An Assessment of Renewable Energy Potential for U.S. National Parks

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ABSTRACT

This article presents the results of an assessment of renewable energy resources for the U.S. National Park Service (NPS) and provides recommendations to the NPS for capitalizing on available renewable resources. The article applied geographic information systems (GIS) to assess renewable energy resource potential within national parks by overlaying solar and wind resource data with NPS boundaries. From the analysis, we could identify parks with a "high renewable energy potential." Maps and tables illustrating the findings were developed to facilitate dissemination of the results. The assessment resulted in the identification of nearly one hundred park units that have superior renewable resource availability, and provides the NPS with a starting point to identify ideal locations within its boundaries for renewable energy technology (RET) use.

INTRODUCTION

Some of the foremost environmental concerns of today—global climate change, acid rain, air pollution, soil and water contamination, and smog—result from the use of fossil fuels for energy generation. Additionally, health, economic, and security concerns are associated with fossil fuel use. Renewable energy resources, including solar and wind, are not associated with the negative effects of fossil fuels and can be produced indefinitely from domestic resources.

The U.S. National Park Service (NPS) has a mandate of protection, conservation, and stewardship of the nation's natural and cultural resources, including over 83 million acres of land. The mandate implies the use of the most environmentally benign technologies whenever possible, including energy generation technologies. However, the availability of renewable energy resources varies considerably across the nation and within NPS borders.

The purpose of this study was to identify the park units (with superior renewable energy availability) within the NPS. The study uses geographic information systems (GIS) to overlay solar and wind resource data with NPS boundaries to identify such locations. Maps and tables were produced which illustrate the findings, and recommendations were developed to assist NPS officials in pursuing renewable energy installation and use.

This article provides a background on the NPS and renewable energy, an overview of previous assessments of renewable energy availability and use on federal lands, a description of the methodology used in this study, a discussion of the results, and finally, a discussion of policy implications and recommendations for NPS officials considering renewable energy technology (RET) installation and use.

BACKGROUND

National Park Service

The NPS has responsibility for over 380 areas, including national parks, rivers, preserves, and monuments [1], and encompasses over 83 million acres of land [2]. Over 275 million people visit national parks annually [3]. The NPS has a mandate of managing and protecting many of the United States' natural, cultural, and historical resources, and according to the NPS mission statement, to "*provide for the enjoyment of the same in such a manner as will leave them unimpaired for the enjoyment of future generations*" (p.2) [4].

The vision for the future of the NPS is provided in *National Parks for the 21st Century: the Vail Agenda* [4], a summary of experts' and NPS officials' recommendations to improve park system stewardship. The recommendations include: protecting park resources from external and internal impairment, designing park facilities in a way that promotes sustainable use of resources, developing an inventory of technologies that minimize resource demands, enhancing public understanding of environmental issues, and, most relevantly, minimizing adverse impacts on the environment by taking advantage of opportunities in energy use [4].

All of the NPS objectives are compatible with the installation of renewable energy technology (RETs) in parks. RETs will decrease the environmental impacts of energy use, reduce use of nonrenewable fossil fuels and associated pollution, and can be observed by millions of visitors annually, providing educational value. RETs also address several federal mandates and executive orders encouraging or requiring the use of renewable energy in federal facilities.

One would imagine that the NPS should be using RETs to the greatest extent economically and technically possible, as the use of RETs fulfills many NPS objectives and requirements as a federal agency. However, renewable energy resource strength varies widely throughout the U.S. due to variations in climate, geography, and topography. For example, annual average wind speed (a crucial factor in wind power production) in one location may be far different than that in a nearby location, and cloud cover and climate—key factors related to solar energy production—vary considerably.

As the NPS covers such a vast expanse of land throughout the U.S., the availability of renewable energy resources varies significantly from park to park. This study assesses the availability of renewable energy resources to help the NPS locate areas best suited for RET development. The renewable energy resources considered in this study include: solar photovoltaic (PV), concentrating solar power (CSP), and wind power.

Renewable Energy on Federal Lands

Unlike fossil fuels such as oil, coal, and natural gas, which are depleted with use, RETs are inexhaustible. The negative environmental effects of fossil fuels, such as acid rain, particulates, smog, and greenhouse gas emissions, are mostly absent from RETs as well. Particularly relevant to national parks, RETs do not create the negative effects of decreased visibility and acid rain damage to monuments that are associated with fossil fuel pollution [5]. In addition, RETs can be effectively used as distributed generation sources, providing electricity in remote locations without grid access. (Many NPS facilities are in remote locations and currently use diesel generators to provide power; diesel generators produce harmful emissions and have resulted in extremely costly fuel spills.) [5]

Despite these advantages, RETs can be much more expensive than conventional energy sources. The principle costs of RETs are the capital costs of the systems, not the continuous cost for fuel as is the case with fossil fuel technologies. As renewable resource strength increases, the average cost per unit of energy decreases because more energy is produced from the same initial investment. Identification of NPS units with stronger renewable resources is therefore valuable for facilitating economical RET use.

Renewable energy availability and RET use within the NPS have not been extensively researched or documented; however, in the mid-1990s, Sandia National Labs paired with the NPS to assess the use of PV systems throughout the NPS [6]. A survey of park units was performed to identify existing PV systems and satisfaction with the systems; also identified were potential future PV projects and the barriers to PV use. According to the survey, there were at least 455 existing PV units, but subsequent visits to parks indicated that more than 600 systems might be in use. The survey also identified 643 proposed PV systems in 125 parks, indicating that there is much room for expanding PV use in the NPS. One of the barriers to PV use identified was "adverse climate," which illustrates the importance of solar resource availability for PV use.

Renewable resource availability on NPS lands has not been assessed, though there have been assessments of other federal lands. In 2002, the National Renewable Energy Laboratory (NREL) and the Bureau of Land Management (BLM) partnered to assess the potential for solar, wind, biomass, and geothermal use on public lands [7]. GIS and surveys were used to identify planning units with high potential for renewable energy use. NREL also used GIS to identify the wind power potential of Native American lands [9, 10] and to assess the solar resources—including PV, solar hot water, and solar ventilation—available at military sites in the United States [11].

However, lands within the NPS have frequently been excluded from such assessments due to NPS land use restrictions, even though an assessment of RET *use* within NPS found that hundreds of renewable energy systems are used with minimal aesthetic or environmental impacts [6]. This study provides an assessment of renewable energy resource availability within the NPS that other studies of renewable energy on federal lands have lacked, and therefore will facilitate informed decision making by NPS officials.

Methodology

Geographic information systems (GIS) is a computer tool that allows geographic data and attributes to be managed, manipulated, visualized, and spatially analyzed. With GIS, geographic information and attributes are linked to a map, which is used to store and access data [12]. GIS is an appropriate tool for renewable energy resource assessment because results can be expressed in maps and tables to easily disseminate findings [9].

In this assessment, we employed GIS to evaluate renewable resource assets in national parks. This was done by overlaying data layers of NPS boundaries with renewable resource data layers of PV, CSP, and wind power potential.

The NPS boundaries data layer was obtained from the National Park Service GIS data website [13]. Renewable resource data and maps were obtained from the NREL GIS website [14]. The layers included:

- *PV Solar Radiation:* the annual average of daily solar resource (in kWh/m^2/day) available to a flat-plate photovoltaic system oriented due south at an angle from the horizontal equal to the latitude of the collector location [14].

- *National Concentrating Solar Power:* the annual average of daily solar resource (in kWh/m^2/day) available to a concentrating solar power system that tracks the path of the sun throughout the day [14].

- *National Wind Resource, High Resolution Wind Data* (covering Illinois, North and South Dakota, the Pacific Northwest, California, and Mid-Atlantic States): the wind power class values for the average annual wind resource at a 50-meter height, with cell resolution varying between 200 and 1000 meters [14].

- *National Wind Resource*: estimates of wind power class values for the average annual wind resource for the conterminous United States, with a resolution of 1/3 degree of latitude by 1/4 degree of longitude [14].

After overlaying these data layers, maps were developed illustrating the resource availability in national parks. Colors (here, grayscale) were assigned to distinct levels of renewable resource assets; as a result, parks with strong assets are clearly visible.

Next, tables highlighting parks with "excellent" potential for RET development were developed. For our study, "excellent potential" for PV and CSP was defined as areas having average solar resources of at least 6 kWh/m^2/day. Parks having areas with wind power class 6 or 7 within their borders were determined to have excellent wind power potential.

Results

Our results are shown in Tables 1, 2, and 3. The tables identify national parks with excellent renewable resource strength in each resource category studied. In addition, Figures 1 through 4* show example maps for PV in the 48 conterminous states, wind power potential for California, CSP in the state of Alaska, and a magnification of the Channel Islands National Park wind potential map.

The results indicate that there is a great deal of renewable energy availability within NPS borders. The results point to nearly one hundred parks with high potential for use of at least one renewable resource. (In actuality, we believe the number of parks exhibiting strong renewable resources is even greater, as the minimum resource requirements for this analysis were more stringent than in most assessments, and maps of all renewable resources were not available for all areas.)

Of the parks identified as having high potential for renewable energy, most are in the western states, as expected. The high availability of renewable resources in western parks is fortunate, as these parks are incredibly popular, having several million visitors annually, and are generally more sizable in land area than parks in the eastern states.

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*Other maps are available for readers by contacting the corresponding author at *jjwgpt@rit.edu.*

TABLE 1: NATIONAL PARKS WITH EXCELLENT SOLAR PV POTENTIAL (>/= 6 KWH/M²/DAY)

STATE	PARK NAME
ARIZONA	CORONADO
	CHIRICAHUA
	FORT BOWIE
	GRAND CANYON
	HOHOKAM PIMA
	HUBBEL TRADING POST
	LAKE MEAD
	MONTEZUMA CASTLE
	NAVAJO
	ORGAN PIPE CACTUS
	PETRIFIED FOREST
	SAGUARO
	SUNSET CRATER VOLCANO
	TONTO
	TUMACACORI
	TUZIGOOT
	WUPATKI
CALIFORNIA	GLEN CANYON
	JOSHUA TREE
	MOJAVE
HAWAII	HAWAII VOLCANOES
	PUUHONUA O HONAUNAU
NEVADA	CANYON DE CHELLY
	CASA GRANDE
	DEATH VALLEY
NEW MEXICO	EL MALPAI
	WHITE SANDS
	GILA CLIFF DWELLINGS
	SALINAS PUEBLO MISSIONS
TEXAS	AMISTAD
	BIG BEND
	CHAMIZAL
	FORT DAVIS
	LAKE MEREDITH
	GUADALUPE MOUNTAINS
UTAH	CAPITAL REEF
	RAINBOW BRIDGE

Table 2: National Parks with Excellent Concentrating Solar Potential (>/= 6 kWh/m²/day)		
STATE	**PARK NAME**	
ARIZONA	CANYON DE CHELLY	ORGAN PIPE CACTUS
	CASA GRANDE	PETRIFIED FOREST
	CHIRICAHUA	PIPE SPRING
	CORONADO	SAGUARO
	FORT BOWIE	SUNSET CRATER
	GRAND CANYON	VOLCANO
	HOHOKAM PIMA	TONTO
	HUBBELL TRADING POST	TUMACACORI
	LAKE MEAD	TUZIGOOT
	MONTEZUMA CASTLE	WALNUT CANYON
	NAVAJO	WUPATKI
CALIFORNIA	GLEN CANYON	
	JOSHUA TREE	
	KINGS CANYON	
	MANZANAR	
	MOJAVE	
	SEQUOIA	
	YOSEMITE	
COLORADO	DINOSAUR	
	GREAT SAND DUNES	
	HOVENWEEP	
	MESA VERDE	
	YUCCA HOUSE	
NEVADA	DEATH VALLEY	
	GREAT BASIN	
NEW MEXICO	AZTEC RUINS	GILA CLIFF DWELLINGS
	BANDELIER	PETROGLYPH
	CARLSBAD CAVERNS	SALINAS PUEBLO MISSIONS
	CHACO CULTURE	WHITE SANDS
	EL MALPAIS	ZUNI-CIBOLA
	EL MORRO	
	FORT UNION	
TEXAS	AMISTAD	
	BIG BEND	
	CHAMIZAL	
	FORT DAVIS	
	GUADALUPE MOUNTAINS	
	LAKE MEREDITH	
UTAH	CAPITOL REEF	
	CEDAR BREAKS	
	NATURAL BRIDGES	
	RAINBOW BRIDGE	
	ZION	

TABLE 3: NATIONAL PARKS WITH EXCELLENT WIND POWER POTENTIAL (WIND POWER CLASSES 6 & 7)		
STATE	**PARK NAME**	
ARIZONA	CANYON DE CHELLY	SAGUARO
	CORONADO	ORGAN PIPE CACTUS
	CHIRICAHUA	PETRIFIED FOREST
	GLEN CANYON	TONTO
	GRAND CANYON	WALNUT CANYON
	LAKE MEAD	WUPATKI
CALIFORNIA	CHANNEL ISLANDS	MOJAVE
	DEATH VALLEY	POINT REYES
	JOSHUA TREE	SANTA MONICA MOUNTAINS
	KINGS CANYON	SEQUOIA
	LASSEN VOLCANIC	WHISKEYTOWN
		YOSEMITE
COLORADO	COLORADO	MESA VERDE
	CURECANTI	ROCKY MOUNTAIN
	GREAT SAND DUNES	DINOSAUR
IDAHO	CITY OF ROCKS	
	CRATERS OF THE MOON	
MASSACHUSETTS	CAPE COD	
MONTANA	BIGHORN CANYON	
	GLACIER	
NEVADA	DEATH VALLEY	
	GREAT BASIN	
	LAKE MEAD	
	MOHAVE	
NEW MEXICO	BANDELIER	PETROGLYPH
	CAPULIN VOLCANO	SALINAS PUEBLO MISSIONS
	CARLSBAD CAVERNS	WHITE SANDS
	GUADALUPE MOUNTAINS	
OREGON	CRATER LAKE	
SOUTH DAKOTA	MOUNT RUSHMORE	
TENNESSEE	GREAT SMOKY MOUNTAINS	
TEXAS	GUADALUPE MOUNTAINS	
UTAH	BRYCE CANYON	DINOSAUR
	CAPITOL REEF	GLEN CANYON
	CANYONLANDS	ZION
VIRGINIA	SHENANDOAH	
	BLUE RIDGE PARKWAY	
WASHINGTON	MT. RAINIER	LAKE CHELAN
	OLYMPIC	ROSS LAKE
	NORTH CASCADES	
WYOMING	GRAND TETON	
	YELLOWSTONE	

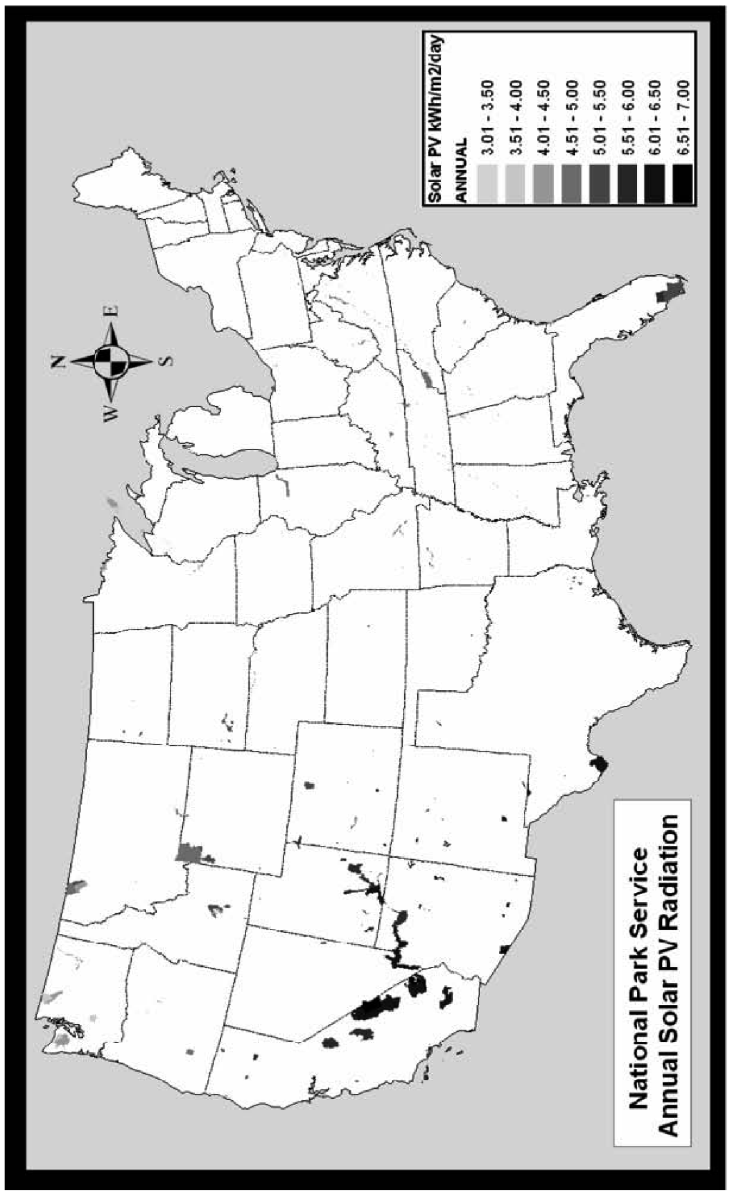

Figure 1. NPS Solar PV Resource Map, 48 Conterminous States

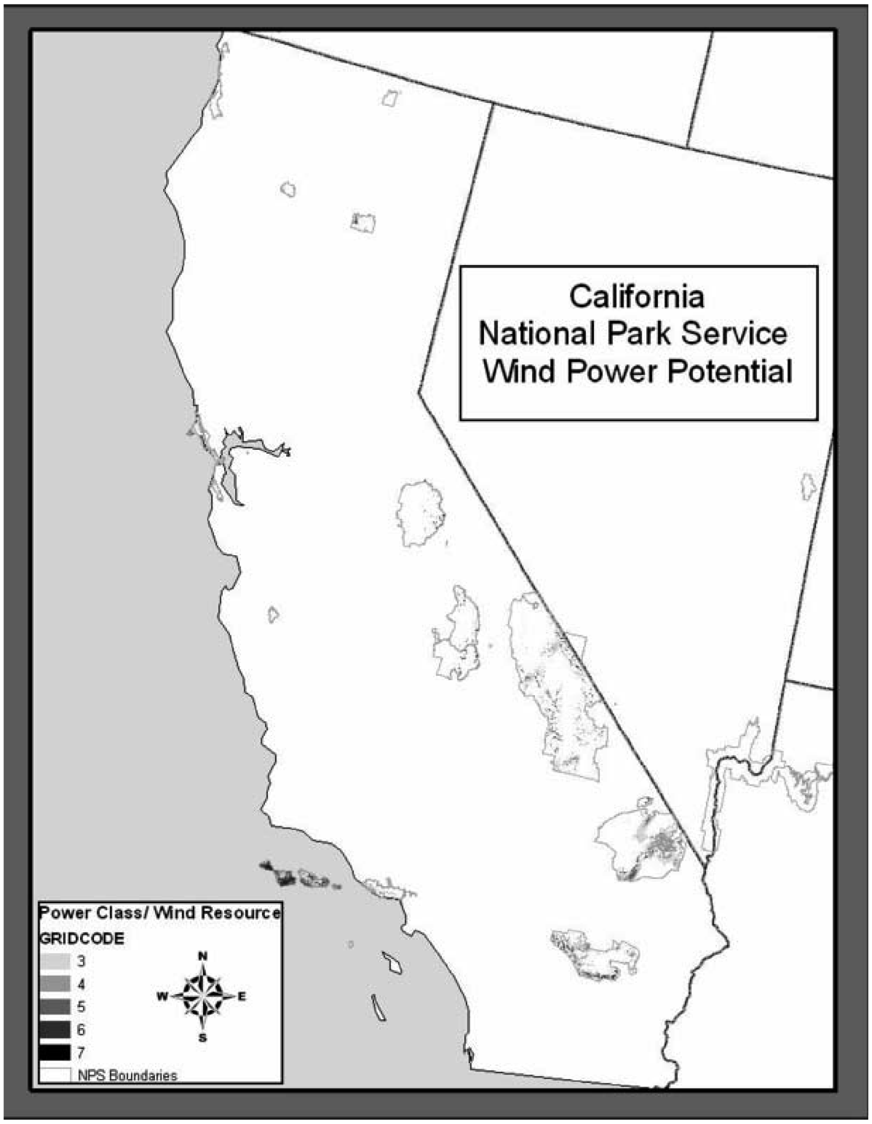

Figure 2. NPS Wind Power Potential Map, California

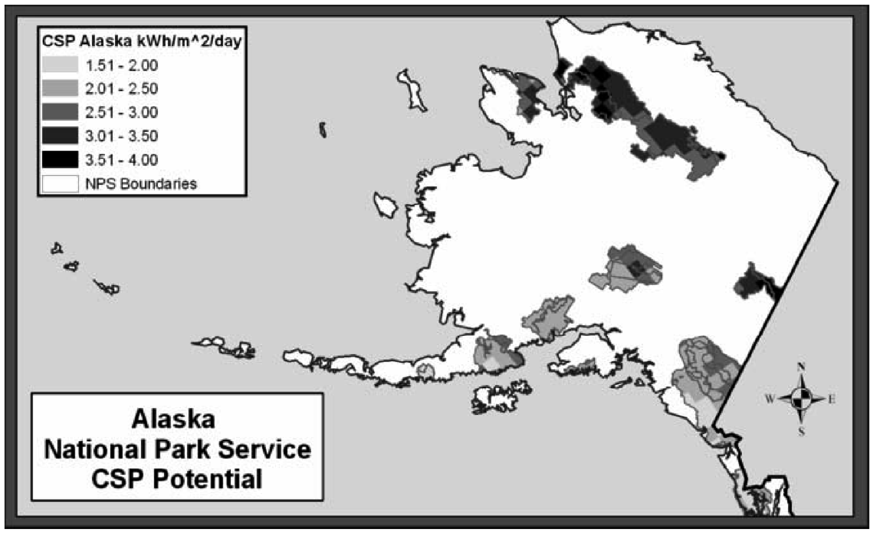

Figure 3. NPS Concentrating Solar Power Map, Alaska

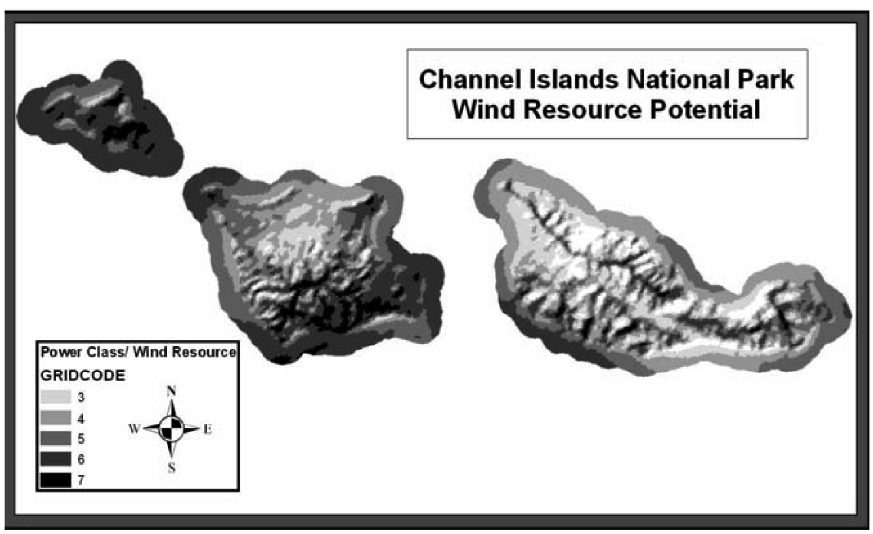

Figure 4. Wind Power Map, Channel Islands National Park

Arizona and California in particular are home to many enormously popular national parks with exceptional renewable resource availability.

The results of this analysis indicate that there are numerous opportunities for the NPS to fulfill its objectives of resource stewardship and environmental leadership by taking advantage of the renewable energy assets within its borders.

Policy Implications

Following the release of the BLM/NREL report “Assessing the Potential for Renewable Energy on Public Lands,” nearly 40 applications for wind technology development and testing were received by BLM; in the ten years before the report was released, fewer than five applications were received annually [7,8].

One could imagine that the identification of many national parks with high renewable energy potential would generate enthusiasm for RET development in national parks as well. The straightforward implication of this assessment is that the NPS should capitalize on the abundance of renewable energy availability within NPS boundaries: the NPS should install and use RETs, including PV, CSP, and wind power.

However, the actual implications of this assessment are not as straightforward. A location identified as having “excellent” renewable resource strength does not guarantee that the location is ideal for RET installation and use. This research is a starting point for identification of parks and facilities that are desirable for RET use. When embarking on a renewable energy development project, the identified parks should be among those first targeted for installation and use. But before a project is seriously considered, a more detailed analysis of the specific park and location are required for several reasons.

First, this study provides an initial feasibility assessment. Though national parks with exceptional resources were identified through this assessment, the terrain, accessibility, location of facilities, energy prices, and other key factors of a particular installation location were not analyzed. Before individual renewable energy projects are embarked upon, these factors should be examined to ensure that the site is desirable for RET development.

Another important issue is the perception that national parks should not use RETs because RETs are visually distracting and detract from the natural or cultural experience at a park. Traditionally, the national parks have not been seen as ideal candidates for RET use, due to the desire to keep the unique resources of national parks visually unchanged. In fact, two significant barriers identified in an assessment of renewable energy use in NPS were "visual quality concerns" and "conflicts with historic resources" (p.10) [6]. These barriers have been of significant concern to many stakeholders in pursuing renewable energy projects in NPS.

Finally, there must be serious consideration of the environment, natural surroundings, and wildlife before installing RETs, particularly wind power. Some of the common restrictions of siting wind turbines include wildlife conservation, forests, and ecologically sensitive areas—all of which essentially comprise many of the national parks.

The results of this assessment are promising, but do call for additional studies and location-specific analysis for RET implementation. In the future, GIS can be used to answer some of the questions raised by this assessment, including terrain, wildlife, and park facility location issues. The assessment results could also be used in conjunction with qualitative methods such as surveys of park personnel to determine additional barriers to or opportunities for renewable energy use within specific parks and regions, as many key issues could arise that would not be made apparent from a GIS analysis. Specifically, questions regarding current distributed energy uses would be particularly helpful for identifying parks that will benefit from RETs.

Despite these issues, we recommend that the NPS invest in RETs to the greatest extent economically possible, using all funding mechanisms available—including partnerships with universities, the private sector, and other federal and state agencies [6]. In particular, we recommend that the NPS:

- Allocate a considerable portion of energy and facilities management budgets to RET procurement, installation, and maintenance;

- Take into account the full life-cycle costs of energy technologies when deciding which to install and use (i.e., environmental costs, fuel costs, educational benefits);

- Incorporate RETs into the design of new buildings and facilities, which will minimize overall costs and aesthetic issues;

- Develop interpretive displays for all prominent RET projects to facilitate public education; and finally,

- Expand partnerships with federal agencies, utilities, and universities to obtain the greatest benefits with the least costs to NPS.

CONCLUSION

The NPS is dedicated to the protection and stewardship of the U.S. natural resources. This mission implies that the NPS consistently use the most environmentally benign technologies, including those for energy sources. Renewable energy sources are associated with far fewer negative environmental effects—such as air pollution, acid rain, and decreased visibility—than conventional fossil fuel generation. However, the strength of renewable energy resources varies considerably throughout the U.S., which prevents some parks from utilizing certain RETs cost-effectively, while other parks are prime locations for use of RETs.

This study has resulted in the identification of nearly one hundred parks that have high potential for use of at least one type of renewable energy. The assessment demonstrates that there is much opportunity for use of renewable energy sources within the NPS, and presents a starting point for identification of ideal locations for RET use within the NPS.

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