WEB-BASED MAPPING APPLICATIONS FOR SOLAR ENERGY PROJECT PLANNING

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ABSTRACT

Determining economically viable locations for solar energy projects depends on many factors, including the level of the solar energy resource, land ownership and use, potential environmental impacts, and grid connectivity. This forum session will highlight public and freely accessible Web-based mapping applications sponsored by the U.S. Department of Energy (DOE) to aid in analyzing solar energy project siting decisions. We will discuss each of the Web applications and their associated projects and then demonstrate the tools.

PVMapper (http://pvmapper.org) is an open-source geographic information system (GIS)-based Web application, currently under development, that will provide utility-scale solar developers with tools and data for site selection and screening of potential photovoltaic (PV) solar energy plants. The Eastern Interconnection States' Planning Commission (EISPC) Energy Zones Mapping Tool (https://eispctools.anl.gov) facilitates planning for clean energy zones and provides an extensive library of energy resources and other siting factors as mapping layers, models to map the suitability for solar energy and other technologies, and region-specific reports. Solar Energy Environmental Mapper (http://solarmapper.anl.gov) concentrates on the southwestern United States and was developed to share information relevant to siting utility-scale solar projects in the six southwestern states included in the scope of the Solar Energy Development Programmatic Environmental Impact Statement. Solar Prospector (http://maps.nrel.gov/prospector) is a mapping and analysis tool designed to provide access to relevant geospatial data to the solar industry in general and for the siting of utility-scale solar plants in particular. National Renewable Energy Laboratory's (NREL) PVWatts calculator (http://pvwatts.nrel.gov) determines the energy production and cost savings of grid-connected PV energy systems, allowing homeowners, small building owners, installers, manufacturers, and researchers to easily develop estimates of the performance of hypothetical PV installations.

1. BACKGROUND AND INTRODUCTION

Among the challenges of building a new solar energy plant (choosing the best technology, financing, business partners, permits, site design, etc.) location is one of the most important factors to address. Choosing the right location can lower costs, increase profits, better satisfy public opinion, and reduce environmental impacts. Determining economically viable locations for solar energy projects depends on many factors, including the level of the solar energy resource, physical characteristics such as slope and water proximity, land ownership and use, potential environmental impacts, and grid connectivity. Much of the location information useful for screening prospective solar project locations is freely available. The federal government has taken an active role in funding the generation and distribution of these data as well as the development of tools to help users analyze this information. While some information is costly and proprietary, especially at the project siting level, solar energy project planners and developers can benefit from the publicly accessible data and the tools presented here.

2. WEB-BASED MAPPING TOOLS

In this paper, we briefly introduce five interactive Web-based mapping applications, each having useful capabilities for determining economically viable locations for solar energy projects. This section describes each application in terms of the context in which it was developed, data content, capabilities, and intended stakeholders.

2.1 PVMapper (http://pvmapper.org)

PVMapper is an open-source geographic information system (GIS)-based tool, currently under development, designed to aid utility-scale solar developers in site selection and screening. The project is a collaborative effort among Boise State University, Idaho National Laboratory, Brigham Young University, Idaho State University, and the University of Idaho. The work is funded by the U.S. Department of Energy (DOE) under the SunShot Initiative, which has the aim of advancing solar technologies by reducing the total costs of implementing them. Within the SunShot Initiative, PVMapper is focused on reducing non-hardware costs, such as those associated with environmental constraints, public opinion, and local government restrictions.

PVMapper provides spatial information in the form of GIS layers to aid developers in site selection. Additionally, PVMapper is unique in that it formally integrates sociopolitical attitudinal information into the project siting process. A measure of social risk is established for specific land features through completion of scientifically conducted surveys that assess a level of social acceptance or opposition to a site. Stated simply, the social data can be integrated with a GIS resource identification and siting tool because the survey sample participants are "valuing" a measure of risk/acceptance in regard to physical resource attributes, land uses, technologies, wildlife and habitat, property values, and aesthetic factors that are tied to a given polygon or geographic space.

Successfully siting and permitting a solar project depends highly on the selected decision path. The quality of early decisions may lead to either increasing or decreasing returns, as the public engagement and permitting processes occur later. In other words, suboptimal choices early in a project's development typically lead to higher costs for alternatives, including redirection or cancellation. Because site identification occurs early in this path-dependent process, screening and identification tools are particularly important.

Another unique characteristic of PVMapper is the site comparison scorecard. This feature allows end-users to evaluate several sites at a time using multiple constraints that can be easily manipulated. The scorecard is populated with a palette of tools that may be selected to generate scorecard results. Third-party programmers can add more functions through a well-defined software plug-in interface, creating a collaborative environment of data and tool sharing that is intended to benefit the industry as a whole.

Figure 1 illustrates the initial version of the graphic user interface (GUI) for the site comparison scorecard. The GUI also provides an interactive weighting mechanism that allows end-users to increase or decrease the significance of various factors.

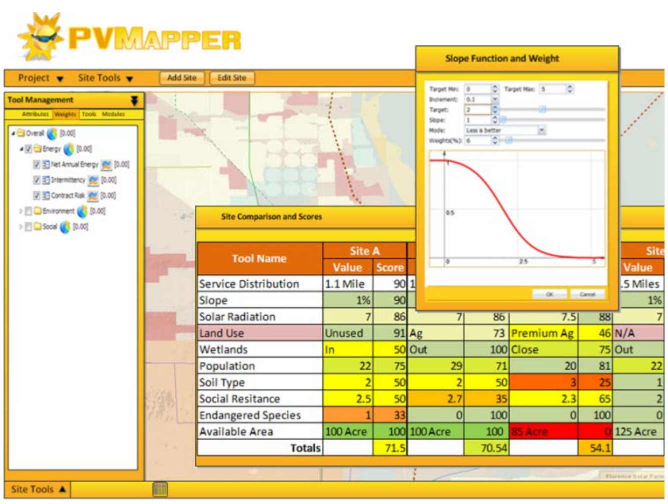

Fig. 1: PVMapper site comparison tool.

The open-source platform is an important feature of this tool because it provides the open-source community the flexibility and freedom to further develop the source code and specialize the tool. PVMapper can be used as a web-based application, but the source code can also provide organizations with a tool that can be further developed and customized for their particular needs. The open-source community can also develop new tools and modules for PVMapper that can be shared with the world.

2.2 EISPC Energy Zones Mapping Tool (https://eispctools.anl.gov)

The Eastern Interconnection States' Planning Council (EISPC) was funded by the DOE to improve Eastern Interconnection-wide energy production planning. The Eastern Interconnection is the electrical transmission grid that includes 39 eastern U.S. states, the District of Columbia, and 8 Canadian provinces. A major component of EISPC activities is the Energy Zones Study, led by the EISPC Energy Zones Working Group. DOE funded three national laboratories – Argonne National Laboratory (Argonne), Oak Ridge National Laboratory, and the National Renewable Energy Laboratory (NREL) (referred to collectively as the Labs) – to provide technical support and subject matter experts for their efforts. One of the main deliverables from the Labs is development of the EISPC Energy Zones Mapping Tool (EZMT).

The primary purpose of EZMT is to facilitate identification of potential energy zones or areas of high resource concentration for solar energy and eight other clean energy resources, spanning over 30 grid-scale energy generation technologies. The major capabilities include providing a library of energy resource and other siting factors as mapping layers, running models to map suitability, generating reports for user-specified analysis areas, and providing information about policies and incentives for energy development. It is intended for Eastern Interconnection-wide and regional-scale applications, rather than project-level siting. Development of models and reports for each energy resource is guided by a resource focus team staffed by subject matter experts from each of the Labs. The Solar Resource Focus Team is led by NREL.

The EZMT is designed for use by:

- EISPC members (states) with significant expertise in electrical generation and transmission planning,
- Eastern Interconnection Planning Collaborative stakeholders, including:
    - Electrical generation companies,
    - Non-governmental organizations (NGOs),
    - Transmission system/regional grid operators,
    - Consumer unions,
- Regulators and policy approvers, and the
- General public.

The solar energy technologies in EZMT include concentrating solar power (CSP), utility-scale photovoltaic (PV), and rooftop photovoltaic (RPV). RPV data and models are regional rather than site-specific. Solar-specific information, data, and capabilities planned for EZMT include:

- Concise technology descriptions with references for further information;
- Static Portable Document Format (PDF) maps showing the distribution of solar resources applied with CSP, PV, and RPV systems;
- Links to related resources such as the other Web applications described in this paper, the Los Angeles County Rooftop Solar Map, and others;
- Solar resource mapping layers from NREL;
- User-adjustable suitability models for CSP and PV which take into account solar resource levels and other siting factors;
- Regional-level reports for RPV; and
- Location-specific information on policies and incentives relevant to solar energy projects.

Developing environmental siting factors including protected lands, habitat, and imperiled species has been a significant part of the project, facilitated through an Environmental Focus Group with involvement of about 20 NGOs, grid operators, and government agencies.

Figure 2 shows an example draft suitability map for PV systems generated by EZMT. Highest suitability areas are red or orange, while unsuitable areas are black. The suitability value is based on a composite score of eight siting factors weighted by their importance, including tilted PV potential, slope, land cover, population density, distance to existing transmission lines of at least 345 kV, protected lands, habitat, and imperiled species. The final interface will allow removal and addition of siting factors, adjustments of weights for each siting factor, and refinements to suitability levels within siting factors. The models have a resolution of 250-m cells, and the map can be zoomed in to provide detailed views of the results. This example model indicates highest suitability for PV in western Texas, Oklahoma, Kansas, and Nebraska, particularly when close to large existing transmission lines. Portions of South Carolina, Georgia, and Florida also have relatively high suitability, but the suitable areas are smaller and more interspersed with unsuitable areas, primarily due to the higher amounts of population and development.

Users will be able to download model results and most of the mapping library of over 250 mapping layers for use in their own systems and to create customized maps. When completed, EZMT will have suitability models for 21 energy production technologies that can be used to create a multi-technology model for locating areas that are promising for combinations of technologies. This will aid in assessing choices among technologies and finding ways to exploit synergies among the technologies. Examples of synergies include co-locating wind turbines and crops used for biomass energy production or co-locating storage technologies with solar or wind energy plants to help mitigate their variable power production.

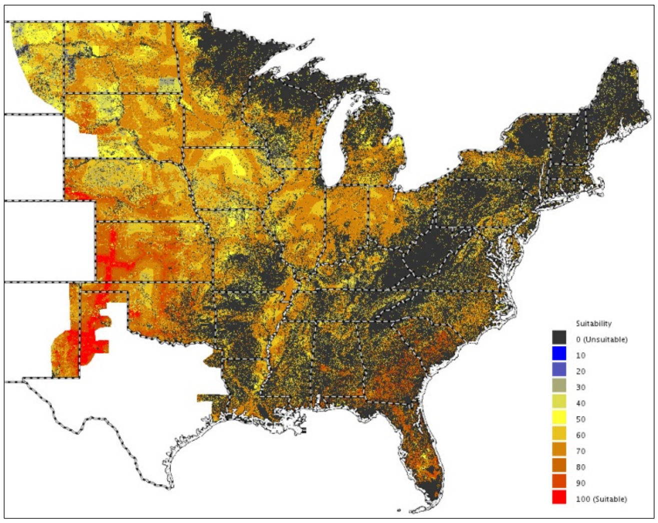

Fig. 2: Draft PV model from the EISPC Energy Zones Mapping Tool.

EZMT was still under development at the time this paper was written, with release for public access scheduled for March 29, 2013. Additional refinements are planned after the public release, including maintaining the database and tool, publishing a final report, adding natural gas as a resource category, generating reports for potential electrical transmission and pipeline corridors input by users, performing stakeholder outreach and training, and adding EISPC white papers as they are finalized.

2.3 Solar Energy Environmental Mapper (http://solarmapper.anl.gov)

The Solar Energy Environmental Mapper (Solar Mapper) provides interactive mapping data on utility-scale solar energy resources and related siting factors in the six southwestern states studied in the Solar Energy Development Programmatic Environmental Impact Statement (Solar PEIS) (1). It was launched for public access in December 2010. Solar Mapper supports identification- and screening-level analyses of potential conflicts between development and environmental resources, and is designed primarily for use by regulating agencies, project planners, and public stakeholders. Solar Mapper consists of an interactive Web application (Fig. 3) and a supporting Web site to provide contextual information.

Fig. 3: Solar Mapper interface with map of federal land jurisdictions and utility-scale CSP (red) and PV (blue) power plants with symbol sizes based on generation capacity.

The main capabilities of Solar Mapper include:

- Interactive mapping display with navigation tools (zoom, pan);
- Table of contents section to control information displayed on the map, show legends, search for layers, and link to layer-specific metadata;
- 70 mapping layers accessed through the table of contents;
- Report tool to draw potential project extent on map and generate location-specific reports about land management protections;
- Panorama tool to access interactive 360° panoramic photographs taken around the Solar Energy Zones analyzed in the Solar PEIS;
- Location search tool allowing searches by place name, address, public land survey system, or coordinates;
- Identify tool permitting users to click on map features and retrieve database information about them; and
- Links to the Web page content, including the home page, an instructional video, project background, data content, release notes, legal notice, contact information, and help.

Solar Mapper was funded by both the Bureau of Land Management (BLM), and DOE. Improvement and maintenance of Solar Mapper continues with BLM funds. Planned future refinements include maintenance of the database and tool; new map layers, including exclusions from development under BLM's Solar Energy Program, pending applications on BLM-administered land, Class II survey sensitivity maps of cultural survey results, conservation priority layers, and National Park Service and U.S. Fish and Wildlife Service areas of concern; reports of exclusions and environmental resources specific to user-input areas; and outreach to publicize the tool and train users.

2.4 Solar Prospector (http://maps.nrel.gov/prospector)

The Solar Prospector (Fig. 4) is a Web-based mapping and analysis tool designed to provide access to geospatial data relevant to the solar industry in general and for the siting of utility-scale solar plants in particular. The application provides easy access to solar resources; land ownership information; and environmental, administrative, and infrastructural data to help assess solar development potential within the United States. The Solar Prospector also provides users with the ability to download solar resource data in a variety of formats for further exploration and analysis.

The main capabilities of the Solar Prospector include:

- Interactive mapping display with navigation tools (zoom, pan);
- Over 40 map layers including solar resource data, solar study area boundaries, environmental and hydrology information, land ownership, as well as the locations of currently operating solar plants;
- Interactive point- and region-based query of map data;
- Ability to drag and drop individual map layers in the layer tree to change drawing order (this is useful when layers are drawn on top of each other and obscure data from underlying layers);
- Downloadable hourly solar resource data for any 10-km solar grid cell, for individual years (1998–2009) or for typical years in either csv or tm2 formats;
- Generation of an interactive graph for any 10-km solar grid cell showing annual solar direct normal irradiance (DNI) resource variability, with minimum, maximum, and mean values for each month; and
- Dynamic generation of charts of the amount of land area by solar DNI resource categories, summarized by county, investor-owned utility service areas, and non-investor-owned utility areas.

The Solar Prospector is not intended to replace a detailed site-specific location assessment, but rather provide a high-level screening tool allowing developers, policymakers, regulators, environmental groups, and other key stakeholders to evaluate potential sites for solar development.

On-line since 2009, the Solar Prospector has received funding and support from the DOE Office of Energy Efficiency and Renewable Energy.

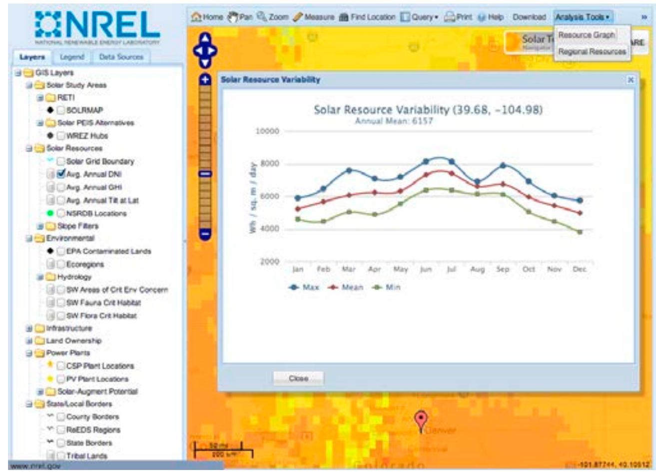

Fig. 4: Solar Prospector interface showing the average monthly solar resource variability for a location in Denver, Colorado.

2.5 PVWATTS (http://pvwatts.nrel.gov)

NREL's PVWatts™ calculator determines the energy production and cost savings of grid-connected PV energy systems throughout the world (Fig. 5). It allows homeowners, installers, manufacturers, and researchers to easily develop estimates of the performance of hypothetical PV installations.

The PVWatts calculator works by performing a per-hour simulation that yields estimated hourly, monthly, and annual energy production in kilowatts and energy value. Users can select a location and choose default values or specify their own system parameters for size, electric cost, array type, tilt angle, and azimuth angle.

Using typical meteorological year weather data for the selected location (TMY2), the PVWatts calculator determines the solar radiation incident on the PV array and the PV cell temperature for each hour of the year. The direct current (DC) energy for each hour is calculated from the PV system DC rating and the incident solar radiation and then corrected for the PV cell temperature. The alternating current (AC) energy for each hour is calculated by multiplying the DC energy by the overall DC-to-AC derate factor and adjusting for inverter efficiency as a function of load. Hourly values of AC energy are then summed to calculate monthly and annual AC energy production.

At the time this paper was written, the PVWatts calculator supported three types of data files, all available through the same map-based viewer (http://gisatnrel.nrel.gov/PVWatts_Viewer/index.html). Users can select specific locations for both U.S. and international sites. A third data type, gridded data, allows users to select any location in the United States. This is useful for locations where there is not a nearby site-specific data file.

Fig. 5: Spring 2013 release of the PVWatts calculator interface showing the modeled monthly production estimates of a 10-kW PV system in Boulder, CO.

In the spring of 2013, NREL expects to release a new PVWatts Web application that will combine the two existing versions into a single seamless interface. The calculation engine underlying the tool will remain the same, but the application will be updated and will allow inclusion of simple financial calculations.

3. DISCUSSION AND CONCLUSIONS

Each of the projects discussed here was funded and developed for specific applications associated with solar energy development. While there may be some overlap in capabilities, functions, and data, each tool fits a specific niche. Recognizing the potential of overlap in the five applications presented here, the SunShot Initiative has encouraged collaboration among the three national laboratories represented to use existing functionality and data where possible.

Collectively, the five Web applications provide an extensive library of mapping data and a diverse set of analytical tools. Table 1 provides a summary of the characteristics of each tool, including geographic scope, technologies supported, data, tools, target markets, and availability of source code.

Development continues on most of these Web-based applications, and feedback from users is welcomed, as it helps influence the data and capabilities provided and improves their effectiveness.

TABLE 1. PRIMARY CHARACTERISTICS OF THE FIVE WEB-BASED MAPPING APPLICATIONS

	PVMapper	Solar Mapper	Solar Prospector	PVWatts	EISPC EZMT
Geographic Scope					
	U.S.	Southwest U.S.	U.S.	U.S.	Eastern Interconnection
Data					
Solar resource	•	•	•		•
Mapping library	•	•	•		•
Policies and incentives	•				•
Solar Energy Development Zones		•	•		
Existing transmission infrastructure	•		•		•
Existing generation facilities		•	•		•
Sociopolitical opposition	•				
User-imported data	•				
360° panoramic photos		•			
Tools					
Site comparison scorecard	•				
Suitability models					•
Visualize/query mapping information	•	•	•		•
Custom map downloads	•		•		•
Customized reports	•	•	•		•
Mapping data download			•		•
Energy production calculations				•	
Basic financial calculations				•	

TABLE 1. (CONTINUED)

	PVMapper	Solar Mapper	Solar Prospector	PVWatts	EISPC EZMT
Technologies Supported					
Utility-scale photovoltaic	•	•	•		•
Rooftop photovoltaic			•	•	•
Concentrating solar power		•	•		•
Target Markets					
Residential			•	•	
Commercial			•	•	
Industrial			•		•
Utility scale	•	•	•		•
Source Code					
Open-source license	•				
Free	•				

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The EISPC Energy Zones Mapping Tool was supported by the U.S. Department of Energy Office of Electricity Energy under interagency agreement through U.S. Department of Energy Contract No. DE-AC02-06CH11357.

5. REFERENCE

(1) U.S. Department of the Interior, Bureau of Land Management, and U.S. Department of Energy, Final Programmatic Environmental Impact Statement for Solar Energy Development in Six Southwestern States, FES 12-24; DOE/EIS-0403, July 2012, available at http://solareis.anl.gov/documents/fpeis (accessed October 2012)