RECLAMATION

Managing Water in the West

Renewable Power Generation For Water Transmission

(S&T ID-7014)

U.S. Department of the Interior
Bureau of Reclamation
Phoenix Area Office

Final Report - May 2014

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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1.0 Introduction

The possibility of adding renewable energy to the existing Bureau of Reclamation (Reclamation) project lands is a prospect that has become popular in recent history. The issue of closing or reducing power generation production at Reclamation and Reclamation partner's facilities because of environmental concerns is heating up. Utilizing renewable energy techniques has the potential of augmenting or replacing power generation coming from existing Reclamation facilities. Now is the time to gather data and explore the possibilities of adding renewable energy to existing Reclamation facilities. This will be valuable information for making informed decisions.

Reclamation's Phoenix Area Office has submitted a request and has been granted funding through Reclamation's Research and Development, Science and Technology program to look at the possibilities of adding renewable energy to project lands in order to add supplemental power for water distribution.

The initial phase of this investigation developed a plan of study. As presented, this plan of study contained the background, purpose and objectives, a description of the study management structure, a breakdown of the study phases, and a schedule. Under this plan of study, a scope of work for the tasks were developed for implementation.

1.1 Research Question

The questions that will be answered under this study are:

Are there opportunities to utilize Reclamation project lands and right-of-way for the installation of solar technologies?

Can Reclamation and water districts better utilize project lands to improve and increase power generation capabilities for water transmission?

Can strategically located solar technology be place on the canal system right-of-way and/or cover the canals?

1.2 Background

Established in 1902, the Reclamation is best known for the dams, power plants, and canals it has constructed in the 17 western states. These water projects led to homesteading and promoted the economic development of the West. Reclamation has constructed more than 600 dams and reservoirs including Hoover and Glen Canyon Dams on the Colorado River in the lower basin, Bartlett and Horseshoe Dams on the Verde River, and five dams on the Salt River system in Arizona.

Today, Reclamation is the largest wholesaler of water in the country. As a whole the bureau supplies water to more than 31 million people, and provide one out of five Western farmers (140,000) with irrigation water for 10 million acres of farmland that produce 60% of the nation's vegetables and 25% of its fruits and nuts.

Reclamation is also the second largest producer of hydroelectric power in the western United States. Reclamation’s 58 power plants annually provide more than 40 billion kilowatt hours generating nearly a billion dollars in power revenues and produce enough electricity to serve 3.5 million homes.

Today, Reclamation is a contemporary water management agency with a Strategic Plan outlining numerous programs, initiatives and activities that will help the Western States, Native American Tribes and others meet new water needs and balance the multitude of competing uses of water in the West. Reclamation’s mission is to assist in meeting the increasing water demands of the West while protecting the environment and the public's investment in these structures. Reclamation places great emphasis on fulfilling its water delivery obligations, water conservation, water recycling and reuse, and developing partnerships with its customers, states, and Native American Tribes, and in finding ways to bring together the variety of interests to address the competing needs for our limited water resources.

In order for Reclamation to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public, it must continue to explore the possibilities for improvement. This has been emphasized in the Commissioner's plan for how Reclamation will attain its vision. In that plan, the Commissioner calls for 1) directing our leadership and technical expertise in water resources development and in the efficient use of water through initiatives including conservation, reuse, and research and 2) implementing innovative, sound business practices with timely and cost-effective, measurable results.

Keying off the Commissioner’s plan, deploying renewable energy technologies on project lands has the potential of augmenting or replacing power generation coming from Reclamation and partner’s facilities for the continues delivery of project water.

Now is the time to begin exploring and planning for these eventualities and gather data that will provide valuable information to making informed decisions for the future.

1.3 Phoenix Area Office

Reclamation has been involved in the critical issue of water development in Arizona since 1902. Working with the state of Arizona and other partners, the Phoenix Area Office has helped the state of Arizona move forward water management goals. The results and accomplishments such as the Salt River Project (SRP) and the Central Arizona Project (CAP), have been instrumental in the delivery and management of the state's scarce water resources.

Central Arizona Project (Figure 1) is a system within Phoenix Area Office service area (Figure 3). The Central Arizona Project is a system of 336 mile of canal system and right of way and appurtenances which moves 1.5 million acre feet of water from the Colorado River at Lake Havasu to the terminus south of the city of Tucson Arizona. The canal brings water to the major metropolitan areas of Phoenix and Tucson, the Native American Tribes and nations and various irrigation districts in between. This project delivers water to nearly 1 million acres of irrigated lands as well as municipal and industrial customers in Central and Southern Arizona.

Water supply remains at the forefront of planning issues. The Phoenix Area Office joins the people of Arizona in exploring new methods of water development. These methods include water conservation, recycling, treatment and technical assistance to help state, county, city, town and tribal governments manage and develop water supplies.

Reclamation's Phoenix Area Office looks forward to a future of continuing cooperation with water users on all levels to help ensure a future of promise and prosperity for Arizona.

1.4 Study Area

The area of concern for this study is within the Phoenix Area Office's service area (Figure 3), but specifically related to the Central Arizona Project (Figure 1) and the Salt River Project (Figure 2). The public lands that are adjacent to these project lands may also be considered as well as partnerships with the various federal, state and local agencies.

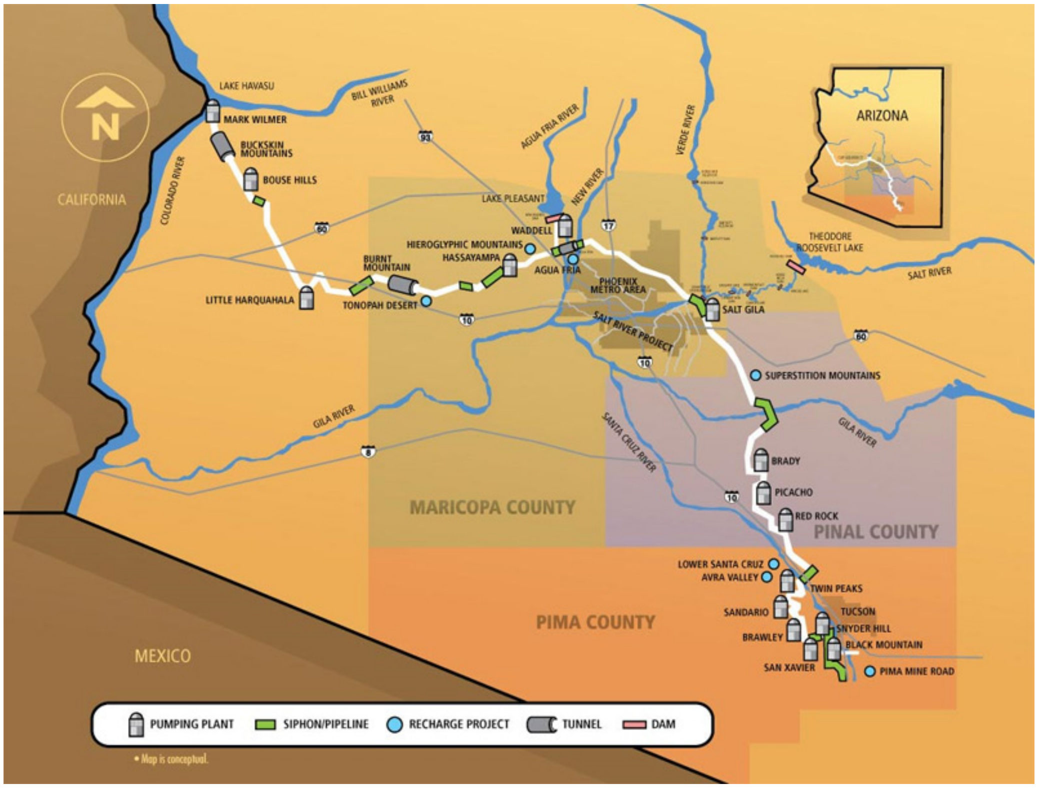


Figure 1: Central Arizona Project Service Area

Figure 2: Phoenix Area Office Service Area

1.5 Project and Study Authorities

The Federal Technology Transfer Act of 1986 will serve as the basis for conducting collaborative research with U.S. industry and other non-federal organizations.

2.0 Study Purpose and Objectives

2.1 Study Purpose

The purpose of this study is to examine the possibilities of adding renewable solar energy to Reclamation project lands in the Phoenix Area Office service area for the augmentation of existing and future energy supplies necessary for water transmission. This study looked at various solar energy options for providing renewable power. Of specific interest are the project lands which intersect major power transmission lines or cross Reclamation Projects. One option that was specifically investigated was the possibility of adding solar panels to existing canal systems to generate power and to reduce evaporation. The intent of the study was to find methods of employing renewable energy so as to reduce Reclamation's dependency on fossil fuels and improve project operations.

2.2 Objectives

The objectives of this study are to look at a variety of renewable energy generation to augment existing Reclamation power generation. The study first looked at the mechanisms for generating renewable power. Solar energy options being considered are:

- Solar Photovoltaic
- Concentrated Solar Photovoltaic
- Solar Thermo
- Sterling Engines
- Other methods as may be determined

The study then looked at locating renewable energy generation on Federal water project properties. Reclamation has large inventories of project lands. There are large power transmission lines which cross these project lands many times. So strategically locating generation near transmission corridors potentially will reduce project operation costs. This was the focus of this study.

Finally, this study explored the possibilities of:

- Covering canals systems with solar PV panels or other methods for power production which the idea to reduce evaporation.
- Other methods as may be determined

This idea has been discussed in the past with Central Arizona Water Conservation District and has received mixed interest. However, some of the small irrigation districts have shown interest in exploring these possibilities and are willing to partner in a demonstration project to verify the workability of various renewable energy technologies.

3.0 Study Approach

The location of renewable power generation was the most important economic consideration examined. Installing renewable power near or in close proximity to existing power transmission may be the key to an economically feasible alternative to renewable solar energy. Since power transmission crosses the Phoenix Area Office's two projects many times it was likely to first examine these locations and then extend the review from there.

This study looked at the methods for generating renewable power for water transmission. The Solar Team looked at varying renewable energy methods such as: solar photovoltaic; concentrated solar photovoltaic; solar thermo; sterling engines; and other methods as was determined during the study.

The GIS Team performed an analysis of all available project lands as well as noted any other public lands which may be suitable and are adjacent to project land. They looked at locating renewable energy generation on project properties in proximity to electrical transmission lines. The GIS team provided their data to the other team.

Both teams provided information of their findings to the project manager for identifying the feasibility of each possible augmentation solution.

The project team analyzed the best renewable solar energy methods in locations of electrical power transmission corridors and then compared to areas which are outside the power transmission corridors.

The project developed the follows:

While the Solar Team compiles the various Solar Energy methods, the GIS team identified and analyzed areas along the Central Arizona Project and associated lands within the Phoenix Area Office Service area and determined the best areas to location solar energy based in the following criteria:

- Reclamation project lands
- Large areas of project right-of-way
- Good alignment for solar radiation
- In close proximity to existing power line distribution

Finally, this report was developed with recommendation for further study.

4.0 Study Results

4.1 GIS Analysis

RECLAMATION GIS METHODOLOGY

BOR holds extensive lands that may well be suited for the development of renewable energies that could augment or supplement power supplies the agency uses for the transmission of water. This study concentrated on identifying BOR project lands to discern suitability for utility scale solar development. Utility scale solar developments are considered one Megawatt (MW) or greater. BOR lands were screened for suitability to employ photovoltaic (PV) or concentrating solar power (CSP) technologies. To accomplish this screening, Geographic Information Systems (GIS) suitability analysis using raster data was selected as the most appropriate method. Mathematically combining rasters and allowing weighting criteria according to importance, resulted in identifying the most suitable lands for solar development.

This methodology is to serve as an example for how Reclamation's Phoenix Area Office GIS Team conducted its GIS suitability analysis. ESRI's ArcGIS Spatial Analyst extension provides a wide array of spatial modeling and analysis tools. Spatial Analyst allows creating, querying, mapping, and analyzing cell-based raster data. Spatial Analyst integrates various environments to perform raster/vector analysis while deriving new information from existing data. Environment functionality permits query attributes across multiple data layers including the integration of cell-based raster data with traditional vector data sources. Spatial Analyst geoprocessing framework offers easy access to numerous functions in ModelBuilder, a graphic modeling tool. Geoprocessing performed in ModelBuilder environment using Map algebra functions enables the combining of multiple maps, suitability analyses, assigning weights and identifying relationships in raster data.

This GIS methodology should provide general framework for GIS analysis to be conducted on additional Reclamation project lands and lands of note that could be used for solar developments. The steps utilized for PXAO's GIS methodology were:

1. defining the problem and criteria to address the problem
2. procuring necessary data sources
3. defining GIS analysis method

4. creating suitability matrix
5. preparing the data
6. creating and executing suitability model computations
7. analyzing the modeling results
8. refining the model as necessary

1. Defining the problem and criteria to address the problem- The suitability model purpose is to identify locations most suitable for utility scale solar developments. What are the influences upon the problem, study area or features? Identify features or criteria to address the problem. Modeling necessitates you understand the features, criteria, study area, and physical phenomena. Establish if the criteria identified to address the problem are significant to discerning most suitable areas. Determine how identified criteria are to be utilized. Features represent spatial local and attribution. How are the attributes of feature utilized to address the problem? Is the relationship of feature important due to its location or attributes it contains? Does feature's relationship to addressing the problem require geoprocessing feature to more accurately represent phenomena's importance? I.e. measure of proximity, allocation of time, is desired characteristic measureable? Revise criteria as needed to address problem and remove extraneous feature to maintain model simplicity.

Optimal siting of solar energy technologies entails familiarity of the solar resource characteristics at any location. Additionally, employing the most suitable technology at any given locale requires a basic understanding of solar energy technologies, applications of the technologies, solar capacities and efficiencies. High-quality information on these topics can be found at NREL's solar research webpage. http://www.nrel.gov/solar/ BLM produced an online center for public information for the Programmatic Environmental Impact Statement for Solar Energy Development in Six Southwestern States (Solar Energy Development PEIS). There is a myriad of information on topics central to solar siting, technologies, and environmental concerns associated with utility solar scale developments. http://solareis.anl.gov/index.cfm Also, the Department of Energy-Energy Efficiency and Renewable Energy webpage contains solid information for how solar energy programs and initiatives are available (http://www.eere.energy.gov/topics/renewable_energy.html) These are excellent resource centers for background information to assist in development of GIS solar project.

PXAO's Reclamation's *Plan of Study* for Renewable Power Generation for Water Transmission introduced three research questions:

- Are there opportunities to utilize Reclamation project lands and right-of-way for the installation of solar technologies?
- Can Reclamation and water districts better utilize project lands to improve and increase power generation capabilities for water transmission?
- Can strategically located solar technology be place on the canal system right-of-way and/or cover the canals?

The *Study Approach* outlined within the *Plan of Study* charged the GIS Team with analyzing all available project lands and other public lands of note that may well be suitable for utility scale solar developments.

GIS Team Objectives:

1. Develop a GIS base layer with all of CAP System right of way (CAPROW).
2. Develop a GIS layer for wash, streams, and river crossings.
3. Develop a GIS layer with all power transmission lines which cross or are within 2 miles and adjacent to the CAP right of way.
4. Develop separate GIS layer with depicting all BLM lands that are adjacent to CAP right of way.
5. Develop a GIS layer depicting all access roads to potential CAP right of way land, BLM land, or other identified lands suitable for solar installation. Access roads were also limited to within 2 miles of CAP Right-of-Way.
6. Develop a GIS layer which locates tracts of the CAP right of way which are at minimum 5 acre, and intersect or are in close proximity to power transmission lines. Consider community viewscapes. Dimensions of solar application will be provided.
7. Develop a GIS layer with geology, topography with contours no greater than a 5 percent slope of the areas identified above.
8. Develop a GIS layer of the various types of land uses (disturbed, undisturbed, agriculture, commercial, and residential) which are adjacent to the CAP right of way, at the county level.***
9. Develop a GIS layer of environmentally withdrawn lands. (Archaeology, critical habitat, endangered vegetation, mitigation areas, etc.)
10. The GIS layers shall be in a format of a standard base plane so information can be easily transferred and usable to other teams. Use NAD83 UTM Zone 12 meters.
11. Develop GIS layer for solar incidence, snowfall, precipitation, and cloud cover.
12. Perform the analysis based on the criteria and above data.
13. Provide a GIS layer of an inventory of property which will be suitable for installation of solar and or renewable energy devices.

Deliverables: A GIS report will be produced with the layers and maps indicated above which identifies the desired information. This report will be suitable for distribution in determining the best locations for siting solar energy applications. The report will be in sufficient detail which will feed into and support the overall project objectives. It will be in a format that can be easily included into the overall report.

Methodology Outline:

1. Research and gather data.
2. Provide metadata for all data sources. \\Ibr3pxaap003\gis_projects\MiscellaneousProjects\11F017PDPOTHR_Haws\Deliverables\Solar_Metadata.docx
3. Identify criteria for analysis and assign weight according to priority of data layers and according to specific criteria of each layer.
4. Develop model to analyze data using weighted factors.
5. Run model for various scenarios, reviewing results and choosing most desirable locations.

6. Prepare documentation of data, development of criteria and weighting of data, process of analysis, and description of results.

2. Data Sources & Procurement-Several federal and state agencies provided datasets (data sources in parentheses) and GIS layers were developed as outlined by *Study Approach Objectives*:

1. Central Arizona Project Canal Right-of-Way (BOR)
2. Hydrology Group Layer: Major Rivers (BOR)
3. Homeland Security Infrastructure Program Transmission Lines (Global Energy Decisions) &
   WAPA Transmission Lines (Western Area Power Adm.)*
4. BLM Lands identified as Suitable for Solar (BLM)
5. Access Roads within 2 miles CAP ROW (ADOT)
6. CAP ROW delineated by solar technology acreage footprint (BOR)
7. Slope derived from 10 meter DEM (BOR)**
8. Surface Management layer identifying managing entity (BLM)***
9. Reclamation Excluded Lands: Critical Habitats, Archaeology, Sensitive Species (BOR)
10. Reclamation Mitigation Lands (BOR)
11. USFS & BLM Designated Wilderness Areas
12. Global Horizontal Insolation (NREL)
13. Latitude Tilt Insolation (NREL)
14. Direct Normal Insolation (NREL)

* *Identified transmission lines within two miles of CAP ROW*
** *Slope derived from DEM used in lieu of contours outlined in GIS Objective #7*
****GIS Objective #8 was determined to be ambiguous and surface management or ownership in lieu of Objective #8*

3. Defining GIS Analysis method -The GIS analysis method to identify Reclamation project lands suitable for utility scale solar development entailed creating a method to screen for spatial, cadastral, atmospheric, economic, cultural, and topographical limiting factors. Suitability analysis using raster data was selected as the most appropriate analytic method. The basic approach was to overlay the rasters representing suitability criteria and mathematically combine them to output a new raster. Mathematically combining rasters allows weighting of criteria according to importance. The new raster will consist of scores that represent relative suitability. The highest scores indicate cells or areas with the highest suitability.

4. Creating Suitability Matrix-The principal GIS layers introduced in the *Plan of Study* was developed into the screening criteria to address the problem. The screening criterion was operationalized into a suitability matrix to quantitatively address the problem. Development of suitability classifications within the matrix allowed the systematic assignment of an integer to an attribute of interest for each layer. Suitability classification was a simple scale of least to highest suitability with integer values of 1-4 used in GIS calculations. Integer values were chosen for ease of Map Algebra calculations performed using Raster Calculator. Any number of suitability classifications could be chosen: ten, seven, five, or four et cetera. Intervals created for each feature were based upon research and guidance received from partner agencies. Matrix ranks screening criteria in order of importance to the overall analysis. Additionally, weighting of layers reflects order of precedence, with the most influential feature being CAP Right-of-Way and least influential feature being the solar insolation datasets. Sensitive areas were scored 0 to remove from developable areas, whereas CAP Right-of-Way was weighted 10 to provide greatest influence on model calculations.

5. Preparing the Data- Geodatabases were designed to reflect work flow: Solar.gdb contains all screening criteria and feature layers necessary to create suitability rasters for modeling. Suitability Analysis.gdb contains all rasters created from screening criteria to be used in modeling calculations. SuitabilityOutputs.gdb contains all Suitability modeling output rasters from ModelBuilder scenarios.

Screening criteria features were converted into common projection and datum. The common projection for PXAO's analysis was NAD_83_UTM_ZONE_12N. The Traverse Mercator projection covers the geographical extend for the study area. The study area boundary for GIS operations was based upon CAP Right-of-Way. The CAP Right-of-Way however is an extremely linear feature and the right-of-way itself was not appropriate to serve as study area boundary. Solar insolation dataset is composed of 10 kilometer. The 10 kilometer solar grids represent the screening criteria with the largest geographic extent. The 10 kilometer solar insolation grids that the CAPROW is present within or intersects were clipped and dissolved to represent the study area boundary.

Geoprocessing and querying of screening criteria was performed to develop rasters for suitability modeling. Geoprocessing of features was performed to represent feature most accurately for suitability classification and raster data type. Point and linear feature are not always best represented by cells and geoprocessing transformed these features into areal representations more appropriate for raster data type (i.e. proximity to access roads and transmission lines). Geoprocessing to transform features was performed to prepare vector data types for conversion to raster data. To accomplish this attribute fields for "Suitability" were created for screening criteria features. Queries of attributes were based upon intervals defining suitability classification developed in matrix. Suitability values were assigned from matrix classifications. Suitability classification was employed by ArcToolbox Conversion Tools to convert polygon features to raster datasets. Value field for polygon to raster conversion was "Suitability" attribute field. Option within Conversion tool allows cellsize to be established (All features utilized cell size of 10, reflecting smallest resolution raster, PXARASTER.DBO.AZ_DEM_10M). Additionally, raster cells can be specifically aligned for overlay function by utilizing “Snap Raster” option. Snap raster aligns the cells to specific extent during execution, resulting in output the same as snap raster cell size.

6. Creating & Executing Model Computations-Suitability model steps included operationalizing screening criteria for siting utility scale solar developments. Significant layers were reclassified within suitability matrix creating a relative scale. Suitability scaling allowed features to be weighted in order of importance to apply precedence to most suitable characteristics. Weighted overlay of rasters allows values to be combined and scored together yielding most suitable areas. A conditional expression was applied to extract areas that would be most suitable based upon screening criteria’s established suitability values. The conditional expression allows queries on attributes or a condition based upon the position of the conditional statement in the list. The conditional expression’s attribute query clearly identifies all cells that are evaluated as true. The logical statement used for our raster calculations states that if raster is null return zero, if not, return value multiplied by weighting factor. The raster products are summed and new raster output is generated with suitability values for each cell.

The solar suitability models created by PXAO GIS Team can be modified to conduct suitability analysis for any given area, substituting layers as needed into models for study area of interest. You may add additional layers, eliminate layers and modify weighting as needed. The changes made will alter the suitability scoring and results will have to be interpreted.

7. Analyzing Model Results- Suitability model combines weighted raster inputs and outputs a suitability raster. Raster cell values represent suitability scores and surface varies with relative importance of each site to another with regards to screening criteria. Modeling results interpretation will depend upon screening criteria established, layers utilized, and weighting of layers. Modeling can be adjusted to any number of given factors, how the factors influence the model and their significance to solar siting need to be identified. Modeled phenomena must be understood to determine if results are applicable.

8. Refining Model as Necessary- Solar suitability model developed identified and addressed factors that affect siting of utility scale solar developments. Suitability model is dependent upon suitability classification and weighting; model might need to be adjusted to determining validity of suitability results. Suitability values assigned in suitability matrix need to accurately reflect feature’s importance as screening criteria. Complexity of model inputs should address the problem and remain simple enough to determine most suitable areas as defined by screening criteria. Values and weights used in model can significantly vary the results. ModelBuilder environment allows for chained processes, model parameters, adding new input data to modify model and easily re-execute deriving new data.

In summary steps utilized for PXAO's GIS solar suitability methodology describe GIS workflow for developing solar suitability model. Identify the factors important to study area; collect and organize this data. Geoprocess the criteria into useful datasets based upon informed decisions. Execute and analyze modeling results. Methodology summarizes framework for GIS analysis to be conducted on additional Reclamation project lands and lands of note that could be used for solar developments. Any future GIS analyses conducted by Reclamation will have to identify significant factors and criteria for their respective study area; and responsibly develop manner for which these criteria should be implemented within a GIS environment.

The following is the detailed GIS methodology utilized by PXAO's GIS Team for ***Renewable Energy Suitability Analysis: Central Arizona Project Right-of-Way.***

RECLAMATION PHOENIX AREA OFFICE GIS TEAM
RENEWABLE ENERGY SUITABILITY ANALYSIS: CENTRAL ARIZONA PROJECT

GIS METHODOLOGY

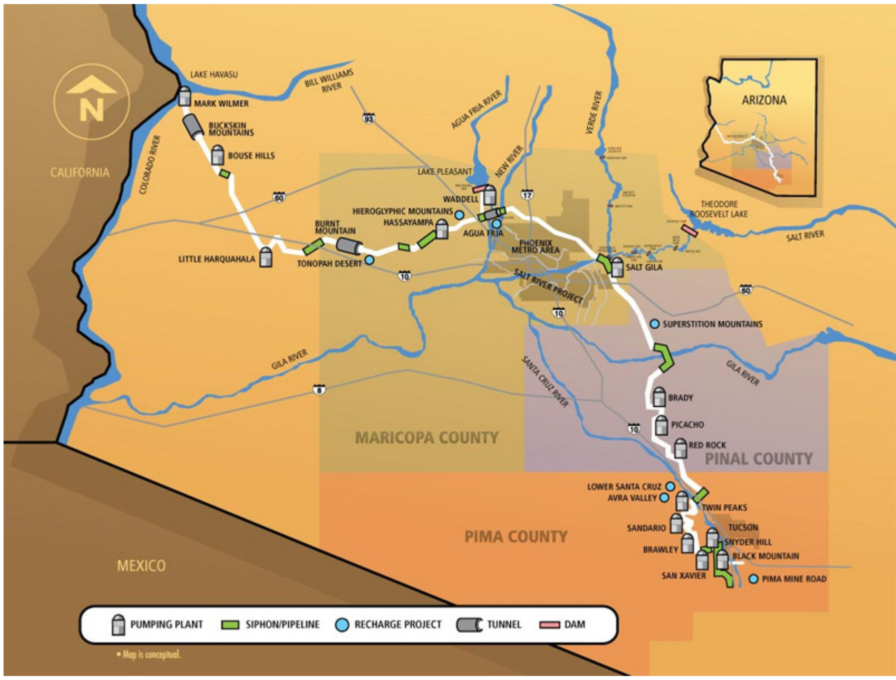
GIS was employed to support Reclamation decision making for optimum locations for a utility scale solar energy development. Reclamation identified necessary screening factors and datasets that needed to be procured to conduct this analysis. The datasets and criteria identified were compiled into a GIS repository. Datasets and variables identified as screening criteria for GIS analysis were: the property that should be considered for development, viable solar technologies, solar insolation, electrical transmission lines, access roads, terrains suitable for development, and the identification of environmentally sensitive areas which development would adversely impact. These are the key elements that were spatially analyzed in the suitability modeling.

GIS Layers Background

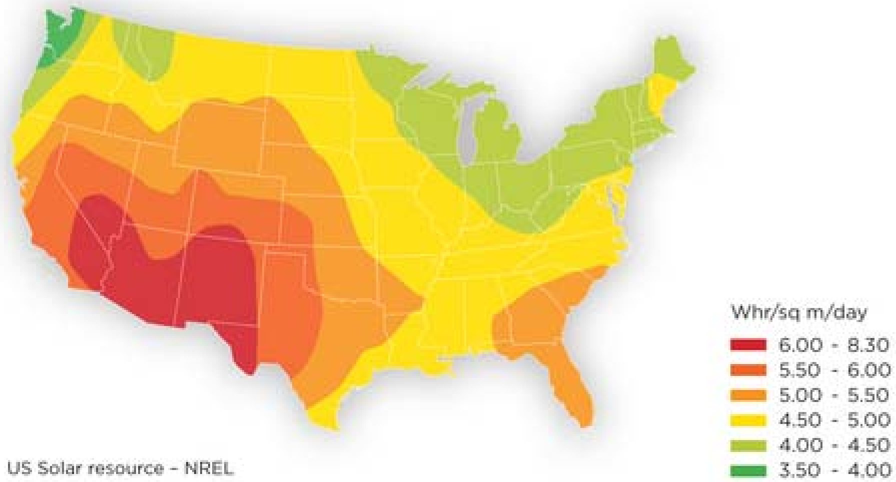
Reclamation real properties considered were CAP Canal (CAP ROW), land holdings surrounding Lake Pleasant and Reclamation Withdrawn Lands. A withdrawal of federal lands withholds the lands from settlement, sale, location, or entry under some or all public land laws. Reclamation has repurposed the lands to minimize activities for public policy, reserving lands deemed for particular public purpose or to transfer administrative authority from one agency to another. These lands were included as possible lands for development, while individual parcels identified as suitable would have to be addressed on a case by case basis.

Reclamation project lands were evaluated to identify where enough right-of-way exists to consider constructing solar facilities. Utility scale solar development was the minimal level of generation to which Reclamation's scope of study adhered. Solar technologies require different footprints due to the efficiency and capacity of PV and CSP. Guidelines provided by the National Renewable Energy Laboratories (NREL) stated typical generating potentials of 9 acres per megawatt for photovoltaic technologies and 5 acres per megawatt for concentrating solar power technologies.

The CAP canal is 336 miles long and the entire right-of-way comprises 43,506 acres. The CAP aqueduct averages 80 feet in width and also contains oversized sections built as internal reservoirs which are approximately 160 feet in width. The exaggerated linear elongation of the CAP's geometry was addressed to define contiguous area and minimum acreage requirements. Minimum acre dimensions utilized for this analysis were one acre square (63.63m^2 or 208.75 ft^2). CAP ROW comprises all land owned and bought by Reclamation to build the aqueduct system. The right-of-way includes the canal and maintenance roads that provide access to the canal for operations, maintenance and repairs. This portion of the CAP ROW is not feasible for development and was removed from consideration.



The solar climate of Arizona is plentiful averaging more than 300 days of sunshine each year. Additionally, Arizona contains substantial quantities of wide-open area with flat landscape which are ideal for utility scale solar installations.

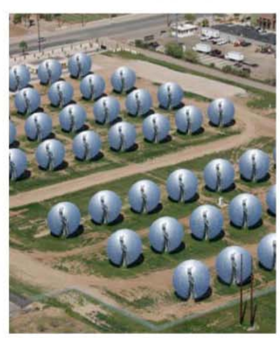


Solar technology categories considered for development are photovoltaic and concentrating solar power. PV technologies utilize solar radiation from direct and diffuse sunlight and directly convert this energy into electricity. PV technology options being considered are fixed axis, single axis and concentrator photovoltaic flat plate collectors.

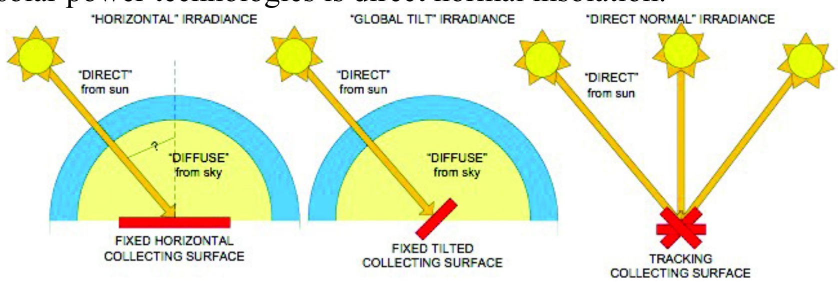
Flat Plate PV (Fixed Axis) | **Flat-Plate PV (Single Axis)** | **Concentrator PV (Dual Axis)**

CSP systems focus the sun's energy to generate heat and turn steam turbines or external heat engines to produce electricity. CSP technologies being considered are parabolic troughs, power towers, sterling engines and linear Fresnel reflectors.

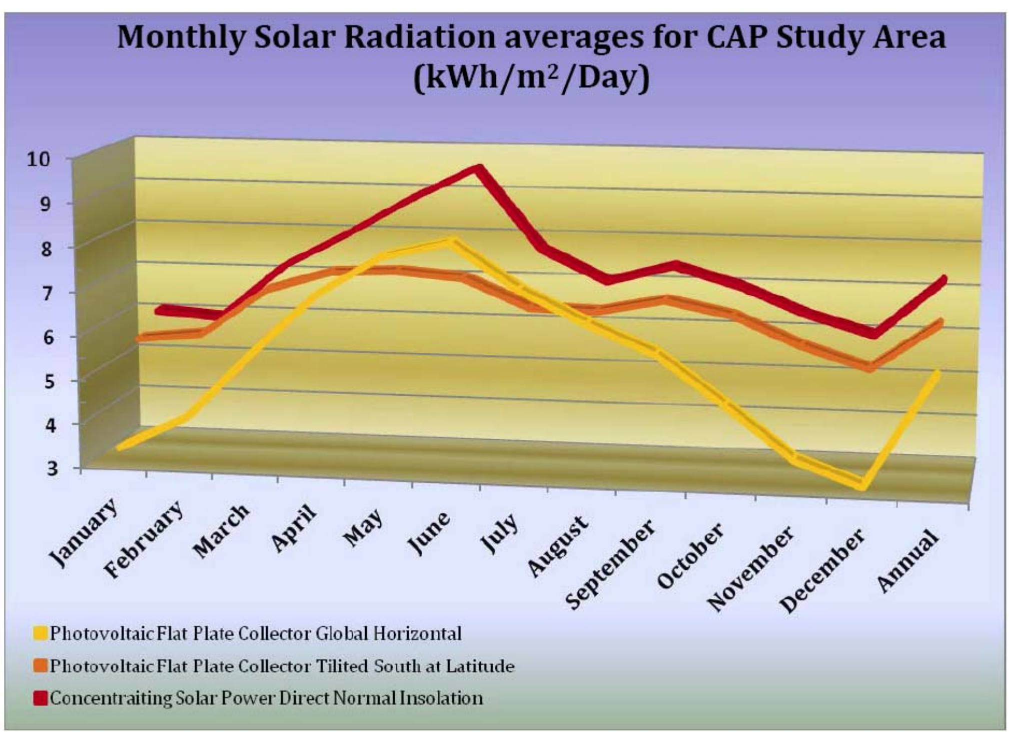
Parabolic Trough | **Power Tower** | **Sterling Engines** | **Linear Fresnel Reflectors**



Solar insolation datasets measuring annual solar radiation were obtained from NREL's National Solar Radiation Data Base (NSRDB). This database incorporates cloud cover, atmospheric water vapor, trace gases and the amount of aerosols in the atmosphere to derive hourly insolation across 10 kilometer grids. The satellite radiation model is used to calculate clear skies, and this is adjusted as a ratio of clear sky and the model predicted clear sky. The uncertainty related with the meterological inputs places the models accuracy between 9 – 15 % of a true measured value for a 10 kilometer grid cell. Also influencing model inaccuracy is complexity of terrain. Solar radiation is typically expressed in kilowatt-hours per meter squared per day (kWh/m^2/Day). The solar insolation datasets used to model solar resource potential for photovoltaic technologies are global horizontal insolation and latitude tilt insolation. Solar insolation dataset for concentrating solar power technologies is direct normal insolation.



Photovoltaic Global Horizontal is solar insolation measured across the horizontal surface and represents the resource potential available to a horizontal flat plate collector such as a photovoltaic panel. Global solar radiation is direct sunlight and/or diffuse light. Photovoltaic latitude tilt insolation dataset represents solar energy across a surface facing due south, equal to latitude, and represents the resource potential available to a photovoltaic panel tilted due south at an angle from horizontal equal to latitude of collector location. Direct normal insolation measures solar radiation for a surface that is continuously tracking the sun and represents the average resource potential to a concentrating collector on a 2-axis tracking system, such as a dish or power tower.



Data Source: National Solar Radiation Data Base (NSRDB) 2007

Transmission connectivity and access roads proximities were important screening criteria to reduce project operational costs. Project lands were screened to identify right-of-way strategically near transmission corridors. Proximity from existing transmission lines to CAP ROW threshold was set at a maximum distance of two miles. Distance criterion was established to reflect NREL analysis that transmission line construction costs are approximately $1.3 million per mile. Proximity to access roads along CAP ROW is also a construction cost concern. A two mile buffer was the maximum distance an existing access road should be from the CAP ROW. Access roads outside the two mile buffer of CAP ROW were screened out.

BLM has 243,528 acres that are adjacent to or intersect the CAP ROW. BLM provided to Reclamation datasets for lands it had determined to be suitable for solar development. BLM's *PEIS for Solar Energy Development in Six Southwestern States* details the methods and analysis BLM conducted to find lands suitable for solar technologies development. Of note for this analysis, was that BLM likewise addressed issues for proximity to access roads and transmission lines, acreage, solar insolation, slope and resources exclusions.

Solar facilities require relatively flat ground for the installation of photovoltaic panels. Areas with more than 5 percent slope were eliminated from site consideration because of the basic needs of solar technologies, and lands with higher slope were assumed too costly due to excessive site excavation. Local terrain for the CAP is typically within this slope threshold, with some areas increasing in slope with distance away from the canal.

Reclamation included BLM lands identified in the PEIS as potential developable lands that it could use in partnership with BLM. Barriers used for exclusion within the PEIS were U.S. Forest Service and BLM wilderness study areas and designated wilderness acquired from BLM's Landscape Conservation System. U.S. Fish and Wildlife Service areas of critical environmental concern and conservation areas were excluded from lands considered. Special recreation management areas and right-of-way avoidance areas were removed from BLM's analysis. Reclamation screened its project lands and excluded some additional areas within the CAP that were deemed to be environmentally sensitive such as Reclamation Mitigation Lands. Reclamation archaeology sites were also excluded from consideration.

GIS Analysis Method

The GIS data format known as raster data defines space or features as an array of equally sized cells arranged in rows and columns. The nature of raster data lends itself to mathematically combining various themes or inputs. Map algebra is the functionality that creates new rasters by combining or overlaying input rasters, utilizing simple and advanced math functions. As a result, raster data is commonly used in suitability analysis.

Suitability analysis using raster data was selected as the most appropriate analytic method. The basic approach was to overlay the six rasters representing suitability criteria and mathematically combine them to output a new raster. Mathematically combining rasters allows weighting of criteria according to importance. The new raster will consist of scores that represent relative suitability. The highest scores indicate cells or areas with the highest suitability.

The steps used in this GIS analysis were:

1. defining the problem and criteria to address the problem
2. procuring necessary data sources
3. defining GIS analysis method
4. preparing the data
5. creating suitability matrix and models
6. executing model computations
7. analyzing the modeling results
8. refining the model as necessary

GIS Operations & Queries for Suitability Matrix

Development of a Suitability Matrix began with identifying criteria for analysis and establishing numeric intervals. Suitability intervals were classified by screening criteria for each layer. The suitability values established in attribute fields were used in the vector to raster conversion tool. Suitability classification was a simple scale of least to highest suitability with integer values of 1-4 used in GIS calculations. Weighting factor for each layer were desinged to highlight emphases or to minimize layer influence on modeling outcomes. Highest weighting was placed upon CAP ROW, power transmission and road buffers. The least emphasis was weighted upon slope and insolation data values. Resources to be excluded were weighted to remove completely from suitable lands.

CAP canal and maintenance roadways were removed from the CAP ROW dataset. The average width of canal is 80 feet and 40 feet was added for roadways to approximate width that needed to be excluded. The canal centerline was buffered to 60 feet on each side, and this buffered output was put into the symmetrical difference tool. Features, or portions of features, in the input (CAP_ROW) and the update feature (CAP_CL_BUFFER) that did not overlap were written to the new output feature class. 'CAPROW_minus_Canalwidth' is the total area minus the buffered area for the canal and maintenance roadways. CAPROW_minus_Canalwidth was queried and all parcels less than 9 acres were removed. This new feature class 'CAPROW_PV_Suitability' represented the minimum acreage necessary for PV development at the utility scale which is 9 acres per MW. Additionally, CSP requires only 5 acres per MW; however, 9 acres per MW was used to optimize larger parcels than would be identified by CSP land requirements.

An important factor this analysis needed to address was the geometry of the available property. Minimum dimensions for parcels were determined to be 1 acre square (63.63 m^2, 208.75 ft^2). Short of measuring the narrowest portion of each polygon, an index of area to perimeter was calculated (Index= [area/perimeter]). The smaller the index, the more elongated the polygon tended to be. Polygons were randomly tested for minimum width requirement and where in the index the polygon met the criteria. An index value of greater than 20 had a propensity to be greater than 60 meters in width. All polygons with an index of less than 20 were queried and removed. The index created was an arbitrary measure to address the geometry necessary for parcel size and to achieve larger contiguous areas necessary for utility scale sites.

Criteria and Ranking

Suitability Criteria	Least Suitable	Low Suitability	Moderate Suitability	High Suitability	Weighting
	1	*2*	*3*	*4*	
CAP ROW Site Acreage	9 - 45 acres (1 - 5 MW)	46 - 135 acres (6 - 15 MW)	136-270 acres (16 - 30 MW)	> 271 acres (31 - 60 MW)	*10
Distance to Power Transmission	1.5 miles - 2 miles	1 - 1.5 miles	1- 0.5 miles	< 0.5mile	*5
BLM Lands adjacent to CAP Right-of-Way (PV)	9 - 45 acres (1 - 5 MW)	46 - 135 acres (6 - 15 MW)	136-270 acres (16 - 30 MW)	> 271 acres (31 - 60 MW)	
Distance to Access Roads	1.5 miles – 2 miles	1 - 1.5 miles	1- 0.5 miles	< 0.5mile	*4
Slope	> 5 % Weighted * 0	4.1 -5 %	3 - 4 %	0 - 3 %	*2
Photovoltaic Fixed Axis (Global Horizontal)	5.0 - 5.2 kWh/m^2/Day	5.21 - 5.4 kWh/m^2/Day	5.41- 5.6 kWh/m^2/Day	>5.61 kWh/m^2/Day	*1
Photovoltaic Single Axis (Latitude Tilt)	5.75 - 6.0 kWh/m^2/Day	6.0 - 6.25 kWh/m^2/Day	6.25 - 6.5 kWh/m^2/Day	>6.5 kWh/m^2/Day	*1
CSP Dual Axis (Direct Normal Insolation)	6.75 -7.0 kWh/m^2/Day	7.0 - 7.25 kWh/m^2/Day	7.25 - 7.5 kWh/m^2/Day	>7.5 kWh/m^2/Day	*1
RESOURCES TO EXCLUDE	*Excluded resources weighted * 0 in raster calculations*				
Reclamation Excluded Lands	Outside	Outside	Outside	Outside	*0
USFS & BLM Designated Wilderness	Outside	Outside	Outside	Outside	*0
Mitigation Fee Lands	Outside	Outside	Outside	Outside	*0

1. **CAP ROW PV & CSP Acreage Suitability Queries**
   PV land requirements were used as a baseline footprint to optimize acreage for PV and CSP. This decision was made to extract the largest parcels from right-of-way possible.
   "ACRES" >=9 AND "ACRES" <=45 is suitability class 1
   "ACRES" >=46 AND "ACRES" <=135 is suitability class 2
   "ACRES" >=136 AND "ACRES" <=270 is suitability class 3
   "ACRES" >=271 is suitability class 4

2. Distance to Power Lines Queries

Western Area Power Administration (WAPA) Power Transmission Lines and Homeland Security Infrastructure Program (HSIP) Electrical Transmission Lines were clipped to CAP Study area (GRID_EXT). These two feature classes were combined into a new dataset utilizing Merge tool from the Data Management Toolbox. Buffer wizard was used to create multiple buffer rings to satisfy suitability distances of ½ mile, 1 mile, 1.5 miles and 2 miles. Each distance buffer ring was assigned to a corresponding suitability class.

Distance=<0.5 miles is suitability class 4
Distance<0.5 and Distance =<1.0 miles is suitability class 3
Distance=>1.0 and Distance=< 1.5 miles is suitability class 2
Distance>=1.5 and Distance =< 2.0 miles is suitability class 1

3. BLM Lands adjacent to CAP ROW Queries

Acreage suitability classes were defined by photovoltaic solar technology megawatt yield. Photovoltaic land requirements were used as the minimum acreage to extract the largest parcels of land. Additionally, Reclamation used the number of megawatts necessary to power pumping plants existing within the CAP system and photovoltaic potential yield to define class intervals for acreage.

"ACRES" >=9 AND "ACRES" <=45 is suitability class 1
"ACRES" >=46 AND "ACRES" <=135 is suitability class 2
"ACRES" >=136 AND "ACRES" <=270 is suitability class 3
"ACRES" >=271 is suitability class 4

4. Distance to Access Roads

Access roads were clipped to a two mile buffer of CAP ROW. The clipped roads were buffered to ½ mile, 1 mile, 1.5 miles and 2 miles. Each distance buffer ring was assigned to a corresponding suitability class.

Distance= 0.5 miles is suitability class 4
Distance= 1.0 miles is suitability class 3
Distance= 1.5 miles is suitability class 2
Distance= 2.0 miles is suitability class 1

5. Slope

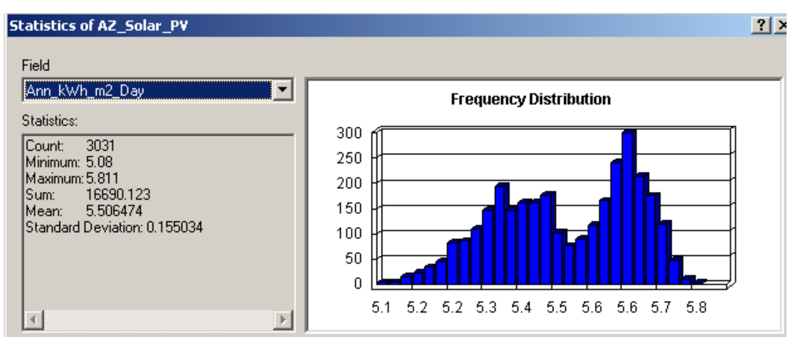
Slope was derived from a 10 meter Digital Elevation Model (DEM) of Arizona using Spatial Analyst Slope tool. The input raster was DEM_10m_Clip and output raster SLOPE_CAPROW, reprojected into the default analysis projection. The raster was exported into a different format, from 32 bit data to 8 bit unsigned data (data values supported range from 0 – 255) and this conversion decreased the file size from 3.2 GB to 818 MB. Environmental Settings for the output projected raster snapped this raster to “GRID_EXT” raster. SLOPE_CAPROW was reclassified using Spatial Analyst Reclassify tool to slice values into intervals deemed suitable for solar development. Output reclassified slope raster is SLOPE_SUIT.

Slope 0 – 3.0% is suitability class 4
Slope 3.1% - 4.0% is suitability class 3
Slope 4.1% - 4.9% is suitability class 2
Slope >= 5.0% is suitability class 0

6. Solar Insolation per Solar Technologies

In examining the NREL (State University of New York) 10 kilometer datasets for solar radiation for the different solar technologies, suitability classes for each individual solar technology were established based upon distribution of the dataset. Solar radiation values for PV Global Horizontal distribution was divided into 4 defined interval classifications ranging from a minimum of 5.08 kWh/m^2/Day to the maximum of 5.81 kWh/m^2/Day. This range represents the range of values for Arizona and not the study area. The intervals were chosen to limit biasing the bimodal and negatively skewed distribution. The first interval for least suitability is the smallest interval, 0.12. The interval for the remaining three classes is 0.02. PV Latitude Tilt insolation data values are higher than Global Horizontal, ranging from 5.86 kWh/m^2/Day to 6.7 kWh/m^2/Day. The negatively skewed distribution depicts values for all of Arizona was divided into 4 defined interval classifications. Interval ranges were defined at 0.25 kWh/m^2/Day. Suitability Class 1 (Least Suitable) begins at 5.75 kWh/m^2/Day. The highest Suitability Class 4 equals values greater than 6.5 kWh/m^2/Day. The Direct Normal Insolation for CSP classification scheme was modified to match NREL research. NREL has determined a Suitability Classification for CSP to be a viable resource if over 6.75 kWh/m^2/Day and was the minimum insolation value used for CSP technology. The Direct Normal Insolation distribution is normally distributed with peak insolation in June.

6a. Photovoltaic Fixed Axis (Global Horizontal) Suitability Query



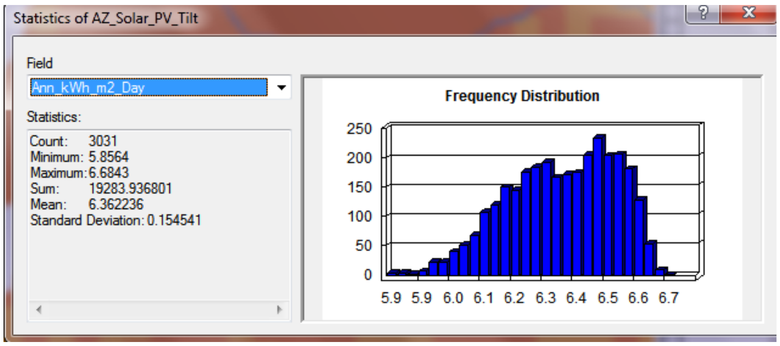
"Ann_kWh_m2_Day">= 5.0 AND "Ann_kWh_m2_Day" <=5.2 is Suitability Class 1

"Ann_kWh_m2_Day">= 5.2 AND "Ann_kWh_m2_Day" <=5.4 is Suitability Class 2

"Ann_kWh_m2_Day">= 5.4 AND "Ann_kWh_m2_Day" <=5.6 is Suitability Class 3

"Ann_kWh_m2_Day">= 5.6 is Suitability Class 4

6b. Photovoltaic Single Axis (Latitude Tilt) Suitability Query



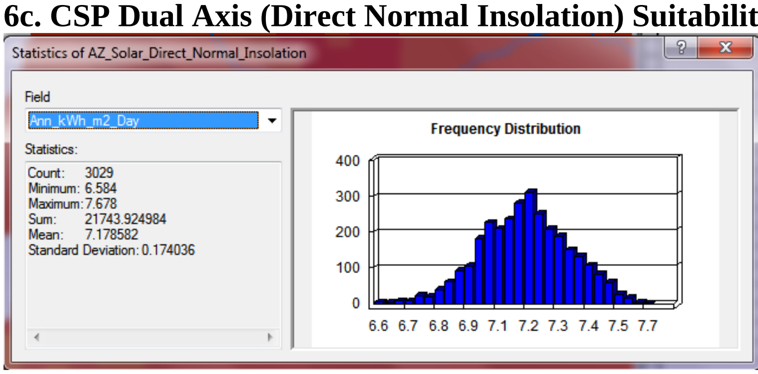
"Ann_kWh_m2_Day">= 5.75 AND "Ann_kWh_m2_Day" <=6.0 is Suitability Class 1

"Ann_kWh_m2_Day">= 6.0 AND "Ann_kWh_m2_Day" <=6.25 is Suitability Class 2

"Ann_kWh_m2_Day">= 6.25 AND "Ann_kWh_m2_Day" <=6.5 is Suitability Class 3

"Ann_kWh_m2_Day">= 6.5 is Suitability Class 4

6c. CSP Dual Axis (Direct Normal Insolation) Suitability Query



"Ann_kWh_m2_Day">= 6.75 AND "Ann_kWh_m2_Day" <=7.0 is Suitability Class 1

"Ann_kWh_m2_Day">= 7.0 AND "Ann_kWh_m2_Day" <=7.25 is Suitability Class 2

"Ann_kWh_m2_Day">= 7.25 AND "Ann_kWh_m2_Day" <=7.5 is Suitability Class 3

"Ann_kWh_m2_Day" >7.5 is Suitability Class 4

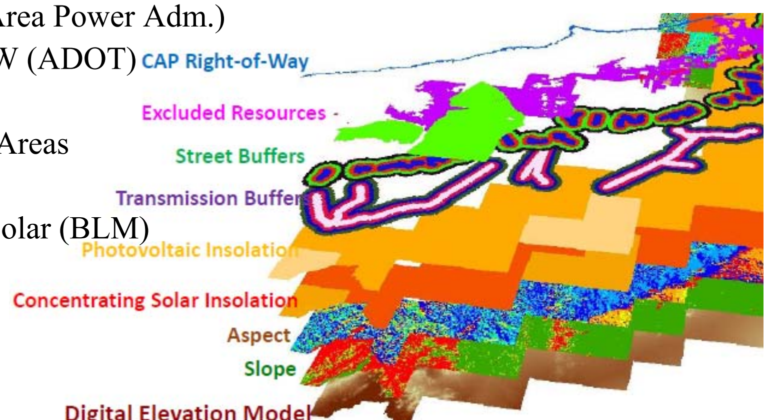
7. Excluded Lands

USFS and BLM Designated Wilderness, Reclamation Excluded Lands and Mitigation Lands were merged into one feature class and assigned a suitability value of 0 to completely exclude these lands from those Reclamation would develop.

Vector to Raster Conversion

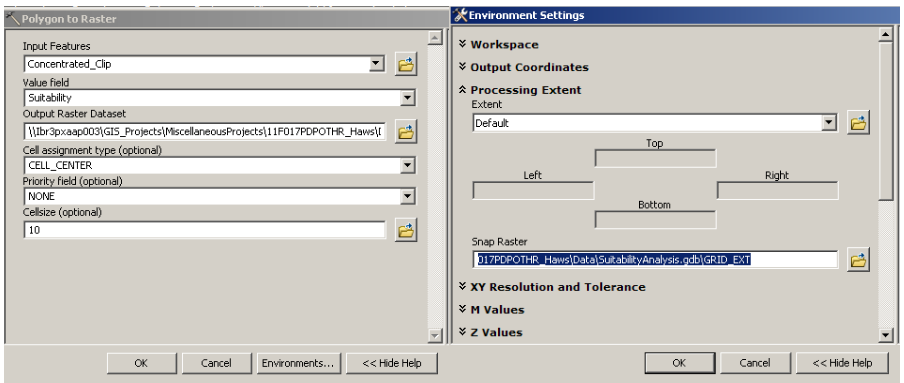
Vector data was the principal data source for most themes compiled for this GIS analysis. Multiple GIS operations were performed on vector datasets in preparation for vector to raster conversion including: clip, intersect, buffer, dissolve, merge, symmetrical differentiation, and editing. Vector data sets converted to raster for this analysis in preparation to run Suitability Model scenarios using Map Algebra included (Data sources):

1. CAP ROW (BOR)
2. Homeland Security Infrastructure Program Transmission Lines (Global Energy Decisions)
3. WAPA Transmission Lines (Western Area Power Adm.)
4. Access Roads within 2 miles CAP ROW (ADOT)
5. Reclamation Excluded Lands (BOR)
6. USFS & BLM Designated Wilderness Areas
7. Reclamation Mitigation Lands (BOR)
8. BLM Lands identified as Suitable for Solar (BLM)
9. Global Horizontal Insolation (NREL)
10. Latitude Tilt Insolation (NREL)
11. Direct Normal Insolation (NREL)



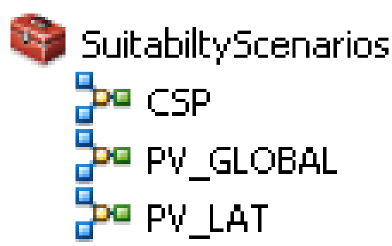
Map algebra functions utilized ArcGIS Spatial Analyst advanced suite of arithmetical operations (addition, subtraction, multiplication and division) for combining multiple maps, suitability analyses, assigning weights and identifying relationships in raster data. Three important steps were conducted to ensure that raster calculations performed optimally. All rasters were projected into the same coordinate system, snapped to the same raster, and converted to the same pixel depth. These functions were performed to ensure that raster projections, cells and cell size matched up accordingly to best align rasters for Map algebra calculations. Raster calculations will 'drill down' through raster layers and mathematically factor cell values to create suitability rasters.

All vector features and subsequent rasters created in this analysis were projected into NAD_1983_UTM_Zone_12. Attribute fields were created to assign suitability values and this field was used as the input value field for the polygon to raster conversion. Within the polygon to raster tool, environmental settings for cell size were set to 10 meters. This cell size reflects the smallest resolution from the Digital Elevation Model (DEM) for which slope was derived. Additionally, all ensuing rasters produced were snapped to raster “GRID_EXT.” The GRID_EXT polygon was derived by utilizing the intersect tool. The intersect tool selected the 10 kilometer solar insolation cells from the AZ_Solar_Direct_Normal_Insolation feature class that intersect the CAP and grids that BLM Lands Suitable for Solar Development resided within. The output polygon from the intersect function was then dissolved to create the geometric boundary extent for “CAP study area.” This “GRID_EXT” polygon represents the North, South, East and West extents for the CAP study area.



Suitability Model Calculations

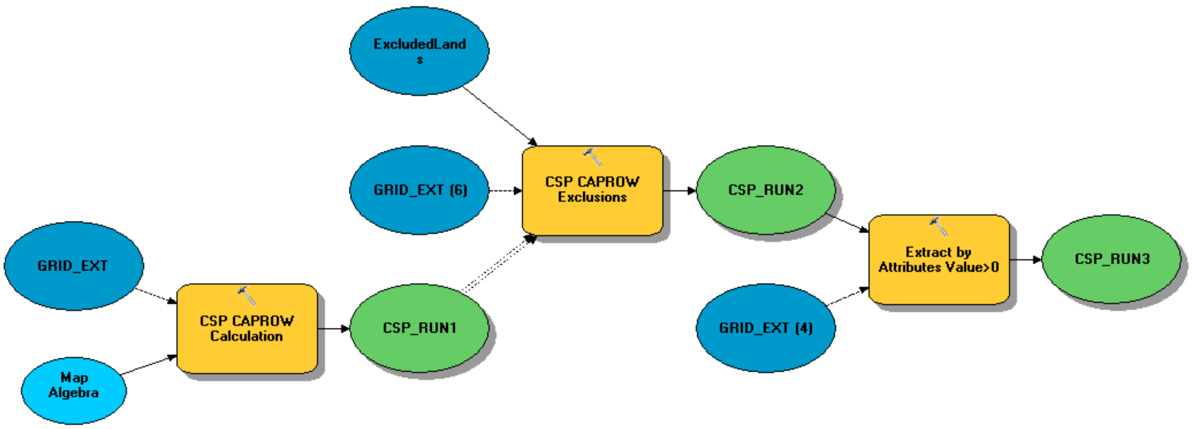
ArcGIS Spatial Analyst extension provides a wide array of spatial modeling and analysis tools. Spatial Analyst allows creating, querying, mapping, and analyzing cell-based raster data. Spatial Analyst integrates environments to perform raster/vector analysis while deriving new information from existing data. Environment functionality permits query attributes across multiple data layers including the integration of cell-based raster data with traditional vector data sources. Spatial Analyst geoprocessing framework offers easy access to numerous functions in ModelBuilder, a graphic modeling tool.



ModelBuilder was used to develop scenario calculations, demonstrate workflows and to automate the multipart sequence of Geoprocessing steps and tools into one process. A ModelBuilder scenario was created for each solar technology type. Each ModelBuilder iteration analyzed CAP ROW acreage, transmission line proximity, access road proximity, slope, and solar insolation values. Geoprocessing calculations extracted most suitable land areas then excluded lands were removed. Geoprocessing environmental parameters were set to snap rasters to “GRID_EXT” as a precondition parameter for output rasters.

A conditional expression within Spatial Analyst Toolbox was applied to extract areas that would be most suitable based upon CAP acreage, solar insolation, distance to transmission lines and access roads and slope. The conditional expression allows queries on attributes or a condition based upon the position of the conditional statement in the list. The conditional expression's attribute query clearly identifies all cells that are evaluated as true. The logical statement used for our raster calculations states that if raster is null return zero, if not, return value multiplied by weighting factor. The raster products are summed and new raster output is generated with suitability values for each cell.

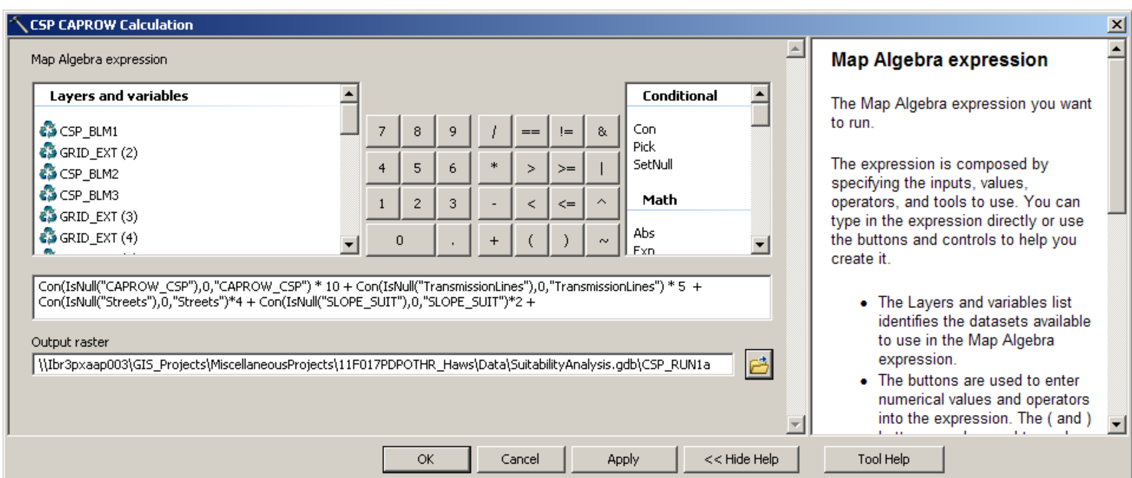
The following is the CSP workflow and screenshots of Map Algebra



expressions used for calculations:

CSP CAPROW Calculation

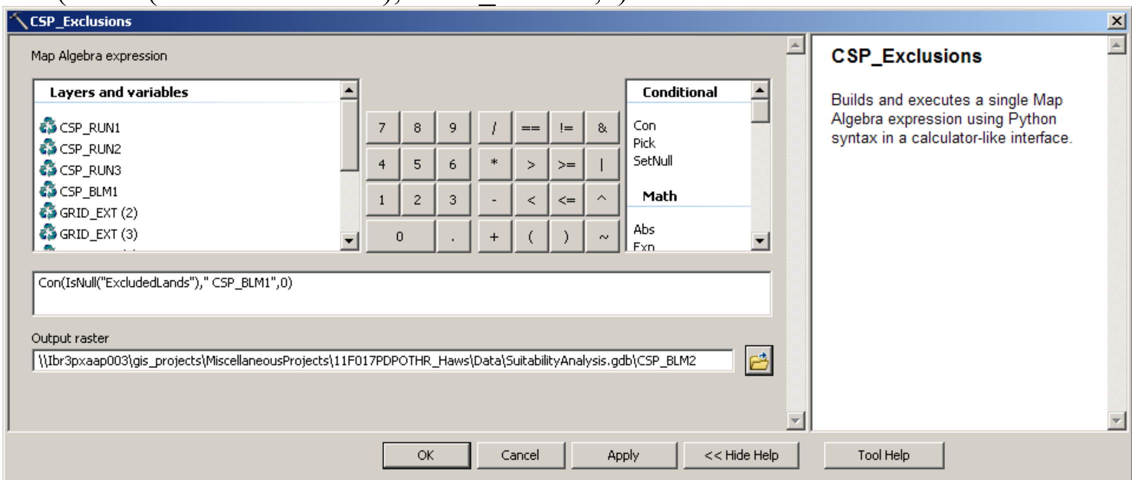
Con(IsNull("CAPROW_PV"),0,"CAPROW_PV") * 10 +
Con(IsNull("TransmissionLines"),0,"TransmissionLines") * 5 +
Con(IsNull("Streets"),0,"Streets")*4 +
Con(IsNull("SLOPE_SUIT"),0,"SLOPE_SUIT")*2 +
Con(IsNull("ConcentratingSolar"),0,"ConcentratingSolar")



Calculation utilizing conditional statements applies a weighting of 10 to CAPROW then conditionally applies weighting of 5 to transmission line proximity based upon suitability ranking. Weighting of 4 for access road proximity by suitability is then applied followed by slope weighting of 2 and then insolation values are factored. Solar insolation values received essentially a weighting of 1. The product of the conditional statement is CSP_RUN1.

CSP Exclusions Calculation

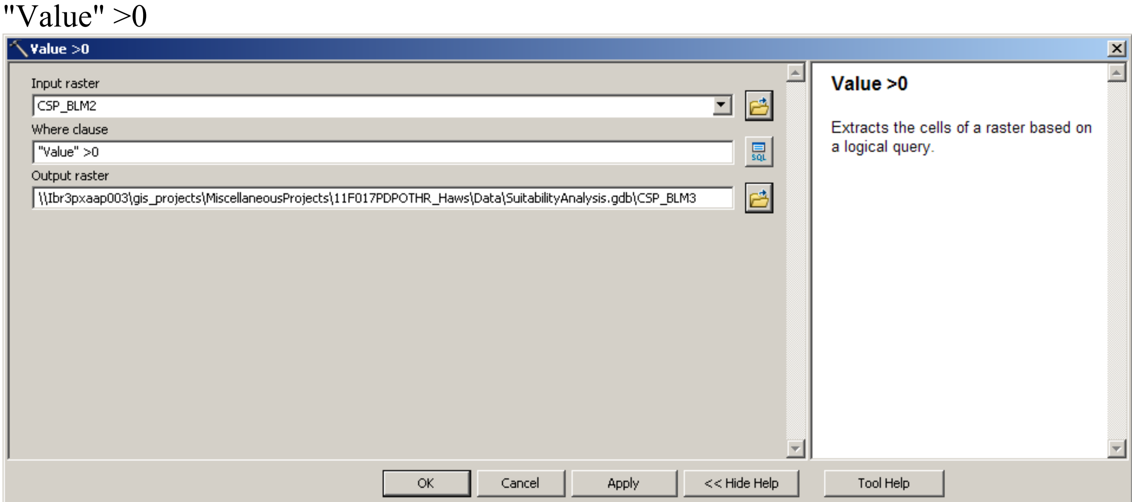
Con(IsNull("ExcludedLands")," CSP_BLM1",0)



Conditional statement takes CSP_RUN1 output and multiplies this raster against excluded areas weighted as 0. The zero value allows the exclusion of these lands from further consideration. Output is CSP_RUN2

Extract by Attributes

"Value" >0



Extraction of all values greater than zero removed excluded lands and returned only lands suitable for development. Output is CSP_RUN3.

Three different models were created and workflows generated per solar technology type: Photovoltaic Global Horizontal (PV_GBL), Photovoltaic

Latitude Tilt (PV_LAT), and Concentrating Solar Power (CSP). Geoprocessing steps and conditional statements used in map algebra expressions utilized the same expression for each solar technology model developed. Variables or layer names were substituted accordingly into the equation to derive modeling results. Three suitability rasters were generated from ModelBuilder scenarios per solar technology type. CSP_RUN1 is raster output for conditional expression factoring suitability's of CAP ROW acreage, transmission line proximity, access road proximity, slope and solar insolation. CSP_RUN2 is output raster from conditional expression that factors out excluded areas from CSP_RUN1. CSP_RUN3 contains all values greater than 1 from CSP_RUN2. CSP_RUN3 represents the range of suitability for lands within the CAP study area.

The three modeling outputs, PV_GBL_RUN3, PV_LAT_RUN3 and CSP_RUN3, attribute tables were used to analyze the total number of unique records created by each suitability model. The extraction of highest suitability values was accomplished by taking total number of unique records and selecting the top 10% of the total records as number of values to use. These unique values were the most suitable areas to develop solar technologies. PV_GBL_INT1 contained 86 records and the top 9 were extracted; PV_LAT_INT1 contained 86 records and the top 9 were extracted; and CSP_INT1 contained 88 records with the top 9 extracted. Selecting the top percentile unique value seemed an unbiased and sound method for selecting highest suitability from modeling results. Extracting the top percentile into a new format was accomplished by Extract by Attribute tool within Spatial Analyst Toolbox.

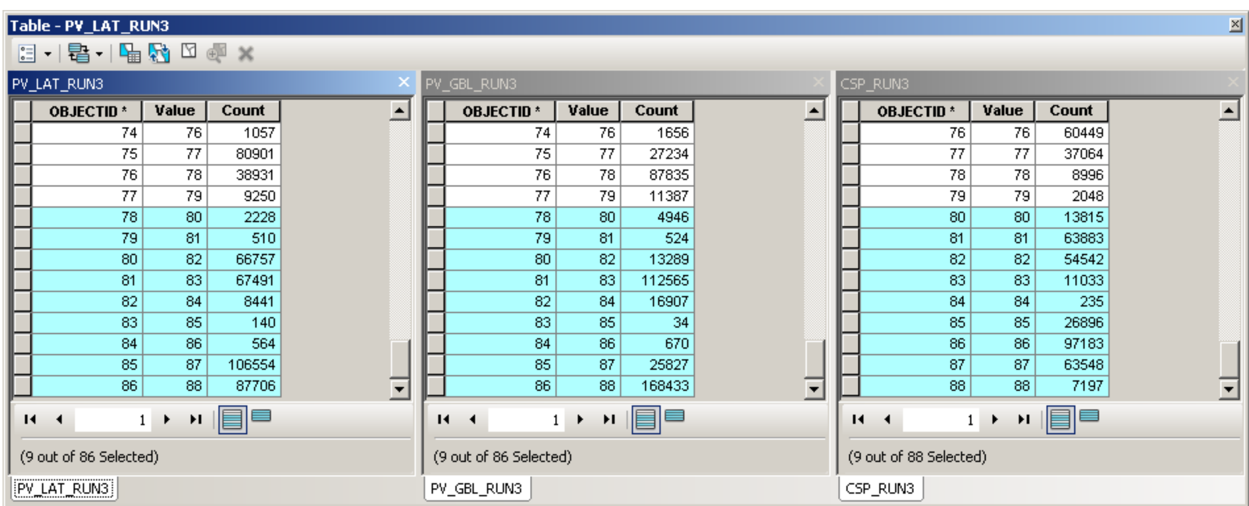
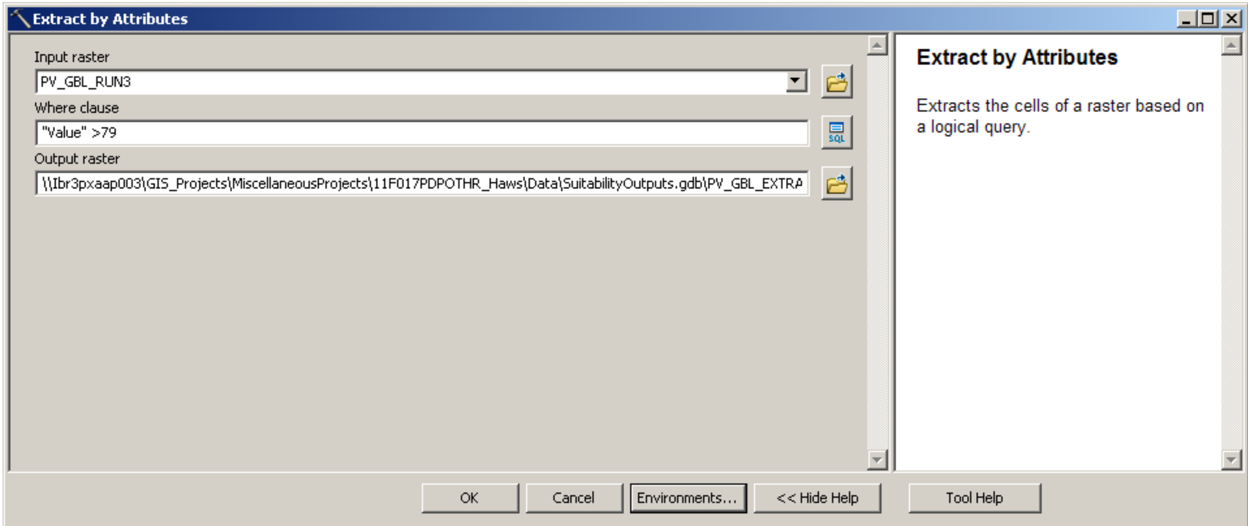


Table - PV_LAT_RUN3

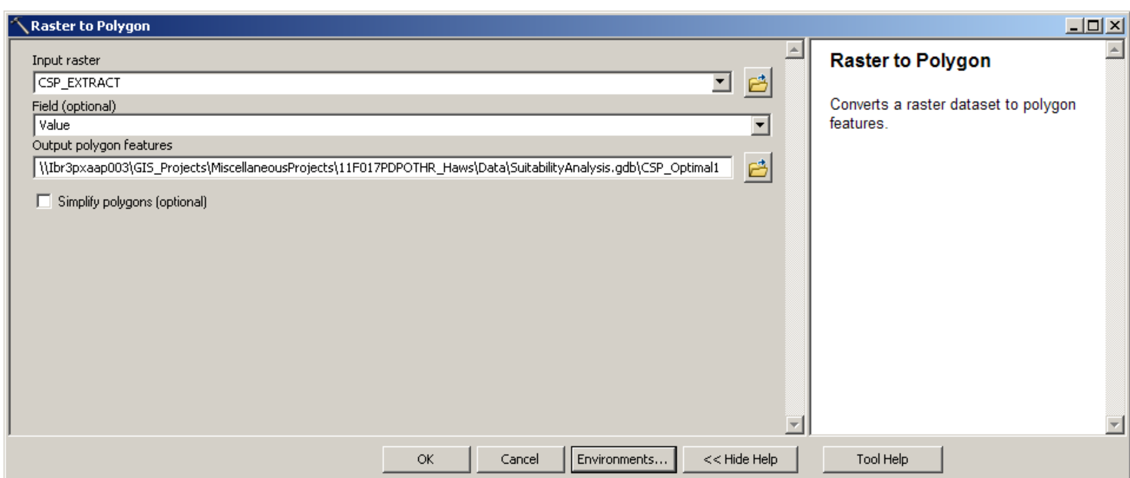
PV_LAT_RUN3 OBJECTID *	Value	Count	PV_GBL_RUN3 OBJECTID *	Value	Count	CSP_RUN3 OBJECTID *	Value	Count
74	76	1057	74	76	1656	76	76	60449
75	77	80901	75	77	27234	77	77	37064
76	78	38931	76	78	87835	78	78	8996
77	79	9250	77	79	11387	79	79	2048
78	80	2228	78	80	4946	80	80	13815
79	81	510	79	81	524	81	81	63883
80	82	66757	80	82	13289	82	82	54542
81	83	67491	81	83	112565	83	83	11033
82	84	8441	82	84	16907	84	84	235
83	85	140	83	85	34	85	85	26896
84	86	564	84	86	670	86	86	97183
85	87	106554	85	87	25827	87	87	63548
86	88	87706	86	88	168433	88	88	7197

(9 out of 86 Selected) — PV_LAT_RUN3; (9 out of 86 Selected) — PV_GBL_RUN3; (9 out of 88 Selected) — CSP_RUN3

Extract by Attributes
Value >
79



These extracted rasters represent the highest suitability values or lands available per solar technology. PV_GBL_EXTRACT represents the highest suitability lands for fixed axis flat plate collector, PV_LAT_EXTRACT represents highest suitability lands for a single axis flat plate collector tilted south at latitude and CSP_EXTRACT is highest suitability lands for CSP technology such as solar trough or power tower. Extracted rasters were also converted back into vector feature classes utilizing Conversion Toolbox Raster to Polygon tool. Attribute fields for acreage and generating potential were created and calculated.



The raster to polygon conversion output feature classes were PV_GBL_OPTIMAL, PV_LAT_OPTIMAL and CSP_OPTIMAL.

RESULTS

Creation of suitability modeling for solar technologies along CAP Canal discerned the potential of Reclamation project lands to develop renewable energy technologies. GIS modeling requisites were transmission lines and access roads within 2 miles of Right-of-Way, best possible solar insolation values, slope less than 5%, not on lands Reclamation excluded, and of sufficient land area designated for a utility scale solar facility. This analysis revealed that there are extensive lands sufficient to develop a utility scale solar facility.

The model calculation for suitability was:

> Con(IsNull("CAPROW_PV"),0,"CAPROW_PV") * 10 +
> Con(IsNull("TransmissionLines"),0,"TransmissionLines") * 5+
> Con(IsNull("Streets"),0,"Streets")*4 +
> Con(IsNull("SLOPE_SUIT"),0,"SLOPE_SUIT")*2 +
> Con(IsNull("ConcentratingSolar"),0,"ConcentratingSolar").

The maximum value within this calculation is:

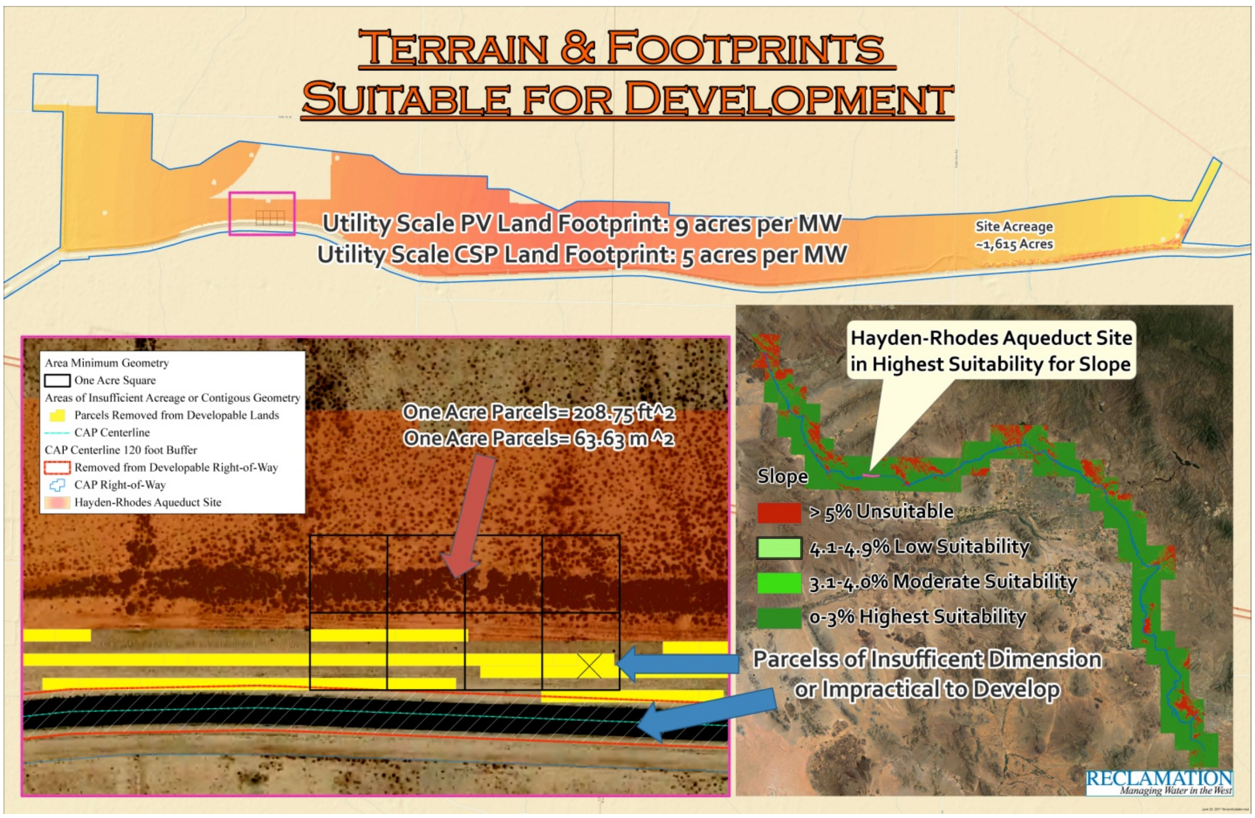
> [(CAPROW_PV=4)*10 + (TransmissionLines=4)*5 +
> (Streets=4)*4 + (Slope=4)*2 + ('Solar Insolation Type'=4)*1]
> ==***88***.

All three suitability models found optimal areas with scores of 88. Variance exists between the models for raw counts of maximum scores. The top 10% of unique values for PV_GBL_RUN3 represented values from 80-88 as did PV_LAT_RUN3 and CSP_RUN3. The raw counts of cells within these ranges were 340,391 for PV_GBL_RUN3. PV_LAT_RUN3 had 343,195 cells fall within this suitability range and CSP_RUN3 contained 338,332 cells within the top 10% suitability. The lone variable that differs between the three models is solar insolation. Solar insolation resource potential varies among global horizontal, latitude tilt and direct normal insolation and thus suitability intervals created vary to reflect resource potentials. The variance in resource potentials for insolation types and thus suitabilty classifications created the differences for raw counts between model outputs. The insolation type suitability classifications directly affected the spatial output among the 3 suitability models. As a result, cells in the same location or geography may have different suitability scores across the 3 models.

Output rasters were changed to polygons utilizing Conversion Toolbox: raster to polygon tool. Two new fields were created to calculate acreage and power generation potential. The power generation potential field used [ACREAGE]/9 for Photovoltaic technologies and [ACREAGE]/5 for Concentrating solar power technologies to approximate each parcel's megawatt generating potential. PV_GBL_OPTIMAL representing fixed axis PV technologies totaled 8,480 acres.

The megawatt potential for these lands at 9 acres per megawatt is 925 MW of power generation. The total acreage derived from PV_LAT_OPTIMAL representing single axis PV technologies was 8,411 acres and this acreage equates to 918 MW of power generation if fully developed. CSP_OPTIMAL totaled 8,360 acres, potentially yielding 1,651 MW of power generation for CSP technologies.

Feature class outputs were edited to remove 'islands' or areas of insufficient acreage created by raster to polygon conversion. Screening of polygons also dictated that areas be merged together to represent contiguous parcels since suitability values could differ from cell to cell.



The largest edit of property available was Southern Belmont Mountains site within the Hayden-Rhodes Aqueduct. This parcel contains 713 acres and could potentially yield 79 MW for PV technologies and 142 MW for CSP technologies. The Right-of-Way parcel was removed because a 500 kilovolt transmission line has been proposed by Intermountain Power Agency, but has yet to be constructed. The proposed transmission line was included to identify parcels within its reach that could be used in the future. This parcel is also adjacent to 11,569 acres of BLM lands identified as suitable within BLM PEIS 2010. Total megawatt potential for BLM land area is 1,285 MW for PV and 2,313 MW for CSP.

Solar Technology	*Total Acreage*	*Undevelopable Acreage*	*Suitable Acreage*	*Generation Yield (MW)*
Photovoltaic Flat Plate Collector	8,480	718	7,762	862
Photovoltaic Flat Plate Tilted South at Latitude	8,411	727	7,683	854
Concentrating Solar Power	8,360	719	7,641	1,528
BLM Lands (PV)	25,171	NA	NA	2,796
BLM Lands (CSP)	25,171	NA	NA	5,034
CAP + BLM PV Totals	*33,651*	--	*32,933*	*3,658*
CAP + BLM CSP Totals	*33,531*	--	*32,812*	*6,562*

The four largest sites identified as optimal locations for new solar facilities are also within close proximity to existing CAP pumping plants. The four largest sites identified are Little Harquahala, Red Rocks, Hassayampa, Twin Peaks and Sandario pumping plants. The largest of the pumping plants is the Hassayampa pumping plant consuming 58 MW annually, followed by Little Harquahala pumping plant (33 MW), Red Rocks (12MW), Twin Peaks (3MW) and Sandario (3MW). All four sites have footprints of more than sufficient size to generateenough solar power to augment existing power demands for each pumping plant.

Site Name	PV Acreage	PV MW Potential	CSP Acreage	CSP MW Potential
Hayden-Rhodes Aqueduct Little Harquahala Pumping Plant	1,614	179	1,577	315
Tucson Aqueduct Red Rocks Pumping Plant	932	104	927	185
Hayden-Rhodes Aqueduct Hassayampa Pumping Plant	429	48	409	85
Tucson Aqueduct Sandario-Twin Peaks Pumping Plants	427	48	427	82
BLM Lands Adjacent to Sites	1,160	101	1,160	171
CAP Site Totals	*3402*	*379*	*3340*	*649*
CAP & BLM Site Totals	*4,562*	*479*	*4,500*	*820*

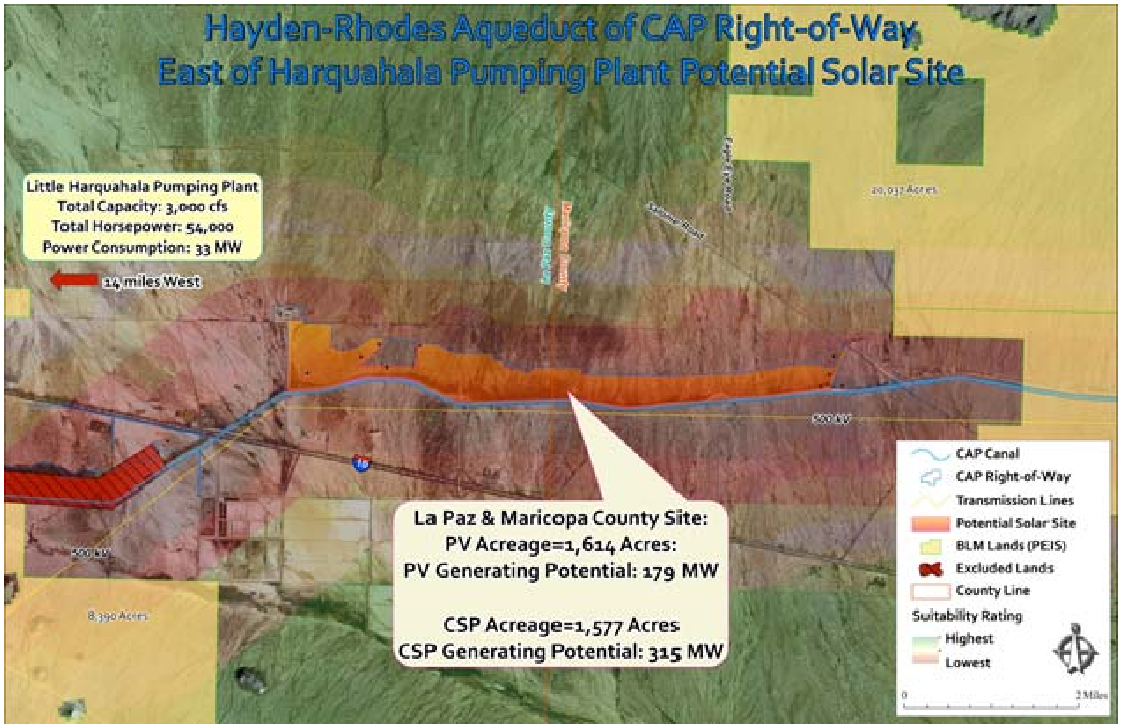


Figure 3 - Harquahala Pumping Plant Site

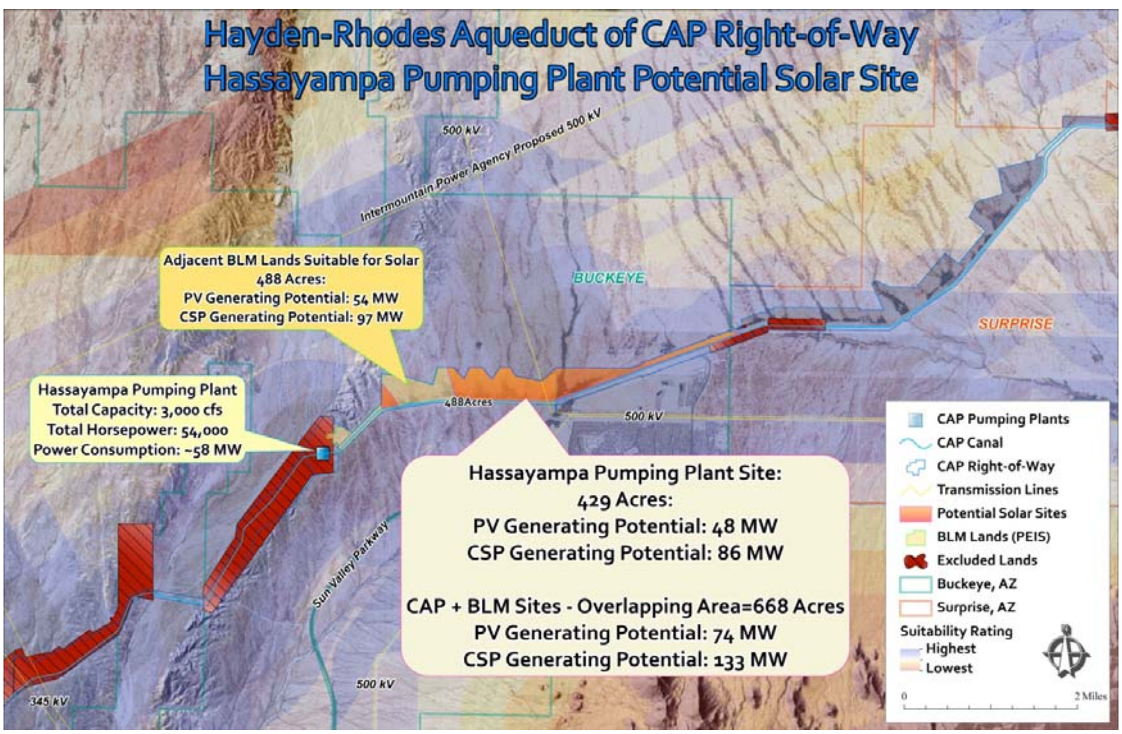


Figure 4 - Hassayampa Pumping Plant Site

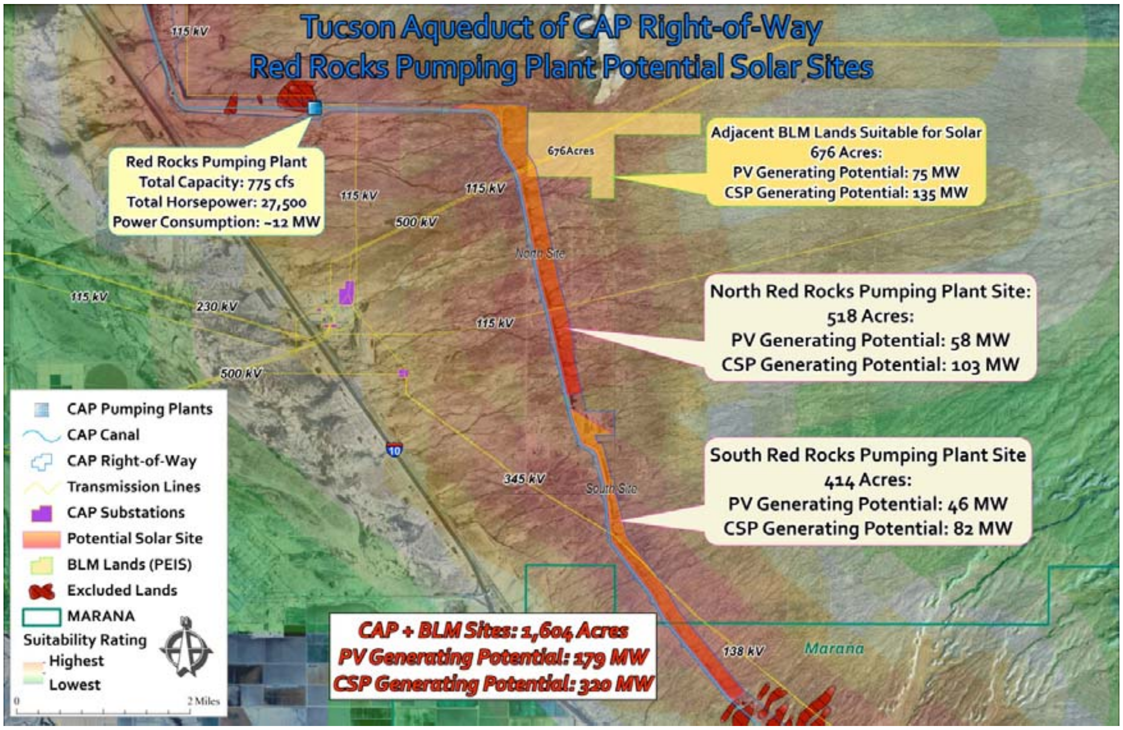


Figure 5 - Red Rocks Pumping Plant Site

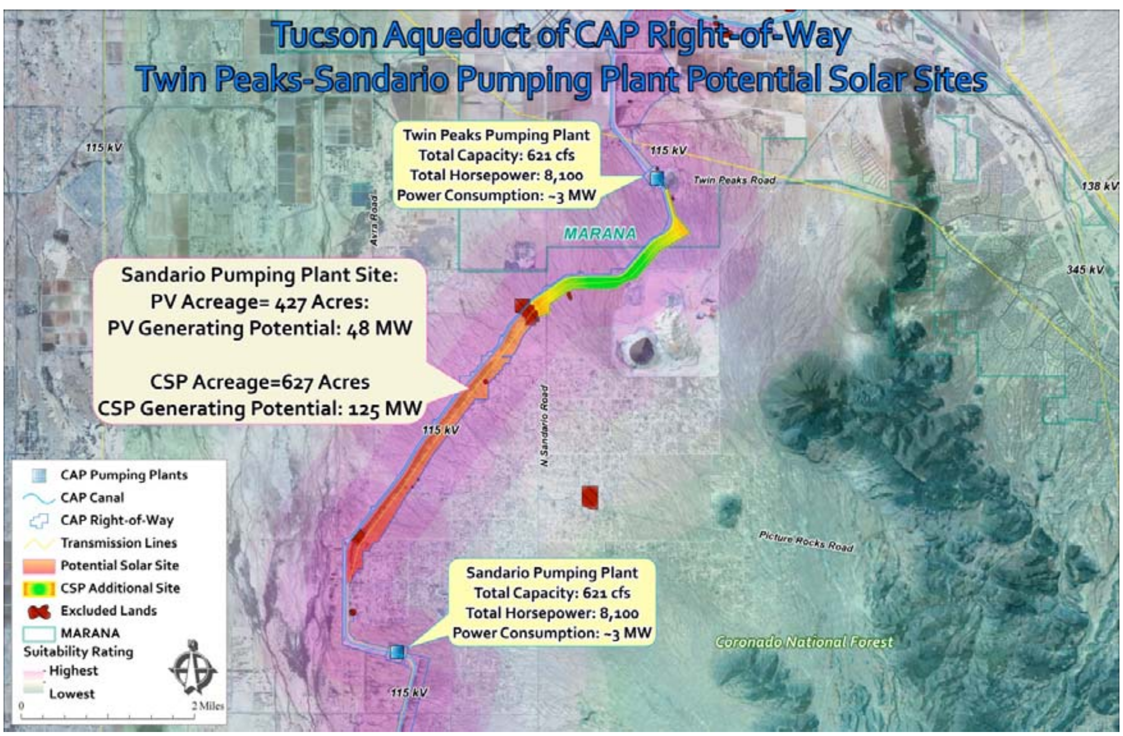


Figure 6 - Twin Peaks Sandario Pumping Plant Site

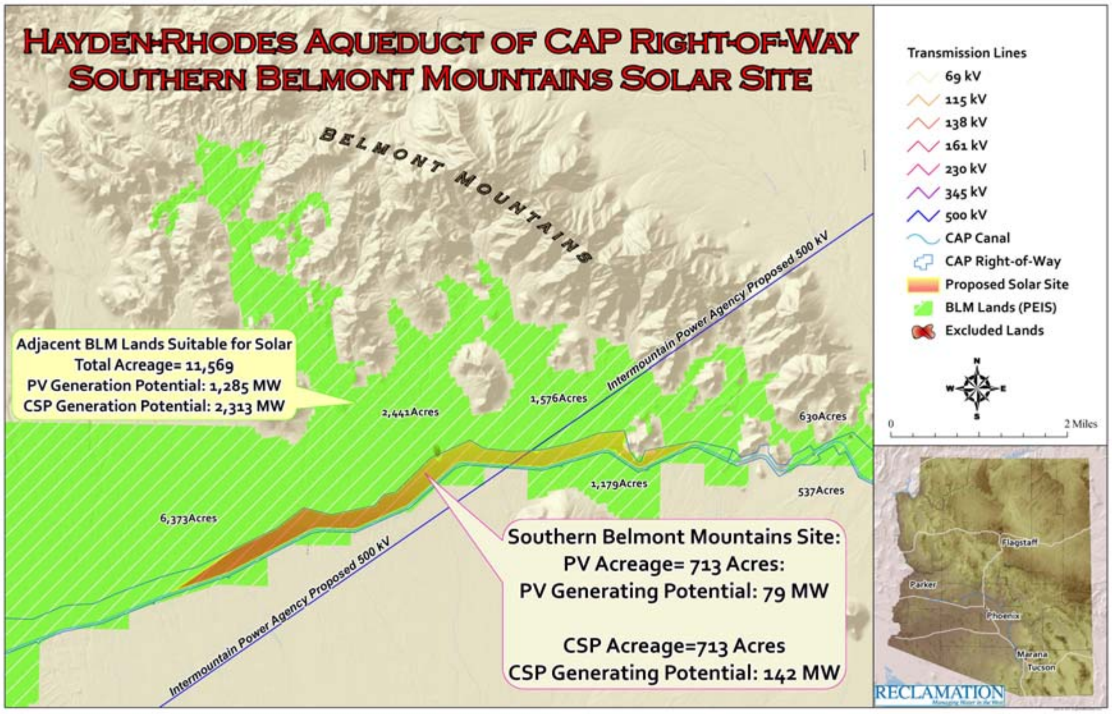


Figure 7 - Belmont Mountain Site

DISCUSSION & CONCLUSIONS

Screening of highest suitability areas identified numerous potential solar sites of significant size and generating potential. Four sites were selected to highlight opportunities Reclamation has to develop solar facilities and one site that has future potential if a proposed transmission line is completed. The four sites in order on generation potential are Little Harquahala Pumping Plant, Red Rocks Pumping Plant, Hassayampa Pumping Plant, and Twin Peaks-Sandario Pumping Plants. The future site is south of the Belmont Mountains in the Hayden-Rhodes Aqueduct, approximately 50 miles west of the Phoenix metropolitan area. The Little Harquahala site is approximately 75 miles west of the Phoenix area and straddles the Maricopa and La Paz counties border. The Hassayampa site is approximately 30 miles west of Phoenix and within the northwestern limits of the Town of Buckeye. Red Rocks site is located a few miles north of Marana and east of I-10. The Twin Peaks-Sandario site is just within Town of Marana limits and north of Wasson Peak, within the Coronado National Forest.

The four largest potential sites are within close proximity of existing Reclamation pumping plants and could augment or supplement energy supplies used for water transmission. Each of the four sites is of substantial size and could generate necessary power to operate each pumping plant. The Hayden-Rhodes Aqueduct contains two potential solar sites in proximity to the Little Harquahala and Hassayampa pumping plants. The Tucson Aqueduct also contains two potential solar sites in proximity to the Twin Peaks, Red Rocks and Sandario pumping plants. The generating potential for the Hayden-Rhodes Aqueduct is 253 MW from PV and 448 MW from CSP, respectively. Tucson Aqueduct generating potential is 227 MW from PV and 445 MW from CSP.

Little Harquahala pumping plant solar site contains 1,614 acres suitable for PV generation and 1,577 acres for CSP. PV technologies at this solar site could potentially yield 179 MW whereas CSP technologies could generate 315 MW. The pumping plant’s annual energy consumption is approximately 33 MW. The potential solar site could generate an additional 146 MW from PV and 146 MW from CSP than is utilized by Little Harquahala pumping plant. A 500 kilovolt (kV) transmission line operated by Southern California Edison Company lies parallel and south of the solar site. Road access to this site would be from U.S. Interstate 10 which crosses the CAP ROW southwest of the potential site and is within one mile of the interstate.

Hassayampa pumping plant solar site contains 429 acres, potentially yielding 48 MW from PV and 86 MW from CSP. The Hassayampa site also has an additional 200 acres of BLM land identified from BLM PEIS. The BLM parcel identified was part of CAP ROW analyzed in the suitability modeling. Selection of the top 10% from suitability modeling removed these 200 acres of BLM land. Suitability values for this parcel scored 77 and the neighboring parcels included scored 82. Suitability rasters Transmission lines, Streets, Slope and CSP_RUN3 were overlaid to discern the discrepancy. This portion fell out of highest suitability due to its proximity to transmission lines (suitability=2). Inclusion of this land adds 26 MW generating potential from PV and 47 MW from CSP. The total site generation from CAP ROW and BLM land is 74 MW for PV and 133 MW from CSP. Hassayampa pumping plant consumes approximately 58 MW annually. This potential solar site could generate an additional 28 MW from CSP. The solar site utilizing PV technologies doesn’t contain enough acreage to fully supply Hassayampa. The additional acreage from BLM land would create a surplus of 16 MW from PV and 75 MW from CSP. Hassayampa site has three 500 kV lines within proximity of its reach. Western Area Power Administration (WAPA) operates one 500 kV line and two 500 kV lines are operated by Arizona Public Service Company (APS). The nearest major road to this solar site would be from the Sun Valley Parkway.

Red Rocks pumping plant solar sites are located approximately one mile east of the pumping plant as the CAP ROW turns south. Red Rocks ‘North’ solar site is 518 acres with 58 MW of PV generating potential and 103 MW from CSP. The Red Rocks ‘South’ site is 414 acres with PV generating potential of 46 MW and CSP generating potential of 82 MW. The combined PV generating potential is 104 MW, whereas CSP combined generating potential is 185 MW. Adjacent to the Red Rocks ‘North’ site is 676 acres of BLM land. This large parcel of land could potentially add 75 MW for PV and 135 MW for CSP. The CAP and BLM sites combined total 1,604 acres with generating potentials of 179 MW for PV and 320 MW for CSP. Red Rocks sites have several transmission lines that traverse the solar sites. There are two 500 kV lines, one 345 kV line, one 230 kV line, one 138 kV line and two 115 kV lines. These lines are operated by Department of Energy, Tucson Electric Power Company and APS. APS also operates the Saguaro Power Plant which is the closest substation to handle the generating capacity load. U.S. Interstate 10 is the closest major access road to the solar sites.

The smallest of the potential solar sites lies between the Twin Peaks pumping plant to the north and Sandario pumping plant to the south. This potential solar site has 427 acres and 48 MW of generating potential for PV technologies. The acreage available to CSP technologies is 627 acres and 125 MW of power generating potential. The Twin Peaks and Sandario pumping plants both annually consume approximately 3 MW. The surplus power generation at this potential site is 42 MW from PV and 119 MW from CSP. The additional acreage identified in the CSP suitability is due to the higher insolation values for CSP from NREL's National Solar Radiation Data Base. Model error associated with the atmospherics and terrain complexities ranges from 9-15%. Further analysis would be required to identify if all acreage identified for CSP is not suitable for PV technologies. Two 115 kV transmission lines traverse the potential solar site providing total capacity of 230 kV. These transmission lines are operated by WAPA. Road access to the potential solar site is provided by North Sandario Road and West Twin Peaks Road.

Several potential solar sites are adjoining to BLM land deemed suitable lands for solar development in the BLM PEIS. BLM Lands adjacent to these sites totaled 1,160 acres. BLM's suitable lands could potentially produce an additional 128 MW from PV or 232 MW from CSP facilities. BLM lands identified as suitable from PEIS that intersect the top 10% of suitability total 25,171 acres. All BLM suitable lands could potentially produce an additional 2,700 MW from PV and 5,034 MW from CSP facilities.

Suitability modeling results affirm that wide-ranging opportunities exist on Reclamation project lands for utility scale solar development. Suitability modeling screened Reclamation project lands for acreage necessary for utility scale sites, close proximity to existing transmission lines and access roads, slope limitations, and most favorable solar insolation. Potential solar sites are within close proximity to existing BOR pumping plants and these sites present opportunities for BOR to augment or supplement energy supplies for the transmission of water.

4.2 Solar Energy Analysis

All data in this section, Section 4.2, "Solar Energy Analysis," is taken directly from, "Renewable Energy Assessment for the Bureau of Reclamation," May 2012 produced for the Bureau of Reclamation by the National Renewable Energy Lab (NREL) under Interagency Agreement No. R11PG81316. The full version of the NREL report is located in Appendix A at the end of this report.

This section summarizes the results of an assessment and analysis of renewable energy opportunities conducted for the U.S. Department of Interior, Bureau of Reclamation (Reclamation) by the National Renewable Energy Laboratory (NREL). The work was conducted under interagency agreement number IAG-11-1816, entitled Technical Assistance for the Bureau of Reclamation's Non-hydro Renewable Energy Program. This report represents the results of Tasks 1.1 and 1.2 of the effort (Resource Screening and Site Assessments).

In particular, this report contains results from the following tasks and activities:

"Task 1.1 – Utility-Scale Analysis." Using Geographic Information System (GIS) technology, identify and rank Reclamation lands potentially suitable for solar energy development and for this report specifically in Arizona.

"Task 1.1.1 – Utility-Scale Site Visits." Using the results of Task 1.1, conduct detailed technical and economic assessments of Reclamation lands potentially suitable for development. Three of the sites were located along the Central Arizona Project (CAP) to capitalize on the detailed screening and ranking of solar energy potential conducted by Reclamation's Phoenix Area Office identified in previous sections of this report. This report documents the results of the assessments of three potential solar sites along the CAP.

"Task 1.2 – Facility-Scale Screening." Using GIS, NREL identify Reclamation facilities that have the best potential for deployment of facility-scale wind and/or solar energy resources.

"Task 1.2.1 – Facility-Scale Site Visit." Based on the results of the ranking conducted in Task 1.2 and other program factors suggested by Reclamation, NREL conduct a technical and economic feasibility study of deploying wind or solar at three different Reclamation facilities. This report provides a brief overview the feasibility of installing solar energy at Reclamation's Phoenix Area Office.

The complete NREL report can found in Appendix A at the end of this report.

4.2.1 Summary Results

Utility-Scale GIS Screening
The full results of the screening are summarized in Appendix A, with summaries of the resource potential with and without exclusions to demonstrate the impact of the exclusion scenario utilized. The top 20 counties based on total potential installed capacity for each technology are shown in Tables 1-1 through 1-3. Note the megawatt (MW) numbers show the potential installed capacity for a larger land area than just Reclamation lands, based on the area of interest defined by Reclamation. Additional site-specific analyses would be required to determine the suitability and potential of individual Reclamation land areas.

Utility-Scale Site Assessments
On August 29, 2011, NREL visited three potential utility-scale sites identified by Reclamation through a detailed screening and ranking process that staff conducted for lands located along the CAP. The Hassayampa pumping plant location was determined to be the most viable site of the three visited. NREL conducted a preliminary assessment for this location.

NREL obtained the hourly load data for the Hassayampa pumping station and used two models to evaluate the potential to develop a solar project on the Hassayampa site for three different sizes of solar production – 20 MW, 50 MW, and 100 MW. The first model, called HOMER[1], models the hourly production of a solar system in congruence with the hourly demand of the pumping plant. This model evaluates the opportunities from the perspective of Reclamation owning and operating the plant. Energy from the photovoltaic (PV) system is used to offset pumping loads at $0.035/kilowatt-hour (kWh), which is CAP's costs of power from the Navajo Generating Station (NGS). NREL assumed that any excess production from the PV is sold on the market as green power for $0.10/kWh. Table 1 summarizes the amount of energy produced by the PV plant, the amount used from the grid, and excess power sold back for each of the three scenarios. The base case has no PV and is 100% power from the grid. As an illustration, a 100-MW PV plant located at Hassayampa would produce over 200 million kWh of solar energy per year, meeting 54% of the load of the pumps. There would still be 176 million kWh purchased from the grid (compared to 288 million kWh under the base case), and 88 million kWh would be available for sale back to the grid.

[1] HOMER Energy LLC, Version 2.81, http://homerenergy.com/

Table 1 - Electrical Production from PV at Hassayampa Pumping Plant

Scenario	PV size (MW)	Electrical PV Production (kWh)	Grid Purchase (kWh)	Grid Sales (kWh)	Percent Renewable Fraction
Base case	0	n/a	288,269,952	n/a	0%
1	20	40,006,296	251,574,272	3,311,413	14%
2	50	100,015,760	206,155,248	17,902,112	33%
3	100	200,031,520	176,725,744	88,488,616	54%

NREL next analyzed the economics of the three different sized PV systems tied to the grid to meet the pumping load at Hassayampa. The capital cost for PV is modeled at $3/watt, and the operation and maintenance (O&M) cost is assumed to be 0.1% of the capital cost annually. The price to purchase power from the grid is assumed to be $0.035/kWh, and the demand price for sellback is modeled at $0.10/kWh. The annual real interest rate is assumed to be 6% for a project lifetime of 25 years (life of the PV system). Table 2 summarizes the capital cost of the PV system, the annual operating cost, total net present cost and levelized cost of energy (LCOE). In scenario 3 (100 MW PV system installed) the PV system produces more average annual power than is consumed by the Hassayampa load, and thus the annual overall purchase cost from the grid is negative. CAP could receive ~$2.4 M annually in excess power sold back.

Table 2 - Comparison of Grid Cost with PV Cost

Scenario	PV size (MW)	Capital Cost for PV ($)	Operating Cost ($/yr)	Total Net Present Cost ($)	LCOE ($/kWh)
Base case	0	n/a	10,089,453	128,977,080	0.035
1	20	60,000,000	8,533,963	169,092,704	0.045
2	50	141,000,000	5,566,226	212,155,056	0.054
3	100	286,000,000	-2,377,463	255,608,048	0.053

The second analysis used the NREL-developed System Advisor Model (SAM) to identify the LCOE in $/kWh for assumed private-sector owned and operated solar plants, with delivery of electrical production through a 20- to 30-year Power Purchase Agreement (PPA). This model assumes that Reclamation provides a private sector developer with a right of way or lease for the land, but the project is financed, owned, and operated by a private company, and 100% of the power is sold on the market as green power.

NREL ran models for the following scenarios:

1. 20-MW single-axis PV
2. 50-MW single-axis PV
3. 100-MW single-axis PV
4. 50-MW Concentrating Solar Power (CSP) Trough – No storage
5. 60-MW CSP Trough – No storage

The key results are summarized in Table 1-5.

Table 3 - Summary Results for Utility-Scale Analysis of Hassayampa Site

Scenario	LCOE $/kWh	Annual (MWh)	Capital Cost ($M)	Land Area (Acres)	Capacity Factor
1	.104	47,524	60	73	27.1
2	.101	118,812	141	183	27.1
3	.101	237,624	286	365	27.1
4	.172	107,476	275	343	27.6
5	.175	128,599	329	409	27.5

These results indicate a 100-MW single-axis tracking PV system may be most cost effective. Generally, the greater production of the single axis tracking PV system, compared to the fixed mount PV system, more than offsets the higher initial cost of the single axis tracking PV system. The owner of the system would need to sell all the power for at least the value listed under LCOE in Table 3 for the project to be economical.

Facility-Scale GIS Screening
NREL undertook facility-scale screening of selected locations. Reclamation selected 748 locations from its entries in the Federal Real Property Profile, its property database, providing NREL with the real property unique identifier (RPUID), address (where available and not sensitive), city, state, and zip code. NREL then georeferenced this information to establish a specific coordinate to represent the location. The accuracy of that location is dependent on the level of specificity of the address. In many cases, multiple real property identifiers are associated with the same location (i.e., same property address used for multiple buildings at one site) due to the structure of the addressing and location information given. These facilities should be further screened, with the more promising sites selected for more detailed site assessments.

Facility-Scale Assessment: Phoenix Area Office
Technical assistance was requested for a feasibility study of ground- and roof-mounted PV tied into the building electric grid for Reclamation's Phoenix Area Office building. A team of engineers from NREL and Reclamation personnel conducted the assessment on August 30, 2011. During the site visit, the NREL

team identified several suitable locations for grid-connected PV. The best locations for PV are the six unshaded carports where up to 120 kW of PV could be installed.[2]

At that time, incentives were available only for systems 30 kW and smaller. It was recommended that Reclamation contact the Salt River Project (SRP) electric utility and reserve incentives for a 30-kW direct current (DC) (or other size, as determined by Reclamation). Even with the incentives and the recent drop in PV prices, the economics of PV are challenging with an expected simple payback period of approximately 27 years. The reasons for the long payback period for the Reclamation-funded PV are that federal agencies cannot take advantage of federal tax incentives and the cost of electricity is inexpensive at $0.09/kWh. If incentives for larger systems become available again, a larger system should be installed. By combining carport- (120 kW), roof- (30 kW) and ground-mounted CPV (100 kW+ potential), at least 200 kW of PV could be installed. This is large enough for a PPA, which could take advantage of federal tax incentives.

Since the publication of the NREL report the prices for PV has come down and will be addressed in the next phase of this study.

Table 4 - PV Economics for the Phoenix Area Office[3]

Tie in Location	Array Tilt (Deg)	Area (ft^2) Reqd	PV Syst. Size (kW)	Annual Output (kWh/yr)	Annual Cost Savings ($/yr)	Annual O&M ($/yr)	Annual Cost Savings after O&M ($/yr)	System Cost with No Incentives ($)	Total System Cost with No Incentives ($)	Payback Period with No Incentive (yrs)	SRP Incentive $1.35/W DC capped at $40,500	Cost $ after incentives	Payback Period after SRP Incentive (years)
BOR Phoenix Area Office = 892,800 kWh annual													
Roof mounted	10	3,750	30	48,600	4,374	255	4,119	150,000	150,000	36	39,000	111,000	27
Carport mounted	10	3,750	30	48,600	4,374	255	4,119	150,000	150,000	36	39,000	111,000	27
					Maximum Carport PV								
Carport mounted	10	15,120	121	195,955	17,636	1,028	16,608	604,800	604,800	36	40,500	564,300	34

[2] Private entities are able to take advantage of certain tax credits and accelerated depreciation schedules which are not available to federally-owned systems since government agencies do not pay taxes. The overall economics are often superior for privately ownes systems, thus there are several financing models which facilitate private, third-party ownership of systems located on federal sites.

[3] Note federal incentives are only available for tax-paying entities.

4.2.2 Utility Scale

Given current power market conditions and the low costs of power from the NGS, the economic case of installing utility-scale solar on Reclamation land and using this power directly to power CAP pumps is challenging on a cost basis. However, given the continued drop in solar prices and an expected increase in NGS generation costs over time, it will be important for Reclamation to monitor market conditions going forward and revisit this analysis as situations change.

If Reclamation desires to pursue siting of utility-scale projects on its land, the best case would be for Reclamation to act simply as a land owner and issue a right-of-way grant to a private sector company. Results of the analysis in this report indicate that the developer would need to obtain a long-term PPA from a utility of at least $0.10/kWh to make the project economically viable. The ability of a private sector company to obtain a purchase price of $0.10/kWh is not known at this time. The demand for renewable energy in the western United States is dependent on a number of factors, including regulatory mandates arising from state Renewable Portfolio Standards, low prices for natural gas, lack of transmission into the California market, and projections for continued drops in PV prices due to technology improvements and structural imbalances (global oversupply of panel manufacturing capacity) in the industry.

One next step to further facilitate siting a project on Reclamation land would be for Reclamation to pre-qualify the development potential of the most promising sites (e.g., Hassayampa) especially in terms of identifying areas that are near transmission lines that have capacity and have the potential for very low environmental and cultural impacts. The Bureau of Land Management (BLM) conducted an analysis in Arizona called the Restoration Design Project to identify the best suitable lands and areas in the state for renewable energy development, Reclamation contacted BLM about lands that are located adjacent to BLM lands and Reclamation sites were included in the programmatic Environmental Impact Statement (EIS) analyses that was conducted. Alternatively, Reclamation could conduct its own programmatic EIS or a site-specific EIS for a given site. Once Reclamation determines that a site is a high quality location with strong development potential, Reclamation can issue a competitive lease solicitation that can be used to evaluate industry interest in moving forward with a project at that site.

4.2.3 Facility Scale

Reclamation’s Phoenix Area Office in Glendale, Arizona, which was considered for a solar PV system in this report, has many near-ideal areas in which to implement a PV system. It is recommended that Reclamation contact SRP and reserve incentives for a 30-kW DC (or other size, as determined by Reclamation). If incentives for larger systems become available again, a larger system should be installed. When the system goes out to bid, a design-build contract should be issued requesting the best performance (in kWh/yr) at the best price and let the vendors optimize the system configuration, including racking, slope, modules, etc. Because of the high cost of energy, the dropping cost of PV, the excellent solar resource, and excellent incentives, a government-owned PV system provides a reasonable payback, is easy to implement, and is therefore recommended. If funding is not available, then a third-party PPA is the most reasonable way for a system to be financed on this site. Upon request, NREL will be glad to help with the procurement, bid evaluation, design reviews, etc., for PV systems.

4.2.4 Utility Scale

Utility-Scale Site Development for Hassayampa

Should Reclamation decide to further pursue utility-scale solar at the Hassayampa site, the following steps should be undertaken:

- Contact transmission line owners, CAP, and the Western Area Power Administration to determine the technical feasibility of interconnecting PV at Hassayampa.
- Conduct a fatal flaw analysis for the presence of any significant cultural and environmental concerns at the site.
- If transmission access is favorable, then
    - Brief key Reclamation decision makers on the potential for large-scale solar project development on Reclamation lands.
    - Identify other stakeholders impacted by project development.
    - Prepare a detailed action plan with milestones for project development.

Utility-Scale Site Development at Other Reclamation Sites

- New environmental regulations are likely to impact the costs of power generation at the NGS. These new regulations include the Environmental Protection Agency's Best Available Retrofit Technology rule for NGS, and the utility Maximum Achievable Control Technology rule. While the exact impacts of these rules cannot be determined at this time, they are likely to increase the costs of generation from NGS. Combined with the expected continued decline of PV prices in the coming years, this means that the economics of utility-scale solar at CAP pumping plants are likely to improve over the next several years. Reclamation should continue to monitor these issues for future evaluation.
- Evaluate load profiles at other CAP pumping plants to determine if there are additional locations that may be suitable for PV deployment.
- Work with Reclamation staff to identify additional sites for more detailed utility-scale analysis.

4.2.5 Facility-Scale GIS Screening

- As appropriate, work with Reclamation staff to improve the level of detail associated with the facility-level GIS screening.
- Determine additional candidate sites to perform a more detailed facility-scale site visits and evaluations similar to what was done for the Phoenix Area Office.

Facility-Scale Site Visit – Phoenix Area Office PV

- NREL and Reclamation staff can contact developers to determine interest in a PPA model for the 30-kW and 200-kW options.

Background

The President's National Energy Policy of 2001 and Section 211 of the Energy Policy Act of 2005 (P.L. 109-58) encourage the development of renewable energy resources, including solar and wind energy, as part of an overall strategy to develop a diverse portfolio of domestic energy supplies for the future. The Department of the Interior and the Department of Energy (DOE) are signatories to a Memorandum of Understanding promoting joint efforts to, among other things, "evaluate the use of non-hydropower renewable resources with water management operations."

The Energy Policy Act of 2005 also requires federal agencies to reduce their internal energy use by 30% by 2015 and obtain 7.5% of their energy needs from renewable sources by 2013. Through Executive Order 13514 (EO 13514), President Obama established greenhouse gas reduction targets for federal agencies. Agencies submitted their draft inventory and plans to the DOE on February 1, 2011.

It is a Department of the Interior Priority Goal to increase approved capacity for production of renewable (solar, wind, and geothermal) energy resources on Department of the Interior-managed lands to at least 10,000 MW by the end of 2012.

Reclamation, while primarily a water and hydropower management agency, holds lands that may be well suited to wind and/or solar power installations (typically, greater than 1 MW) insofar as these lands:

- are in parts of the West receiving abundant solar radiation and wind
- have good road access but restricted public access
- are often adjacent to power plants, substations, pumps, transmission lines, or other components of the energy grid

In addition, Reclamation has a number of facilities, such as visitor centers, that may be suitable for deployment of renewable energy and energy efficiency technologies.

Reclamation is also developing rural water development projects that may be suitable for deployment of a variety of renewable energy technologies.

To this end, Reclamation and NREL entered into an interagency agreement in mid-2011 for Reclamation to obtain technical assistance from NREL. NREL is supporting Reclamation through four primary activities:

1. Technical Assistance. Provide Reclamation with assistance on renewable energy deployment activities including: resource screening, estimation of generation potential from wind and solar on Reclamation lands, integration of wind and solar into existing hydro generation, technology evaluation of advanced hydro technologies, and suitability of renewable energy technologies for use at Reclamation facilities such as dams, buildings, pumps and visitor centers.
2. Acquisition and Financing Strategies. Develop strategies to assist Reclamation to understand the various options of deploying renewable energy technologies on Reclamation-owned lands or facilities. Potential strategies include direct leasing of land or identifying interest in third-party financing of projects on Reclamation lands or facilities.
3. Technology Training. Provide staff training on renewable energy technologies, including wind, hydro, solar, transmission and other topics as may be requested by Reclamation.
4. Program Management and Coordination. Manage the work to be performed under the Agreement. Provide integrated technical and policy program support and ensure coordination of Reclamation activities across the Department of the Interior and the DOE technology programs (e.g., Solar, Wind and Water Power, Federal Energy Management Program, Tribal, Geothermal).

GIS Screening

Utility-Scale Screening

The utility-scale screening was conducted to broadly identify the renewable energy potential for Reclamation lands. Reclamation provided a generalized representation of its land interests in the 17 western states, depicting the survey sections that contained some Reclamation lands of interest. Individual sites were not specified. The analysis was subdivided into state and county-level tables to aid in reporting and ranking individual areas. This analysis is intended to provide general information on renewable energy resource intensity in different regions of interest to Reclamation, with the potential for more detailed analysis of specific areas of interest. State-level maps and overall tables are presented in full in Appendix A.

This analysis examined potential resource intensity for CSP, utility-scale solar PV, and onshore wind. NREL used resource exclusion scenarios developed for characterizing overall technical potential in its resource assessments and modeling. The exclusion scenarios are described in Appendix A. Other site-based characteristics (proximity to transmission lines and roads) were omitted because the specific locations of the Reclamation land interests were unknown.

Concentrating Solar Power

CSP is power generated from a utility-scale solar power facility in which the solar heat energy is collected in a central location. The resource potential estimates utilize annual average direct normal solar radiation produced by the State University of New York-Albany and NREL (Wilcox, 2007)[4]. The data are modeled at a 10-km horizontal resolution and are averaged over the period from 1998 to 2005. The resource areas have been filtered to identify only the areas that are more likely to be developed based on their resource intensity and general site characteristics. The minimum annual average resource value used is 6 $kWh/m^2/day$. Site characteristics that are incompatible with utilization for solar power include steeply sloped areas, urban areas, and protected environmental areas.

A trough system, dry-cooled with 6 hours of storage and a solar multiple of 2.0, was used in NREL's System Advisor Model (https://sam.nrel.gov) to estimate generation capacity factor values within five solar resource ranges. An overall installation density of 32.8 MW/km^2 was also estimated for this configuration.

Utility-Scale Photovoltaic

Utility-scale PV is defined as large-scale PV deployed outside urban boundaries, as defined by the U.S. Census Bureau's urbanized area boundaries data set (http://www.census.gov/geo/www). The data used to represent this resource is a

[4] Wilcox, S. (2007). National Solar Radiation Database 1991-2005 Update: User's Manual. 472 pp.; NREL Report No. TP-581-41364

single-axis tracking collector facing the equator with 0 degrees tilt with a power density of 48 MW/km^2 (Denholm and Margolis 2008[5]). The site characteristic exclusion criteria utilized are the same as described for CSP, and the minimum annual average resource value used is 6 $kWh/m^2/day$. State-level annual capacity factors were generated using the National Solar Radiation Database Typical Meteorological Year 3 (TMY3) data set and the System Advisor Model.

Facility-Scale Screening

Facility-scale screening of selected locations has begun with the extraction of resource information from NREL databases. Reclamation selected 748 locations from its property database and provided NREL with the real property identifier, address (where available and not sensitive), city, state, and zip code. This information was georeferenced by NREL to establish specific coordinates to represent the locations, with the accuracy of that location dependent on the level of specificity of the address. In many cases, multiple real property identifiers are associated with the same location due to the structure of the addressing and location information given.

4.2.6 Utility-Scale Assessment of Pumping Plants Along the Central Arizona Project

On August 29, 2011, a team from NREL, Reclamation, and the BLM conducted visits to three sites to assess Reclamation-owned lands for potential utility-scale solar energy power plant development. The sites were previously identified by Reclamation through a screening and ranking analysis conducted by staff from Reclamation Phoenix Area Office.

Site Assessments

All three sites were north of Reclamation's Hayden-Rhodes Aqueduct right of way. The sites were located: 1) east of Little Harquahala Pumping Station (La Paz and Maricopa County Site), 2) at Bellmont Mountain, and 3) east of Hassayampa Pumping Station.

Site 1. The site is a 300-plus acre site east of the Little Harquahala Pumping Station on the western end of La Paz and Maricopa Counties; the site has an acceptable slope ($\leq$ 3%) and a reasonable amount of mesquite vegetation to remove for a CSP PV plant of 50–60 MW. See Figure 8 and Figure 99.

[5] Denholm, P.; Margolis, R. M. (2008). Impacts of Array Configuration on Land-Use Requirements for Large-Scale Photovoltaic Deployment in the United States: Preprint. 7 pp.; NREL Report No. CP-670-42971

Figure 8 - High potential solar site east of Little Harquahala pumping station (©2011 Google Image)

Figure 9 - View of Site 1 looking north from northern edge of CAP (Source: Scott Haase, NREL)

Site 2. The Bellmont Mountain Site is located on Avenue 395 near Tonopah, Arizona. The site is covered with mounds and outcroppings of saguaro cactus, which would require significant grading, etc. for removal of cactus and construction of a CPS PV plant. An environmental assessment will be required at this particular location; therefore, this site was not considered reasonable for solar development. Also, the road to the site, which is about 4 miles, would require major improvement to handle the large vehicles used for material delivery. In addition, there are no power transmission lines running through or adjacent to the site although there is a proposed 500-kV line being considered at this time. This site is not being considered at this time, but future study is recommended since transmission may be available, and large quantities of BLM land (about 11,000 acres) are adjacent to this site.

Site 3. The site east of the Hassayampa Pumping Station just off the Sun Valley Parkway near the Sun City Festival housing development proved to be the best location. It has a slope ≤ 1% and little vegetation. The 400-plus acre site could support a utility-scale solar plant up to 60+ MW CSP and 60–70 MW PV. It is adjacent to a 500-kV transmission line for interconnection to the grid. This interconnection could be used if a feasible offtaker is available and if transmission capacity on the line is available. Also, it may be possible to access the 69-kV lines that serve the Hassayampa pumping station, with peak load of 58 MW. See Figure 8 and Figure 9.

Figure 10 - High potential solar site east of Hassayampa pumping station (©2011 Google Image)

Figure 11 - View looking north at Site 3 from northern edge of CAP

PV Potential to Meet Hassayampa Pumping Load

Pumping loads at the Hassayampa pumping station were analyzed for the potential for PV to meet its electrical pumping load. Three different sized PV systems were analyzed: 20 MW, 50 MW, and 100 MW.

Electrical production analysis

The annual hourly load data for 2010 at the Hassayampa pumping station was provided by Douglas Crosby, Water Operations Supervisor, CAP. The average load in 2010 was ~33 MW with a peak load of 55 MW. The total annual energy consumption is 288,272 MWh/year. The annual average daily load profile is consistently around 30 MW (Figure 12).

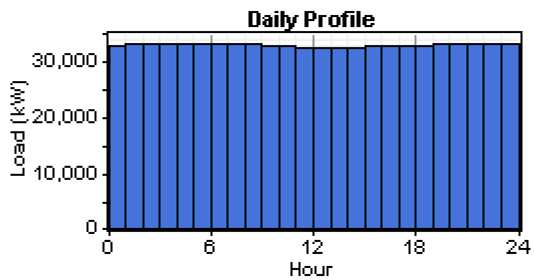


Figure 12 - Annual average daily load profile at Hassayampa

The seasonal load profile is shown in Figure 13. The maximum loads occurred in November and December 2010, and the minimum loads occurred in July and August. This unusual load pattern is due to the requirement to fill Lake Pleasant in the off-peak power demand season and the ability to conserve energy during high power demand in the summer season when water is released from the reservoir for power generation and water consumption.

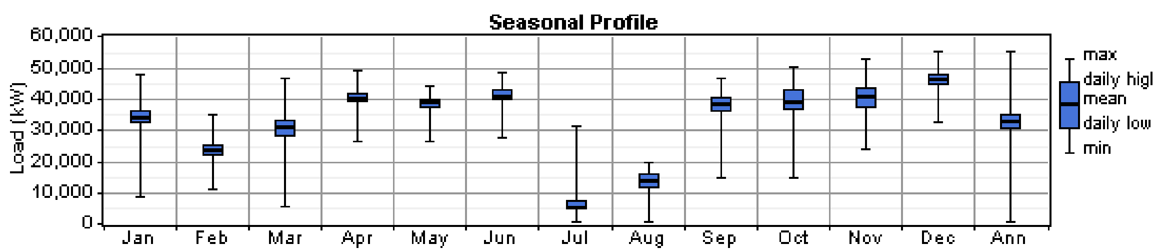


Figure 13 - Seasonal load profile for Hassayampa

The software optimization tool HOMER was used to analyze a PV grid-tied system with three different PV system sizes installed: 20 MW, 50 MW, and 100 MW. The results are summarized in Table 5. The PV system is modeled as a horizontal, continuous adjustment tracking system with a lifetime of 25 years and a derating factor of 80%.

Table 5 - Electrical Production

Scenario	PV size (MW)	Electrical PV Production (kWh)	Grid Purchase (kWh)	Grid Sales (kWh)	Percent Renewable Fraction
Base case	0	n/a	288,269,952	n/a	0%
1	20	40,006,296	251,574,272	3,311,413	14%
2	50	100,015,760	206,155,248	17,902,112	33%
3	100	200,031,520	176,725,744	88,488,616	54%

Figure 14 shows the monthly average electric source of power (yellow is power produced from PV, and blue is power provided by the grid) for scenario 3, a 100-MW PV system installed to meet the Hassayampa electric load.

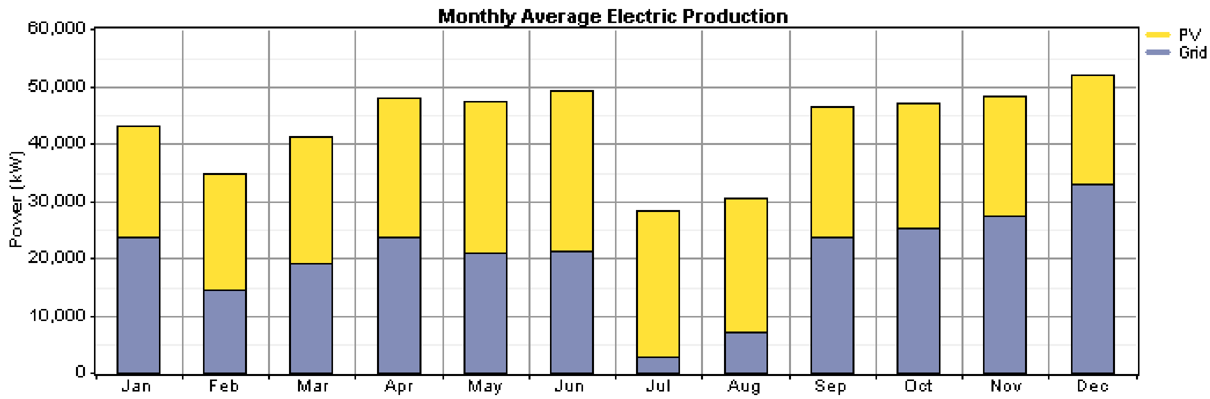


Figure 14 - Monthly average electric production (100 MW System)

Figure 15 shows the hourly annual PV production (yellow) with a 100-MW system installed at Hassayampa. The amount of power sold back to the grid is shown in green, and the annual monthly load demand for Hassayampa is shown in blue. In July, for the scenario of a 100-MW PV system, nearly all the power from the PV production could be sold back to the grid.

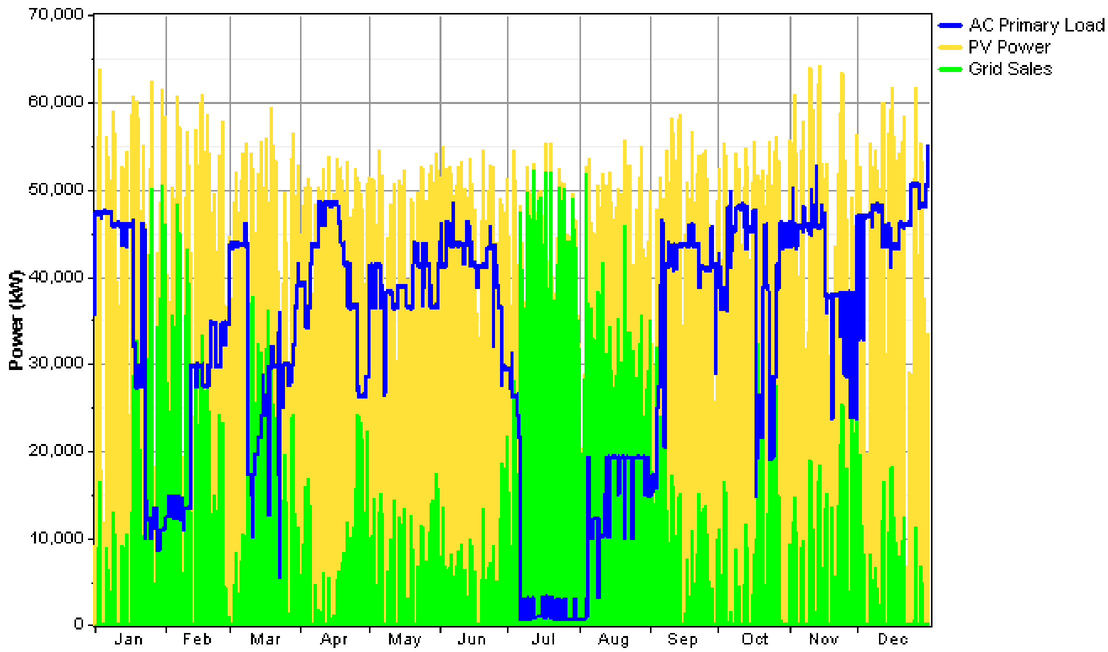


Figure 15 - Annual hourly PV production at Hassayampa

Economics

NREL analyzed the economics of the three different sized PV systems tied to the grid to meet the pumping load at Hassayampa. The capital cost for PV is modeled at $3/W and $2.50/W for replacement cost. The O&M cost for PV is assumed to be 0.1% of the capital cost annually. The price to purchase power from the grid was estimated to be $0.035/kWh, and the demand price for sellback was modeled at $0.10/kWh. The annual real interest rate was assumed to be 6% for a project lifetime of 25 years (life of the PV system). Table 6 summarizes the capital cost of the PV system, the annual operating cost, total net present cost, and LCOE. In scenario 3 (100 MW PV system installed), the PV system produces more power annually than is consumed by the Hassayampa load and thus the annual overall purchase cost from the grid is negative. CAP could receive ~$2.4 M annually in excess power sold back.

Table 6 - Comparison of Grid Cost with PV Sizes

Scenario	PV size (MW)	Capital Cost for PV ($)	Operating Cost ($/yr)	Total Net Present Cost ($)	LCOE ($/kWh)
Base case	0	n/a	10,089,453	128,977,080	0.035
1	20	60,000,000	8,533,963	169,092,704	0.045
2	50	141,000,000	5,566,226	212,155,056	0.054
3	100	286,000,000	-2,377,463	255,608,048	0.053

NREL performed a sensitivity analysis that assumed the cost to purchase power from the grid will increase to see at what cost the PV systems would be economically viable. We modeled the increase in purchase price from $0.035/kWh to $0.15/kWh. The sell-back price to the grid remained the same at $0.10/kWh. The capital cost of the PV system also remained the same. The analysis indicates that a 50-MW PV system would have the most cost-effective solution at $0.12/kWh. The graph in Figure 16 illustrates the price of power (x-axis) compared to the capacity size of the PV system (y-axis).

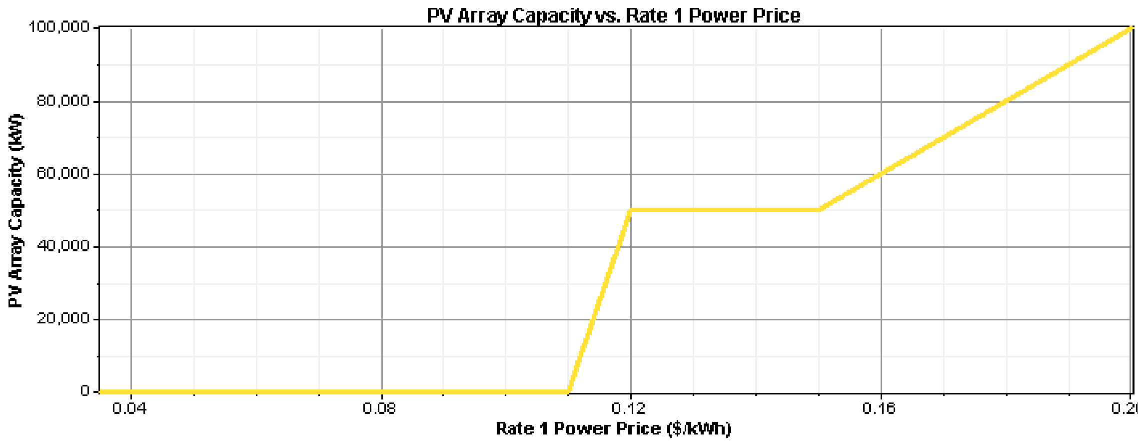


Figure 16 - Sensitivity analysis on increase price of power

Initial economic analyses indicate a single-axis tracking PV system may be the most cost effective. The greater production of the single axis tracking PV system, compared to the fixed mount PV system, more than offsets the higher initial cost of the single axis tracking PV system. The owner of the system would need to sell power for at least the LCOE to be economically feasible.

4.2.7 Facility-Scale Assessment of Phoenix Area Office

On August 30, 2011, a team led by NREL together with Reclamation personnel conducted an assessment of Reclamation's Phoenix Area Office building. During the site visit, the team identified several suitable locations for grid-connected PV and a possible location for solar hot water.

Reclamation's Phoenix Area Office is located at 6150 W. Thunderbird Rd., Glendale, Arizona. The structure is a two-story steel frame, exterior masonry office building with roof-mounted mechanical equipment. The building faces south, with the main entry on the south side. An aerial image of the building and surrounding carports is shown in Figure17, and a south elevation view is shown in Figure18.

The building is 6 years old and has a white membrane roof manufactured by Versico (Carlisle). The roof is in excellent condition and has 4 years left under warranty. It is important to confirm with the structural engineers that the roof is be capable of supporting a new ballasted PV system with a weight of about 4 lbs/ft^2. NREL believes that it will support such a system and has assumed so for this report.

Figure 17 - Aerial view of Phoneix Area Office (via Google Earth image provided by Reclamation)

Figure 18 - Phoenix Area Office South Elevation View

Energy Use and Utility Data

The Phoenix Area Office is connected to the SRP electric utility and Southwest Gas for natural gas. The electric rate structure is General Service (E36) http://www.srpnet.com/prices/business/general.aspx, which is an energy (kWh)-driven rate (85% of cost is energy) with minimal demand charges (6% of cost is demand) and minimal monthly service charges. The highest energy and demand charges are during the "summer peak" of July and August. The annual electrical energy use was 892,800 kWh in FY2010, and the average rate during FY2010 was $0.09/kWh.

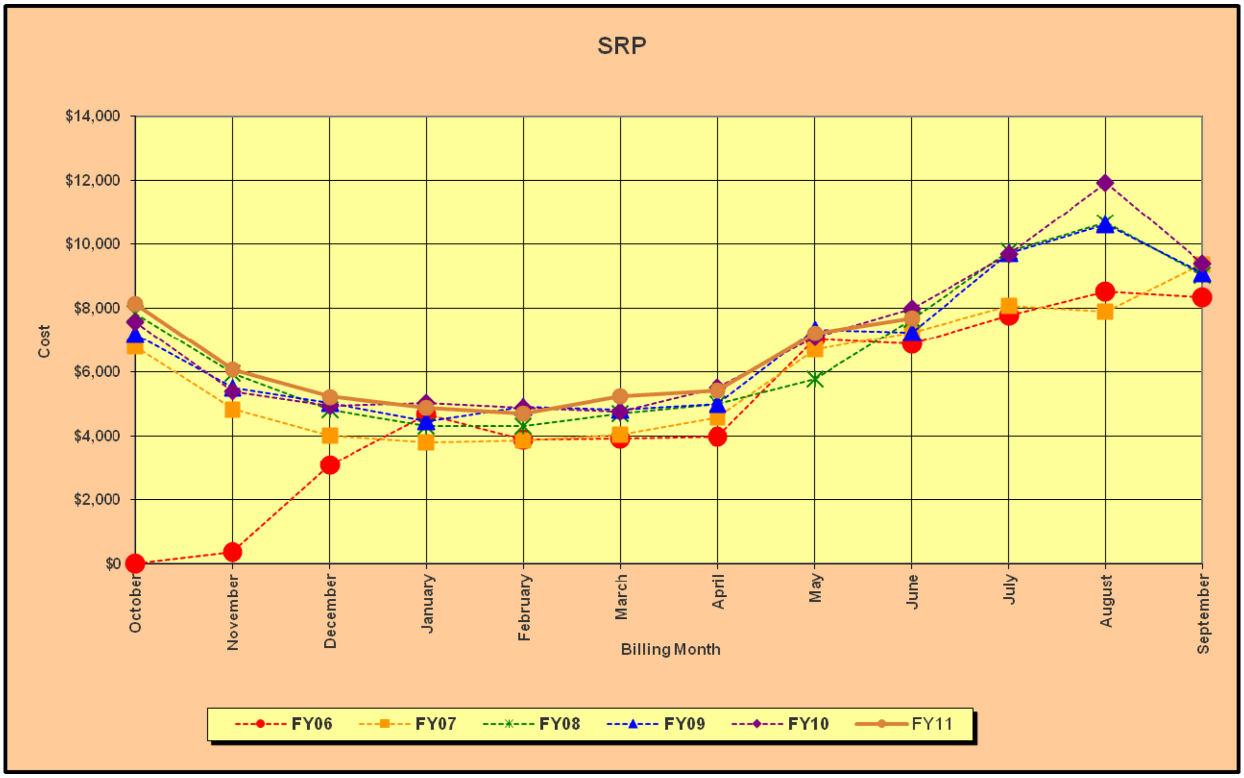


Figure 19 - Electrical Cost (FY 06 - FY 11)

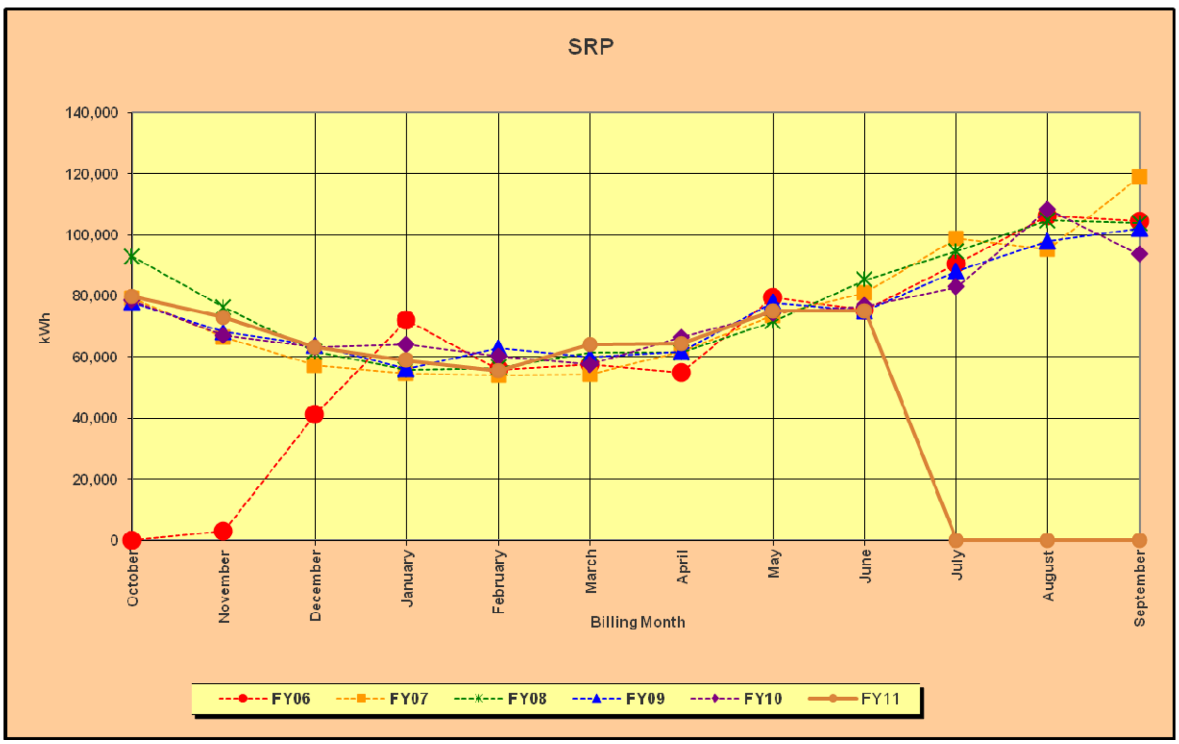


Figure 20 - Electrical Usage (kWh, FY 06 - FY 11)

The annual gas use during FY 2010 was 6,533 therms, and the total annual cost was $8,716 for an average of $1.33/therm. Gas is used just for space heating; the minimal amount of domestic hot water is generated by an electric water heater. The average cost per therm is high due to the monthly meter fee of about $50.

Facility-Scale PV Systems

The amount of energy produced by a PV panel depends on several factors, including type of collector, tilt and azimuth of the collector, temperature, level of sunlight, and weather conditions. An inverter is required to convert DC to alternating current (AC) of the desired voltage compatible with building and utility power systems. The balance of the system consists of conductors/conduits, switches, disconnects, and fuses. Grid-connected PV systems feed power into the facility’s electrical system and do not include batteries. Figure 21 shows the major components of a grid-connected PV system and illustrates how these components are interconnected.

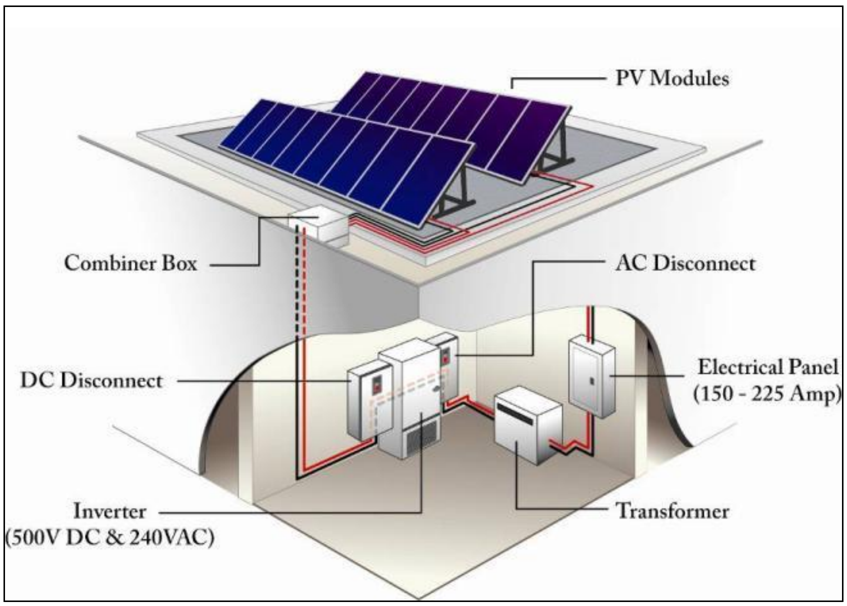


Figure 21 - Depiction of Major Components of Grid-Connected PV Systems

PV panels are very sensitive to shading. When shade falls on a panel, that portion of the panel is no longer able to collect the high energy beam radiation from the sun. PV panels are made up of many individual cells that each produce a small amount of current and voltage. These individual cells are connected in series to produce a larger current. If an individual cell is shaded, it will act as a resistance to the whole series circuit, impeding current flow and dissipating power rather than producing it. By estimating the amount of shading, the NREL team can determine whether the area is appropriate for solar panels.

If a site is found to have good potential for a PV system, the next step is to determine the size of that system. This is highly dependent on the average energy use of the facilities on the site. It is generally not advisable to provide more power than the site will use due to the economics of most net metering agreements.

PV systems have the following components:

- PV arrays that convert light energy to DC electricity
- Inverters that convert DC to AC and provide important safety, monitoring, and control functions
- Various wiring, mounting hardware, and combiner boxes
- Monitoring equipment

PV array. The PV array, which is the primary component of a PV system, converts sunlight to electrical energy; all other components simply condition or control energy use. Most PV arrays consist of interconnected PV modules that range in size from 50 to 300 peak DC watts. Peak watts are the rated output of PV modules at standard operating conditions of 25°C (77°F) and insolation of 1,000 W/m^2. Because these standard operating conditions are nearly ideal, the actual output will be less under typical environmental conditions. PV modules are the most reliable components in any PV system. They have been engineered to withstand extreme temperatures, severe winds, and impacts. Testing under ASTM E specification1038-93 subjects modules to impacts from 1-in. hail balls at terminal velocity (55 mph) at various parts of the module. PV modules have a life expectancy of over 30 years, and manufacturers warranty them against power degradation for 25 years. The array is usually the most expensive component of a PV system; it accounts for approximately two-thirds the cost of a grid-connected system. There is large choice of PV manufacturers although it is recommended that the PV panels be approved by Go Solar California.[6]

Inverters. PV arrays provide DC power at a voltage that depends on the configuration of the array. This power is converted to AC at the required voltage and number of phases by the inverter. Inverters enable the operation of commonly used equipment such as appliances, computers, office equipment, and motors. Current inverter technology provides true sine wave power at a quality often better than that of the serving utility. A location for the inverter along with the balance of the system equipment should be considered.

Inverters are available that include most or all of the control systems required for operation, including some metering and data-logging capability. Inverters must provide several operational and safety functions for interconnection with the utility system. The Institute of Electrical and Electronics Engineers, Inc. (IEEE) maintains standard P929, Recommended Practice for Utility Interface of Photovoltaic Systems, which allows manufacturers to write “Utility-Interactive” on the listing label if an inverter meets the requirements of frequency and voltage limits, power quality, and nonislanding inverter testing. Underwriters Laboratory

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[6] Go Solar California: http://www.gosolarcalifornia.org/equipment/pv_modules.php

maintains standard UL 1741, Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems, which incorporates the testing required by IEEE P929 and includes design (type) testing and production testing. There is a large choice of inverter manufacturers, although it is recommended that the inverter be approved by Go Solar California.[7]

Operation and Maintenance. The PV panels will come with a 25-year performance warranty; the inverters come standard with a 5- or 10-year warranty (extended warranties are available) and would be expected to last 10 to 15 years. System performance should be verified on a vendor-provided Web site. Wire and rack connections should be checked. For this economic analysis, an annual O&M cost of 0.17% of total installed cost is used based on O&M costs of other fixed-axis grid-tied PV systems.

PV Site Location and Performance

The PV arrays must be installed in unshaded locations on the ground or on building roofs that have an expected life of at least 25 years. The proposed roof site has excellent annual solar access. The predicted array performance was found using PVWatts version 2 for Phoenix, a performance calculator for grid-connected PV systems created by NREL's Renewable Resources Data Center.[8]

Table 7 - Annual AC Energy and Cost Savings Results in kWh/kW for 10-degree Fixed-Tilt PV from PVWatts for Phoenix

City:	Phoenix
State:	Arizona
Latitude:	33.43° N
Longitude:	112.02° W
Elevation:	339 m
PV System Specifications	
DC Rating:	1.0 kW
DC to AC Derate Factor:	0.820
AC Rating:	0.8 kW
Array Type:	Fixed Tilt
Array Tilt:	10.0°
Array Azimuth:	180.0°
Energy Specifications	
Cost of Electricity:	9.0 ¢/kWh

Results			
Month	**Solar Radiation ($kWh/m^2/day$)**	**AC Energy (kWh)**	**Energy Value ($)**
1	3.93	93	8.37
2	4.99	107	9.63
3	6.03	138	12.42
4	7.54	163	14.67
5	8.19	178	16.02
6	8.21	167	15.03
7	7.82	166	14.94
8	7.39	158	14.22
9	6.70	140	12.60
10	5.68	127	11.43
11	4.37	97	8.73

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[7] Go Solar California: http://www.gosolarcalifornia.org/equipment/inverters.php
[8] http://rredc.nrel.gov/solar/calculators/PVWATTS/version/

12	3.62	86	7.74
Year	6.21	1620	145.80

Figure 22 - Reclamation's Phoenix Area Office Building Proposed PV System Locations (Highlighted in Blue)

The south rooftop area and carports designated for PV installations are flat, have excellent solar exposure (see Figure 22 and Figure 23), and have few existing obstructions. The north, east and west roofs have too much shading for PV.

Potential and Carport Areas

The potential roof area assumes a 4-ft setback from the roof edge. A PV power density of 8 W/ft^2 was assumed, which is representative of a crystalline silicon panel tilted at 10˚ installed on a ballasted racking system similar to GSA Denver Federal Center (Figure 23).

Figure 23 - Typical Ballasted PV System at GSA Denver Federal Center

Roof area. The roof is in excellent condition and suitable for a ballasted PV system. The south wing has approximately 2,300 sq ft total unshaded area available (Figure 24), the east wing has approximately 750 sq ft available (Figure 25), for an assumed total available area of approximately 3,000 sq ft. Using an installed PV power density of 8 W/ft^{2}, up to 24 kW of PV could be installed. If the areas are optimized or higher efficiency modules are used, up to 30 kW could be installed, which is what is assumed for this study. The existing electrical panel LP2A has spaces and capacity for PV breakers (Figure 26). The electrical room has has adequate room for PV inverters (Figure 27)

Figure 24 - South wing looking west where PV is proposed (Top); and looking east (bottom) 2,300 ft2 unshaded area view

Figure 25 - East wing roof looking east (top) is also suitable for PV (750 ft2); typica parapet is about 28-inches high (bottom)

Figure 26 - Panel LP2A has many spaces where PV breakers could be installed (top); 225 A, 480 V Panel LP2A has adequate capacity for PV (bottom)

Figure 27 - Panel LP2A is located in the electrical room near the roof, room has adequate room for PV inverters

Carport area: The Phoenix area office has six large, unshaded carports that should be used for PV (Figure 28 and Figure 29). The two northeast-most carports have an existing SRP PV system. Each carport is 18 ft × 140 ft (2,520 sq ft each), so the available area is 15,120 sq ft, which is enough for 120 kW at 8 W/sq ft. The carport area is the best location for PV because there are no issues with roof warranties, potential roof leaks, etc. There is a minor concern about possible vandalism from people throwing rocks on the east-most carports.

Figure 28 - Existing carports are excellent for PV looking southeast (top); looking northeast note the existing PV on the east-most carport (bottom)

Figure 29 - Northwest carports looking northwest (left); carport structure (right) PV support racking would need to be attached to structure

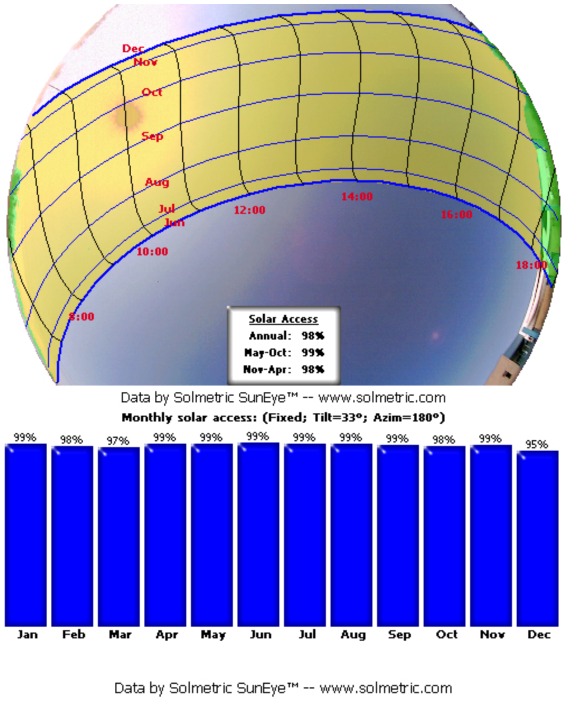

Figure 30 - Solmetric SunEye used to measure solar access; all areas have excellent solar access

Another good option to consider is concentrating PV (CPV), which uses optics to concentrate sunlight on high efficiency PV cells. Solfocus http://www.solfocus.com/en/ has a manufacturing plant in Mesa, Arizona, and should be contacted by Reclamation for a possible highly visible demonstration project at the Phoenix Area Office. There are several other good CPV manufacturers that could also be considered, but they do not have Phoenix area manufacturing facilities. The southwest corner of the site behind the southeast sidewalk and the picnic area north of the building are all excellent highly visible locations (Figure 31 and Figure 32).

Figure 31 - Possible CPV locations (top); close up of area (bottom)

Figure 32 - Possible CPV Locations (left); southwest corner of site (right) behing southeast sidewalk

4.2.8 Economics and Performance

Assumptions and Input Data for Analysis

For this analysis, the following input data were used. The prices used include the PV array and the balance of system components for each system, including the inverter and electrical equipment, and installation. The economics of grid-tied PV depend on incentives, the cost and rate structure of electricity, and the solar resource, including panel tilt and orientation.

A system DC-to-AC conversion of 82% was assumed. This includes losses in the inverter, wire losses, PV module losses and temperature effects, etc. Figure 33 summarizes average system installation costs for grid-tied U.S. PV systems in 2010 and 2011; the costs have dropped since June 2011—an installed cost of \$5/W is assumed.

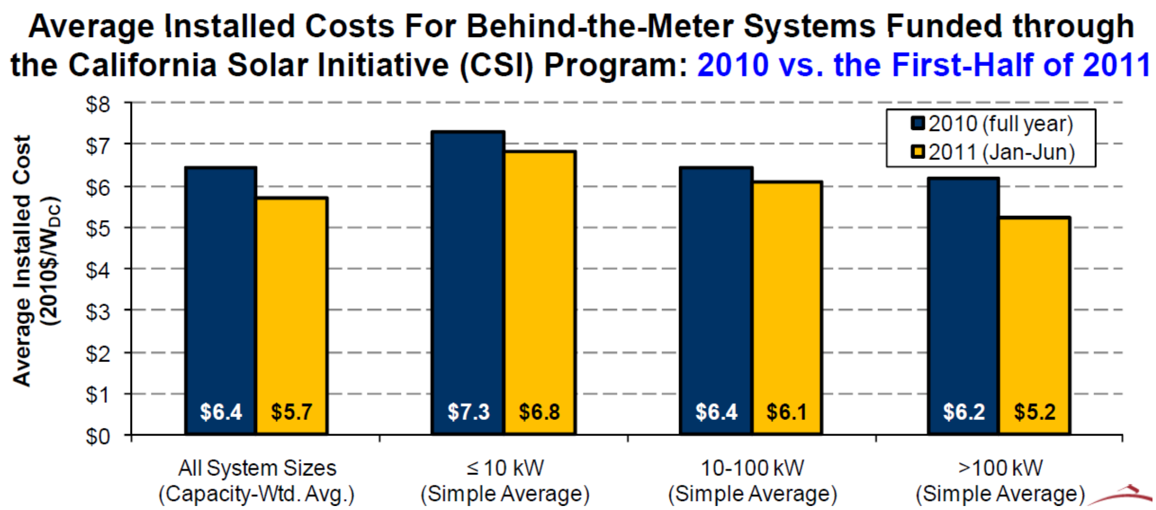

Figure 33 - PV Costs[9]

Other Incentives and Financing Opportunities
The Database for State Incentives for Renewable Energy (DSIRE) www.dsireusa.org provides a summary of net metering, interconnection, and incentives available to customers. The utility for the site is SRP.

Net Metering Agreement—SRP net metering is available to customers who generate electricity using PV, geothermal, or wind systems up to 100 kW in AC peak capacity.

The kilowatt-hours delivered to SRP shall be subtracted from the kWh delivered from SRP for each billing cycle. If the kWh calculation is net positive for the billing cycle, SRP will bill the net kWh to the customer under the applicable price plan (Standard Price Plan E-21, E-23, E-26, E-32, E-36, E-47, E-48, E-61, E-63, E-65 and E-66) for which they take service. If the kWh calculation is net negative for the billing cycle, SRP will carry forward and credit the kWh against customer kWh usage on the next monthly bill. However, if the kWh is net negative at the end of the April billing cycle, SRP will credit the net kWh from the customer at an average annual market price. No credits will be carried forward to the May billing cycle.

Interconnection— In June 2007, the Arizona Corporation Commission (ACC) initiated a rulemaking process to establish statewide interconnection standards for distributed generation (DG). This proceeding is still in progress. Until the new

[9] Wiser, R., et al., *Tracking the Sun II*, Environmental Energy Technology Division, Lawrence Berkeley National Laboratory, 2011.

official rules go into effect, the commission has recommended that the utilities use the Interconnection Document (http://images.edocket.azcc.gov/docketpdf/0000074361.pdf) as a guide. This document applies to systems up to 10 MW in capacity.

The state's utilities independently developed interconnection agreements for DG prior to the ACC's ongoing proceeding to establish statewide standards. The SRP, which is not regulated by the ACC on utility matters, developed DG interconnection guidelines and an interconnection agreement based on draft rules and a report released by the ACC in 1999 and 2000, respectively. SRP's rules include technical protection requirements, a flow chart of interconnection procedures, and a two-page interconnection application. The rules establish separate requirements for units based on system capacity:

- Class I: 50 kW or less, single or three-phase
- Class II: 51 kW to 300 kW, three-phase
- Class III: 301 kW to 5 MW, three-phase
- Class IV: greater than 5 MW, three-phase

For more information on SRP interconnection requirements see http://www.srpnet.com/electric/Generators.aspx?res

SRP's EarthWise Solar Energy Program provides incentives to its residential and commercial customers to purchase PV or solar water-heating systems. In exchange for the incentives, SRP will receive all the renewable energy credits (RECs) associated with the systems. SRP's Board of Directors set a voluntary goal in 2004 of having 15% of their retail sales come from renewable resources by 2025, mirroring the renewable energy standard that other Arizona utilities are required to meet. The RECs that SRP receives through the EarthWise program will help the utility meet this goal. Note that if Reclamation sells the RECs and wants to take credit for the solar system, Reclamation would need to buy replacement RECs.

As of June 28, 2011, small commercial PV systems (30 kW and smaller) can receive a one-time incentive of $1.35/watt DC, up to a maximum of $40,500. The budget for larger commercial PV systems (30 kW to 600 kW) is currently exhausted. See website above for more details. SRP has funding for a total of 1.1 MW of small commercial PV systems and 6 MW of large PV systems, through April 30, 2012. PV incentives are scheduled to step down twice during this time period as certain MW levels are installed.

For details, see http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=AZ11F&re=1&ee=1

As of August 2011, funding set aside for production-based incentives for PV systems larger than 30 kW has been exhausted through April 30, 2012. SRP will, however, honor applications that have already been awarded an incentive reservation. SRP will also accept an additional 2 MW of applications in the event a previously approved project is cancelled. See the website above for more information.

There are several options for getting a solar PV system financed. The best option is to obtain agency appropriations, which is analyzed in detail below. One potentially plausible financing option is third-party ownership. The agreement works by having a solar contractor install, finance, and operate the system while the customer (Reclamation) purchases the electricity generated by the system. This arrangement is called a Power Purchase Agreement. For more information on PPAs, see
http://www1.eere.energy.gov/femp/financing/power_purchase_agreements.html

A solar lease agreement is another option that could be considered. If the PV system is owned by a private tax-paying entity, this entity can qualify for a 30% federal tax credit and accelerated depreciation on the PV system, which is worth about 15%. The total potential tax benefits to the tax-paying entity are about 45% of the system cost. Because the state and federal governments do not pay taxes, private ownership of the PV system would be required to capture tax incentives. In this configuration, the land or roof area that the solar system is on would need to be leased to the owner of the system for the duration of the contract. Because of the high transaction costs of a PPA, only large PV systems should be considered. By combining carport (120 kW), roof (30 kW) and ground-mounted CPV (100 kW?), at least 200 kW of PV could be installed, which is large enough for a PPA.[10]

Data and Assumptions

Because the PV system size preferred by Reclamation is unknown, NREL assumed a 30-kW PV system; because of economies of scale, a large system will have lower costs and better economics. However, no incentives currently exist for larger systems. If incentives for larger systems become available again, NREL could analyze the economics based on the incentives.

Performance and Savings Results

A 30-kW system will generate approximately 48,600 kWh per year, offsetting approximately 5% of the Reclamation Phoenix Area Office annual electrical energy needs. The system would cost approximately $111,000 AFTER the SRP incentive of $39,000. The payback would be marginal at 27 years. By including

[10] Power Purhase Agreements, or PPAs, represent a contract between a utility and a private company under which the company sells power to the utility over a period of time, usually 20 years. Due to the legal complexities and high costs of negotiating and monitoring these agreements, PPAs typically only make sense for large systems – at a minmum over 150 kW, and often much larger than this.

the carports (120 kW) with the rooftop system (30 kW), a 150-kW system could be installed that would generate approximately 243,000 kWh per year, offsetting approximately 27% of the Reclamation Phoenix Area Office's annual electrical energy needs. If incentives for larger systems become available again, a PPA would be feasible (150 kW and larger) and would be recommended. If CPV is installed, the savings would be even larger.

Table 8 - PV Economics

Tie in Location	Array Tilt (Deg)	Area (ft^2) Reqd	PV Syst. Size (kW)	Annual Output (kWh/yr)	Annual Cost Savings ($/yr)	Annual O&M ($/yr)	Annual Cost Savings after O&M ($/yr)	System Cost with No Incentives ($)	Total System Cost with No Incentives ($)	Payback Period with No Incentive (years)	SRP Incentive $1.35/W DC capped at $40,500	Cost $ after incentiv
BOR Phoenix Area Office = 892,800 kWh annual												
Roof mounted	10	3,750	30	48,600	4,374	255	4,119	150,000	150,000	36	39,000	111,0
Carport mounted	10	3,750	30	48,600	4,374	255	4,119	150,000	150,000	36	39,000	111,0
					Maximum Carport PV							
Carport mounted	10	15,120	121	195,955	17,636	1,028	16,608	604,800	604,800	36	40,500	564,3

Note that federal tax incentives are only available for taxpaying entities.

4.2.9 Facility Scale – Conclusions and Recommendations

Reclamation's Phoenix Area Office in Glendale, Arizona, considered for a solar PV system in this report has many near-ideal areas in which to implement a PV system. It is recommended that Reclamation contact SRP and reserve incentives for a 30-kW DC (or other size, as determined by Reclamation). If incentives for larger systems become available again, a larger system should be installed. When the system goes out to bid, a design-build contract should be issued requesting the best performance (in kWh/yr) at the best price and let the vendors optimize the system configuration, including racking, slope, modules, etc. Because of the high cost of energy, dropping cost of PV, excellent solar resource, and excellent incentives, a government-owned PV system provides a reasonable payback, is easy to implement, and is therefore recommended. If funding is not available, then a third-party PPA is the most plausible way for a system to be financed on this site. Upon request, NREL will be glad to help with the procurement, bid evaluation, design reviews, etc., for PV systems.

4.2.10 Overall Conclusions and Recommendations

Utility Scale

Given current power market conditions and the low costs of power from the NGS, the economic case for installing utility-scale solar on Reclamation land and using this power directly to power CAP pumps is challenging on a cost basis. However, given the continued drop in solar prices and an expected increase in NGS generation costs over time, it will be important for Reclamation to monitor market conditions going forward and revisit this analysis as situations change.

If Reclamation desires to pursue siting of utility-scale projects on its land, the best case would be for Reclamation to act simply as a land owner and issue a right-of-way grant to a private-sector company. Results of the analysis in this report indicate that the developer would need to obtain a long-term PPA from a utility of at least $0.10/kWh to make the project economically viable. The ability of a private-sector company to obtain a purchase price of $0.10/kWh is not known at this time. The demand for renewable energy in the western United States depends on a number of factors, including regulatory mandates arising from state RPSs, low prices for natural gas, lack of transmission into the California market, and projections for continued drops in PV prices due to technology improvements and structural imbalances (global oversupply of panel manufacturing capacity) in the industry.

One next step to further facilitate siting a project on Reclamation land would be for Reclamation to pre-qualify the development potential of the most promising sites (e.g., Hassayampa), especially in terms of identifying areas that are near transmission lines that have capacity and have the potential for very low environmental and cultural impacts. The BLM is conducting an analysis in Arizona called the Restoration Design Project that aims to identify the best suitable lands and areas in the state for renewable energy development, Reclamation could talk to BLM to determine if any Reclamation lands that are located adjacent to BLM lands can be included in any programmatic Environmental Impact Statement (EIS) analyses that get conducted. Alternatively, Reclamation could conduct its own programmatic EIS or even a site-specific EIS for a given site. Once Reclamation determines that a site is a high quality location with strong development potential, Reclamation can issue a competitive lease solicitation that can be used to evaluate industry interest in moving forward with a project at that site.

Facility Scale

The Reclamation Phoenix Area Office in Glendale, Arizona, which is considered for a solar PV system in this report, has many near-ideal areas in which to implement a PV system. It is recommended that Reclamation contact SRP and reserve incentives for a 30-kW DC (or other size, as determined by Reclamation). If incentives for larger systems become available again, a larger system should be installed. When the system goes out to bid, a design-build contract should be issued requesting the best performance (in kWh/yr) at the best price and let the vendors optimize the system configuration, including racking, slope, modules, etc. Because of the dropping cost of PV, excellent solar resource, and good incentives, a government-owned PV system provides a reasonable payback, is easy to implement, and is therefore recommended. If funding is not available, then a third-party PPA is the most plausible way for a system to be financed on this site. Upon request, NREL will be glad to help with the procurement, bid evaluation, design reviews, etc., for PV systems.

4.3 Solar Panels Covering the CAP Canal

Many people have the idea of covering the CAP Canal with solar panels in order to generate electricity and prevent evaporation on the system. Although this is a good thought there are may issue which need to be addressed if this idea should go forward.

The Phoenix Area Office performed a 40,000 foot look at the possibility of adding solar panels the CAP in order to reduce evaporation. In a study performed by Manifest Energy in 2007 the following information was provided:

Q: How much water is lost through evaporation (or seepage)?

A: Due to the design, constant delivery system and efficient operation methods, CAP's average annual evaporation loss is 4.4 percent, or 16,000 acre feet from the aqueduct and 50,000 acre feet from Lake Pleasant. Seepage losses are 0.6 percent, or 9,000 acre feet per year.

The Central Arizona Water Conservation District measured evaporation and seepage losses from the aqueduct during tests in August and September of 1989. Water was lost at an average daily rate of 0.062 cubic feet per square foot of aqueduct (Central Arizona Water Conservation District, 1989). This translates to a relatively constant water loss of about 82,000 acre-feet per year. Approximately 17,000 acre-feet of the total were lost to evaporation and 65,000 acre-feet lost to seepage (U.S. Bureau of Reclamation, 1986)[11].

11 http://www.azwater.gov/azdwr/StatewidePlanning/RuralPrograms/OutsideAMAs_PDFs_for_web/Lower_Colorado_River_Planning_Area/Colorado_River_Watershed.pdf

SOLAR PANEL – MANIFEST ENERGY

Aqueduct Losses from CAP Aqueduct (for 2007)
* per CAWCD's 2007 Aqueduct Loss Study Report

Actual loss = 22,202 acre-feet
Total Canal Miles = 319 miles
Loss per mile = 22,202/319 = 69.5 acre-feet/mile

Seepage vs. Evaporation

Seepage Rate = 0.45 ft/month
Evaporation Rate = 0.12 to 0.90 ft/month (depends on season)
= 0.50 ft/month

Results
For estimating purposes use net loss of: **36 acre-ft/mile for evaporation (annually)**
34 acre-ft/mile for seepage (annually)

Potential Net Savings of Evaporation from Shading
* net savings percentage estimate uses no engineering basis

Estimate 10% net savings in Evaporation
= 0.10 x 36 acre-feet/mile
= **4 acre-feet/mile, annually**

/s/ Peter Castaneda
7/28/09

5.0 Appendices

Appendix A – NREL Report

"Renewable Energy Assessment for the Bureau of Reclamation" - Haase et all; May 2012, under Interagency Agreement R11PG81316

http://www.nrel.gov/docs/fy13osti/57123.pdf

Appendix B – Various Renewable Energy Concepts

Figure 34 - Example of Solar VP at Alamosa Colorado

Figure 35 - Stirling Engine Solar Array

Figure 36 - Amonix Concentrated Photovoltaic Solar Array

Figure 37 - Opel Concentrated Photovoltaic Solar Arrays

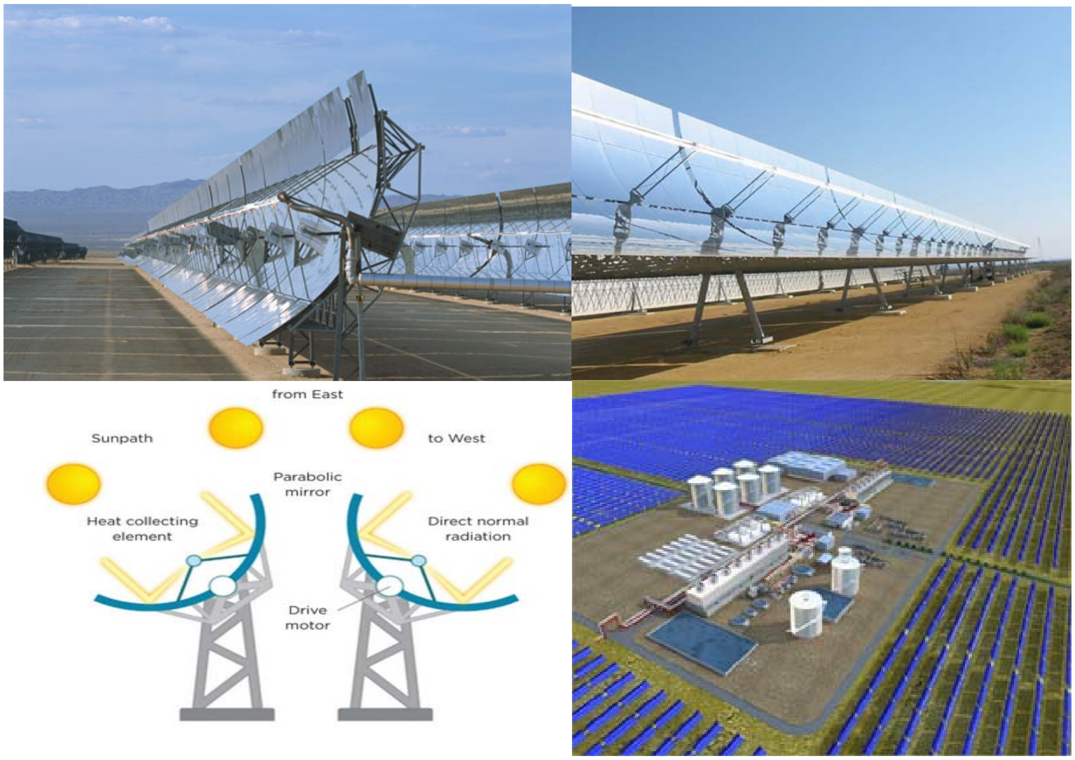

Figure 38 - Concentrated Solar Thermal Parabolic Trough Technology

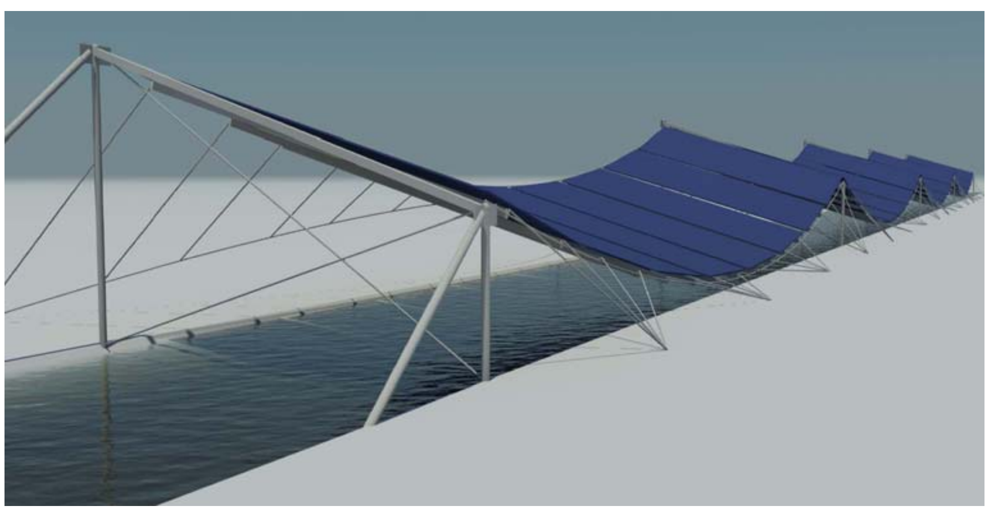

Figure 39 - Concept of Solar Over Canals

Figure 39 - Conceptual Look at Solar Along CAP Canal