Solar Power Technology Selection: 
Multiple Resource Economics and Policy

2011 Group Project Proposal

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ABSTRACT

The development of utility-scale solar energy projects is a major component in achieving the State of California's greenhouse gas reduction and renewable energy goals. However, major tradeoffs are inherent in the land use changes required to develop renewable energy facilities. For the purpose of informing AECOM, the solar industry, and the Californian public, the goal of this Group Project is to create a methodology that can determine, using selected significance criteria, the best technology to install at any specific site within a California desert ecosystem. To do so, we will approach the selection of solar technologies from a different angle than is currently used by developers. This Group Project will utilize a Multiple Criteria Decision Assessment methodology to assist in identifying the key tradeoffs in any decision-making regarding large-scale solar development. This broader approach has the potential to shift the way that solar development is conducted, resulting in more appropriate technology selection at specific sites. Our end results will be useful in providing recommendations to decision-makers regarding which solar technology is best suited for a selected location.
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LIST OF ABBREVIATIONS

AFC – Application for Certification
ANP – Analytic Network Process
BLM – Bureau of Land Management
CARB – California Air Resources Board
CDFG – California Department of Fish and Game
CDPA – California Desert Protection Act
CEC – California Energy Commission
CEQA – California Environmental Quality Act
CSP – Concentrating Solar Power
CUP – Conditional Land Use Permit
DOE – Department of Energy
EIR – Environmental Impact Report
EIS – Environmental Impact Statement
EO – Executive Order
ESA – Endangered Species Act
GHG – Greenhouse Gases
LSSP – Large-Scale Solar Projects
MCDA – Multiple Criteria Decision Analysis
MOU – Memorandum of Understanding
MW – Megawatt
NEPA – National Environmental Policy Act
NREL – National Renewable Energy Laboratory
PEIS – Programmatic Environmental Impact Statement
PMPD – Presiding Member’s Proposed Decision
POD – Plan of Development
PV – Photovoltaic
REAT – Renewable Energy Action Team
RPS – Renewable Portfolio Standard
SB – Senate Bill
SEGS – Solar Electricity Generation Station
TES – Thermal Energy Storage
USFWS – US Fish and Wildlife Service
1. EXECUTIVE SUMMARY

Climate change, defined as the recent warming of the Earth due to increased greenhouse gas (GHG) emissions, is largely caused by combustion of fossil fuels. Coal supplies more than half the electricity consumed by Americans and coal-fired power plants contribute substantially to the accumulation of GHGs in the atmosphere. To address the global problem of increasing GHG emissions, policymakers are looking to alternative and renewable energy sources. As awareness of climate change increases, legislation to regulate GHG emissions and encourage the use of renewable energy technology is becoming increasingly prevalent.

California law currently mandates that 20% of the state’s electricity must come from renewable sources by 2010 and Governor Schwarzenegger has issued an Executive Order raising this target to 33% by 2020 (Schwarzenegger, 2009). Encouraged by these actions, many utility-scale solar thermal and solar photovoltaic projects have been proposed and installed in the state in recent years. Because of their land use and solar radiation requirements, large-scale solar power plants (LSSPs) are restricted geographically to open, arid, and underdeveloped or ‘pristine’ lands. Proposed solar power plants therefore have the potential to impact a wide range of natural and cultural resources.

In order to install LSSPs, an Environmental Impact Statement (EIS) and an Environmental Impact Report (EIR) are required by the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA), respectively. These lengthy documents report on the resource impacts of the project and require extensive investigation by specialists in many disciplines. This process is time-consuming and expensive, and can delay or even halt project development.

AECOM is a large international corporation whose purpose is to enhance and sustain the world’s built, natural and social environments (AECOM, 2010). AECOM Environment offers critical in-depth knowledge of emerging technologies, impact assessment and permitting. For this reason, AECOM is often contracted as a consultant by technology and utility firms to assist with the permitting process for LSSPs. AECOM’s approach is to address the project employing critical issues and cost-benefit analyses, with the political, social and economic benefits included with energy yield, and the costs equivalent to the sum of 1) technology installation; 2) maintenance and operation; and 3) permitting. The permitting costs cover a range of engineering, environmental, public health and safety issues.

AECOM has years of experience working as a consultant for solar technology firms, providing its clients critical assistance and guidance in the permitting and licensing process. Currently, AECOM approaches the permitting process with the selected technology generally predetermined by their client. AECOM helps to license a site by securing the appropriate environmental permits and developing the requisite mitigation actions. By exploring alternatives to this technology-driven approach, our Bren Group Project will offer a broader perspective on the solar utility site selection process.

For the purpose of informing AECOM, the solar industry, and the California public, our goal is to create a methodology that can determine, using selected significance criteria, the best
technology to install at any specific site within two distinct California ecosystems. Through extensive research, we plan to perform a multi-faceted analysis to provide this summary and synthesis of each solar technology’s overall impacts, costs, and benefits.

Our project will be conducted in four phases:

**Phase I. Conceptual Framework**
- Establish a conceptual framework that will incorporate all of the inputs, outputs, costs, and benefits of large-scale solar power technology development in California.

**Phase II. Criteria Identification and Quantification**
- Research each of the inputs, impacts and benefits included in our conceptual framework and choose the ten most important criteria related to solar energy development.
- After choosing the criteria, we will assign a metric for each criterion that can be compared across technologies and locations.

**Phase III. Multi-Criteria Decision Assessment**
- Assign weights to each of the ten selected criteria.
- Develop and test a multiple-criteria decision analysis (MCDA) tool using the selected criteria on two case study locations.
- Gather information on how different population subsets value each of the criteria, and apply to the MCDA.

**Phase IV. Synthesis**
- Synthesize our tested approach into a comprehensive methodology that will assist in identifying the key tradeoffs in any decision regarding large-scale solar development.

Our vision for this Bren Group Project approaches the selection of solar utility sites from a unique angle. We will evaluate and compare how different solar technologies impact specific California locations from a broad perspective, taking into consideration the most significant inputs, outputs, costs and benefits of large-scale solar technology. Our results will provide AECOM, state and federal government, investors, and the multiple stakeholders with a new perspective on the resource impacts, costs, and benefits of solar technology. This project will help improve the efficiency and appropriateness of solar technology selection, and help move California towards its renewable energy goals.
2. INTRODUCTION

Renewable energy has firmly captured the attention of the State of California. There is growing public awareness of fossil fuels’ contribution to global climate change, and increasing concern over U.S. reliance on foreign oil. This interest has led to the implementation of one of the nation's most ambitious renewable energy development plans to date (CPUC, 2010). In 2006, the California legislature passed Senate Bill 107, the California Renewable Portfolio Standard (RPS), mandating that 20% of the state's electricity come from renewable sources by 2010 (CPUC, 2010). A 2008 Executive Order by Governor Schwarzenegger raised the goal to 33% by 2020 (Schwarzenegger 2008), officially declaring renewable energy development a priority for California.

Solar energy is particularly attractive for California, as the state is endowed with generous sunshine, open space, and the political will necessary to invest in these projects. The development of large-scale solar power projects will be a major component in achieving the state’s RPS target.

AECOM is a large international corporation invested in its mission "to enhance and sustain the world's built, natural, and social environments” (AECOM, 2010). In the last three years, AECOM's Camarillo office has worked on the complex permitting and licensing process required for utility scale projects in California. As a result of working closely with solar project applicants and regulatory agencies, AECOM is experienced in the full arc of a project's trajectory: project design and proposal, application, permitting, and mitigation. The permitting phase of a solar project is particularly challenging because of the multiple stakeholders and the many statutory requirements involved. AECOM has identified permitting as being a critical bottleneck in the development of solar utilities, and has requested this Bren Masters Group Project to investigate new ways of looking at the permitting process.

At the core of this project is the understanding that trade-offs are inherent in the development of renewable and solar projects. Renewable energy is not a panacea for our nation's energy and environmental concerns, but comes with unique costs of its own. Land use changes, water use requirements, and habitat impacts are just some of the issues that solar developers must address before their projects are accepted by regulatory agencies and the public. Our aim is to help these stakeholders and the solar power industry to better understand the many cost-benefit decisions that are incorporated into any solar energy project.

To do so, we plan to develop a methodology that assists in the technology selection component of the solar development process. We believe assisting AECOM at this stage in their process is valuable because: 1) solar power technologies have differing impacts on ecosystems, species and water; 2) a tool is needed to assess constantly evolving solar technologies; and 3) technology developers who are informed of the impacts large-scale solar are more likely to incorporate environmentally-friendly improvements as the technology advances. A new approach to this part of the process has the potential to shift the way that solar development is conducted, resulting in more appropriate technology selection at selected sites and a permitting process that is less costly and time consuming.
This project will provide a broader perspective on the site selection and permitting process for solar utility projects than currently exists. Our efforts to inform the decision making process will ultimately help to smooth the way to a clean energy economy in California.
3. OBJECTIVES

This Bren Group Project approaches the selection of solar utility sites from a unique angle. For the purpose of informing AECOM, the solar industry, and the California public, our goal is to create a methodology that can determine, using selected significance criteria, “What is the best technology to install at a specific site within a distinctive California ecosystem?” Our goal is to provide a fresh perspective on the resource impacts, regulatory hurdles, costs and benefits of solar technology as well as create a user-friendly tool that can be used to recommend which technology is best suited for a selected location.

Phase I. Conceptual Framework
Our objective in Phase I is to develop a comprehensive conceptual model in which we will identify all of the inputs necessary for the development of large-scale solar projects, their benefits, and an overview-level assessment of their environmental impacts.

Phase II. Criteria Identification and Quantification
The final product of Phase II will be identifying and quantifying the critical information needed to construct a Multiple Criteria Decision Assessment (MCDA) tool. The objectives of Phase II include:

- Identifying the ten most important criteria related to solar energy development to use in our decision-making assessment.
- Defining a measurement unit for each of the ten criteria, so that they can be compared and contrasted across multiple technologies and in varying locations.

Phase III. Multi-Criteria Decision Assessment
In Phase III our goal is to input the information identified and quantified during Phase II into a Multiple Criteria Decision Assessment (MCDA) tool. The MCDA can be used proactively, before initiating the permitting process, to determine which type of technology should be considered for a given site. The objectives for our MCDA tool include:

- Assigning weights to each of the ten criteria based on stakeholder priorities.
- Creating a general MCDA tool that can identify the preferred type of solar technology for a selected site, based on the resource impacts, schedule and costs.
- Applying the MCDA tool to two different case studies to demonstrate its feasibility and accuracy.

Phase IV. Synthesis
Once we have used the case studies to test our methodology, we will assess the applicability of our approach to future large-scale solar power projects. We plan to synthesize our tested approach into a comprehensive methodology that will assist in identifying the key tradeoffs in any decision regarding large-scale solar development. Our end results can be used to provide a recommendation for which technology is best suited for a selected location.
4. SIGNIFICANCE

California law has mandated an accelerated timetable for alternative energy development. This mandate creates an incentive to develop, approve, and construct solar power projects. The resource impacts of utility-scale solar projects can be considerable and the cumulative effects of multiple projects remain unclear. Government agencies, local communities and tribes, NGOs, and other parties are engaged in ongoing debates over the role of solar energy in meeting the state’s RPS. Tension lies between the rapid expansion of solar energy projects and the minimization of their environmental impacts.

Currently, solar utility development is driven by technology choices made by companies. A company will invest in a specific type of solar technology and then look for a site on which to develop the project. The technology may or may not be the best fit for a site, but the company needs a return on its investment, and so development pushes forward. Permitting, mitigation, and litigation costs accumulate and may increase the amount of time required to permit a project, or may halt it entirely.

This Bren Masters Group Project has an opportunity to address these problems by developing an approach to site selection used in the preliminary decision making stages of a solar development project. Our project will:

- Offer a broad perspective of the most significant impacts that different solar technologies will have at a site.
- Create a tool for assessing and presenting information regarding solar power project costs and benefits.
- Determine which technology is the best choice for a site, considering the ten most significant economic, regulatory, schedule and resource impacts. By using the most appropriate technology and most feasible size, a project is more likely to move smoothly through the permitting process and to be approved.

By addressing appropriate technology and site selection prior to the permitting process, we will compare the costs and benefits of various technologies and site features that could help to streamline permitting. This project will help to improve the efficiency and appropriateness of solar technology selection, and move California towards its renewable energy goals more efficiently.
5. BACKGROUND

5.1 RENEWABLE ENERGY POLICY

With climate change action stalled at the international level and U.S. climate legislation appearing increasingly unlikely, many states have enacted, either separately or within regional initiatives, GHG mitigation policies. These policies include climate action plans, climate registries, RPSs, and state GHG reduction targets. California has adopted many such initiatives, and is one of three states to establish a state-wide GHG reduction target (Pew Center on Global Climate Change, 2010).

5.1.1 Assembly Bill 32

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

5.1.2 The California Renewable Energy Portfolio Standard

California’s RPS is among the most ambitious in the US (CPUC, 2010a). Established by Senate Bill (SB) 1078 in 2002, and expanded in 2006 under SB 107, the RPS requires electric utilities to procure 20 percent of their retail electricity from renewable sources by 2010. In 2008, Governor Schwarzenegger signed Executive Order (E.O.) S-14-08, raising the state’s renewable energy target further, to 33 percent by 2020 (Schwarzenegger, 2008). E.O. S-14-08 was also intended to remove some of the impediments to the permitting of renewable energy projects. In 2009 he issued E.O. S-21-09, directing the California Air Resources Board (CARB) to adopt regulations to achieve this target (Schwarzenegger, 2009).

To reach a 33% RPS by 2020, each retail electricity seller would have to increase the percentage of its electrical load sourced from renewable energy by at least one percent each year (CPUC, 2010b); however, the main factor limiting such an increase is transmission capacity. Currently, California has 8,000 MW of renewable energy capacity, and needs another 15,000 to 25,000 MW to achieve its target (Renewable Energy Focus, 2010). Solar energy will be an important source of renewable power (CPUC, 2010b).
5.2 SOLAR TECHNOLOGY OVERVIEW

Solar photovoltaic and solar thermal systems are the two solar power technologies most commonly used in California. As of August 2010, approximately 43.5% of all utility-scale solar power projects, which are in operation, under construction, or under development in California, are concentrating solar power and the remaining 56.5% are solar photovoltaic (PV) (Solar Energy Industries Association, 2010). Appendices I and II review the differences in function, land and water use, and cost and energy yield between the two technologies.

5.2.1 Solar Thermal Systems

Solar thermal systems, unlike solar PV systems, convert solar radiation into thermal energy and use that heat to generate electricity. The most commonly used solar thermal systems today are Concentrating Solar Power (CSP) technologies. CSP uses mirrors to reflect and concentrate solar radiation onto receivers that collect solar energy and convert it to heat. In the receivers, a high-temperature heat transfer fluid absorbs the sun light, reaching its temperature up to 750 degrees Fahrenheit, and then the thermal energy is used to generate electricity via a steam turbine or heat engine driving a generator (U.S. EPA, 2009). Three categories of CSP systems are used in most of today’s commercial CSP facilities: parabolic trough systems, power tower systems, and parabolic dish/engine systems.

Limitations of Solar Thermals
A fundamental limitation of solar power technology is its intermittency, as electricity output is reduced on cloudy days and ceases after sunset. Thermal energy storage (TES), which retains thermal energy during the day and releases it when sunlight is not available, has therefore become a critical component of CSP systems. Today, conventional TESs have the potential to increase CSP production time up to 16 hours per day, increasing the capacity factor (the ratio of an energy generation system's actual energy output to the output that would have been generated if the system was running at full capacity) to more than 50% (Price & Margolis, 2008).

Solar Thermal Projects in California
Currently (as of April, 2010), 432 MW of grid-tied CSP plant capacity is in operation in the U.S. (Solar Energy Industries Association, 2010). The largest facility in the world is the Solar Electricity Generating Station (SEGS), located in Mojave Desert of southern California, accounting for 354 MW of installed capacity. SEGS is comprised of nine parabolic trough power plants, each ranging from 14 to 80 MW installed capacity, located at three different sites in the desert. Parabolic trough systems account for the majority (421 MW) of installed capacity. The California Energy Commission recently (August, 2010) approved the Blythe Solar Power Project, which will become by far the largest solar power facility in the United States. The Sierra Sun Tower in California’s Antelope Valley, with 5 MW of installed capacity, is the only power tower system operating in the U.S.

5.2.2 Solar Photovoltaic Systems
Solar photovoltaic (PV) systems use sunlight directly to produce an electric current in an active layer of silicon, or poly or single crystalline film (U.S. DOE, 2010a). Inside PV cells, free
electrons in a semiconductor material are stimulated by solar radiation, producing an electric current (U.S. DOE, 2010a). Two categories of PV cells are used in most of today’s commercial PV modules: crystalline silicon and thin film.

**Limitations of Photovoltaic**
Like CSP systems, PV systems can only generate electricity during daylight hours and energy output varies with weather conditions (U.S. DOE, 2010b). PV cells produce maximum electricity on hot, sunny days, which coincide with high demand.

**Photovoltaic Systems in California**
As of August 2010, there are four utility-scale solar PV plants operating in California (excluding Concentrating Photovoltaic): FSE Blythe in Blythe, Sacramento Soleil 2008 in Sacramento, CalRENEW-1 in Mendota, and Vaca-Dixon Solar Station. Installed capacities for each facility are 21MW, 1.25MW, 5MW, and 2MW, respectively (Solar Energy Industries Association, 2010). A number of PV plants are also proposed, under development, or being constructed but have yet to come online. If each of these plants comes online, total installed PV capacity in California will rise to 13,411MW (Solar Energy Industries Association, 2010). California leads the U.S. PV market, accounting for nearly 95% of the new growth in grid-connected PV installation from 2007 to 2008 (Prince & Margolis, 2010).

**5.3 ENVIRONMENTAL IMPACTS**
Utility-scale solar thermal and photovoltaic solar power typically share a common set of environmental challenges; however, different technologies vary in their ability to meet these challenges. Additionally, some solar power technologies may be better suited to one site versus another, depending on the availability of resources and the geographic location of sensitive species and habitats. Overall, the most significant of these challenges in California are impacts on water resources and impacts on habitat and wildlife. These categories of impact have been identified by AECOM, regulatory agencies, and other interested parties as the most important and contentious issues in the solar utility permitting process. Biological impacts, in particular, trigger major on-site and off-site mitigation requirements, such as land purchase, habitat improvement and translocation of special status species, in order to comply with regulatory agencies. There are a broad range of environmental, archeological and cultural considerations inherent in the placement and approval of solar facilities. All environmental and social impacts are assessed, and mitigation options are identified in the EIS/EIR documentation required by NEPA and CEQA. Failure to adequately address these impacts may create permitting obstacles that can stall or even halt development of a solar project.

**5.3.1 Impacts on Biological Resources**
Solar photovoltaic installations, or “solar farms,” and solar thermal plants require large areas of open land to produce a grid-equivalent amount of energy. In California, these lands are predominantly desert or grassland, which are cleared and graded before installation. The land is then covered with gravel or treated with chemicals to retard the growth of weeds. Tall fences are
often erected around these facilities. These actions contribute to the loss of habitat for native species, and in some cases, to the spread of invasive species (NREL, 2010). Additionally, fences and transmission lines disrupt habitat connectivity for certain species of mammals, birds and reptiles (Bare et al., 2009).

California is home to more species than any other state and has the greatest number of endemics (CDFG, 2008). This high level of biological diversity and endemism is due, in part, to the diversity of habitats in California. For instance, two California regions with significant numbers of solar projects and particularly contentious projects are the Carrizo Plain and the Sonoran desert in the Blythe region. Vulnerable species have been identified in both areas and, according to the Nature Conservancy, the Carrizo Plain National Monument has the greatest number of threatened and endangered species in the state. These include the San Joaquin kit fox, the blunt-nosed leopard lizard, the giant kangaroo rat, and a candidate species, the San Joaquin antelope squirrel. The Colorado Desert eco-region is characterized by creosote bush scrub, mixed scrub, and desert dunes. State-endemic species of special status in the Colorado Desert region include many reptiles and mammals, most notably the desert tortoise and the peninsular desert bighorn sheep. Many species listed under special status are threatened by the disruption of corridors between critical and widely dispersed aquatic or wetland habitats. Solar development in both of these eco-regions will affect habitat availability and connectivity.

5.3.2 Impacts on Water Resources

Although California has experienced near-average precipitation in 2010, the previous year was the third consecutive year of drought (Osugi, 2010). California’s recent water scarcity has exacerbated contentious water rights issues and complicated the development of water-intensive projects (Osugi, 2010). California deserts are desirable locations for large-scale solar projects because the consistently high levels of direct solar radiation they receive maximize energy conversion efficiency. Unfortunately, deserts are also characterized by infrequent rain and scarce water resources, creating an obstacle for large-scale solar plants which require accessible and stable water supplies to operate. The wet cooling towers of solar thermal plants consume copious amounts of water (NREL, 2008): approximately 760 – 920 gallons per megawatt-hour, second only to geothermal wet cooling systems which use 1400 gallons per megawatt-hour (Carter & Campbell, 2009). Water is also used in day-to-day operations, particularly for cleaning off the dust that collects on solar panel surfaces to ensure that the panels receive maximum sunlight (NREL, 2008). The volume of water used for cleaning, however, is minimal in comparison to the large volume of water evaporated in the cooling towers; photovoltaic plants therefore use a very small fraction of the water resources used by solar thermal plants (SWRR, 2009). Concerns have arisen over the impacts that large-scale solar thermal plants may have on water allocation rights, on water flow diversion and intensity, and on the people and wildlife that depend on scarce water resources.

In California, water allocation is a contentious issue because agriculture, industry, and urban areas must often operate on less than optimal amounts of water. This year, California was able to grant just 45% of water allocation requests (this figure is low, but an improvement over the initial water allocation forecast for 2010) (Joaquin & Coast, 2010). It is already difficult to
satisfy all parties desiring access to water; adding large-scale solar power plants to the allocation pool may mean less water for previously established uses.

In addition to water allocation and rights issues, water quality and availability are also affected when water is pumped into wet cooling towers and later released at a warmer temperature, greater velocity, and/or a direction of flow not previously experienced by surrounding habitats. When water from a cooling tower is expelled into a nearby water source, the change in temperature can cause the death of aquatic life (Gleick, 2010). Additionally, diverting water for plant operation deprives wildlife of access to the water sources on which they depend for survival in arid environments. Additionally, water source diversion and take diminishes the amount of water available for downstream dependents, and can disrupt species migration (PowerScorecard, 2000). Lastly, changes in water flow can alter sediment movement in a river, and result in sediment accumulation, decreased water clarity and weakened riverbanks (PowerScorecard, 2000).

Under California law, only water that does not meet drinking water standards may be used for power plant cooling (Griffiths-Sattenspiel, 2010). Sub-standard water from aquifers and reclaimed water, however, may be used for cooling. Using water that is claimed before treatment may save money and energy, but leaves less water for wildlife (Woody, 2010).

5.3.3 Other Environmental and Social Impacts

Large-scale solar energy projects may also impact the resources listed below. These impacts are addressed in the environmental review process. Impacts include:

**Air Quality:** Considerations include how a project will conform to the Clean Air Act, its GHG emissions, estimations of criteria pollutant emissions and sources, and whether a Fugitive Dust Control Plan is necessary.

**Cultural & Paleontological Resources:** Solar projects are often sited in areas with valuable archaeological and cultural resources. These resources are inventoried pursuant to the National Historical Preservation Act. If impacts on archaeological, cultural, and historical resources are identified, a Historic Preservation plan is prepared.

**Geologic & Soils Resources/Hazards:** A project’s potential risk due to earthquakes and its impacts on soils and the crypto-biotic crust are assessed. A drainage, erosion, and sediment control plan is also prepared.

**Hazardous Materials Handling:** Risks of handling hazardous materials must be assessed, and a plan to manage existing risks must be formulated.

**Land Use:** Because of the amount of land required, land use is one of greatest concerns for large solar operations. Each project is evaluated for how it will support or conflict with existing land use plans in the area. Future land uses and associated impacts resulting from additional power supply are also considered.

**Noise:** Noise produced by the power plants must be evaluated for its effects on sensitive wildlife and nearby human communities.

**Public Health:** An assessment of the public health risks of potentially hazardous materials and wastes associated with project construction and operations & maintenance (O&M) must be
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conducted. Considerations include pesticide and herbicide use, evaporation ponds management, risk of soil contamination, and influence on wildfire risk. **Socioeconomics:** An evaluation must be conducted of the economic impacts of construction, operation, and land use changes, such as decreased commerce due to loss of tourism, and/or the number of jobs created during plant construction and/or O&M of plant. **Traffic & Transportation:** An assessment of the impacts on the environment of increased traffic and access to previously inaccessible areas, as well as impacts on air traffic for nearby airports and military facilities, must be included. **Transmission Systems Safety & Nuisance:** An assessment of how transmission lines will affect the area is also conducted. **Visual Resources:** The primary visual resource evaluation concerns the project’s effects on tourism in the area due to impacts on visually sensitive areas, including wilderness areas and areas valued for their remote and aesthetic qualities. **Waste Management:** A discussion of the handling of construction and operational wastes according to federal and state guidelines is included. **Worker Safety:** A plan for dealing with worker safety and health issues, including risks from natural disasters such as wildfire, is required.

Each of these considerations will have varying degrees of applicability to a particular project, but must be thoroughly researched and considered before a project permit is granted.

**5.4 THE PERMITTING AND ENVIRONMENTAL REVIEW PROCESS**

The range and significance of environmental impacts associated with solar utilities necessitate an extensive permitting and environmental review process to identify and mitigate these impacts. Many of the challenges to solar power development in California are related to this environmental review process, required by NEPA and CEQA. Failure on the part of solar project developers to comply with regulations and address the full spectrum of environmental impacts may halt or significantly slow proposed projects. An outside consulting firm such as AECOM often performs the environmental assessment, compiles the necessary documentation in cooperation with the relevant regulatory agencies, and guides the project developer through the permitting process. This process is complicated by numerous statutory requirements, requires the effort of teams of environmental specialists, and is generally costly and time-consuming.

**5.4.1 The California Environmental Quality Act and National Environmental Policy Act**

The California Environmental Quality Act (CEQA) is one of the state’s most important environmental laws, applying to numerous physical developments within California and driving the permitting and environmental review process. CEQA is both a procedural and substantive statute, requiring state and local agencies to assess and identify the major environmental impacts of their actions, and if feasible, to mitigate or avoid those impacts. CEQA’s procedural requirements include, at minimum, an initial review of a project and its environmental impacts, and potentially an additional, more substantial environmental impact report (EIR) (California, 1970). Like NEPA, the Federal statute after which it was modeled, CEQA is intended to force public agencies to consider the environmental impacts of their actions and to disclose their
findings to the public (NEPA, 2000). CEQA’s procedural requirements are analogous to those of NEPA, creating some overlap. NEPA also requires the preparation of a detailed statement, the Environmental Impact Statement or EIS, but differs in that it does not require mitigation or implementation of feasible alternatives, and is therefore not as substantive as CEQA.

5.4.2 California Energy Commission Certification and Environmental Review Process

The California Energy Commission (CEC) is the state’s primary energy policy and planning agency and the lead agency under CEQA for the power plant certification and environmental review process. The CEC is responsible for licensing all thermal power plants with a capacity of 50 MW or greater. The CEC is therefore responsible for licensing large solar thermal – though not photovoltaic – power plants. The CEC uses a regulatory program certified under CEQA which exempts it from preparing a standard EIR, but requires analysis and documentation of the environmental impacts, alternatives and mitigation measures for any significant negative environmental effects (California Energy Commission; Bureau of Land Management, 2007). The CEC’s more rigorous EIR-equivalent document is called the Staff Assessment (SA) and is prepared by CEC staff.

The environmental review and permitting, or siting, process entails a specific set of protocols and typically generates thousands of pages of documentation per project. Because the majority of California’s proposed renewable energy projects are on lands owned by the Bureau of Land Management (BLM), these projects are often subject to both BLM and CEC jurisdiction. Each applicant for a permit to build power plants on these lands needs a right-of-way permit from the BLM and certification from CEC, thereby requiring both NEPA and CEQA compliance. To expedite the environmental review and permitting process, avoid duplication of agency efforts and facilitate intergovernmental coordination, the CEC and BLM have entered into a memorandum of understanding to provide a joint NEPA and CEQA review for utility-scale solar and other renewable energy facilities under their jurisdictions (California Energy Commission and Bureau of Land Management, 2007). As lead agency for large solar thermal plants, the CEC plays the primary role, but remains in communication with the BLM to ensure that NEPA requirements are met. The joint document produced is referred to as the SA/EIS; however, break-down in cooperation between the two agencies occasionally leads to the preparation of a separate EIS by the BLM. By statute, the CEC is supposed to make a final decision regarding a project within 12 months of the filing of an Application for Certification (AFC) (California Energy Commission 2010; California Energy Commission and Bureau of Land Management, 2007). However, permitting challenges have resulted in a process that has typically taken about 18 months to complete (AECOM, personal communication).

The environmental review and permitting process for photovoltaic plants, while somewhat less onerous than for solar thermal, is still complex. The BLM is the lead agency for PV plants constructed on entirely on federal land. In this case, the document analogous to the AFC is the Plan of Development (POD), and only an EIS is prepared. For PV plants located on private or county-owned lands, the local County Planning Department is typically the lead CEQA agency.
The permitting path in these cases is a Conditional Land Use or similar permit, for which an EIR must be prepared.

5.4.4 Public Participation

The CEC employs a unique system for public participation, using an adjudicatory process with formal evidentiary hearings and testimonial in addition to public workshops. The BLM and county planning departments, in contrast, follow the standard CEQA and NEPA non-adjudicatory procedures for scoping and public review. The CEC allows several options for public participation in the siting process. The public may attend CEC meetings and make oral or written comments to the commissioners, although these comments will not be considered as formal evidence. Citizens and organizations may also petition for “intervener status” to be considered full parties to the proceedings, with the same rights and obligations as project applicants and staff. Interveners may formally present evidence and witnesses, obtain information from other parties, cross-examine witnesses at public hearings and receive all case documents, among other rights and responsibilities. A Public Advisor assists public participation in and understanding of the CEC’s certification process as well (California Energy Commission, 2010).

5.4.5 AECOM’s Role

For solar thermal projects, the environmental review documentation in the Staff Assessments is compiled by CEC staff, while consulting firms like AECOM prepare the initial AFC and respond to the CEC’s and others’ Data Requests on behalf of their clients. AECOM, which consults on a large portion of utility-scale solar projects in California, is involved in the permitting process early on. Prior to the developer’s submission of a formal AFC, AECOM conducts an initial Critical Issues Analysis (CIA) – a pre-screening assessment of environmental and regulatory feasibility for each potential site offered by the developer for a project. The CIA, which typically costs about $25,000 to prepare, is a relatively brief, non-public document that identifies key issues and ‘fatal flaws’ in siting, and strategies or recommendations for dealing with them. The CIA is used by developers for financing and planning purposes. Once a site is selected based on the CIA, and the decision is made to move forward with development, AECOM conducts the more detailed, publicly available environmental impact assessments contained in the AFC.

5.4.6 Project and Permitting Barriers

California’s 33% RPS has generated massive interest in establishing utility-scale solar plants in the California desert (California Public Utilities Commission, 2009). As of 2007, BLM had received right-of-way requests for the development of 34 large solar thermal plants, collectively generating about 24,000 MW and covering over 300,000 acres of land. Many of these projects have not yet reached the Application for Certification (AFC) stage (California Energy Commission; Bureau of Land Management, 2007). Permitting for renewable generation facilities tends to be a long, complex process subject to significant uncertainty and potential lawsuits. In addition to CEC certification and the necessary environmental review
documentation, a typical project must obtain agreements with utilities for electricity sales and numerous permits from the counties, air quality districts and other agencies involved (California Public Utilities Commission, 2009). The possibility of additional future regulation and policy changes also introduces uncertainty. In particular, the proposed designation of new protected areas in the Southern California desert may conflict with the siting of solar plants. For instance, the California Desert Protection Act (CDPA) of 2010 introduced in the U.S. Congress, would, among other provisions, add to the area already protected by the 1994 California Desert Protection Act.

Environmental permitting of new renewable energy projects is complicated by all of these factors. The sensitivity of desert ecosystems, the large acreages involved, the number of interested parties and possible litigants, the intensive permitting processes under various jurisdictions and regulatory frameworks, the policy uncertainty, and the sheer volume of potential projects combine to create significant permitting bottlenecks and challenges.

5.5 CASE STUDIES: GENESIS PROJECT AND TOPAZ PROJECT

The technology considerations, environmental impacts, and environmental review requirements involved in permitting large-scale solar power plants may be better understood in the context of specific projects. For this reason, we have selected two California case studies, the Genesis Solar Energy Project in Blythe, and the Topaz Project in the Carrizo Plain region. These two projects were selected based on the ecological distinctiveness of their respective locations, the different solar technologies proposed, and their proximity to other solar projects and protected lands. By examining the unique environmental and permitting considerations involved in these two case studies, we will demonstrate the applicability of our proposed methodology and decision tool.
5.5.1 Genesis Solar Energy Project, Blythe


The Genesis Project is composed of two plants, each with a net output of 125 MW. The Project will produce electricity with solar parabolic trough arrays feeding steam turbine generators. The Project proposes to use about 1,644 acre-feet of water per year for a wet cooling system. Additionally, an on-site boiler fueled by a six mile pipeline is expected to use 60 million cubic feet of natural gas per year.

The Genesis Project will be located entirely on federal land located south of the Palen/McCoy Wilderness Area, north of Interstate 10 and Ford Dry Lake, and about 25 miles west of the city of Blythe in east central Riverside County. The right-of-way (ROW) grant requested from the BLM is for approximately 4,640 acres in an undeveloped area of the Colorado Desert. Land use in this area is characterized largely by open space and conservation and wilderness areas. The Project also lies within the BLM California Desert Conservation Area Plan (CDCA Plan). Currently, the area is undisturbed; however, it has been used for grazing and off-road vehicle recreation in the past.

Blythe, with a population of about 16,000, is located in an agricultural area near the border between California and Arizona. This area has been identified by REAT as a high potential site for renewable energy development (Pletka et al., 2010). There are numerous proposed and existing solar energy projects located near Interstate 10 within the vicinity of the Genesis Project, raising possible concerns about cumulative impacts.

5.5.2 Topaz Solar Farm, Carrizo Plain, San Luis Obispo County

Topaz Solar Farm is a proposed 550 MW, thin film photovoltaic power plant to be built by First Solar, Inc. on 4,200-acres in the Carrizo Plain, in eastern San Luis Obispo County. First Solar purchased the land option from Ausra CA II, LLC, which had originally intended to build a 177 MW, 640-acre facility (Wang, 2009; Kessler, 2010). The San Luis Obispo County Planning and Building Department is the lead agency for this project.

The land parcel contains farmland protected under California’s Williamson Act, which provides tax breaks to landowners in exchange for restricting land use to agriculture and other open-space uses (Wang, 2009). Although legal restrictions do not preclude construction of the solar farm, such a project could engender political resistance. However, First Solar may be able to locate at least some of the project on non-Williamson Act land (Wang, 2009). The project has the potential to conflict with agricultural uses as well as wildlife conservation issues. The San
Joaquin kit fox, a federally listed endangered species, uses the Carrizo Plain area as habitat and migration corridors. The developer submitted a Conditional Land Use Permit (CUP) application in July of 2008 and an EIR has not yet been prepared. Topaz is expected to be operational by 2013.

5.6 MOVING FORWARD

An understanding of current solar technologies, policies, resource impacts, and permitting is essential to the successful completion of an environmentally responsible and profitable solar power plant. By creating a methodology that considers a broader perspective of all of these issues than is currently taken by any single stakeholder, the Bren Group Project will assist in addressing appropriate technology and site selection criteria prior to starting the permitting process. We will compare the costs, benefits, and resource impacts of different technologies and hope to ultimately help streamline the siting and permitting of solar facilities.

6. METHODS

Our approach is divided into the following four phases:

**Phase 1. Conceptual Framework**
The first step in our project is to establish a conceptual framework that will incorporate all aspects of large-scale solar power technology development in California. This will aid in understanding the trade-offs between various forms of solar energy generation and the myriad of environmental impacts associated with the development of different solar power technologies. The conceptual framework will map out the inputs needed for solar energy development (e.g., water, land and energy requirements, financial costs), the impacts on biological resources, water resources, cultural resources, society, etc., and the benefits of large-scale solar power development (e.g., meet renewable energy goals, less fossil-fuel based energy). Figure 1 below maps out a coarse-grained look at our conceptual framework:

![Conceptual Model for Large-scale solar power.](image-url)
Phase II. Criteria Identification and Quantification
During Phase II, we will research each of the inputs, impacts and benefits included in our conceptual framework and choose the ten most important criteria related to solar energy development. After selecting the criteria, we will assign a metric for each criterion that can be compared across technologies and locations.

Specifically, we will take the following steps in Phase II:
1) Review past Staff Assessment and EIS documents and conduct interviews with experts in each of the areas identified in the conceptual framework. The information gained will aid us in narrowing down all inputs, impacts and benefits to ten criteria that are most significant to consider when developing a solar power project.

2) Determine a metric for each criterion that can be used to compare across technologies and locations. For example, if one of the top ten criteria is water use, we would assign a unit of measurement for water such as gallons per megawatt hour. We will assign units of measurement for each of the ten criteria based on the best available data on real costs and the impacts and benefits of solar power technology.

3) Assign a comparative ranking to each impact measurement based on the distribution of possible values for the impact measurement. This is analogous to organizing the impact measurements into five general categories: no significant impact, less than significant impact, average impact, moderate impact, and significant impact. Each categorical ranking will be given a numerical value (-2, -1, 0, +1, and +2).

Phase III. Multi-Criteria Decision Assessment
In Phase III of our project, we will take the information from Phase II and assign a weighting scheme for each criterion. We will use Multiple-Criteria Decision Assessment (MCDA) to quantify and compare the criteria across different technology options for a given site.

MCDA is a method for weighing different options according to several key criteria, often used in the context of a multifaceted decision-making process (Belton & Stewart, 2002). MCDA is performed by assigning comparative quantitative values to key criteria, which are essential factors in choosing between two or more options. These criteria values are weighted according to the preferences of the decision-maker. These weighted criteria values are then summed for each option under consideration, providing the decision-maker with comparable values for each choice. While assigning weights to each criterion is partially subjective, the MCDA technique is a transparent process that allows outside observers to understand why a particular option was chosen.

Phase III will include the following two steps:

1) Assign weights to each criterion. For each criterion, we will assign a weight that reflects how the criteria are valued in comparison to the others. For example, if all criteria are equally valued, then each is weighted as 0.10. More likely, we will want to value one criterion more than the others. For example, in an area that faces contentious water supply issues, we may want to weight the water criteria more heavily than the others.
2) Test the MCDA model on two case study sites. Using the various weighting schemes that we gather from survey information, we will conduct an MCDA on two project sites: the Genesis Project in Blythe, CA and the Topaz Project in the Carrizo Plain. For each particular site, we will determine an impact measurement for each criterion, assign a corresponding ranking and apply a weighting scheme. We will do this for each technology option in a particular site. The MCDA will render the most optimal technology choice for a specific site. We can compare this technology choice with the chosen technology and provide recommendations to developers and decision-makers based on our results.

**Phase IV. Synthesis**
Once we have employed the case studies to test our methodology, we will assess the applicability of our approach to future large-scale solar power projects by approaching experts in the field with our tool. We plan to synthesize our tested approach into a comprehensive methodology that will assist in identifying the key tradeoffs in any decision regarding large-scale solar development.

**7. DELIVERABLES**

After achieving the described objectives, our deliverables will include a public presentation, a project poster, and a final product which will include the following components:

- A report to AECOM comparing solar thermal and photovoltaic technologies for their costs and resource impacts for two locations in California.
- A replicable MCDA decision-making tool that AECOM can use to compare the costs and resource impacts of solar thermal and photovoltaic technologies in arid regions of California.
- A recommendation to AECOM for how to aggregate and weigh the costs and impacts of technology selection at specific California sites.
- A project website where documents, presentations and the decision-making tool can be accessed.
### 8. MILESTONES

<table>
<thead>
<tr>
<th>SPRING 2010</th>
<th>Deadline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submit proposal draft</td>
<td>18-May-2010</td>
</tr>
<tr>
<td>Submit final proposal to review committee</td>
<td>1-Jun-2010</td>
</tr>
<tr>
<td>Meet with Advisory Committee for feedback</td>
<td>4- Jun-2010</td>
</tr>
<tr>
<td>1 Page Summary of proposal review meeting due to Advisor</td>
<td>11-Jun-2010</td>
</tr>
<tr>
<td>Group Project web link due to GP Coordinator</td>
<td>11-Jun-2010</td>
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<tr>
<td>Submit Self &amp; Peer Evaluations</td>
<td>11-Jun-2010</td>
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<table>
<thead>
<tr>
<th>SUMMER 2010</th>
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<tbody>
<tr>
<td>Amy interns at AECOM Camarillo office</td>
<td>Sept 2010</td>
</tr>
<tr>
<td>Expand literature review on assigned topics.</td>
<td>Sept 2010</td>
</tr>
<tr>
<td>Complete group conference call #1</td>
<td>31-Jul-2010</td>
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<tr>
<td>Complete group conference call #2</td>
<td>20-Aug-2010</td>
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<table>
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<tr>
<th>FALL 2010</th>
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<tr>
<td>Identify and arrange all MCDA criteria</td>
<td>18-Oct-2010</td>
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<tr>
<td>Develop and test MCDA model</td>
<td>25-Oct-2010</td>
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<tr>
<td>Complete Progress Reviews</td>
<td>12-Nov-2010</td>
</tr>
<tr>
<td>Begin writing final report</td>
<td>15-Nov-2010</td>
</tr>
<tr>
<td>Begin creating final presentation</td>
<td>15-Nov-2010</td>
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<tr>
<td>Begin drafting poster</td>
<td>15-Nov-2010</td>
</tr>
<tr>
<td>Written Progress Report due to Advisor</td>
<td>3-Dec-2010</td>
</tr>
<tr>
<td>Submit Self &amp; Peer Evaluations</td>
<td>3-Dec-2010</td>
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### WINTER 2011

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<tr>
<th>Task</th>
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<tbody>
<tr>
<td>Complete first draft of Final Report</td>
<td>Week 2</td>
</tr>
<tr>
<td>Complete first draft of Presentation &amp; Poster</td>
<td>Week 2</td>
</tr>
<tr>
<td>Project Defense</td>
<td>Week 5/6</td>
</tr>
<tr>
<td>Draft of Final Report to Advisor</td>
<td>18-Feb-2011</td>
</tr>
<tr>
<td>Title, Abstract, &amp; Acknowledgments</td>
<td>9-Mar-2011</td>
</tr>
<tr>
<td>Submit Project Brief</td>
<td>18-Mar-2011</td>
</tr>
<tr>
<td>Submit Self &amp; Peer Evaluations</td>
<td>18-Mar-2011</td>
</tr>
<tr>
<td>Submit Advisor Evaluation</td>
<td>18-Mar-2011</td>
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### SPRING 2011

<table>
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<tr>
<th>Tasks</th>
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<tr>
<td>Submit Keynote Presentation to Advisor</td>
<td>2 weeks before</td>
</tr>
<tr>
<td>Send Poster to printer</td>
<td>1 week before</td>
</tr>
<tr>
<td>Practice Videotaping Presentation</td>
<td>3 days before</td>
</tr>
<tr>
<td>Public Project Presentation</td>
<td>TBD</td>
</tr>
<tr>
<td>Submit Final Project Poster to Bren</td>
<td>TBD</td>
</tr>
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</table>
9. MANAGEMENT PLAN

<table>
<thead>
<tr>
<th>POSITION</th>
<th>NAME</th>
<th>CONTACT</th>
<th>DUTIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Manager</td>
<td>Sarah Amspacher</td>
<td><a href="mailto:samspacher@bren.ucsb.edu">samspacher@bren.ucsb.edu</a></td>
<td>• Primary contact with client, AECOM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Coordinate meetings</td>
</tr>
<tr>
<td>Modeling Specialist</td>
<td>Stephanie Dashieell</td>
<td><a href="mailto:sdashiell@bren.ucsb.edu">sdashiell@bren.ucsb.edu</a></td>
<td>• Modeling impacts on ecological and biological resources</td>
</tr>
<tr>
<td>Internal group organizer</td>
<td></td>
<td></td>
<td>• Managing internal deadlines and meetings</td>
</tr>
<tr>
<td>Data Manager</td>
<td>Tetsuhisa Kamiya</td>
<td><a href="mailto:tkamiya@bren.ucsb.edu">tkamiya@bren.ucsb.edu</a></td>
<td>• Collect and manage data to be available to group for analysis</td>
</tr>
<tr>
<td>Financial Manager</td>
<td>Vanessa Arent</td>
<td><a href="mailto:varent@bren.ucsb.edu">varent@bren.ucsb.edu</a></td>
<td>• Manage finances for the project</td>
</tr>
<tr>
<td>Web Manager</td>
<td>Amy Linn</td>
<td><a href="mailto:alinn@bren.ucsb.edu">alinn@bren.ucsb.edu</a></td>
<td>• Create and maintain website for project</td>
</tr>
<tr>
<td>Internship Coordinator</td>
<td></td>
<td></td>
<td>• Complete summer internship with AECOM</td>
</tr>
<tr>
<td>Web Manager</td>
<td>Sydney Ward</td>
<td><a href="mailto:sward@bren.ucsb.edu">sward@bren.ucsb.edu</a></td>
<td>• Create and maintain website for project</td>
</tr>
<tr>
<td>Faculty Advisor</td>
<td>Christina Tague</td>
<td><a href="mailto:etague@bren.ucsb.edu">etague@bren.ucsb.edu</a></td>
<td>• Review work and guide project</td>
</tr>
</tbody>
</table>

Meeting Structure
Meetings will generally be held twice a week. One weekly meeting will be held for group members, with a second meeting, when scheduling permits, of the group members and faculty advisor. Meetings with the advisor will take place in the Bren Hall Visitor Center, and group member meetings will be in Davidson Commons. Each meeting will be led by one group member, on a rotating basis. This individual will be responsible for providing the meeting agenda beforehand, and will keep the group on point according to the agenda.

Deadlines
Both the Project Manager and the Internal Group Organizer will set clear deadlines for the project milestones. Group members will be made aware of approaching deadlines during biweekly meetings and via regular email contact. Leniency will be granted to group members who voice difficulty in reaching them, especially if these concerns are known in advance. Given
the number of short intensive courses throughout the course of the project, all members must remain aware of deadlines.

**Group Data and File Sharing**

A shared DropBox folder to store relevant literature, proposal drafts, documents, meeting notes and other vital information has been established. The Data Manager is responsible for managing this folder and maintaining the integrity of all data used and collected, including metadata. The group will use Mendeley to organize citations. Members are responsible for their maintaining and organizing citations for individual work and ensuring consistency with the format determined by the group.

**Group Interactions and Possible Conflicts**

Meetings will be run in a professional manner. Since we are meeting twice weekly, and once a week without advisors or clients present, we will seek to establish a strong rapport. Group members should be comfortable voicing concerns and suggesting ideas as the project continues to evolve. While following meeting agendas will be important for efficiency, members are encouraged to make additions and convey their thoughts to the group.

If conflicts should arise between group members, they should first be dealt with one-on-one between those members in an open, constructive way. In order to maintain functional and civil relationships between members over the project’s course, no personal criticisms should be made. Constructive suggestions, compromise and cooperation is strongly encouraged. Any matter that cannot be settled individually will be relayed to the group. Self evaluations and peer evaluations will be made at the end of each quarter and used, if necessary, to make improvements.

**Expectations and Goals**

Group members are expected to behave courteously and professionally towards each other, as well as toward advisors and clients. Maintaining this project as a priority while balancing other academic and external duties will be challenging, but imperative. All members should work hard on their individual Group Project responsibilities, as well as contribute to those of the group. Information and advice from external parties will be essential to our becoming experts on the project material. The success of the Group Project will depend on each member’s participation and motivation, as well as the group’s as a whole.
10. BUDGET

<table>
<thead>
<tr>
<th>Expense</th>
<th>Amount</th>
</tr>
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<tbody>
<tr>
<td>Printing</td>
<td>$200</td>
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<tr>
<td>Phone Calls</td>
<td>$52</td>
</tr>
<tr>
<td>Photocopies</td>
<td>$50</td>
</tr>
<tr>
<td>Travel (AECOM meetings, visit case study locations)</td>
<td>$400</td>
</tr>
<tr>
<td>Final Poster</td>
<td>$300</td>
</tr>
<tr>
<td>Presentation Expenses</td>
<td>$50</td>
</tr>
<tr>
<td>Miscellaneous (materials, business cards, unanticipated expenses)</td>
<td>$448</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$1500</strong></td>
</tr>
</tbody>
</table>

Budget Justification
- We are allocated $200 in printing costs in addition to the $1300 in group funds
- Phone calls cost $10 to set up + $1 per month + Call fees (which is estimated at $30)
- Travel costs are set aside for day trips to the AECOM office in Camarillo and for day trips to our case study sites. The largest expense will be gas (miles traveled x price of gas per mile)
11. CONTACT INFORMATION

Project Members:
Sarah Amspacher          samspacher@bren.ucsb.edu
Stephanie Dashiell       sdashiell@bren.ucsb.edu
Tetsuhisa Kamiya         tkamiya@bren.ucsb.edu
Vanessa Arent            varent@bren.ucsb.edu
Amy Linn                 alinn@bren.ucsb.edu
Sydney Ward              sward@bren.ucsb.edu

Faculty Advisor:
Christina Tague          ctague@bren.ucsb.edu
Jeff Dozier              dozier@bren.ucsb.edu

Project Website:         T.B.D

Project Email:           solar@bren.ucsb.edu

Client:
Chad Roper               chad.roper@aecom.com
AECOM

External Advisors:
Sangwon Suh              suh@bren.ucsb.edu
Bren Faculty
Lee Hannah               lhannah@bren.ucsb.edu
Bren Faculty
12. REFERENCES


Bare, Lucas, Tessa Bernhardt, Toby Chu, Melissa Gomez, Christopher Noddings, and Milena Viljoen. 2009. Cumulative Impacts of Large-scale Renewable Energy Development in the West Mojave. Santa Barbara, CA.


## APPENDIX I. System Description, Land Use, Water Use, Cost and Energy Yield of Solar Thermal Systems

<table>
<thead>
<tr>
<th>System Description</th>
<th>Parabolic trough systems</th>
<th>Power tower systems</th>
<th>Parabolic dish/engine systems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Parabolic trough systems consist of U-shaped reflectors with oil-filled pipes (the receivers) at their focal point. The oil heated in the receiver is used to boil water to produce steam, which then runs conventional steam turbines and electricity generators.</td>
<td>A power tower system uses many large, flat reflectors to focus sunlight onto a receiver usually located at the top of a tall tower. The receiver is filled with a fluid, such as molten salt, which is heated to produce thermal energy and steam for electricity generation.</td>
<td>A parabolic dish/engine system uses mirrored dishes to concentrate sunlight onto a receiver mounted at the focal point of the dish. The receiver is integrated into a high-efficiency external combustion engine which generates energy, with the heat collected by the system.</td>
</tr>
<tr>
<td>Land Use</td>
<td>5-10 acres/MW of installed capacity*</td>
<td>6-12 acres/MW of installed capacity</td>
<td>10 acres/MW of installed capacity</td>
</tr>
</tbody>
</table>
| Water Use          | Wet cooling systems:  
  - 90% of water consumption is dedicated to cooling a condenser.  
  - 8% is used to replace water in the steam cycle.  
  - 2% is used for washing the mirrors of the solar condensing troughs. | Dry cooling systems:  
  - Consumes 90% less water than a wet cooling system.  
  - More energy intensive than a wet cooling system. | Mainstream dish/engine systems have a dry cooling system. |
|                    | 800-1000 gal/MWh (wet) | 500–750 gal/MWh (wet) | 800–1000 gal/MWh (dry) |
| Cost               | Building/Capitol Cost: $2.98/W | Building/Capitol Cost: $2.57/W | Building/Capitol Cost: $1.63/W |
|                    | Operation & Maintenance (O&M) Cost: $0.005/ kWh | O&M Cost: $0.003/ kWh | O&M Cost: $0.011/ kWh |
| Energy Yield       | Efficiency** of a large-scale CSP plant can be up to 14.6%. Efficiency is expected to improve by 5-10% from 2020 to 2030, as technology performance improves. | A 10 MW test plant achieved efficiency of about 8.5% in the 1980s. By 2020, efficiency is expected to improve by about 20% from the 1980 8.5% efficiency level as the mirrors improve to minimize radiation loss. | Energy yield ranges from 10kW to 35 kW per dish with a turbine or a stirling engine. Efficiency of current technology can be up to 30%. |

*Installed capacity: a maximum amount of electricity that a plant can generate at any given point in time

**Efficiency: the ratio of incoming sunlight to electricity output

Sources:


APPENDIX II. Description, Land Use, Water Use, Cost and Energy Yield of Solar PV Systems

<table>
<thead>
<tr>
<th>System Description</th>
<th>Crystalline silicone cells</th>
<th>Thin film cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Includes monocrystalline and multicrystalline cells. One of the most efficient cells among the mainstream PV technologies.</td>
<td>Includes PV cells that produce electricity via extremely thin layers of semiconductor material made of amorphous silicon (aSi), copper indium diselenide (CIS), copper indium gallium diselenide (CIGS), or cadmium telluride (CdTe). Multijunction cells use multiple layers of semiconductor material.</td>
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<tr>
<td>Accounted for about 84% of PV produced in 2008.</td>
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<table>
<thead>
<tr>
<th>Land Use</th>
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<tbody>
<tr>
<td>Amount of land use depends primarily on efficiency of cells and on the levels of solar radiation at a site.</td>
<td></td>
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<tr>
<td>Land use in existing facilities: FSE Blythe - 9.5 acres/MW; Sacramento Soleil 2008 - 6.8 acres/MW; CalRENEW-1 - 8 acre/MW</td>
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<tr>
<th>Water Use</th>
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<tbody>
<tr>
<td>Water is used to clean the surface of panels in order to maintain optimal efficiency.</td>
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<tr>
<td>Water consumption can be minimized through recycling.</td>
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<tr>
<th>Cost</th>
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<tbody>
<tr>
<td>The installation cost declined from $7.8/W in 2007 to $7.5/W in 2008.</td>
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<tr>
<td>Cost for Operations and maintenance was on average $0.004/kWh.</td>
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<thead>
<tr>
<th>Energy Yield</th>
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<tbody>
<tr>
<td>The amount of electricity produced by PV systems depends primarily on the following factors: capacity factor*, solar resource**, and cell type and its efficiency.</td>
<td></td>
</tr>
<tr>
<td>The average solar resource in California ranges from 4.5 to 6.8 kWh/m²/day.</td>
<td></td>
</tr>
<tr>
<td>Efficiency of research-cell: 20% - 28%.</td>
<td>Efficiency of research-cell: 12% - 20%.</td>
</tr>
<tr>
<td>Module efficiency: 13.5% - 17.5%.</td>
<td>Module efficiency: 6.5% - 10%.</td>
</tr>
</tbody>
</table>

*Capacity factor: the ratio of an energy generation system's actual energy output during a given period to the energy output that would have been generated if the system ran at full capacity for that period
**Solar resource: the amount of solar radiation received by a unit of area for a given period of time
***Research-cell: a cell that is manufactured under ideal laboratory conditions and refined to attain the highest possible efficiencies
****Module efficiency: efficiency of a solar module (an interconnected assembly of PV cells) as a whole

Sources:


APPENDIX III. CEC Siting and Environmental Review Stages

The CEC’s siting process consists of six phases:

1. **Pre-application phase**: This is an informal planning and preparation period during which potential applicants attend pre-application meetings and are informed of the CEC and BLM’s data and information requirements prior to the Application for Certification (AFC).

2. **Data Adequacy**: CEC staff review AFCs to determine whether they meet CEC and BLM informational requirements. Upon accepting the application as “data adequate,” the CEC’s statutory review begins, with 12 months allowed for a final decision.

3. **Discovery Phase**: The CEC and BLM develop the scope of the NEPA/CEQA joint document and hold a public scoping meeting. This is the data gathering phase, during which the CEC collects information, and conducts public information hearings and workshops and site visits. The CEC staff also prepares an Issue Identification report.

4. **Analysis Phase**: The CEC holds workshops and prepares assessments of project impacts and mitigation measures for a range of engineering, environmental, public health and safety issues. In consultation with the BLM, the CEC staff prepares a joint Preliminary Staff Assessment/Draft EIS, and later, a joint Final Staff Assessment/Final EIS. Additional consultation and documentation are required by the BLM pursuant to the National Historic Preservation Act (NHPA) and the Endangered Species Act (ESA). For each proposed project, a standardized set of criteria are assessed.

5. **Hearings Phase**: In cooperation with BLM, the Energy Commission Committee (composed of two of the five Commissioners) which are appointed to oversee a particular project, holds formal evidentiary hearings at which the applicant, staff, intervenors, and other agencies present their findings and conclusions and the public may present oral and written comments.

6. **Proposed Decision/Decision Phase**: The Committee issues a Presiding Member’s Proposed Decision (PMPD), followed by a public hearing. The full Commission then determines whether to approve or deny an AFC at a regularly scheduled bi-monthly meeting.