



Image source: UANews.org
Solar Zone at UA Tech Park

Renewable Energy Opportunity Analysis Summary Report

Solar Facility Siting Analysis for the South Region of Arizona
(Pima, Cochise, and Santa Cruz Counties)

April, 2013

Prepared by University of Arizona Cooperative Extension with the University of Arizona College of
Architecture, Planning and Landscape Architecture

Contents

INTRODUCTION.....	3
GENERAL CRITERIA USED FOR SITING SOLAR FACILITIES	3
METHODS.....	4
RESULTS AND INTERPRETATION.....	5
HOW THE RESULTS OF REOA MAY BE USED.....	6
ABOUT THE UNIVERSITY OF ARIZONA AND COOPERATIVE EXTENSION.....	7
CREDITS.....	8
CONTACT INFORMATION.....	8
APPENDIX 1 –GIS DATA, GOALS, OBJECTIVES AND WEIGHTS.....	9
APPENDIX 2 –SUITABILITY MAPS.....	11

INTRODUCTION

In 2012, Cooperative Extension's Land Use Planning and Sustainable Development Program was requested by Cochise County to conduct an analysis for solar energy development potential on the 6200 square miles within their jurisdiction. Any county surpassing 125,000 in population per the 2010 Census is required by state statute (ARS §11-804.B.4) to amend their comprehensive plan with an Energy Element. The analysis was expanded to include other counties around the state, regardless of their population size. It is the hope that this analysis will aid counties, cities and towns in developing sound land use policies for siting renewable energy facilities. The analysis, using the Renewable Energy Opportunity Analysis (REOA) model, was conducted to identify areas of low, moderate and high potential for small and large solar projects on a regional basis. The resulting outputs should help renewable energy developers and the counties begin the more complex task of focusing on specific areas with sites that show the highest potential within their region. This report will explain the methodology behind the analysis, summarize the results, and provide some direction for the use of the outputs.

GENERAL CRITERIA USED FOR SITING SOLAR FACILITIES

While many factors go into siting solar facilities, REOA assesses fundamental physical and economic opportunities and constraints on any given piece of land. First and foremost, the insolation factor, the amount of solar radiation reaching a given area, is high for virtually all of Arizona. United States Solar Resource maps for photovoltaic (PV) and concentrated solar projects (CSP) produced by the National Renewable Energy Lab (<http://www.nrel.gov/gis/solar.html>) show Arizona and the southwest US to have the highest insolation rates in the entire country - on average, greater than 6 kWh per meter² per day. Our analysis weights areas that have a minimum of 7 kWh per meter² per day as the best.

Topography is taken into account by analyzing the slope of the land, which, for solar installations, needs to be no greater than a 4% grade. Slopes less than 2% are given the highest consideration. In addition, topography is more critically assessed using digital elevation models to look at the potential impact of shading from steep sloped areas.

The presence of major washes is taken into consideration by creating a 600' buffer around all major wash centerlines and 1000' from major rivers and lakes. This analysis does not preclude the presence of 100-year floodplains nor minor washes. These would need to be considered in site-specific studies, since construction is feasible in some floodplains, depending on flood elevations.

Land jurisdictions that were designated as National Forest, National Park Service, wildlife refuges, and other areas precluded from solar development, were also filtered out. Altogether, these physical factors were applied as a "mask" to eliminate areas, as a primary filter, where renewable energy development would not be feasible at all. Incorporated versus unincorporated areas were not differentiated in this analysis.

The remaining areas were then modeled using the physical and economic factors as weighted criteria for determining high, medium or low suitability for solar development. The Methods section will go into greater detail about the modeling.

The resolution (level of detail) for this REOA is a cell size of 10 meters by 10 meters, or approximately 1100 square feet. A conventional solar PV project requires approximately 10 acres per megawatt, so this modeling is aptly suited to understanding not only the spatial opportunities for projects, but also the amount of potential energy output based on available and consolidated acreage.

While REOA is limited to these particular factors regarding the siting of solar facilities, other criteria can be used by a planning jurisdiction or developers to further assess the potential of a particular parcel of land. As data is available, overlays like wildlife corridors, city, county or state designated scenic corridors, open space, archaeological and cultural sites, clusters of address points, recharge areas and any other constraints, may be applied as transparent layers to preclude certain acreages. For more focused analyses on sub-areas of a region, an overlay of vacant properties and/or properties for sale would be very useful to further narrow the search for areas of high opportunity and available land for any particular renewable energy project.

METHODS

The Renewable Energy Opportunity Analysis (REOA) is a systematic process that uses the concepts of capability and suitability. Capable areas are those areas that are limited by absolute constraints, whereas suitable or potential areas are ranked within those areas that have already been determined to be capable. Incapable areas are any areas that are not considered feasible for siting a solar energy facility, such as those areas with certain land ownerships or management constraints, steep slopes, poor soil conditions, shading, or major washes, as described in the previous section. A mask, or modeling extent, that consists only of those areas that are capable of siting a solar energy facility is generated with all incapable areas removed (Figure 1).

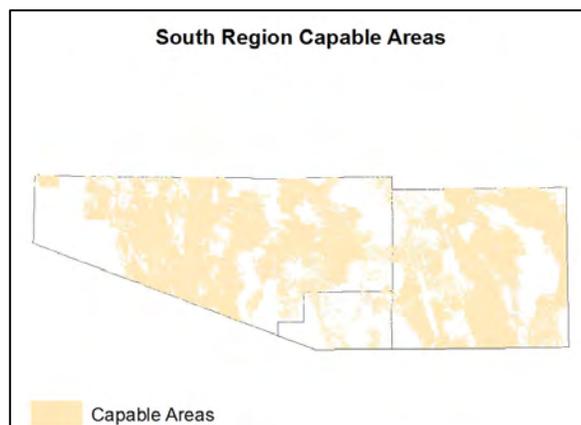


Figure 1

After capable areas are determined, Goals and Objectives, which are hierarchical statements that define what is to be accomplished (goal) and how to achieve the goal (objectives and sub-objectives), are written to model suitability or potential. Each goal includes physical and economic objectives, as well as a series of sub-objectives that attempt to capture the complexity of land-use suitability or potential. For this analysis, there are two main goals – one to determine the potential for small scale solar projects of 5 MW or less and one for large scale solar projects, greater than 5 MW. Each of the goals has two main objectives - physical and economic factors, and a range of sub-objectives. The objectives and sub-objectives are all assigned weights based on their relative importance to each other, according to expert consensus.

The physical objective used in the modeling was the aspect of land (north facing, south facing, etc.). The economic objectives include the proximity to existing roads, railroads as well as proximity to transmission lines and sub-stations. Proximity to railroads is more important for larger projects since transporting equipment from a railroad siding to a construction site can be very costly, depending on the distance. This objective is not considered at all in the model for small scale projects. Distance to large transmission lines (115-230 kV) becomes a more important objective for larger projects (> 5 MW), especially where capacity in the existing line and regulatory approvals for new lines from the Arizona Corporation Commission (ACC) may be an issue. Proximity to existing sub-stations is an important economic factor as well for larger projects greater than 5 MW (personal communication, David Bryan, SSVEC).

This analysis used a wide range of geographic information system (GIS) data layers in raster and vector formats from a variety of data sources. All of the data was managed in a geodatabase in ArcCatalog and converted to the same projection and coordinate system (NAD 83 UTM Zone 12N) for consistency.

After all of the data were collected and processed, GIS models were created in ArcGIS ModelBuilder. As this spatial modeling is all raster-based, a cell size of 10 meters by 10 meters (.026 acres), the Pima, Cochise and Santa Cruz county boundaries as the project extent, and the capable areas (Figure 1) were used as the project mask. A unique model is created in ModelBuilder for each of the different goals, objectives and sub-objectives. Depending on what the objective or sub-objective asks for, different tools from the ArcGIS Spatial Analyst Extension are used. For example, the Goals & Objectives refer to proximity to substations, roads, railroads, and transmission lines. To determine proximity, the model uses the Euclidean Distance function, which measures straight-line distance from each raster cell to the closest source. The output of a Euclidean Distance function is a raster that shows the distance from a source to all other sources. Figure 2 shows an example of proximity ranges for sub-stations in a county. This raster is assigned a weight from the Goals & Objectives, and it is later combined and weighted with all the other rasters to create a final suitability grid with value ranges of 1 (low suitability or potential), 2 (moderate suitability or potential), and 3 (high suitability or potential).

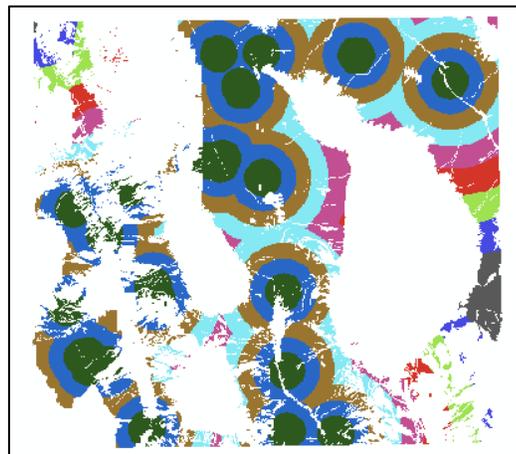


Figure 2 - Euclidean Distance to Substations

A detailed description of the GIS data, goals and weighted objectives can be found in Appendix 1.

RESULTS AND INTERPRETATION

As mentioned previously, the goals of this analysis were to identify opportunities for large and small utility-scale solar facilities within the South Region of Arizona (Pima, Cochise and Santa Cruz Counties). As part of the REOA, the number of acres identified as high, moderate and low potential were calculated and are listed in Table 1. More importantly, the spatial locations of these solar facility opportunity classes are provided in the two maps found in the appendices. A CD is provided as part of this report with map files as well as the ArcCatalog GeoDatabase and opportunity classes GIS shapefiles for this project.

Table 1. Opportunity Analysis Results for Potential Solar Installations in East Central Arizona

Potential for Solar Installations	Small Projects 5 MW or Less (acres)	Large Projects Greater than 5 MW (acres)
High Potential	1.6 million	1.1 million
Moderate Potential	2.6 million	2.5 million
Low Potential	1.6 million	2.1 million

The results of the modeling are ranked by suitability or potential on the maps. The color scheme is consistent throughout the maps presented, with red indicating low, yellow indicating moderate, and green indicating high suitability. White areas in the REOA maps along with National Park Service,

Forest Service and other conservation properties are those areas that are not capable. There are two map outputs – one for small-scale and one for large-scale solar projects. There are some very noticeable differences between the small and large-scale solar opportunity maps. For example, in the large-scale solar opportunity map, there are many areas that are ranked low-suitability. This is due to the requirement of a specific distance to transmission lines of 115 KV or greater in the Goals & Objectives. In this example, we did not use the Euclidean distance function, but rather a specific distance buffer of 300' to transmission lines (high potential), 300' – 1000' to transmission lines (moderate potential), and greater than 1000' to transmission lines (low potential). Therefore, when you examine areas that are immediately adjacent to transmission lines, you can see there is often higher suitability. However, suitability is also impacted by the other objectives such as proximity to roads to access a project site. Since transportation routes aren't weighted as heavily for smaller projects, there are greater expanses of highly suitable areas for small-scale solar projects throughout the region (see Table 1).

One can also see the presence of the effects of the different sub-objectives in the final suitability maps. For example, there are often areas of high or moderate suitability that are circular within an area around a substation. This is due in part to the use of the Euclidean distance function. These types of results are to be expected from a spatial modeling process such as this one, and it is important to remember that any model is only as good as the data inputs it uses and not all data is up to date or complete, though we have strived to use the most current data. Additionally, all models must be ground-truthed, as they are only a first-cut and not a final assessment of the real-world suitability of a given area of land for a specific purpose.

HOW THE RESULTS OF REOA MAY BE USED

As noted earlier in this report, counties with populations greater than 125,000 are required to amend their comprehensive plans with an Energy Element and those with less than 125,000 may do so voluntarily. ARS §11-804.B.4 stipulates planning for energy use in counties that (a) encourages and provides incentives for efficient use of energy; and (b) identifies policies and practices for greater use of renewable energy. For cities and towns, ARS §9-461.05 stipulates that general plans include consideration of air quality and access to incident solar energy for all categories of land uses. These maps may be adopted by any county, city or town as a baseline resource for any new plan policies that may be developed forthwith regarding renewable energy development.

The results of the analysis may be used to develop factors in favor or factors against any one proposal proposed to a county, city or town through their special/conditional use process. Or, in the case of permitted uses, the analysis may be used to determine any project's feasibility or validity.

In addition to planning jurisdictions, the REOA is the first step in helping any renewable energy developer, chamber of commerce, utility company or economic development interest understand, spatially, where the greatest potential for solar energy power facilities is within any given area. This analysis, however, is only the first step in determining the on-the-ground feasibility of constructing any utility-scale facility. Further site planning and engineering will certainly be required. With the results of this REOA, potential solar developers may save considerable amounts of time and money by focusing on those geographic areas with moderate to high potential. Any further analysis will most certainly be coupled with other considerations and policies, such as economic impact, ACC permitting requirements, access, impacts to nearby residential neighborhoods, water use, scale and type of solar development.

As an example of economic impact, the Public Service Company of New Mexico is actively siting 5 MW projects around their state to meet their statewide renewable energy goal. Using the standard of 10 acres required for one megawatt of generated power, a typical 5 MW solar PV project requires

about 50 acres of land. A project of this size has the potential to power approximately 3,000 to 4,000 homes and generate 60 to 75 construction jobs over a period of two to three months. In New Mexico, PV panels are less than four feet high and require no concrete footing. A typical 5 MW solar PV construction project involves the installation of approximately 79,000 panels mounted on 8,000 posts at a cost of approximately \$23 million (source: Gary Barnard, Public Service Co. of New Mexico, 2011).

The Bureau of Land Management (BLM) recently conducted a statewide assessment of solar potential in Arizona. Their Draft Environmental Impact Statement says, “The BLM proposes to identify Renewable Energy Development Areas (REDAs) and a Solar Energy Zone (SEZ) for Arizona that include disturbed sites such as brownfields, landfills, retired agricultural lands, or abandoned mines, and lands with low resource sensitivity and few environmental conflicts.” (Arizona Restoration Design Energy Project Draft EIS, 2012). However, there are some distinctions between the BLM’s analysis and this one worth noting:

BLM analysis

- Utility-scaled solar projects are defined by BLM as 20 megawatts or greater. This analysis (REOA) considers smaller utility scale projects that do not necessarily have the same fundamental requirements, such as proximity to transmission lines greater than 115 kV.
- The BLM assessment looked for sites of 100 acres or more for commercial applications. REOA has a resolution of 100 square meters and therefore considers a much broader range of potential acreage.
- Sensitive Resources and Land Management designations were criteria used by BLM. While property ownership for certain lands was taken into consideration, REOA allows for the consideration of sensitive resources by a developer or jurisdiction as a follow-up to the initial assessment of the county’s overall potential for siting utility-scale solar facilities.
- The weighting of distance to transmission lines was less than other factors in the BLM analysis. In REOA, this is a more heavily weighted objective, given the regulatory process, time and money it takes to site and build new transmission lines.
- REOA provides for a broader range of acreage with high and moderate suitability for siting solar facilities of various sizes. The results of REOA favor smaller scale projects of 5 MW or less.

The REOA results provided here are available for a more detailed review for any given sub-area of the region. For example, if a city, town or unincorporated community are interested in the high opportunity areas in their vicinity, these results can be made available as shapefiles, sub-area maps or files for viewing in Google Earth. Arizona Cooperative Extension can provide and present this data upon request.

ABOUT THE UNIVERSITY OF ARIZONA AND COOPERATIVE EXTENSION

The Land Use Planning and Sustainable Economic Development Programs were established within the University of Arizona Cooperative Extension to create, apply and transfer multidisciplinary knowledge to help people understand community change and identify opportunities. The programs provide and facilitate public issues education so that citizens are actively involved in defining and contributing to the future of their communities and decision makers are better informed about issues addressing use and management of natural resources, the rural-urban interface, economic development, land use planning and local government structure and operation. Extension Agents develop and generate information/data and conduct and evaluate educational programs on community issues that address priority needs of the county, state and nation.

The mission of the College of Architecture, Planning and Landscape Architecture (CAPLA) at the University of Arizona includes the advancement of the college, university, community, and profession

through service and outreach. The faculty and outreach units within CAPLA are engaged in a variety of projects including the Drachman Institute, dedicated to the environmentally sensitive and resource-conscious development of neighborhoods and communities, and individual faculty research, ranging in growth management and land use research with Native American tribes to GIS modeling to identify conflicts among land use stakeholders.

Funding for this project was provided by a grant from the US Department of Commerce's Economic Development Administration (EDA) and administered through the University of Arizona's Department of Agricultural and Resource Economics.

CREDITS

Mark Apel, Area Associate Extension Agent, University of Arizona, College of Agriculture and Life Sciences, Arizona Cooperative Extension

Iris E. Patten, Ph.D., Assistant Professor, University of Arizona, School of Landscape Architecture and Planning

R. Aaron Galvez, GIS Technician, University of Arizona, School of Landscape Architecture and Planning

George Frisvold, Ph.D., Specialist, University of Arizona, College of Agriculture and Life Sciences, Department of Agricultural and Resource Economics

CONTACT INFORMATION

Mark B. Apel, Project Manager

Area Associate Agent

Cooperative Extension-Cochise County

University of Arizona

1140 N. Columbo

Sierra Vista, Arizona 85635

Tel: (520) 458-8278, ext. 2181

Email: mapel@cals.arizona.edu

Website: <http://rurallandscapes.extension.arizona.edu>

APPENDIX 1 – GIS Data, Goals, Objectives and Weights

Renewable Energy Opportunity Analysis (REOA) Modeling Details

REOA-Model Goal

1. SOLAR: Identify areas suitable for
 - a. Photovoltaic Arrays (PV)
 - b. Concentrating Solar Power (CSP)

REOA-Modeling Notes

- Model Extent: Pima, Santa Cruz and Cochise Counties, AZ
- Raster Cell Size: 0.0025 acres (~33 x 33 feet) or (10 x 10 m)
- Model Mask (i.e. Absolute physical constraints for solar siting capability)
 - Land owner: National Park Service lands, US Forest Service lands, AZ State parks & monuments, all wilderness and conservation areas (capable land owners include BLM, State Trust, Private, County, Military, and Indian Reservations).
 - Major streams: All major streams as classified by ALRIS with 600' total width buffer from centerline of stream and 1000' total width buffer from the centerline of the San Pedro and Santa Cruz Rivers.
 - Lakes: A 500' buffer around lakes will be employed.
 - Slope: All lands with slope greater than 4% (areas with 2% or less slope = high suitability, 2.01 - 3% slope = moderate suitability, and 3.01 – 4% slope = low suitability).
 - Solar insolation (7 kw or greater)¹
- Subjective Constraints (to be overlaid, transparently, on final model output or considered by individual jurisdictions as data availability permits):
 - Soils: Anchoring and compaction
 - Floodplains
 - 404 permit areas
 - Wildlife corridors & critical habitat
 - Scenic corridors & viewsheds
 - Others if available
- Project Size:
 - Small scale: 5 megawatts or less
 - Large scale: greater than 5 megawatts
- Data Storage: ArcCatalog GeoDatabase
- Projection & Coordinate System: North American Datum 1983 Universal Transverse Mercator Zone 12 North (NAD 83 UTM Zone 12N)
- Modeling System: ArcGIS ModelBuilder
- Data Sources:
 - Pima County GIS
 - Santa Cruz County GIS
 - Cochise County GIS
 - Arizona Land Resource Information System (ALRIS)
 - National Renewable Energy Labs (NREL)
 - Southern Arizona Data Services Program
 - University of Arizona
 - US Census Bureau
 - University of Arizona - Advanced Resources Technology (ART) GIS Service Center

Notes

¹ Regarding solar insolation, Arizona has been deemed suitable (7 kW or greater) state-wide. Thus, solar insolation has not been introduced in the modeling process. http://www.nrel.gov/csp/pdfs/csp_sw.pdf

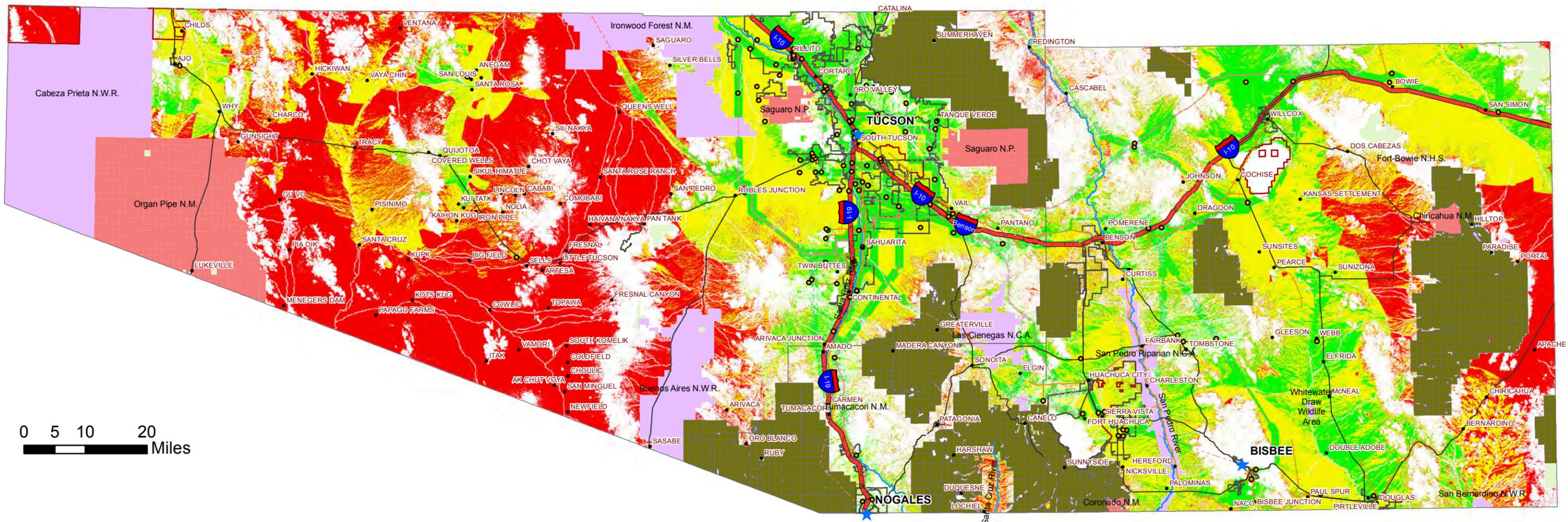
Goals and Objectives

Scaled Renewable Energy Goals and Objectives – Large Scale Projects (Greater than 5 MW)

- Goal 1: Solar: Identify areas suitable for photovoltaic (PV) arrays and Concentrating Solar Power (CSP).**
- 1.1 Physical Suitability – (Weight: .25)
 - 1.1.1 Areas with S, SE, SW, and flat **aspects** as highest potential, all other **aspects** as lowest potential (Weight: .5)
 - 1.1.2 Areas with **slope** 4% or less (areas with 2% or less slope = high suitability, 2.01 – 3% slope = moderate suitability, and 3.01 to 4% slope = low suitability) (Weight: .5)
 - 1.2 Economic Suitability – (Weight: .75)
 - 1.2.1 Identify lands proximal to **transmission lines** (within 300' of 115 kV or greater = high suitability, 300' – 1000' = moderate suitability, and greater than 1000' = low suitability) (Weight: .35)
 - 1.2.2 Identify lands proximal to **sub-stations** (Weight: .35)
 - 1.2.3 Identify lands proximal to **roads** (Weight: .2)
 - 1.2.4 Identify lands proximal to **railroads** (Weight: .1)

APPENDIX 2 – Suitability Maps for Large Scale and Small Scale Solar Projects

Southern Arizona: Opportunities for Large-Scale Solar Operations Greater Than 5 Megawatts



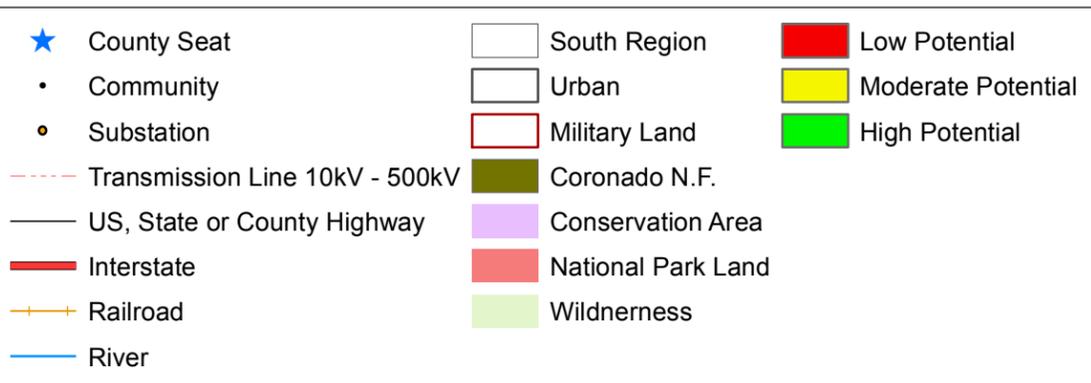
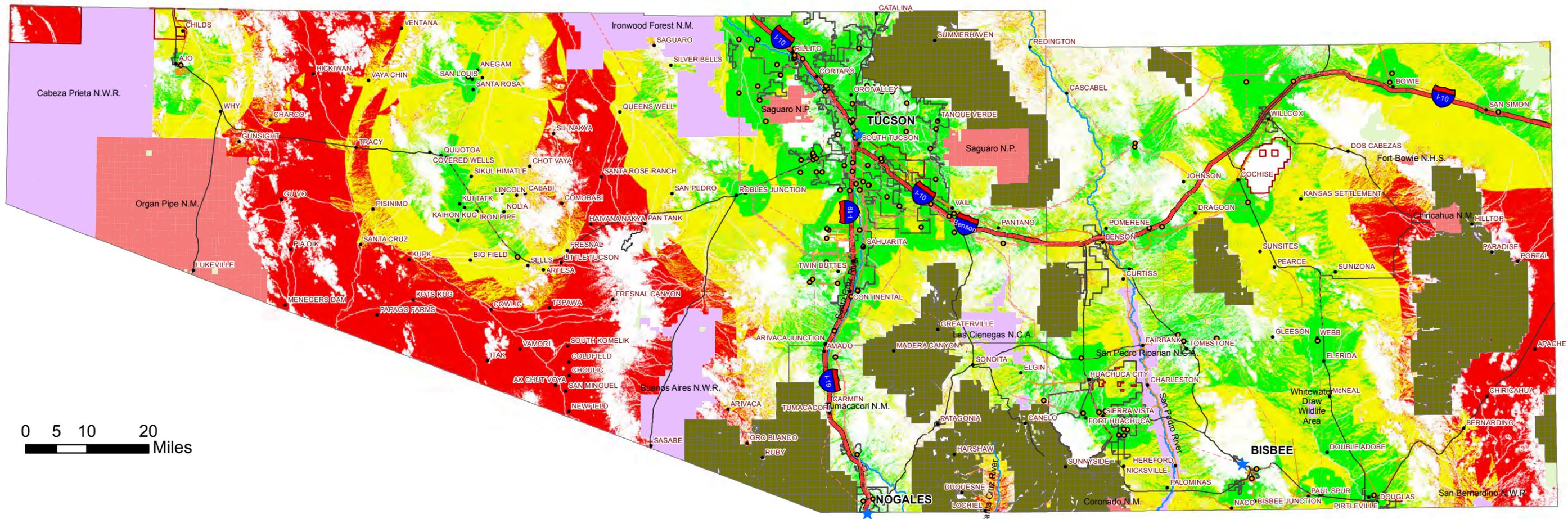
0 5 10 20 Miles

★ County Seat	□ South Region	■ Low Potential
• Community	□ Urban	■ Moderate Potential
● Substation	□ Military Land	■ High Potential
— US, State or County Highway	■ Coronado N.F.	
— Interstate	■ Conservation Area	
— Railroad	■ National Park Land	
— River	■ Wilderness	
- - - Transmission Line 115kV - 500kV		

Large-Scale Solar Potential:
 Low Potential - 2,109,805 acres
 Moderate Potential - 2,463,503 acres
 High Potential - 1,139,843 acres

This is not a survey product. The information is derived from various national, state and county GIS databases. The University does not assume any liability for damages arising from errors, omissions, or use of this information. Users of this map are advised to be aware of the locational accuracy, data collection dates, compilation methods, and cartographic format.

Southern Arizona: Opportunities for Small-Scale Solar Operations of 5 Megawatts or Less



Small-Scale Solar Potential:
 Low Potential - 1,562,627 acres
 Moderate Potential - 2,570,059 acres
 High Potential - 1,580,464 acres

This is not a survey product. The information is derived from various national, state and county GIS databases. The University does not assume any liability for damages arising from errors, omissions, or use of this information. Users of this map are advised to be aware of the locational accuracy, data collection dates, compilation methods, and cartographic format.