, utility-scale solar facilities in the California desert. They will experience many of the positive and negative impacts of development, and their support or opposition could influence the approval or denial of these projects.[531] Because these communities have the potential to exert exceptional influence, it is important to consider the degree to which communities support or oppose solar development, reasons behind those opinions, the level of understanding of the technology and its impact, and the level of participation in the decision-making process. Answering these questions allows decision makers to both consider barriers and drivers to achieving objectives and to plan around them.



Map 9.1 Location of Proposed Solar Facilities and the Surveyed Communities.

The importance of public opinion and public involvement in natural resource management is well recognized. A reflection of the need to involve "stakeholders" in land management decisions can be seen in NEPA, which requires that federal agencies hold public scoping meetings and public comment periods for major federal actions. Decisions made without adequate participation of affected groups often results in disputes, stymied decision-making, and costly administrative and judicial reviews.[532]

Using a case study like Nevada Solar One to analyze past impacts in tandem with additional research to predict future impacts offers valuable insight into how utility-scale solar development might, from a socioeconomic perspective, positively or negatively affect nearby communities. These methods, however, do not take into account the thoughts and concerns of residents of communities prior to construction. Moreover, our research extends beyond socioeconomic impacts, and we believe that public opinion of such developments is based on much more than jobs and housing. As described in our methods section, we therefore set out to complement our socioeconomic research with a stakeholder survey of those communities modeled, Lucerne Valley and El Centro, as well as Newberry Springs (Map 9.1). Our survey was intended to provide insight into stakeholder opinions and actions, information that might be used by both government agencies and private developers to consider how to best engage, inform and potentially influence stakeholders.

STAKEHOLDER SURVEY

Altogether, 5,079 surveys were mailed to the three communities described in our methods section: 2,000 were sent to El Centro, 1,910 were sent to Lucerne Valley, and 1,169 were sent to Newberry Springs (of which 559 were identified as absentee owners). Of the 5,079 surveys sent, 577 hard copies and 47 online versions of the survey were returned, representing a 12.3 percent overall response rate. With an aggregate sample size of 624 respondents out of a total population of 43,600, our study has a confidence level of 95 percent and a margin of error of roughly 4 percent (Table 9.1).

Table 9.1 Stakeholder Survey Response Rate by Community. Newberry Springs includes residents & absentee respondents.

Community	Population	Surveys Sent	Returned	Response Rate	Percent Total
El Centro	44,259	2,000	150	7.5 percent	24.0 percent
Lucerne Valley	7,500	1,919	180	9.4 percent	28.8 percent
Newberry Springs	2,895	1,169	294	25.1 percent	47.1 percent
Totals	43,600	5,079	624	12.3 percent	100.0 percent

In terms of age, the majority of respondents were older than 40, with 44 percent reporting to be between the ages of 40 and 60 and 46 percent reporting to be older than 60 (Figure 9.1). These results are surprising, since the median age in El Centro is 30 and the median in Lucerne Valley and Newberry Springs is 40.[533] This might indicate that older residents pay more attention to the issue, though it might also suggest that they are more likely to respond to surveys in general.

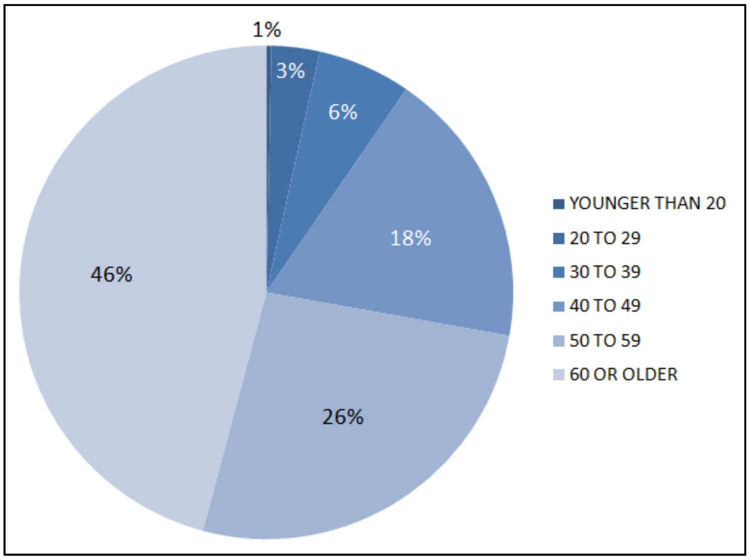


Figure 9.1: Survey Respondents by Age Group.

ATTITUDES TOWARD UTILITY-SCALE SOLAR DEVELOPMENT

In aggregate, respondents generally favored utility-scale solar development, with a mean rank of 5.4 on a scale of 7, with nearly half of all respondents across the three communities marking 7 or "very supportive" of solar development (Figure 9.2). The distribution was clearly skewed toward extreme support, bottoming out at mild opposition, and trending back upward toward extreme opposition.

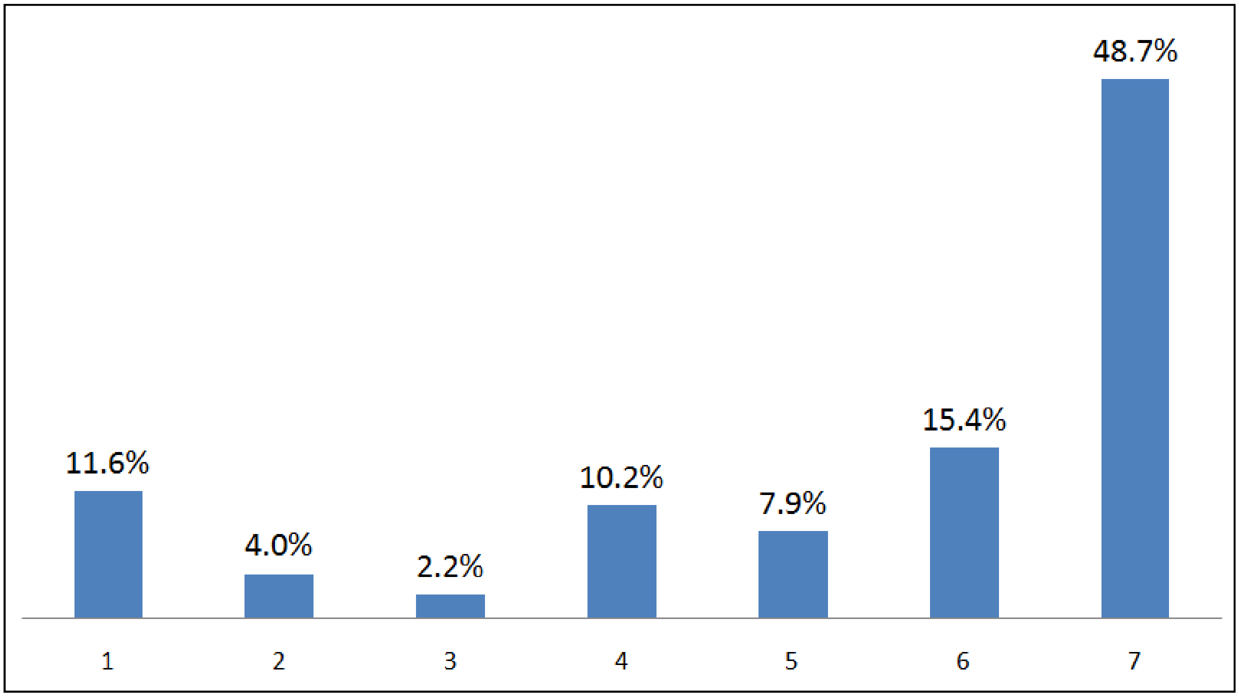


Figure 9.2 Aggregate Distribution of Attitudes Toward Solar, with 7 being favorable. Percentages are percent of total respondents who circled that score. The number of respondents totaled 624.

Geographically, the three communities showed similar results, although Lucerne Valley residents reported slightly more opposition to and less support for solar, roughly 3.5 percentage points greater than the overall mean and nine percentage points less than the overall mean, respectively (Figure 9.3). Reasons for this do not appear to be related to differences in age, residence time, or education levels across the respondents. In fact, distribution in age, residence time, and education level was generally flatter for Lucerne Valley than for the other two communities, where age and residence time trended in different directions. Lucerne Valley was in the middle. Likewise, community economic indicators did not distinguish Lucerne Valley from the other two communities. For example, at 27 percent, El Centro has a much higher rate of unemployment than do the other two communities, at five percent, respectively.[534] Participation in the process, however, did vary slightly: 19.4 percent of respondents from Lucerne Valley claim to have participated in BLM public comment opportunities, compared to 12.7 percent for El Centro and 17.8 percent for Newberry Springs. Absentee ownership appeared to play no role. As such, residents of Newberry Springs and El Centro appear to be more aligned in public opinion than residents of Lucerne Valley. A deeper dive into why Lucerne Valley appears to exhibit slightly less support for utility-scale solar, such as handling of the process, could be a useful follow up to our survey.

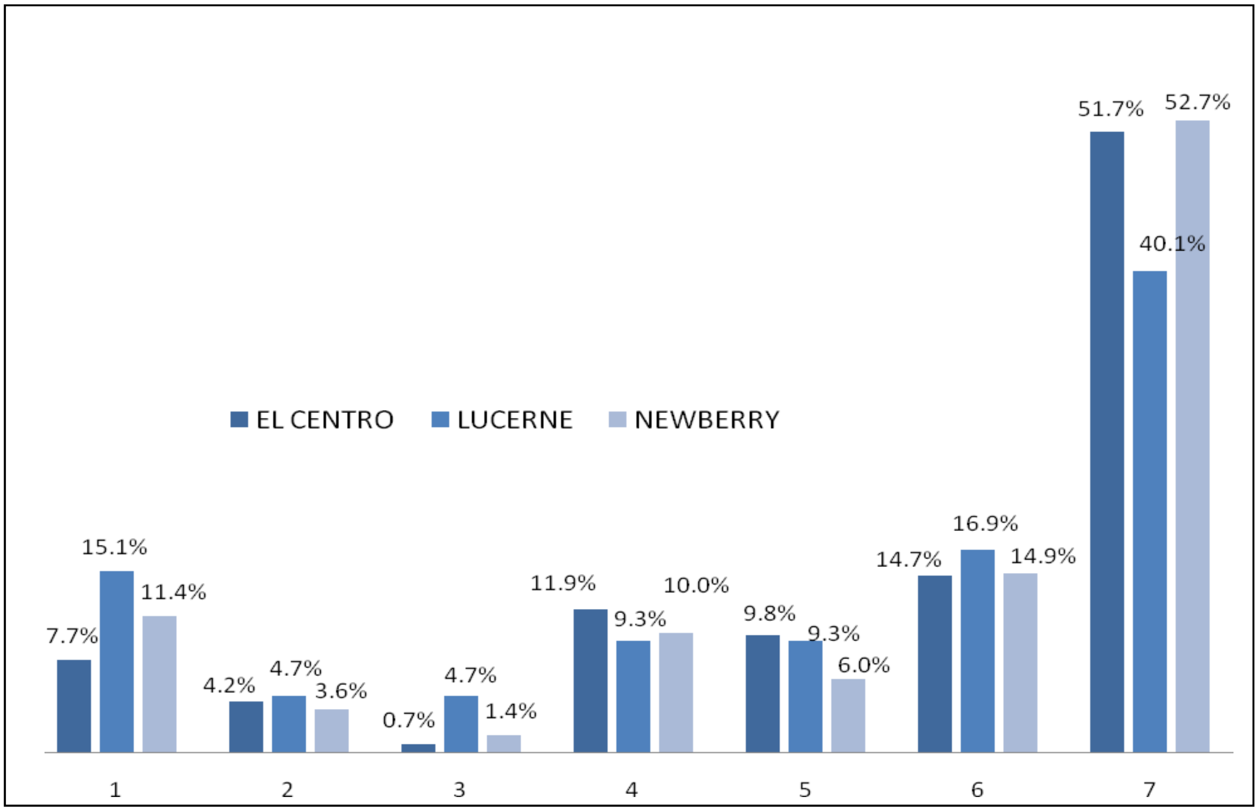


Figure 9.3 Distribution of Attitudes toward Solar by Community, with 7 being favorable. Percentages are in terms of share from each community.

It is not clear whether age is a significant differentiator in terms of overall opinion. Respondents less than 40 years old exhibited slightly less extreme opposition to solar, at 5.4 percent ranking support at one versus 12.3 percent for the other two age groups. That said, only 9.6 percent of respondents reported to be less than 40 years old — 58 in total — and may not accurately represent that demographic. Additionally, those who had lived in their respective community for a shorter period of time tended to

report slightly more support for solar than those who had lived in the region for more than 10 or 20 years, 48 percent and 41 percent, respectively. However, the distribution is generally the same.

The one demographic category in which support appeared to be more divergent from group to group was education level. Interestingly, the more educated people were, the less they tended to support solar and the more they tended to oppose it, as measured by mean response. In addition, those with higher education claimed to be more familiar with various solar technologies than those with less education (Figure 9.4). This trend had a significance level of 0.05 and a p value of 0.048, as calculated using a chi square test in Table 9.2.

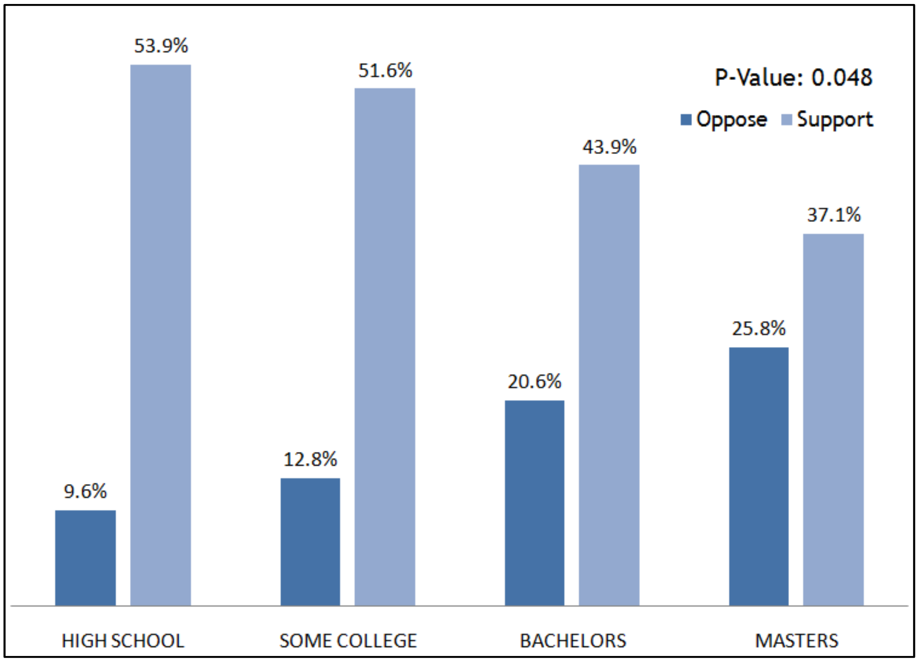


Figure 9.4 Percent of Education Group that Opposes and Supports Solar.

There might be several reasons for this trend. For instance, those who have higher levels of education might know more about the negative impact solar could have on plant and animal habitats than those who do not, and might therefore be more apt to oppose development. In fact, those with more higher education did, on average, have a greater concern for loss of habitat, and a qualitative analysis of open-ended questions suggest that those with more higher education are concerned about local plant and animal habitats, as well as viewsheds. But a pattern of greater or less concern from one education category to another was not discernable in the mean response, and tests did not return statistically significant results. Reasons behind this trend are therefore speculative.

Table 9.2 Chi Squared Test to Determine Statistical Significance Between Education and Opinion of Solar.

Chi Squared Test for Independence | Education Level and Attitude toward Solar					
Observed					
	High School	Some College	Bachelors	Masters	Total
Oppose Solar	10	27	16	16	69
Support Solar	64	133	47	36	280
Total	74	160	63	52	349
Expected					
Oppose Solar	14.63037249	31.63323782	12.45558739	10.28080229	69
Support Solar	59.36962751	128.3667622	50.54441261	41.71919771	280
Total	74	160	63	52	349
Chi Squared					
Oppose Solar	1.465468458	0.678618257	1.008612467	3.181582671	6.334281854
Support Solar	0.361133299	0.167230928	0.248550929	0.784032873	1.560948028
Total	1.826601757	0.845849185	1.257163397	3.965615544	7.895229882
p-value					0.04823

Negative and Positive Impacts

We asked respondents to rank, on a 5-point scale, the likelihood of various potential impacts of utility-scale solar development (Figure 9.5, Table 9.3). The outcomes that respondents thought were most likely to occur were positive in nature and consistent with their overall support for solar: more construction jobs (4.16 out of 5), more energy available to them (4.10 out of 5), and more post-construction jobs (4.04 out of 5). Respondents also placed the most value on these outcomes, rather than on other potential outcomes. Respondents in Lucerne Valley, where residents appear to be generally less supportive of solar development, tended to fall slightly below the mean on these three categories. In other words, they reported to be less convinced that these outcomes will happen. On the other hand, residents of Lucerne Valley also did not report to believe that negative impacts are more likely to happen than did residents in Newberry Springs or El Centro.

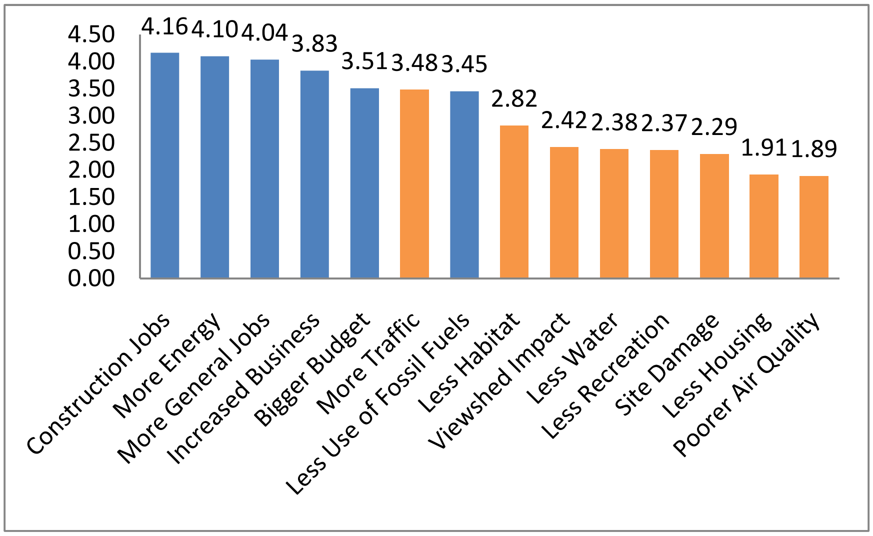


Figure 9.5 Issues most and least likely, were of greatest and least concern, and were of most and least value. Negative outcomes are colored in orange.

Table 9.3 Distribution of Overall Mean Response on a 5-ponit Scale of Likelihood of Outcomes of Solar Development.

What Issues Rise to the Top?		
Question Type	Highest Ranked	Second Highest Ranked
Most Likely to Occur	More Construction Jobs	More Energy for Community
Least Likely to Occur	Poorer Air Quality	Decrease In Housing
Least Certainty About	Negative Impact On Water	Increased Town Budget
Greatest Cause of Concern	Negative Impact On Water	Decreased Natural Habitat
Greatest Potential Value	More Energy For Towns	More Post-Construction Jobs
Most Valuable Additional Info	Water Use Estimates	Job Creation Estimates

Aggregated across all three communities, respondents tended to report that less housing (1.91) and poorer air quality (1.89) were least likely to happen. On the other hand, water rose to the top of concerns across all three communities, registering an average of 3.2 on a 5 scale. Interestingly, more than 14 percent of respondents reported to not know if water would be affected, the potential outcome with the greatest share of respondents who could not commit to an opinion about its likelihood of occurring. Therefore, while many are unsure about the impact of solar on water resources, they appear to be somewhat concerned about it. Concern over water, as well as a desire for jobs, fit the socioeconomic and geographic realities of these desert communities, where water is scarce and the unemployment is high — more than 27 percent in El Centro.[535]

GROUPED SAMPLE RESULTS

A series of two-sample t-tests allowed us to determine the issues for which the two groups' opinions were statistically different, the degree of those differences, and the directional orientation of each group with respect to the median (Table 9.4). In our analysis, statistical significance was determined by the two-tailed p-value. Degree of difference was measured by difference between the two mean values. Orientation was measured by where the mean response fell with respect to the median option, in other words, greater than or less than three on our 5-point scale. For instance, mean responses below three for the third question — "How likely do you think the following outcomes will be if a utility-scale solar facility is constructed near your town?" — denotes "not likely to happen." In this example, a zero would indicate "will not happen" and a three would indicate "equally to happen as not to happen."

Across every category, those who were classified as supporters of solar believe that the positive outcomes are more likely to happen than do those who oppose solar, and vice versa. The most divisive issue was water, where opponents believe utility-scale solar might lead to less water (3.15) and supporters believe it is far less likely (2.01). Water was followed by viewshed impact, where opponents believe that the scenery might be impacted (3.15) and supporters believe it is far less likely (2.04). Less housing was the only outcome option that did not show statistical significance in opinion between

Table 9.4 Two-Sample t-Tests Between Respondents Who Favor and Respondents Who Oppose Solar.

Two Sample t-Test Results						
	Supporters		Opponents			
	Likelihood	Value	Likelihood	Value	Differential*	P-Value*
Construction Jobs	4.45	4.41	3.51	3.54	-0.87	2.42×10^{8}
General Jobs	4.33	4.41	3.30	3.61	-0.80	3.29×10^{7}
Less Fossil Fuel Use	3.59	3.89	2.87	3.32	-0.57	5.74×10^{4}
Bigger Budget	3.61	3.95	3.14	3.29	-0.65	3.06×10^{5}
Increased Business	4.07	4.34	3.31	3.47	-0.86	1.39×10^{8}
More Energy	4.34	4.59	3.44	3.67	-0.93	1.07×10^{9}
	Supporters		Opponents			
	Likelihood	Concern	Likelihood	Concern	Differential	P-Value
Less Housing	1.81	1.63	1.97	1.85	0.22	0.0956
Less Habitat	2.42	2.68	3.35	3.64	0.96	1.45×10^{8}
Poorer Air Quality	1.56	2.53	2.45	3.38	0.85	2.18×10^{6}
Less Recreation	1.95	2.16	3.05	3.25	1.09	1.08×10^{9}
Less Water	2.01	2.89	3.15	3.79	0.89	2.75×10^{7}
More Traffic	3.31	2.25	3.75	3.15	0.90	6.56×10^{8}
Site Damage	1.92	2.37	2.82	3.46	1.09	9.3×10^{10}
Viewshed Impact	2.05	2.12	3.14	3.31	1.18	1.1×10^{10}

Reported p-values and differentials in this table are a function of the value and concern columns. Differential is value or concern mean response from supporters support minus those of opponents.

the two groups. The questions that followed asked respondents to rate their degree of concern for and degree of value placed on potential outcomes: supporters were far less concerned about the potential negative outcomes and place more value on the potential positive impacts. In terms of greatest concern, the biggest differential was viewshed impact, where opponents consider it somewhat concerning (3.30) and supporters of solar were less concerned (2.12). However, the issue of greatest concern to opponents remained water (3.78). In terms of value, supporters and opponents disagreed most on the value of more energy to their communities. Neither group, however, reported to find little value in any of the potentially positive impacts — all mean responses were greater than three.

Given these results, it seems as if opponents of solar differ the most from supporters in their concern over water resources. Habitat and viewshed appear to be close behind. For their part, supporters seem to value the potential increase in the availability of energy, more jobs, and greater commercial activity. Given that all mean responses to issues of concern fall below 3, supporters appear to be generally optimistic whereas opponents tend to be more cynical of the positive outcomes.

ANALYSIS OF OPEN-ENDED QUESTIONS

We asked two open-ended questions: “What do you think are the positive impacts of these facilities?” and “What do you think are the negative impacts of these facilities?” Out of 624 responses, 27 left these questions blank. The remaining respondents offered views ranging from a few words to entire paragraphs. To make use of this data, we went through these responses and gave each unique word or phrase a code, and then counted the frequency of the appearance of the word or phrase as a way to validate close-ended responses and to capture sentiment missing in our questions (Table 9.5).

Table 9.5 Top 20 Words and Phrases Identified in Stakeholder Survey. Shaded words are negative in nature.

Word or Phrase	Count
Renewable or clean energy	286
More jobs	236
Reduced or no pollution	125
Cheaper electricity	122
Viewshed impact or loss of scenery	86
Supports solar tech development	74
Better land use	73
Reduced conventional fuel use	65
Damage to habitat or desert	64
More electricity	53
Increase property values	48
Harm to animals and plants	44
Income for community or business	43
Taxpayer burden or higher costs	42
Need more information	41
Low environmental impact	40
None or do not believe in any	39
Water shortage or threat to water	39
Energy independence	34
Paves way for other technologies	34

Consistent with respondents' overall positive outlook on utility-scale solar in their communities, the words that appeared most were "clean energy" (286), "jobs" (236), "reduced pollution" (125), and "cheaper electricity" (122). Yet, "viewshed impact" and "unsightly" ranked fifth (84), and "destruction of desert" and "damage to desert" ranked eighth (66). We also found that most of these phrases and words were also met with a contrarian viewpoint: some people said that these facilities would not produce much energy, unemployment might go up, or utility bills might increase. In addition, these views were often qualified. For example, several people wrote that these facilities would provide jobs, but that these jobs would not be given to locals. (A few expressed anger over immigration.) Another group believed that electricity would be cheaper, but not for their local community, and that the utilities would benefit.

Mistrust

These less positive views were part of a larger theme of mistrust, described in the following section. Mistrust was one of several themes that arose out of both the keyword count and the open-ended observations, but was not specifically tested for in our close-ended questions. Interestingly, these negative views did not necessarily mean the respondent was against solar, as ranked support associated with these comments ranged from one to seven. One respondent from Lucerne Valley, who indicated a 1 in opposition to solar, wrote, "[I do] not see any [benefits to solar development], I see only a corporate scam." A respondent from Newberry Springs, who indicated mild opposition of 3, wrote, "Sounds like another corporate rip-off of public land. We have a solar plant just west of our town, in the town of Yermo. Take a look at that town and tell me if there has been any economic improvements." On the other hand, an extreme supporter from Newberry Springs wrote, "I have very low regard for the BLM and their handling of our desert and find anything they have to say a waste of time." Another extreme supporter expressed similar sentiment: "BLM has effectively stopped progress on the Newberry facility with its unrealistic regulations, such as not allowing water to be applied on the soil in order to move drilling and construction equipment on to the site."

The general sentiment of these respondents appeared to be that of either not trusting the process in general or believing their land was being used without their regard. A Lucerne Valley supporter wrote that the "BLM has kept this under the table." Another supporter wrote "[I] have not received any info as to the degree of benefits by allowing this solar plant to go forward, or even its exact proposed location." These comments shed light on the high rate of respondents who said they have not participated because they were unaware of opportunities to participate. The belief may be that the information about participation opportunities is intentionally hidden rather than just poorly communicated.

Environmentalists were also a target of mistrust. One supporter from Lucerne Valley wrote, "Environmentalists are insensitive to the needs of the people who live here, and private companies [are running] a financial scam to benefit only a few manipulators of the system." Another supporter from Newberry Springs wrote, "Environmentalists are mean spirited and think their good intentions make everything okay, [but] the locals are the ones who actually know the land and what will work or not." A resident of El Centro referenced global warming as "a big lie."

Taxpayer Burden

Another theme that emerged was taxpayer burden or overall cost to the community. In 42 surveys, "higher taxes" was observed. While this represents only 6.7 percent of our sample, the idea that individuals and households would carry a higher tax burden was not expected. We did test for increased community budgets through taxes paid by private companies, but not for citizens. An opponent of solar from Lucerne Valley contends that "solar energy plants quadruple energy costs when compared to coal fired or nuclear power generation." A respondent from El Centro agrees that jobs will be created, "but most hiring is done out of area." Inconsistency was found in other issues: energy bills will either go down or up, unemployment will either decrease or increase, and property values will either rise or fall, depending on the individual and his or her view.

In contrast, some believed they could benefit from solar development. One supporter from Newberry Springs wrote, “I have started classes at Barstow College to hopefully get a job at the plant or to help put the plant in operation.” Another supporter from El Centro wrote, “Maybe my five acres would be of use, I’m unemployed right now.” One respondent from Newberry Springs wanted to profit: “Open the grid, make it public, let me plug in and profit.”

Rift over Land Use

The most disagreement appeared to be with regard to land use. Quite a few respondents said that the land is unproductive, and that solar energy development would be one way to extract value. “There is an over-supply of empty land in Lucerne Valley,” wrote one supporter. “Any development in this area would be a positive improvement.” Another supporter from Newberry Springs wrote, “It is a perfect use for land that, except for the sunshine, has very little else going for it.” Similar sentiment was expressed by a supporter from Newberry Springs, writing that “[this would be a good] use of land in areas [that are] otherwise not useful.”

In contrast, a number of other respondents expressed great concern over the potential negative outcomes. “The desert is very fragile: once [the] surface is disturbed, it takes many years to recover, if at all,” wrote one moderate supporter from Newberry Springs. “Any development must be sensitive to the desert habitat, particularly the desert tortoise.” A supporter from Newberry Springs cited air quality, expressing concerns over the “possible dust bowl effect caused by removing plants and top soil.” A Newberry Springs supporter wrote: “Using BLM lands for solar projects destroys the natural environment for endangered species in the high desert areas.” In fact, that is related to another theme that emerged: outside parties taking and using land that belongs to the local communities.

These views on land use represented a small sampling of the conflicting comments on land use. In addition, some supported distributed generation, while others pitched their views on nuclear development in the region. From the standpoint of qualitative observation, land use was the issue which residents seemed to disagree over most.

STAKEHOLDER PERCEPTIONS AND STUDY FINDINGS

We then explored how community attitudes relate to the ecological and socioeconomic impacts predicted in other segments of our study. We found that, in some cases, public perception was aligned with what we determined to be a likely outcome, and in others, public perception was misguided and should be addressed through modified messaging and message distribution, as well as additional community outreach tactics through those channels preferred by community stakeholders, as discussed later in this chapter. Table 9.6 summarizes these relationships.

Table 9.6. Public Perception of Potential Impacts from Solar Facilities and Their Likelihood of Happening.

Impact Category	Public Perception	Study Findings
Technological		
Energy Availability	Likely and Valuable	Likely but Value Uncertain
Water Quantity	Most Concerned	Cause for Concern
Ecological		
Water Quality	Most Concerned	Cause for Concern
Habitat Damage	Somewhat Likely	Probable
Air Quality	Not Likely	Possible
Spatial		
Viewshed	Less Concerned	Probable
Socioeconomic		
Construction Jobs	Likely and Valuable	Not Likely
Operation Jobs	Likely and Valuable	Not Likely
Town Budget	Likely and Valuable	Not Likely

Technological

We asked respondents how likely they thought "increased energy availability/reliability for California residents" would be if a utility-scale solar facility were constructed near their town. Based on the survey responses received, greater availability of energy was seen as both highly likely (4.10 on a 5-point scale) and valuable (4.31 on a 5-point scale). In fact, energy was seen as the most valuable of all the potential positive outcomes listed in the survey. This stakeholder perception is aligned with probable outcomes, since the development of these facilities will have some impact on the availability of energy in California. Even if only 13 out of the 54 projects currently being reviewed by the CEC and BLM were developed, they would provide an additional 13 million MWh of electricity annually, enough to power more than 1.1 million U.S. homes, given that the average U.S. home uses 11,040 kWh per year.[536] Electricity from solar facilities will then be fed into the grid and sent wherever there is demand.

However, respondents interpreted the question as an increase in availability of electricity to their community, or a lower cost of electricity, which is unlikely. This potential misconception demonstrates the need for additional education at the public meetings regarding how and where the new electricity will be utilized.

Ecological

We also gauged the degree of concern over "decreased quantity or quality of water in streams, springs, and wells," an issue which respondents cited as their greatest concern (3.20 on a 5-point scale). It was also the issue that the most respondents — 14 percent — expressed uncertainty about the likelihood of happening. Given the importance of water in this region as well as respondents' uncertainty about the impacts of these facilities, it is not surprising that respondents also indicated that they would find more information about water usage of these facilities useful (4.36).

Our analysis has indicated that the communities' concerns as well as their uncertainty about water are reasonable. Utility-scale solar energy facilities, similar to other industrial operations, have substantial water needs. In an effort to combat the potentially irreversible draw down of desert aquifers, the CEC has issued guidance to developers that dry cooled systems should be utilized and that wet cooled systems are extremely unlikely to be allowed by the agency. It would be useful to communicate this measure to desert residents. However, all technology types will require some water for panel or mirror washing, though water sources vary on a project-by-project basis. A compounding factor to this issue is the complexity of aquifers and hydrologic systems in our study area, making predictions about the impacts to regional water levels difficult. Additionally, site engineering and surface water diversions could alter water infiltration and flow to natural streams and springs, while water quality could be compromised if chemicals used for vegetation control end up as runoff into the surrounding ecosystem. Again, given the results of our survey, we believe it would be in the BLM's best interest to develop information campaigns around water use estimates and conservation measures.

At 3.04 out of 5, "Decreased Wildlife and Plant Habitat" was ranked second on the list of concerns for our respondents. However, they scored the likelihood of this happening lower, at 2.82. With a variance of 2.21, it was also an issue that residents disagreed about, more so relative to other issues. These scores suggest that, while desert residents are unsure about whether habitat loss or disturbance will occur as a result of solar development, local communities should examine these potential consequences in more detail. As our ecological impact analyses suggest, the public may currently be underestimating the potential for habitat loss following facility construction. Perimeter fencing will effectively eliminate habitat for species unable to penetrate the barrier, while grading and vegetation removal may destroy habitat within the site for birds or smaller species that still may be able to access the area despite fencing. Given the level of concern regarding these impacts, our survey analysis suggests education about the likelihood of potential impacts to wildlife and plant habitat may be of value to local residents.

The survey results also indicate that respondents believe decreased air quality is a relatively unlikely impact of solar development (1.89 on a 5-point scale). This public perception, however, may represent an underestimation of this potential, or a lack of understanding about how air quality may be affected by facility construction in our study area. The site engineering associated with development, especially grading and vegetation removal, has a high potential for dust emission. These processes will disturb soil structure and stability, releasing dust into the atmosphere. Large dust emissions could also occur if dust-sequestering biological soil crusts are on the facility site and are crushed during construction. Additionally, activities that result in drier soil surfaces may lead to increased dust; this may include vegetation removal, soil compaction that reduces water infiltration, and groundwater pumping that diminishes streams, springs and seeps. Given the high potential for dust emission as a result of solar development, air quality may be reduced for residents living in close proximity to, or downwind of a facility — especially during the construction phase. As discussed earlier, dust can travel great distances, so impacts to air quality should be considered for residents in a broad geographic area.

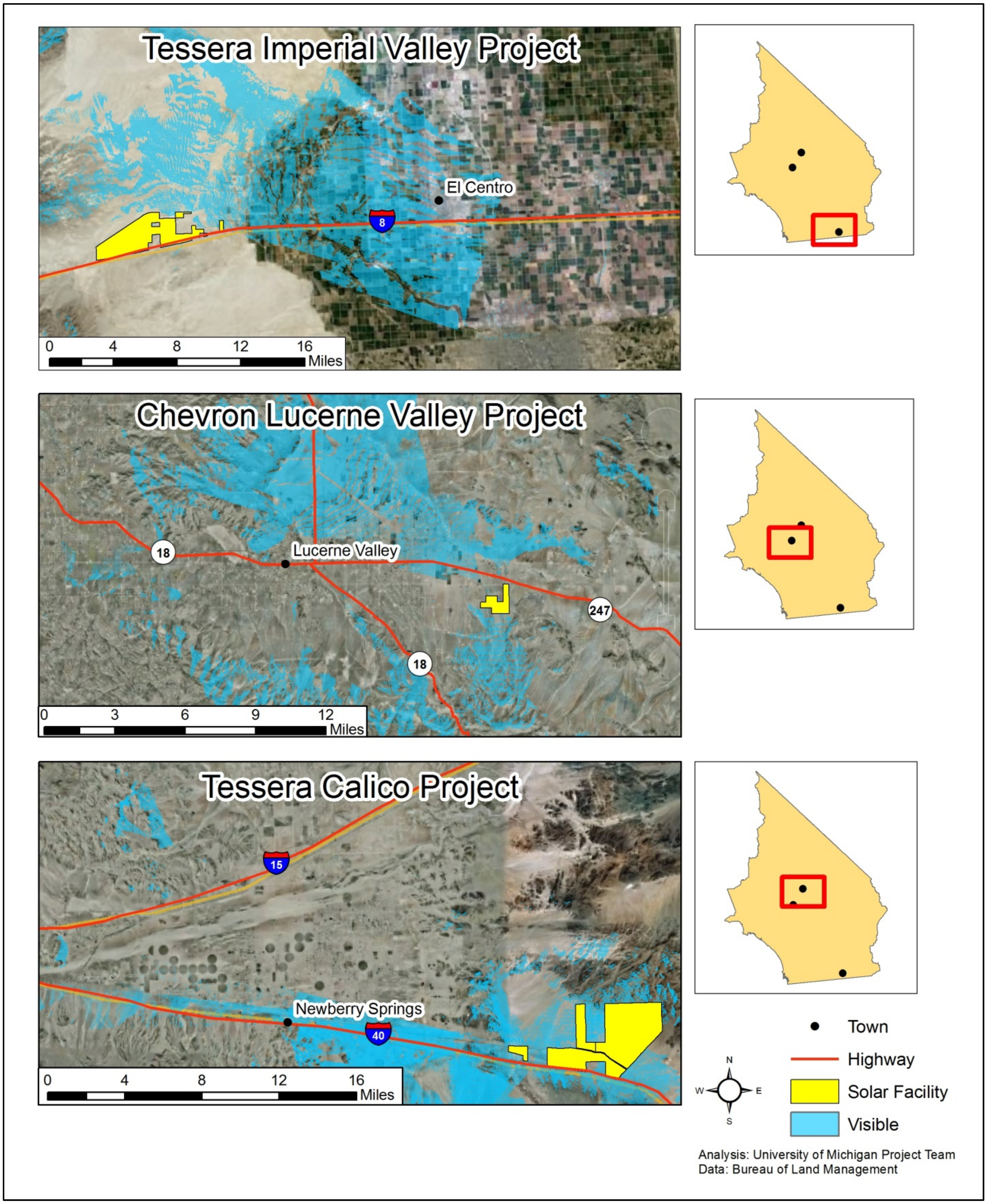
Spatial

The impact to the viewshed was the fifth most cited negative consequence of solar development in our open-ended response keyword analysis. However, respondents rated “decreased quality of vistas from your town” as the outcome they were least concerned about with an average rating of 2.5 out of 5. This discrepancy might be best explained by the nature of the open-ended responses; half of those who cited viewshed impact suggested that it would have an impact on the view but that it was not something that might bother them. A related sentiment observed in the open-response questions was that of the desert being “barren” or “otherwise useless.” That said, the variance of the closed-ended response was 2.27, indicating that there is quite a bit of disagreement between respondents, where responses were grouped at extremes. While concern over an altered viewshed varies, a closer look at the likely visual impacts indicates that residents are likely to be affected by the proposed facilities, both in many parts of the communities and along primary highways leading in and out of town. This being the case, it might be useful for the BLM to mock up what the visual impact will be from ground level to allow residents to either temper their concern or reevaluate their indifference. We have created an example of such a map (Map 9.2).

Socioeconomic

Respondents ranked increased employment opportunities during facility construction and operation as both highly likely and quite valuable. Unfortunately, this optimistic outlook may prove unfounded. Although facility construction will create hundreds of temporary jobs, the labor pool in the California desert includes thousands of individuals; residents will face stiff competition for these positions. Once in operation, each facility will require relatively few full-time employees: of 14 proposed facilities reviewed in this study, 10 expected to create fewer than 100 permanent positions each, whereas the other four could create more. While a handful of respondents indicated skepticism about job creation for their communities, many more expressed hope.

Respondents also believe that it is likely that solar development in the California desert will have a positive impact on local municipal budgets. However, facilities sited on federal land will have few direct local fiscal impacts; all lease payments will go to the U.S. Treasury. Given that federal land is



Map 9.2. Visibility of Facilities from Surveyed Communities.

property tax exempt, facilities on public land will probably not result in increased local property tax revenue, unless payments in lieu of taxes are made. Facilities sited on both public and private land may have local fiscal benefits; for example, these private landowners will benefit directly from lease payments. Furthermore, infrastructure on private land that is unrelated to energy production, such as office buildings, may be assessed property tax, thereby benefiting the local unit of government. Some of these misunderstandings are related to a lack of understanding of the technology and what it does, an issue also explored in our survey.

INFORMATION GAPS AND SOURCES

Overall, respondents claimed to be moderately familiar with solar technologies (2.94). On average, respondents claimed to be most familiar with parabolic trough technologies, although the data suggest that respondents are more familiar with solar energy in general than they are with specific technologies. Generally, people in El Centro reported to have less familiarity than those in Newberry Springs, and older respondents claimed to know more than younger ones. In addition, those with only a high school education reported to be less familiar with solar technologies than those with a master's degree. Finally, those who oppose solar appeared to claim slightly more familiarity with solar than those who support solar (Table 9.7). However, when regressed against opinion, knowledge of solar is not statistically significant to opinion, with R-Square at 1.24 x 10^6 and a proxy correlation of -0.001. Table 5.9 offers a rough profile of those who reported to be most familiar with solar and those who reported to be least supportive of utility-scale solar development in their region.

Table 9.7 Profile of Respondents Who Claim to be Most Familiar and Least Familiar with Solar Technologies in General.

Familiarity With Solar		
Category	Most Familiarity	Least Familiarity
Community	Newberry Springs	El Centro
Age	60 or Older	40 or Younger
Residence Time	Less than 10 Years	10 to 20 Years
Education Level	Masters	High School
Support for Solar	Oppose	Support

In addition, opponents of solar reported to be more familiar with solar technologies (2.40) than did supporters (1.94), with a p-value of 5.3 x 10^3. But neither group claimed to be very familiar. In terms of information sources, we did notice a statistically significant difference in mean values associated with the value of local government as a source of information. Supporters reported 2.35, and opponents 2, meaning neither group holds local government in particularly high regard. Finally, opponents (30.4 percent) claim to participate more than supporters (16.2 percent), and opponents were again slightly more cynical than supporters, with 29.7 percent reporting that their opinion does not matter versus 17.5 percent, respectively.

In addition to assessing what respondents claimed to know about solar, we measured what respondents said they might like to know about utility-scale solar facilities. While we did not frame the question by suggesting this information might help in decision making, we did hope to connect responses about useful information with concerns for and value placed on outcomes. (The question itself was, “In the future, how helpful would you find the following information about utility-scale solar facilities?”) We also sought to know what people who support and oppose solar want to know. Respondents were asked to rank preferences on a scale of five, and as such, we looked at mean answers above three as being helpful and mean answers below three as trending toward less helpful. Assuming that logic, respondents on the aggregate indicated that all nine information options would be helpful to them, to varying degrees. In fact, none of the nine received a mean score of less than three when filtered through each of the four demographic categories designed into the survey (Figure 9.6). Given that the greatest proportion of respondents said they were uncertain if utility scale solar would have an impact on water resources, and that impact over water resources was reported to be the greatest concern, it might not be surprising that more information on water usage rose to the top as the most helpful. Details on the technology itself, job creation estimates, and ecological impacts fell behind water, in that order. In our observation, nothing else with regard to helpfulness of additional information stood out in the data as being significant.

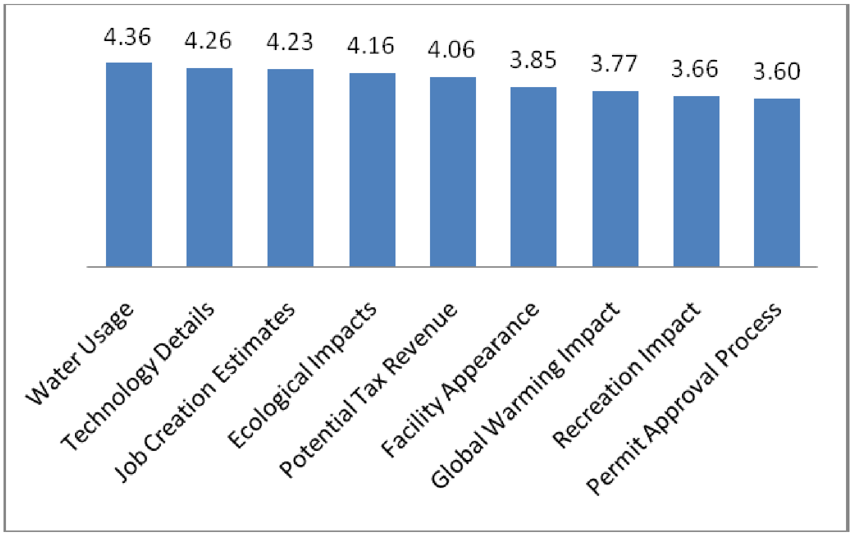


Figure 9.6 Mean Response of the Value of Additional Information by Topic.

Information Sources

From a list of 12 possible sources for solar information, 85 percent of respondents chose television and radio as their most helpful information source. Eighty-two percent use newspapers, 79 percent listen to family and friends, and 78 percent rely on the internet. Far fewer respondents reported to glean information from trade journals (60 percent), recreation clubs (63 percent), or teachers (63 percent). Drawing from Figure 9.7, while mass media is consumed at a higher rate than books and the internet, mass media is seen as less valuable. In addition, advertisements and the government are viewed as the least useful, which is consistent with a number of the open-ended responses we received that indicated a lack of trust in big business, government, and the BLM generally.

Respondents from Lucerne Valley tended to find these government sources less valuable than the mean, rating both local government and the Chamber of Commerce below a ranking of trwo on the five-point scale. This observation appears to be consistent with the overall opinion of respondents from Lucerne Valley, which is less than the mean.

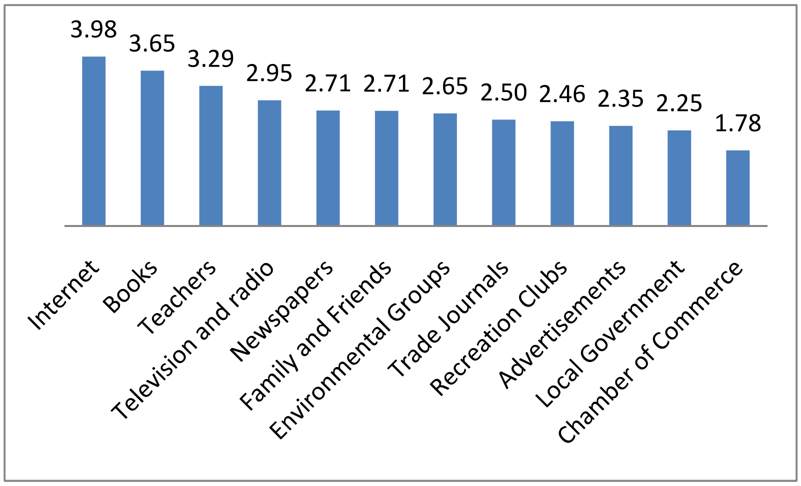


Figure 9.7 Mean Response of Value for Information Sources on a 5-point Scale.

SUMMARY

Overall, we found that residents in communities that will be affected by utility-scale solar are generally supportive. The following points summarize our additional findings:

- As evidenced in the open-ended responses, claims of support for solar did not necessarily equate to a lack of concern over potential outcomes.
- Of the list of possible positive outcomes, job creation and energy were reported to be the most valued. These potential benefits were also cited as the most likely to occur.
- Impact on water and habitat topped the list of those possible negative outcomes over which respondents were most concerned. However, opinion was mixed about their likelihood.
- Respondents also reported to know the least about how water would be impacted but to want more information about it relative to information on other possible outcomes. Open-ended responses also suggested a general concern over water.
- Respondents across the board seem to want more information about issues relevant to solar. While they reported to consume mass media more than other information sources, they tend to value information online and from teachers more.
- They also reported to value information from local governments and advertisers the least. This is consistent with many of the open-ended responses indicating a general mistrust of government organizations and private companies.
- Part of this mistrust appears to come from observation of what has happened in other communities, while some of it appears to come from a belief that they are left in the dark. In fact, the top two reasons people tended not to participate in the BLM process were lack of awareness and lack of belief that their opinions mattered.

- This lack of trust resulted in some believing that taxes will go up, property values will do down, and profits will not come to them. These views were, however, minority views.
- In fact, many are optimistic about job creation and additional energy. The economic impact was one issue over which respondents were split.
- Impact on the environment and land use seemed to be the most divisive issues. Some believe that the land is currently not of much use and should be used productively, while others believe that these facilities will do more harm than good. Yet, these issues do not necessarily correspond directly to support for or opposition to solar.
- Opponents of solar appear to differ the most from supporters in their concern over water resources. Habitat and viewshed appear to be close behind. For their part, supporters seem to value the potential increase in the availability of energy, more jobs, and greater commercial activity. Given that all mean responses to issues of concern fall below three, supporters appear to be generally optimistic whereas opponents tend to be more cynical of the positive outcomes.

We believe these results offer valuable insight into what matters to these residents, what they disagree over, what they know and do not know, and how best the BLM and other stakeholders can engage them.

CHAPTER 10 | DECISION-MAKING PROCESS

Due to the ecological and socioeconomic impacts described in previous chapters, it is important to discuss how decisions will be made regarding proposed utility-scale solar facilities on public lands. The process of development for proposed facilities on public lands involves a Right-of-Way (ROW) grant from the BLM, a license from the CEC, approval of a power purchase agreement from the CPUC, and feasibility, system impact, and facilities studies from the California Independent System Operator (CalISO), among others. The following is an explanation of these individual processes, how they interact, and how these agencies are attempting to create a single process for solar developers.

As the BLM is the major agency responsible for approving the siting of solar facilities and is currently implementing the Solar PEIS, through which it is possible to change the permitting process, an evaluation of the process was conducted. The evaluation highlighted strengths as well as weaknesses of the process. To assist in creating recommendations to address the weaknesses, two alternative processes, onshore oil and gas leasing and wind right-of-way grants, were analyzed to identify components that could be applied to the solar process to improve it.

PERMITTING PROCESSES FOR SOLAR DEVELOPMENT

Due to the interconnected nature of power generation infrastructure and overlapping jurisdictions of federal and state agencies, there are multiple agencies and processes through which solar developers must navigate to receive permits necessary to build their facilities. Some of the processes apply to specific stages of solar development, such as linking into the transmission grid or approving power purchase agreements between utilities and developers, while other processes overlap when multiple permits are needed to develop a facility on federal land within the State of California. The primary permitting processes are conducted by the BLM and the CEC. Other federal and state agencies also play a role in the siting of solar facilities on BLM land in the CDCA.

BLM Right-of-Way Grants for Solar Facilities

Current applications for utility-scale solar facilities on BLM land are processed as ROW grants under Title V of the FLPMA and Title 43, Part 2802 of the Code of Federal Regulations (CFR).[537] Solar developers need to apply for a ROW grant from the BLM field office within which the proposed facility is located for systems for generating, transmitting, and distributing electricity. This process can take two years or more. All utility-scale CSP or PV electric generating facilities must also comply with the BLM's current land use plans. The scope of the environmental analysis required by NEPA for a solar energy development project must address all aspects of the solar project, including direct, indirect, and cumulative effects of the proposed action.[538] If granted, the length of the ROW authorization is not limited by regulation; however, it must recognize the overall costs and useful life of solar energy facilities.[539]

Currently, ROW applications for solar energy development are being accepted and processed on a first-come, first-served basis. While the entire process has yet to be completed for an individual facility, one BLM staff member noted that the process is expected to take approximately 18 months.[540] The ROW regulations provide authority for offering public lands under competitive bidding procedures. The BLM has indicated they will initiate a bidding process if a land use planning decision has specifically identified an area for competitive leasing. The SESAs may be designated for competitive leasing as part of the Solar PEIS.[541]

Steps for the BLM ROW Solar Facility Siting Process[542] (Figure 10.1):

1. Applicant submits a SF-299 ROW application to the BLM field office with jurisdiction over the proposed project location. The SF-299 is a two page document requiring a short project description, location, and possible environmental impacts.
2. Applicant submits a comprehensive Plan of Development (POD), a $50,000 processing deposit, and initial engineering designs on surface water drainage within 90 days of submitting the SF-299.
3. The BLM Field Office Project Manager reviews the POD to determine data adequacy. Data adequacy is met when the BLM has received all necessary information to process the application. If necessary, the BLM reports deficiencies to the applicant.
   a. The engineering designs are sent to the BLM state office for review by an engineer contractor, who determines if changes are necessary. This can take up to 45 days.
   b. The DOD is consulted to determine conflicts with low-flight zones and other military activities.
   c. State Historic Preservation Officer (SHPO) is consulted to determine conflicts with national historic and cultural places.
   d. Tribes are engaged for Government-to-Government consultation.
4. If deficiencies are reported, the applicant has 30 days to make changes if they are small, or 60 days if significant changes need to be made.
5. When the BLM Field Office Project Manager deems the POD to be data adequate and it has been approved by the Field Office Manager, a briefing process within the BLM is initiated. The BLM District Manager is briefed on the project, and if approval is given, the project moves forward to the BLM State Director for approval.
6. If the project is approved by the State Director, the BLM publishes a Notice of Intent in the Federal Register to begin the NEPA process for the project.
7. The BLM completes a NEPA analysis for project.

        a. The BLM conducts public scoping meetings for the project.
        b. The BLM publishes a Draft EIS for the project.
            i. While preparing the Draft EIS, the BLM conducts a Section 7 Consultation with the FWS regarding possible impacts to species listed under the Endangered Species Act (see FWS process below).
        c. A 90-day public comment period is held for the Draft EIS.
        d. The BLM publishes a Final EIS for the project.
        e. The BLM holds a 30-day no-action period for public review.
8. The BLM issues a Record of Decision (ROD), approving or denying the ROW grant.

BLM Right-of-Way Fees

Solar facilities granted a ROW are subject to rent based on fair market value of the land using real estate appraisals.[543] Since the rental payment reflects the full use of public land for solar facilities, similar to a lease for industrial purposes, there are no additional royalty payments for electric generation.[544]

The submission of a solar facility application are assessed a $50,000 deposit fee. Each facility is also estimated to spend $200,000 to $300,000 in cost recovery over the course of the permitting process.[545] Cost recovery funds are used to pay for BLM employee time spent on processing individual solar applications. If a facility is granted a ROW there will also be cost recovery fees associated with monitoring and administrative work through the life of the project.

Solar facilities granted a ROW are also required to bond for funds used to ensure compliance with the conditions of the authorization and the requirements of the regulations, including reclamation after termination of the permit. The reclamation provisions within the POD should include not only removal of solar collectors and other structures, but also the reclamation of access roads and other disturbed areas.[546] The amount of the bond will vary by project based on the predicted cost of facility removal and land reclamation. For example, wind projects are assessed a $10,000 reclamation bond per turbine.[547]

Environmental mitigation is required for all approved solar facility ROWs. Presently, a standard protocol for determining mitigation requirements has not been adopted by the BLM. Traditionally, mitigation has required the ROW grantee to purchase and donate to the federal government private land or purchase mitigation credits at a ratio of one acre for every acre granted under the ROW.[548]

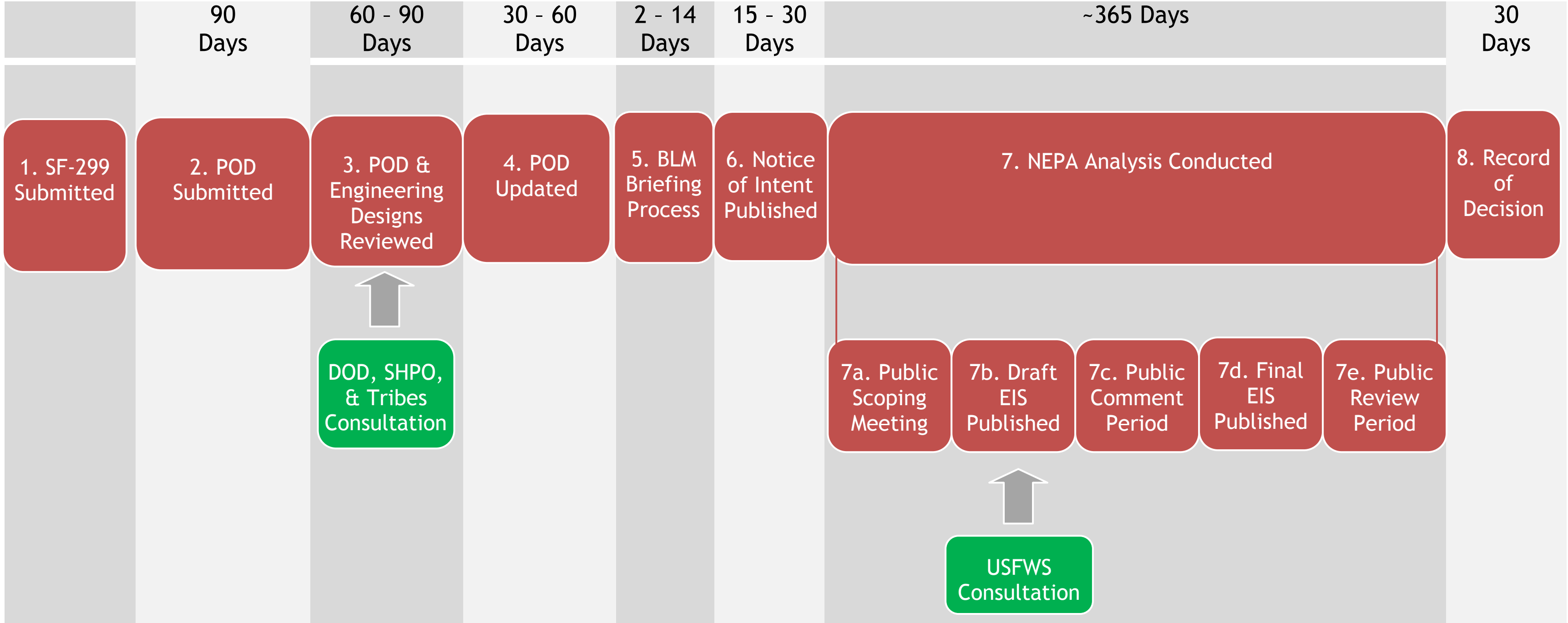


Figure 10.1 Flowchart of the Bureau of Land Management Right-of-Way Process for Solar Projects. Red boxes denote a step in the BLM process. Green boxes denote consultations with or input other agencies and governments.

CEC Application for Certification for Solar Facilities

The CEC has the statutory authority for licensing all thermal energy projects larger than 50 MW. Solar developers must apply for an AFC from the CEC, which will issue a separate decision from the BLM. The CEC's AFC process is certified under the CEQA and is equivalent to CEQA's Environmental Impact Report (EIR) process. This allows for replacement of the EIRs that would normally be completed by the DFG with the CEC's staff assessments and committee reports. As stated in the statute, an AFC process must be completed within 12 months of the project being deemed data adequate; however, currently the CEC is completing applications, on average, in 17 months.[549]

Steps for the CEC AFC Solar Facility Siting Process[550] *(Figure 10.2):*

1. Applicant submits 125 copies of their AFC application to the CEC's Docket Unit. Required information includes a project, site, engineering, and environmental description, related transmission information, and proof of compliance with federal, state, and local laws.
2. CEC staff reviews the AFC for data adequacy. Data adequacy is determined by the inclusion of all required siting information. Relevant agencies participate in this review process. CEC staff makes a data adequacy recommendation to the Commission within 30 days of the AFC being filed.
3. CEC issues decision on AFC data adequacy at a public meeting within 45 days of the AFC being filed.
    a. If there are deficiencies, the applicant must submit a supplement with the changes.
    b. If deemed data adequate, an Energy Commission Committee is formed, which contains two Energy Commissioners, to preside over the process.
4. When the Commission deems the AFC to be data adequate, CEC staff begins to collect data for impact analysis from the applicant and other agencies.
    a. The CEC holds informational public hearings and workshops.
    b. The CalISO files findings on System Impact Study (SIS). This is an evaluation of the impact of the transmission connection with the grid.[551]
    c. State and federal agencies issue draft permits or opinions.
5. The CEC completes a Staff Assessment for the project.
    a. The CEC publishes a Preliminary Staff Assessment for the project.
    b. A 20 day period of public workshops is held for the Preliminary Staff Assessment.
    c. The CEC publishes a Final Staff Assessment.
6. CEC staff, applicant, and related agencies present findings to the Energy Commission Committee.
7. The Energy Commission Committee releases the Presiding Members Proposed Decision (PMPD) for a 30 day public comment period.
8. The Energy Commission Committee issues a Final Presiding Members Proposed Decision.

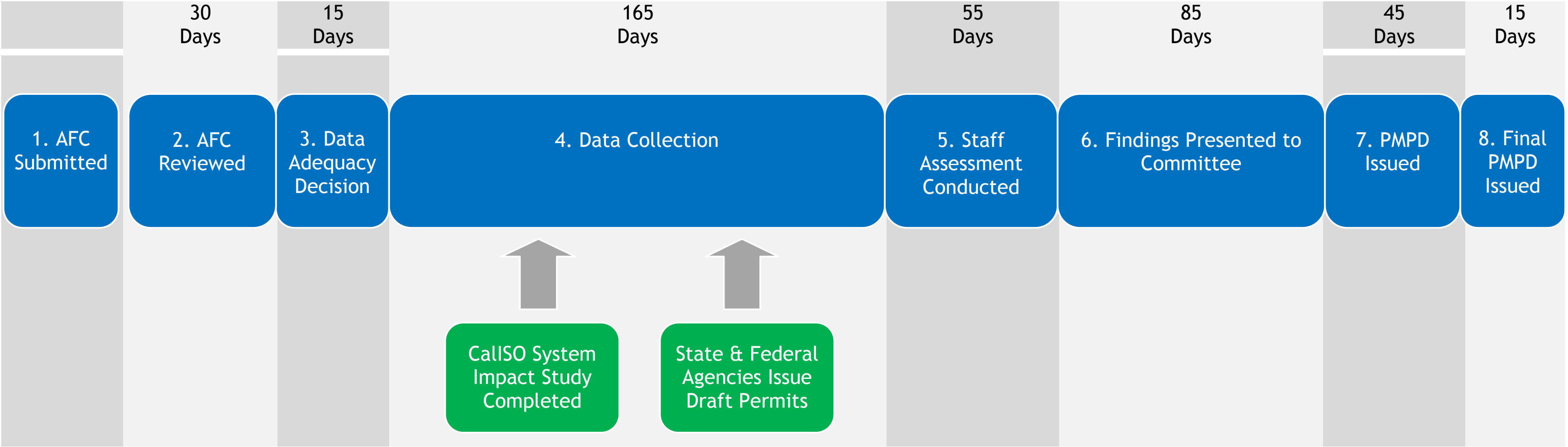


Figure 10.2 Flowchart of California Energy Commission's Certification Process for Solar Projects. Blue boxes denote a step in the CEC process. Green boxes denote consultations with or input from other agencies and governments.

Linking the BLM and CEC Processes

The CEC entered into a MOU with the BLM in August 2007 to create a joint process for completing solar applications on BLM land (Figure 10.3). The two processes require similar information from the developer, public participation opportunities, consultation with relevant agencies, and environmental analysis. There are differences in that CEC analyzes the engineering of a project and the BLM considers alternatives under the NEPA. The goal of the MOU is to have a single process with joint workshops, meetings, and environmental analysis in order to streamline and expedite the application process.

As a CEC staff member said, “They’re [the processes] similar but different. BLM has their plan of development that has to be submitted, and it’s more general than the Energy Commission [requirements]… We [the Energy Commission] also evaluate the engineering of the project and we also do socioeconomics of the project. So it’s more than just environmental. So our processes are similar. BLM has a little more [required by NEPA], we’ve incorporated theirs but they have sections on recreation and alternatives that are different between the two processes so we use the BLM more, if you would. BLM has more info required in their alternatives analysis than the CEQA does and we expand the alternatives to cover that. So we’ve merged the two processes to come up with a document that covers everything.”[552]

The agencies have combined the CEC’s informational hearing and site visit with the BLM’s public scoping meeting.[553] During the joint NEPA/CEQA process, the BLM is responsible for preparing the Purpose of Need, the NEPA alternatives, and Native American consultation.[554] The CEC is responsible for preparing an environmental and engineering assessment of the project.[555] However, there will be separate permits issued by each agency, a ROD from BLM and a PMPD from CEC.

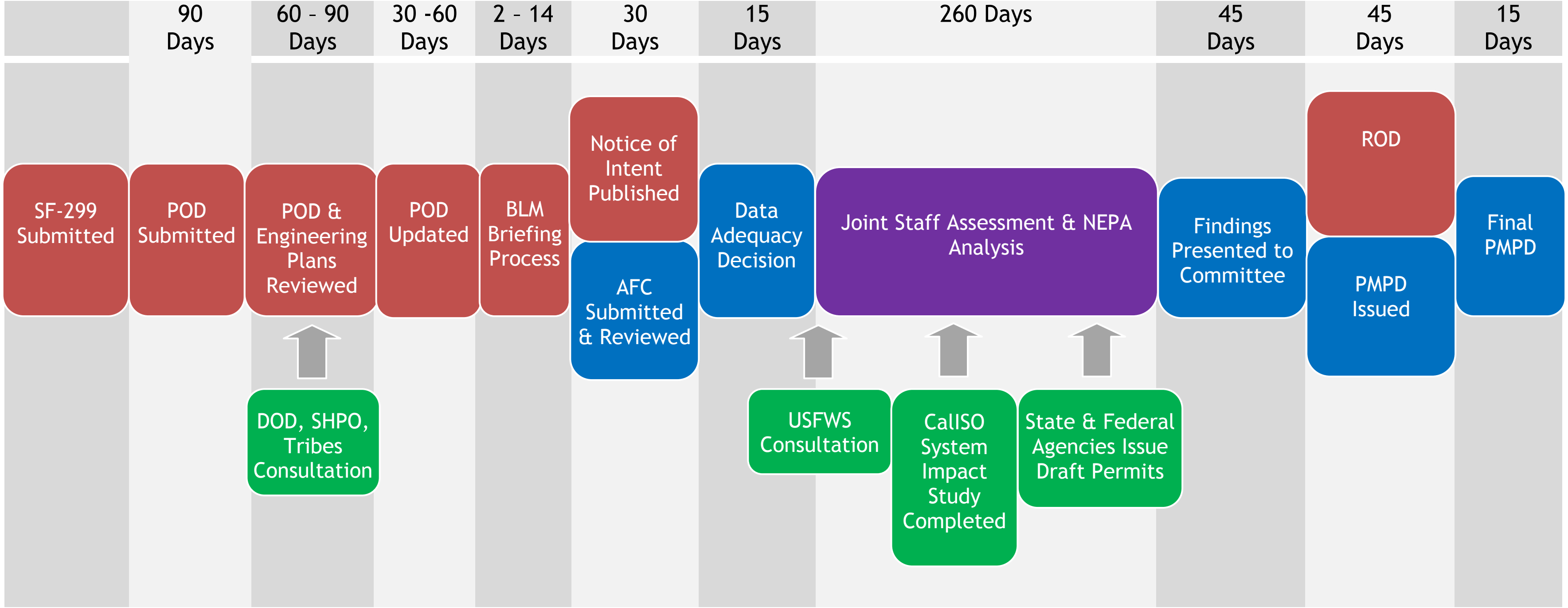


Figure 10.3 Flowchart for Joint BLM and CEC Processes for Permitting Solar Projects. Red boxes denote a step in the BLM process. Blue boxes denote a step in the CEC process. Purple boxes denote a joint activity by the BLM and CEC. Green boxes denote consultations with or input from other agencies and governments.

Other Agencies and Governments Involved in Permitting

The California Public Utilities Commission

The CPUC regulates investor-owned utilities in California, oversees the procurement of renewable energy in the state under the RPS implementation program, and permits electrical transmission.[556]

In order to sell the power produced by a new facility, a solar developer must enter into a long term contract, known as a Power Purchase Agreement (PPA), with a utility for the purchase of the power that the solar energy facility will produce. Before the PPA is finalized, the CPUC must approve the contract.[557] In doing so, the CPUC considers the perceived viability of the project, the price of power in the contract, and how purchasing that power will contribute to the utility's goals under the RPS program before approving or denying the contract.[558] As an analyst at CPUC noted, "It's rare that we deny contracts, because we have been working with them all along. If we have concerns about a project, we would have given the utility that feedback beforehand. It is pretty rare that they would get to the point of filing a contract with us, and then we would deny the approval for that project."[559] PPA contracts can come to CPUC before the developer submits permit applications, during the approval process, or after the facility has been approved. This can vary because developers must obtain permits to construct the facility, obtain transmission connection, and obtain a PPA, and progress on one component can hinge on the progress of another.[560]

In addition to approving individual PPAs and ensuring utilities sign contracts that will help them achieve their goals under the state RPS program, the CPUC has statutory responsibility to permit transmission lines. Most of the transmission grid in California is owned by investor-owned utilities. CalISO operates the transmission grid in California, but the CPUC is responsible for determining if a new line is needed, for determining if the cost of the lines recovered through increased rates is a justifiable to rate payers, and for permitting the routing of new lines, including those undergoing environmental review under the CEQA.[561]

The California Independent System Operator

CalISO operates the majority of California's high-voltage transmission grid.[562] They conduct technical planning for electrical transmission, including determining availability across various lines to ensure power can be delivered through the grid to meet demand. CalISO works closely with CPUC in the permitting of new transmission lines.[563] In order for a solar facility to gain interconnection into the grid, CalISO performs three studies. The feasibility study "evaluates the feasibility of the proposed interconnection by performing power flow and short circuit analyses."[564] This study requires a $10,000 deposit and takes 60 days. The system impact study "evaluates the impact of the proposed interconnection on the reliability of the grid."[565] This study requires a $50,000 deposit and takes 120 days. The facilities study evaluates the impact on interconnection facilities and determines if any network upgrades needed. This study requires a $100,000 deposit and takes 120 to 210 days. In addition to the deposits noted, the solar facility developer must pay for the actual costs of these studies.

The U.S. Fish and Wildlife Service

The FWS is responsible for administering the Endangered Species Act (ESA). Section 7 of the ESA requires federal agencies to "consult with the FWS to ensure that the effects of actions they authorize, fund, or carry out will not jeopardize the continued existence of listed species."[566] Permitting solar facilities on BLM land qualifies as an agency action. A Section 7 Consultation, as this process is known, is likely to be required for most, if not all, solar facility right-of-way applications because of the numerous listed species found throughout the CDCA, notably the widely dispersed and threatened desert tortoise (*Gopherus agassizii*). The consultation process is typically initiated by the BLM during their development of the biological assessment as part of the Draft EIS for a proposed solar facility.[567]

During this Section 7 Consultation, the FWS issues a biological opinion on the proposed action that analyzes the impacts of the action on listed species and determines if the action will jeopardize the continued existence of the species.[568] If a jeopardy determination is made, which is rare, the agency offers alternative recommendations for how the proposed action can be altered to avoid jeopardy.[569] If the determination is that there will be impacts to the species, but such impacts will not jeopardize its existence or substantially lead to its extinction, the FWS issues terms and conditions within a biological opinion document. These are measures that the FWS feels need to be implemented to minimize impacts to the species under the proposed action.[570]

The California Department of Fish and Game

The DFG is responsible for the management of fish and wildlife in the state, which includes administering the California Endangered Species Act (CESA). Under the CESA, the CEC must consult with the DFG to determine any impacts to species listed under the CESA. Similar to implementation of the federal ESA, the DFG must issue an incidental take permit for any action that would impact one or more species listed under the CESA before the action impacting the species can be undertaken.[571]

The Office of Historic Preservation

The Office of Historic Preservation (OHP) for the State of California is responsible for ensuring the projects carried out or sponsored by federal or state agencies comply with appropriate federal and state historic preservation laws, including the National Historic Preservation Act (NHPA). Section 106 of the NHPA requires any federal agency undertaking an action that may affect historic properties to consult with the SHPO.[572] Historic properties are those included in the National Register of Historic Places or properties that meet National Register criteria.

For any proposed solar facilities that may affect historic properties, the BLM must initiate a Section 106 consultation. During this consultation, the SHPO identifies any historic properties that may be impacted and assesses possible adverse effects. If adverse effects are found, the SHPO and the BLM will typically sign a Memorandum of Agreement outlining the measures that the BLM will take to avoid, minimize, or mitigate the adverse effects.[573] The parties may also agree that "no such measures are possible, but that the adverse effects may be accepted in the public interest".[574]

The U.S. Department of Defense

The DOD operates several large military installations in the CDCA, including Fort Irwin, Twentynine Palms Marine Corps Base, China Lake Naval Weapons Center, and Edwards Air Force Base. The DOD reviews all applications processed by the BLM to determine if proposed facilities will have any effect on the ability for the DOD to carry out its mission.[575] While the DOD has no authority or jurisdiction in altering or denying an application, they may issue recommendations to the BLM on individual projects regarding any possible conflicts with DOD missions. The DOD issues red, yellow, or green recommendations based on possible conflicts with missions in established low-flight zones.

Tribes

There are many tribes in the California desert that have historic and cultural ties to BLM land. For any proposed solar facilities, the BLM must conduct Government-to-Government consultation with the Tribes as mandated under Section 106 of the NHPA. The CDD formally notifies the tribes of each project, with follow–up, and they are encouraged to provide their views and comments through all available processes, including NEPA, Section 106, and formal government-to-government meetings.[576] Tribal views and comments are then taken into consideration during decision-making for solar projects.

EVALUATION OF THE BLM RIGHT-OF-WAY PROCESS FOR SOLAR FACILITIES

As the BLM will be using the ROW process to evaluate proposed solar facilities, it is important that this process allows for siting decisions to made in a comprehensive and effective manner. A critical analysis of the BLM's right-of-way process as it is applied to solar facilities was conducted using a set of normative criteria. Input from interviews, the stakeholder survey, and a survey of organizations supported our evaluation. The analysis determined whether the solar ROW process effectively addressed each of the criteria. The results of the analysis highlight the strengths and weaknesses of the process as well as considers other factors affecting processing. We have chosen to focus our evaluation and recommendations on the BLM ROW process since the agency is currently in the process of conducting a Solar PEIS, which will consider changes to the process. The analysis was conducted in order to inform and offer recommendations for improvement of the process for BLM staff, solar developers, and other interested and involved agencies and organizations. The CEC is not considering changes to their AFC process; therefore, their process is not analyzed. However, the integration of the BLM and CEC process was included in the analysis, as some changes to the BLM process may affect how the two processes integrate.

Two strengths and eleven weaknesses with the BLM process for siting solar facilities as it currently exists were identified (Table 10.1). When the Solar PEIS is released in draft and then in final form it may address some or all of these weaknesses, but these remain important as applications are processed in the meantime. Additionally, seven other factors were identified as affecting the processing of solar development applications. These are situational factors that are creating concerns and not weaknesses of the process itself. Most of these factors stem from the high level of interest in solar project development, which has generated a large number of solar ROW applications in a short time period in the California desert.

Table 10.1 List of Criteria, the Strengths (+) and Weaknesses (—) of the Current ROW Process as Applied to Solar Projects, and Other Factors (○) Affecting Application processing.

Efficiency

- (+) ROW process familiarity
- (—) No authority to reject applications
- (—) No method for prioritizing applications
- (—) CEC & BLM collaboration
- (—) BLM guidance for SF-299 and POD
- (○) Number of applications
- (○) BLM staff levels
- (○) Inter-agency coordination

Clarity of Process

- (—) CEC & BLM collaboration
- (—) Undefined environmental mitigation
- (—) Undefined Land Rental Rate
- (—) BLM guidance for SF-299 and POD
- (○) Initial BLM — developer contact
- (○) Process applied to new use

Robust Set of Options

- (+) Use of the NEPA process
- (—) First come, first serve
- (—) Limited alternatives considered

Environmental Protection

- (+) Use of the NEPA process
- (—) Combined agency enviornmental analysis
- (—) Undefined environmental mitigation
- (○) "Fast Track" projects

Spatial or Temporal Scale

- (—) Lack of desert scale consideration
- (—) Lack of cumulative impact consideration

Public Engagement

- (+) Use of the NEPA process
- (—) Inefficient public communication
- (○) "Fast Track" projects

Efficiency

An efficient process reduces costs to developers and the BLM, BLM staff time, and other resource inputs while allowing for decisions to be made in a timely manner.

1. BLM Familiarity with the ROW Process

The BLM issues right-of-way grants for roads, transmission lines, communication towers, wind turbines, and similar developments, so BLM staff is well versed in the right-of-way process. BLM staff feel this is a strength since applying the process to solar facilities presents some challenges, discussed below, but the process itself does not impose a learning curve on the BLM. This adds to the efficiency of the process.

2. Lack of BLM Authority to Reject Applications

The BLM does not have the authority to reject "bad" applications before the NEPA process begins. Applications that are clearly speculative, include fatal flaws based on staff experience, or are located in areas with many existing land use conflicts must be reviewed even when BLM staff know will never get through the process for approval. Instead of rejecting applications, BLM staff may inform the applicant of likely conflicts with their application but cannot require the applicant to move or change their application. BLM staff at the state, district, and field offices and an environmental group mentioned this weakness.

For example, the Ridgecrest Field Office rejected several right-of-way applications for solar facilities because the proposed siting was in a designated Mojave Ground Squirrel Conservation Area. Based on that designation, a BLM staff member noted, "Within the Mojave Ground Squirrel Conservation Area, between 2006 and the year 2036, there can only be new surface disturbance totaling 10,387 acres scattered across the entirety of the Conservation Area. If you do the math, it comes up to about 300 surface acres a year that we can absorb in new disturbances within the area. When we had applications coming in for 6,000 acres, we were looking at one permitee consuming 60 percent of the available acres for the 30 year life of the plan. As you can imagine, that created quite some concern for us in management. We determined that in the conservation area that was not compatible, so we rejected the application."[577] The Interior Board of Land Appeals later overturned the rejection and declared that the BLM must treat each application seriously and equally as they do not have the authority to be pre-decisional, that is making a decision before a full analysis has been completed.[578]

Since BLM cannot simply reject applications they see as unfeasible, they are forced to use time and resources processing those applications, which reduces efficiency. This detracts from their ability to process applications that are better developed and potentially face fewer conflicts, as well as their ability to perform the numerous other duties of their office beyond solar facility siting.

3. No Method for Prioritizing Application Processing

Both a BLM field office staff member and a solar developer noted that field offices do not have a standard method or protocol for prioritizing application processing. With so many right-of-way applications filed at the same time within each field office, BLM staff must attempt to effectively process all applications with limited staff while completing the numerous other duties of the office, which reduces efficiency. As a BLM staff member stated, "We started off on a project by project basis and then got slammed. We're working under pretty strict deadlines: there are targets to be made here in California, and there are national targets. There are commitments made by the [Obama] administration. How do we do that with a large flood [of applications]? How do we do it in a fair process for everyone?"[579] The October 2009 MOU between the State of California and the DOI places a higher priority on applications within SESAs and renewable energy zones identified in the DRECP and in RETI and areas that do not require new transmission. Additionally, 10 projects are self-identified as "Fast Track" projects in an attempt to take advantage of ARRA Funding. These projects are also prioritized as the funding deadline is December 2010. Even with these priorities the BLM has not established a method for prioritizing applications within these groups. Field office staff continue to face pressure from solar developers to process their application quickly and efficiently, while some environmental stakeholders pressure them to slow down in order to ensure all possible impacts are completely analyzed. Thus, the lack of a prioritization method means the BLM is subject to political and stakeholder pressures. An established method would insulate the agency from these pressures.

4. CEC & BLM Collaboration

Solar projects located on BLM land must go through both the BLM and the CEC permitting process. To reduce processing time, the two agencies entered into an MOU to combine the two processes. However, BLM and CEC have never collaborated on large projects before. Employees of both agencies are struggling to work out the differences in the two processes and the timelines, but the joint process is not yet clear or efficient

As one BLM employee stated regarding energy efficiency, "That's not our area. I work for a land management company. That's why we have such a tight partnership with CEC on this. I mean when I say a tight partnership, a planner in my office spends an hour or two every day on conference calls with CEC, because between them and CPUC their expertise and their knowledge of the electrical side of the equation, they're a critical part of this. I manage the land; they manage pretty much the power needs of the citizens of the state. It's getting those two integrated in a very good process. It has been painful. They don't know how to talk BLM; we don't know how to talk power company. And I think if you want to get into that, you start looking, there's just a lot that's unknown. The economics of the industry are just not out, they're not public. Nobody knows those numbers. So even if we were asked to make a judgment, we can't do it. We don't have the factual information to do that."[580]

5. Inconsistency and Lack of Thoroughness of BLM Guidance

Interviews with BLM staff indicate the developers have been submitting ROW SF-299 applications and associated PODs with varying levels and relevancies of information. One BLM staffer mentioned, "Some of them will give us everything we never wanted to know on how their boilers are going to be designed and they skip the basics on the biological community and what their plan is for vegetation recovery.

And those are the types of things we're interested in as surface manager. What's going to happen to the vegetation? What going to happen to the soils?"[581]

Commenting on this issue, another BLM staffer noted, "The right-of-way application is not bad, it's just that the applicants all respond to it different. I think it's because while the right-of-way application isn't bad, it's not explained very well. There's the chance that maybe folks look at the website and pull off the SF-299 and have never met with the field office. They don't understand how to describe all of the things that fit into an SF-299. We don't get good legal descriptions. It would be good actually if the right-of-way said 'check the master title plot or make sure you check any other applications in this area before you submit for this specific section', but it doesn't say that."[582]

While the SF-299 is a standard form and the BLM provides some guidance for what should and should not be included in a POD, the BLM has not produced clear and detailed guidance to developers to ensure these submissions are adequate when they are first submitted. When an inadequate SF-299 and/or POD is received, BLM staff must use more time and resources to inform the applicant of the gaps in their application and what types of information is needed for the BLM to move forward processing it. Another BLM staff member noted that BLM was in the process of developing a checklist for developers, but that it was not complete as of the time of the interview.

6. Large Number of Applications to Process

Solar development has been referred to as a land rush in the California desert, as there have been a multitude of applications submitted in the past 4 years. With the creation of policy and financial incentives for solar projects there has been a flood of applications into the region. The BLM field offices are faced with new projects every week and this has led to staffing and time management issues. The number of applications also makes it difficult to get individual projects through the process in a timely and efficient manner as new applications constantly need to be reviewed.

7. Insufficient BLM Staffing

BLM staff, solar developers, and environmental organizations all noted the limitations of BLM offices in efficiently processing the right-of-way applications received simply because many BLM offices are short-staffed. Some field offices hired contractors to come in and assist with analysis and the BLM responded nationally by creating Renewable Energy Coordination Offices to focus solely on processing renewable energy applications, alleviating field office staff that spend a significant amount of their time working on solar facility applications. One BLM Field Office Manager said, "[working on solar applications takes] probably about 25 percent of my time. It's pretty significant."[583] Given the number of applications, the man-hours required to process just one application, and the fact that staff resources continue to be limited, this problem remains significant.

8. Inter-Agency Coordination

As noted above, there are multiple processes among different agencies that solar developers must go through to receive all of the permits and grants to construct and operate a solar facility on public lands in California. In an attempt to ease the burden on developers, the agencies are focused on integrating the processes. The BLM participates in multiple working groups to achieve this goal. Aside from integrating the processes there are also many groups that are attempting to plan where solar development and transmission should go, including the Western Governor's Association's Western Renewable Energy Zones (WREZ), California's Renewable Energy Action Team (REAT) and RETI, the Renewable Energy Policy Group (REPG) and the DRECP group. Both the REPG and the DRECP are collaborative groups of federal and State of California agencies. The BLM participates in all of these groups in order to provide and gather feedback on the status and future of solar development in the desert. Inter-agency coordination requires a significant dedication of time spent in meetings with other agencies discussing individual projects and on coordinating public meetings and environmental reviews, which can reduce efficiency in processing individual applications.

Clarity of Process

A process whose steps, requirements, and other components are well understood by the applicant, regulatory agencies, interested stakeholders and the public reduces uncertainty and ultimately adds to the efficiency of the process.

1. CEC & BLM Collaboration

The integration of the CEC and BLM processes resulted in an inefficient process largely due to the unfamiliarity with the combined processes. The unfamiliarity with the joint process also leaves stakeholders, solar developers, and regulatory agencies unsure about process steps and agency responsibilities.

2. Undefined Environmental Mitigation

A major weakness identified by the BLM state and district offices as well as by environmental and citizens' groups is the lack of a clear set of standardized mitigation measures for solar facilities. The lack of defined environmental mitigation standards is concerning for solar developers who face uncertainty and lack clear direction for how and what to include for environmental mitigation in their PODs. A BLM staff member stated that, "When we come to making a mitigation decision it's not just the BLM; we have to make the mitigation decision with other agencies as well, which involves staffing and coordination issues along the way."[584] The Solar PEIS may include policies and best management practices that provide mitigation requirements or guidelines for solar projects.

3. Undefined Land Rental Rate

Traditionally, ROW grants are assessed an annual land rental rate based on the fair market value of the land. However, as a ROW has never been granted for a solar facility, which requires more land than traditional uses such as road or transmission corridors, the rental rate is undetermined. One BLM employee stated, "The Washington [DC] Office is still in the middle of developing policy for rental for solar."[585] Only one solar project has progressed far enough in the process to request an appraisal, which is still under review.[586] The lack of a defined rental rate leaves the financial investment required of solar developers uncertain. The Solar PEIS may include a standardized policy for assessing a rental rate for solar facilities.

4. Inconsistency and Lack of Thoroughness of BLM Guidance

As noted above, there is a lack of consistent and thorough guidance provided by the BLM to solar developers, which has created inefficiency in the process. This lack of guidance contributes to the uncertainty faced by solar developers.

5. Unclear BLM-Developer Initial Contact

When a solar developer applies for a right-of-way grant for siting a solar facility on BLM land, they commonly meet with BLM staff to discuss their proposal. However, there is no consistency with which office they contact first because the process is not clearly defined. As one BLM staff member noted, "Some of them come to the state office because they think if they get on the state director's radar that they'll get more attention, while others will go to the field office because they know the field office is the one doing the work."[587] Other developers contact the district office first. In a process that has yet to be executed to completion, developers may be given less information on expectations or status of the lands they are interested in if they do not contact the field office first, which creates inconsistency with application materials.

6. Established Process Applied to New Energy Development

The right-of-way process is well established and familiar within the BLM. However solar energy development presents a new use of the land surface for which the impacts of the technologies at the scale proposed are still unknown because similar facilities do not exist. According to a BLM staff member, "What's difficult is that we're not that familiar with large-scale projects of this size."[588] In the CDCA, most ROW grants are used for roads, electrical transmission corridors, communication towers, and wind energy projects. These uses differ from solar as they still allow for multiple use of the land and do not take a large portion of land away from public use.

Consideration of a Robust Set of Options

An effective process considers a robust set of options, promoting choice beyond simply whether or not to site the facility. Considering multiple alternatives allows for an evaluation of tradeoffs and encourages a more informed decision-making process.

1. Use of the NEPA Process

Much of the solar facility permitting process falls under the NEPA process. Citizen and environmental groups refer to this as a strength of the process as NEPA laws were created to protect the environment, provide public participation opportunities, and require multiple alternatives to be considered. Additionally, many organizations, stakeholders, and the public are familiar with this process. Therefore, they know what to expect and have the opportunity, as required under NEPA, for public participation through commenting at many stages throughout the process.

2. Effects of First-come, First-serve

The BLM must process the first application for a given location fully before second or third applications for that same location can be considered. There are currently 19 second- and third-in-line applications in Barstow and Palm Springs Field offices.[589] While the first-come, first-serve system may seem fair, it restricts the ability of the BLM to analyze multiple proposals for the same location at the same time and choose the one that minimizes water use and impact to environmental, cultural and historical, recreational, or visual resources, maximizes electricity produced per acre of land developed.

3. Consideration of Limited Alternatives

The current right-of-way process does not allow for a wider range of alternatives to be considered during the NEPA process. The facilities to be constructed in the rights-of-way are proposed by private developers, so the alternatives the BLM can consider are essentially limited to (1) approving the right-of-way and corresponding facility as proposed, (2) approving the right-of-way and corresponding facility at a smaller scale or different layout than proposed, and (3) a “no action” alternative of simply denying the right-of-way.[590] The BLM cannot analyze and consider as an alternative a more efficient technology type for the facility, granting the right-of-way at an alternate location, or some level of distributed generation.[591] Distributed generation has been identified by both citizen’s groups and environmental organizations as a favorable alternative to utility-scale solar facilities, but BLM cannot consider development it has no jurisdiction over this alternative.

Level of Environmental Protection

Under NEPA, environmental impact must be analyzed for major federal decisions, including solar facility siting. A good process goes beyond simply analyzing environmental impact and seeks to only approve applications that minimize impact while providing appropriate environmental mitigation measures.

1. Use of the NEPA Process

While use of the NEPA process provides a set of options in its environmental analysis it also provides strong environmental protection. In constructing the EIS for a facility, a full environmental analysis is conducted, addressing impacts to threatened and endangered species, species habitats, ecological processes, water use, and visual resources, among others. While the most environmentally protective alternative does not have to be selected under NEPA, completing the EIS and allowing public input throughout the process ensures that environmental impacts are considered.

2. Effects of the Combined BLM-CEC Environmental Analysis

As directed in the August 2007 MOU between the CDD and the CEC, the two agencies must conduct a joint environmental review of solar projects.[592] The MOU stipulates that the BLM is responsible for preparing an analysis of NEPA alternatives and Purpose of Need. However, the CEC is responsible for preparing an assessment that addresses air quality impacts, biological resources, cultural resources, water resources, land use, visual resources, and facility design engineering among others. An environmental group categorized the use the CEC CEQA equivalent process to fulfill NEPA requirements as a weakness, as the CEC process has a shorter time frame and does not fully analyze alternatives. The CEC must complete their entire AFC process within 12 months whereas the BLM has no legislated timeline to complete a ROW or NEPA process. In order to complete the process in the short 12 month timeframe the CEC process has shorter public commenting periods. An environmental assessment is also completed more rapidly in the CEC process, which has led to concerns about short-cuts and completeness of impact and environmental studies. In addition to the time frame, the CEC process does not require a full analysis of alternatives, which is required by the NEPA process. To resolve this issue between the two processes the BLM will identify the alternatives and CEC will conduct the analysis. However, the CEC has not previously conducted full analyses on alternatives and it is unknown how comprehensive the analyses will be.

3. Undefined Environmental Mitigation

Undefined environmental mitigation standards have contributed to making the BLM process unclear for developers and the lack of defined environmental mitigation standards is concerning to environmental groups, since the BLM could potentially require a different level of environmental mitigation for each project.

4. “Fast Track” - Too Fast?

In the CDCA there are 10 projects that are self-identified as “fast track” projects. “Fast track” status may help developers take advantage of grant funding in lieu of tax credits from the U.S. Treasury Department as part of the ARRA. In order to be eligible for the grant, the projects must begin construction by December 31, 2010. The BLM has pledged to complete EISs for each of the projects by the deadline to ensure the projects receive the funding (provided a ROW permit is also approved). However, in order to complete the NEPA process for these projects the BLM truncated the timeline, and the fast track projects are not required to wait for the Solar PEIS to be completed. The BLM conducts an individual EIS for each project, and without the guidance of the PEIS, these projects will lack clear best management practices and a standardized set of mitigation requirements, possibly reducing the level of environmental protection provided.

Consideration of Spatial and Temporal Scale

It is important to consider not only the immediate, predicted impacts at the site itself, but also the impacts that will extend beyond the immediate site, the cumulative impacts of multiple facilities on the landscape, and impacts over time to the siting of one or more facilities.

1. Project Scale vs. Desert Scale

Currently, the right-of-way process is designed to analyze each application separately at the site specified. The EIS process conducts an assessment of impacts of the individual project on the ecosystem. The process cannot be used to determine the optimum placement of projects throughout the entire desert and it lacks full consideration of the spatial scale of likely impacts beyond the project boundary. The process does not take a holistic look at the desert biology and ecosystem across California, Nevada, and Arizona. It only takes a snapshot of each project area and cannot cross state boundaries. The Solar PEIS may address this issue, but at this time it is unclear how it will incorporate spatial and temporal impacts. BLM staff at the state and district office as well as a citizen’s group mentioned this as a weakness.

2. Lack of Cumulative Impact Analysis

Due to the large number of applications currently being processed by the BLM it is difficult, if not impossible, to address the concerns of cumulative impacts of multiple facilities across the desert landscape and over time. Each project is reviewed individually and the process does not consider the possibility of one project located in the same area as another potential project. As a BLM Staff Member stated, “When you're looking at an application, you can easily look at what's already gone on and do a cumulative impact analysis on that, but what's difficult is predicting the future.”[593] Tribes and environmental groups have voiced concerns over the BLM’s inability to address cumulative impacts due to the many solar applications submitted within a narrow time frame, with, each being assessed only for individual impacts. If development proposals occurred singly and over a longer period of time, the impacts of adding each new facility could be analyzed. The Solar PEIS may be looking at cumulative impacts inside the designated SESAs; however, this will not apply to previously proposed projects not in SESAs.

Public Engagement

An effective process will go beyond the minimum requirements for public participation outlined in NEPA to ensure that affected parties are involved, local concerns are heard, meaningful participation is achieved, and any concerns are addressed early in the process before decisions are made.

1. Use of the NEPA Process

The application of the NEPA process to proposed solar facilities ensures consideration of a set of alternatives and environmental protection. It also requires agencies to offer public participation opportunities, including commenting at many stages throughout the process.

2. Inefficient Public Communication

The lack, or perceived lack, of communication between the BLM and the public has been noted by tribes, citizens groups, and a local government. It is important for the BLM to announce public participation opportunities, to educate the local stakeholders, and receive feedback regarding the proposed facilities. While the BLM has held multiple scoping meetings for the Solar PEIS and individual projects, many groups remain unaware of these opportunities. Based on responses to a survey of organizations, the most popular form of public participation was attending a public scoping meeting for an individual project. The groups that did not take part in any form of public commenting responded that they were “unaware of participation opportunities.”

The results of the stakeholder survey show that local residents are not taking the opportunity to participate in the process, with only 17 percent of respondents participating. Of those residents who participated in the process, the most popular form of participation was attending a public meeting held for an individual proposed solar project (Figure 10.4). When asked why they did not participate, 74.5 percent of residents indicated that they were unaware of participation opportunities (Figure 10.5).

Further analysis of the results indicated that residents younger than 40 years old have a higher likelihood of being unaware of participation opportunities. Residents over the age of 60 may be more aware of participation opportunities, however they are also more likely to think that their opinions are irrelevant or will make no difference (Figure 10.6). In order to test the statistical significance of this trend, we used a chi-square test for independence, and calculated the p-value to be 0.00016. This result indicates that there is a connection between age group and rationale for not participating in the

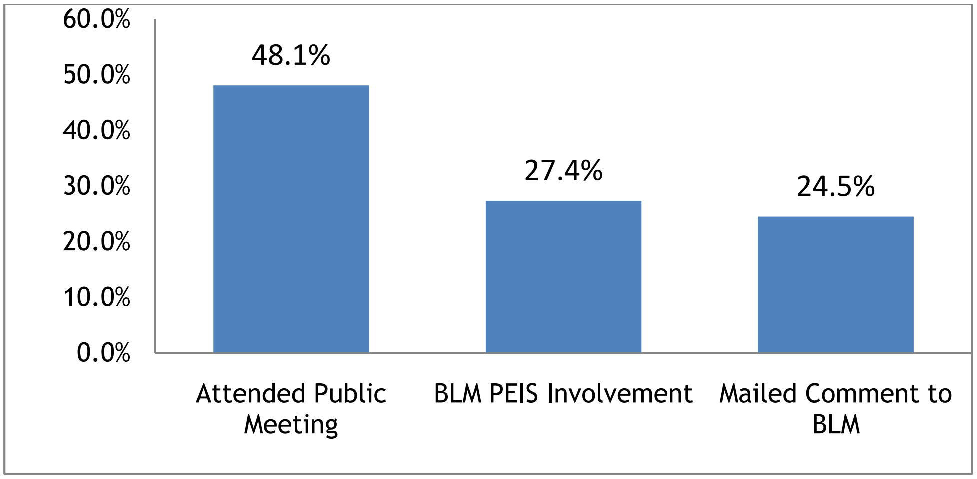


Figure 10.4 Forms of Participation by Residents who Participated in the BLM Process.

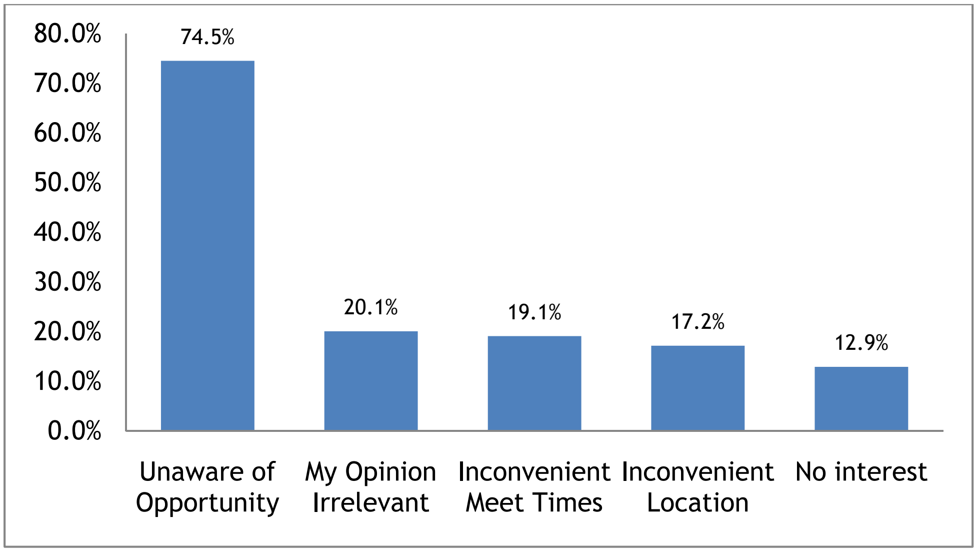


Figure 10.5 Reasons for Not Participating in the BLM Process.

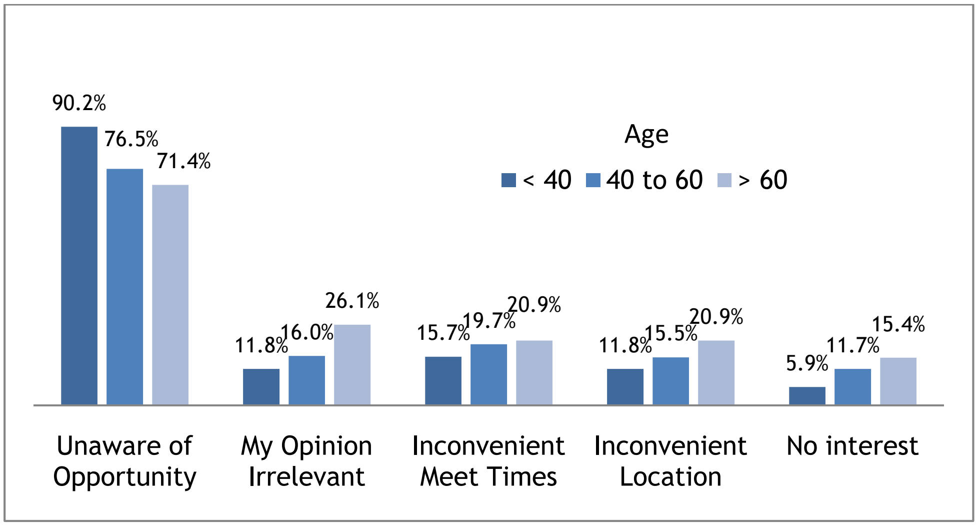


Figure 10.6 Reasons Given for Not Participating in the BLM Process by Age.

process: the older respondents were, the more aware they were of participation opportunities, but the less they believed their opinion would make a difference. The results of both surveys indicate that the BLM has not effectively communicated opportunities for stakeholders to participate in the process.

3. "Fast Track" - Too Fast?

The truncated timeline for the environmental analysis of "Fast Track" projects is a source of concern among environmental organizations. Similarly, the truncated timeline is of concern to a citizens group and an environmental organization who noted that the BLM is ignoring information requests, scheduling scoping comment deadlines next to holidays, and scheduling multiple scoping meetings at the same time, making it impossible to attend them all.

ANALYSIS OF ALTERNATIVE PROCESSES

There are many types of resource extraction already taking place on public lands, including wind energy, cattle grazing, timber harvesting, mining, and oil and gas drilling. Proposed projects for each of these land uses have a different permit application process within the BLM. Solar energy facilities currently utilize the right-of-way process; however, the Solar PEIS is considering changes to this process. We completed a comparative analysis, using the same set of normative criteria as the solar process analysis, of two processes used for energy generation: the wind energy right-of-way process and the oil and gas leasing process. The comparative analysis of these two processes builds off the results of the solar process analysis by identifying components which could offer solutions to weaknesses identified in the solar process. Both BLM staff and the public are familiar with these established processes and incorporating some or all of either of these processes into a new solar process could feasibly be considered. Key components of all three processes are summarized in Table 10.2.

Onshore Oil and Gas Resource Leasing Process

Based in the General Mining Act of 1872 and the Mineral Leasing Act of 1920, the BLM's process for leasing onshore federal oil and gas resources has been in place for decades and is well established, though some changes have occurred in these acts. This process is distinct from ROW processes used for solar and wind energy development because it deals primarily with subsurface property rights instead of surface rights.

Process Background

For each BLM field office with oil and gas resources, BLM-managed lands within the field office are first declared open or closed to drilling through the Resource Management Plan (RMP) process. In the RMP process, the BLM analyzes reasonably foreseeable oil and gas development and spells out stipulations

Table 10.2 Processes Comparison Matrix

	Wind	Oil & Gas	Solar
Type of Process	Right-of-Way	Lease	Right-of-Way
Site Competition	First-Come, First-Served; Second application rejected	Competitive bidding	First-Come, First-Served; Second application held in queue (TBD in Solar PEIS)
Application Processing Timeline	Site-testing ROW: 30-90 days; Development ROW: ~2 years (for full EIS)	Varies based on project size	~18 Months
Length of Lease or ROW	Varies by project, generally 30 years with possible renewal	10 years with possible renewal	Will vary by project, generally 30 years with possible renewal
Fees	**3-year study grant:** $1,000 or $1/acre whichever is larger; **Development grant:** $4,155/MW of installed capacity	**Rental:** $1.50/acre for 1st 5 years; $2/acre every year after; **Royalties:** based on amount of resources extracted and determined by state office	**Current:** Rental fee based on fair market value of land; **Future:** TBD in Solar PEIS
Mitigation Guidance	Included in Wind PEIS (excluding CA & AZ)	Varies by State BLM Office	TBD (may be included in Solar PEIS)
Adaptable to Multiple Technologies	N/A	No	Yes
Set of NEPA Alternatives	**EIS** - 3 Actions 1. No Action 2. Proposed Action 3. Approve with Modifications **EA** - 2 Actions 1. Approve 2. Deny	**APD EIS** - 3 Actions 1. No Action 2. Proposed Action 3. Approve with Modifications -OR- Defer Action	**EIS** - 3 Actions 1. No Action 2. Proposed Action 3. Approve with Modifications

to attach to leases.[594] The RMP process includes a full NEPA analysis and a corresponding EIS. Once the RMP is adopted, a parcel can be nominated for leasing, and if the parcel is congruent with the RMP, the BLM attaches appropriate stipulations and brings the parcel to a lease sale.[595] Lease sales, which typically happen quarterly and are conducted by the state BLM office, are competitive. The lease is for a period of 10 years, and is a conveyance of the property right for the subsurface estate in the given parcel. If a parcel is nominated and brought to the lease sale but receives no bids, it can be leased non-competitively after the sale.[596]

As the lease sale is a conveyance of the property right for the subsurface estate, the leaseholder must then file an Application for Permit to Drill (APD) to gain permission to place infrastructure on the surface and to engage in resource extraction.[597] Additional project-level analysis then occurs. For large projects, a full EIS is produced, but for smaller projects where the BLM feels the impacts of the proposed drilling has already been accounted for in the RMP process, a Documentation of NEPA

Adequacy (DNA) statement is issued. When granting an APD, the BLM attaches Conditions of Approval, which are additional stipulations dealing with surface management issues, and then approves, approves with modification, denies, or defers action on the application. Once granted, an APD is valid for 2 years, or until the lease expires, whichever comes first.[598]

Additional requirements exist for oil and gas drilling. The leaseholder must pay rental fees of $1.50 per acre for first 5 years of the lease, and $2 per acre every year after, whether or not the lease is in production.[599] Royalties, collected by the Minerals Management Service, must be paid of resources extracted and are shared by the federal and state governments. Bonding is also required to fund the reclamation of the disturbed lands. Reclamation begins as soon as possible after drilling ends and continues until the BLM determines reclamation efforts successful. Each BLM state office has established standards for environmental mitigation to provide uniformity across the state offices. Specific mitigation standards are attached to APDs and put in through the project-level EIS or DNA.

Implications for Solar Facilities

Many strengths of the oil and gas leasing process could, hypothetically, be applied to solar facilities (Table 10.3). One strength, use of the NEPA process, already exists in the solar process. Another, process familiarity, comes with time. Other aspects would not be as easily transferable.

Table 10.3. Process Evaluation of Positive Implications for Solar in the Oil and Gas Leasing Process.

Efficiency	•Competitive Leasing •Process Familiarity
Clarity of Process	•Land Rental and Royalty Fees
Robust Set of Options	•Use of the NEPA process
Environmental Protection	•Use of the NEPA process
Spatial or Temporal Scale	•Identification of Open and Closed Areas
Public Engagement	•Use of the NEPA process

The land use planning process for portions of the CDCA or for the CDCA as a whole could identify areas open and closed to solar development, allowing for spatial scale considerations. Legally prohibited or other high conflict areas could be excluded at this stage, leaving no ambiguity for solar developers. Parcel nomination could likewise be applied to solar development if a competitive lease or competitive ROW process was adopted.

With a direct application of the oil and gas leasing process, solar developers would be required to obtain a lease for land through competitive bidding, then submit a POD and wait for approval for the actual facility, similar to an APD. This could present some challenges. If the BLM sold a lease for an area and then did not approve the developer's proposed solar facility, the BLM could not revoke the lease and sell it to a different company. This would be taking of property, prohibited under the 5th Amendment to the Constitution. A lease of the surface estate in place of a ROW easement would also prevent the continued management the land by the BLM for the term of the lease. This is a likely reason BLM uses a ROW process for surface rights. A competitive ROW process may be more favorable than a competitive lease sale. Whether a lease sale or ROW is used, the length of the lease or ROW would have to be appropriate for solar facilities, likely longer than the 10-year term used in oil and gas. Once the lease or ROW is granted, an EIS would be needed for the proposed solar facility before the facility could be approved.

As with the oil and gas leasing process, rental fees, reclamation bonding, and environmental mitigation standards are needed for solar development, either at the national or state levels. This would reduce uncertainty for developers and BLM staff. BLM does not have the authority to assess royalties based on energy production on public lands, but could base rental rates on total installed capacity of a solar facility.

Integration with Other Processes

If the oil and gas leasing process were to be applied to solar facilities in California, the process would need to be integrated with other approval processes. During the land use planning process and designation of open and closed areas, it would be necessary for the BLM to consult with the CalISO to ensure that access to the transmission grid is feasible from the areas designated open for solar, likely requiring one or more system impact studies. Because an additional EIS (beyond the EIS for the land use planning process) is likely to be required for all utility-scale solar facilities, the CEC process would be able to work in parallel with this project-level EIS, much like the current application of the ROW process for solar.

Wind Energy Right-of-Way Process

The DOI completed a Wind PEIS in June 2005 and issued a ROD in January 2006. These documents determined that wind energy development on public lands would utilize a standard ROW process with wind specific requirements. To date, the BLM has approved 28 wind development projects nationwide with a total generation of 437 megawatts.[600]

Process Background

For a typical wind project a 2800-14 ROW form is submitted for a 3-year project area grant with the possibility for renewal.[601] This short-term ROW grant allows the developer to test the wind energy potential of the site. An environmental review is required for these short-term ROW grants under NEPA; however, they do not need to include an analysis of wind energy facility impacts.[602] The review is limited to the scope of the meteorological towers and sonar equipment necessary to test for wind potential. A POD is also required before the end of the 3-year ROW grant and the developer is assessed an annual fee of $1,000 or $1 per acre, whichever is larger.[603] If the developer determines that a site has sufficient wind energy potential, they must submit another 2800-14 ROW form and POD for a long-term utility-scale wind project.[604] This development application also has a broader NEPA scope to determine compliance with the ESA, the Migratory Bird Act, and the NHPA. This environmental review can utilize information gathered in the Wind PEIS. Therefore, an Environmental Assessment (EA) may be sufficient rather than a full EIS.[605] An EA is a less detailed environmental impact analysis to determine if a full EIS is needed for a project. The annual rent assessed to developers is $4,155 per MW of total anticipated installed capacity.[606] Both of these processes are subject to cost-recovery bonding with the BLM.

Included in the Wind PEIS is a set of policies and BMPs that provide information and action requirements for developers and application processing instructions for land managers. Specifically, the policies require BLM staff to consider visual resource impacts and to consult with the DOD, the SHPO, tribes, and the FWS regarding conflicts and concerns.[607] A policy also requires developers to include all BMPs in their POD. BMPs are adopted for each step in a project's life span: site monitoring and testing, POD preparation, construction, operation, and decommissioning. They attempt to mitigate a wide spectrum of concerns including land-use conflicts, obstruction or disruption of visual resources, creation of roads, generation of harmful air emissions, increased ground transportation, disturbance of cultural and historic resources, noise creation, and harm to wildlife and ecological resources.

Table 10.4. Process Evaluation of Positive Implications for Solar in the Wind ROW Process.

Efficiency

- Processing Instructions for BLM
- ROW process familiarity

Clarity of Process

- Information Requirements for POD
- Developer Guidance through BMPs
- Processing Instructions for BLM
- Royalty Fee Based on Energy Production

Robust Set of Options

- Use of the NEPA process

Environmental Protection

- Developer Guidance through BMPs
- Use of the NEPA process

Public Engagement

- Use of the NEPA process

Implications for Solar Facilities

The process for wind energy facilities is similar to the current process for solar in that they both cause surface disturbance and utilize ROW grants and the NEPA process. However, the Wind PEIS instituted positive changes to the standard ROW process that the Solar PEIS may incorporate (Table 10.4). While wind energy projects need large amounts of land, 17 acres per MW on average, it allows for multiple land uses whereas solar facilities necessitate large scale surface disturbance and do not allow for other land uses within the facility boundary.[608]

The Wind PEIS provides information requirements for PODs, which developers must follow, adding to the clarity of the process. This provides detailed guidance to developers and a checklist of information for BLM staff to use to analyze the completeness of an application, increasing efficiency of processing. In addition to the POD requirements, the Wind PEIS established a set of BMPs, which provide further guidance to developers on information needs and expected conduct throughout the life span of a facility. These BMPs are a management tool for the BLM to enforce standards of on-site environmental mitigation.

Wind developments are not subject to the regular ROW land rental assessment, which is based off of fair market value for the land. Instead, the Wind PEIS introduced a royalty fee for annual energy production. The BLM uses an equation to assess the fee which includes the nameplate capacity of the facility, the capacity factor, the federal rate of return, and the average price of electricity. A similar equation could be used for future solar facilities instead of assessing a lease fee based on acreage. A final change made to the standard ROW process by the Wind PEIS was the inclusion of policies which dictate necessary consultations between the BLM and other agencies, including DOD, SHPO, and tribes. This provides a framework to ensure affected stakeholders have input during the process of analyzing each application.

While the Wind PEIS provided many positive changes, it did not solve the issue of land speculation. The solar process is first-come, first-served, which prevents the BLM from choosing the best proposed project in terms of megawatts produced, size of ecological footprint, and socioeconomic impacts. This concern also applies to the wind process since once an application has been received for a tract of land, a second application will be rejected without consideration.

Integration with Other Processes

An application of the Wind PEIS to solar facilities would not require significant changes in other agency’s processes. There is not a parallel CEC process for new wind facilities. However, as the wind utilizes ROW grants, an integration framework has already been established for the BLM and CEC processes. Wind energy projects already complete CalISO required studies for integration with the electric grid and sign PPAs with a utility, identical to solar energy projects.

CHAPTER 11 | RECOMMENDATIONS

Our research and analysis reveals the many complexities, controversies, and uncertainties that exist within the issue of solar development in the California desert. Despite these challenges, state and federal administrations, solar developers, and renewable energy advocates are exerting pressure on regulatory agencies to finalize the processes necessary to move development forward. Given the unknown impacts of solar development, an adaptive management approach, which includes BMPs and mitigation requirements, should be carefully and thoughtfully developed. An adaptive management approach might require a slower pace of development with a high level of monitoring of constructed facilities in order to measure the true efficacy of BMPs and mitigation measures. If BMPs and mitigation measures are found to be ineffective, the management plan should then be adapted to address these deficiencies.

We have developed recommendations based on our findings, which can be used to establish a siting, development and implementation process that can proceed deliberately and adaptively. Our recommendations aim to improve the solar facility approval process, address potential ecological impacts, and support continued growth of the distributed generation market. We have also identified areas in need of future research.

Table 11.1 Recommendations for the BLM Process Based on Evaluation Criteria.

Efficiency
- Establish Authority to Reject Applications

Clarity of Process
- Define Environmental Mitigation Measures
- Establish a Rental Rate
- Establish Payments to Affected Communities
- Provide Guidance for SF-299 and POD
- Establish a Clear Process

Robust Set of Options
- Analyze Distributed Generation

Environmental Protection
- Establish a Land Use Efficency Standard
- Define Environmental Mitigation Measures
- Establish Alternative Mitigation Measures
- Ensure Effective Mitigation
- Evaluate and Establish BMPs

Spatial or Temporal Scale
- Designate Potentially Available and Closed Areas

Public Engagement
- Increase Public Involvement

RECOMMENDATIONS FOR THE BLM

Based on our analyses of the environmental and visual impacts (Chapters 5, 6, and 7), socioeconomic impacts (Chapter 8), and community attitudes (Chapter 9) regarding solar development, along with the analysis of the BLM ROW process for solar and wind development and the oil and gas leasing process (Chapter 10), we developed recommendations for improving the BLM process for evaluating solar development and siting individual solar facilities in the California desert (Table 11.1). These recommendations are meant to address concerns of potential environmental impacts, predicted socioeconomic consequences, and deficiencies identified in our evaluation of the solar ROW process. Many of these recommendations are also based on the strengths of the wind ROW and oil and gas leasing processes. As the BLM evaluates solar development on its lands through the nationwide Solar PEIS, we recommend the following actions be taken and components be added to the evaluation of solar development and the permitting process.

1. Analyze Distributed Generation vs. Utility-Scale Generation

Determining how the nation will go about increasing production of energy from renewable sources is a major public policy decision. At the heart of this question is not simply the issue of siting utility-scale solar energy facilities, but also how the government should promote and incentivize solar energy production. While it may not be within the jurisdiction of the BLM, an agency of the federal government should conduct a comprehensive analysis comparing the energy production potential, land requirements, and environmental and socioeconomic impacts of distributed generation and utility-scale generation. In doing so, the government and the public will be better able to make critical decisions regarding how and if these types of solar generation facilities should be promoted. This recommendation does not apply to the BLM process for assessing individual facilities; however, it is important that this study be conducted before development begins.

2. Designate Closed and Potentially Available Areas

The BLM should designate areas as either “potentially available” or “closed” to solar development, so as to eliminate any ambiguity about which areas are appropriate for solar facilities. Legally delineating geographic units as closed for solar development would enable the BLM to automatically eliminate applications for projects in these areas. An area designated as “potentially available” could be developed for solar energy; however the right to develop that land would not be automatic. Proposed projects must still undergo a full process evaluation to ensure suitability at the proposed site. Designating potentially available solar energy zones would give developers more certainty about areas to be studied for facility location proposals, though all site conflicts would not be eliminated by these area designations. For example, our analysis shows that SESAs could be designated as areas potentially available for development as they appear to have lower ecological and visual impacts.

For consistency across field offices, potentially available solar energy zone and closed area designations should be coordinated across the CDCA and would require amendments to all affected RMPs. Any future changes to these designations would occur through the RMP amendment process.

In designating potentially available solar energy zones and closed areas, the BLM will likely have to justify each area's designation. Potentially available solar energy zones should include those places with the least amount of known conflict and that are nearby to existing or planned transmission and other necessary infrastructure, such as roads. Closed areas should include all areas that are legally incompatible with utility-scale solar development, areas where a high conflict with existing uses or management designations is present, and other areas that are otherwise inappropriate for solar energy development. These closed areas would include, but not be limited to: Wilderness areas, WSAs, Wild and Scenic Rivers, National Monuments, National Trails, ACECs, DWMAs, critical habitat areas, special management areas including Mojave Ground Squirrel Conservation Areas and Flat-tailed Horned Lizard Management Areas, and areas containing significant cultural or historical resources. Other areas that may be appropriate for closure include Class L lands, LTVAs, OHV open areas, and other areas of high-conflict as identified by the BLM field, district, or state office.

3. Establish Authority for BLM to Reject Applications

The BLM should be given the ability to reject applications that are inappropriate due to land use conflicts, regardless of whether or not the recommendation to create potentially available and closed areas is adopted. The BLM should also be able to reject applications that remain incomplete even after the applicant has been notified and given the opportunity to correct any discrepancies. To make this rejection process transparent, standard criteria for rejecting an application should be developed and published. Criteria for rejecting applications should include failing to meet land and water use efficiency standards (Recommendation 4), failing to adhere to all published deadlines for application materials, and proposing facilities on critical habitat, ACEC, DWMA, special management area, or other incompatible area. The BLM should still notify applicants of application deficiencies and allow them 60 days to make changes to the POD and resubmit. With clearer application criteria, developers would have a better understanding of what standards their applications must meet, while still being encouraged to consult with the BLM to ensure any conflicts or information gaps are resolved as best as possible.

4. Establish Efficiency Standards for Solar Technologies

The BLM should establish minimum land use and water use efficiency standards for all proposed solar projects in the Southwest U.S. Although environmental groups have concerns about inefficient technologies with large footprint sizes and water demand, the BLM has no authority to dictate types of solar technologies for proposed projects. By establishing these standards the BLM will have an additional criterion for rejecting applications. The DOE, familiar with solar technology development and research, should develop this standard. The standards should be suitably high to effectively deny solar applications with technologies that are grossly inefficient.

Furthermore, efficiency standards will incentivize solar developers to propose more efficient technologies, such as dish/engine or power tower, and solar companies to develop more efficient solar technologies. Solar developers are currently incentivized to use parabolic trough technology because it is proven and investors are comfortable with proven technologies. However, our land use analysis showed that parabolic trough is one of the least land-use-efficient technologies with an average efficiency of 372 MW produced per acre disturbed. Meanwhile, dish/engine systems have a high land use efficiency with 923 MW produced per acre disturbed. Additionally, our water use analysis also showed that parabolic trough is one of the least water-use-efficient technologies with an average efficiency of 1,071 gallons of water consumed per MWh. Dish/engine systems appear to be highly efficient with four gallons of water consumed per MWh. The tools we developed for calculating the land use and water use efficiencies of a proposed solar energy facility, or their equivalent, should be used to calculate the efficiencies of each new project proposal once standards have been set.

5. Define Effective Environmental Mitigation Measures

Mitigation is required for projects on public lands to offset development impacts to natural resources. Environmental, citizen, tribal, solar industry, and recreation groups have all raised concerns about yet to be determined mitigation standards for solar projects. It is necessary for the BLM to define these mitigation standards which guide whether a facility site can be suitably mitigated, how much private land must be acquired to compensate for impacts to particular species, and quality of mitigation land.

Solar facility applications consistently state that BMPs and mitigation measures will render all ecological impacts of the facility “less than significant.” However, determining the amount of mitigation necessary to render impacts “less than significant” is difficult. The processes for determining the impact of the facility and the amount of land or money that would be necessary to reduce that impact is both subjective and expensive. The amount of land purchased or the amount of money set aside for mitigation is often negotiated among agency and developer representatives, and sometimes other interested stakeholders; as a result, these negotiations are often political in nature and not based on ecological knowledge.[609] In the California desert, developers must currently fulfill mitigation requirements for impacts to special-status species, which includes the desert tortoise, western burrowing owl, Mohave ground squirrel, and flat-tailed horned lizard. However, these ratios are not standardized and are different across regulating agencies such as the BLM, DFG, and FWS. Some examples from solar applications are:

- Desert tortoise mitigation ratios = 3:1, 1:1, and 0.5:1 (in acres).
- Western burrowing owl mitigation ratios = 6.5 to 19.5 : 1 (in acres) or 2:1 (in burrows).
- Mohave ground squirrel mitigation ratios = 2:1 and 0.5:1 (in acres)

Clear, standardized, and publicly available environmental mitigation ratios would allow developers to better predict future mitigation costs and allow BLM staff to establish a standard implementation and enforcement process for mitigation.

Additionally, while agency mitigation ratios can help guide land purchase decisions, they do not give adequate consideration of land quality. Whether it is even possible for mitigation measures to reduce the ecological impact of development to levels that are “less than significant” is addressed even less frequently. Therefore, the BLM should establish suitably high standards for the quality of mitigation land as well as define “less than significant” and evaluate whether each proposed facility site can successfully mitigate impacts to this level. Facility locations that can’t meet this mitigation level should not be given approval for development.

6. Establish Alternatives to Acquisition-Based Mitigation

Given a likely shortage of suitable mitigation land, the BLM should establish alternatives as a complement to the traditional strategy of acquisition-based mitigation. Large solar facilities may require developers to acquire a substantial amount of mitigation land. One solar application determined that a total of about 215 acres would be needed to mitigate impacts to desert tortoise and Mohave ground squirrel. In another application, the developer determined that two-thirds of the mitigation requirement could be met by acquiring no less than 8,146 acres of land.

Considering that many utility-scale solar facilities could be sited in the California desert, and that many facilities will seek to acquire land for mitigation purposes, it is easy to imagine a shortage of suitable mitigation land. As Amy Fesnock, the Endangered and Threatened Species Lead for the California BLM, notes:

> “When we’re the looking at the amount of projects currently proposed, there isn’t that much land with willing sellers to be purchased, and I think we have to begin to assess whether it is possible for us to actually mitigate the impacts of those projects on the land that we already have.”[610]

Suggested alternative mitigation strategies include funding research, restoration, agency staffing, and education. However, if a developer chooses to use one or more of these suggested alternative mitigation strategies, it is important that the specific use of funds must actually mitigate impacts by improving the status of sensitive species and habitats.

Research

In lieu of land acquisition, developers could give funds to be used for researching the California desert. In our interviews, desert scientists emphasized the high level of uncertainty in understanding impacts of utility-scale solar development on the desert ecosystem. Says Debra Hughson, Science Advisor for the Mojave National Preserve, “Our understanding is vastly dwarfed by the things that we don’t know, and even the things that we think we do know, sometimes the correlations are pretty poor, and the uncertainty is very broad.”[611] Many scientists echoed this sentiment. Mitigation funding could go towards biological surveys of the desert and answering fundamental questions about presence/absence, abundance, and location of desert species.

Restoration

Mitigation funds could also go towards improving the quality of existing habitat. Suggestions include:

- Removal or control of invasive species;
- Reclamation or restoration of degraded habitat (e.g., abandoned agricultural areas, old grazing allotments, and illegal OHV areas) on BLM land;
- Mitigation of existing barriers to migration (e.g., highways).

Some solar facility applications include a statement about funding provided by the developer for restoration of the facility site upon the decommissioning of the facility and removal of infrastructure. We recommend that this be required of all facilities in the application process.

Staffing

With such a large area to manage and in an age of budget cuts, agencies are continually asked to take on more responsibility with fewer resources. Mitigation funding could fund individuals at the BLM and FWS who are specifically charged with protecting biological resources against illegal use in special designation areas. Areas that might benefit from increased enforcement include ACECs, DWMAs, WSAs, Wilderness Areas, and Critical Habitat.

Education

Mitigation funding could go towards educating California desert residents and visitors. Education efforts could help residents and visitors gain a better general understanding of the desert ecosystem and the benefits it provides to people. Such efforts might also reduce accidental or purposeful harm to desert flora or fauna.

7. Ensure Effective Mitigation

The BLM should ensure that any adopted alternative mitigation measures, including the above recommended measures or others, are effective. It is difficult to know how much research, restoration, additional staff, and education would be needed to adequately mitigate the impacts of a single solar facility, let alone the cumulative impacts of multiple solar facilities and associated infrastructure like roads and transmission lines. An independent economic analysis of the value of the resources at each individual facility is necessary to determine parameters for the proposed alternatives. If multiple facilities are to be developed, the economic analysis should consider cumulative impacts to be mitigated as well, especially from associated disturbances like roads. In addition, funds set aside for alternative mitigation must be used effectively. An assessment team or task force, partnering with the BLM, should define desired results, and evaluate and monitor the implementation and impact of alternative mitigation. Evaluation and monitoring should occur on a regular basis so that the effectiveness of these measures can be improved upon and the financial contribution of developers can be adjusted accordingly.

8. Establish a Rental Rate Based on Installed Nameplate Capacity

Because solar energy is a natural resource that, similar to wind and oil and gas, will be extracted from federal lands, solar development should not use the standard ROW land rental fee. Instead, the BLM should assess an annual land rental fee based on total installed nameplate capacity. A rental fee should be assessed using the following formula:

Annual Rental Rate = (Anticipated total installed capacity in kilowatts on public land as identified in the approved POD) x (8760 hours per year) x (capacity factor) x (5.27 percent federal rate of return) x ($0.03 average price per kilowatt hour)

This rate is based on the current annual rental rate for wind development rights-of-way. The rental rate will be phased in with 25 percent of the total rental fee due the first year, 50 percent due the second year, 75 percent due the third year, and 100 percent due the fourth year and every year thereafter. The capacity factors that the calculation uses should be determined for each facility.

9. Establish Payments to Affected Local Communities

Generally, solar development will have few negative socioeconomic impacts. However, California desert residents living in proximity to development will bear the brunt of these negative impacts. For example, it may be necessary for construction vehicles to pass through downtown areas to get to project sites, thereby increasing local traffic and dust emissions in these urban centers. Facilities may also affect the community’s viewshed, which may decrease the quality of life for nearby residents. Although communities near solar development will arguably be most affected, there is not currently a program for compensating these residents. The BLM should develop a funding program whereby a portion of facility rental payments is distributed among nearby communities to aid funding for public services.

10. Provide Guidance for SF-299 and POD Document Completion

One major cause of delay in the project application process is incomplete SF-299 or POD documentation, which requires BLM staff to request missing information and to review documentation. To alleviate this problem, the BLM should provide clear guidance on the content and level of information needed in an SF-299 and POD. The Wind PEIS, which created a set of policies and best management practices and mandated what information was necessary in an application, may be used as a model. Developers would then know the extent of information and level of detail required, thereby placing the burden on them to file complete applications. Additionally, BLM staff would be able to determine the seriousness of an application based on whether the developer has followed the guidance.

11. Increase Public Involvement

It is important to educate local residents regarding the proposed facilities. This provides the BLM and developer with feedback on local community concerns that should be incorporated into the project design or EIS. The stakeholder survey showed that desert residents are generally supportive of solar development, which is surprising given that many communities strongly oppose industrial development which would negatively impact their quality of life. This support may be the result of misconceptions regarding socioeconomic benefits, such as jobs and cheaper electricity, which are not likely to happen. Therefore, stakeholder outreach and involvement need to be better incorporated into the decision-making process.

However, based on the stakeholder survey, 74.5 percent of residents are unaware of opportunities to submit comments to the BLM on local concerns, 19 percent of residents are unable to attend a meeting due to inconvenient times, and 17 percent of residents are unable to attend meetings due to inconvenient locations. The BLM must increase public outreach and promote public involvement above and beyond the current minimum NEPA requirements. As the survey indicated, 85 percent of residents receive information from television and radio and 82 percent from newspapers. Therefore, the BLM should solicit public involvement through announcements in TV news media and local newspapers. Multiple public hearings should be held at different times of the day in communities within the vicinity of a proposed project, allowing residents with scheduling conflicts an opportunity to participate.

12. Establish a Clear Process

Whether through the Solar PEIS process or independently, the BLM should establish an open process that is well defined and easily understood by BLM staff, developers, and interested stakeholders. The updated or newly established process will likely be refined as it is applied multiple times to process all applications, as is currently occurring with the solar ROW process. Despite knowing that the new process will likely not be perfect or please all stakeholders, standards can and should be developed to increase processing clarity and efficiency for both the BLM and developers.

13. Evaluate and Establish Best Management Practices

Once permitted, solar developers will need to abide by several federal, state, and local environmental laws, ordinances, regulations, and standards (LORS). These LORS include the ESA, Migratory Bird Treaty Act, Clean Water Act, and CEQA. Biological Resources Best Management Practices, or BMPs, are on-site impact avoidance and/or minimization measures that are intended to reduce impacts to sensitive biological resources and aid in compliance with LORS. Currently, there is no formal guidance provided by the BLM on BMPs for solar developers. Therefore, some developers are proposing BMPs designed with general construction and facility operation impacts in mind. The BMPs being proposed need to be evaluated for effectiveness and the BLM should establish a standardized set of BMPs to provide clarity to developers and ensure minimal impacts to biological resources.

As an example, we sampled six solar facility applications and evaluated 35 of the proposed BMPs for their effectiveness in the context of the California desert. Our objective was to focus on the types of BMPs that are being considered, not to highlight individual projects. BMPs were not attributed to specific facilities, though some language from the applications is used here for the purpose of description. BMPs were placed into one of three categories: green (●), yellow (▲), or red (■). If a BMP received a green rating, it was considered to be an effective BMP (i.e., have a high likelihood of reducing ecological or biological impacts from development), with a low likelihood of unanticipated impacts and which the BLM should adopt. A yellow rating was given to BMPs that had potential to be effective, but had a medium likelihood of unanticipated impacts; the BLM needs to improve such BMPs or needs more information or clarification to evaluate it. A red rating was given to BMPs with a high likelihood of unanticipated impacts and/or ineffective reduction of ecological or biological impacts. The BLM should not adopt BMPs which received a red rating and should require developers to use an alternative BMP.

BMPs and ratings are presented in Table 11.2. BMPs with yellow and red ratings have comments attached which explain why that rating was given as well as suggestions for alternatives. We also commented on BMPs that were given green ratings and could be useful to all solar facilities, but were only found in few applications. Overall, areas where proposed BMPs should be improved by the BLM include:

- Preventing or reducing the establishment and spread of invasive plants in disturbed areas.
- Preventing or reducing indirect mortality of desert tortoise and other wildlife.
- Monitoring the effectiveness of BMPs and allowing for adjustment if inadequate or ineffective.

Table 11.2 Best Management Practices.

ID #	Type of BMP	BMP	Rating	# of Facilities with BMP (of 6)	Comments or Concerns	Suggestions for Alternatives
01	Personnel	Worker Environmental Awareness Program/Training	●	5		
02	Personnel	On-site Designated Biologist(s), Authorized Biologist(s), and/or Biological Monitor(s)	●	6		
03	Pollution	Fueling of equipment will take place within existing paved roads and not within or adjacent to drainages or native desert habitats. Contractor equipment will be checked for leaks prior to operation and repaired as necessary.	●	3		(a) Pre-construction surveys for contaminants in drainages and off-site, “downstream” runoff areas. (b) Monitoring of drainages and off-site, downstream runoff areas during construction. (c) Adjust BMPs if BMPs are not adequately preventing/minimizing contamination.
04	Pollution	"All vehicles and equipment will be in proper working condition to ensure that there is no potential for fugitive emissions of motor oil, antifreeze, hydraulic fluid, grease, or other hazardous materials…contaminated soil will be properly disposed of at a licensed facility."	●	5		
05	Pollution	Will use BMPs to minimize contamination of water or ephemeral drainages from construction site runoff.	▲	2	Need more information on what BMPs will be utilized.	
06	Pollution	Avoid use of toxic substances for road surfacing, road sealants, soil bonding and weighting agents.	●	1	Concern that only one project out of six mentions this BMP.	
07	Soil and Vegetation	"The anticipated impact zones...will be delineated with stakes and flagging prior to construction...Construction-related activities outside of the impact zone will be avoided."	●	4		

● - Effective ▲ - Potentially Effective ■ - Ineffective

ID #	Type of BMP	BMP	Rating	# of Facilities with BMP (of 6)	Comments or Concerns	Suggestions for Alternatives
08	Soil and Vegetation	"Spoils should be stockpiled in disturbed areas presently lacking native vegetation."	▲	2	Concern about the establishment of invasive plants on stockpiled spoils.	(a) Cover the stockpile with tarp(s) or similar to prevent establishment and growth of invasive plants. (b) Monitoring and physical removal of invasive plants.
09	Soil and Vegetation	"New and existing roads that are planned for either construction or widening will not extend beyond the planned impact area."	●	3		
10	Soil and Vegetation	All vehicles will maneuver within the planned impact area.	●	2		
11	Soil and Hydrology	"BMPs will be employed to prevent loss of habitat due to erosion caused by project-related impacts." And/Or "Erosion and sedimentation control will be implemented during Project construction to retain sediment on-site and to prevent violations of water quality standards."	▲	4	Need more information on what BMPs will be utilized.	(a) Monitoring of soil/sediment runoff. (b) Adjust BMP if BMP is not adequately preventing/minimizing erosion and sedimentation.
12	Soil and Hydrology	"The solar fields shall be graded generally following the existing contours of the site to minimize the amount of ground disturbance."	●	1	Could also benefit site-level hydrology by minimizing alterations to water flow across the landscape.	

● - Effective ▲ - Potentially Effective ■ - Ineffective

ID #	Type of BMP	BMP	Rating	# of Facilities with BMP (of 6)	Comments or Concerns	Suggestions for Alternatives
13	Vegetation	"…working around all shrubs and trees within the construction zone to the extent feasible" and/or "special-status plant impact avoidance and minimization."	▲	2	We are concerned about the extent to which this BMP can actually be applied to a solar facility. Contrast this BMP with a statement from another project: "Avoidance of some special-status plants may be feasible during construction of the proposed project, but over the long-term, avoidance is not practicable because of the need to reduce the standing vegetation to prevent fire hazards and to maintain clear access to wash the...mirror arrays and otherwise operate the facility." Developers have indicated that fire is a potential hazard and that vegetation underneath the solar arrays will need to be cleared. Vegetation may also need to be cleared for installation of solar arrays and potentially kept clear for maintenance.	Because vegetation has several important ecosystem functions, including reducing wind erosion, dust emission, water erosion, and loss of soil moisture, there is value in retaining as much existing native vegetation as possible. (a) Appropriate buffers around solar arrays to prevent fire hazards and allow for maintenance should be developed. (b) Site plans should indicate areas where vegetation can be left, such as areas along the perimeter of the facility.
14	Vegetation	"A Weed Management Plan shall be developed and implemented to minimize the introduction of exotic plant species."	●	3		Plan should include monitoring of invasive plants in and around facility site.
15	Vegetation	The disturbance area "shall be maintained free from nonnative invasive plant species. This can be accomplished through physical or chemical removal and prevention. If necessary, application of an approved herbicide (non toxic to wildlife) shall be" applied.	■	2	We are concerned with the residual chemicals that could runoff the facility site and into the surrounding native habitat. Exposure to herbicides has the potential to kill or alter the species composition of soil crusts.[612] Though non-toxic to wildlife species, runoff containing herbicides could negatively impact native plants and soil crusts off-site.	The control and removal of invasive plants is still necessary. (a) The BMP should rely primarily on physical removal of invasive plants. (b) If chemical means are necessary, conduct comparative testing of herbicides to determine if some are non-toxic or less toxic to native plants and soil crusts than others. (c) Monitoring of "downstream" native plants and soil crusts for impacts of chemical runoff.

● - Effective ▲ - Potentially Effective ■ - Ineffective

ID #	Type of BMP	BMP	Rating	# of Facilities with BMP (of 6)	Comments or Concerns	Suggestions for Alternatives
16	Vegetation	“Preventing exotic plants from entering the site via vehicular sources shall include measures such as implementing Trackclean or other similarly effective methods of vehicle cleaning…Earth-moving equipment shall be cleansed prior to transport to the Project site.”	🟢	3		
17	Vegetation	“Preventing exotic weeds from entering the site via materials sources shall require that weed-free rice straw or other certified weed-free straw be used for erosion control.”	🟢	2	Concern that only two projects of six mention weed-free materials.	
18	Vegetation	Reclamation and restoration of temporary disturbance areas and/or reestablish vegetation quickly on disturbed sites.	▲	2	Need more information on methods for reclamation, restoration, and/or revegetation.	
19	Vegetation	"After Project completion, a seed mix of dominant plant species will be distributed within any extensive temporarily disturbed areas."	🟥	1	We are concerned that this will not aid in the establishment of native plant species. Considering that the estimated time for unassisted recovery of desert lands is hundreds of years, that complete ecosystem recovery is estimated to take over 3,000 years, and that invasive plants are better able to take advantage of habitat disturbances than native plants, we believe that it will likely take more than distributing seeds to ensure the recovery of native plants.[613,614] Resources might be wasted on a measure like BMP-19 when they could be better spent on more effective methods of habitat recovery.	(a) BMP should include a restoration plan for temporarily disturbed areas. (b) Plan should be implemented by a restoration ecologist. (c) Restoration efforts should use native and (if possible) local seeds to propagate plants. (d) Plants that have germinated (not seeds) should be used to increase the probability of successful plant re-establishment. (e) The restoration ecologist should monitor restoration efforts and employ adaptive management techniques to ensure successful restoration.

🟢 - Effective ▲ - Potentially Effective 🟥 - Ineffective

ID #	Type of BMP	BMP	Rating	# of Facilities with BMP (of 6)	Comments or Concerns	Suggestions for Alternatives
20	Fire	"Wildfires shall be prevented by all means possible by exercising care when driving and by not parking vehicles where catalytic converters could ignite dry vegetation. In times of high-fire hazard…trucks shall carry water and shovels or fire extinguishers in the field, and high-fire-risk installations (e.g., electric lines) shall be delayed. The use of shields, protective mats, or other fire-prevention equipment shall be used during grinding and welding to prevent or minimize the potential after fire. No smoking or disposal of cigarette butts shall take place within vegetated areas."	●	1	Concern that only one project out of six mentions a BMP to reduce fire hazards. This type of BMP should be adopted by other projects.	

● - Effective ▲ - Potentially Effective ■ - Ineffective

ID #	Type of BMP	BMP	Rating	# of Facilities with BMP (of 6)	Comments or Concerns	Suggestions for Alternatives
21	Desert Tortoise	"Water will be applied to the construction right-of-way, dirt roads, trenches, soil piles, and other areas where ground disturbance has taken place to minimize dust emissions and topsoil erosion." "During the desert tortoise active season, a Biological Monitor will patrol these areas to ensure that water does not puddle for long periods of time and attract desert tortoise, common ravens, and other wildlife to the site."	🟥	4	This BMP raises two concerns. While dust emission and soil erosion are both serious problems for a desert ecosystem, we are concerned that the application of water will facilitate the proliferation of invasive plants. Invasive plants are able to take advantage of both disturbed areas and water runoff from impermeable surfaces, including paved and dirt roads. The application of water as a dust suppressant may create ideal conditions for invasive plant growth, though we recognize the importance of minimizing erosion and dust emission. The four projects that discuss the application of water to ground disturbances acknowledge that standing water could attract desert tortoise or non-native predators, like common ravens. To prevent tortoises, ravens, or other wildlife from being attracted to these water sources, BMP-21 states that a Biological Monitor will patrol these areas during the desert tortoise active season to ensure that water does not puddle for long periods of time. While this may reduce the likelihood that desert tortoises may become accustomed to this anthropogenic water source, we are concerned about the potential for these practices to attract a resident population of ravens. Ravens could be attracted to the water source at any time of year, become established around the water source, and then prey on tortoises during their active season.	If the only way to control dust emission from construction areas is to apply water, (a) an invasive plant control program should be implemented for areas where water is applied to minimize the establishment of invasive plants in disturbance areas. (b) A Biological Monitor should patrol the areas where water has been applied at all times (instead of just during the desert tortoise active season). However, developers will likely not be able to prevent common ravens from being attracted to and established around the site. This impact likely cannot be minimized.

● **- Effective** ▲ **- Potentially Effective** 🟥 **- Ineffective**

ID #	Type of BMP	BMP	Rating	# of Facilities with BMP (of 6)	Comments or Concerns	Suggestions for Alternatives
22	Desert Tortoise	BMPs on desert tortoise site clearance surveys and relocation/translocation before construction.	🟥	5	While translocation can prevent direct mortality of desert tortoises from construction, it can sometimes be a cause of indirect mortality. Tortoise translocation in the California Desert has been characterized by a high-profile attempt by the Fort Irwin Army Base to translocate approximately 600 desert tortoises.[615, 616] In 2008, 27.2% of translocated tortoises died and in the following year 23.5% of translocated tortoises died, primarily from predation in both years.[617] Other reasons for translocation failures include extensive movement of translocated animals and homing behavior (i.e., attempts by animals to return to original habitats), inability of animals to locate food or water sources, and/or inability to find shelter in a new habitat.[618,619] Says Cameron Barrows, a researcher for the Desert Studies Initiative, "So what did we achieve? You feel better because we didn't let a bulldozer run over the tortoises, but all we did was move them someplace else where they often die anyway, and may spread disease to and disrupt the resident population." Under BMP-22, desert tortoise would be translocated (i.e., physically removed from the site) by a Designated Biologist to an off-site location. The number of individuals being translocated, the acreage of habitat being removed by the solar project, and the capacity of "new" habitats to support additional individuals are all important factors that influence the survival of translocated tortoises; these factors are not acknowledged by this BMP. Therefore, we are concerned that BMP-22 may not significantly reduce overall desert tortoise mortality from solar development.	There are no better alternatives. In some cases, translocated tortoises may survive, but at the population level, the only way to effectively reduce the impact of a solar facility on the desert tortoise is to not build the facility. If translocation is used as a BMP, desert tortoises should be monitored for survival post-translocation.

🟢 - Effective ▲ - Potentially Effective 🟥 - Ineffective

ID #	Type of BMP	BMP	Rating	# of Facilities with BMP (of 6)	Comments or Concerns	Suggestions for Alternatives
23	Desert Tortoise	Desert tortoise will be excluded from the project area via permanent tortoise-proof fencing and tortoise-proof gates at site entry points. Temporary fencing of utility corridors and tower locations during construction.	🟢	5		
24	Desert Tortoise	Personnel will utilize established roadways and existing tracks onsite. Cross-country vehicle and equipment use outside designated work areas will be prohibited. Personnel will follow established speed limits.	▲	5	Concern that speed limits vary between projects (15mph, 20mph, 25mph) to achieve the same objective. Which speed limit is most effective?	(a) Consult desert tortoise biologists and set an appropriate speed limit for all solar facilities across the desert.
25	Desert Tortoise	Vehicle and equipment parking and storage will occur within tortoise exclusion fence. If vehicle or equipment parking occurs outside of the tortoise exclusion fence, the ground under the vehicle will be inspected for the presence of desert tortoise before it is moved. BMPs provide rules for moving tortoises if found.	🟢	5		
26	Desert Tortoise	"Proposed channels that reroute the washes around the site shall be made as natural as feasible, with earthen bottoms that facilitate desert tortoise movement outside the site."	▲	1	Concern with type/material of channel bottom and whether it will obstruct groundwater recharge.	Construct artificial channels with permeable bottoms, using gravel and sand instead of packed earth.
27	Ravens and other predators	Raven management, monitoring, and control program or similar.	🟢	5		

🟢 **- Effective** ▲ **- Potentially Effective** 🟥 **- Ineffective**

ID #	Type of BMP	BMP	Rating	# of Facilities with BMP (of 6)	Comments or Concerns	Suggestions for Alternatives
28	Ravens and other predators	Trash Abatement Program. "Trash & food items will be contained in closed containers & removed daily to reduce the attractiveness to opportunistic predators such as common ravens, coyotes, & feral dogs."	●	5		
29	Ravens and other predators	"Standing water shall be minimized on site to the extent feasible to minimize the attractiveness to opportunistic predators…that may prey on sensitive species."	●	2	BMP-29 recognizes that opportunistic predators (e.g., the common raven) may be attracted to artificial water sources, and therefore seeks to minimize standing water on-site. We believe that BMP-29 is a very important BMP, but are concerned that it may have been overlooked by other applications. Contrast this BMP with statements from other projects about the need for/use of evaporation ponds.	
30	Ravens and other predators	"Road killed animals or other carcasses detected in the project area or on roads near the project area shall be picked up immediately upon detection and appropriately disposed of to avoid attracting common ravens and coyotes."	●	1	Concern that only 1 project out of 6 mentions a BMP to remove roadkill. This type of BMP should be adopted by other projects.	
31	Wildlife	"Underground pipeline construction shall involve nearly simultaneous trenching, laying of pipe, and backfilling so that no open trenches shall be left unattended during daylight hours. Any open trenches that cannot be backfilled shall be covered with steel plates at night."	●	3	Reduces potential for wildlife to become trapped in trenches or holes.	

● - Effective ▲ - Potentially Effective ■ - Ineffective

ID #	Type of BMP	BMP	Rating	# of Facilities with BMP (of 6)	Comments or Concerns	Suggestions for Alternatives
32	Wildlife	Pre-construction clearance surveys and/or relocation for a variety of wildlife species, including western burrowing owl, American badger, desert kit fox, flat-tailed horned lizard, nesting migratory birds, gila monster.	🟥	6	As stated in BMP-22, relocation can prevent direct mortality from construction or other activities, but it can also be a cause of indirect mortality. In a 2000 study by Fischer and Lindenmayer, the authors found that translocations used to solve human-animal conflicts were often unsuccessful, resulting in high mortality of animals after translocation.[620] For more on why translocation can fail, see BMP-22. BMP-32 indicates that special-status wildlife, including western burrowing owl (*Athene cunicularia*), American badger (*Taxidea taxus*), and desert kit fox (*Vulpes macrotis arsipus*), would be passively relocated. These animals would be prevented from re-entering burrows, burrows would be destroyed, and individuals would be required to move off-site before the site is fenced. The distances that individuals would have to move in order to find suitable habitat may result in stress-induced mortality of those animals. The number of individuals being relocated, the acreage of habitat being removed by the solar facility, and the capacity of "new" habitats to support additional individuals are all important factors that influence the survival of relocated species; these factors are not acknowledged by this BMP. Therefore, we are concerned that BMP-32 may not significantly reduce overall wildlife mortality from solar development.	There are no better alternatives. In some cases, relocated wildlife may survive, but at the population level, the only way to effectively reduce the impact of a solar facility on the special status wildlife is to not build the facility. If relocation is used as a BMP, special status wildlife populations surrounding the project should be monitored to determine impacts from relocated individuals on the resident populations.
33	Wildlife	"If construction activities occur at night, all project lighting…shall be directed onto the roadway or construction site and away from sensitive habitat. Light glare shields shall be used, when necessary, to reduce the extent of illumination into adjoining areas."	▲	2	Concerns: potential for significant insect mortality and potential for lighting to affect nocturnal wildlife.	(a) Determine level of insect mortality and research impacts to nocturnal wildlife. (b) If necessary, restrict construction to daylight hours.

🟢 - Effective ▲ - Potentially Effective 🟥 - Ineffective

ID #	Type of BMP	BMP	Rating	# of Facilities with BMP (of 6)	Comments or Concerns	Suggestions for Alternatives
34	Wildlife	"Prioritize and acquire land within the immediate vicinity of the Project that contributes to the preservation of adequate wildlife habitat connectivity." And/Or off-site mitigation for the permanent loss of special-status species' habitat.	▲	3	Concern about the availability and quality of habitat, especially if all permitted solar facilities attempt to acquire land as mitigation and the mitigation ratio is greater than 1:1.	See [the following chapter on mitigation]
35	Wildlife	Evaporation Pond Monitoring Program: monitoring bird populations and water quality at site evaporation ponds. "If significant adverse effects to birds are observed during the evaporation pond monitoring...additional monitoring may be needed to further assess impacts to bird species."	🟥	1	We are concerned that standing water in evaporation ponds could attract common ravens and other predators to the site. Two applications that we reviewed require on-site evaporation ponds for industrial wastewater, both of those applications indicate that they will monitor water quality, one of those applications (i.e., the source of BMP-35) acknowledges the need to monitor potential impacts to birds that might use the pond (e.g., waterfowl, shorebirds), but neither of those applications mentions that the evaporation ponds might also be attractive to common ravens. We are concerned that evaporation ponds could provide another resource that might attract opportunistic predators to a solar facility site. We are also concerned about the potential for minerals to bioaccumulate in birds that use the ponds. The health of birds that use the ponds might be negatively affected by minerals that could be in the water, including chloride, sodium, sulfate, selenium, chromium, and phosphate. Wording in the BMP also leads us to believe that birds might be at risk for salt toxicity.	(a) Prevent birds from using the ponds entirely, such as a physical barrier that still allows for evaporation. (b) Reduce the attractiveness of the pond(s) to ravens. This may involve covering up or disguising the pond(s).

● - **Effective** ▲ - **Potentially Effective** 🟥 - **Ineffective**

RECOMMENDATIONS FOR SUPPORTING CONTINUED GROWTH OF DISTRIBUTED GENERATION IN CALIFORNIA

California's renewable energy goals will require a mix of utility-scale and distributed generation capacity. Achieving a high level of distributed generation will contribute significantly to meeting RPS goals and reduce the need for utility-scale development. At a recent conference hosted by Greentech Media for the solar industry, panelists and speaker representing all aspects of the solar value chain spoke about the several key challenges for achieving growth in the residential PV market, the primary market for distributed generation. The following are recommendations for federal, state, and local governments, elected officials, and environmental organizations to address these challenges.

1. Streamline and Improve Incentive Programs

Federal, state, and local governments must streamline and improve incentive programs in order to reduce administration costs. Residential solar installations in many cities throughout the country achieve grid parity with market electricity rates but the time and expenses associated with processing incentive payments and securing financing is a significant barrier to both customers and installers. Although material and labor costs are coming down as a trained workforce develops, the cost of paperwork can account for about 40 percent of a business owner's installation costs. As a representative from Akina Solar noted, the downward stepping incentive payment structure of the California Solar Initiative may be a problem for solar installers because the buy down rate drops as total mega-watts installed increases. Installers will have a difficult time lowering installed costs to keep pace with the buy down rate once it reaches 35 cents per watt installed because of the high transaction costs of processing paperwork. This will leave homeowners with higher out-of-pocket costs and will lead to lower demand in the residential market.[621] In addition, PACE programs received some pushback from many industry representatives for the same reasons- they are too time consuming and complicated to scale statewide or nationwide. PACE programs have room for improvement and will likely see competition among alternative forms of financing from non-municipal sources.

2. Support the Expansion and Extension of Incentive Programs

Environmental organizations and elected officials should support expansion and extension of incentive programs such as utility rebates and tax-based incentives since they have the lowest administration costs to property owners and installers. Because the industry is subject to "stroke of pen" risks associated with expiring incentives, the best way to insure continued growth of the residential industry is to support policy continuity which prevents boom-bust cycles in residential customer's willingness to install solar. With certainty regarding federal and state level tax incentives, financing programs of all kinds will have an opportunity to mature and offer proven options in a growing market.

3. Educate the Public about Energy Management

A major challenge for distributed generation is behavioral preferences. Most utility customers are not consciously aware of the fact that every time they turn on a light or plug in an appliance, they are making a purchase. In addition, there is an even greater knowledge gap about how much utilities pay for electricity, which depends on time of day and overall demand, since residential customers pay a flat rate rather than the minute-by-minute wholesale prices paid by the utility. The simplicity of our current system is a significant barrier to behavioral change that can only be overcome with improved energy data visibility and management at the residential level. Advances in information technology are creating automated and affordable systems that provide homeowners with information that is both timely and actionable.

Environmental organizations should conduct community outreach to educate the public about new technologies for energy management and promote their adoption. This will contribute to making energy management signals ubiquitous and speed behavioral changes necessary for improving energy efficiency and adoption of renewable energy. The information generated by household-level energy management systems will not only help reduce overall energy consumption but will allow homeowners to more easily assess the costs and benefits of installing a PV system.

RECOMMENDATIONS FOR FUTURE RESEARCH

Through our research we identified gaps in knowledge areas related to ecological understanding, ecosystem services, and transmission. As solar development has the potential to have widespread impacts on the California desert, it is important to have as much information as possible regarding the natural ecosystem, impacts of facilities and related infrastructure, and the role that distributed solar generation may have. We identified the following areas as topics that would benefit from additional research.

1. Natural History of the California Desert

Interviews with scientists who study California desert ecology frequently revealed concerns about the great uncertainty associated with predicting the impacts of utility-scale solar development. Much of this uncertainty is due to incomplete information at the most basic level: what is out there, where is it, and how much is there? These questions regarding the location, structure, composition, and abundance of species and natural communities speak to a need for more natural history research on the California desert. Not only would this research help scientists predict the impacts of utility-scale solar development, but developers would also benefit, specifically from more complete maps of sensitive species. Since the presence of sensitive species, particularly those protected by federal mandate, can complicate, prolong, or even prohibit project approval, this research could assist developers during site selection.

If utility-scale solar development occurs in the California desert, research should be conducted on the cumulative impacts facilities will have on ecological processes and species. To understand the cumulative impacts from development, baseline studies must be undertaken before more development occurs. While these studies could help inform future siting decisions within the study area, they might also be used to extrapolate potential impacts of other types of development within the ecosystem as well as potential impacts to similar ecosystems outside of the study area where similar development may occur.

Data on plant species in particular is lacking. While many flowering species are surveyed by wildflower enthusiasts, these surveys typically take place in areas that are both easily accessible to the public and during a time of year that is tolerable for being outside for prolonged periods of time. For this reason, much of the survey data for plants are for flowering species in National Parks and Preserves, at higher elevations, at times of full bloom, and in the cooler spring months. It is important to note that another reason for a proportionately low amount of data on desert plants is the sheer number of plant species in the CDCA. As noted by Dr. Jim Andre, plant expert and Director of UC Riverside's Sweeney Granite Mountains Desert Research Center, there are still many undescribed species throughout the desert, and a large number of rare plant species across the California desert.[622] In reference to a site survey he completed for a proposed solar facility, Andre notes, "The CNDDB showed no previous records of rare plants there - it'll say that for almost every site - and yet during project surveys 11 rare plant species were documented at the site. So if you get down and do the work, get out into the field and look…in a square mile…you are likely to find both rare or possibly new taxa there."[623]

2. Regional-Level Impacts

While our research focused on the California desert, it is important to recognize that utility-scale solar development is proposed for much of the Southwest. Solar development that occurs in bordering states such as Nevada and Arizona could affect the California desert. For example, if Nevada places fewer restrictions on water use and solar technology than California, developers who wish to utilize water intensive technologies may decide to site their facilities in Nevada instead of California. However, water use in Nevada could potentially affect aquifers and surface waters that plant and wildlife species in California depend upon. Because ecological impacts are not contained by state boundaries, research on the cumulative impacts of multiple utility-scale facilities across the Southwest is necessary.

3. Ecological Restoration Techniques

Ecological restoration can be very expensive and many traditional restoration techniques may be inappropriate for desert ecosystems. Hence, more research should be undertaken to identify the most effective and economical methods for restoration of disturbed desert ecosystems. Long-term landscape-level impacts may be more effectively mitigated if we have better techniques in place for restoring disturbed parts of the desert – both following construction-phase impacts as well as after a facility is decommissioned. Existing and new restoration techniques may be made more effective if developed specifically for the region to which they are applied.

4. Climate Change and the California Desert

Most land management and development decisions are made without regard for climate change. There is a great need to understand how and to what degree climate change will impact the California desert. A better understanding of the potential impacts on species and ecological processes could both inform public land management in the context of climate change, and inform an analysis of the tradeoffs between renewable energy development and habitat conservation in the CDCA.

5. Ecosystem Services and the Non-Market Value of the Desert

Although most stakeholders are in favor of solar power generation, many are concerned about how the BLM will make siting decisions and issue permits because these decisions will have an impact on the non-market value of the land. The stakeholder survey revealed concern about the negative impacts on ecosystem services and varying opinions about the net benefit of solar development. One respondent commented:

> “It is a perfect use for land that, except for the sunshine, has very little else going for it. However, to make such a project work it cannot put any further burden on existing facilities, waster use or emergency services. Water use is getting to be a very large deal breaker with the locals. They also need to hire local residents wherever possible. Also a big factor with the locals will be possible contamination of groundwater and dust control during construction.”

The issues identified by this respondent reveal a disconnection between the desire to maintain ecosystem service value (dust control) and a perception that the landscape has no current value other than solar resources. Solar development in the California desert will clearly have an impact on the ecosystem. How can we use our increasing knowledge of the desert ecosystem and evaluate the impacts from an anthropocentric perspective? Ecosystem processes provide critical services that benefit human existence including regulation of biogeochemical cycles, preservation of genetic diversity, conversion of solar energy to plant material, and even opportunities for spiritual or cultural enrichment (Appendix F). A better understanding of ecosystem service values in the California desert could greatly benefit the decision-making process for renewable energy siting dilemmas that must consider the tradeoffs from a human perspective. The lack of complete information about ecosystem services and functions, the presence of environmental externalities, and market interventions are all contributing to an economic market failure, which results in continued land conversion and negative impacts on ecosystem services.

The conflict surrounding development of utility-scale solar facilities in the California desert stems from the differing opinions about the inherent and instrumental resource values of the region. A tradeoff exists between the benefits of preserving the desert for conservation purposes, a non-use value, and developing the land for the purpose of providing an alternative source of energy, a use value. One respondent to our stakeholder survey expressed the need to evaluate the tradeoff: “Desert flora and fauna will be impacted. However the value to humans outweighs the loss to the amount of land used for the facility.” In order to understand the value of services provided by the landscape in its present state, we need to pause and consider the tradeoffs that result from solar development, which will impact water resources, erosion control, recreational resources, landscape aesthetics, wildlife, and creation of sound and light pollution. It is also important to consider how investments and demands drive decision making and how accounting for environmental externalities is somewhat subjective but still critical for understanding the societal costs and benefits associated with energy resource development. Research in the field of environmental economics is needed in order to compare the values of various development scenarios to society as a whole.

6. Transmission

The current transmission system has also been identified as an area of concern for solar development for two primary reasons. First, the existing grid is aging and loaded down, making the addition of multiple new power plants difficult. According to the DOE, electricity demand in the U.S. has risen by nearly 25 percent since 1990, yet the construction of transmission lines has declined by approximately 30 percent.[624] This trend is manifested by congestion and bottlenecks, which can lead to electricity losses that reduce the overall efficiency of the system. Second, almost all solar proposals in California are located in the Mojave and Colorado deserts, which are within the CDCA. Because the CDCA has only modest pockets of development and a relatively small population, there are very few existing transmission towers and lines that could be connected to new solar energy power plants.

Given the relatively remote locations of many of these proposed projects and the limited amount of available capacity on the existing transmission grid, new utility-scale solar facilities will require new sections of transmission to be built. Additionally, the development of hundreds of miles of new transmission infrastructure is likely to have serious environmental implications. Potential effects on the local ecology include habitat fragmentation, increased threat of wildfires, and species disturbances and fatalities that could occur during the construction process. Unfortunately, our attempts to gather and analyze information related to the development of new transmission infrastructure to accommodate the boom in solar development faced unanticipated obstacles. First and foremost, the highly sensitive and secure nature of transmission data made it difficult to obtain information unless formally working with a government agency. Second, information that was available was often incomplete, insufficiently labeled, or dated, and never included any information on the specifics of proposed transmission. However, we believe that the ecological impacts related to transmission are both unavoidable and significant, and thus should not be overlooked.

There are currently two professional models and assessments of transmission in development: the Renewable Energy Transmission Initiative (RETI) model and the Planning Alternative Corridors for Transmission (PACT) model. The RETI model is a joint effort by the California Public Utilities Commission (CPUC), the California Energy Commission (CEC), the California Independent System Operator (CalISO), and various utilities working in the state.[625]. The goal of RETI is to identify the location and nature of upgrades needed to California's electric transmission system necessary to connect to competitive renewable energy zones (labeled as CREZs) to fulfill the state's energy demands. The RETI model also includes some analysis of the potential environmental impacts related to the build-out of transmission infrastructure. The PACT model is slightly less well-known and is being developed by the CEC to assist in identifying and developing the best routes for new transmission lines. As these models represent the most comprehensive and up-to-date information available as of this writing, we highly recommend that individuals and organizations working on renewable energy development make maximum use of these two models to inform their decisions.

Although the RETI model is one of the most comprehensive analyses to date, there are still areas of this issue that would benefit from additional research. One key concern is that Black & Veatch, the consulting firm working on the model, chose to exclude the costs of environmental mitigation as a factor in the economic analysis of transmission development. This is a relatively substantial omission. Due to the large amount of new transmission infrastructure that will need to be built, the mitigation requirements are also likely to be substantial. We believe this area in particular should be a prime consideration for future research.

APPENDIX A | STAKEHOLDER SURVEY

Methods

Research Objectives

Prior to identifying locations and developing survey questions, we developed research objectives to guide our work and to form the basis of the survey instrument. The objectives, designed as a set of questions, were in part derived from what we identified as underexplored or altogether missing information from academic literature and current discourse. The questions, designed to capture ordinal, or ranked, data, sought to understand the interests, opinions, and concerns of local community stakeholders toward utility-scale solar development within their regions. In particular, we hoped the collected data would enable us to answer the following questions:

- Do people in affected communities generally favor or oppose solar development in their communities, and how do those opinions break down by community or demographic?
- Which outcomes do respondents think are most likely to occur as a result of this development? How concerned are they about these expected outcomes?
- Why do people participate or fail to participate in the decision-making process? Is this participation or lack thereof linked to opinion?
- Isolating those who *oppose* solar, how informed are they, do they participate in the process, do they want information, and how do they want that information?
- Isolating those who *support* solar, how informed are they, do they participate in the process, do they want information, and how do they want that information?
- Comparing those who support with those who oppose solar in or near their communities, how do these groups differ? Do they have different opinions on potential outcomes, do they receive information in different ways, or do they participate more or less in the process?

The stakeholder survey addressed these questions and captured demographic information to allow us to perform statistical analyses that explored the relationship between each community's perceptions and the respondents' age, education, and length of residence in the California Desert region. We hoped that understanding what people think, what they claim to know, how they get their information, and the degree to which they participate would be useful to the BLM and other decision-making stakeholders in designing information campaigns, modifying public comment processes, and assessing risk, among other potential actions.

Target Respondents

Three communities in the California desert region were selected to receive the stakeholder survey: El Centro, Lucerne Valley, and Newberry Springs. Three criteria were used to select these communities:

- Current stage of the proposed project: To capture the most informed opinions possible, we selected communities that had already held at least one public meeting regarding the proposed solar project. In order for a public meeting to be held, a project must have been through a certain level of analysis by the developer, the BLM, and the CEC. Since many of the proposed solar energy applications are still in the early stages of the permitting process, we felt it was important that communities were only considered if they were near projects that had demonstrated a substantial time and financial commitment.
- Proximity to a proposed solar project: To ensure that those surveyed were representative of true community stakeholders, we only considered locations within 25 miles of a proposed solar energy project. This proximity requirement maximized the likelihood that the individuals surveyed had a vested interest in the construction of these projects. The communities of El Centro and Lucerne Valley were within 14 miles of the Tessera Imperial Valley project and eight miles of the Chevron Lucerne Valley project, respectively. The community of Newberry Springs was within 17 miles of the Tessera Calico project.
- Population size: For statistical reasons, we chose to only survey communities that were 1,500 residents or more, though the community of Newberry Springs did require a partial exception to this rule. Though Newberry Springs included land parcels that were owned by over 1,500 unique persons, many of these were "absentee owners", meaning that they owned the land and title, but did not permanently reside in the community. The 2009 population estimate for El Centro was 44,259, while the 2000 U.S. Census population estimate for Lucerne Valley was 2,870.[626,627] Since Newberry Springs is an unincorporated area of San Bernardino County, precise population data is not available; however, estimates based on the primary zip code (92365) place the population at approximately 2,895 as of 2000.[628]

We relied on multiple sources to obtain mailing addresses for these three communities. For El Centro and Lucerne Valley, lists of consumer mailing addresses were ordered from www.directmail.com, an online database for designing and obtaining mailing lists. However, for Newberry Springs we felt that directmail.com did not provide a sufficient number of addresses when compared to the census data for that community. Therefore, for Newberry Springs we contacted the Assessor's Office at San Bernardino County and requested a list of the on-file addresses for landowners in Newberry Springs. We sent surveys to all of the addresses within Newberry Springs. For the remaining addresses of absentee owners, we assigned randomly selected 610 addresses for the survey mailing.

Survey Instrument Design and Dissemination

The survey instrument was distributed by mail and included both a paper copy of the survey with a stamped and addressed return envelope, and a website link that respondents could use if they preferred to complete the survey online. Each community received its own version of the survey with the name, distance, and size of the nearest solar energy facility proposed. The questions within the survey were identical across the three versions, helping to maintain consistent data collection and allowing us to pool respondents for statistical analysis. Households received two copies of the survey, one in English and one in Spanish, as census figures indicated a high level of Hispanic populations in these communities. The survey requested that responses be submitted within two weeks. Ultimately, survey responses were received between early December 2009 and the end of January 2010. The six versions of the survey instrument, one in English and one in Spanish for each community, are included below.

Survey questions drew from the research objectives. Overall, there were 14 questions asked, three of which were demographic in nature. Of the 14, two were open response: "What do you think are the positive impacts of these facilities?" and "What do you think are the negative impacts of these facilities?" We included open-response questions to allow respondents to offer uninfluenced opinions of solar, and as such, these questions were placed at the beginning of the survey. The remaining 12 questions required respondents to either choose one of a set or to check all that applied, most of which offered the option to fill-in a response. We used this type of question because:

1. We believed it would greatly improve our response rate because the survey would be easier to fill out;
2. We wanted to control response choices;
3. It provided us with the ability to conduct quantitative analyses using ranked data.

The first question in our survey — "How supportive are you of using government land in the California Desert for the development of utility-scale solar facilities?" — presented respondents with a one to seven scale, from "very unsupportive" to "very supportive," respectively. We believed that including seven options in this initial question, which served as our dependent variable in most aspects of the analysis, would give us an optimal spectrum with which to group and compare respondents. All other rank questions were on a scale of one to five, which we believed would offer the appropriate range of options: extreme, moderate in either direction, or neutral.

Data Capture

Through December and into January 2010, responses were received by mail and online. Each of these surveys was issued a unique identifying number, physically written at the top of each survey, and placed in order in a filing cabinet. One by one, answers to these surveys were manually keyed into a master spreadsheet in Excel, coupling the unique number with the matching line in Excel. Data validation controls were placed into each answer column in the form or drop-down menus to avoid error. Open-response answers were typed into an assigned field for subsequent analysis. All additional comments were noted at the end of each row, which represented a complete data set for an individual survey. In the event where a respondent circled two adjacent options — for instance, three and four — data validation was turned off and the average was manually inserted. Additionally, each survey was initialed by the entrant and recorded that information in the spreadsheet to allow other entrants to verify data and ask questions as they arose. Unanswered questions were left blank in the spreadsheet. Those surveys that only included written comments but otherwise were incomplete were recorded but not included in the final data set.

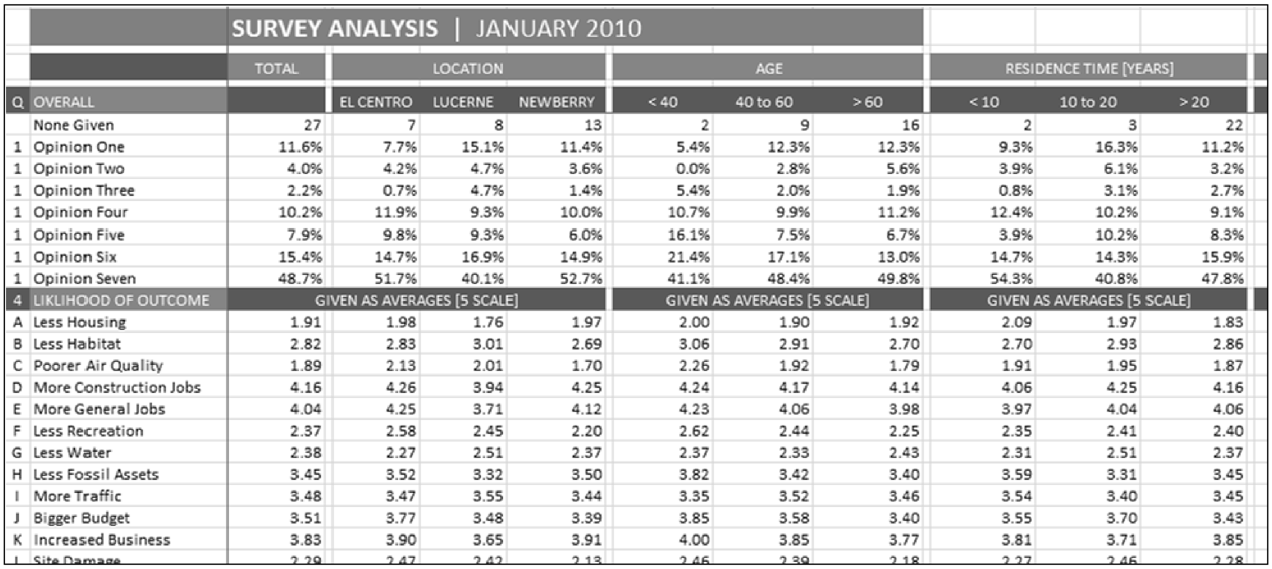
Analysis Approach

We analyzed the data in three primary ways: 1. We calculated the mean response for each question as an aggregate number from the sample and by demographic category; 2. We placed those in favor of and those opposed to solar into two groups, and calculated the means and variances of each question to identify divergence of opinion; 3. We read each open-response question and assigned a numerical value to individual words or phrases as they appeared, such as “jobs” or “green.” In our evaluation we did not correct for missing data, which was primarily in the form of skipped questions. In such cases, we left the field blank so it did not factor into the mean value for a given question.

Because the data is ranked, as opposed to continuous, we used correlation analysis to get a rough idea of liner relationship. We also used regression in some cases to test relationships, such as public participation’s influence on opinion. In addition, we used contingency table analysis in those cases where proportional patterns were observed, and manually calculated P-values. The bulk of the analysis focused on comparative relationship between groups by observing means and differences in means, as well as percent-of-total responses in order to provide insight into what representative communities think, what they know, and how they are involved.

Contingency Table

A master contingency table, which is often used to record and analyze the relationship between two or more categorical variables, was constructed in Excel and formed the primary basis of analysis. Figure A.1, pictured below, analyzed each question against each demographic category. Pivot tables were used to identify patterns between some subgroups, a task which involved, for instance, breaking each community down by age then by education level. However, no significant patterns were identified using this technique. In all cases, the mean response for each question was calculated. In some cases, such as in Question 9, the percent of total was used to allow for comparable scales or to evaluate yes-no type questions, which simultaneously asked respondents to comment on the value of individual



SURVEY ANALYSIS | JANUARY 2010

		TOTAL	LOCATION			AGE			RESIDENCE TIME [YEARS]		
Q	OVERALL		EL CENTRO	LUCERNE	NEWBERRY	< 40	40 to 60	> 60	< 10	10 to 20	> 20
	None Given	27	7	8	13	2	9	16	2	3	22
1	Opinion One	11.6%	7.7%	15.1%	11.4%	5.4%	12.3%	12.3%	9.3%	16.3%	11.2%
1	Opinion Two	4.0%	4.2%	4.7%	3.6%	0.0%	2.8%	5.6%	3.9%	6.1%	3.2%
1	Opinion Three	2.2%	0.7%	4.7%	1.4%	5.4%	2.0%	1.9%	0.8%	3.1%	2.7%
1	Opinion Four	10.2%	11.9%	9.3%	10.0%	10.7%	9.9%	11.2%	12.4%	10.2%	9.1%
1	Opinion Five	7.9%	9.8%	9.3%	6.0%	16.1%	7.5%	6.7%	3.9%	10.2%	8.3%
1	Opinion Six	15.4%	14.7%	16.9%	14.9%	21.4%	17.1%	13.0%	14.7%	14.3%	15.9%
1	Opinion Seven	48.7%	51.7%	40.1%	52.7%	41.1%	48.4%	49.8%	54.3%	40.8%	47.8%
4	LIKLIHOOD OF OUTCOME	GIVEN AS AVERAGES [5 SCALE]				GIVEN AS AVERAGES [5 SCALE]			GIVEN AS AVERAGES [5 SCALE]		
A	Less Housing	1.91	1.98	1.76	1.97	2.00	1.90	1.92	2.09	1.97	1.83
B	Less Habitat	2.82	2.83	3.01	2.69	3.06	2.91	2.70	2.70	2.93	2.86
C	Poorer Air Quality	1.89	2.13	2.01	1.70	2.26	1.92	1.79	1.91	1.95	1.87
D	More Construction Jobs	4.16	4.26	3.94	4.25	4.24	4.17	4.14	4.06	4.25	4.16
E	More General Jobs	4.04	4.25	3.71	4.12	4.23	4.06	3.98	3.97	4.04	4.06
F	Less Recreation	2.37	2.58	2.45	2.20	2.62	2.44	2.25	2.35	2.41	2.40
G	Less Water	2.38	2.27	2.51	2.37	2.37	2.33	2.43	2.31	2.51	2.37
H	Less Fossil Assets	3.45	3.52	3.32	3.50	3.82	3.42	3.40	3.59	3.31	3.45
I	More Traffic	3.48	3.47	3.55	3.44	3.35	3.52	3.46	3.54	3.40	3.45
J	Bigger Budget	3.51	3.77	3.48	3.39	3.85	3.58	3.40	3.55	3.70	3.43
K	Increased Business	3.83	3.90	3.65	3.91	4.00	3.85	3.77	3.81	3.71	3.85
L	Site Damage	2.29	2.47	2.42	2.13	2.46	2.39	2.18	2.27	2.46	2.28

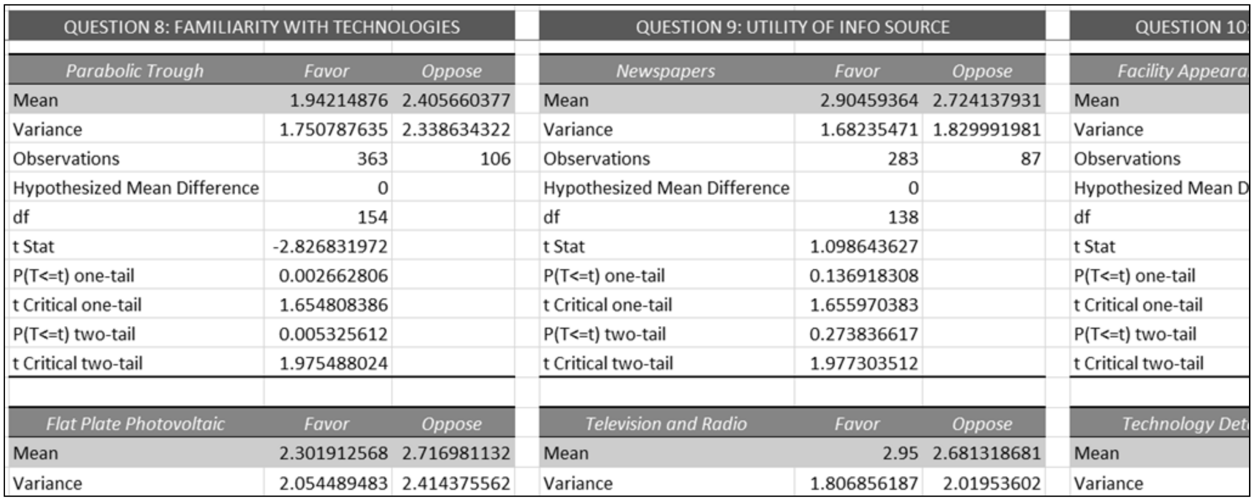
Figure A.1 Contingency table used to compare group data and mean responses.

information sources and to answer whether they had used that information source or not. In cases where we noticed patterns in the data, we manually calculated P-values and probabilities.

In addition, we grouped together demographic categories in the contingency table based on the volume of responses from a given group. For example, our survey offered respondents five options for residence time, ranging from less than one year to more than 20 years. To ensure enough respondents were in a given group, we pared these down to three: less than 10 years (22.5%), between 10 and 20 years (17.3%), and more than 20 years (60.2%). We followed a similar grouping approach for age and education level. In each case, we conducted sample testing to ensure that we were not merging two groups that exhibited significant differences in mean response to the questions.

Group Comparison

Additionally, we used two-sample t-tests assuming unequal variances to compare the mean, variances and p-values of two groups: those who reported to oppose utility-scale solar development (one and two on a scale of seven) and those who reported to support it (six and seven on a scale of seven). We did this for each question as the basis to identify issues where mean responses were significantly different, and to identify each group's orientation to that issue — positive or negative (Figure A.2). We believed that this approach would provide valuable insight into issues that are split down opposition and a support lines.

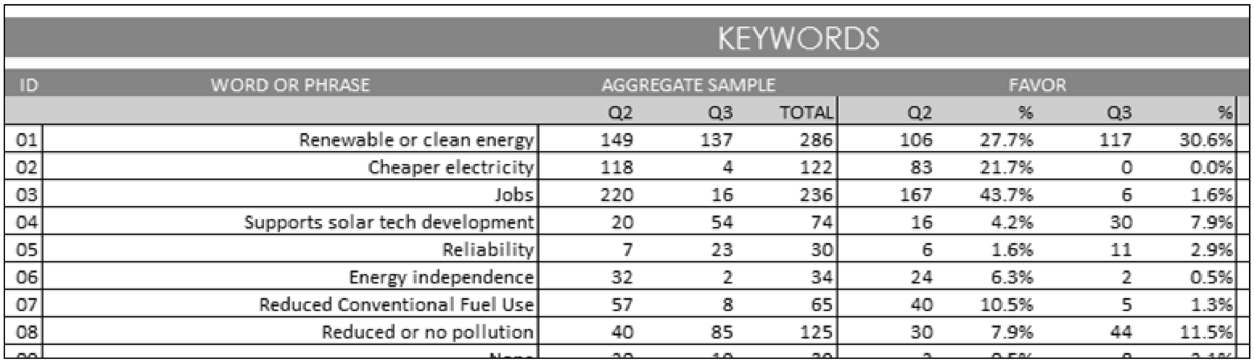


QUESTION 8: FAMILIARITY WITH TECHNOLOGIES			QUESTION 9: UTILITY OF INFO SOURCE			QUESTION 10
Parabolic Trough	*Favor*	*Oppose*	*Newspapers*	*Favor*	*Oppose*	*Facility Appeara*
Mean	1.94214876	2.405660377	Mean	2.90459364	2.724137931	Mean
Variance	1.750787635	2.338634322	Variance	1.68235471	1.829991981	Variance
Observations	363	106	Observations	283	87	Observations
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0		Hypothesized Mean D
df	154		df	138		df
t Stat	-2.826831972		t Stat	1.098643627		t Stat
P(T<=t) one-tail	0.002662806		P(T<=t) one-tail	0.136918308		P(T<=t) one-tail
t Critical one-tail	1.654808386		t Critical one-tail	1.655970383		t Critical one-tail
P(T<=t) two-tail	0.005325612		P(T<=t) two-tail	0.273836617		P(T<=t) two-tail
t Critical two-tail	1.975488024		t Critical two-tail	1.977303512		t Critical two-tail
Flat Plate Photovoltaic	*Favor*	*Oppose*	*Television and Radio*	*Favor*	*Oppose*	*Technology Det*
Mean	2.301912568	2.716981132	Mean	2.95	2.681318681	Mean
Variance	2.054489483	2.414375562	Variance	1.806856187	2.01953602	Variance

Figure A.2 Two-sample t-test assume unequal variances, testing every question between supporters and opponents of solar.

Keyword Analysis

Finally, we assigned values to each key word or phrase that appeared in the open-response questions, identifying a total of 44 words that had value to the study. For example, “jobs” received a code of 03, “increased property values” received a code of 20, and “renewable,” “clean,” and “green” all received a code of 01. Neither words that would be ambiguous on their own, such as “property,” nor articles and verbs received codes. The intent was to both reconcile the ranked data and to identify sentiment not explicitly captured in the close-ended questions. Figure A.3 is shown below with an example of this analysis.



KEYWORDS

ID	WORD OR PHRASE	AGGREGATE SAMPLE			FAVOR			
		Q2	Q3	TOTAL	Q2	%	Q3	%
01	Renewable or clean energy	149	137	286	106	27.7%	117	30.6%
02	Cheaper electricity	118	4	122	83	21.7%	0	0.0%
03	Jobs	220	16	236	167	43.7%	6	1.6%
04	Supports solar tech development	20	54	74	16	4.2%	30	7.9%
05	Reliability	7	23	30	6	1.6%	11	2.9%
06	Energy independence	32	2	34	24	6.3%	2	0.5%
07	Reduced Conventional Fuel Use	57	8	65	40	10.5%	5	1.3%
08	Reduced or no pollution	40	85	125	30	7.9%	44	11.5%

Figure A.3 View of the keyword analysis table

You are invited to be a part of a research study being conducted by the University of Michigan's School of Natural Resources and Environment. We are researching the potential impacts of solar energy development in the California Desert.

A number of solar facilities have been proposed and we would like to learn what local residents believe will be the most significant impacts from these facilities. **Your input will inform government agencies and other interested organizations so that they can better address your concerns about solar energy development.**

Our focus is on "utility-scale" solar facilities, which are commercial structures that provide electricity for a large number of people. They are <u>not</u> the same as residential or rooftop solar panels. For the purposes of this survey, a "solar facility" includes all the buildings, mirrors, transmission lines, and access roads that are built to serve the facility.
You have been selected to participate because you live near El Centro and a solar facility has been proposed near your town. This facility is 14 miles west of El Centro. It will use 6,140 acres of federal land and supply at least 230,000 homes with electricity per year.

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Please complete either the attached paper survey or follow the link listed below to an Internet version of the survey. This survey will take 10 to 15 minutes to complete.

Participating in this study is completely voluntary. You may choose not to answer an individual question and can skip any section of the survey. Please complete only one version of the survey (English or Spanish).

Researchers will not be able to link your survey responses to you. If you chose to complete the survey online, the survey software keeps your identifying information separate from the answers you provide to the survey. We plan to publish the results of this study, but will not include any information that would identify you.

Please respond to this survey by Friday, December 11, 2009.

<u>Link to Internet Survey</u>: http://www.surveymonkey.com/EC1

If you have questions about this research study, please contact Sarah Tomsky, University of Michigan, School of Natural Resources and Environment, 440 Church Street, Ann Arbor, MI 48109-1041, (734) 615-6431, desertsolar@umich.edu. If you have questions about your rights as a research participant, please contact the University of Michigan Institutional Review Board Health Sciences and Behavioral Sciences, 540 E. Liberty, Ste. 202, Ann Arbor, MI 48104-2210, (866) 936-0933 (toll-free), irbhsbs@umich.edu, IRB# HUM00035010. By following the link above or returning the paper survey via mail, you are consenting to participate in this research survey. We appreciate your willingness to contribute to our academic research.
~~~

Multiple "utility-scale" solar facilities have been proposed for development in the California Desert. *A "utility-scale" solar facility is a commercial structure that provides electricity for a large number of people – it is* not *the same as residential or rooftop solar panels. For the purposes of this survey, a "solar facility" includes all the buildings, mirrors, transmission lines, and access roads that are built to serve the facility.*

1) In general, how **supportive** are you of using government land in the California Desert for the development of utility-scale solar facilities?

Very Unsupportive			**Neutral**			**Very Supportive**
1	2	3	4	5	6	7

2) What do you think are the positive impacts of these facilities?

3) What do you think are the negative impacts of these facilities?

4) How **likely** do you think the following outcomes will be if a utility-scale solar facility is constructed near your town? Circle your answers.

		Very Unlikely				**Very Likely**	
A	Decreased availability of apartments or other rental housing	1	2	3	4	5	Don’t Know
B	Decreased wildlife and plant habitat	1	2	3	4	5	Don’t Know
C	Decreased air quality in your town	1	2	3	4	5	Don’t Know
D	Increased employment opportunities in your town during facility *construction*	1	2	3	4	5	Don’t Know
E	Increased employment opportunities in your town during facility *operation*	1	2	3	4	5	Don’t Know
F	Decreased recreational opportunities	1	2	3	4	5	Don’t Know
G	Decreased quantity or quality of water in streams, springs, and wells	1	2	3	4	5	Don’t Know
H	Decreased need for new coal or natural gas power plants	1	2	3	4	5	Don’t Know
I	Increased traffic during facility construction	1	2	3	4	5	Don’t Know
J	Increased town budget due to taxes or other payments from the solar facility	1	2	3	4	5	Don’t Know
K	Increased business in local restaurants and stores	1	2	3	4	5	Don’t Know
L	Increased damage to cultural and historic sites	1	2	3	4	5	Don’t Know
M	Decreased quality of vistas from your town	1	2	3	4	5	Don’t Know
N	Increased energy availability/reliability for California residents	1	2	3	4	5	Don’t Know

5) Assuming that they happen, how **concerned** would you be about the following outcomes if a utility-scale solar facility is constructed near your town?

		Not Concerned				**Very Concerned**
A	Decreased availability of apartments or other rental housing	1	2	3	4	5
B	Decreased wildlife and plant habitat	1	2	3	4	5
C	Decreased air quality in your town	1	2	3	4	5
D	Decreased recreational opportunities	1	2	3	4	5
E	Decreased quantity or quality of water in streams, springs, and wells	1	2	3	4	5
F	Increased traffic during facility construction	1	2	3	4	5
G	Increased damage to cultural and historic sites	1	2	3	4	5
H	Decreased quality of vistas from your town	1	2	3	4	5

6) Assuming that they happen, how **valuable** to you are the following outcomes if a utility-scale solar facility is constructed near your town?

		Not Valuable				**Very Valuable**
A	Increased employment opportunities in your town during facility *construction*	1	2	3	4	5
B	Increased employment opportunities in your town during facility *operation*	1	2	3	4	5
C	Decreased need for new coal or natural gas power plants	1	2	3	4	5
D	Increased town budget due to taxes or other payments from the solar facility	1	2	3	4	5
E	Increased business in local restaurants and stores	1	2	3	4	5
F	Increased energy availability/reliability for California residents	1	2	3	4	5

7) How familiar are you with solar energy technologies? Please circle your answers.

Not familiar				**Very familiar**
1	2	3	4	5

8) How familiar are you with the following solar technology types?

		Not Familiar				**Very Familiar**
A	Parabolic Trough	1	2	3	4	5
B	Flat Plate Photovoltaic	1	2	3	4	5
C	Thin-Film Photovoltaic	1	2	3	4	5
D	Dish Engines	1	2	3	4	5
E	Fresnel Lens	1	2	3	4	5
F	Power Tower	1	2	3	4	5

9) How helpful have you found the following sources of information when trying to learn about solar energy technology?

		Have Not Used	**Not Helpful**				**Very Helpful**
A	Newspaper articles	N/U	1	2	3	4	5
B	Television/radio reports	N/U	1	2	3	4	5
C	Internet	N/U	1	2	3	4	5
D	Books	N/U	1	2	3	4	5
E	Teachers	N/U	1	2	3	4	5
F	Friends/Family/Neighbors	N/U	1	2	3	4	5
G	Trade Journals	N/U	1	2	3	4	5
H	Local Government	N/U	1	2	3	4	5
I	Chamber of Commerce	N/U	1	2	3	4	5
J	Recreation Organizations (ORV clubs, hiking groups, etc.)	N/U	1	2	3	4	5
K	Environmental Groups	N/U	1	2	3	4	5
L	Advertisements	N/U	1	2	3	4	5
M	Other (please list)	N/U	1	2	3	4	5

10) In the future, how helpful would you find the following information about utility-scale solar facilities?

		Not Helpful				**Very Helpful**
A	Appearance of the facility	1	2	3	4	5
B	Details about how the technology works	1	2	3	4	5
C	Water use estimates	1	2	3	4	5
D	Potential ecological impacts	1	2	3	4	5
E	Potential to reduce global warming impacts	1	2	3	4	5
F	Potential impacts to recreation areas	1	2	3	4	5
G	Potential tax revenue	1	2	3	4	5
H	Job creation estimates	1	2	3	4	5
I	Planning and permit approval process	1	2	3	4	5

11) The Bureau of Land Management (BLM) is soliciting the public's opinion on changes to their management plans to include solar development. Have you participated in any of the BLM's public comment opportunities below? (Check all that apply.)

Yes, I have participated in one or more of the following:

___A. Attended a public meeting for the BLM's Solar Programmatic Environmental Impact Statement
___B. Attended a public meeting for the solar project near your town
___C. E-mailed or mailed comments to the BLM
___D. Other (Please list):

No, I have not participated for the following reason(s):

___E. Do not wish to participate
___F. Unaware of participation opportunities
___G. Meeting time inconvenient
___H. Location of meeting inconvenient
___I. My opinion does not matter or will make no difference
___J. Other (Please list):

12) How old are you? Please check one.

___ A. Less than 20 years
___ B. 20 to 29 years
___ C. 30 to 39 years
___ D. 40 to 49 years
___ E. 50 to 59 years
___ F. 60 years and above

13) How long have you lived in the California Desert region? This includes the desert areas of Imperial, Inyo, Kern, San Bernardino, San Diego, and Riverside counties.

___ A. 1 year or less
___ B. 2 to 5 years
___ C. 6 to 10 years
___ D. 11 to 20 years
___ E. More than 20 years

14) What is the highest level of education you have completed?

___ A. Less than high school
___ B. High school or GED
___ C. Some college, no degree
___ D. Two-year college degree (Associates)
___ E. Four-year college degree (BA, BS)
___ F. Graduate or Professional degree

End of Survey – Thank you for participating!!
Please use the enclosed stamped envelope to return the survey

APPENDIX B | UTILITY-SCALE SOLAR PROJECTS IN CALIFORNIA

Utility-Scale Projects in California

Developer	Project Name	Electricity Purchaser	Location	Land Type	Technology	Phase	Online Date	Capacity (MW)
Concentrating Solar Power (including Concentrating Photovoltaics)								
Ausra	Kimberlina	California's wholesale market	Bakersfield		Linear Fresnel	Operation	2008	5
esolar	Sierra Sun Tower	Southern California Edison	Angelope Valley, CA		Tower	Operation	2009	5
Luz	Solar Energy Generating Systems (SEGS) I	Southern California Edison	Daggett		Trough	Operation	1985	14
Luz	Solar Energy Generating Systems (SEGS) II	Southern California Edison	Daggett		Trough	Operation	1986	30
Luz	Solar Energy Generating Systems (SEGS) III	Southern California Edison	Kramer Junction		Trough	Operation	1987	30
Luz	Solar Energy Generating Systems (SEGS) IV	Southern California Edison	Kramer Junction		Trough	Operation	1988	30
Luz	Solar Energy Generating Systems (SEGS) V	Southern California Edison	Kramer Junction		Trough	Operation	1989	30
Luz	Solar Energy Generating Systems (SEGS) VI	Southern California Edison	Kramer Junction		Trough	Operation	1989	30
Luz	Solar Energy Generating Systems (SEGS) VII	Southern California Edison	Kramer Junction		Trough	Operation	1990	80
Luz	Solar Energy Generating Systems (SEGS) IX	Southern California Edison	Kramer Junction		Trough	Operation	1991	80
GreenVolts, Inc.	GV1	Pacific Gas & Electric	Byron		CPV	Construction		2
Abengoa Solar	Mojave Solar	Pacific Gas & Electric	San Bernadino County		Trough	Development		250
Acciona Solar Power	Ft. Irwin Solar Power Project	U.S. Army/surrounding utilities	Ft. Irwin		Trough	Development		980
BrightSource Energy	Ivanpah Solar Electric Generating System (SEGS) I	Pacific Gas & Electric	Barstow		Tower	Development		126
BrightSource Energy	ivanpah Solar Electric Generating System (SEGS) II	Southern California Edison	Barstow		Tower	Development		133
BrightSource Energy	ivanpah Solar Electric Generating System (SEGS) III	Pacific Gas & Electric	Barstow		Tower	Development		133
eSolar	Gaskell Sun Tower (Phase I)	Southern California Edison	Kern County		Tower	Development		105
eSolar	Gaskell Sun Tower (Phase II)	Southern California Edison	Kern County		Tower	Development		140
eSolar	Alpine SunTower	Pacific Gas & Electric	Lancaster		Tower	Development		92
Harper Lake, LLC	Harper Lake Solar Plant				Trough	Development		250
Inland Energy, Inc.	Palmdale Hybrid Gas-Solar		Palmdale		Trough	Development		50
Inland Energy, Inc.	Victorville Hybrid Gas-Solar		Victorville		Trough	Development		50
NextEra Energy Resources	Beacon Solar Energy Project		Kern County		Trough	Development		250
NextEra Energy Resources	Genesis Solar Energy Project	Pacific Gas & Electric	Riverside County		Trough	Development		250
San Joaquin Solar, LLC	San Joaquin Solar 1	Pacific Gas & Electric	Coalinga		Trough	Development		53
San Joaquin Solar, LLC	San Joaquin Solar 2	Pacific Gas & Electric	Coalinga		Trough	Development		53
SkyFuel	SkyTrough demonstration	Southern California Edison	Daggett		Trough	Development		43
Solar Millennium	Blythe Solar Power Project	Southern California Edison	Blythe		Trough	Development		1000
Solar Millennium	Ridgecrest Solar Power Project	Southern California Edison	Ridgecrest		Trough	Development		250
Solar Millennium	Palen Solar Power Project	Southern California Edison	Desert Center		Trough	Development		250
SolarReserve	Rice Solar Energy Project	Pacific Gas & Electric	Riverside County		Tower	Development		150
Solel	Mojave Solar Park	Pacific Gas & Electric	Mojave Desert		Trough	Development		553
Tessera Solar	SES Solar One	Southern California Edison	Victorville		Dish-engine	Development		850
Tessera Solar	SES Solar Two	San Diego Gas & Electric	Imperial County		Dish-engine	Development		750
Tessera Solar	SES Solar Three		Imperial County		Dish-engine	Development		550

Utility-Scale Projects in California								
Developer	Project Name	Electricity Purchaser	Location	Land Type	Technology	Phase	Online Date	Capacity (MW)
Photovoltaics (excluting Concentrating Photovoltaics)								
First Solar	FSE	Southern California Edison	Blythe		Thin-film	Operation	2009	21
Cleantech America, Inc.	CalRENEW-1	Pacific Gas & Electric	Mendota		Thin-film	Construction		5
Acciona Solar Power	Ft. Irwin Solar Power Project	U.S. Army/surrounding utilities	Ft. Irwin		PV	Development		20
C.F. Properties			Barstow		PV	Development		19
Chevron Energy Solutions	Lucerne Valley Solar Project	Southern California Edison	San Bernadino County		Thin-film	Development		45
Clear Skies Solar, Inc.			Cantil		PV	Development		6
First Solar	Topaz Solar Farm	Pacific Gas & Electric	Carissa Plains		Thin-film	Development		550
First Solar	Desert Sunlight	Pacific Gas & Electric	Desert Center		Thin-film	Development		300
First Solar	Desert Sunlight	Southern California Edison	Desert Center		Thin-film	Development		250
Fotowatio Renewable Ventures		U.S. Air Force	Lancaster		PV	Development		500
Needle Mountain Power, LLC	Sterling Promect		Lake Havasu City		PV	Development		1200
PowerWorks	Golden Hills		Almeda County		PV	Development		70
Recurrent Energy		Southern California Edison	Kern County		PV	Development		6
Recurrent Energy		Southern California Edison	Kern County		PV	Development		22
Recurrent Energy		Southern California Edison	San Bernadino County		PV	Development		22
Recurrent Energy	San Francisco Sunset Resrvoir Solar Project	San Francisco Public Utilities Commission	San Francisco		PV	Development		5
Solar Energy Initiatives, Inc.	California Solar Park				PV	Development		100
Solargen Energy			San Benito County		PV	Development		420
Solar Project Solutions		Pacific Gas & Electric	Tulare County		PV	Development		20
Solar Project Solutions		Pacific Gas & Electric	Tulare County		PV	Development		20
Solar Project Solutions		Pacific Gas & Electric	Tulare County		PV	Development		20
Solar Project Solutions		Pacific Gas & Electric	Kings County		PV	Development		20
Solar Project Solutions		Pacific Gas & Electric	Tulare County		PV	Development		50
Solon Corporation	PG&E Solon Project	Pacific Gas & Electric			PV	Development		2
SunEdison		California State Universities			Thin-film	Development		8
SunPower	California Valley Solar Range	Pacific Gas & Electric	San Luis Obispo County		PV	Development		250
		Los Angeles Department of Water & Power	Owens Lake		PV	Development		10

APPENDIX C | ROAD ESTIMATES SUMMARY TABLE BY PROJECT

Proposed Road Types and Lengths for select "Fast Track" Solar Facility Proposals in California						
Proposal Name	**Paved Off-Site Access Roads**	**Site Paved Roadways**	**Unpaved Roadways**	**Solar Field Access Roads**	**Unspecified Roads**	**Comments**
Solar Millennium - Blythe	3 miles long	N/A	N/A	N/A	Misc. "Stub" access roads 100ft long each	Although the AFC mentions that other roads will be built, our group could not find details regarding total area or length of road to be constructed.
Solar Millennium - Ridgecrest	700ft long, 24ft wide	N/A	1,800ft long, 15ft wide	N/A	Two 1,500 acceleration lanes and two 1,000 deceleration lanes added to existing road	N/A
Solar Millennium - Palen	1,350ft long, 24ft wide	N/A	N/A	N/A	N/A	15ft wide access road will be constructed along the distance of the transmission tower alignment
Beacon Solar Energy Project	N/A	N/A	N/A	N/A	Two 1,500 acceleration lanes and two 1,000 deceleration lanes added to existing road; Misc. "Stub" access roads 115ft long by 12ft wide each; transmission line access road 17,300ft long by 14ft wide	Within the Biological Resources section, the developer has laid out two options for road development, both of which would have a different level of impact. Until an option is chosen, the level of road impacts remain uncertain.
Abengoa Mojave	Site access is provided by an existing road (Harper Lake Road)	N/A	N/A	N/A	States that each 20 acre power island would include ~1.75 acres of paved area	N/A
Genesis Solar	6.5 miles long, 50ft wide, 16 acres of temporary construction disturbance	6.5 miles long, 30ft wide, 24 acres of permanent disturbance	N/A	60 spur roads 70ft long, 14ft wide each for a total permanent disturbance area of 114 acres	Internal Road System will include roads that are 24ft wide with an unspecified total length	N/A
City of Palmdale - Hybrid Gas-Solar	N/A	22ft wide on-site access roads with an unspecified total length	N/A	N/A	Unspecified number of stub roads will be added averaging 50ft long and 14ft wide	This project is in an area characterized by more dense development than any of the other fast track applications. There are multiple existing roadways.

Proposed Road Types and Lengths for select "Fast Track" Solar Facility Proposals in California

Proposal Name	**Paved Off-Site Access Roads**	**Site Paved Roadways**	**Unpaved Roadways**	**Solar Field Access Roads**	**Unspecified Roads**	**Comments**
Solar One	3 miles long, 30ft wide, permanent disturbance area of 11 acres	38 miles long, 12ft wide, permanent disturbance area of 111 acres	10 miles long, 12ft wide, permanent disturbance area of 15 acres	587 miles long total, 12-15ft wide, permanent disturbance area of 995 acres	N/A	N/A
Solar Two	1.3 miles long, 30ft wide, permanent disturbance area of 3.6 acres	25.2 miles long, 45ft wide, permanent disturbance area of 137.6 acres	11.2 miles long, 12ft wide, permanent disturbance area of 16.2 acres	270 miles long total, 12ft wide, permanent disturbance area of 393 acres	N/A	N/A
Ivanpah	N/A	N/A	N/A	N/A	N/A	Although the AFC mentions that other roads will be built, our group could not find details regarding total area or length of road to be constructed.
San Joaquin Solar 1 & 2	N/A	7.5 miles long, 20ft wide (serves both plants)	N/A	N/A	N/A	The AFC indicates that the 7.5 miles of proposed roads will be the total needed for both plants. This may be due to the fact that there is active agriculture in the area and therefore multiple existing roadways.
Rice Solar Energy Project	N/A	N/A	4.6 miles long, 24ft wide for the gen tie-in service road	N/A	AFC mentions a road of unspecified width, length, and type that will serve as a perimeter access road to the heliostats.	N/A

** "N/A" indicates the AFC did not specifically reference the type of road and construction details*

** All estimates are taken from the Application for Certification materials in the following sections: Project Description, Biological Resources, Land Use, Visual Resources, and Traffic and Transportation.*

APPENDIX D | LAND USE EFFICIENCIES FOR INDIVIDUAL PROJECTS

Abengoa - Parabolic Trough

Area Efficiency Analysis

	Quantity	Total (acres)
Total Site Area (acres)	1	**1,765**
Solar thermal collector array fields[1]	*2*	*1,420.00*
Total bldgs[2]	*1*	*4.25*
Power Island[2]	*2*	*40.00*
Total paved road[2]	*1*	*1.75*
Total Disturbed Land (acres)	**1,466**	
Ratio of Disturbed Land to Site Area as %	**83.06%**	
Nameplate Capacity (MW)	*250*	
Capacity Factor	*0.274*	
Actual Annual Electricity Production (MWh)	**600,471**	
Ratio of Elec Production to Disturbed Land (MWh/acre)	**409.60**	
Ratio of Disturbed Land to Elec Production (acres/MW)	**5.86**	

NOTES

1: Each field is 710 acres and there are two fields for this project. Page 2.0-5 of Project Description document in Application for Completion (AFC).

2: Page 2.0-24 of Project Description document in the AFC.

Beacon - Parabolic Trough

Area Efficiency Analysis

	Quantity	Total (acres)
Total Site Area (acres)	1	**2,012**
Solar thermal collector array fields[1]	*1*	*1,244.00*
Total bldgs[2]	*1*	*0.71*
Power Block[2]	*1*	*23.00*
Total paved road[2]	*1*	*6.00*
Total Disturbed Land (acres)	**1,274**	
Ratio of Disturbed Land to Site Area as %	**63.31%**	
Nameplate Capacity (MW)	*250*	
Capacity Factor	*0.265*	
Actual Annual Electricity Production (MWh)	**580,748**	
Ratio of Elec Production to Disturbed Land (MWh/acre)	**455.95**	
Ratio of Disturbed Land to Elec Production (acres/MW)	**5.09**	

NOTES

1: Page 2-8 of Project Description Document.

2: Page 2-24 of Project Description Document.

Chevron Lucerne Valley - Thin-Film Photovoltaic

Area Efficiency Analysis

	Quantity	Total
Total Site Area (acres)	-	**516**
"Facility Footprint" I.e. total area w/n disturbance area that is inside security fencing encompassing all four units; excludes off-site linears {gen-tie transmission line and gas pipeline}	-	*273*
Total Disturbance Area (acres)	**279**	
Nameplate Capacity (MW)	*60*	
Capacity Factor	*0.110*	
Actual Annual Electricity Production (MWh)	**57,856**	
Ratio of Elec Production to Disturbed Land (MWh/acre)	**207.64**	
Ratio of Disturbed Land to Nameplate Capacity (acres/MW)	**4.64**	

NOTES

The application materials for PV facilities are managed by the BLM and as of the time of this writing, were not available online. Therefore, we set an assumed capacity factor. Additionally, since application materials were not readily accessible, we determined the average percentage of disturbed area for a given site area and used this percentage to estimate the amount of Total Disturbance Area (in acres).

Desert Sunlight - Thin-Film Photovoltaic

Area Efficiency Analysis

	Quantity	Total
Total Site Area (acres)	-	**4,410**
"Facility Footprint" I.e. total area w/n disturbance area that is inside security fencing encompassing all four units; excludes off-site linears {gen-tie transmission line and gas pipeline}	-	*3,500*
Total Disturbance Area (acres)	**2,381**	
Nameplate Capacity (MW)	*550*	
Capacity Factor	*0.110*	
Actual Annual Electricity Production (MWh)	**530,343**	
Ratio of Elec Production to Disturbed Land (MWh/acre)	**222.70**	
Ratio of Disturbed Land to Nameplate Capacity (acres/MW)	**4.33**	

NOTES

The application materials for PV facilities are managed by the BLM and as of the time of this writing, were not available online. Therefore, we set an assumed capacity factor. Additionally, since application materials were not readily accessible, we determined the average percentage of disturbed area for a given site area and used this percentage to estimate the amount of Total Disturbance Area (in acres).

Genesis - Parabolic Trough

Area Efficiency Analysis

	Quantity	Total (acres)
Total Site Area (acres)	1	**1,800**
Solar thermal collector array fields[1]	*2*	*1,360.00*
Total bldgs[2]	*1*	*0.90*
Power Block[2]	*1*	*24.00*
Site access roads[3]	*1*	*24*
Total Disturbed Land (acres)	**1,409**	
Ratio of Disturbed Land to Site Area as %	**78.27%**	
Nameplate Capacity (MW)	*250*	
Capacity Factor	*0.265*	
Actual Annual Electricity Production (MWh)	**580,748**	
Ratio of Elec Production to Disturbed Land (MWh/acre)	**412.20**	
Ratio of Disturbed Land to Elec Production (acres/MW)	**5.64**	

NOTES

1: Two facilities 125 MW each.

2: Page 3-22 in Facility Description in Application for Completion (AFC)

3: Page 3-3 in Facility Description document in AFC.

Ivanpah - Solar Power Tower

Area Efficiency Analysis

	Quantity	Total
Total Site Area (acres)	1	3,400
Ivanpah Solar Plant 1	*1*	*6.635*
Ivanpah Solar Plant 2	*1*	*5.197*
Ivanpah Solar Plant 3	*1*	*7.464*
Administration and Storage Building	*1*	*3.188*
Electrical Substation Building	*1*	*27.736*
Heliostats - 10.5' x 10.5'	*272,000*	*688.430*
Miles of Paved and Unpaved Roads[1]	-	-
Total Disturbed Land (acres)	**739**	
Nameplate Capacity (MW)	*400*	
Capacity Factor	*0.270*	
Actual Annual Electricity Production (MWh)	**946,728**	
Ratio of Elec Production to Disturbed Land (MWh/acre)	**1,281.7**	
Ratio of Disturbed Land to Elec Production (acres/MW)	**1.8**	

NOTES

1.) The AFC does not include specific details on road construction, so it is not provided here.

2.) The AFC did not include a list of proposed buildings, so the coverage areas listed here were calculated based on the proposed site maps included in the "Biological Resources" section.

Palmdale - Parabolic Trough

Area Efficiency Analysis

	Quantity	Total (acres)
Total Site Area (acres)	1	**2,012**
Solar thermal collector array fields[1]	*1*	*250.00*
Total bldgs[2]	*1*	*0.84*
Power Block[2]	*1*	*19.00*
Total paved road[2]	*1*	*5.00*
Drainage, setbacks and access roads[3]	*1*	*51*
Total Disturbed Land (acres)	**326**	
Ratio of Disturbed Land to Site Area as %	**16.19%**	
Nameplate Capacity (MW)	*50*	
Capacity Factor	*0.265*	
Actual Annual Electricity Production (MWh)	**116,150**	
Ratio of Elec Production to Disturbed Land (MWh/acre)	**356.46**	
Ratio of Disturbed Land to Elec Production (acres/MW)	**6.52**	

NOTES

1: The solar power plant is part of a hybrid natural gas power project.

2: Page 2-28 in Project Description PDF document in the Application for Completion (AFC).

3: Page 1 of NOR of AFC.

Rice - Solar Power Tower

Area Efficiency Analysis

	Quantity	Total (acres)
Total Site Area (acres)	1	**2,560**
Project/facility site[1]	*1*	*1,410.00*
Site access roads[2]	*1*	*5.50*
Total Disturbed Land (acres)	**1,416**	
Ratio of Disturbed Land to Site Area as %	**55.29%**	
Nameplate Capacity (MW)	*150*	
Capacity Factor	*0.340*	
Actual Annual Electricity Production (MWh)	**447,066**	
Ratio of Elec Production to Disturbed Land (MWh/acre)	**315.84**	
Ratio of Disturbed Land to Elec Production (acres/MW)	**9.44**	

NOTES

1: This includes heliostats, administration buildings, power block and evaporation pond areas. Page 1-7 of Rice Introduction Document.

2: Page 1-8 of Rice Introduction Document.

Tessera Solar One (Calico) - Stirling Dish Engine

Area Efficiency Analysis

	Quantity	Total
Total Site Area (acres)	1	**8,230**
Off-Site Access Road	-	*11.0*
Off-Site Transmission Line	-	*0.9*
Construction Staging, Administration, and Laydown Areas	-	*63.0*
Site Boundary Fence	-	*55.0*
Paved and Unpaved Roadways (Main and Perimeter)	-	*153.0*
Main Services Complex	-	*42.0*
Satellite Services Complex	-	*21.0*
Solar One Substation and On-Site Transmission Line	-	*25.3*
Water Pipeline	-	*3.6*
SunCatchers[1]	*34,000*	*986.5*
North-South Access Routes	-	*262.0*
East-West Access Routes[2]	-	*733.0*
Debris Basins for Off-Site Flows	-	*220.0*
Debris Basins for On-Site Flows	-	*65.0*
Electrical Collection System[3]	-	*333.0*
Total Direct Disturbance Area (acres)	**2,974.3**	
Nameplate Capacity (MW)	*850*	
Capacity Factor	*0.399*	
Actual Annual Electricity Production (MWh)	**2,975,000**	
Ratio of Elec Production to Disturbance Area (MWh/acre)	**1,000.2**	
Ratio of Disturbed Land to Elec Production (acres/MW)	**3.50**	

NOTES

1: Includes foundations, pad clearing, and drainage swales. Square footage of the pedastals for each SunCatcher are 14' x 14'.

2: Includes access roads within the area of limited disturbance and roads servicing each SunCatcher PCU.

Tessera Solar Two (Imperial Valley) - Stirling Dish Engine

Area Efficiency Analysis

	Quantity	Total
Total Site Area (acres)	-	**6,500**
Off-Site Access Roads	-	*4.5*
On-Site Paved and Unpaved Roadways	-	*153.8*
Off-Site Transmission Line	-	*91.6*
On-Site Transmission Line[2]	-	*109.1*
Waterline and Pumping Station	-	*8.0*
Construction Staging, Administration, and Laydown Areas	-	*37.0*
Site Boundary Fence	-	*29.9*
Main Services Complex[1]	-	*28.4*
On-Site Wet and Dry Utilities Access	-	*12.5*
Solar Two Substation	-	*7.7*
North-South Access Routes	-	*245.0*
East-West Access Routes	-	*148.3*
Electrical Collection System	-	*55.0*
SunCatcher Generating Systems	*30,000*	*2,175.0*
Total Direct Disturbance Area (acres)	**3,106**	
Nameplate Capacity (MW)	*750*	
Capacity Factor	*0.399*	
Actual Annual Electricity Production (MWh)	**2,625,000**	
Ratio of Elec Production to Disturbance Area (MWh/acre)	**845.2**	
Ratio of Disturbed Land to Elec Production (acres/MW)	**4.14**	

NOTES

1: Includes service building, parking area, assembly buildings, and storage.

2: Includes an estimated 75 acres of disturbance from transmission poles.

Solar Millennium Blythe - Parabolic Trough

Area Efficiency Analysis

	Quantity	Total
Total Site Area (acres)	-	**7,030**
"Facility Footprint" I.e. total area w/n disturbance area that is inside security fencing encompassing all four units; excludes off-site linears {gen-tie transmission line and gas pipeline}	-	*259,182,000*
Total Disturbance Area (acres)	**5,950**	
Nameplate Capacity (MW)	*1,000*	
Capacity Factor	*0.239*	
Actual Annual Electricity Production (MWh)	**2,095,074**	
Ratio of Elec Production to Disturbed Land (MWh/acre)	**352.11**	
Ratio of Disturbed Land to Elec Production (acres/MW)	**5.95**	

NOTES

Solar Millenium provided the "facility footprint" within their Application for Certification - a specific breakdown of buildings was not included.

Solar Millennium Palen - Parabolic Trough

Area Efficiency Analysis

	Quantity	Total
Total Site Area (acres)	-	**5,200**
Facility "Footprint" (i.e. area inside the fence line, which excludes gen-tie transmission line route outside the ROW)	*1*	*2,970*
Central Warehouse and Main Office Buildings[3]	*1*	*2.801*
Buildings in Power Block 1[3]	*1*	*0.716*
Buildings in Power Block 2[3]	*1*	*0.716*
Total Disturbance Area (acres)	**2,970**	
Nameplate Capacity (MW)	*500*	
Capacity Factor	*0.228*	
Actual Annual Electricity Production (MWh)	**999,324**	
Ratio of Elec Production to Disturbed Land (MWh/acre)	**336.5**	
Ratio of Disturbed Land to Elec Production (acres/MW)	**5.94**	

NOTES

1.) This capacity factor was not provided in the AFC, but was calculated using information taken from the "Project Description" section.

2.) Solar Millenium provided the "facility footprint" within their Application for Certification - a specific breakdown of buildings was not included.

3.) These square footages were not included into the Total Disturbance Area row, as they area they covered is included in the Facility "Footprint" listed in the first row.

Solar Millennium Ridgecrest - Parabolic Trough

Area Efficiency Analysis

	Quantity	Total
Total Site Area (acres)	-	**3,920**
Facility "Footprint" (i.e. area inside the fence line, which excludes gen-tie transmission line route outside the ROW)	-	*1,760*
Footprint of buildings outside the power block[3]	*1*	*2.801*
Footprint of buildings inside of the power block[3]	*1*	*0.716*
Total Disturbance Area (acres)	**1,760**	
Nameplate Capacity (MW)	*250*	
Capacity Factor	*0.228*	
Actual Annual Electricity Production (MWh)	**499,662**	
Ratio of Elec Production to Disturbed Land (MWh/acre)	**283.90**	
Ratio of Disturbed Land to Elec Production (acres/MW)	**7.04**	

NOTES

1.) This capacity factor was not provided in the AFC, but was calculated using information taken from the "Project Description" section.

2.) Solar Millenium provided the "facility footprint" within their Application for Certification - a specific breakdown of buildings was not included.

3.) These square footages were not included into the Total Disturbance Area row, as they area they covered is included in the Facility "Footprint" listed in the first row.

APPENDIX E | SPATIAL ANALYSIS PROCESSING STEPS

APPENDIX E1 | STANDARD DATA PROCESSING

Protocol for Projecting Data

All files are in datum NAD 1983 (D_North_American_1983) and projected coordinate system UTM 11N (NAD_1983_UTM_Zone_11N). If files were not received in these formats, we used a geographic transformation and/or projection.

For vector data:

1. In ArcToolbox, select "**Project**" under Data Management Tools > Projections and Transformations > Feature > **Project**.
2. In the "Project" dialogue box:
   - A. Under "Input Dataset or Feature Class", select the layer you want to project from the dropdown menu.
   - B. Under "Output Dataset or Feature Class", rename the layer (if necessary) and make sure that it will be saved in the desired folder.
   - C. Under "Output Coordinate System", click the button to the right of the field.
     - i. Under the "Spatial Reference Properties" dialogue box, click "**Select**".
     - ii. Click the "Projected Coordinate Systems" folder, then the "UTM" folder, then the "NAD 1983" folder.
     - iii. Select the "NAD 1983 UTM Zone 11N.prj" file, and click "**Add**".
     - iv. Click "**OK**" in the Spatial Reference Properties" dialogue box.
   - D. If the original datum was NAD 1983, click "**OK**".
   - E. If the original datum was not NAD 1983, a drop-down arrow will appear on the right of the "Geographic Transformation" field. In that menu, select the top transformation between the original datum and NAD 1983. Then click "**OK**".

For raster data:

1. In ArcToolbox, select "**Project Raster**" under Data Management Tools > Projections and Transformations > Raster > **Project Raster**.
2. In the "Project Raster" dialogue box:
   - F. Under "Input Raster", select the raster you want to project from the dropdown menu.
   - G. Under "Output Raster Dataset", rename the layer (if necessary) and make sure that it will be saved in the desired folder.
   - H. Under "Output Coordinate System", click the button to the right of the field.
     - i. Under the "Spatial Reference Properties" dialogue box, click "**Select**".

        - ii. Click the “Projected Coordinate Systems” folder, then the “UTM” folder, then the “NAD 1983” folder.
        - iii. Select the “NAD 1983 UTM Zone 11N.prj” file, and click “**Add**”.
        - iv. Click “**OK**” in the Spatial Reference Properties” dialogue box.
    - I. If the original datum was NAD 1983, proceed to step F.
    - J. If the original datum was not NAD 1983, a drop-down arrow will appear on the right of the “Geographic Transformation” field. In that menu, select the top transformation between the original datum and NAD 1983.
    - K. If the data is categorical, under the field “Resampling Technique”, select “NEAREST” from the drop-down menu. Note: CUBIC was used for continuous data.
    - L. The field “Output Cell Size” should equal 30m.
    - M. Click “**OK**” in the “Project Raster” dialogue box.

Protocol for Clipping Data

Most files are clipped to either the boundaries of the California Desert District (CDD) or the California Desert Conservation Area (CDCA).

For vector data:

1. Add the file you wish to clip to an ArcMap session.
2. Add the desired boundary file (e.g. CDD or CDCA) to the ArcMap session.
3. In ArcToolbox, select “**Clip**” under Analysis Tools > Extract > **Clip**.
4. In the “Clip” dialogue box:
    - A. Under “Input Features”, select the layer you want to clip from the drop-down menu.
    - B. Under “Clip Features”, select the boundary file you want to clip to (e.g. CDD, CDCA).
    - C. Under “Output Feature Class”, rename the layer (if necessary) and make sure that it will be saved in the desired folder.
    - D. Leave “XY Tolerance (Optional)” field blank.
    - E. Click “**OK**”.
5. The new clipped layer will be added to your map.

For raster data:

1. Add the file you wish to clip to a blank or existing ArcMap session.
2. Add the desired boundary file (e.g. CDD or CDCA) to the ArcMap session. For this example, we will use the file name “DEM_CDD_30”.
3. Turn on “**Spatial Analyst**” tool. Select “Spatial Analyst” under Tools > Extensions > **Spatial Analyst**.
4. Open up the “**Spatial Analyst Toolbar**”. Under View > Toolbars > **Spatial Analyst**.
5. Click on the Spatial Analyst Toolbar and select “Options”.

    A. Under the “General” tab:
        i. Working directory: specify where you want to hold the working version of the map.
        ii. Analysis Mask: Insert “DEM_CDD_30”.
    B. Under the “Extent” tab: select “same layer as DEM_CDD_30”.
    C. Under the “Cell Size” tab:
        i. Analysis cell size: select “Same as layer DEM_CDD_30”. Note: 30 meter cell size is used for all rasters in this project.
        ii. Cell size: 30

6. To perform the mask/clip, click on the Spatial Analyst Toolbar and select “**Raster Calculator**”. Double click the layer that you want to clip so that it appears in the blank space in the Raster Calculator field. Click “**EVALUATE**”.

APPENDIX E2 | DEFINING THE SCOPE

For Steps 1 and 2, See Appendix E1

The following Steps 3 to 7 describe the processing involved to create a file that will later be used as the mask and extent. The file is used as the mask and extent in any geoprocessing involving species (Steps 6, 7, 8 of Appendix E4 | Ecology Processing).

Step 3: Convert Land Management Designation File from Vector to Raster[a]

A. ArcToolbox > Conversion Tools > To Raster > **Polygon to Raster**

B. Setting the "**Environments**" in the dialogue box**:** In the environments window, set the extent, cell size and mask equal to DEM_CDD_30:

   1. General Settings: Extent= DEM_CDD_30.
   2. Raster Analysis Settings: Cell Size, Extent= DEM_CDD_30.
   3. Select **OK.**

C. Once the environments are set, fill in the rest of the dialogue box.

   1. Input Features: Select a land management vector file.
   2. VALUE FIELD: See Table E.1.

Table E.1 Value Fields Used in Processing Land Management Vector Files

Vector File	VALUE Field
Wilderness	WLDPCA_ID
WSA	WSA_Suitab
ACEC	ACCPCA_
National Monument	FID
Flat-tailed Horned Lizard Management Area	HMPPTHL_
Land Ownership	Agency_NUM*

***Note: We created Agency_NUM, and the following numbers were assigned: 0=Unclassified, 1=BLM, 2= Bureau of Reclamation, 3=Military, 4=NPS, 5=FWS, 6=US Forest Service, 7=State, 8= Other Federal, 9=Local Government**

   3. Output Raster: In the "output feature class", locate the output location and name the file.
   4. All other boxes should be automatically filled in by setting the environments in the previous step.
   5. Click **OK**. A new raster file is created.

Step 4: Reclassify the raster file in ArcMap

A. Open the "Reclassify" tool:

---

[a] Note: For critical habitat, complete processing steps described below under "FWS Critical Habitat Processing" in place of steps 3-5.

    1. ArcToolbox > Spatial Analyst > Reclass > **Reclassify**

B. In the dialogue box:
    1. Input raster: Select the land management raster that was just created.
    2. Reclass Field : VALUE.
C. Setting the **"Environments"** in the dialogue box**:** In the environments window, set the extent, cell size and mask equal to DEM_CDD_30:
    1. General Settings: Extent= DEM_CDD_30.
    2. Raster Analysis Settings: Cell Size, Extent= DEM_CDD_30.
    3. Select **"OK".**
D. Click under the "New Values" column and change:
    1. ACECs, Wilderness Areas, WSAs, National Monument, Flat-tail Horned Lizard Management Areas: 0 and NoData = 0, All other values = 1000.
    2. Land Ownership: NPS, FWS, BOR, and DOD were reclassified as 1000 and all others were reclassified as 0 (BLM, USFS, State, Local Govt., Private, Unclassified).
E. Output Raster: In the "**Output raster**", locate the output location and name the raster.
F. Click **OK**. This creates a new raster with high conflict areas scored at 1000 and all other areas scored at 0.

Step 5: Repeat Steps 3 and 4 for all land management vector files

Step 6: Overlay all land management raster files by adding all files using Raster Calculator in the Spatial Analyst Toolbar

Step 7: Reclassify resulting land management raster with 0 and NoData as 0 and all other values as 1000

FWS Critical Habitat Data Processing

Use these steps in place of Steps 3 to 5 above for U.S. Fish and Wildlife Service critical habitat areas.

Step 1: Union all [37] FWS critical habitat files in ArcMap

A. Open ArcMap, then open the union tool: ArcToolbox > Analysis Tools > Overlay > **Union.**
B. Once the dialogue box opens, locate and select all of the critical habitat files from the catalog tree, then drag them under the "**Features**" heading in the dialogue box.
C. In the "**Output feature class**", locate the output location and name the file.
D. Leave all other options as they are, click "**OK**"**.** This creates a single shapefile consisting of all 37 critical habitat files.

Step 2: Convert the critical habitat union vector to a raster using ArcMap

A. ArcToolbox > Conversion Tools > To Raster > **Polygon to Raster.**
B. Setting the "**Environments**" in the dialogue box**:** In the environments window, set the extent, cell size and mask equal to DEM_CDD_30:
    1. General Settings: Extent = DEM_CDD_30.
    2. Raster Analysis Settings: Cell Size, Extent = DEM_CDD_30.
    3. Select "**OK**"**.**
C. Once the environments are set, fill in the rest of the dialogue box:
    1. Input Features: Select the critical habitat union shapefile.
    2. VALUE FIELD: Inspect the attribute table of the habitat union shapefile. Find the value field with the fewest number of different variables. In this case, "FID_caenot" has only values of -1 and 0 so it is chosen as the Value Field.
    3. Output Raster: In the "Output feature class", locate the output location and name the file.
    4. All other boxes should be automatically filled in by setting the environments in the previous step.
    5. Click "**OK**". A new raster file is created.

Step 3: Reclassify the new raster in ArcMap

A. ArcToolbox > Spatial Analyst > Reclass > **Reclassify.**
B. Input raster: select the raster that was just created.
C. Reclass Field : VALUE.
D. Setting the **Environments** in the dialogue box**:** In the environments window, set the extent, cell size and mask equal to DEM_CDD_30:
    1. General Settings: Extent= DEM_CDD_30.
    2. Raster Analysis Settings: Cell Size, Extent= DEM_CDD_30.
    3. Select "**OK**"**.**
E. Click under the "**New Values**" column and change NoData to 0 and all other values to 1000.
F. Output Raster: In the "Output raster", locate the output location and name the raster.
G. Click **OK**. This creates a new raster with cell values of only 1000 or 0.

APPENDIX E3 | ECOLOGY NUMERICAL SCORES

Global Rank

We assigned the NatureServe Global Rank (GRank) classification system with scores between 0 and 60. In order to distribute scores evenly between all possible classifications, we used increments of 10. Special classifications include:

- GH = Historical occurrence (element has not been seen in at least 20 years but suitable habitat exists)
- GX = Species is extirpated in the wild
- G? = Global Rank has not been established or is unknown

GH was given a score of 10 because suitable habitat might still exist for that species and there is potential for the species to reoccupy the area. GX was given a score of 0 because the species is extirpated from the wild and would not be able to reoccupy an area even if suitable habitat remained. G? was given a score of 0 because no rank has been provided.

G Rank	Score
G1	60
G2	50
G3	40
G4	30
G5	20
GH	10
GX	0
G?	0
GnTn	Gn + Tn
GnT1	9
GnT2	7
GnT3	5
GnT4	3
GnT5	1

Examples:

The Desert pincushion (*Coryphantha chlorantha*) has a GRank of G2G3. The numerical score is:

G2G3 = (50 + 40) / 2 = 45

The Cima milk-vetch (*Astragalus cimae* var. *cimae*) subspecies has a GRank of G2T2. The numerical score is:

G2T2 = 50 + 7 = 57

Peirson's milk-vetch (*Astragalus magdalenae* var. *peirsonii*) subspecies has a GRank of G3G4T2. The numerical score is:

G3G4T2 = (40 + 30)/2 + 7 = 35 + 7 = 42

The Curved-pod milk-vetch (*Astragalus mohavensis* var. *hemigyrus*) subspecies has a GRank of G3G4T2T3. The numerical score is:

G3G4T2T3 = (40 + 30)/2 + (7 + 5)/2 = 35 + 6 = 41

NatureServe sometimes uses "T" to indicate the score for a particular subspecies or variety, following the same categories as "G" (i.e. T1 = critically imperiled, T2 = imperiled, etc.). We wanted to distinguish between subspecies because rarity/endangerment can vary between subspecies, and therefore provided scores between 0 and 10 to be added to the "G" score.

State Rank

We assigned the NatureServe State Rank (SRank) classification system with scores between 0-60. In order to distribute scores evenly between all possible classifications, we used increments of five. Special classifications include:

- SH = Historical occurrence in California (suitable habitat exists)
- SX = Species is extirpated from California
- SNR = No SRank

SH was given a score of five because we thought if a species was able to persist in that area historically, then suitable habitat might still exist for that species. SX was given a score of 0 because an extinct species would not be able to reoccupy an area even if suitable habitat remained. SNR was given a score of 0 because no rank has been provided. Scores were not assigned in a linear fashion because we felt that the level of threat to the species warranted a greater score than the number of element occurrences, individuals, or acres. Species that were given ranks of S1, S2, or S3 were assumed to not have an associated threat ranking and therefore were assigned the same value as a ranking with 0.3 attached (no current threats known).

S Rank	Score
S1.0	30
S1.1	60
S1.2	45
S1.3	30
S2.0	25
S2.1	55
S2.2	40
S2.3	25
S3.0	20
S3.1	50
S3.2	35
S3.3	20
S4	15
S5	10
SH	5
SX	0
SNR	0

Examples:

The Algodones Dunes sunflower (*Helianthus niveus* ssp. *tephrodes*) has an SRank of S1.2. The numerical score is:

S1.2 = 45

Townsend's big-eared bat (*Corynorhinus townsendii*) has an SRank of S2S3. The numerical score is:

S2S3 = (25 + 20)/2 = 22.5

Because reclassifying in ArcGIS does not allow for decimals, we rounded up to 23.

Endangered Species Act

We assigned the Federal Endangered Species Act classification system with scores between 0 and 60. In order to distribute scores evenly between all possible classifications, we used increments of 10.

ESA	Score
Endangered	60
Threatened	50
Proposed Endangered	40
Proposed Threatened	30
Candidate	20
Spp of Concern	10
Delisted	0
None	0

Examples:

The Amargosa vole (*Microtus californicus scirpensis*) is listed as endangered and received a score of 60.

The San Fernando Valley spineflower (*Chorizanthe parryi* var. *fernandina*) is listed as a candidate and received a score of 20.

California Endangered Species Act

We assigned the California Endangered Species Act classification system with scores between 0 and 60. In order to distribute scores evenly between all possible classifications, we used increments of 15.

CESA	Score
Endangered	60
Threatened	45
Rare	30
Candidate	15
Delisted	0
None	0

Examples:

The Coachella Valley fringe-toed lizard (*Uma inornata*) is listed as endangered and received a score of 60.

The Mojave ground squirrel (*Xerospermophilus mohavensis*) is listed as threatened and received a score of 45.

California Native Plant Society

We assigned the California Native Plant Society classification system with scores between 0 and 60. In order to distribute scores evenly between all possible classifications, we used increments of five. Plants without rankings and non-plant element occurrences were given scores of 0.

CNPS	Score
1B.1	60
1B.2	55
1B.3	50
2.1	45
2.2	40
2.3	35
3.1	30
3.2	25
3.3	20
4.1	15
4.2	10
4.3	5
1A	0

Examples:

The Algodones Dunes Sunflower (*Helianthus niveus* ssp. *tephrodes*) was listed as 1B.2 (rare, threatened, or endangered in California and elsewhere AND fairly threatened in California). It was given a score of 55.

Booth's evening-primrose (*Camissonia boothii* ssp. *boothii*) was listed as 2.3 (rare, threatened, or endangered in California, but more common elsewhere; not very threatened in California). It was given a score of 35.

APPENDIX E4 | SENSITIVE HABITAT PROCESSING

Step 1: Download Data

A. Install the CNDDB RareFind 3 CD. RareFind 3 was provided to this project as an academic subscription. To obtain a copy of this database, go to <http://www.dfg.ca.gov/biogeodata/cnddb/>.

B. Download Element Occurrence data (vector) from CNDDB RareFind 3 into ArcMap.

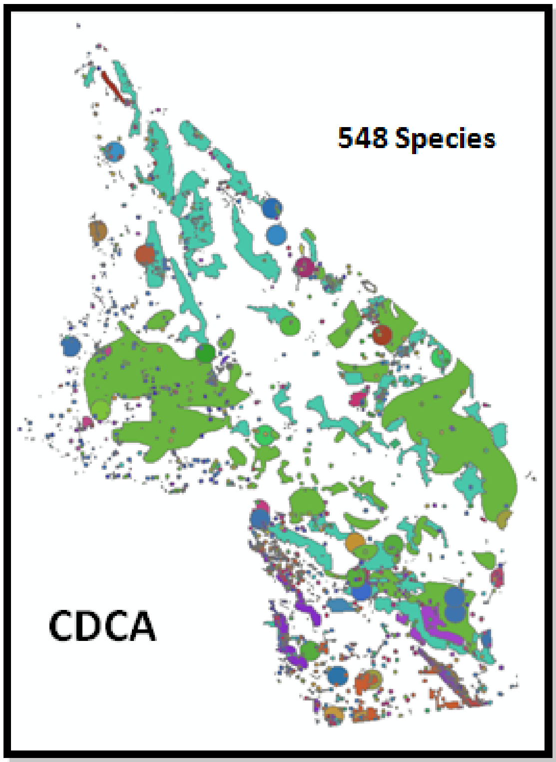
Step 2: Clip the CNDDB species data to the CDCA in ArcMap

A. Open ArcMap and add the CNDDB file (ECO_cnddb) and the outline of the CDCA (GEN_CDCA_Outline) to a blank or existing ArcMap session.

B. Use the “Clip” tool: Arc Toolbox > Analysis tools > Extract > **Clip:**

  1. In the dialogue box:
      a. Input Features: ECO_cnddb.
      b. Clip Features: GEN_CDCA_Outline.
      c. Leave the XY Tolerance field blank.
      d. Click “**OK**”.

The CNDDB clipped to the CDCA:

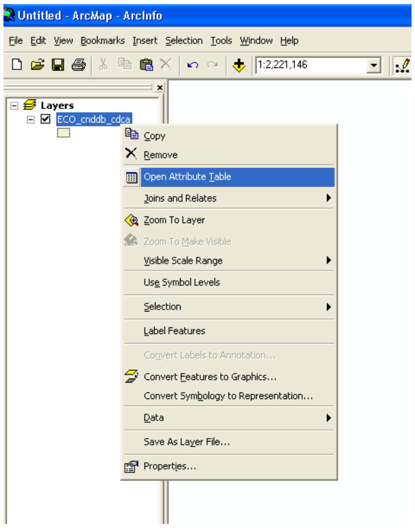


Step 3: Add numerical scores to the species attribute table

In this step, the calculated numerical scores for each species are entered into the CNDDB attribute table so that the scores can be used later for reclassification. The five categories of numerical values will be entered based on GRANK, SRANK, ESA, CESA, and CNPS. To see the scores and how they were calculated, refer to Appendix E3. ECO_cnddb_cdca is the layer created in Step 2.

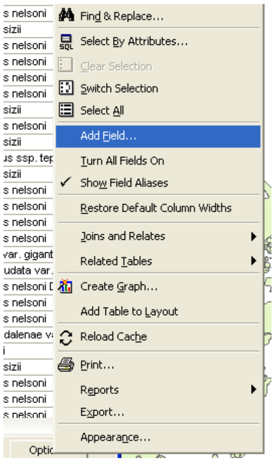
A. Add the ECO_cnddb_cdca layer to a new or existing ArcMap Session.

B. In the table of contents, right click on the layer and click “Open Attributes Table”.

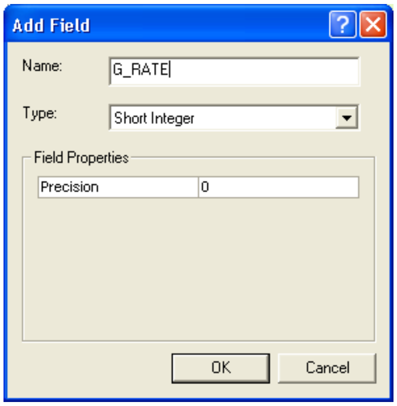


C. Add a new field to the attributes table:

1. Click Options > **Add Field.**



2. In the “Name” field of the “Add Field” dialogue box, type **“G_RATE”.**
3. Set the “Type” field to **“Short Integer”.**
4. Click **“OK”.**



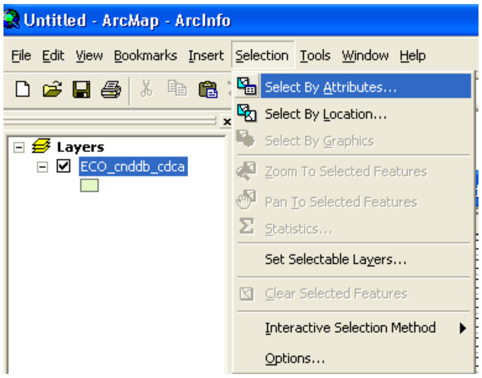
Name: G_RATE

Type: Short Integer

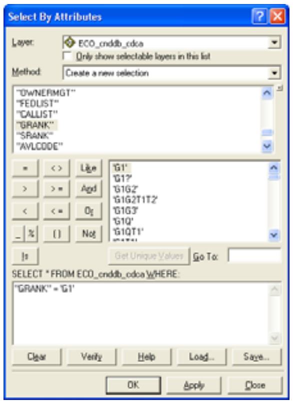
Precision: 0

D. Create a selection of one category of GRANK (e.g. G1):

1. In the main window of ArcMap, click Selection > **Select by Attributes.**



2. In the "**Select by Attributes**" dialogue box:
   a. Set the "Layer" to **"ECO_cnddb_cdca".**
   b. Leave "Only show selectable layers in this list" **unchecked.**
   c. Set the "Method" to **"Create new selection"**.
   d. DOUBLE CLICK **"GRANK"** from the list of fields. GRANK should now be added to the blank box at the bottom of the dialogue box.
   e. Click the **equal** button [=].
   f. Click **"Get Unique Values".**
   g. DOUBLE CLICK the first result from the list of unique values to add it after the **equal** sign.
   h. The dialogue box should look like the one below.
   i. Click **"Apply".**



Layer: ECO_cnddb_cdca

☐ Only show selectable layers in this list

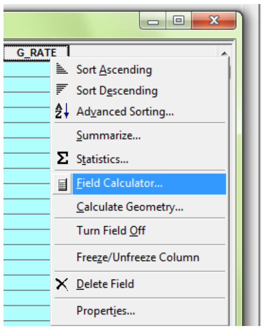
Method: Create a new selection

SELECT * FROM ECO_cnddb_cdca WHERE:

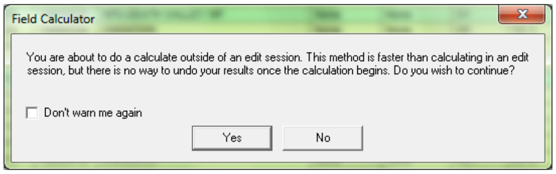
"GRANK" = 'G1'

E. Use the field calculator to add records to G_RATE:

1. With the selection made, open the attributes table of “**ECO_cnddb_cdca**”.
2. Right click the heading **“G_RATE”.**
3. Click **“Field Calculator…**”



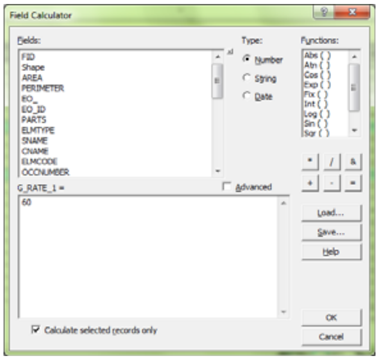
4. A warning message will appear. Click **“Yes”**



You are about to do a calculate outside of an edit session. This method is faster than calculating in an edit session, but there is no way to undo your results once the calculation begins. Do you wish to continue?

☐ Don't warn me again

5. Click in the blank space and type the code for the GRATE that was selected. In this case, the GRATE G1 is selected. Type **60**. Click **“OK”**.



Type: ● Number ○ String ○ Date

☐ Advanced

G_RATE_1 =

60

☑ Calculate selected records only

6. Now, only the GRANKS equal to G1 are calculated.

    7. Repeat Steps D and E for every different GRATE.

F. Repeat Steps C to E for each of the remaining categories.

Step 4: Create a new file for each species

In order to analyze individual species, they each need to be separated from the larger ECO_cnddb_cdca file and made into their own shapefile. There are several hundred species in the file, which could become time consuming if it is done manually in ArcGIS, but there is a faster and more efficient way to do it through the use of Microsoft Excel and the ArcGIS Command Line.

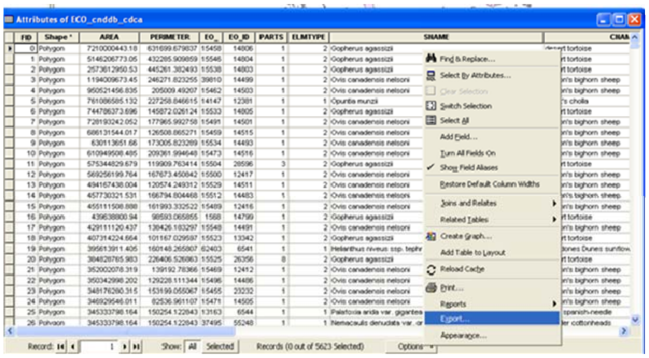
Excel can be used to automate the creation of a command line text. Excel can automatically fill out multiple cells, and by using the "&" sign, one cell can be filled with the contents of several cells. For example, the contents in cells A1, B1 and C1 can be pieced together and placed in the cell D1 using the formula: **D1= A1&B1&C1**

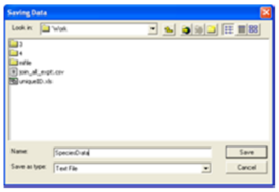
Then, this cell's content is copied and pasted into the command line of ArcGIS. The command line can perform any task in ArcGIS that is normally done through the use of dialogue boxes. For example, the species named "Mimulus mohavensis" can be selected from a list of species and made into its own shapefile using the dialogue box "Select by Attribute". The command line behind this task is:

```
SELECT ECO_cnddb_cdca M:\NRE-540\polygonfolder\172.shp ("SNAME" = 'Mimulus mohavensis?')
```

The directions for setting up the excel sheet and executing hundreds of commands at once is described below.

A. Export the data from the species attribute table in .txt format (in ArcGIS):
    1. Add the file "ECO_cnddb_cdca" to the table of contents.
    2. Open the "ECO_cnddb_cdca" attribute table.
    3. Click Options > **Export.**
    4. Export the data from the species attribute table in .txt format:
        a. In the "Export Data" dialogue box:
            i. Export: All records
            ii. Make sure to change the file format from ".dbf" to ".txt".





Look in: Work

Name: SpeciesData

Save as type: Text File

B. In Excel:

1. Import the .txt file into Excel

    b. Click the **"Data"** tab in the Excel ribbon.

    c. Click **"From Text".**

    d. In the **"Import Text File"** dialogue box, select the .txt file.

    e. Click **"Import".**

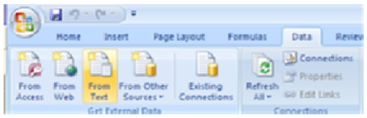
    f. In the **"Text Import Wizard"** dialogue box:

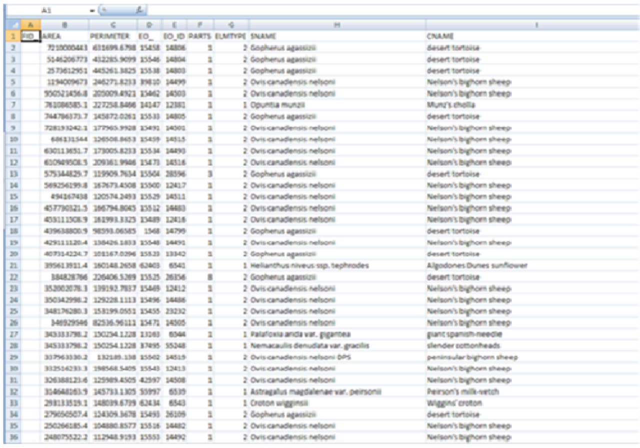
        i. Make sure the radio button **"Delimited"** is clicked.

        ii. Click **"Next".**

        iii. In Step 2, make sure the box next to **"Comma"** is checked.

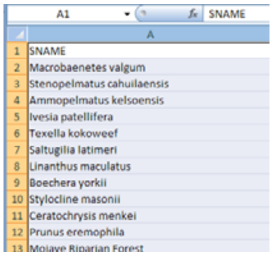
        iv. Click **"Finish"**.





2. Delete all columns but SNAME, this is the species scientific name. The field CNAME is the species common name and was not used because some of the names contain apostrophes. This type of symbol is not accepted in the command line window.

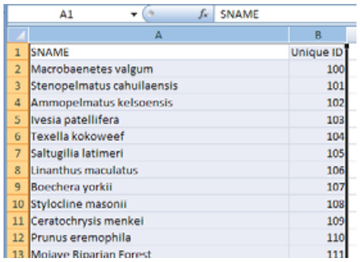
3. Delete duplicate rows:
    a. Select the entire column that contains “SNAME”.
    b. In the **Data** tab, click **“Remove Duplicates”.**
    c. A warning box appears: Make sure the radio button next to **Expand the selection** is clicked.
    d. Click **“Remove Duplicates…”**
    e. Click **“Unselect All”.**
    f. Click the box next to **“SNAME”.**
    g. Click **“OK”.**



A1 fx SNAME

	A
1	SNAME
2	Macrobaenetes valgum
3	Stenopelmatus cahuilaensis
4	Ammopelmatus kelsoensis
5	Ivesia patellifera
6	Texella kokoweef
7	Saltugilia latimeri
8	Linanthus maculatus
9	Boechera yorkii
10	Stylocline masonii
11	Ceratochrysis menkei
12	Prunus eremophila
13	Mojave Riparian Forest

4. Create a new column for unique ID’s. When saving the new file, ArcGIS does not accept file names of more than 13 characters. For this reason, each species is assigned a unique ID number to be used as the new filename. The species unqiue ID will be used as the filename when the selection is exported into a shapefile. For example, “Macrobaenetes valgum” will be “100.shp”.



A1 fx SNAME

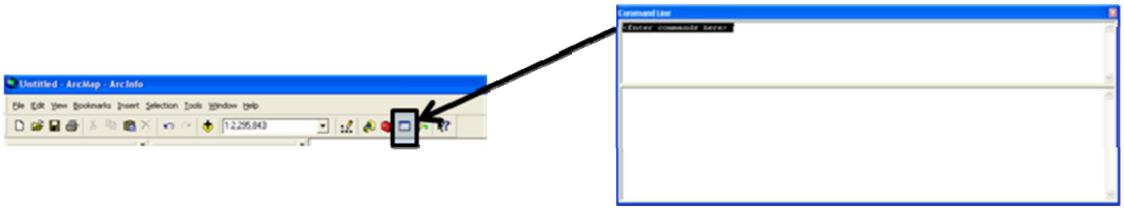
	A	B
1	SNAME	Unique ID
2	Macrobaenetes valgum	100
3	Stenopelmatus cahuilaensis	101
4	Ammopelmatus kelsoensis	102
5	Ivesia patellifera	103
6	Texella kokoweef	104
7	Saltugilia latimeri	105
8	Linanthus maculatus	106
9	Boechera yorkii	107
10	Stylocline masonii	108
11	Ceratochrysis menkei	109
12	Prunus eremophila	110
13	Mojave Riparian Forest	111

5. Fill in the rest of the columns in Excel based on the command line script format. The format of the command line is:

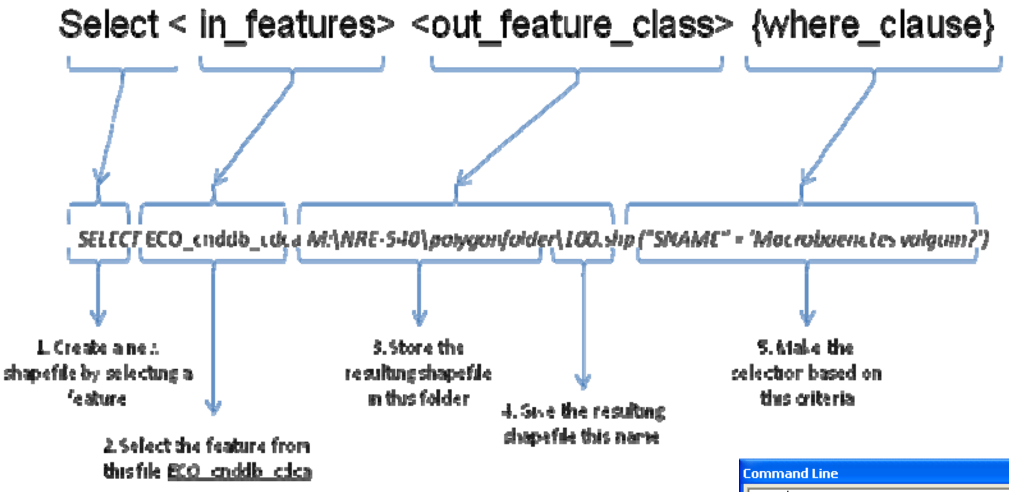
Select < in_features> <out_feature_class> {where_clause}

C. Understanding Command Line:

1. Add the file “ECO_cnddb_cdca” to a new or existing ArcMap session. Note the Command Line Window:



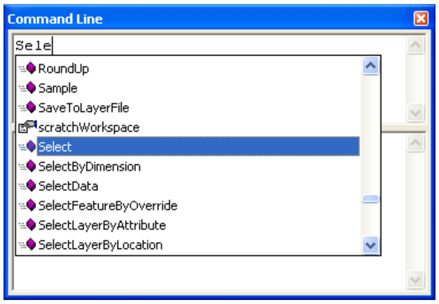
The command for selecting a piece of a shapefile and creating a new shapefile from it is:



Each of the pieces are described below:

1. SELECT <command>.

   This tells the program to create a new selection from a layer.



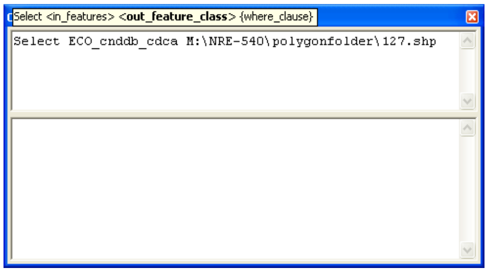
2. ECO_cnddb_cdca <in_features>

   The feature to create the selection from is the layer called "ECO_cnddb_cdca". It is the only layer displayed in the map so it is the only option to choose from.

```
Select
```

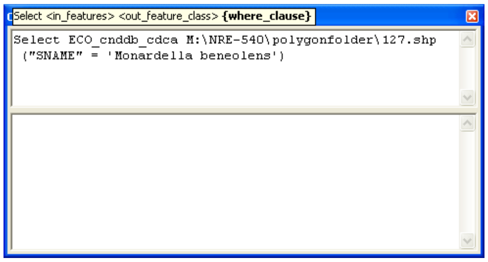
3. C:\FileLocation\127.shp <out_feature_class>

   There are two parts to this. The first part is the destination for the file.



```
Select ECO_cnddb_cdca M:\NRE-540\polygonfolder\127.shp
```

4. The second part is the new file name, 127.shp. This is the unique ID for the species "Monardella beneolens".



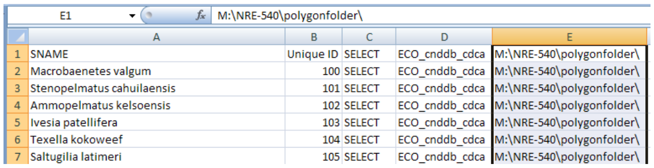
```
Select ECO_cnddb_cdca M:\NRE-540\polygonfolder\127.shp
 ("SNAME" = 'Monardella beneolens')
```

5. (“SNAME”= ‘Monardella beneolens’) {where_clause}
   This line specifies which species to select from the list of species in the shapefile attribute table. In this case, the species with the scientific name “Monardella beneolens” will be selected.

   This completes the command line. Once executed, a new shapefile is created called “127.shp” and contains only habitat for the species “Mandardellla beneolens”.

D. Creating Command Line using Excel

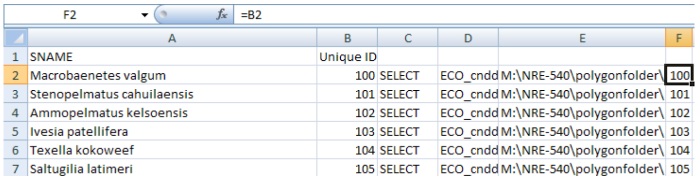
1. Creating pieces 1 through 5 in Excel: Add these columns to the spreadsheet that was created from the “ECO_cnddb_cdca” attribute table. Note: All of this is case sensitive.
2. To create pieces 1, 2, and 3 in Excel, simply type it once. The same line can be repeated for all files.
3. The column containing piece 1 (Column C) should say “SELECT” all the way down to the last row of species. This is the same for the column containing piece 2 (Column D), the “in” feature: “ECO_cnddb_cdca”, and the same for the column containing piece 3 (Column E), the “out” feature: “M:\NRE-540\polygonfolder\”. This is the location to store the output file however it may be different depending on the user’s preference.



E1 fx M:\NRE-540\polygonfolder\

	A	B	C	D	E
1	SNAME	Unique ID	SELECT	ECO_cnddb_cdca	M:\NRE-540\polygonfolder\
2	Macrobaenetes valgum	100	SELECT	ECO_cnddb_cdca	M:\NRE-540\polygonfolder\
3	Stenopelmatus cahuilaensis	101	SELECT	ECO_cnddb_cdca	M:\NRE-540\polygonfolder\
4	Ammopelmatus kelsoensis	102	SELECT	ECO_cnddb_cdca	M:\NRE-540\polygonfolder\
5	Ivesia patellifera	103	SELECT	ECO_cnddb_cdca	M:\NRE-540\polygonfolder\
6	Texella kokoweef	104	SELECT	ECO_cnddb_cdca	M:\NRE-540\polygonfolder\
7	Saltugilia latimeri	105	SELECT	ECO_cnddb_cdca	M:\NRE-540\polygonfolder\

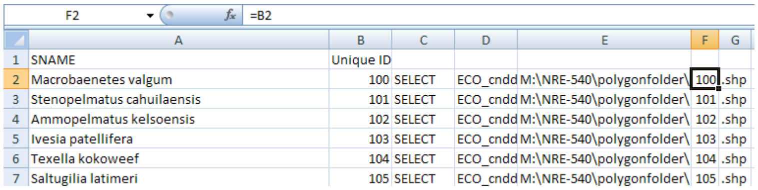
4. Create a new column to contain the second part of the out feature, which is the output filename. In this case, it is Column F. In cell F2, insert an equation that references Column B (=B2), the column containing “Unique ID”. The rest of this column can be filled in by using “autofill” in Excel.



F2 fx =B2

	A	B	C	D	E	F
1	SNAME	Unique ID				
2	Macrobaenetes valgum	100	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	100
3	Stenopelmatus cahuilaensis	101	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	101
4	Ammopelmatus kelsoensis	102	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	102
5	Ivesia patellifera	103	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	103
6	Texella kokoweef	104	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	104
7	Saltugilia latimeri	105	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	105

5. Create a new column to complete the out feature class portion of the command line, in this case Column G. This column is filled with “.shp” for every row that contains the species. Later, these two columns (F and G) will be merged together to form one. For example, 100.shp. This avoids the process of needing to type in 100.shp.

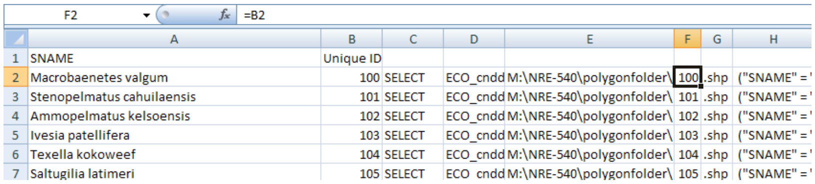


F2 =B2

	A	B	C	D	E	F	G
1	SNAME	Unique ID					
2	Macrobaenetes valgum	100	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	100	.shp
3	Stenopelmatus cahuilaensis	101	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	101	.shp
4	Ammopelmatus kelsoensis	102	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	102	.shp
5	Ivesia patellifera	103	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	103	.shp
6	Texella kokoweef	104	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	104	.shp
7	Saltugilia latimeri	105	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	105	.shp

6. Piece 5 is the “where clause”: (“SNAME”=’Mandardella beneolens’).
7. The first part of the where clause is the SNAME. Create a new column (H) filled with “SNAME”. This is the same for all lines. The exact text to type is:

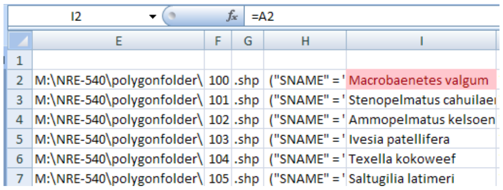
(“SNAME=’



F2 =B2

	A	B	C	D	E	F	G	H
1	SNAME	Unique ID						
2	Macrobaenetes valgum	100	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	100	.shp	("SNAME" = '
3	Stenopelmatus cahuilaensis	101	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	101	.shp	("SNAME" = '
4	Ammopelmatus kelsoensis	102	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	102	.shp	("SNAME" = '
5	Ivesia patellifera	103	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	103	.shp	("SNAME" = '
6	Texella kokoweef	104	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	104	.shp	("SNAME" = '
7	Saltugilia latimeri	105	SELECT	ECO_cndd	M:\NRE-540\polygonfolder\	105	.shp	("SNAME" = '

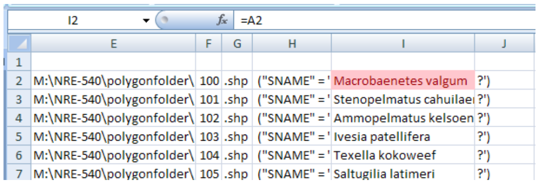
8. The second part is the species name ‘Mandardella beneolens’. Create a new column (I) that references the column that holds the species name (A). Later, these two columns will be merged together to form one. For example, “SNAME=Mandardella beneolens”.



I2 =A2

	E	F	G	H	I
1					
2	M:\NRE-540\polygonfolder\	100	.shp	("SNAME" = '	Macrobaenetes valgum
3	M:\NRE-540\polygonfolder\	101	.shp	("SNAME" = '	Stenopelmatus cahuilae
4	M:\NRE-540\polygonfolder\	102	.shp	("SNAME" = '	Ammopelmatus kelsoen
5	M:\NRE-540\polygonfolder\	103	.shp	("SNAME" = '	Ivesia patellifera
6	M:\NRE-540\polygonfolder\	104	.shp	("SNAME" = '	Texella kokoweef
7	M:\NRE-540\polygonfolder\	105	.shp	("SNAME" = '	Saltugilia latimeri

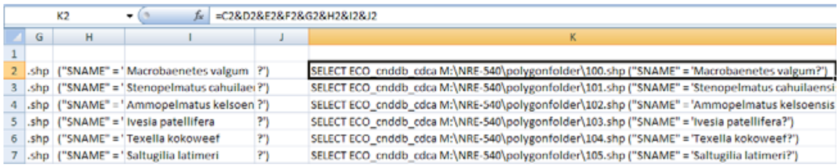
9. Creating the pieces in-between the bulk. Column J contains a single quote that surrounds the scientific name. Since Excel won’t allow just **‘)**, a question mark needs to be added: **?’)** Later, the question mark will be removed.



I2 =A2

	E	F	G	H	I	J
1						
2	M:\NRE-540\polygonfolder\	100	.shp	("SNAME" = '	Macrobaenetes valgum	?')
3	M:\NRE-540\polygonfolder\	101	.shp	("SNAME" = '	Stenopelmatus cahuilae	?')
4	M:\NRE-540\polygonfolder\	102	.shp	("SNAME" = '	Ammopelmatus kelsoen	?')
5	M:\NRE-540\polygonfolder\	103	.shp	("SNAME" = '	Ivesia patellifera	?')
6	M:\NRE-540\polygonfolder\	104	.shp	("SNAME" = '	Texella kokoweef	?')
7	M:\NRE-540\polygonfolder\	105	.shp	("SNAME" = '	Saltugilia latimeri	?')

10. Column K: Columns C through J are combined. The formula bar shows this, and the cell shows the actual text.

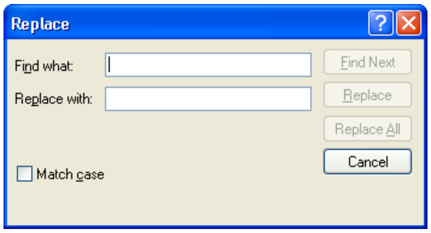


K2 =C2&D2&E2&F2&G2&H2&I2&J2

	G	H	I	J	K
1					
2	.shp	("SNAME" = '	Macrobaenetes valgum	?')	SELECT ECO_cnddb_cdca M:\NRE-540\polygonfolder\100.shp ("SNAME" = 'Macrobaenetes valgum?')
3	.shp	("SNAME" = '	Stenopelmatus cahuilae	?')	SELECT ECO_cnddb_cdca M:\NRE-540\polygonfolder\101.shp ("SNAME" = 'Stenopelmatus cahuilaensi
4	.shp	("SNAME" = '	Ammopelmatus kelsoen	?')	SELECT ECO_cnddb_cdca M:\NRE-540\polygonfolder\102.shp ("SNAME" = 'Ammopelmatus kelsoensis
5	.shp	("SNAME" = '	Ivesia patellifera	?')	SELECT ECO_cnddb_cdca M:\NRE-540\polygonfolder\103.shp ("SNAME" = 'Ivesia patellifera?')
6	.shp	("SNAME" = '	Texella kokoweef	?')	SELECT ECO_cnddb_cdca M:\NRE-540\polygonfolder\104.shp ("SNAME" = 'Texella kokoweef?')
7	.shp	("SNAME" = '	Saltugilia latimeri	?')	SELECT ECO_cnddb_cdca M:\NRE-540\polygonfolder\105.shp ("SNAME" = 'Saltugilia latimeri?')

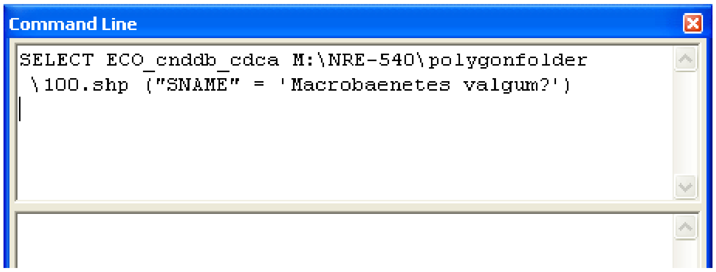
11. Add the contents from Excel to Notepad:
    a. In Excel, right click on cell K2 > **Copy.**
    b. Open Microsoft Notepad.

    c. Right click > **Paste.**
    d. Click Edit > **Replace…**



    e. In **“Find what”** type: **?.**
    f. In **“Replace with:”** type a blank (spacebar).
    g. Click **“Replace All”.**

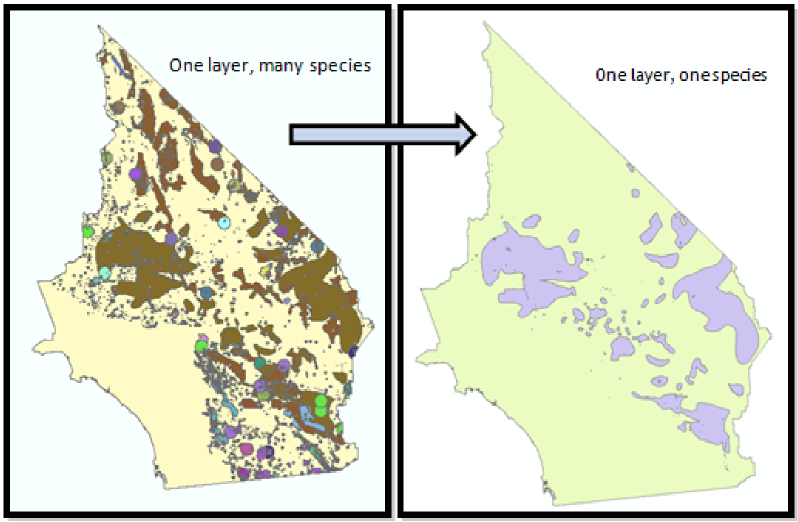
12. Now, the **?** should be gone from the text.Add Contents from Notepad to ArcGIS Command Line:
    a. In Notepad, select all the text, right click > **copy.**
    b. Add the file **ECO_cnddb_cdca** to a new or existing ArcMap session.
    c. Open the Command Line Window.
    d. Where it says “Enter commands here”, right click > **paste.**
    e. Hit the **“enter”** key on the keyboard.
    f. ArcGIS will run the command which creates a new shapefile for the species “Macrobaenetes valgum”.



```
SELECT ECO_cnddb_cdca M:\NRE-540\polygonfolder
 \100.shp ("SNAME" = 'Macrobaenetes valgum?')
```

E. Using Command Line to speed up processing:
    1. To make the best use of the Command Line, the user may copy and paste several hundred commands at once into the window and run it at one time. Depending on the speed of the machine, running several hundred at once may take too long, so the user also has the option to run the process in batches of a more manageable size.

Final result: one layer per species



Step 5: Convert species files from vector to raster

The next step is to rasterize the vector. A raster format is preferred over a vector for this type of analysis because it allows us to perform raster calculations. With a raster, every cell of an element occurrence has one value, and where different shapes overlap, those different values are added together.

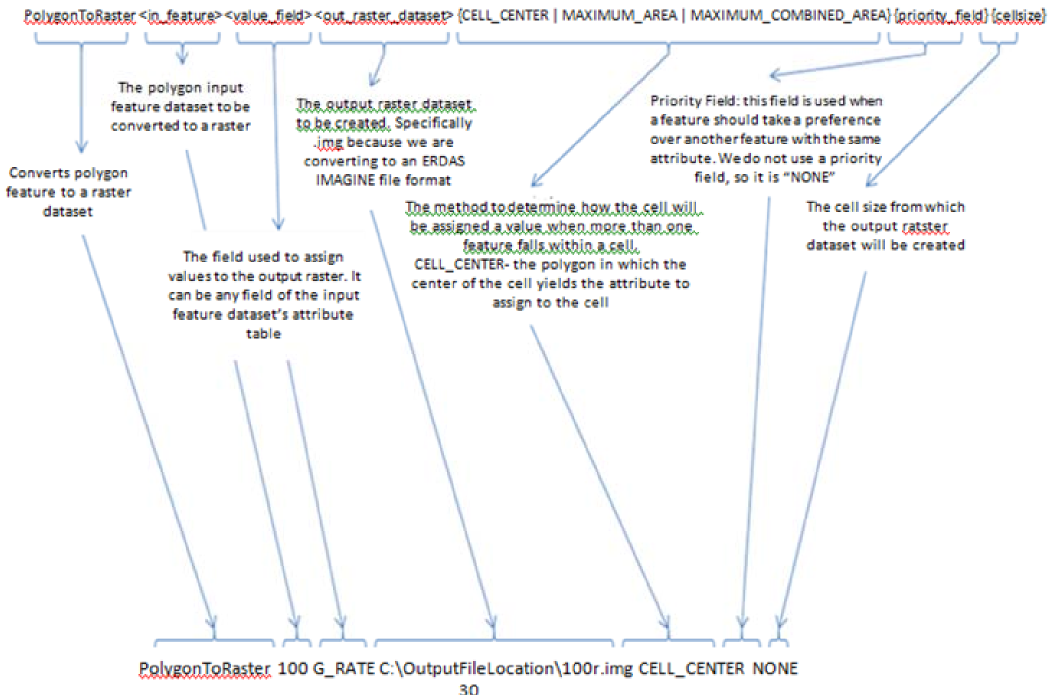
Excel is used to expedite the process of rasterizing all of the vectors. The command line behind this task is:

```
PolygonToRaster 100 G_RATE M:\NRE-540\rasterfolder\100r.img CELL_CENTER NONE 30
```

The directions for setting up the Excel sheet and executing multiple commands at once is described below. This step uses the vectors that were created in Step 4, Appendix E4:

A. Open ArcGIS and add the polygons to the map. Multiple polygons can be added, depending on your computer's speed. It is a good idea to start with a batch of 10 to see how fast the process works.
B. Open Excel to start creating the command line used for executing "Polygon to Raster".

The graphic below describes the purpose behind each piece of the command line, along with the appropriate fields to fill it in for our purpose.



```
PolygonToRaster <in_feature> <value_field> <out_raster_dataset> {CELL_CENTER | MAXIMUM_AREA | MAXIMUM_COMBINED_AREA} {priority_field} {cellsize}
```

Converts polygon feature to a raster dataset

The polygon input feature dataset to be converted to a raster

The field used to assign values to the output raster. It can be any field of the input feature dataset's attribute table

The output raster dataset to be created. Specifically .img because we are converting to an ERDAS IMAGINE file format

The method to determine how the cell will be assigned a value when more than one feature falls within a cell. CELL_CENTER- the polygon in which the center of the cell yields the attribute to assign to the cell

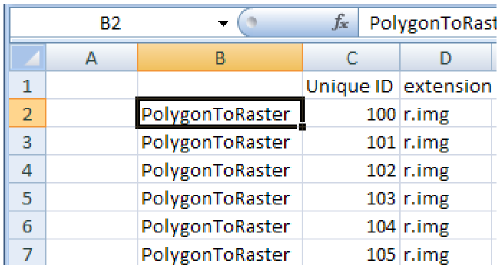
Priority Field: this field is used when a feature should take a preference over another feature with the same attribute. We do not use a priority field, so it is "NONE"

The cell size from which the output ratster dataset will be created

```
PolygonToRaster 100 G_RATE C:\OutputFileLocation\100r.img CELL_CENTER NONE
30
```

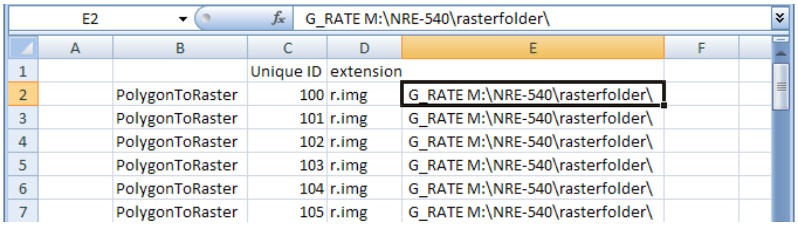
C. In Excel, start with three columns: "Unique ID", "filename extension" and the command "Polygon to Raster":

1. Column B is the beginning of the command line.
2. Column C is the unique ID and is used as the input feature.
3. Column D is the file extension. It will be used later in the command line in "out_raster_dataset". The output raster will have the same unique ID as the input feature, only with "r" added to the end to signify it is a raster, and ".img" as the filename extension because it is now an ERDAS IMAGINE file.



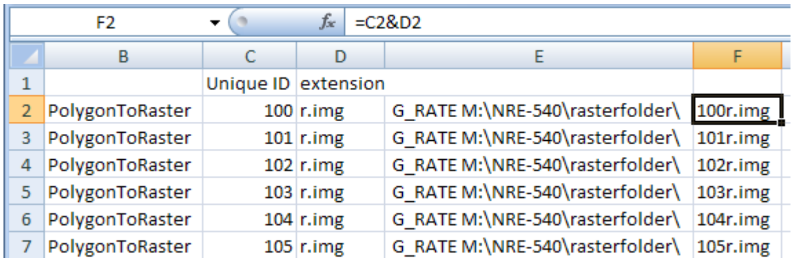
	A	B	C	D
1			Unique ID	extension
2		PolygonToRaster	100	r.img
3		PolygonToRaster	101	r.img
4		PolygonToRaster	102	r.img
5		PolygonToRaster	103	r.img
6		PolygonToRaster	104	r.img
7		PolygonToRaster	105	r.img

D. In **Column E**, type in the value_field, which is the field used to assign values to the output raster. In this case, we use “G_RATE”. In the same column, type the beginning of the file location. End this line with “\” so that the next column (which contains the new filename) can be appended.


E2 | G_RATE M:\NRE-540\rasterfolder\

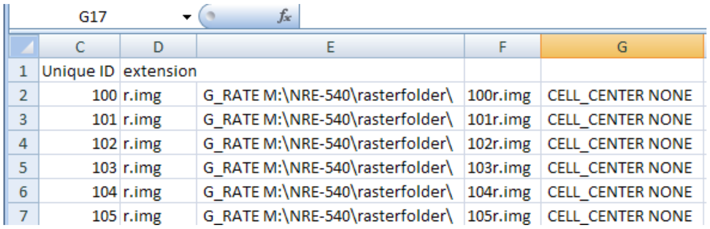
	A	B	C	D	E	F
1			Unique ID	extension		
2		PolygonToRaster	100	r.img	G_RATE M:\NRE-540\rasterfolder\	
3		PolygonToRaster	101	r.img	G_RATE M:\NRE-540\rasterfolder\	
4		PolygonToRaster	102	r.img	G_RATE M:\NRE-540\rasterfolder\	
5		PolygonToRaster	103	r.img	G_RATE M:\NRE-540\rasterfolder\	
6		PolygonToRaster	104	r.img	G_RATE M:\NRE-540\rasterfolder\	
7		PolygonToRaster	105	r.img	G_RATE M:\NRE-540\rasterfolder\	

E. In **Column F**, prepare the output filename by combining column C&D as shown below:


F2 | =C2&D2

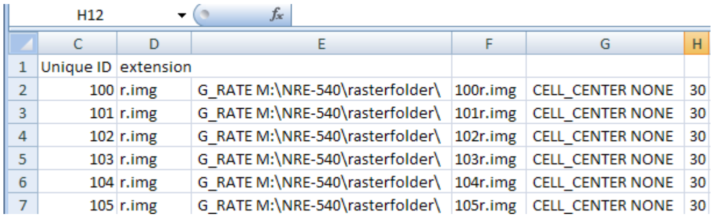
	B	C	D	E	F
1		Unique ID	extension		
2	PolygonToRaster	100	r.img	G_RATE M:\NRE-540\rasterfolder\	100r.img
3	PolygonToRaster	101	r.img	G_RATE M:\NRE-540\rasterfolder\	101r.img
4	PolygonToRaster	102	r.img	G_RATE M:\NRE-540\rasterfolder\	102r.img
5	PolygonToRaster	103	r.img	G_RATE M:\NRE-540\rasterfolder\	103r.img
6	PolygonToRaster	104	r.img	G_RATE M:\NRE-540\rasterfolder\	104r.img
7	PolygonToRaster	105	r.img	G_RATE M:\NRE-540\rasterfolder\	105r.img

F. In **Column G**, type both the cell assignment type, and priority field. Here, the cell assignment type is “CELL_CENTER” and the priority field is “NONE”.


G17

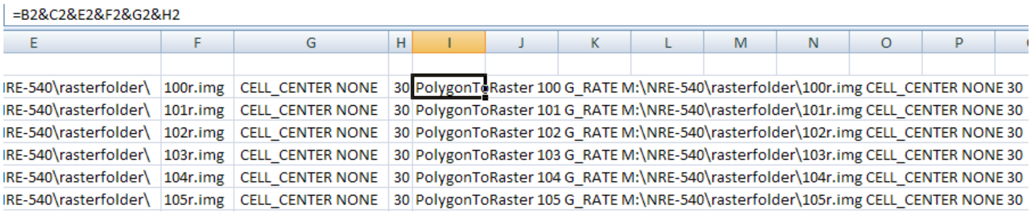
	C	D	E	F	G
1	Unique ID	extension			
2	100	r.img	G_RATE M:\NRE-540\rasterfolder\	100r.img	CELL_CENTER NONE
3	101	r.img	G_RATE M:\NRE-540\rasterfolder\	101r.img	CELL_CENTER NONE
4	102	r.img	G_RATE M:\NRE-540\rasterfolder\	102r.img	CELL_CENTER NONE
5	103	r.img	G_RATE M:\NRE-540\rasterfolder\	103r.img	CELL_CENTER NONE
6	104	r.img	G_RATE M:\NRE-540\rasterfolder\	104r.img	CELL_CENTER NONE
7	105	r.img	G_RATE M:\NRE-540\rasterfolder\	105r.img	CELL_CENTER NONE

G. In **Column H**, type the cell size of the output raster. Here the cell size is 30.


H12

	C	D	E	F	G	H
1	Unique ID	extension				
2	100	r.img	G_RATE M:\NRE-540\rasterfolder\	100r.img	CELL_CENTER NONE	30
3	101	r.img	G_RATE M:\NRE-540\rasterfolder\	101r.img	CELL_CENTER NONE	30
4	102	r.img	G_RATE M:\NRE-540\rasterfolder\	102r.img	CELL_CENTER NONE	30
5	103	r.img	G_RATE M:\NRE-540\rasterfolder\	103r.img	CELL_CENTER NONE	30
6	104	r.img	G_RATE M:\NRE-540\rasterfolder\	104r.img	CELL_CENTER NONE	30
7	105	r.img	G_RATE M:\NRE-540\rasterfolder\	105r.img	CELL_CENTER NONE	30

H. In **Column I**, piece together all of the columns that were just built. This forms the final command line. After this is entered **once**, drag the formula down to fill in the rest of the columns.


=B2&C2&E2&F2&G2&H2

E	F	G	H	I
IRE-540\rasterfolder\	100r.img	CELL_CENTER NONE	30	PolygonToRaster 100 G_RATE M:\NRE-540\rasterfolder\100r.img CELL_CENTER NONE 30
IRE-540\rasterfolder\	101r.img	CELL_CENTER NONE	30	PolygonToRaster 101 G_RATE M:\NRE-540\rasterfolder\101r.img CELL_CENTER NONE 30
IRE-540\rasterfolder\	102r.img	CELL_CENTER NONE	30	PolygonToRaster 102 G_RATE M:\NRE-540\rasterfolder\102r.img CELL_CENTER NONE 30
IRE-540\rasterfolder\	103r.img	CELL_CENTER NONE	30	PolygonToRaster 103 G_RATE M:\NRE-540\rasterfolder\103r.img CELL_CENTER NONE 30
IRE-540\rasterfolder\	104r.img	CELL_CENTER NONE	30	PolygonToRaster 104 G_RATE M:\NRE-540\rasterfolder\104r.img CELL_CENTER NONE 30
IRE-540\rasterfolder\	105r.img	CELL_CENTER NONE	30	PolygonToRaster 105 G_RATE M:\NRE-540\rasterfolder\105r.img CELL_CENTER NONE 30

I. The output from this process will be used in the next step.

Step 6: Reclassify raster files using command line

The next step is to reclassify the raster value created in the previous step. The purpose of the reclassify is to transform the “NoData” values contained in the attribute table of the raster to 0. This allows users to view the boundary of the study area. The raster value from the numerical score needs to remain unchanged, but is still included in the reclassify processes. There are only two values of the raster, 0 and GRANK (or SRANK, ESA, CESA, or CNPS), so only two values need to be reclassified.

As with the previous three tasks, the best way to do this is by using the command line in ArcGIS.

The command line syntax to reclassify the values of a raster:

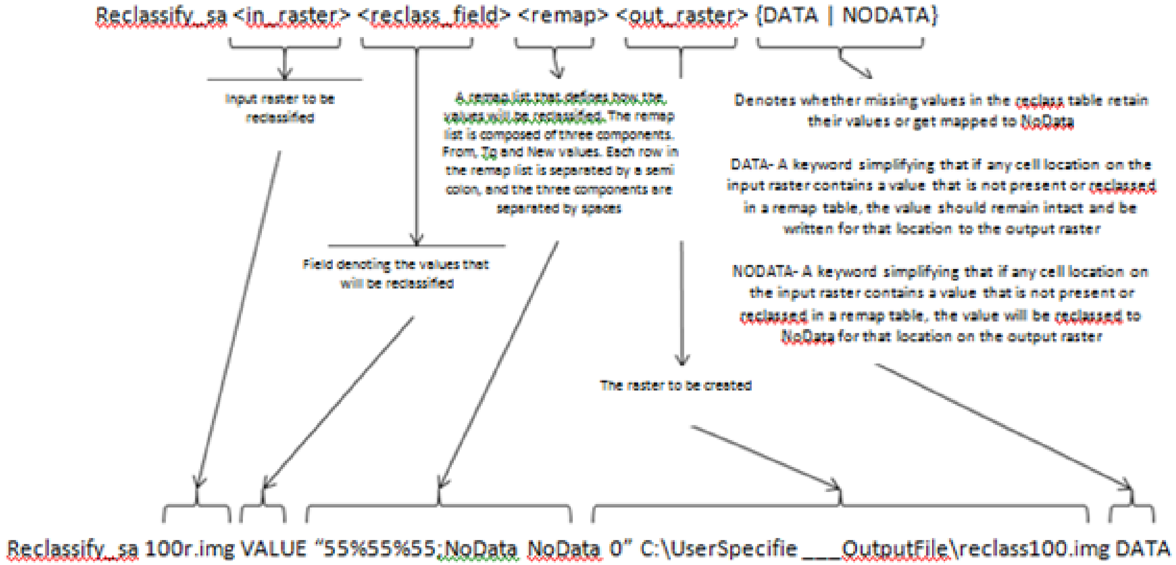
Reclassify reclass100.img VALUE "old value old value new value;0 0 0 " reclass100_S.img

The directions for setting up the excel sheet and executing multiple commands at once is described below. This step uses the rasters that were created in Step 6.

A. Open ArcGIS and add the rasters to the map. Many can be added, depending on your computer’s speed. It is a good idea to start with a batch of 10 to see how fast the process works.

B. Open Excel to start creating the command line used for executing “Reclassify”.

The graphic below describes the purpose behind each piece of the command line, along with the appropriate fields to fill it in for our purpose.



```
Reclassify_sa <in_raster> <reclass_field> <remap> <out_raster> {DATA | NODATA}
```

Input raster to be reclassified

Field denoting the values that will be reclassified

A remap list that defines how the values will be reclassified. The remap list is composed of three components. From, To and New values. Each row in the remap list is separated by a semi colon, and the three components are separated by spaces

The raster to be created

Denotes whether missing values in the reclass table retain their values or get mapped to NoData

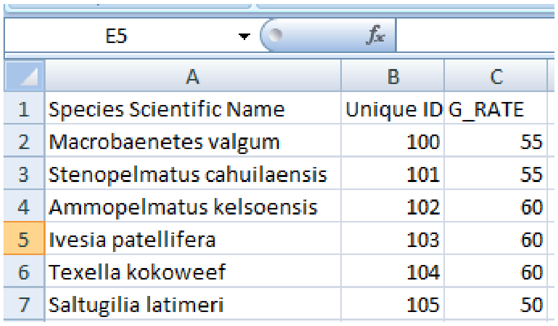
DATA- A keyword simplifying that if any cell location on the input raster contains a value that is not present or reclassed in a remap table, the value should remain intact and be written for that location to the output raster

NODATA- A keyword simplifying that if any cell location on the input raster contains a value that is not present or reclassed in a remap table, the value will be reclassed to NoData for that location on the output raster

```
Reclassify_sa 100r.img VALUE “55%55%55;NoData NoData 0” C:\UserSpecifie___OutputFile\reclass100.img DATA
```

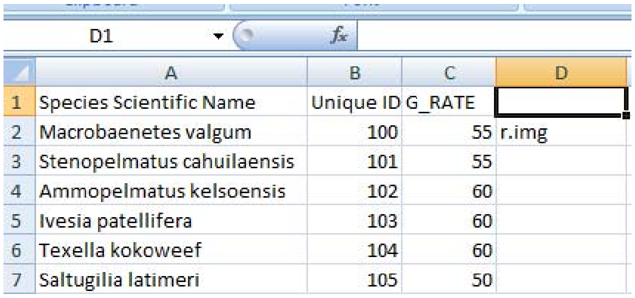
1. In excel, add a column that contains the species name (Column A).

2. Add a column that contains the species unique identifier (Column B).
3. Add a column that contains the species numerical score, in this case G_RATE (Column C).



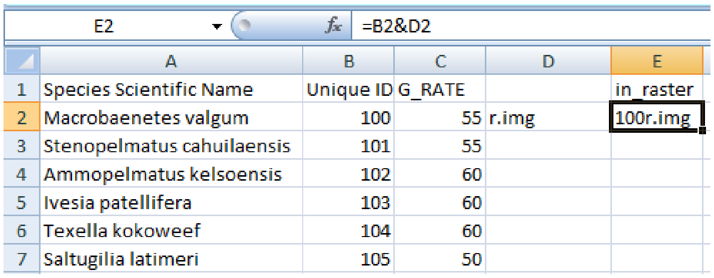
	A	B	C
1	Species Scientific Name	Unique ID	G_RATE
2	Macrobaenetes valgum	100	55
3	Stenopelmatus cahuilaensis	101	55
4	Ammopelmatus kelsoensis	102	60
5	Ivesia patellifera	103	60
6	Texella kokoweef	104	60
7	Saltugilia latimeri	105	50

4. The next column (D) contains “r.img”. This is the file extension that will be pieced together with the unique ID. Once pieced together it creates the input filename.



	A	B	C	D
1	Species Scientific Name	Unique ID	G_RATE	
2	Macrobaenetes valgum	100	55	r.img
3	Stenopelmatus cahuilaensis	101	55	
4	Ammopelmatus kelsoensis	102	60	
5	Ivesia patellifera	103	60	
6	Texella kokoweef	104	60	
7	Saltugilia latimeri	105	50	

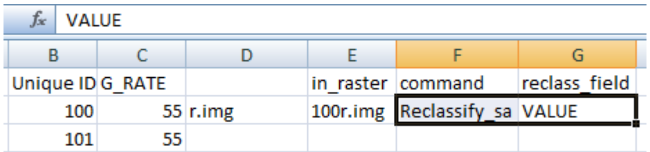
5. Next, the contents of Columns B and D are put together to create the input raster in Column E.



=B2&D2

	A	B	C	D	E
1	Species Scientific Name	Unique ID	G_RATE		in_raster
2	Macrobaenetes valgum	100	55	r.img	100r.img
3	Stenopelmatus cahuilaensis	101	55		
4	Ammopelmatus kelsoensis	102	60		
5	Ivesia patellifera	103	60		
6	Texella kokoweef	104	60		
7	Saltugilia latimeri	105	50		

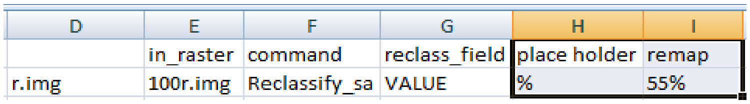
6. Columns F and G begin the actual command line syntax. The command is “Reclassify_sa” and is the same for all of the rasters, as well as the reclass field “VALUE”.



VALUE

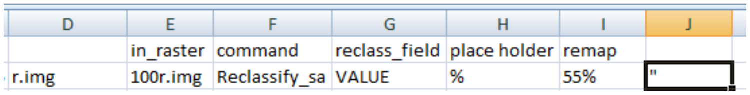
B	C	D	E	F	G
Unique ID	G_RATE		in_raster	command	reclass_field
100	55	r.img	100r.img	Reclassify_sa	VALUE
101	55				

7. Insert a new column (H) for a placeholder (%). Also, insert another column (I) called “remap”. In Column I, combine the place holder and G_RATE.



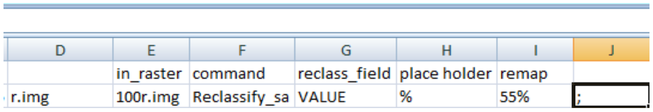
D	E	F	G	H	I
	in_raster	command	reclass_field	place holder	remap
r.img	100r.img	Reclassify_sa	VALUE	%	55%

8. In a new Column (J), insert a double quote. Later, this will sandwich the line “remap”.



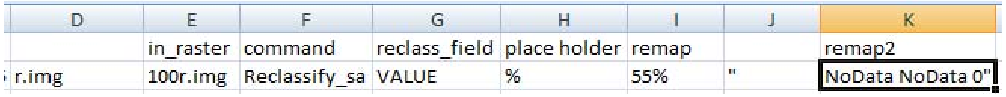
D	E	F	G	H	I	J
	in_raster	command	reclass_field	place holder	remap	
r.img	100r.img	Reclassify_sa	VALUE	%	55%	"

9. In Column J, insert a semicolon. Later this will be put between the first and second parts of the remap line.



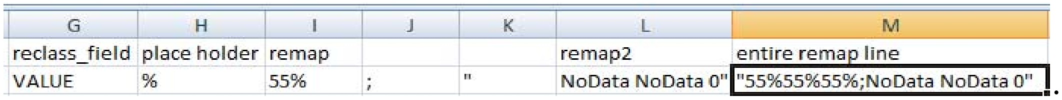
D	E	F	G	H	I	J
	in_raster	command	reclass_field	place holder	remap	
r.img	100r.img	Reclassify_sa	VALUE	%	55%	;

10. Insert a new column (K) called “remap2”. In this column, type “**NoData NoData 0**”. This ends the components of the remap portion of the command line.



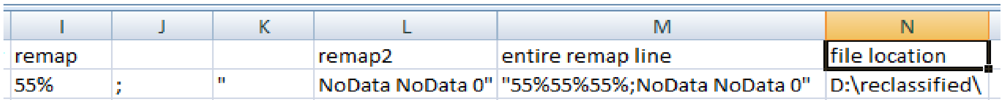
D	E	F	G	H	I	J	K
	in_raster	command	reclass_field	place holder	remap		remap2
r.img	100r.img	Reclassify_sa	VALUE	%	55%	"	NoData NoData 0"

11. Title Column M “entire remap line”. In Column M, combine Columns K, I, J and L using the formula: **=K2&I2&I2&J2&L2**. This step adds together the entire remap line, which is now ready to be added to the entire command line syntax.



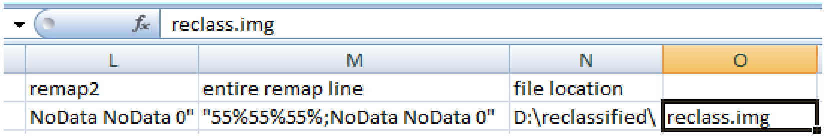
G	H	I	J	K	L	M
reclass_field	place holder	remap			remap2	entire remap line
VALUE	%	55%	;	"	NoData NoData 0"	"55%55%55%;NoData NoData 0"

12. The next column (N) contains the file location. Here, enter the file location where you would like the resulting raster to be stored.



I	J	K	L	M	N
remap			remap2	entire remap line	file location
55%	;	"	NoData NoData 0"	"55%55%55%;NoData NoData 0"	D:\reclassified\

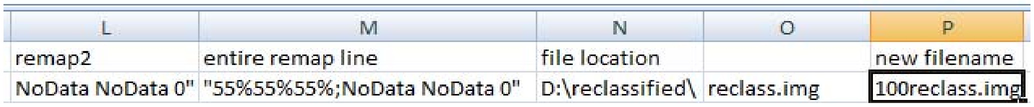
13. The next column (O) is for part of the filename for the reclassified raster. The new filename is the name of this input raster with **reclass.img** added onto it.



reclass.img

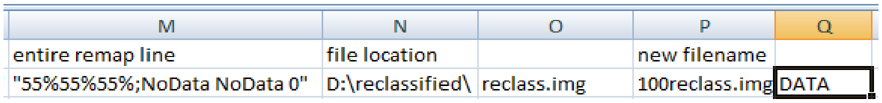
L	M	N	O
remap2	entire remap line	file location	
NoData NoData 0"	"55%55%55%;NoData NoData 0"	D:\reclassified\	reclass.img

14. Column P contains the new filename. To create this, use the formula: **=B2&O2**



L	M	N	O	P
remap2	entire remap line	file location		new filename
NoData NoData 0"	"55%55%55%;NoData NoData 0"	D:\reclassified\	reclass.img	100reclass.img

15. The last piece to be put together in the command line is **DATA**. Create a new column (Q) to hold the word DATA.

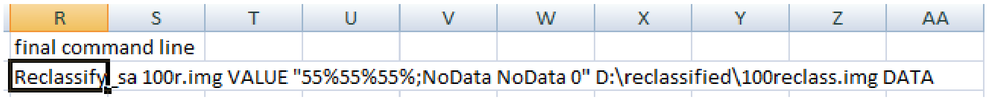


M	N	O	P	Q
entire remap line	file location		new filename	
"55%55%55%;NoData NoData 0"	D:\reclassified\	reclass.img	100reclass.img	DATA

16. Now the spreadsheet is set up with all of the necessary components to piece together the final command line. Create a new column (R) titled “final command line”. Use this formula:

    =F2&G2&E2&M2&N2&P2&Q2

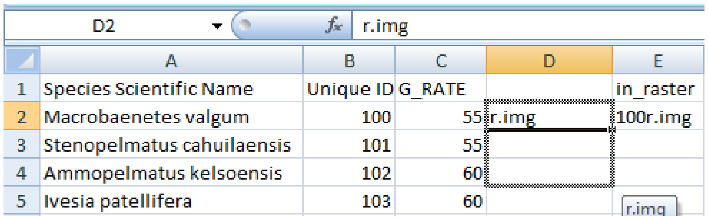
    The command should look like the one below. If there are not spaces in the command line where they should be, simply go back to the cell that contains the text and type a space before or after the text, depending on where it is needed.



R	S	T	U	V	W	X	Y	Z	AA
final command line									
Reclassify_sa 100r.img VALUE "55%55%55%;NoData NoData 0" D:\reclassified\100reclass.img DATA									

C. Fill in the rows below Row 2:

1. Click on Cell D2 and drag it down to fill in the rows below.



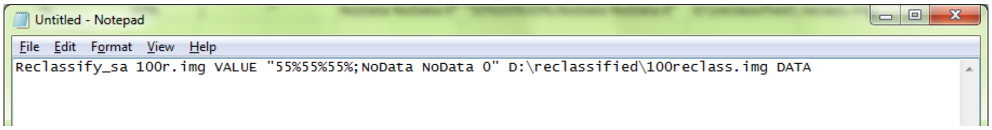
D2 r.img

	A	B	C	D	E
1	Species Scientific Name	Unique ID	G_RATE		in_raster
2	Macrobaenetes valgum	100	55	r.img	100r.img
3	Stenopelmatus cahuilaensis	101	55		
4	Ammopelmatus kelsoensis	102	60		
5	Ivesia patellifera	103	60		

2. In the next cell (E2), double click on the lower right corner of the cell. This will automatically fill in all of the rows.
3. Repeat these steps for all of the remaining columns, including R.
4. Now, Column R can be selected and pasted into the command line window of ArcGIS.

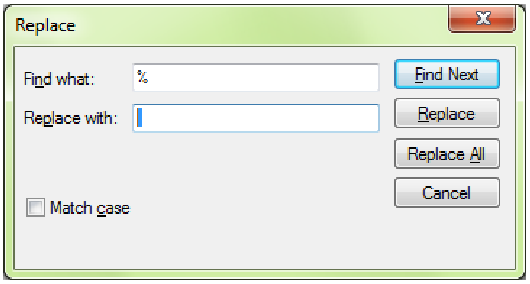
D. Open ArcGIS and run a sample of the command line.

1. In ArcGIS, add a few rasters to the map to be reclassified using the command line from Excel.
2. Once the rasters are added to the map, open Excel and select the rows from Column R that match the rasters added to the map.
3. Once the cells are selected, click “Copy”.
4. Next, open NotePad.
5. Click “Paste”. The contents from excel are pasted into NotePad.



```
Reclassify_sa 100r.img VALUE "55%55%55%;NoData NoData 0" D:\reclassified\100reclass.img DATA
```

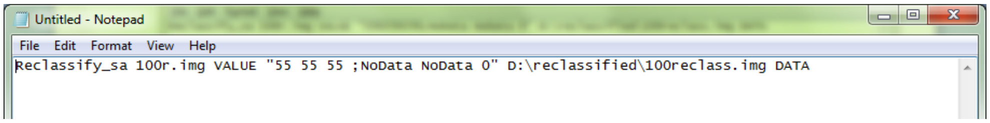
6. Next, erase % from the line:
    a. In NotePad, click Edit > **Replace…**
    b. In the dialogue box, type % in the first line, and a space in the next line.



Find what: %

Replace with:

c. Click “**Replace All**”. This will take out the % signs and replace them with spaces. The command line should look like the one below.



```
Reclassify_sa 100r.img VALUE "55 55 55 ;NoData NoData 0" D:\reclassified\100reclass.img DATA
```

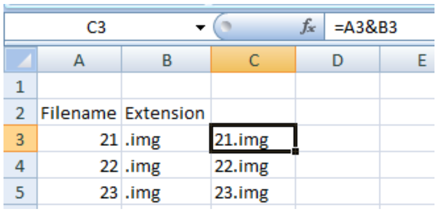
E. Run the command line in ArcGIS:
   1. In Notepad, highlight the command line and click **“Copy”.**
   2. Open ArcGIS, open the command line dialogue box and click **“Paste”.**
   3. Hit the **“Enter”** key on the keyboard.
   4. The command line is running. The input raster will be reclassified and saved in the specified location. Once this runs smoothly, many rasters can be reclassified at once.

Step 7: Overlaying raster files using single output map algebra

The final step overlays all the different species rasters using single output map algebra to create one map with all the scores added up. This will result in one map for GRank, one for SRank, one for ESA, and so on.

Create the command line in Microsoft Excel:

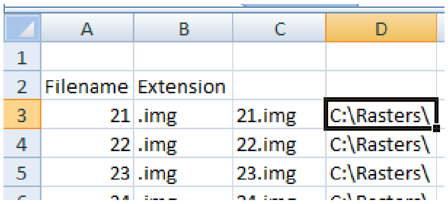
A. Open an Excel document that contains the filename of all the rasters to be added:
   1. If there is not a spreadsheet with the appropriate filenames, use Microsoft Excel to create them.
   2. Create a column with the filename (Column A).
   3. Create another column with the filename extension (.img).
   4. Use “**&**” to combine the two, creating one filename.



=A3&B3

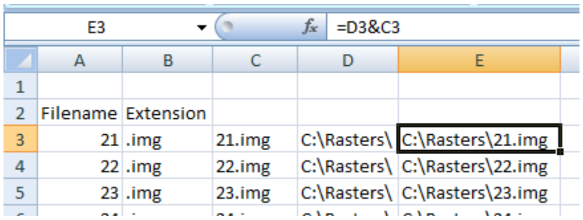
	A	B	C	D	E
1					
2	Filename	Extension			
3	21	.img	21.img		
4	22	.img	22.img		
5	23	.img	23.img		

B. After creating a column that contains the filename, create a new column (D) to contain the file’s pathname (the location of the file).



	A	B	C	D
1				
2	Filename	Extension		
3	21	.img	21.img	C:\Rasters\
4	22	.img	22.img	C:\Rasters\
5	23	.img	23.img	C:\Rasters\

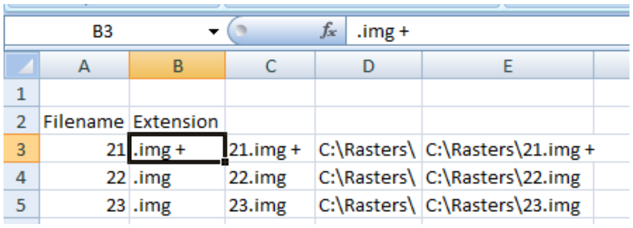
C. In the next column (E), combine the pathname and the filename. This creates the complete filename and path required from the tool “Single output map algebra”.



E3 =D3&C3

	A	B	C	D	E
1					
2	Filename	Extension			
3	21	.img	21.img	C:\Rasters\	C:\Rasters\21.img
4	22	.img	22.img	C:\Rasters\	C:\Rasters\22.img
5	23	.img	23.img	C:\Rasters\	C:\Rasters\23.img

D. The next step is to add a **+** sign after the filename extension in column B. Leave a space between **.img** and **+**. This is done in the column containing the text **“.img”**, not the column that references the text. The text in Columns C and E will automatically reflect the changes made in Column B since they both reference Column B.



B3 .img +

	A	B	C	D	E
1					
2	Filename	Extension			
3	21	.img +	21.img +	C:\Rasters\	C:\Rasters\21.img +
4	22	.img	22.img	C:\Rasters\	C:\Rasters\22.img
5	23	.img	23.img	C:\Rasters\	C:\Rasters\23.img

E. Drag the contents of Column B down to add **+** to every line in Column E.

F. Once complete, select the contents in Column E and click **“Copy”**.

Apply the command line from Excel to ArcGIS

A. Open ArcGIS.

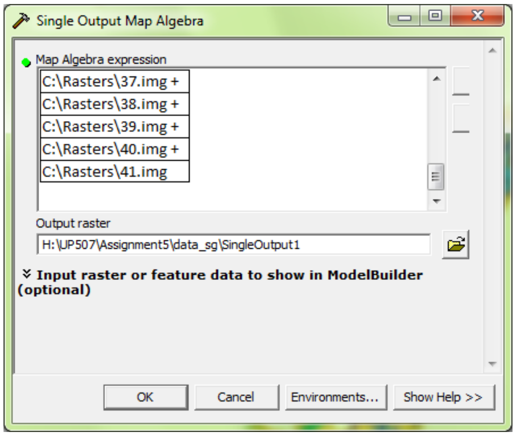
B. If necessary, expand the toolbox to view its contents.

C. Find the **Single output map algebra tool**. Spatial analyst tools > Map Algebra > **Single output map algebra.**

D. Open the Single output map algebra dialogue box and right click in the blank area below **Map algebra expression** and click **“Paste”**.

E. The text from Microsoft Excel is now pasted and creates an expression that will add all of the input rasters.

F. Remove the last **+** sign from the expression.



```
C:\Rasters\37.img +
C:\Rasters\38.img +
C:\Rasters\39.img +
C:\Rasters\40.img +
C:\Rasters\41.img
```

Output raster: H:\UP507\Assignment5\data_sg\SingleOutput1

G. Create a filename for the output raster and click “**OK**”.

H. The rasters are now added together to create a single raster.

I. Repeat for remaining categories (e.g., SRank, ESA, CESA, CNPS).

APPENDIX E5 | TRANSMISSION AND GRADING DISTURBANCE PROCESSING

Distance to Transmission

Note: Steps 1 to 4 refer to the specific processing of the transmission data file we used here. If different data is used in its place, begin with Step 5.

Step 1: Download Data

Step 2: Clip file to CDD (See Appendix A)

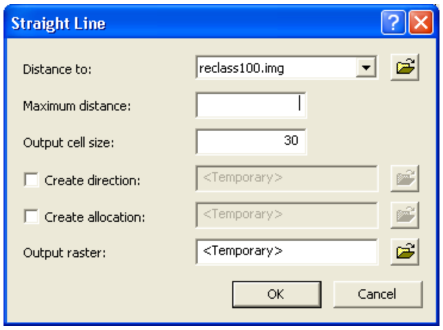
Step 3: Using "Select by Attributes", select power lines

Step 4: Export selected features to new shapefile

Step 5: Perform straight line distance function

A. Set the environments using the Spatial Analyst toolbar:
   1. Add the toolbar to the view: View > Toolbars > **Spatial Analyst.**
   2. Click the dropdown Spatial Analyst > **"Options…"**
   3. Click the tab **"Cell size"** and chose the file DEM_CDD_30.
   4. Click the tab **"Extent"** and chose the file DEM_CDD_30.
   5. Click the tab **"Mask"** and chose the file DEM_CDD_30.

B. Using spatial analyst toolbar, run a straight line distance function. This creates a raster with each cell measuring the distance from the transmission line.
   1. Spatial Analyst dropdown > Distance > **Straight Line…**
      - i. Distance to: Add the transmission line file.
      - ii. Maximum Distance: Leave blank.
      - iii. Output cell size: 30.
      - iv. Leave the next two options blank.
      - v. Chose a filename and location to save the output raster.
      - vi. Click **OK.**



Distance to: reclass100.img
Maximum distance:
Output cell size: 30
☐ Create direction: <Temporary>
☐ Create allocation: <Temporary>
Output raster: <Temporary>

Percent Slope

Step 1: Download DEM pieces of the CDD from <http://seamless.usgs.gov>

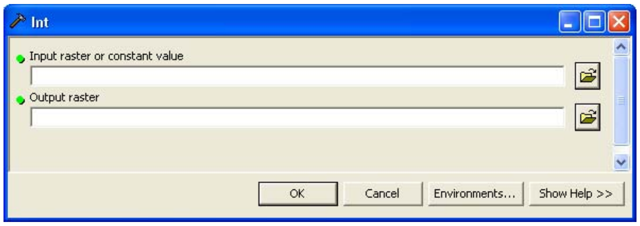
Step 2: Integerize each DEM piece separately

A. Open ArcGIS and find the "Int" tool in ArcToolbox: Spatial Analyst > Math > **Int.**

B. Add the first DEM file to the "**Input raster or constant value"** box.

C. In the **"Output raster"** box, name the file and chose a location to save it.

D. Click "**OK**". Repeat steps A-D for each raster.



Step 3: Mosaic all DEM pieces together

A. Locate the tool "mosaic to new raster" in the data management toolbox: Data Management tools > Raster > Raster Dataset > **Mosaic to New Raster.**

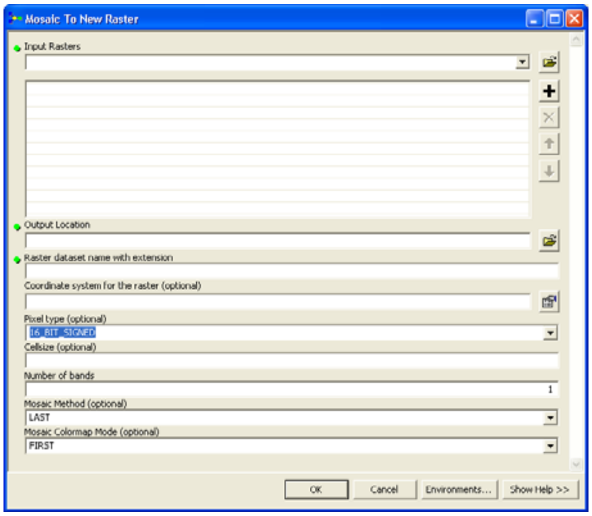
B. Add the input rasters to the space provided.

C. Output location: Name the file and chose a location to save it.

D. For **Pixel** Type, Use **16-bit signed.**

E. Leave everything else as the default.

F. Click **"OK"**.



Pixel type (optional)
16_BIT_SIGNED

Number of bands
1

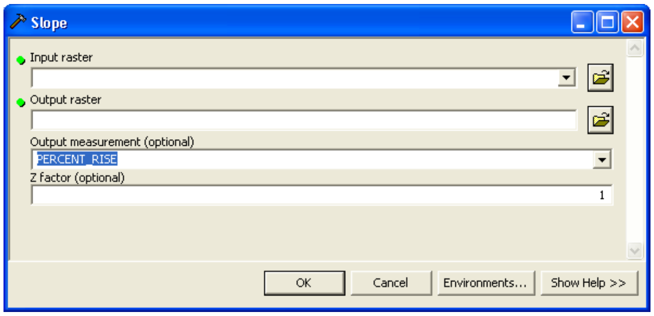
Mosaic Method (optional)
LAST

Mosaic Colormap Mode (optional)
FIRST

Step 4: Convert elevation to percent rise

A. Add the newly created DEM to a new or existing ArcMap session.

B. Open the **Slope** tool: Arc toolbox > Spatial Analyst > Surface > **Slope.**



Input raster

Output raster

Output measurement (optional): PERCENT_RISE

Z factor (optional): 1

C. Add the DEM to the box: **"Input Raster".**

D. Name the output raster and chose a place to save it.

E. Set the output measurement to "**PERCENT_RISE**".

F. Leave everything else as the default.

G. Click "**OK**".

Step 5: Display elevation with a classified color scheme

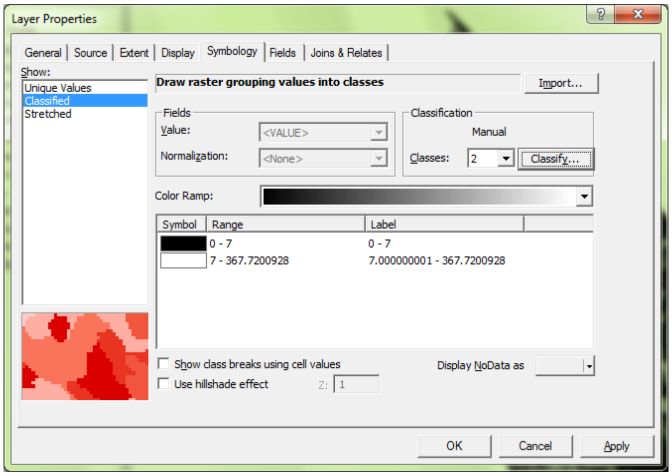
A. In ArcMap, add the percent rise layer.

B. Double click on the layer to open the layer properties dialogue box.

C. Click the symbology tab and click **"classified"** on the left panel.

D. When a box appears that asks if you want to generate unique values, click **"Yes"**.

E. Change the number of classes to **2.**



Draw raster grouping values into classes

Fields
Value: <VALUE>
Normalization: <None>

Classification
Manual
Classes: 2
Classify...

Symbol	Range	Label
■	0 - 7	0 - 7
□	7 - 367.7200928	7.000000001 - 367.7200928

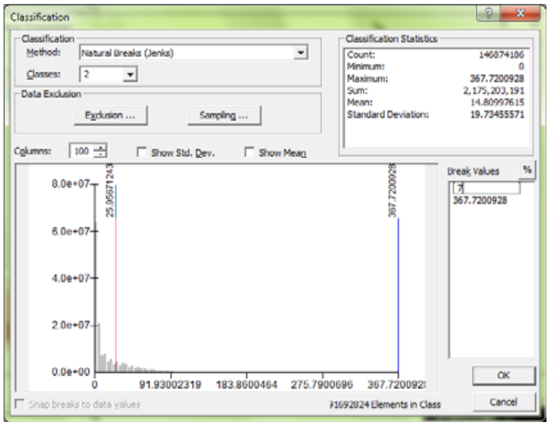
☐ Show class breaks using cell values

☐ Use hillshade effect Z: 1

Display NoData as

F. Click **"Classify".**

G. Replace the first break value with 7. Click **"OK".**



Method: Natural Breaks (Jenks)
Classes: 2

Classification Statistics

Count:	146874186
Minimum:	0
Maximum:	367.7200928
Sum:	2,175,203,191
Mean:	14.80997615
Standard Deviation:	19.73455571

Columns: 100
☐ Show Std. Dev.
☐ Show Mean

Break Values
7
367.7200928

☐ Snap breaks to data values

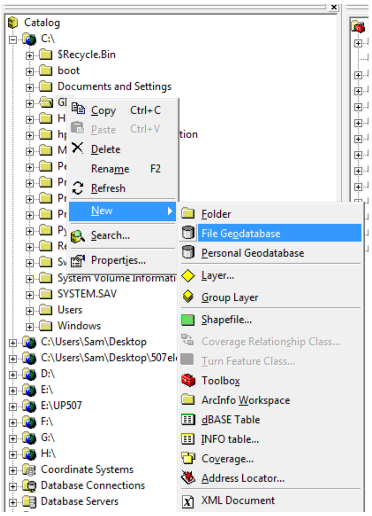
H. Click **"OK"** again. The map now shows suitable areas based on percent rise of slope as one color, and all other areas a different color.

APPENDIX E6 | VISUAL IMPACT PROCESSING

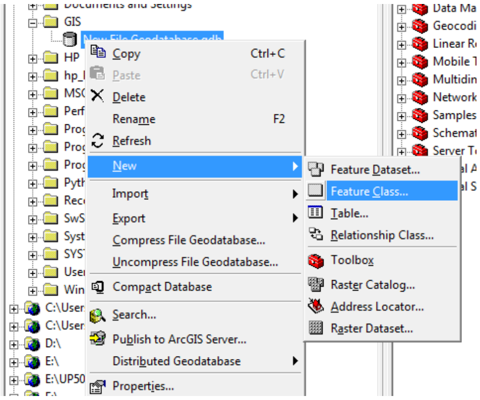
Step 1: Create the observation point

A. In ArcCatalog, create a geodatabase in which the points will be added:

1. Right click on a folder and chose: New > **File Geodatabase.**



2. Add points to the new geodatabase: Right click on the newly created geodatabase and chose: New > **Feature class:**



   i. This is where the point is created. In the **"New Feature Class"** dialogue box, name the point feature and change **Type** to **Point Feature**.

   ii. Click **"Next".**

   iii. Chose the coordinate system based on the location of the points.

   iv. Click **"Next"** though the screens and finally click **Finish**. There is no need to make any other changes in the dialogue box.

   v. The point has been created but it still needs to be located on the map. Close Arc Catalog and open ArcMap.

B. Locate the observation point:

   1. In ArcMap, add the spatial data layers needed to locate the observation point. In this case, add the layer of proposed solar facilities.
   2. Add the Editor toolbar to the map, and click Editor > **Start Editing**.
   3. Make sure the Task is set to "**Create New Feature**".
   4. Make sure the Target is set to the newly created point.

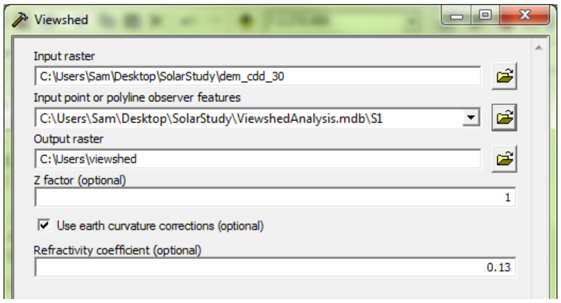
Task: Create New Feature

Target: Observation Point

   5. Click the pencil tool, and using the tool click on the map where you want to locate the observation point.
   6. The point is now located. Save the edits and stop editing.

C. Perform the viewshed analysis on the new observation point.

   1. In ArcMap, with the newly created point in the map, add the DEM that will be used for the viewshed analysis.
   2. Locate the viewshed tool in ArcToolbox: Spatial Analyst Tools > Surface> **Viewshed**
   3. Fill in the fields with the DEM and the newly created observation point.
   4. Make sure to check "Use earth curvature corrections".



Input raster

C:\Users\Sam\Desktop\SolarStudy\dem_cdd_30

Input point or polyline observer features

C:\Users\Sam\Desktop\SolarStudy\ViewshedAnalysis.mdb\S1

Output raster

C:\Users\viewshed

Z factor (optional)

1

☑ Use earth curvature corrections (optional)

Refractivity coefficient (optional)

0.13

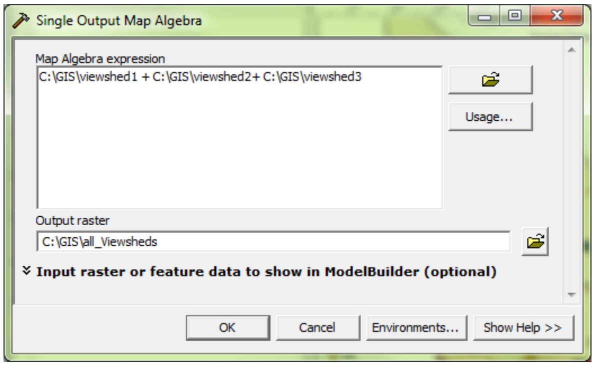
   5. Click "**OK**". The viewshed will be created.

D. Repeat Steps A.2. through C to create an individual viewshed for every point of interest.

E. Add viewsheds together to produce one raster:

   1. In ArcCatalog, locate the single output map algebra tool: Spatial Analyst > Map Algebra > **Single output map algebra.**
   2. Use the folder symbol to navigate to the viewshed. Double click the file to add it to the dialogue box.
   3. Once the file is added to the dialogue box, type "**+**".
   4. Add the next viewshed and so on until all desired viewsheds are added.
   5. Name and locate the output viewshed.

6. Click **"OK".** A single raster of all the individual viewsheds is created.



Map Algebra expression: C:\GIS\viewshed1 + C:\GIS\viewshed2+ C:\GIS\viewshed3

Output raster: C:\GIS\all_Viewsheds

APPENDIX E7 | TOTAL ECOLOGICAL IMPACT SCORES BY FACILITY

Identification Number	Total Ecological Impact Score	Category
CACA 049430	0.00	LOW
CACA 049585	0.00	
CACA 049432	0.00	
CACA 049002 **	0.00	
CACA 049008	0.00	
CACA 049424	0.00	
CACA 050117 **	0.00	
CACA 049006	0.00	
CACA 048875	0.00	
CACA 049561 *	0.00	
CACA 049004	0.00	
CACA 048808 **	0.00	
CACA 049493 **	0.00	
CACA 049584	0.00	
CACA 049491 **	0.00	
CACA 049488 **	0.00	
CACA 049423	0.00	
CACA 048742	0.00	
CACA 048810 ***	0.00	
CACA 048880 ***	0.00	
CACA 048811 ***	0.00	
CACA 049813	0.03	
CACA 049494 **	0.04	
CACA 050705	0.08	
CACA 049615	0.27	
CACA 048741	0.36	
CACA 049150	1.01	
CACA 049537 ***	1.14	
CACA 049397 **	1.47	
CACA 049016 *	1.53	
CACA 049511	2.16	
CACA 049539 ***	3.90	
CACA 049097 **	7.03	
CACA 051369	9.58	
CACA 047740 *	12.73	MEDIUM
CACA 049613	18.79	
CACA 050116 **	19.76	
CACA 050704	20.04	
CACA 048649 ***	20.14	
CACA 049431	26.33	
CACA 049884 **	30.12	
CACA 048820	33.12	
CACA 050174 **	40.57	
CACA 049702 **	44.08	
CACA 048818	49.79	
CACA 049490/ 048728 **	52.11	
CACA 050150	93.28	HIGH
CACA 048669	150.45	
CACA 049017	153.00	
CACA 050103	153.49	
CACA 048668 *	155.23	
CACA 050528	178.60	

* = Fast Track facility, ** = SESA facility, *** = Both Fast Track and SESA facility

APPENDIX F | ECOSYSTEM SERVICES: THE NON-MARKET VALUE OF THE DESERT

Solar development in the California desert clearly will have an impact on the ecosystem but what does this mean from an anthropocentric perspective? Ecosystem processes provide critical services that benefit human existence including regulation of biogeochemical cycles, preservation of genetic diversity, conversion of solar energy to plant material, and even opportunities for spiritual or cultural enrichment. A better understanding of ecosystem service values in the California desert could greatly benefit the renewable energy siting decision-making process. The lack of complete information about ecosystem services and functions, the presence of environmental externalities, and market interventions are all contributing to an economic market failure, which results in continued land conversion and negative impacts on ecosystem services. The costs and benefits of solar development, in the dollar values often associated with land use decisions, are difficult to enumerate because many ecosystem services such as species preservation, habitat conservation, or aesthetics are non-market goods associated with non-use values. A calculation of ecosystem service values in monetary terms may never be absolute but an attempt to calculate their value to society in a common unit, the dollar, can help guide discussions and contribute to building a framework for evaluating the landscape-level impacts of various solar development scenarios.

Whether economic or ethical, systems of valuation exist in order to provide moral or normative frameworks for assigning importance and necessity to beliefs, actions, or objects.[629] Ecosystem services, whether considered from a use or non-use perspective, are public goods that are not typically traded in traditional markets despite the instrumental value they provide for human existence (Table F.1). This leads to the common misconception that services such as nutrient cycling or habitat provision are “free” or non-existent because they do not have a market value. Non-market, or public, goods are particularly vulnerable to degradation from environmental externalities, or indirect impacts of human activities on the environment not accounted for in our market-based economic system, are difficult to quantify outside of a market system. Research that reveals the value of the ecosystem services provided by the desert will give land managers and other stakeholders important new information for decision making.

The decision-making processes for renewable energy development requires new approaches to gathering data and quantifying the value of the ecosystem services in order to legitimately assess the costs and benefits to society. Criteria for evaluating the impact of solar facility siting decisions must include metrics for measuring instrumental values, but such metrics are incredibly difficult to define due to the incomplete, and often subjective, information available. This is an important area for future research because well-defined metrics for measuring the value of ecosystem services based on improved methods of data collection and analysis will improve the process of reaching a land use decision with the greatest net benefit to society.

In order to define or estimate the value of an ecosystem, a process of expressing a value for the goods or services that the ecosystem provides for human use is required. This is a critical distinction. We are not suggesting that future research on ecosystem services should determine the moral or ethical values inherent in habitat conservation or in land development choices, although policy choices must consider both. Rather, we see a need to determine the value of the "beneficial outcomes, for the natural environment or people, which result from ecosystem services."[630] This value is purely anthropocentric in that it measures instrumental value rather than the inherent value. Instrumental value is the difference something makes to the satisfaction of human preferences and is a reflection of how people allocate resources, or dollars, for a good or service.

In addition to the distinction between instrumental and inherent values made above, a second important distinction is that resources such as non-renewable minerals and oil, solar energy, wind, or the atmosphere are not included in these categories. Non-renewable resources such as fossil fuels or minerals sequestered underground certainly have a market value when they are extracted by people but, in their natural state, do not play a role in ecosystem functions. Renewable resources such as wind or solar energy are ubiquitous and have infinite value; the ecosystem functions, which regulate the atmosphere or convert solar energy into food, however, are providing a service that is of instrumental value to society.

Accounting for ecosystem services in dollar terms is controversial due to the difficulty in defining the boundary of the system, collecting data, and in assigning monetary value to environmental externalities. Although several methods for collecting data through surveys, purchase of goods and services, or real estate value exist, they rely on reported values or are otherwise not adequate for understanding the landscape-level values of multiple ecosystem services. This often results in undervaluing the service compared to established market goods and services. Estimating the economic value of ecosystem services is further complicated by uncertainty about how evolving human preferences about the utility of ecosystem services will affect the instrumental value of the ecosystem service at some point in the future.[631] For example, our preference for fossil-fuel based energy resources, is changing due to a better understanding of the risks associated with increased carbon emissions. Similarly, unrestrained land use and development is no longer a part of the American land ethic now that some unique ecosystems and habitats are threatened to the point of extinction. The nature of the conflict surrounding solar development in the California desert is rooted in human preferences and the uncertainty regarding which, habitat conservation or development of renewable energy resources, will be worth more in the future based on actions taken today. Most economic theory operates in the short-term and assumes fixed preferences. But human preferences do change in the long-term, the time frame over which we must consider ecosystem functions. In this sense, the moral and ethical goals of society are important for determining the appropriate time preference and discount rate for valuing ecosystem services in the long-term, which is one of the most controversial issues in developing methods for ecosystem service valuation.

An early attempt to determine the value of the world's ecosystem services estimated the value of 17 ecosystem services for 16 global biomes to be in the range of $16 to 54 trillion per year, or up to three times the global gross national product in 1997.[632] This study has many gaps and likely underestimates true value. The authors state that they could not find any data for desert ecosystem service valuation and attributed a value of $0 per hectare to this biome. Yet, clearly, there are recreational and cultural values among many other services discussed in this report including dust control, biodiversity, aesthetic value, and habitat connectivity. We had difficulty finding studies specifically estimating the value of ecosystem services in desert habitats with two notable exceptions: a 2007 Defenders of Wildlife report titled "Economic Benefits Provided by Natural Lands: Case Study of California's Mojave Desert" and a report published by the Wilderness Society in 2005 titled "The Economic Benefits of California Desert Wildlands: 10 Years Since the California Desert Protection Act of 1994." Although these reports specifically address the ecosystem service values within our study areas, we did not find enough data about ecosystem services to construct a spatial analysis of the impacts of solar development on ecosystem service values in the California desert. To build upon the existing knowledge of ecosystem service values in the California desert, we recommend using the following approaches to future research for this area.

GIS-Based Approaches

Although the availability of data layers for spatial analysis of landscape-level data has increased dramatically in recent years, valuation data about ecosystem services is limited. Environmental economists are working to improve the available data, but usually data are collected as needed for specific projects, which may result in discrepancies between data collection techniques and limitations in transferring values to areas outside the original study. To date, many of the studies applying this approach focus on forests, coastal areas, and climate change modeling. As the approach is applied more broadly and metrics for calculating values of a number of ecosystem services are expanded and standardized, this will be a valuable tool for decision makers in all sectors. As the data availability and connectivity improves, land managers, developers, and elected officials can use GIS models to more rapidly assess impacts under a number of scenarios both at the site level and at the landscape scale.

Early in this study, we imagined developing a cost-benefit analysis tool based on GIS data layers with quantified ecosystem service values. We were inspired by a study published in 2008 which created a semi-automatic modeling tool for valuing the effects of development on ecosystem services in the Swiss Alps.[633] Ultimately, development of a similar tool was beyond the capabilities of our project team.

Although we could not help further ecosystem service research, we believe future research should focus on developing a GIS-based tool that will allow decision makers to input information about a proposed facility's location, technology type, and capacity into an interface that will produce a balance sheet accounting of the project's net present value including ecosystem service values. Assets could include displacement of fossil fuels, number of jobs created, and lower energy costs. Liabilities could include depletion of water resources, impacts on air quality, habitat fragmentation, and loss of recreational space. Each of the line items will need a coefficient that monetizes the disturbance or benefit provided in order to calculate a net present value. The tool should also produce landscape models of the ecosystem service impacts at the site level and at the cumulative level. We realize that using a net present value calculation method to answer questions about the siting decisions does not fully account for ecosystem service values due to the difficulties in monetizing those services. However, this approach provides a framework for discussing the market and non-market values of solar energy development and can be used to enhance the decision-making process by providing an array of modeled scenarios based on a common set of data and calculation methods.

Market-Based Approaches

Payment for ecosystem services originated as a voluntary program in the agricultural sector when farmers were offered compensation from the government for adopting soil-conserving practices. Since the early days of agricultural conservation subsidies, the concept of rewarding landowners for sustainable land use practices has expanded to non-governmental or private investment in water conservation and wildlife stewardship projects around the world. The direct investment in conservation creates an immediate value for projects that protect a variety of ecosystem services. While the services themselves do not need to be measured and accounted for, the projects must be well defined in order to maintain the value of the investments. Spatial data will be an important tool in developing new investment and conservation incentive programs for the California desert. The models of landscape level impacts will create new information about how land use practices at the site level can create conservation value for broad ecosystem functions. Environmental economic research should employ spatial models in making a case for conservation values and conservation payment programs. These models can be used to support proposals for federal and state conservation expenditures and to define appropriate mitigation measures to offset the cost of damage to ecosystem services from solar power development.

Voluntary markets for greenhouse gas emissions trading, renewable energy credits (RECs), and RPS targets also help create a market value for carbon sequestration. While the market price of carbon or the cost of creating a REC may not reflect the true ecosystem service value, it does create a market signal for investors and businesses that generate, offset, or sequester carbon. Environmental benefits associated with solar energy market development arise when solar technologies are used to offset generation from new or existing fossil fuel facilities. For example, NREL estimates that “if 4,000 MW of CSP solar were deployed in the state in order to replace combined cycle natural gas production, carbon dioxide would be reduced annually by 7,600,000 tons.”[634] However, disturbance to soil crusts in the desert reduces the ecosystem’s carbon sequestration function and the lifecycle energy use of the materials required to build a solar facility contributes to carbon emissions. Conservation advocates and renewable energy developers should work with regulators and lawmakers to make sure the measurements for tracking carbon offsets and renewable energy credits account for land use disturbance as well as lifecycle assessments of material production for solar equipment and project development.

Table 1 Methods for Measuring Economic Value of Ecosystem Services.

Function	Ecosystem processes and components	Goods and Services (examples)
Regulation Functions	Maintenance of essential ecological processes and life support systems	
Gas regulation	Role of ecosystems in bio-geochemical cycles (e.g. CO_2/O_2 balance, ozone layer, etc.)	UVb protection by O_3 prevents disease Maintenance of good air quality Influence on climate
Climate Regulation	Influence of land cover and biologically mediated process on climate	Maintenance of a favorable climate (temperature, precipitation, etc.) for human habitat, health, and cultivation
Disturbance Prevention	Influence of ecosystem structure on dampening environmental disturbances	Storm protection by coral reefs Flood prevention by wetlands and forests
Water Regulation	Role of land cover in regulating runoff and river discharge	Drainage and natural irrigation Commerce and transportation
Water Supply	Filtering, retention, and storage of fresh water	Provision of water for consumptive use
Soil Formation	Weathering of rock, accumulation of organic matter	Maintenance of productivity on arable land

Soil Retention	Role of vegetation root matrix and soil biota in soil retention	Maintenance of arable land Prevention of damage from erosion and siltation
Nutrient Regulation	Role of biota in storage and recycling of nutrients	Maintenance of healthy soils and productive ecosystems
Waste Treatment	Role of vegetation and biota in removal or breakdown of xeric nutrients and compounds	Pollution control and detoxification Filtering of dust particles Abatement of noise pollution
Pollination	Role of biota in movement of floral gametes	Pollination of wild plant species Pollination of crops
Biological control	Population control through trophic-dynamic relations	Control of pests and diseases Reduction of herbivory (crop damage)
Habitat Functions		Maintenance of biological and genetic diversity
Refugium Function	Suitable living space for wild plants and animals	Maintenance of commercially-harvested species
Nursery function	Suitable reproduction habitat	Maintenance of commercially-harvested species
Production Functions	Provision of natural resources	
Food	Conversion of solar energy into edible plants and animals	Hunting, gathering of fish, game, fruits, etc. Small-scale subsistence farming and aquiculture
Raw Materials	Conversion of solar energy into biomass for human construction and other uses	Building and manufacturing Fuel and energy (fuel wood, organic matter Fodder and fertilizer
Genetic Resources	Genetic material and evolution in wild plants and animals	Improve crop resistance to pathogens and pests
Medicinal Resources	Variety in biochemical substances in, and other medicinal uses for, natural biota	Health care, drugs and pharmaceuticals Chemical models and tools Test organisms

Ornamental resources	Variety of biota in natural ecosystems with potential ornamental use	Resources for fashion, handicraft, jewelry, pets, worship, decoration, and souvenirs
Information Functions	Providing opportunities for cognitive development	
Aesthetic Information	Attractive landscape features	Enjoyment of scenery
Recreation	Variety in landscapes with potential recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
Cultural and Artistic	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architecture, advertizing, etc.
Spiritual and Historic	Variety in natural features with spiritual and historical value	Use of nature for religious of historic purposes (heritage value)
Science and Education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc. Use of nature for scientific research

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