Case Studies of Potential Facility-Scale and Utility-Scale Non-Hydro Renewable Energy Projects across Reclamation

S. Haase, K. Burman, D. Dahle, D. Heimiller, A. Jimenez, J. Melius, B. Stoltenberg, and O. VanGeet

Produced under direction of Bureau of Reclamation by the National Renewable Energy Laboratory (NREL) under Interagency Agreement IAG-11-1816 and Task No WFJ2.1000.

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

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Technical Report
TP-7A30-57123
May 2013
Contract No. DE-AC36-08GO28308

NREL
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Cover photos courtesy of NREL (NREL 15549 and NREL 16706)

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Acknowledgments

The National Renewable Energy Laboratory (NREL) thanks the Bureau of Reclamation for funding this work. In particular, NREL is grateful to Dr. Curt Brown, Miguel Rocha, and Erin Foraker for their leadership and assistance with the overall work.

Additional thanks to:

- Mitch Haws, Aaron Adam Ricks, and Don Reiff for their initial GIS analysis of the Central Arizona Project, and to Mitch Haws, Don Reiff, Mike Pryor, and David Trimm for hosting the NREL team during the site visit in August 2011.
- Diana Weigmann for her insights into Reclamation's sustainability program and efforts to integrate renewable into existing facilities.
- Bruce Whitesell for providing utility-scale Reclamation data layers.

List of Abbreviations and Acronyms

AC	alternating current
ACC	Arizona Corporation Commission
APS	Arizona Public Service
BLM	U.S. Department of the Interior, Bureau of Land Management
CAISO	California independent system operator
CAP	Central Arizona Project
CPUC	California Public Utilities Commission
CPV	concentrating photovoltaics
CSI	California solar incentives
CSP	concentrating solar power
DC	direct current
DG	distributed generation
DNI	direct normal irradiance
DOE	U.S. Department of Energy
DRECP	Desert Renewable Energy Conservation Plan
DSCR	debt service coverage ratio
DSIRE	Database for State Incentives for Renewable Energy
EIS	environmental impact statement
ft^2	square-foot
FTHL	flat-tailed horned lizard
FY	fiscal year
GHG	greenhouse gas
GHI	global horizontal irradiance
GIS	geographic information system

GSA	U.S. General Services Administration
IEEE	Institute of Electrical and Electronics Engineers
IRR	internal rate of return
ITC	investment tax credit
km^2	square-kilometer
kV	kilovolt
kW	kilowatt
kWh	kilowatt-hour
lbs	pounds
LCOE	levelized cost of energy
LEED	Leadership in Energy and Environmental Design
m^2	square-meter
MA	management area
MACRS	modified accelerated cost-recovery system
MW	megawatt
MWh	megawatt-hour
NEPA	National Environmental Policy Act
NEG	net excess generation
NGS	Navajo Generating Station
NREL	National Renewable Energy Laboratory
O&M	operation and maintenance
PBI	performance-based incentives
PG&E	Pacific Gas and Electric
PPA	power purchase agreement
PV	photovoltaics

RE	renewable energy
REC	renewable energy certificate
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
ROW	right-of-way
RPS	renewable portfolio standard
RPUID	real property unique identifier
SDGE	San Diego Gas & Electric
SEZ	solar energy zone
SHPO	State Historic Preservation Office
SROPTTC	Site, Resource, Offtaker, Permits, Technology, Team, and Capital
SRP	Salt River Project (electric utility)
TMY	typical meteorological year
TOU	time of use
USFWS	U.S. Fish & Wildlife Service
W	watt
WAPA	Western Area Power Administration

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Executive Summary

The following report summarizes the results of an assessment and analysis of renewable energy opportunities conducted for the U.S. Department of the 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–GIS Utility-Scale Screening. Using geographic information system (GIS) technology, identify and rank Reclamation lands potentially suitable for wind and solar energy development. This publication gives only a summary of the results. Full results are given in the publication "Renewable Energy Assessment of Bureau of Reclamation Land and Facilities Using Geographic Information Systems."[1]

Task 1.1.1–Utility-Scale Site Visits. Conduct detailed technical and economic assessments of Reclamation lands potentially suitable for development. This report includes solar assessments of a site along the Central Arizona Project (CAP), solar assessments for two sites near Yuma, AZ, and a wind energy development assessment for the North Platte cluster in Wyoming.

Task 1.1.1–Montana Screening Analysis. Conduct a screening analysis of Reclamation-owned property in Montana to identify the parcels most suitable for wind energy development.

Task 1.2–GIS Facility-Scale Screening. Using GIS, identify Reclamation facilities that have the best potential for deployment of facility-scale wind and/or solar energy resources. This publication gives only a summary of the results. Full results are given in the publication "Renewable Energy Assessment of Bureau of Reclamation Land and Facilities Using Geographic Information Systems."

Task 1.2.1–Facility-Scale Site Visits. Conduct an analysis of the technical and economic feasibility of installing solar energy technologies at Reclamation's Phoenix Area Office and the Willows and Lake Barryessa (California) offices.

[1] Haase, et al. *Renewable Energy Assessment of Bureau of Reclamation Land and Facilities Using Geographic Information Systems* (forthcoming). NREL/TP-7A30-57123. Golden, CO: National Renewable Energy Laboratory.

Summary Results

The specific activities completed and key results are highlighted in Table ES-1.

Table ES-1. Summary of Specific Tasks and Results

Task	Description	Key Results
Geographic Information System (GIS) Screening	**Utility:** Used GIS to identify Reclamation-owned land (by county) potentially suitable for utility-scale concentrating solar power (CSP), photovoltaic (PV), and wind power development **Facility:** Used GIS to analyze 748 Reclamation facilities' potential suitability for solar vent preheating, PV, and small wind power	• The counties with the greatest potential for CSP, PV, and wind power development on Reclamation lands were identified and ranked from highest to lowest. Further analysis is necessary at each individual site to identify the specific capacity potential based on Reclamation's land and facilities. • For each technology, the facilities were ranked in terms of the available resource.
Facility-Scale Assessment at Phoenix Area Office	Conducted a technical and economic feasibility analysis of installing PV at the Phoenix area office	• The facility can host up to 200 kW of PV. • Salt River Project (SRP) incentives are available for systems up to 30 kW in size. • The payback for a federal government-owned system (up to 30 kW) is estimated to be 27 years. A power purchase agreement (PPA) with a private developer may have better economics. Systems larger than 30 kW in size are currently ineligible for SRP incentives and thus will have longer payback periods.

Task	Description	Key Results
Facility-Scale Assessment at Willows Office (Mid-Pacific Construction Office) and Lake Barryessa Facility	Conducted a technical and economic feasibility analysis of installing PV at the Willows Office and Lake Barryessa facility (located in California)	• The Willows Office already has a small PV installation that generates approximately 12,000 kWh/year. • The east roof (Area 1) at the Willows Office can accommodate 15 kW of PV. Estimated payback is 22-25 years for a federal government-owned system. • The south courtyard roof at the Willows Office can accommodate up to 20 kW of PV but will require extensive tree trimming or removal. Estimated payback is 15 years for a third party-owned system or 22 years for a federal government-owned system. • A carport at the Willows Office could accommodate up to 220 kW of PV (93 kW is sufficient to make the office net zero). Operational constraints preclude a carport at this time. Payback is estimated to be 15 years for a third party-owned system. • The Lake Barryessa facility has three ground-mounted PV opportunities totaling 133 kW. Estimated payback is 15 years for a third party-owned system and 22 years for a federal government-owned system. • The Lake Barryessa facility has two potential carport-mounted PV opportunities. Estimated payback is 16 years for a third party-owned system and 24 years for a federal government-owned system. Operational considerations preclude carports in some locations at this time.

Task	Description	Key Results
Utility-Scale Assessment of Pumping Along the Central Arizona Project (CAP)	Conducted site assessments of three potential sites for utility-scale CSP and PV facilities: • East of Little Harquahala Pumping Station (La Paz and Maricopa Counties) • Belmont Mountain • East of Hassayampa Pumping Station	• The location east of the Hassayampa Pumping plant determined to be the most viable site. • Most cost-effective option is a 20-100 MW third party-owned, single-axis tracking PV plant. The levelized cost of energy (LCOE) is estimated at $0.10/kWh. • LCOE of comparable CSP plant is approximately $0.17/kWh. • The analysis used publicly available capital cost data. Informal discussions with developers indicate that current capital costs are lower than those used in the analysis. Thus the actual LCOEs are likely to be less than shown in the analysis. Recent PPA prices for solar projects appear to be in the $0.07-$0.10/kWh range. In terms of costs of energy, this site appears to be competitive for a PV project. • Near-term demand for PV project is uncertain. Many utilities have met their near- and mid-term solar renewable portfolio standards (RPS) obligations. Despite dropping costs for PV power plants, LCOEs from PV plants are higher than current LCOEs from natural gas-fired power plants due to current low natural gas prices.
Utility-Scale Solar Assessment at Yuma	Conducted site assessments of two sites for utility-scale CSP, power tower, and PV facilities: • Brock Reservoir • A22	• Shape of the Brock Reservoir parcel precludes CSP or power tower facilities. Estimated LCOE for PV is approximately $0.10/kWh. • For A22, the most cost-effective option is PV, with an LCOE of approximately $0.10/kWh. Power tower is a close second choice with an LCOE of approximately $0.11/kWh. • The analysis used publicly available capital cost data. Informal discussions with developers indicate that current capital costs are lower than those used in the analysis. Thus the actual LCOEs are likely to be less than shown in the analysis. Recent PPA prices for solar projects appear to be in the $0.07-$0.10/kWh range. In terms of costs of energy, this site appears to be competitive for PV and perhaps power tower projects. • Near-term demand for PV project is uncertain. Many utilities have met their near- and mid-term solar RPS obligations. Despite dropping costs for PV power plants, the LCOEs from PV power plants are higher than current LCOEs from natural gas-fired power plants due to current low natural gas prices.

Task	Description	Key Results
Utility-Scale Wind Assessment of North Platte Cluster	Evaluated the North Platte cluster, a set of Reclamation-owned parcels along the North Platte River west of Casper, Wyoming, for suitability for wind energy development	• Compared with neighboring land, the Reclamation-owned parcels within the North Platte cluster do not appear especially attractive for wind energy development. The Reclamation-owned parcels in this area are generally of relatively small size (which limits wind farm size unless the wind farm extends into non-Reclamation land), awkwardly shaped (which leads to inefficient turbine layout), and either in low-lying terrain (which generally has less of a wind resource) and/or is comprised of rugged terrain (which increases the cost of construction and transmission). • Estimated LCOEs (busbar) for a small, utility-scale wind energy project (approximately 10 MW) are $0.07-$0.08/kWh for federal government owned projects and $0.08-$0.10/kWh for privately owned projects. These LCOEs are higher than the current PPA price range of $0.04-$0.06 per kWh for non-California, non-“Wind Belt” wind farms.
Montana Wind Screening Analysis	Conducted a screening analysis of Reclamation-owned property in Montana to identify the parcels most suitable for wind energy development	• Identified one set of parcels, (Chouteau County cluster), that can support over 300 MW of wind energy development, and two parcels (Glacier County cluster, Philips County cluster) that can support approximately 100 MW each. • Identified five additional parcels that can potentially support modest (50-100 MW) wind energy development. • Selected Reclamation-owned parcels appear to have development potential; however, in general, Reclamation-owned parcels do not appear to offer compelling advantages over nearby non-Reclamation-owned land. In most cases, Reclamation-owned parcels will need to be aggregated with adjacent non-Reclamation-owned land to support a large wind farm.

Conclusions

Facility-Scale Renewables

Reclamation's Phoenix Area Office, Willows Construction Office, and Lake Barryessa Office each have near-ideal areas in which to implement a PV system. However, the Willows Construction Office and Lake Barryessa Office both have operational considerations that preclude implementation for some of the identified carport areas at this time. The remaining potential project at Willows is less cost-effective, but may still merit consideration.

If Reclamation chooses to proceed with this type of installation at the Phoenix office, it should contact Salt River Project (SRP) and reserve incentives for a 30 kW direct current (DC) system (or other size, as determined by Reclamation). If incentives for larger systems become available again, a larger system should be installed. Similarly, if Reclamation chooses to proceed with these installations at Willows and/or Lake Barryessa, Reclamation should reserve incentives with Pacific Gas and Electric Company (PG&E).

When the systems go out to bid, a design-build contract should be issued that requests the best performance (in kWh/yr) at the best price, letting 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, government-owned PV systems provide reasonable payback, are easy to implement, and are therefore recommended.

If funding is not available, then a third-party PPA is the most reasonable way for a system to be financed at these sites. Due to high transaction costs, third-party ownership of PV systems sited at government facilities is generally only feasible for systems larger than 90-100 kW or so. A possible method to install smaller (< 90 kW) systems under a third-party ownership scenario would be to aggregate the installation of PV systems at several facilities under one contract.

More generally, Reclamation should consider a program to systematically screen and assess Reclamation-owned facilities for suitability for renewable energy projects. The recently completed facility GIS screening is a key step in this process. This would be followed by RE installations at those facilities found to be most suitable. It is anticipated that solar PV will be generally suitable, but opportunities to deploy other technologies such as solar preheating, small wind, and geothermal may exist. When evaluating facility-scale RE projects, consideration should be given to EISA Sec 434, which mandates a 40-year analysis period when conducting life cycle cost (LCC) analysis of major equipment replacement, expansion, renovation, etc.

Utility-Scale Solar

Given current power market conditions and the low costs of power from the Navajo Generating Station (NGS), the economic case of installing utility-scale solar on Reclamation land and using this power directly to power Central Arizona Project (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.

Evaluation of the Brock Reservoir and A22 sites indicates that these sites are potentially suitable for utility scale solar projects. Of the available solar technologies, single axis PV appears to be the most cost-effective, with a levelized cost of energy (LCOE) of $0.10-$0.11 per kWh using published installation cost data. Informal discussions with developers and more recent data indicate that installation costs have continued to drop. Using these costs would likely result in LCOEs of $0.08-$0.10 per kWh for PV projects, which is comparable to the most recent PPA prices.

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 (perhaps lower if more recent installation costs are used) 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 (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. Many utilities have met their near- and mid-term solar RPS requirements. Currently, due to low natural gas prices, the LCOEs of natural gas power plants are lower than for PV plants, which may limit utility appetite for PV plants in the short term.

One next step to further facilitate siting a project on Reclamation land would be for Reclamation to prequalify the development potential of the most promising sites (e.g., Hassayampa, Brock Reservoir, and A22), especially in terms of identifying areas that are near transmission lines that have the capacity and the potential for very low environmental and cultural impacts. The Bureau of Land Management (BLM) is conducting 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's Phoenix Area Office has submitted the top five sites identified in its "Renewable Energy Suitability Analysis for the Central Arizona Project Canal System" to the BLM for inclusion in the Restoration Design Energy Project Environmental Impact Statement (EIS). 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.

Utility-Scale Wind

In general, Reclamation-owned parcels are not strong candidates for utility-scale wind energy development. Due to its mission, Reclamation-owned parcels tend to be relatively small compared to the area needed for a wind farm. In addition, most Reclamation-owned land is generally located near water, which being at a comparatively lower elevation, has a weaker wind resource than nearby areas. Finally, many Reclamation-owned parcels are awkwardly shaped, precluding efficient turbine array layout. For these reasons, Reclamation-owned land is, in general, less attractive for wind energy development than nearby privately owned or BLM land.

While most Reclamation-owned parcels may not be suitable for hosting whole wind farms, some parcels may be suitable to host portions of wind farms that are mainly sited on adjacent land. Reclamation-owned parcels are often located near larger parcels of BLM-owned land. By harmonizing its procedures with BLM, Reclamation may encourage developers to expand projects onto Reclamation-owned land.

Next Steps

Utility-Scale GIS Screening

As appropriate, NREL can work with Reclamation to improve the level of detail associated with the GIS screening. One possible next step is to replace the “land areas of interest” with the actual size and location of Reclamation-owned parcels. This will allow for more accurate estimates of the solar and wind energy potential of Reclamation-owned parcels. Follow-on analysis may also include consideration of regional wholesale electricity prices and regional demand for utility-scale RE facilities.

Facility-Scale GIS Screening

As appropriate, NREL can work with Reclamation staff to improve the level of detail associated with the facility-level GIS screening. A potential next step would be to redo the analysis taking into consideration the cost of electricity at each facility, as well as potential incentives available at each location. In addition to the available renewable energy resource, the cost of electricity greatly impacts the economics of facility-scale renewable energy projects.

Identify additional candidate sites to perform more detailed facility-scale site visits and evaluations similar to what was done for the Phoenix Area Office, Willows Office, and Lake Barryessa facility.

Facility-Scale Site Visit for Phoenix Area Office Photovoltaics and Willows/Lake Barryessa Photovoltaics

Should Reclamation decide to further pursue facility-scale solar at the Phoenix, Willows, or Lake Barryessa sites, the following steps should be undertaken (as desired by Reclamation, NREL can assist with any or all of these steps):

- Determine the preferred ownership models (government ownership or third-party ownership)
- Determine if PV should be installed at other Reclamation-owned facilities in the region (a larger aggregate purchase may allow for lower unit costs)
- If there is interest in third-party ownership, contact developers to determine interest in a PPA model for the various options at each site
- Procure the system (procurement, bid evaluation, design reviews, etc.).

Utility-Scale Site Development for Hassayampa, Brock Reservoir, or A22

Should Reclamation decide to further pursue utility-scale solar at the Hassayampa, Brock Reservoir, or A22 sites, the following steps, comprising an initial project development roadmap, 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.

Montana Wind-Screening Analysis

If Reclamation desires a more in-depth evaluation of the top two or three clusters identified in this analysis (such as Chouteau, Glacier, or Philips) NREL can assist with this process.

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.

Should Reclamation decide on further work in this area, NREL recommends the following next steps:

- Evaluate load profiles at other CAP pumping plants to determine if there are additional locations that may be suitable for PV deployment
- Determine whether there are opportunities to use PV to offset CAP's use of energy from NGS energy during peak periods, thus increasing potential sales of excess NGS energy during these periods
- Work with Reclamation staff to identify additional sites for more detailed utility-scale analysis.

1 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. A partial listing of laws, executive orders, and polices promoting use of renewable energy by federal agencies includes:

- Energy Policy Act of 2005 (Public Law 109-58), which addresses energy savings, energy management requirements, and energy use accountability
- The Energy Independence and Security Act of 2007 features goals that include increasing the production of clean renewable fuels, increasing the efficiency of products, buildings and vehicles, and improving the energy performance of the federal government
- The Omnibus Public Land Management Act of 2009 (Public Law 111-11, Title IX Bureau of Reclamation Authorizations, Subtitle F–Secure Water) authorizes grants to enhance water management, including increasing the use of renewable energy in the management and delivery of water
- EO 13423, Strengthening Federal Environmental, Energy, and Transportation Management, was signed in 2007, building on a body of federal work aimed at improving environmental and energy performance. It directs federal agencies to implement a number of sustainable practices, including "energy efficiency and reductions in greenhouse gas emissions," and "use of renewable energy"
- EO 13514, Federal Leadership in Environmental, Energy, and Economic Performance, was signed in 2009 and establishes greenhouse gas (GHG) emission reductions as an overarching, integrating performance metric for all federal agencies.

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 U.S. Department of Energy (DOE) on Feb. 1, 2011.

The Department of the Interior and U.S. DOE are signatories to a memorandum of understanding promoting joint efforts to, among other things, "evaluate the use of nonhydropower renewable resources with water management operations."

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, which may be suitable for deployment of renewable energy and energy efficiency technologies.

Reclamation is also developing rural water 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).

This report represents the major deliverable under the technical assistance portion of the interagency agreement.

2 Solar Technology Overview

2.1 Introduction

Two general technology approaches exist to creating electricity using solar energy. The first approach, termed solar thermal or concentrating solar power (CSP), converts the sun's energy into heat which is used to create steam that then drives a conventional generator. With the exception of dish Stirling technology, CSP technologies are generally best suited for utility-scale applications.

The second approach, photovoltaics (PV), uses panels comprised of special semiconductor material that converts light directly into electricity. PV is very modular and is used in application sizes ranging from individual devices (such as calculators) through facility-scale to utility-scale applications.

2.2 Solar Thermal (Concentrating Solar Power) Technologies

The three principal CSP technologies use direct normal insolation, which is defined as the rate of delivery of solar radiation directly from the sun per unit of surface. These technologies make little use of indirect insolation, which is the portion of solar radiation that comes from the parts of the sky where the sun is not located and also radiation that is reflected off the ground.

2.2.1 Parabolic Trough

Most commercial systems to date are parabolic trough systems that reflect and focus sunlight onto a linear receiver tube (Figure 2-2). The receiver contains a high-temperature fluid that is heated by sunlight and then pumped through a heat exchanger with water to produce superheated steam that drives the turbine generator. The parabolic trough CSP technology has been in commercial operation in southern California since 1981 (nine plants with a total of 350 MW). The latest CSP trough plant in southern Nevada, Nevada Solar One (64 MW), came on line in 2009. Figures 2-1 and 2-2 show schematics of a thermal electric CSP power tower. Figures 2-3, 2-4, and 2-5 show photographs of operating trough plants.

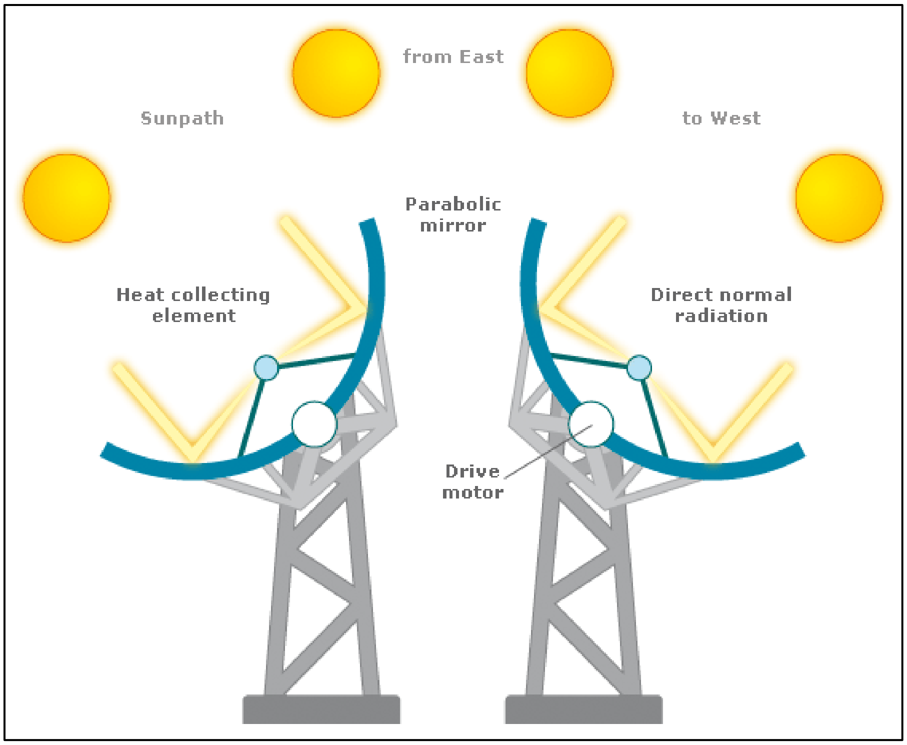

Figure 2-1. Parabolic troughs are aligned north-south and track the sun from east to west

Source: Josh Bauer, NREL

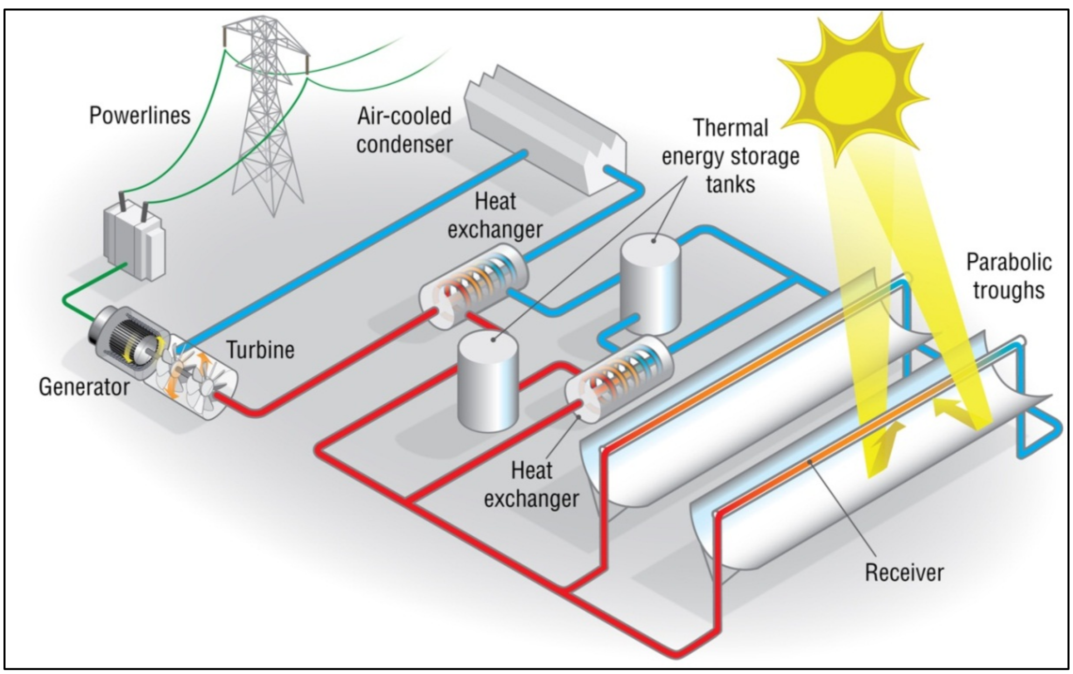

Figure 2-2. Schematic of a CSP thermal electric plant that can also use thermal storage

Source: Alfred Hicks, NREL

Figure 2-3. 280 MW Arizona trough plant. ***Photo by Dennis Schroeder, NREL 20097***

Figure 2-4. Aerial view of CSP trough plants at Kramer Junction, California (in operation for 30 years). ***Photo by Warren Gretz, NREL 01225***

Figure 2-5. Solar trough at a 50 MW plant. ***Photo by Geri Kodey, NREL 14390***

2.2.2 Power Tower

The second type of CSP thermal electric plant is called a power tower. A solar power plant utilizes hundreds of ground-mounted two-axis tracking mirrors called heliostats that focus sunlight on a receiver at the top of the tower, which is 100–300 feet high. In the receiver, a heat transfer fluid, commonly molten salt, is heated into liquid form and piped to a steam generation system to produce superheated steam. The superheated steam drives a Rankine cycle turbine generator to produce electricity. This technology is currently becoming commercialized and financeable. A 377 MW three-tower plant is being constructed on BLM lands in Ivanpah, California. Figure 2-6 and Figure 2-7 show demonstration solar power tower plants.

Figure 2-6. DOE solar demonstration power tower in southern Nevada. ***Photo from Sandia National Laboratories, NREL 06051***

Figure 2-7. Aerial view of Daggett, California, DOE solar demonstration power tower. ***Photo by Joe Flores, NREL 02163***

2.2.3 Dish Stirling

The third CSP technology is the dish Stirling engine system (Figure 2-8 and Figure 2-9). This technology uses a parabolic dish or mirrors to direct and concentrate sunlight onto a single-stroke Stirling engine. This engine powers an alternator to generate electricity.

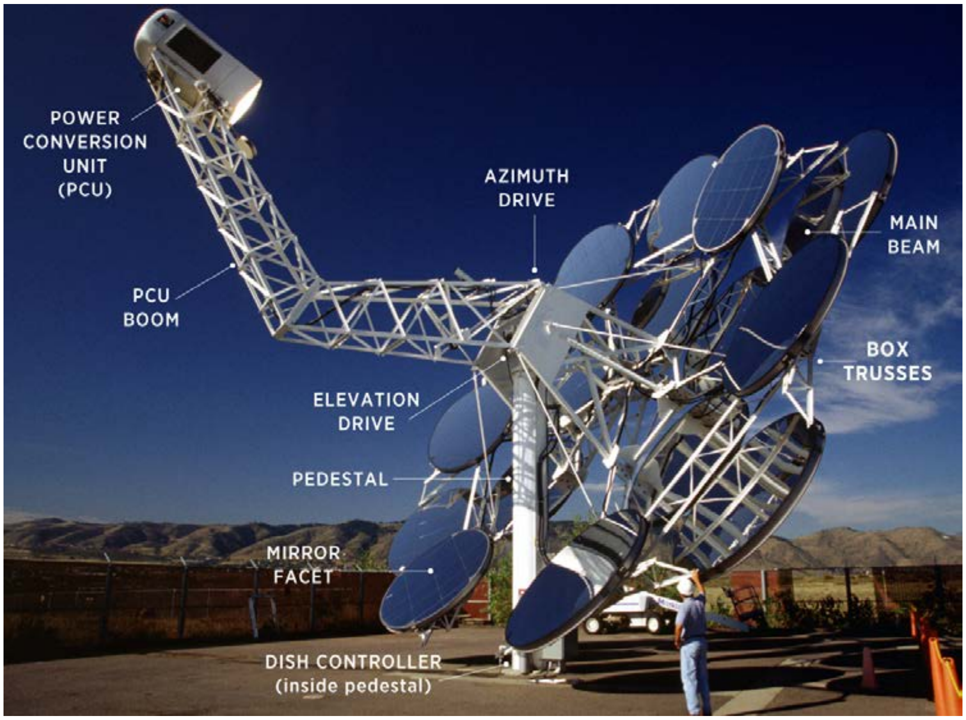

Figure 2-8. Characteristics of a CSP dish engine system

Source: Josh Bauer, NREL

Figure 2-9. 1.5-MW Maricopa, Arizona, solar power plant–60 25-kW dish Stirling systems. ***Photo by David Hicks, NREL 18379***

2.3 Photovoltaic Technologies

Photovoltaics are semiconductor devices that convert sunlight directly into electricity. They do so without any moving parts and without generating any noise or pollution. They must be mounted in unshaded locations—rooftops, carports, and ground-mounted arrays are common mounting locations. PV is highly scalable, suitable for both facility- and utility-scale applications.

2.3.1 How Solar Cells Work

Solar PV technology converts energy from solar radiation directly into electricity. Solar PV cells are the electricity-generating component of a solar energy system. When sunlight (photons) strikes a PV cell, an electric current is produced by stimulating electrons (negative charges) in a layer in the cell designed to give up electrons easily. The existing electric field in the solar cell pulls these electrons to another layer. By connecting the cell to an external load, this current (movement of charges) can then be used to power the load, e.g., light bulb (see Figure 2-10).

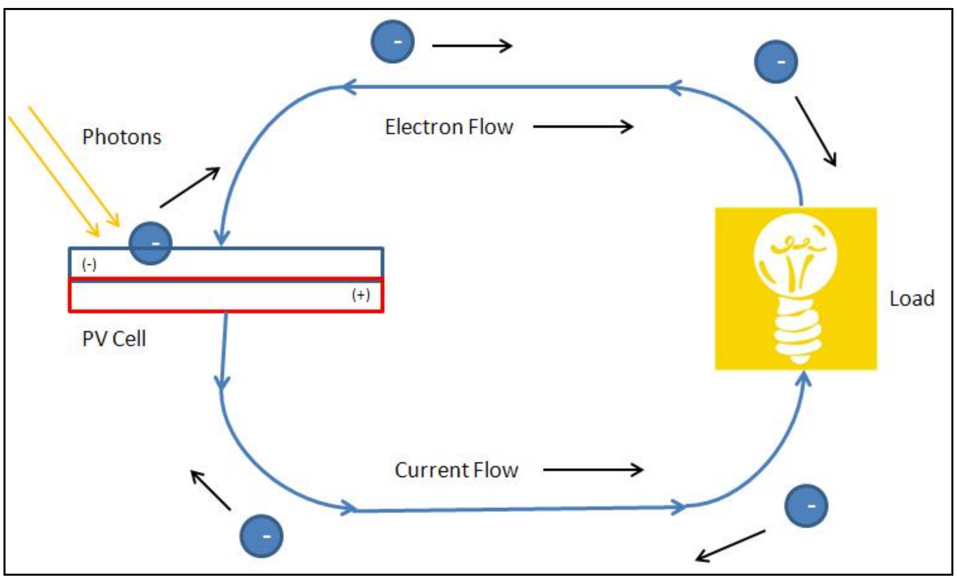

Figure 2-10. Generation of electricity from a PV cell

2.3.2 PV System Components

PV cells are assembled into a PV panel or module. PV modules are then connected to create an array. The modules are connected in series and then in parallel as needed to reach the specific voltage and current requirements for the inverter. The direct current (DC) electricity generated by the array is then converted by an inverter to useable alternating current (AC) that can be consumed by interconnected buildings and facilities or exported to the electricity grid (see Figure 2-11). PV system size varies from small residential [2-10 kilowatts (kW)], commercial (100-500 kW), to large utility scale [1-100+ megawatts (MW)].

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 watt/square-meter (W/m²). 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. PV modules have a life expectancy of over 30 years, and manufacturers warranty them against power degradation for 20-25 years. The array is usually the most expensive component of a PV system, typically accounting for approximately two-thirds the cost of a grid-connected system.

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 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.[2]

2.3.3 Facility-Scale PV

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 AC. A transformer may or may not be needed to change the inverter output voltage to a 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 typically

[2] "List of Eligible Inverters per SB1 Guidelines." Go Solar California, 2007-2012. http://www.gosolarcalifornia.org/equipment/inverters.php.

include batteries unless backup power is desired. Figure 2-11 shows the major components of a grid-connected PV system and illustrates how these components are interconnected.

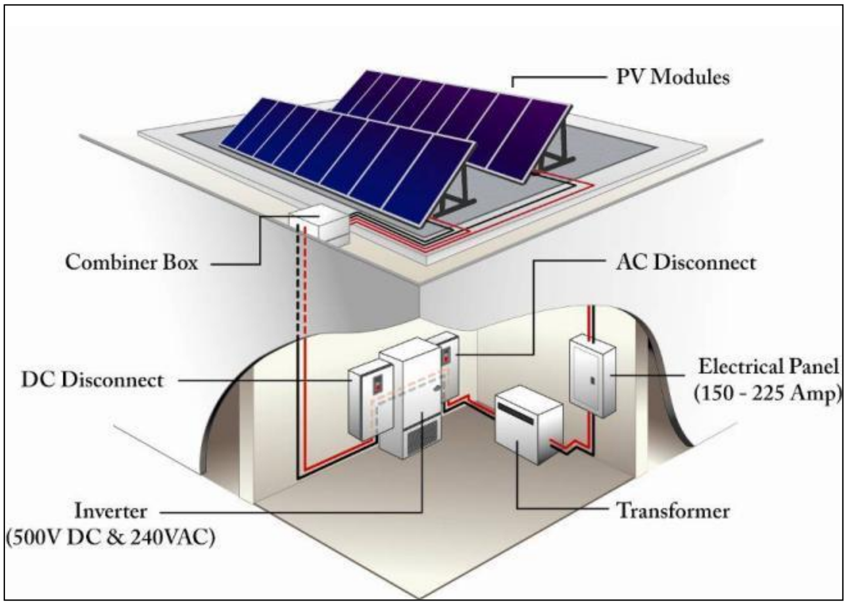

Figure 2-11. Depiction of major components of grid-connected PV systems

Source: Alfred Hicks, NREL

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.

2.3.4 Utility-Scale PV

Utility-scale PV systems are growing in number and benefit from economies of scale to reduce the dollar per watt cost of large-scale plants. Although PV provides variable power, the technology is financeable and the cost of PV modules has dramatically dropped in the last few years.

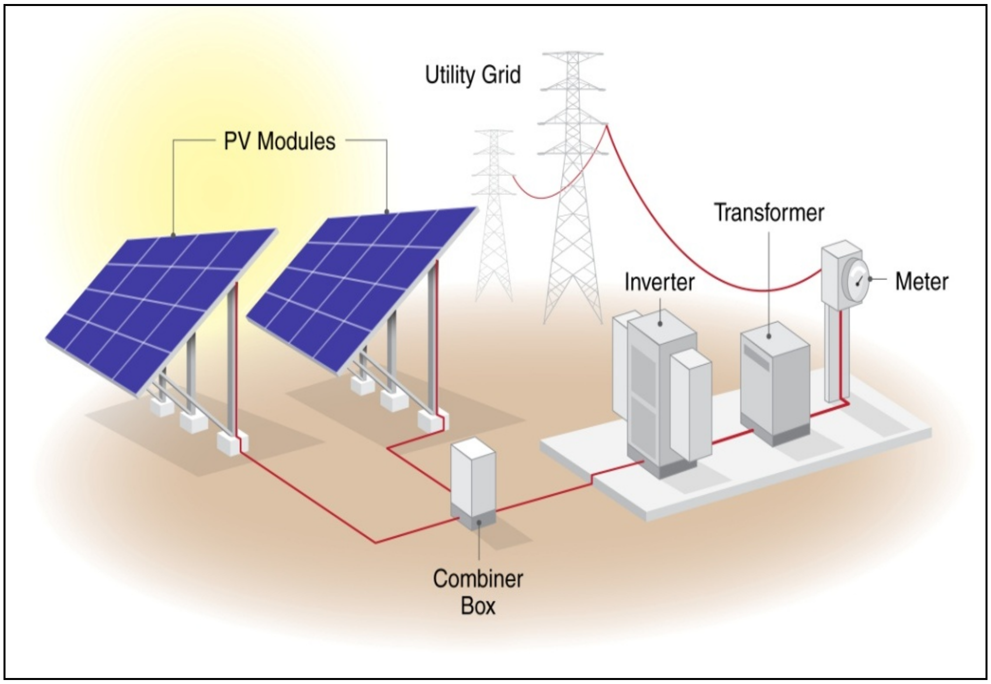

Figure 2-12. Ground mount array diagram

Source: Kosol Kiatreungwattana, NREL, *EPA Photovoltaic Solar on Landfills Technical Guidance* (forthcoming)

In the 1980s and 1990s, due to the high cost of PV systems (≥$10/W) most PV installations were small roof-mounted or ground-mounted systems. Today, due to dramatic reductions in PV system costs ($3-4/W), private and federal landowners are developing utility-scale 50-200 MW PV plants.

The typical choices are equator-facing rows of fixed panels tilted at 10-30 degrees or single-axis tracking arrays oriented north-south that tilts from east to west during the day to track the sun. Single-axis tracking PV systems use 10% more land to minimize adjacent panel shading; however, the cost increase over fixed panels is small (10%) and the system produces up to 35% more electrical energy. Two such installations are shown in Figure 2-13 and Figure 2-14.

Figure 2-13. 8 MW, single-axis tilt-PV system in Alamosa, Colorado. ***Photo by Tom Stoffel, NREL 15558***

Figure 2-14. Photovoltaic field at the National Wind Technology Center. ***Photo by Dennis Schroeder, NREL 19794***

2.4 Government Incentives for Solar Energy Plants

Like most renewable technologies, there are market driving policies. The main driver has been state renewables portfolio standards (RPS), where utility companies are mandated to increase power generation from renewable energy resources. State and utility financial incentives, and state and federal tax incentives are also allowing the utility-scale solar power cost of electrical generation to approach that of conventional fossil fuel-generation plants.

2.4.1 Federal and States Incentives

Federal incentives for corporate sector-developed utility-scale solar projects include:

- Federal Investment Tax Credit: 30% of cost basis, expires 2016

- 5-year Accelerated Depreciation: no expiration

Arizona incentives for corporate-sector developed projects include:

- Renewable Energy Production Tax Credit, where:
    - Minimum size is 5 MW
    - Maximum incentive of $2 million per year
- Program budget of $20 million per year on first come, first serve basis (timing is critical)
    - Energy Equipment Property Tax Exemption: 100% of asset value
    - Solar Equipment Sales Tax Exemption: 100% of sales tax on equipment

The financial and tax incentives for solar equipment for all states with Reclamation lands or facilities are provided at http://www.dsireusa.org/incentives/index.cfm?state=us&re=1&EE=1.

3 Wind Technology Overview

3.1 Introduction

Wind turbines convert the mechanical motion of moving air into electricity. While not as modular as PV, wind turbines come in a range of sizes ranging from small units with a rated power of a few hundred watts that provide energy to yachts or cabins, to large units with a rated power of several megawatts that provide bulk energy to the grid. While turbines of all sizes have the same basic physics, turbines can be grouped into three size classes, small, medium, and large, each subject to very different sets of market forces.

3.2 How Wind Turbines Work

3.2.1 Wind Turbine Topologies

Wind turbine design involves difficult trade-offs. While horizontal-axis, three-bladed upwind machines are most common, wind turbines employing a variety of topologies have been deployed. This section describes the major categories of machines.

Drag versus lift: Drag machines use the wind to push the blades. Lift machines use the wind to lift the blades, with similar physics to that of an airplane wing. Lift machines are much more efficient than drag machines, and thus the vast majority of wind turbines on the market are lift machines. An example of a drag machine is the classic water pumping wind mill. Drag machines typically have high solidity (i.e. the blades cover most or all of the swept area. Lift machines typically have two or three blades. Drag machines always have a tip speed ratio of less than one. In other words, the speed of the blade tip is always less than the wind speed. In contrast, lift machines have a tip speed ratio greater than one (i.e., the speed of the tip of the blade is greater than the wind speed). It is this higher tip speed ratio that accounts for the greater efficiency of lift machines. Drag machines do have the advantage of greater torque, something that is useful in direct mechanical water pumping applications.

Vertical axis versus horizontal axis: Vertical axis wind turbines have an axis of rotation that is vertical, while horizontal-axis turbines have an axis of rotation that is horizontal. An advantage of vertical-axis turbines is that much of the heavy equipment such as the generator can be located close to the ground. This is also a big disadvantage. Being located closer to the ground, vertical-access turbines are not exposed to the greater wind resource that is located higher off the ground and thus produce less energy than a comparable horizontal-axis wind turbine. Despite long-standing interest and the introduction of several small vertical-axis turbines in recent years, horizontal-axis turbines dominate the market.

Upwind versus downwind: Upwind machines have the blades upwind of the tower. Downwind machines have the blades downwind of the tower. Especially on larger machines, the force of the wind on the blades causes the blades to bend in the downwind direction. The blades in upwind machines need to be stiff enough to avoid bending so much that they hit the tower. In downwind machines the blades bend away from the tower and thus don't have to be as stiff, which reduces materials costs. A disadvantage of the downwind configuration is tower shadow. As the blades go behind the tower, they are partially sheltered from the wind. This sheltering leads to cyclic loads on the blades that can lead to increased maintenance requirements. While there is continuing interest in downwind machines and downwind machines are available, especially in the small turbine category, most wind turbines use the upwind configuration.

Two blades versus three blades: The advantage of two-bladed machines is cost. Two blades are less expensive than three blades. The disadvantage of two-bladed machines is that the gravitational forces on the rotor are different when the blades are horizontal as compared to when the blades are vertical. Thus as the rotor spins, two-bladed machines are subject to cyclic loads that can lead to more wear and tear. A three-bladed rotor is always balanced, regardless of blade orientation and is thus subject to fewer cyclic loads. Three-bladed machines dominate the market. Interest remains in two-bladed machines, and some two-bladed models are available in the market.

3.2.2 Wind Turbine Components

All turbines work by converting the energy in moving air into electricity. Figure 3-1 shows the major wind turbine components of a utility-scale turbine. The blades, comprising the rotor, capture energy from the wind. The rotor is connected via a shaft to the generator, which converts the shaft's rotation into electricity. In smaller turbines and in some larger turbines, the shaft is directly connected to the generator. This configuration is called direct drive. In most larger turbines the rotor is connected to the generator via a gearbox, which increases the rotational speed to a value more suitable for typical generators. Most turbines include a brake on either the low speed or high speed shaft. The shaft(s), brakes, gearbox, and generator together comprise the drive train, which is typically housed within a nacelle that protects the drive train components from the elements. The nacelle is mounted on a tower that exposes the turbine to the higher wind speeds that are typically found higher off the ground.

Large turbines typically have an active yaw system (a yaw drive, powered by a yaw motor), that orients the turbine into the wind. The motor is controlled by a signal coming from a wind vane mounted on top of the nacelle. A nacelle-mounted speed sensor signals the rotor to start spinning when the wind speeds are above the minimum "cut-in" wind speed, typically about 8 mph. Signals from the speed sensor will cause the turbine to shut off if the winds exceed the turbine's "cut-out" speed, typically around 50 mph.

Small turbines (up to 10-20 kW in rated power) typically have passive yaw systems (no yaw drive or yaw motor) and use a tail to orient the rotor into the wind. These small turbines also use passive strategies to protect themselves from extreme winds. A common strategy is furling, where the force from high winds causes the turbine nacelle to tilt out of the wind. Other passive protection strategies involve twisting the blades in high winds to reduce the blade's lift and thus reduce the forces on the turbine.

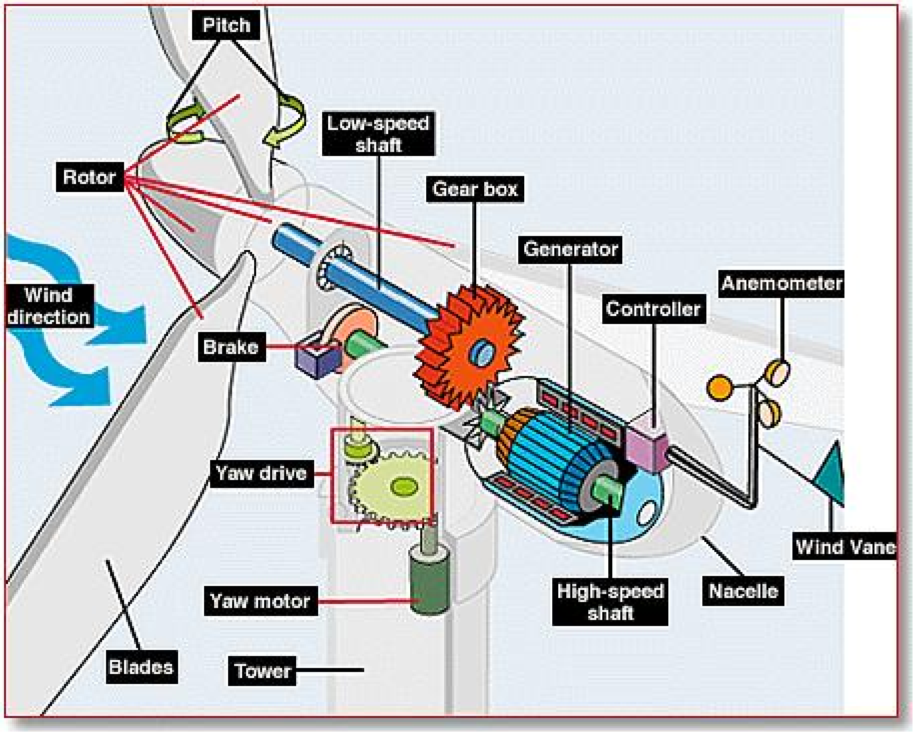

Figure 3-1. Large wind turbine components

Source: DOE/EERE

3.2.3 Wind Turbine Siting

The power in the wind is proportional to the cube of the velocity. This means that a 10% increase in wind speed results in a 30% increase in power. The take away is that the key consideration in siting a wind turbine is to place it in a location with a good wind resource. For maximum energy production, a wind turbine should be away from or above any ground obstacles (ground clutter) that could cause local turbulence. Figure 3-2 shows the zone of turbulent winds that is typically found downwind of buildings and trees. For utility-scale turbines, ground clutter is typically not an issue as these turbines are mostly located outside of urban areas in locations with good wind exposure. Ground clutter is more of an issue for smaller turbines that provide energy to a specific load. Ideally, the turbine should be located upwind of the load (per the prevailing wind direction) and on a tower taller than any other building or tree within several hundred meters. However, given on-the-ground realities, the best available turbine location on a given property may not meet the criteria for ideal siting. In this case, the prospective turbine owner should realize that the turbine energy production will suffer and determine if the project is still worthwhile.

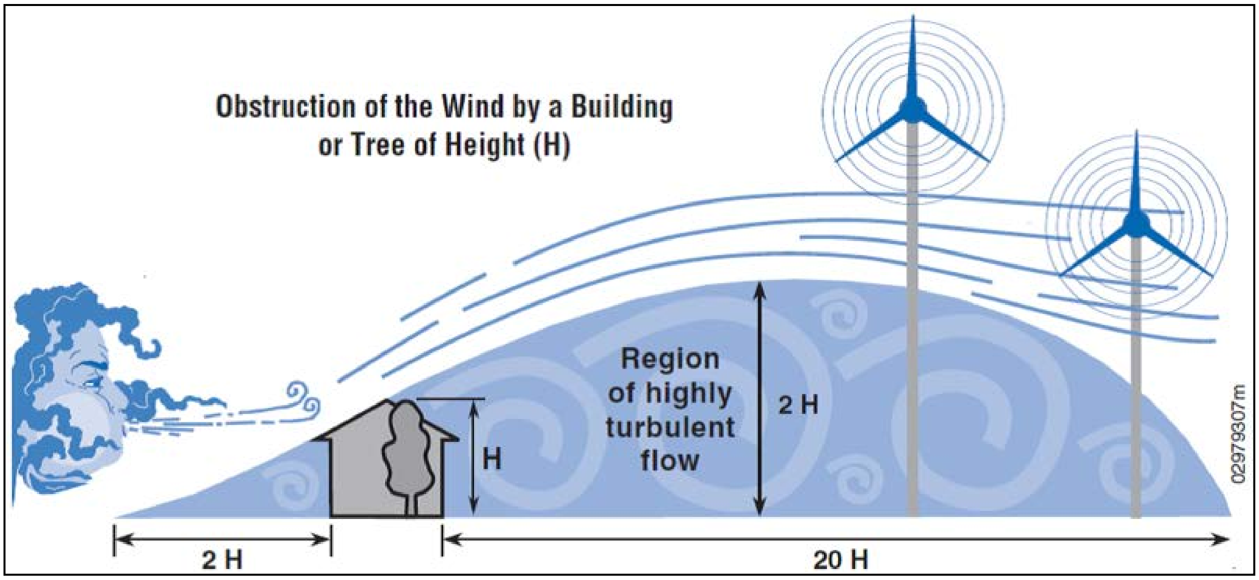

Figure 3-2. Wind turbine siting

Source: OpenEI

3.3 Wind Turbine Market and Applications

3.3.1 Introduction

Wind turbines can be loosely grouped into three different size categories, small, medium, and large. Each have different applications, and encounter different regulatory and market environments.

3.3.2 Small Wind Turbines

There is no universally accepted maximum cutoff for small wind turbines. For this publication, a small turbine is defined as a turbine with a rated power less than 100 kW. Turbines within this category are mostly used to power a specific load such as a cabin, house, farm, commercial facility, or industrial facility. Economically, these turbines are competing against retail electricity rather than wholesale electricity. Because most infrastructure is located in less windy areas, small turbines are more likely to be placed in less windy locations and in spots that are subject to the effects of ground clutter. Thus, small turbines tend to have lower capacity factors than larger turbines.

Small turbine design at the small end of this category typically emphasizes maximum reliability and a minimum number of moving parts. As can be seen, there are many fewer parts than for larger turbines. Figure 3-3 shows a schematic of a small turbine. Figure 3-4 shows a couple of sample small wind turbines. Small turbines are mounted on either monopole or lattice towers. Less expensive guyed towers (monopole or lattice) are commonly used for the smaller turbines in this category.

A dizzying variety of turbines rated up to 20 kW is available in the small end of the small category. Above 20 kW there are fewer choices. At the larger end of this category there is an active market in refurbished turbines. The original 1980's wind farms that used the then current 50-100 kW wind turbines are being "repowered" with modern, multi-MW, turbines. The usable old turbines are being refurbished and sold on the secondary market. Cost and quality of these refurbished turbines vary drastically.

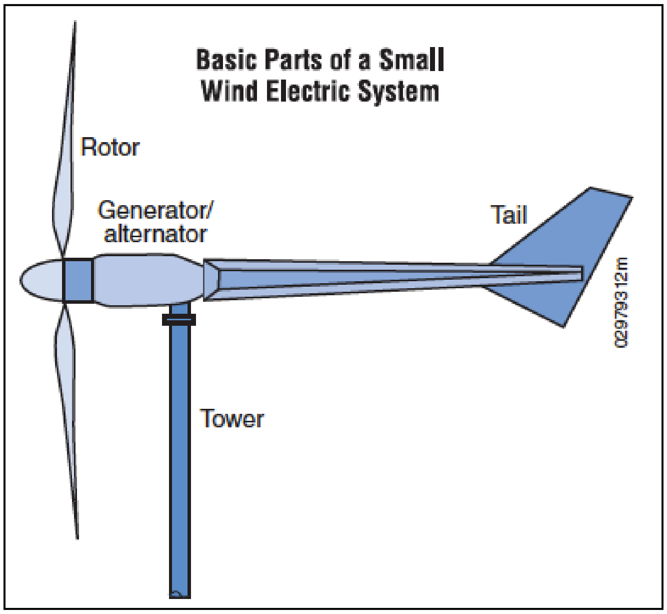

Figure 3-3. Basic parts of a small wind turbine

Source: OpenEI

Figure 3-4. Examples of small wind turbines. ***Photos by (left) Abigail Krich, NREL 13491, and (right) Lee Jay Fingersh, NREL 14642***

3.3.3 Large Wind Turbines

The size of utility-scale turbines has steadily increased since these turbines were first deployed in the early 1980s. Since then, turbine-rated power has increased from 50 kW to over 3 MW. Similar to the situation with small turbines, there is no universally accepted definition of a large wind turbine. This paper will categorize as "large" or "utility scale" any turbine with a rated power greater than 1 MW. Current utility-scale turbine blade length ranges from 35 meters (m) to over 50 m. Hub heights range from 60 m to over 100 m. The overwhelming majority of large turbines are mounted on steel monopole towers. Large turbines are deployed in projects using anywhere from one to several hundred turbines. These projects supply bulk power to the grid and thus compete in the wholesale electric market. Since these projects are not tied to a specific load, project developers have more flexibility to select the windiest sites. The largest portion of large turbine projects is owned by independent power producers (IPPs) that sell electricity to utilities under long-term (10-20 year) power purchase agreements. A significant minority of projects are owned directly by utilities. Figure 3-5 shows a schematic of a wind farm. Figure 3-6 shows a couple of example utility-scale wind turbine installations.

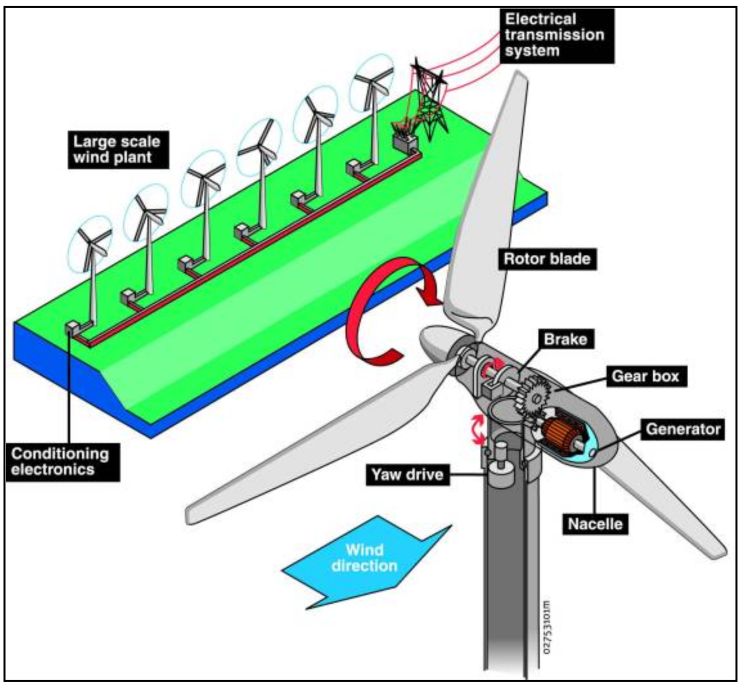

Figure 3-5. Wind farm schematic

Source: DOE/EERE

Figure 3-6. Large wind turbines. ***Photos by (left) Dennis Schroeder, NREL 19022, and (right) Ruth Baranowski, NREL 21207***

3.3.4 Mid-Size Wind Turbines

For the purposes of this publication, turbines with a rated power of 100 kW–1000 kW comprise the category of mid-size wind turbines. Turbines of this size range are not as competitive as larger turbines for providing bulk power, while the applications that require mid-size turbines are fewer in number compared to the number of small turbine applications. Most newly installed turbines in this category supply electricity to a specific load. Performance and economics of mid-size turbines are between those of the large and small turbines. As can be expected, the larger mid-size turbines are similar to large turbines, while the smaller mid-size turbines are similar to the (larger) small turbines. This size market segment is not as active as the large and small turbine market segments. The lower level of activity means that there are only a few suppliers manufacturing new turbines in this size range. This market segment sees steady business in refurbished older machines. Figure 3-7 shows a sample mid-size wind turbine.

Figure 3-7. Mid-size wind turbine. ***Photo by Lee Jay Fingersh, NREL 16641***

3.4 Government Incentives for Wind Energy Projects

Like most renewable technologies, there are market driving policies to encourage wind turbine deployment. A large driver has been state RPSs, where utility companies are mandated to increase power generation from renewable energy resources. State and utility financial incentives, and state and federal tax incentives are also allowing the utility-scale wind power cost of electrical generation to approach that of conventional fossil fuel-generation plants.

3.4.1 Federal Incentives

Federal incentives for corporate sector developed utility-scale solar projects include:

- Federal Investment Tax Credit (turbines up to 100 kW): 30% of cost basis, expires 2016.
- Production Tax Credit: $0.022 (escalating with inflation) for each kWh sold to an unrelated third party for the first 10 years of the facility. Facilities must begin construction by Dec. 31, 2013 to qualify. The credit may be extended.
- 5-year Accelerated Depreciation: No expiration.

The financial and tax incentives for solar equipment for all states with Reclamation lands or facilities are provided at http://www.dsireusa.org/incentives/index.cfm?state=us&re=1&EE=1.

4 GIS Screening

4.1 Utility-Scale Screening

A 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 fully presented in the separate publication titled "Renewable Energy Assessment of Bureau of Reclamation Land and Facilities Using Geographic Information Systems."[3]

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 of "Renewable Energy Assessment of Bureau of Reclamation Land and Facilities Using Geographic Information Systems." Other site-based characteristics (proximity to transmission lines and roads) were omitted because the specific locations of the Reclamation land interests were unknown.

4.1.1 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[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. The site exclusion criteria are detailed in the separate publication. 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 (SAM) (https://sam.nrel.gov) to estimate generation capacity factor values within five solar resource ranges. An overall installation density of 32.8 MW/square-kilometer (km^2) was also estimated for this configuration.

4.1.2 Utility-Scale Photovoltaics

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 single-axis tracking collector at a 0-degree tilt with a

[3] Haase, et al. *Renewable Energy Assessment of Bureau of Reclamation Land and Facilities Using Geographic Information Systems* (forthcoming). NREL/TP-7A30-57123. Golden, CO: National Renewable Energy Laboratory.
[4] Wilcox, S. *National Solar Radiation Database 1991-2005 Update: User's Manual.* NREL/TP-581-41364. Golden, CO: National Renewable Energy Lab, 2007. http://www.nrel.gov/docs/fy07osti/41364.pdf.

48 MW/km^2 power density[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 (see Table A-3 from "Renewable Energy Assessment of Bureau of Reclamation Land and Facilities Using Geographic Information Systems."[6]) and SAM.

4.1.3 Onshore Wind

The onshore wind resource was calculated for wind at 80 m height above the ground, extrapolating from validated onshore wind power estimates at 50 m height. These data were compiled from several sources that have released their data to NREL for use in its modeling efforts. These sources include NREL's internal modeling (North Dakota, South Dakota, and portions of Texas), Alternative Energy Institute (Texas), and AWS Truepower with NREL (the remaining 14 states). The 50-m estimates were shifted to 80 m height by increasing the resource by ½ power class for those areas below 500 W/m^2 annual average wind power density. A resource threshold of class 3 or better was applied, and site characteristic exclusions were applied as detailed in Table A-4 of "Renewable Energy Assessment of Bureau of Reclamation Land and Facilities Using Geographic Information Systems." In estimating generation from wind resource areas, capacity factors by class were utilized, representing estimates for typical utility-scale wind turbines within that resource profile (Table A-5 of "Renewable Energy Assessment of Bureau of Reclamation Land and Facilities Using Geographic Information Systems."). A power density of 5 MW/km^2 was used,[7] representing a turbine spacing of 10x10 rotor diameters.

4.2 Results

"Renewable Energy Assessment of Bureau of Reclamation Land and Facilities Using Geographic Information Systems." includes summaries of the resource potential with and without exclusions to demonstrate the impact of the exclusion scenarios utilized. The top 20 counties for solar and wind (based on total potential installed capacity) are shown in Figure 4-1. Table 4-1, Table 4-2, and Table 4-3 list the top 20 counties for CSP, utility-scale PV, and onshore wind, respectively. NREL was not provided the actual Reclamation land area, but rather the boundaries that were provided were public land survey sections (each section consisting of 640 acres/1 square mile) that contained some portion of Reclamation-owned lands. The exact amount of Reclamation-owned land within each section is unknown. Thus, the MW values shown represent the potential capacity within the land survey sections provided by Reclamation within a county, not just Reclamation lands. Therefore, the potential installed capacity estimates are slightly high, serving as an index of the relative potential in areas owned by Reclamation. Additional site-specific analyses would be required to determine the suitability and potential of actual Reclamation lands.

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[5] Denholm, P.; Margolis, R. M. "Impacts of Array Configuration on Land-Use Requirements for Large-Scale Photovoltaic Deployment in the United States." Preprint. Prepared for SOLAR 2008-American Solar Energy Society, May 3–8, 2008. NREL/CP-670-42971. Golden, CO: National Renewable Energy Laboratory, May 2008. http://www.nrel.gov/docs/fy08osti/42971.pdf.

[6] Haase, et al. *Renewable Energy Assessment of Bureau of Reclamation Land and Facilities Using Geographic Information Systems* (forthcoming). NREL/TP-7A30-57123. Golden, CO: National Renewable Energy Laboratory.

[7] DOE EERE. *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply*. NREL/TP-500-41869. Golden, CO: National Renewable Energy Laboratory, July 2008; pp. 179.

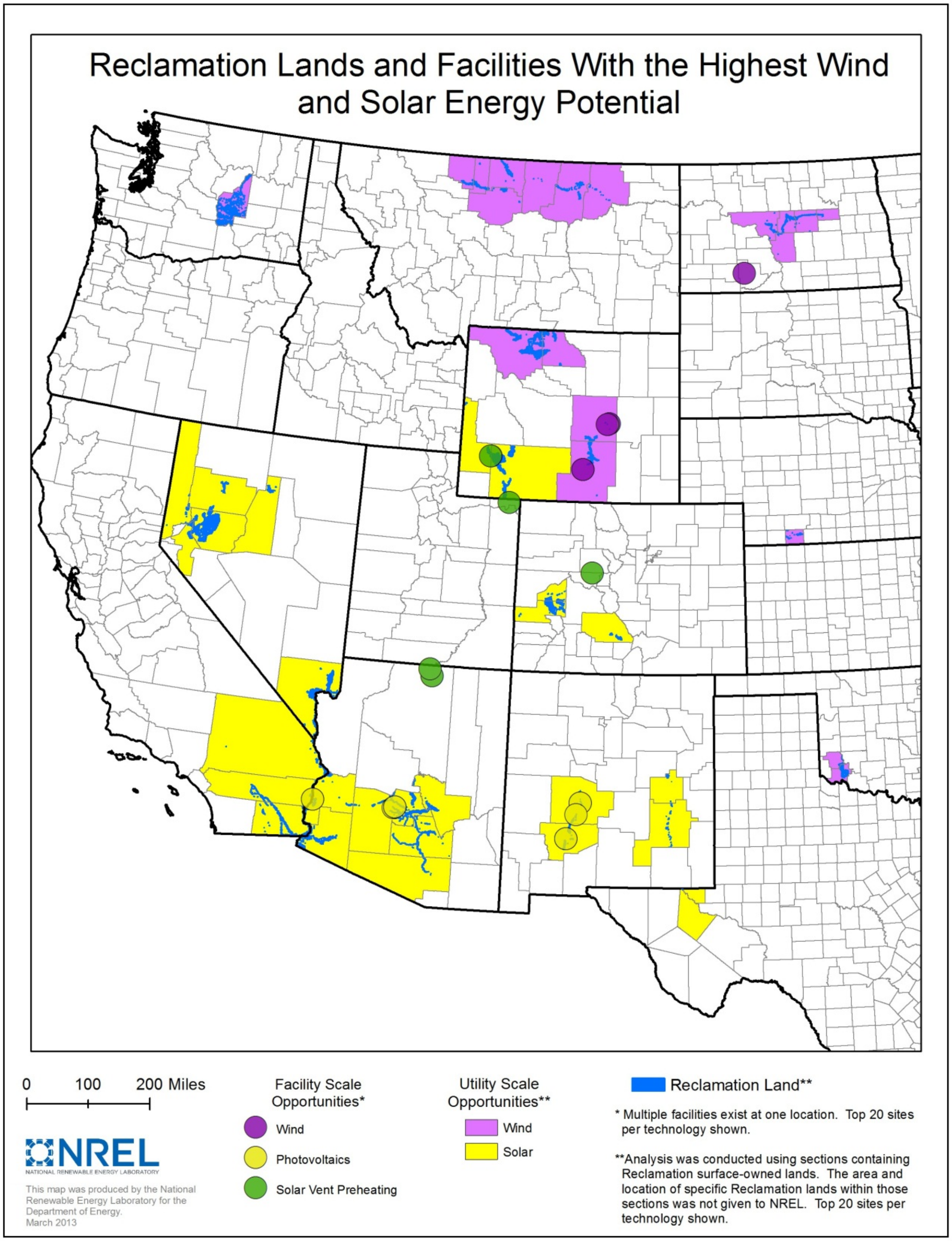

Figure 4-1. Summary of top 20 counties and top 20 facilities (by technology) for potential renewable energy deployment

As shown in the figure and tables, southern Arizona and southeast California show good promise for both CSP and PV. Western Nevada and southwest Wyoming also have promising parcels for CSP, while additional promising sites for PV are located in southern New Mexico. The

Reclamation parcels with the greatest wind resource are generally located in the northern Rocky Mountains and northern plains (Wyoming, Montana, and North Dakota).

Table 4-1. Top 20 Counties by CSP Potential Installed Capacity

CSP		
County	**MW Rank**	**MW Capacity for Reclamation Area of Interest (by County)[a]**
Churchill, NV	1	44,432
Lyon, NV	2	43,544
Pershing, NV	3	42,899
Imperial, CA	4	26,720
Yuma, AZ	5	22,688
La Paz, AZ	6	21,593
Maricopa, AZ	7	14,599
Pinal, AZ	8	11,856
Pima, AZ	9	8,125
Washoe, NV	10	7,434
Riverside, CA	11	5,934
Delta, CO	12	5,386
Montrose, CO	12	5,386
Eddy, NM	14	4,547
Loving, TX	14	4,547
Reeves, TX	14	4,547
Lander, NV	17	2,204
Lincoln, WY	18	1,926
Sweetwater, WY	18	1,926
San Bernardino, CA	20	1,605
Clark, NV	20	1,605

[a] Listed capacities are for an area somewhat larger than actual Reclamation-owned land. For more details, see section 4.2 Results.

Table 4-2. Top 20 Counties by Utility-Scale PV Potential Installed Capacity

Utility-Scale PV		
County	**MW Rank**	**County-Level MW Potential for Reclamation Area of Interest[a]**
Imperial, CA	1	38,990
Yuma, AZ	2	33,106
La Paz, AZ	3	31,508
Maricopa, AZ	4	21,303
Pinal, AZ	5	17,301
Pima, AZ	6	11,856
Churchill, NV	7	11,189
Riverside, CA	8	8,659
Eddy, NM	9	6,635

Utility-Scale PV		
County	**MW Rank**	**County-Level MW Potential for Reclamation Area of Interest[a]**
Loving, TX	9	6,635
Reeves, TX	9	6,635
San Bernardino, CA	12	2,341
Clark, NV	12	2,341
Saguache, CO	14	1,891
Sierra, NM	15	1,733
Socorro, NM	15	1,733
De Baca, NM	17	1,519
Chaves, NM	18	1,389
Gila, AZ	19	1,294
Lyon, NV	20	1,002

[a] Listed capacities are for an area somewhat larger than actual Reclamation-owned land. For more details, see section 4.2 Results.

Table 4-3. Top 20 Counties by Wind Potential Installed Capacity[a]

Big Horn, WY	1	2,975
Park, WY	1	2,975
Hill, MT	3	1,370
Liberty, MT	4	1,336
Sheridan, ND	5	1,201
Carbon, WY	6	1,152
Natrona, WY	6	1,152
Chouteau, MT	8	1,023
Wells, ND	9	967
Greer, OK	10	922
Burleigh, ND	11	829
McLean, ND	11	829
Red Willow, NE	13	748
Phillips, MT	14	715
Valley, MT	15	694
Blaine, MT	16	671
Eddy, ND	17	663
Toole, MT	18	645
Jackson, OK	19	612
Grant, WA	20	571

[a] Listed capacities are for an area somewhat larger than actual Reclamation-owned land. For more details, see section 4.2 Results.

4.3 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. Results for all properties are given in the related publication titled "Renewable Energy Assessment of Bureau of Reclamation Land and Facilities Using Geographic Information Systems."[8] Table 4-4, Table 4-5, and Table 4-6 show some of these results for the properties with the highest annual average potentials for energy delivered utilizing solar vent preheating to preheat air coming into a facility and for PV solar resources. The top 20 locations (for each technology) are also shown in Figure 4-1.

As shown in the figure and tables the facilities with the greatest PV resource are located in the southern Arizona and New Mexico. The facilities with the greatest resource for solar vent pre-heating are in an area extending from northern New Mexico to southern Wyoming. The facilities with the greatest wind resource are located in the northern plains states (Wyoming and North Dakota).

Other data extracted from the database that are included in the separate publication are annual global horizontal solar resource, annual solar resource from an east-west oriented single-axis tracking collector, maximum solar resource from a fixed flat-plate system with tilt equal to latitude, and annual heating degree days and annual cooling degree days (both relative to 65 degrees).

These sites represent potential sites that can be further evaluated for deployment of facility-scale renewable energy systems.

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[8] Haase, et al. *Renewable Energy Assessment of Bureau of Reclamation Land and Facilities Using Geographic Information Systems* (forthcoming). NREL/TP-7A30-57123. Golden, CO: National Renewable Energy Laboratory.

Table 4-4. Reclamation Facilities with the Highest Potential Energy Delivered from Solar Vent Preheating

Real Property Identifier	City	State	Solar Vent Preheat Annual Energy Delivered (kWh/m^2/yr)
N0557000200B	Page	Arizona	844.0
N0557000400B	Page	Arizona	844.0
N0557000100B	Page	Arizona	844.0
N0557000500B	Page	Arizona	844.0
N0557000300B	Page	Arizona	844.0
N0382000100B	Meredith	Colorado	808.0
N0382000400B	Meredith	Colorado	808.0
N0154000300B	Kemmerer	Wyoming	805.0
N0154000400B	Kemmerer	Wyoming	805.0
N0154000200B	Kemmerer	Wyoming	805.0
N0154000500B	Kemmerer	Wyoming	805.0

Table 4-5. Reclamation Facilities with the Highest Annual Average Photovoltaic Resource from a Fixed Flat-Plate Collector with Tilt Equal to Latitude

Real Property Identifier	City	State	Tilt = Latitude Solar (Annual Average kWh/m^2/day)
N0423000100B	Ehrenberg	Arizona	6.55
N0423000200B	Ehrenberg	Arizona	6.55
N0423000300B	Ehrenberg	Arizona	6.55
N0423000400B	Ehrenberg	Arizona	6.55
N0163202500B	Socorro	New Mexico	6.55
N0024000100B	Truth Or Consequences	New Mexico	6.54
N0024000200B	Truth Or Consequences	New Mexico	6.54
N0024000300B	Truth Or Consequences	New Mexico	6.54
N0024000400B	Truth Or Consequences	New Mexico	6.54
N0024000500B	Truth Or Consequences	New Mexico	6.54
N0024000600B	Truth Or Consequences	New Mexico	6.54

Table 4-6. Reclamation Facilities with the Highest Annual Average Wind Resource at 50 m Height Above Ground

Real Property Identifier	City	State	Annual Wind Power Density at 50 m height (W/m^2)
N0144005000B	Mills	Wyoming	555
N0144005100B	Mills	Wyoming	555
N0467006400B	Mills	Wyoming	555
N1112000100B	Elgin	North Dakota	515
N1112000200B	Elgin	North Dakota	515
N0144000200B	Casper	Wyoming	477
N0144005600B	Casper	Wyoming	477
N0144001200B	Sinclair	Wyoming	476
N0144001300B	Sinclair	Wyoming	476
N0144001400B	Sinclair	Wyoming	476
N0144001700B	Sinclair	Wyoming	476

5 Facility-Scale Assessment of Phoenix Area Office

On Aug. 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 Road, Glendale, AZ. 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 Figure 5-1, and a south elevation view is shown in Figure 5-2.

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 pounds (lbs)/square-feet (ft^2). NREL believes that it will support such a system and has assumed so for this report.

Figure 5-1. Aerial view of Phoenix Area Office

Source: Google Earth image provided by Reclamation

Figure 5-2. Phoenix Area Office south elevation view. ***Photo by Otto VanGeet, NREL***

5.1 Energy Use and Utility Data

The Phoenix Area Office is connected to the Salt River Project (SRP) electric utility and Southwest Gas for natural gas. The electric rate structure is General Service (E36)[9], which is an energy (kilowatt-hour)-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 (see Figure 5-3 and Figure 5-4). The annual electrical energy use was 892,800 kilowatt-hour (kWh) in fiscal year (FY) 2010, and the average rate during FY 2010 was $0.09/kWh.

[9] For more information, see http://www.srpnet.com/prices/business/general.aspx.

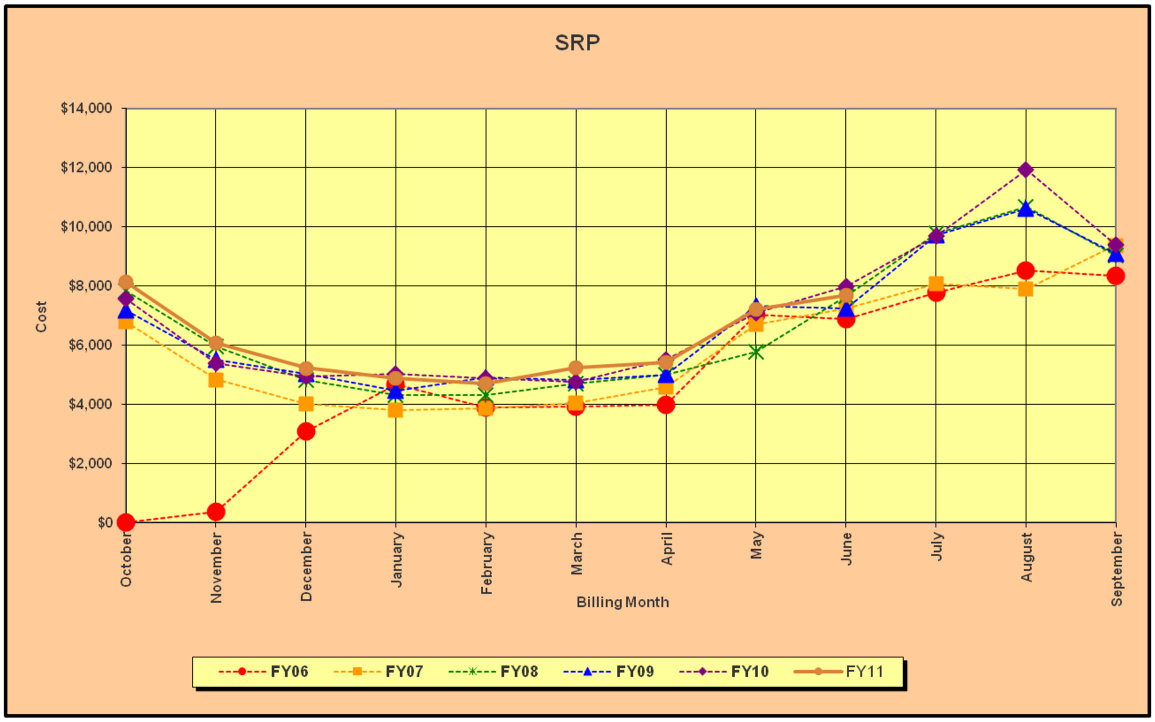

Figure 5-3. Electrical cost (FY06 – FY11)

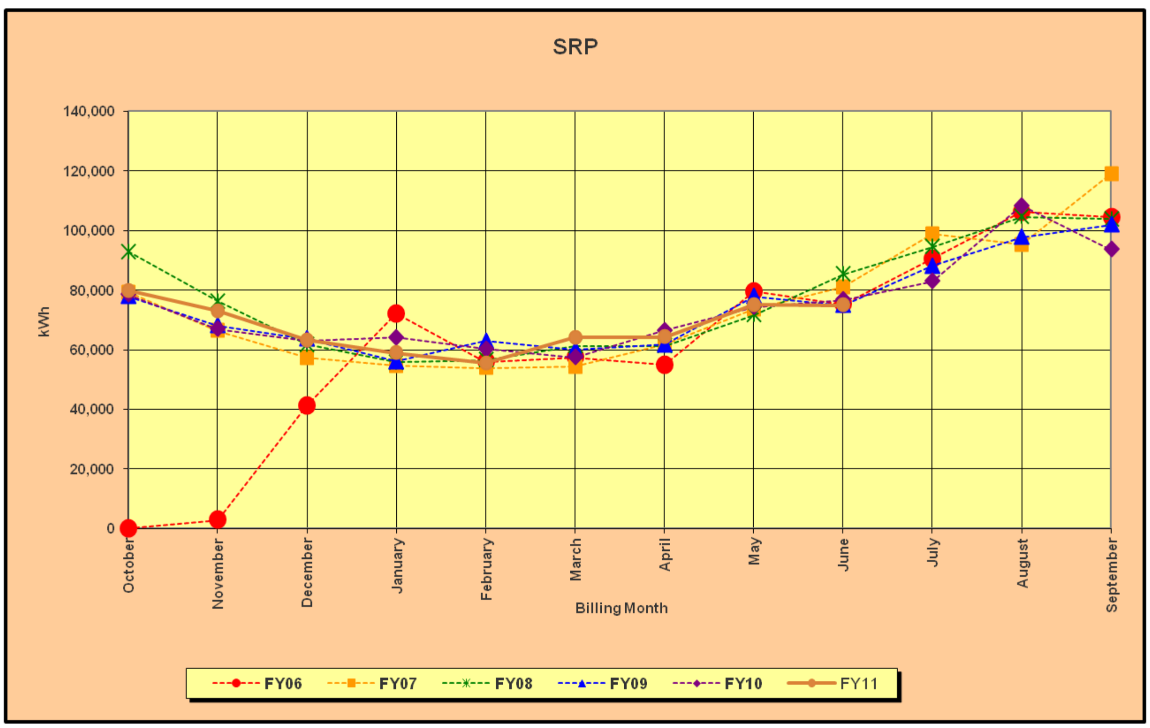

Figure 5-4. Electrical usage (kWh, FY06 – FY11)[a]

[a] At the time of this writing, only data from September to June was available for FY11.

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.

5.2 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 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. Section 2 Solar Technology Overview provides additional detail on the major components and functioning of 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.

5.3 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.[10]

[10] For more information on NREL's PVWatts Version 2, see http://www.nrel.gov/rredc/pvwatts/grid.html.

Table 5-1. 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/m2/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
12	3.62	86	7.74
Year	6.21	1620	145.80

Figure 5-5. Proposed PV system locations for Reclamation's Phoenix building

Source: Google Earth (modified by Otto VanGeet, NREL)

The south rooftop area and carports designated for PV installations are flat, have excellent solar exposure (see Figure 5-6 and Figure 5-7), and have few existing obstructions. The north, east, and west roofs have too much shading for PV.

5.4 Potential Roof 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 5-6).

Figure 5-6. Typical ballasted PV system at GSA Denver Federal Center (Phoenix Area Office building roof PV would be similar). ***Photos by Otto VanGeet, NREL***

Roof area. The roof is in excellent condition and suitable for a ballasted PV system. The south wing has approximately 2,300 ft^2 total unshaded area available (Figure 5-7), the east wing has approximately 750 ft^2 available (Figure 5-8), for an assumed total available area of approximately 3,000 ft^2. 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 5-9). The electrical room has adequate room for PV inverters (Figure 5-10).

Figure 5-7. South wing looking west where PV is proposed (left) and looking south (right). ***Photos by Otto VanGeet, NREL***

Figure 5-8. East wing roof looking east is also suitable for PV (left) and typical parapet is approximately 28" high (right). ***Photos by Otto VanGeet, NREL***

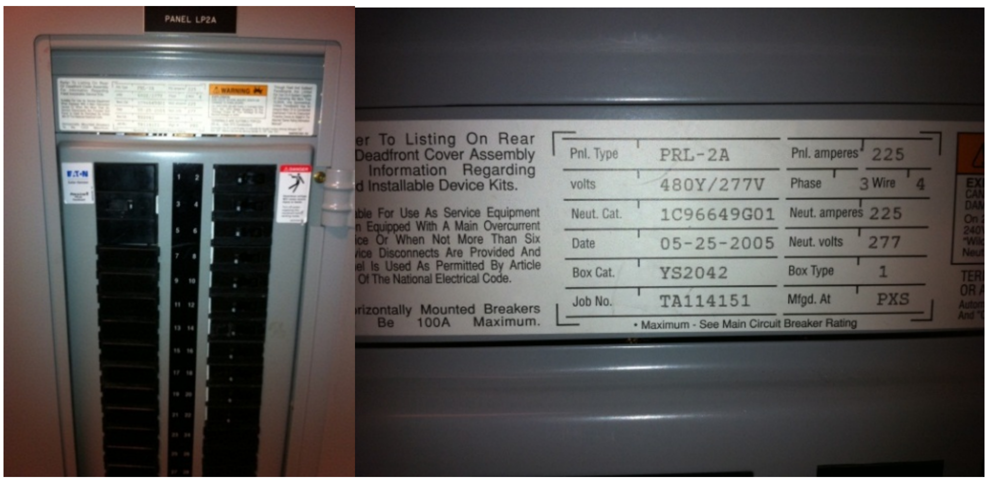

Figure 5-9. Panel LP2A has many spaces where a PV breaker could be installed (left) and 225 ampere (A) 480 V Panel LP2A has adequate capacity for PV (right). ***Photos by Otto VanGeet, NREL***

Figure 5-10. Panel LP2A is located in the electrical room near the roof. ***Photos by Otto VanGeet, NREL***

Carport area: The Phoenix Area Office has six large, unshaded carports that should be used for PV (Figure 5-11 and Figure 5-12). The two northeast-most carports have an existing SRP PV system. Each carport is 18 ft × 140 ft (2,520 ft^2 each), so the available area is 15,120 ft^2, which is enough for 120 kW at 8 W/ft^2. 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 5-11. Existing carports looking southeast (left) and looking northeast (note existing PV on east-most carports) (right). ***Photos by Otto VanGeet, NREL***

Figure 5-12. Northwest carports looking northwest (left) and carport structure, which would require the attachment of PV support racking (right). ***Photos by Otto VanGeet, NREL***

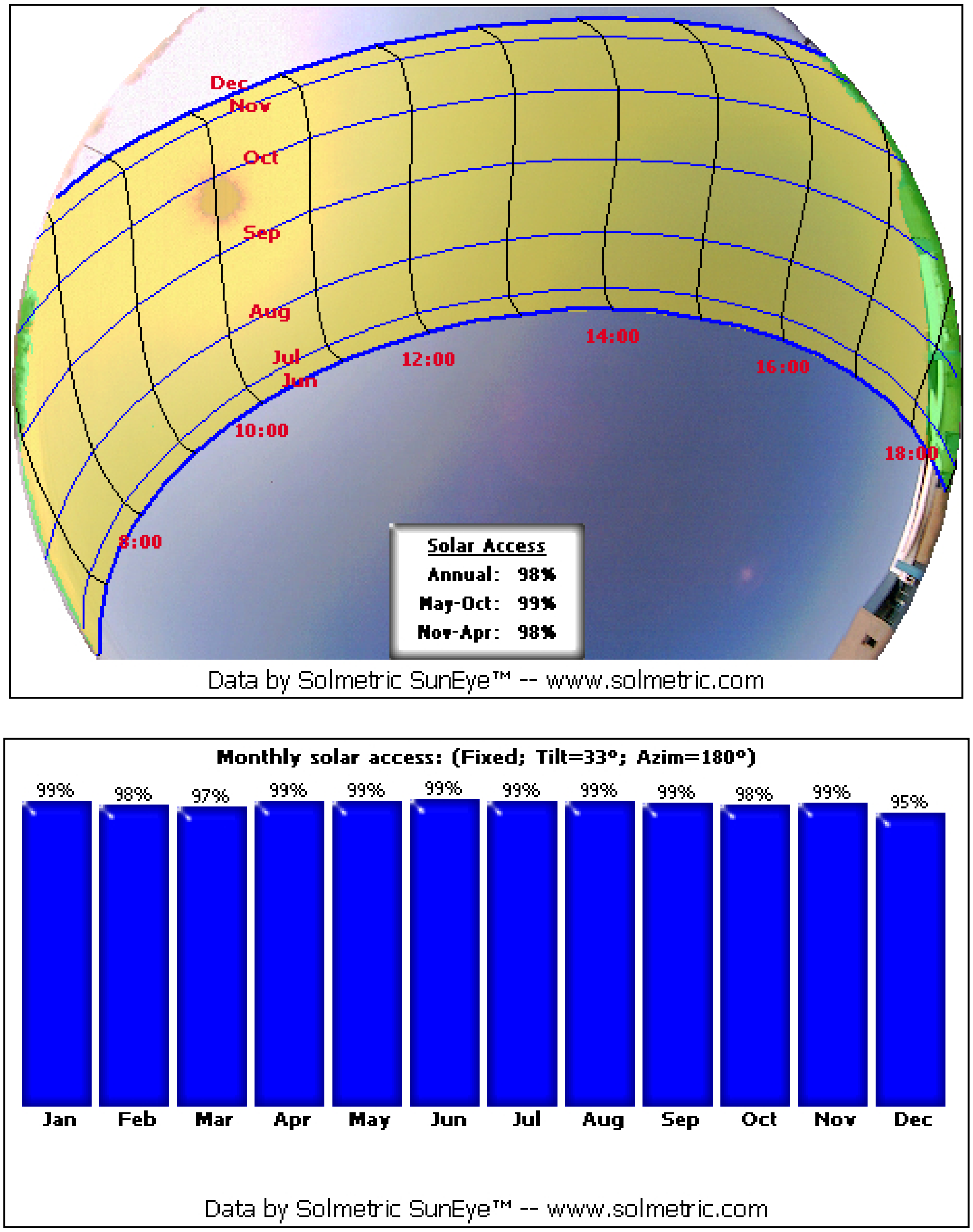

Figure 5-13. Solmetric SunEye used to measure solar access (all recommended areas have excellent solar access)

Source: Images generated by Otto VanGeet, NREL

Another good option to consider is concentrating PV (CPV), which uses optics to concentrate sunlight on high efficiency PV cells. Solfocus[11] has a manufacturing plant in Mesa, Arizona, and could 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

[11] For more information about Solfocus, see http://www.solfocus.com/en/.

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 5-14 and Figure 5-15).

Figure 5-14. Possible CPV location behind center light post (which would need to be removed) (left) and close up of area (right). ***Photos by Otto VanGeet, NREL***

Figure 5-15. Possible CPV locations at southwest corner of site (left) and behind southeast sidewalk (right). ***Photos by Otto VanGeet, NREL***

5.5 Economics and Performance

5.5.1 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 5-16 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. For the 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.

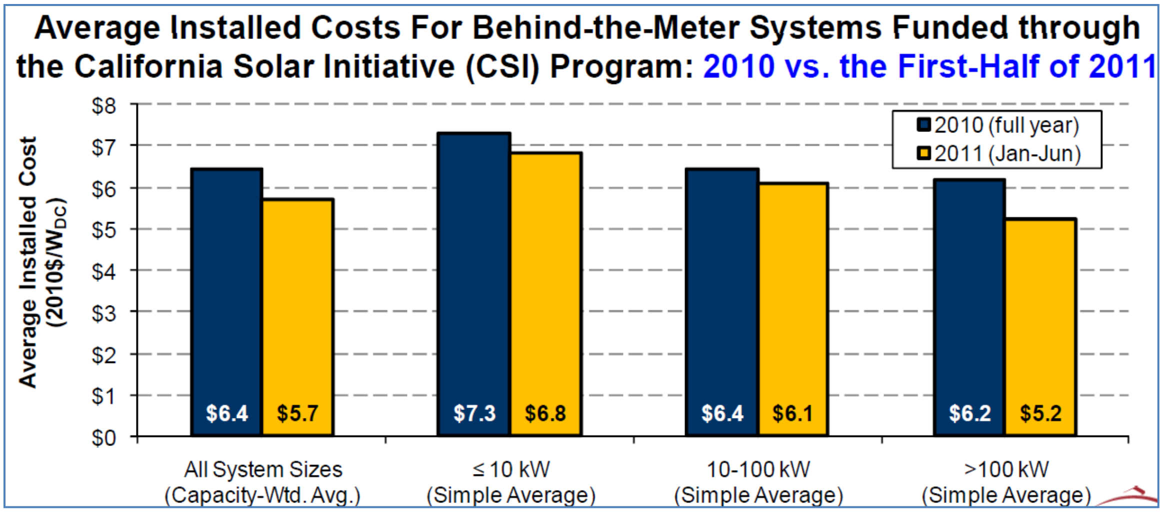

Figure 5-16. PV costs

Source: Ryan Wiser, Lawrence Berkeley National Laboratory[12]

5.5.2 Other Incentives and Financing Opportunities

The Database for State Incentives for Renewable Energy (DSIRE)[13] 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 kilowatt-hours delivered from SRP for each billing cycle. If the kilowatt-hours calculation is net positive for the billing cycle, SRP will bill the net kilowatt-hours 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 kilowatt-hours calculation is net negative for the billing cycle, SRP will carry forward and credit the kilowatt-hours against customer kilowatt-hours usage on the next monthly bill. However, if the kilowatt-hours are net negative at the end of the April billing cycle, SRP will credit the net kilowatt-hours 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 official rules go into effect, the commission has recommended that the utilities use the Interconnection Document[14] 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

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[12] Wiser, R., et al. *Tracking the Sun II*. Berkeley, CA: Environmental Energy Technology Division, Lawrence Berkeley National Laboratory, 2011.
[13] For more information on DSIRE, see www.dsireusa.org.
[14] *Interconnection of Distributed Generation Facilities in the Generic Investigation of Distributed Generation*. Arizona Corporation Commission. (June 2007). http://images.edocket.azcc.gov/docketpdf/0000074361.pdf.

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[15]. 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.

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[16]. 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[17].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 listed website above for updated 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 (PPA)[18].

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

[16] For details, see http://www.srpnet.com/electric/Generators.aspx?res.

[17] For more information on PV incentives in Arizona, see http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=AZ11F&re=1&ee=1.

[18] 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 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. A possible method to install smaller (< 90 kW) systems under a PPA would be to aggregate the installation of PV systems at several installations under one contract.

5.5.3 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.

5.5.4 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 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 5-2. PV Economics–Phoenix Area Office

Tie-in Location	Array Tilt (°)	Area Reqd (ft²)	PV System Size (kW)	Annual Output (kWh/yr)	Annual Cost Savings ($/yr)	Annual O&M ($/yr)	Annual Cost Savings After O&M ($/yr)	System Cost With No Incentives ($)	Payback Period With No Incentive (years)	SRP Incentive $1.35/W DC capped at $40,500	Cost After Incentives ($)	Payback Period After SRP Incentive (years)	System Cost After Federal (45%) and SRP Incentives ($)	Payback Period After SRP and Federal 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	36	39,000	111,000	27	61,050	15
Carport mounted	10	3,750	30	48,600	4,374	255	4,119	150,000	36	39,000	111,000	27	61,050	15
Maximum Carport PV														
Carport mounted	10	15,120	121	195,955	17,636	1,028	16,608	604,800	36	40,500	564,300	34	310,365	19

Note: Federal tax incentives are only available for taxpaying entities.

5.6 Facility-Scale Conclusions and Recommendations

Reclamation’s 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. If Reclamation proceeds with this type of installation, it is recommended that Reclamation contact SRP and reserve incentives for a 30 kW DC system (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 that requests the best performance (in kWh/yr) at the best price, letting 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.

6 Facility-Scale Assessments of Willows Office and Lake Barryessa Facility

On June 21, 2012, a team led by NREL together with Reclamation personnel conducted an assessment of Reclamation's Willows Office building and the Lake Barryessa site. During the site visit, the team identified several suitable locations for grid-connected PV.

6.1 Willows Office

6.1.1 Willows Office—Facility Overview

Reclamation's Willows Office building is located at 1140 W. Wood St., Willows, CA 95988. The structure is a single-story wood frame office building with roof-mounted mechanical equipment. The building faces south, with the main entry on the north side. An aerial image of the building is shown in Figure 6-1. Figure 6-2 shows elevation views, and a site plan is shown in Figure 6-3.

The building has a composite shingle sloped roof. The roof is in excellent condition. The south facing roof has an existing PV array that annually generates approximately 12,000 kWh. Figure 6-4 shows photos of the existing PV array and inverters.

The Willows Office is connected to Pacific Gas and Electric Company (PG&E) electric utility. The electric tariff is "A1–Small General Service"[19], which is complex time of use (TOU) energy (kWh) only (no demand charges) and minimal monthly service charges. The rate has a summer (May 1 to October 31) week day on-peak, partial-peak, and off-peak rate, and a winter partial-peak and off-peak rate. The rate is very favorable for PV systems because the highest rates are mid-day during the summer when PV output is at its maximum. The annual electrical energy use was 125,520 kWh in FY 2011, and the average rate during FY 2011 was $0.17/kWh.

[19] For details regarding the A1-Small General Service electric rate, see http://www.pge.com/tariffs/tm2/pdf/ELEC_SCHEDS_A-1.pdf.

Figure 6-1. Aerial view of Willows Office

Source: Google Earth image provided by Reclamation

Figure 6-2. Willows Office entrance and north elevation view (left), and Willows Office northeast view (right). ***Photos by Otto VanGeet, NREL***

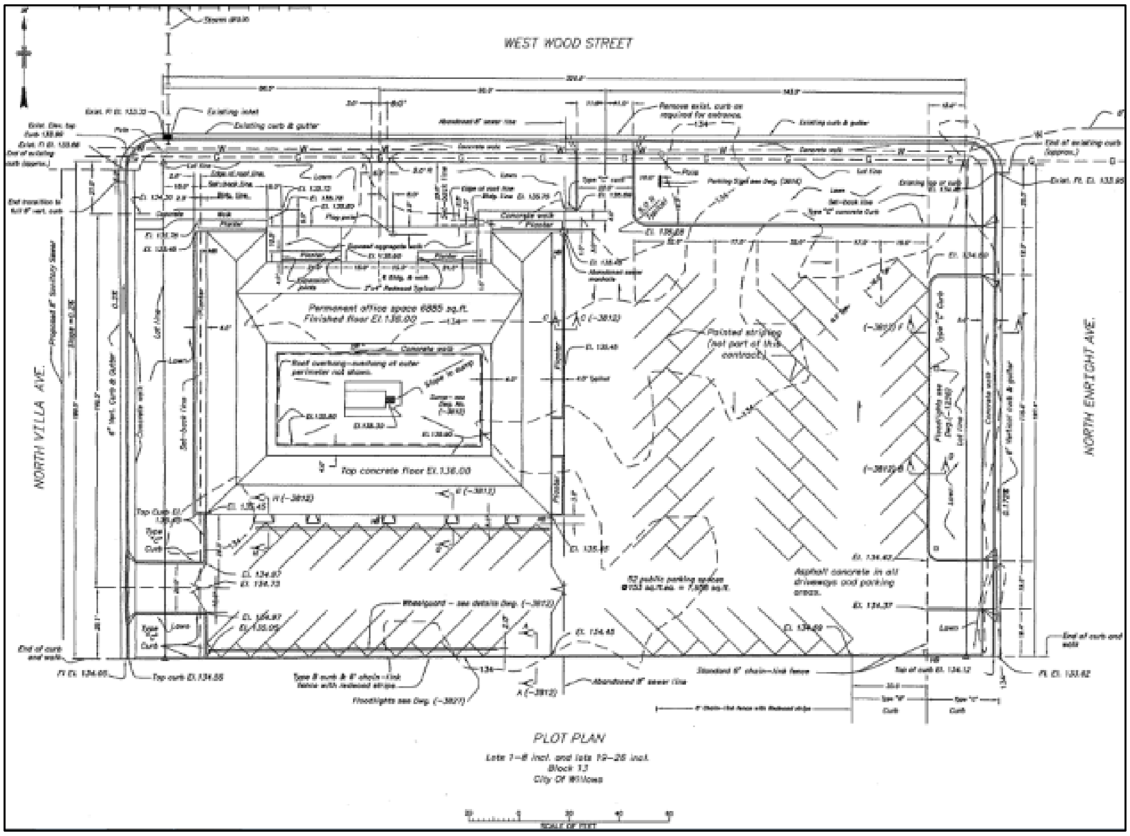

Figure 6-3. Site plan of Willows Office

Figure 6-4. Existing inverters and PV system at Willows Office. ***Photos by Otto VanGeet, NREL***

6.1.2 Willows Office—PV 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 site has excellent annual solar access. The predicted array performance was found using PVWatts Version 2 for Willows, a performance calculator for grid-connected PV systems created by NREL's Renewable Resources Data Center.[20]

Table 6-1. Annual AC Energy and Cost Savings Results in kWh/kW for South-Facing, 5-Degree-Sloping, Fixed-Tilt PV from PVWatts for Willows (Carport PV)

City:	Willows
State:	California
Latitude:	39.3° N
Longitude:	122.3° W
Elevation:	42 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:	5.0°
Array Azimuth:	180.0°
Energy Specifications	
Cost of Electricity:	17.0 ¢/kWh

Results			
Month	**Solar Radiation (kWh/m2/day)**	**AC Energy (kWh)**	**Energy Value ($)**
1	2.25	52	8.84
2	3.39	74	12.58
3	4.35	104	17.68
4	5.76	132	22.44
5	6.82	158	26.86
6	7.46	162	27.54
7	7.78	173	29.41
8	7.06	158	26.86
9	5.86	127	21.76
10	4.25	98	16.66
11	2.71	60	10.20
12	2.14	49	8.33
Year	4.99	1348	229.16

Figure 6-5. Proposed PV system locations at Reclamation's Willows building (highlighted in blue) Willow's staff indicate the carport is not feasible at this time due to operational space requirements. Source: Google Earth (modified by Otto VanGeet, NREL)

[20] For more information on NREL's PVWatts Version 2, see http://www.nrel.gov/rredc/pvwatts/grid.html.

The rooftop area and carports designated for PV installations have excellent solar exposure (see Figure 6-5) and few existing obstructions. The north and west roofs have too much shading for PV.

6.1.3 Willows Office—Potential PV System Locations

Roof area. The roof is asphalt composite shingles in excellent condition and suitable for a direct attached PV system similar to the existing system. The east roof (Area 1) is sloped to the east at 5/12 (23 degrees) and has approximately 967 ft^2 total unshaded area available (Figure 6-7). Using an installed PV power density of 10 W/ft^2, up to 10 kW of PV could be installed. If higher efficiency modules with power density of 15 W/$ft^2$are used, up to 15 kW could be installed (this is assumed for this study). From PVWatts, the annual PV production of an east-facing roof that slopes at 23 degrees is 1,226 kWh/kW.

The south-facing courtyard roof (Area 2) is sloped to the south at 3/12 (14 degrees) and has approximately 1,373 ft^2 total area available that is currently shaded by courtyard trees (Figure 6-8) PV could not be installed on Area 2 without significant trimming or removal of existing trees. From PVWatts, the annual PV production of a south-facing roof sloped at 14 degrees is 1,426 kWh/kW. Using an installed PV power density of 10 W/ft^2, up to 14 kW of PV could be installed. If higher efficiency modules with a power density of 15 W/ft^2 are used, up to 20 kW could be installed (this is assumed for this study).

The existing electrical panel LP2A has spaces and capacity for PV breakers (Figure 6-6). The outside of the building has adequate room for additional PV inverters similar to the existing installation.

Figure 6-6. Existing PV system electrical breaker subpanel (left) and right building main 240 V, 600 A electrical panel with spaces for future solar breakers. ***Photos by Otto VanGeet, NREL***

Figure 6-7. East roof of Willow building looking north (Area 1) (left), and east side of building and roof looking northwest (right). ***Photos by Otto VanGeet, NREL***

Figure 6-8. South-facing courtyard roof of Willow building looking west (Area 2) (left) and south-facing courtyard roof looking north from courtyard (right). ***Photos by Otto VanGeet, NREL***

Carport area: The east and south parking lots areas have a total unshaded area of approximately 22,533 ft^2, which is enough for up to 220 kW at 10 W/ft^2. From PVWatts (see Table 6-1), the annual PV production of a south-facing roof sloped at 5 degrees is 1,348 kWh/kW. A 93 kW PV system would have an annual output of 125,364 kWh, which would make the office net-zero electrical annual energy. The assumed size of the carport that would be installed is 93 kW. A carport PV system would be a nice amenity in the hot sunny Willows area; however, Willow's staff indicates the carport is not feasible at this time due to operational space requirements.

Figure 6-9. PV-covered carports could be installed over parking lot: (clockwise from upper left) looking northeast, looking east, east edge looking north (notice shade from trees defines east boundary), and looking southeast. *Willow's staff indicates the carport is not feasible at this time due to operational space requirements. Photos by Otto VanGeet, NREL*

6.2 Lake Barryessa Office

6.2.1 Lake Barryessa Office—Facility Overview

Reclamation's Lake Barryessa Office is located at 5520 Knoxville Road, Napa, CA 94558.

The Lake Barryessa Office is connected to PG&E electric utility. The electric tariff is "A1–Small General Service"[21], which is a complex Time Of Use (TOU), energy (kWh) only (no demand charges) rate with minimal monthly service charges. The rate has a summer (May 1 to October 31) week day on- peak, partial-peak, and off-peak rate, and a winter partial-peak and off-peak rate. The rate is very favorable for PV systems because the highest rates are mid-day during the summer when PV output is at its maximum. The annual electrical energy use was 182,080 kWh in FY 2011, and the average rate during FY 2011 was $0.15/kWh.

[21]. For details regarding the A1-Small General Service electric rate, see http://www.pge.com/tariffs/tm2/pdf/ELEC_SCHEDS_A-1.pdf.

Figure 6-10. Aerial view of Lake Barryessa Office

Source: Google Earth image provided by Reclamation

Figure 6-11. Existing PV system and inverters at Lake Barryessa Office (existing PV 1). ***Photos by Otto VanGeet, NREL***

Figure 6-12. Second existing PV system and inverters at Lake Barryessa Office (existing PV 2). ***Photos by Otto VanGeet, NREL***

6.2.2 Lake Barryessa—PV 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 ground-mounted and carport PV sites have excellent annual solar access. The predicted array performance was found using PVWatts Version 2 for Lake Barryessa, a performance calculator for grid-connected PV systems created by NREL's Renewable Resources Data Center.[22]

Table 6-2. Annual AC Energy and Cost Savings Results in kWh/kW for South-Facing, 5-Degree, Fixed-Tilt PV from PVWatts for Lake Barryessa

City:	Napa
State:	California
Latitude:	38.3° N
Longitude:	122.3° W
Elevation:	227 m
PV System Specifications	
DC Rating:	1.0 kW
DC to AC Derate Factor:	0.820
AC Rating:	0.82 kW
Array Type:	Fixed Tilt
Array Tilt:	5.0°
Array Azimuth:	180.0°
Energy Specifications	
Cost of Electricity:	15.0 ¢/kWh

Results			
Month	**Solar Radiation (kWh/m2/day)**	**AC Energy (kWh)**	**Energy Value ($)**
1	2.47	57	8.55
2	3.57	77	11.55
3	4.61	111	16.65
4	6.10	140	21.00
5	7.04	168	25.20
6	7.73	174	26.10
7	7.77	179	26.85
8	6.84	158	23.70
9	5.91	132	19.80
10	4.38	101	15.15
11	2.97	66	9.90
12	2.29	53	7.95
Year	5.15	1717	212.55

[22]. For more information on NREL's PVWatts Version 2, see http://www.nrel.gov/rredc/pvwatts/grid.html.

Figure 6-13. Proposed PV system locations at Reclamation's Lake Barryessa site (highlighted in blue)

Source: Google Earth (modified by Otto VanGeet, NREL)

6.2.3 Lake Barryessa Office—Potential PV System Locations

It would be difficult to install PV on the tile rooftop area so only ground-mount and carports PV installations are considered. All are nearly flat, have excellent solar exposure (see Figure 6-13), and few existing obstructions. Photographs of potential ground mount and carport locations are shown in Figures 6-14 to 6-17. Lake Barryessa staff indicates PV Carport Area 1 and the south half of PV Carport Area 2 are not feasible at this time because of operational space requirements.

Figure 6-14. PV Area 1 looking west (note existing PV 1 near sidewalk in distance) (left) and east side of PV Area 1 looking northeast (right). ***Photos by Otto VanGeet, NREL***

Figure 6-15. PV Area 2 beyond fence looking north (left) and PV Area 3 looking northeast (right). ***Photos by Otto VanGeet, NREL***

Figure 6-16. PV Carport Area 1: looking southeast (left) and looking north (right)-Lake Barryessa staff indicates PV Carport Area 1 is not feasible at this time because of operational space requirements. ***Photos by Otto VanGeet, NREL***

Figure 6-17. PV Carport Area 2: looking northeast (left), and main meter and electrical panel that serves south buildings at Lake Barryessa and possible PV tie in location (right). ***Photos by Otto VanGeet, NREL***

6.3 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 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. Section 2 Solar Technology Overview provides additional detail on the major components and functioning of 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.

6.4 Economics and Performance

6.4.1 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 6-18 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 for roof- and ground-mounted PV, and $5.50/W for carport PV.

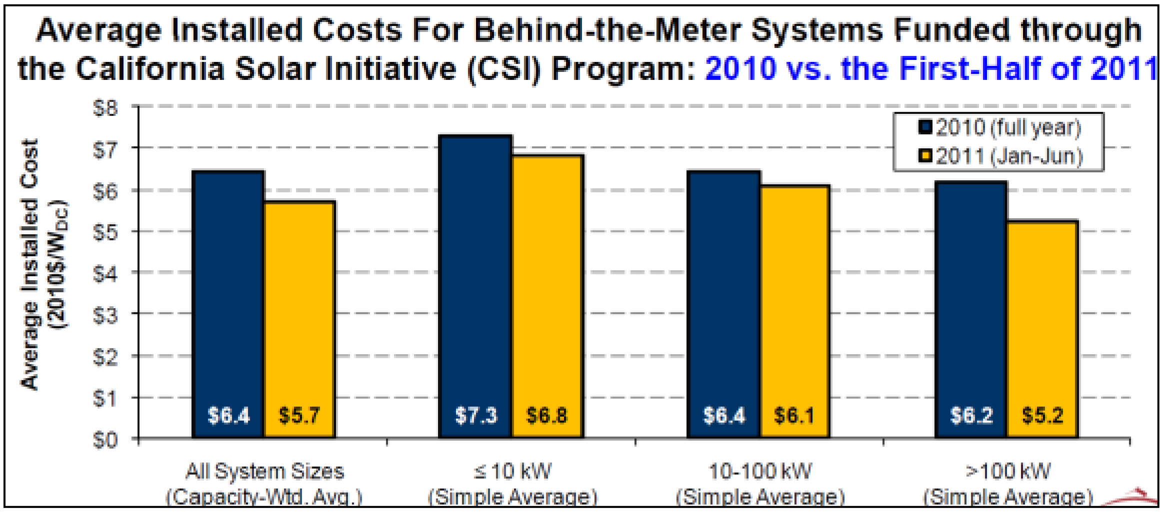

Figure 6-18. PV costs

Source: Ryan Wiser, Lawrence Berkeley National Laboratory[23]

6.4.2 Other Incentives and Financing Opportunities

DSIRE[24] provides a summary of net metering, interconnection, and incentives available to customers. The utility for both sites is PG&E.

Expected performance-based buydowns for systems under 30 kW—Began in 2007 at $2.50/W AC for residential and commercial systems (adjusted based on expected performance) and $3.25/W AC for government entities and nonprofits (adjusted based on expected performance). The incentive levels decline as the aggregate capacity of PV installations increases. Incentives will be awarded as a one-time, up-front payment based on expected performance, which is calculated using equipment ratings and installation factors such as geographic location, tilt, orientation, and shading. At the time of writing this report the PG&E incentive was in "step 10," which provides $0.70/W if the system is owned by the government.

Performance-based incentives (PBI) for systems 30 kW and larger—Began in 2007 at $0.39/kWh for the first five years for taxable entities, and $0.50/kWh for the first five years for government entities and nonprofits. The incentive levels decline as the aggregate capacity of PV installations increases. PBI will be paid monthly based on the actual amount of energy produced for a period of five years. At the time of writing this report, the PG&E incentive was in "step 10" which provides $0.025/kWh for commercial (if system is owned by a third party) or $0.088/kWh if the system is owned by the government[25].

Net Metering Agreement—California's net-metering law, which took effect in 1996, requires all utilities to offer net metering to all customers for solar energy systems up to 1 MW. Net excess generation (NEG) is carried forward to a customer's next bill. Under prior law, any NEG remaining at the end of each 12-month period was granted to the customer's utility. AB 920 of 2009 gave customers two additional options for the NEG remaining after a 12-month period—customers have the option of rolling over any remaining NEG month to month indefinitely, or they can receive financial compensation from their utility for the remaining NEG. The California

[23] Wiser, R., et al. *Tracking the Sun IV*. Berkeley, CA: Environmental Energy Technology Division, Lawrence Berkeley National Laboratory, 2011.
[24] For more information on DSIRE, see www.dsireusa.org.
[25] Current incentives can be found at http://www.csi-trigger.com/.

Public Utilities Commission (CPUC) set the compensation rate at the 12-month average spot market price for the hours of 7 a.m. to 5 p.m. for the year in which the surplus power was generated.

Publicly owned utilities may elect to provide coenergy metering, which is the same as net metering, but incorporates a time-of-use rate schedule. Customer-generators with systems sized between 10 kW and 1 MW who are subject to time-of-use rates are entitled to deliver electricity back to the system for the same time-of-use (including real-time) price that they pay for power purchases. However, time-of-use customers who choose to coenergy meter must pay for the metering equipment capable of making such measurements. Customer-generators retain ownership of all RECs associated with the generation of electricity they use on site[26].

Interconnection—Nonexporting systems (sized and designed so that the electricity is only used on-site and will never deliver electricity to the grid) and all net metered systems, regardless of nameplate capacity, can qualify for the fast track process. After a customer applies for interconnection, the utility performs an initial review. If the applicant passes through initial review screen A through M, the system will be able to interconnect without a supplemental review. There is no interconnection size limit. The CPUC has explicitly ruled that technologies eligible for net metering (up to 1 MW) are exempt from interconnection application fees, as well as from initial and supplemental interconnection review fees.

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 PPA[27].

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 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 (90 kW+) should be considered.

6.4.3 Data and Assumptions

Because the PV system size preferred by Reclamation is unknown, NREL analyzed each possible PV system individually.

6.4.4 Performance and Savings Results

PV performs well in the sunny Willows and Lake Barryessa offices. The California Solar Incentives (CSI) and falling PV prices lead to payback times of 21 to 24 years depending on location and system type (see Table 6-3). Carport PV systems have an approximately 2-year longer payback time because of the added structure cost for the carport but would provide a nice

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[26]. For additional information on PG&E net metering see http://www.pge.com/b2b/newgenerator/netenergymetering/.

[27] For more information on PPAs, see http://www1.eere.energy.gov/femp/financing/power_purchase_agreements.html.

amenity in the hot sunny locations. Both office could become net-zero annual electrical energy by installing 93 kW of PV at Willows (would require a carport system that Willow staff has indicated could not be built at this time because of operational space requirements) or 128 kW at Lake Barryessa. If these large systems are installed, a PPA could be considered that would bring the payback down to about 16 years.

A possible method to install smaller (< 90 kW) systems under a PPA would be to aggregate the installation of PV systems at several installations under one contract.

Table 6-3. PV Economics

Tie-In Location	Array Tilt (°)	Area Available (ft^2)	PV System Size (kW)	Annual Output kWh/yr	Annual Cost Savings ($/yr)	Annual O&M ($/yr)	Annual Cost Savings After O&M ($/yr)	Total System Cost With No Incentives ($)	Payback Period With No Incentive (yr)	CSI Incentive $0.7/W AC or Over 30 kW $0.088/kWh for 5 years	Cost After incentives ($)	Payback Period After CSI Incentive (yr)	System Cost After Federal (45%) and CSI Incentives($) of $0.025/kWH for 5 years	Payback Period After PG&E and Federal Incentive (yr)
BOR Willows Office = 125,520 kWh annual														
East Roof Area 1	23	967	15	18,390	3,126	128	2,999	75,000	25	8,400	66,600	22	NA	NA
South Roof Area 2	14	1,373	20	28,520	4,848	187	4,661	110,000	24	11,200	98,800	21	NA	NA
					Max. Carport PV									
Carport Mounted	5	22,533	93	125,364	21,312	870	20,442	511,500	25	55,160	456,340	22	297,498	15
BOR Lake Barryessa Office = 182,080 kWh annual														
Area 1	5	5,431	54	76,957	11,544	462	11,082	271,550	25	30,414	241,136	22	162,930	15
Area 2	5	1,200	12	17,004	2,551	102	2,449	60,000	25	6,720	53,280	22	36,000	15
Area 3	5	6,684	67	94,712	14,207	568	13,639	334,200	25	37,430	296,770	22	200,520	15
					Max. Carport PV									
Carport 1	5	8,270	83	117,186	17,578	773	16,805	454,850	27	51,562	403,288	24	264,121	16
Carport 2	5	5,532	55	78,388	11,758	517	11,241	304,260	27	34,491	269,769	24	176,677	16

Notes: (1) Federal tax incentives are only available for taxpaying entities. (2) Willow staff indicated the carport could not be built at this time because of operational space requirements. (3) Lake Barryessa staff indicated PV Carport Area 1 and the south half of PV Carport Area 2 could not be built at this time because of operational space requirements.

6.5 Facility-Scale Conclusions and Recommendations

Reclamation's Willows and Lake Barryessa offices in California considered for a solar PV system in this report have many good areas in which to implement a PV system. It is recommended that Reclamation consider installing PV at these offices while PG&E incentives under CSI exist. 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, letting the vendors optimize the system configuration, including racking, slope, modules, etc. Because of the high cost of energy, dropping cost of PV, good solar resource, and fair incentives, a government-owned PV system provides a marginal payback, is easy to implement, and is therefore worth considering. If funding is not available and a 90+ kW system is desired, then a third-party PPA is the most plausible way for a system to be financed on this site. A possible method to install smaller (< 90 kW) systems under a PPA would be to aggregate the installation of PV systems at several installations under one contract.

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

On Aug. 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.[28]

7.1 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 Belmont 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 (≤ 3%) and a reasonable amount of mesquite vegetation to remove for a CSP or PV plant of 50–60 MW (see Figure 7-1 and Figure 7-2).

Figure 7-1. High potential solar site east of Little Harquahala Pumping Station

Source: Google Earth

[28] Reclamation's Science and Technologies Project ID 8343, "Renewable Power Generation for Water Transmission" study identified in the GIS analysis entitled "Renewable Energy Suitability Analysis for the Central Arizona Project Canal System."

Figure 7-2. View of site 1 looking north from northern edge of CAP. ***Photo by Scott Haase, NREL***

Site 2. The Belmont 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 CSP or 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 kilovolt (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 7-3 and Figure 7-4).

Figure 7-3. High potential solar site east of Hassayampa Pumping Station

Source: Google Earth

Figure 7-4. View looking north at site 3 from northern edge of CAP. ***Photo by Otto VanGeet, NREL***

7.2 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.

7.2.1 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 approximately 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 7-5).

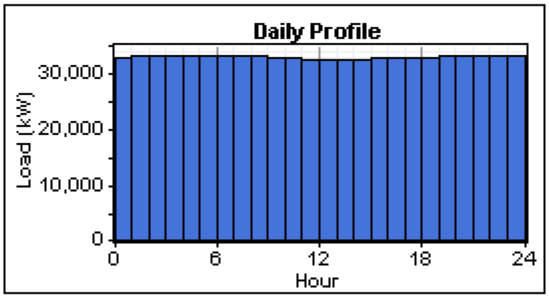

Figure 7-5. Annual average daily load profile at Hassayampa

The seasonal load profile is shown in Figure 7-6. 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.

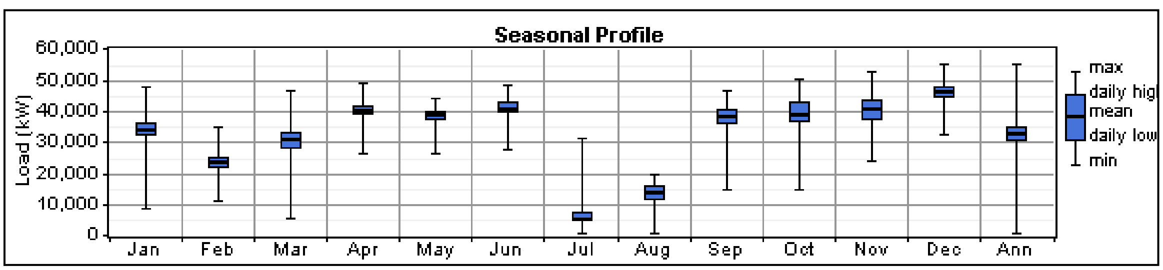

Figure 7-6. Seasonal load profile for Hassayampa

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 7-1. The PV system is modeled as a horizontal, continuous adjustment tracking system with a lifetime of 25 years and a derating factor of 95%. Note: The tracking algorithm in the HOMER model is not identical to the algorithm in the SAM model. To ensure the same annual power production from the PV, the derate factor was increased in the HOMER model.

Table 7-1. Electrical Production

Scenario	PV Size (MW)	Electrical PV Production (kWh)	Grid Purchase (kWh)	Grid Sales (kWh)	PV Production as a Fraction of the Load
Base case	0	N/A	288,269,952	N/A	0%
1	20	47,507,504	245,133,200	4,371,542	16%
2	50	118,768,464	196,803,952	27,303,842	41%
3	100	237,536,928	172,086,144	121,354,960	82%

Figure 7-7 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.

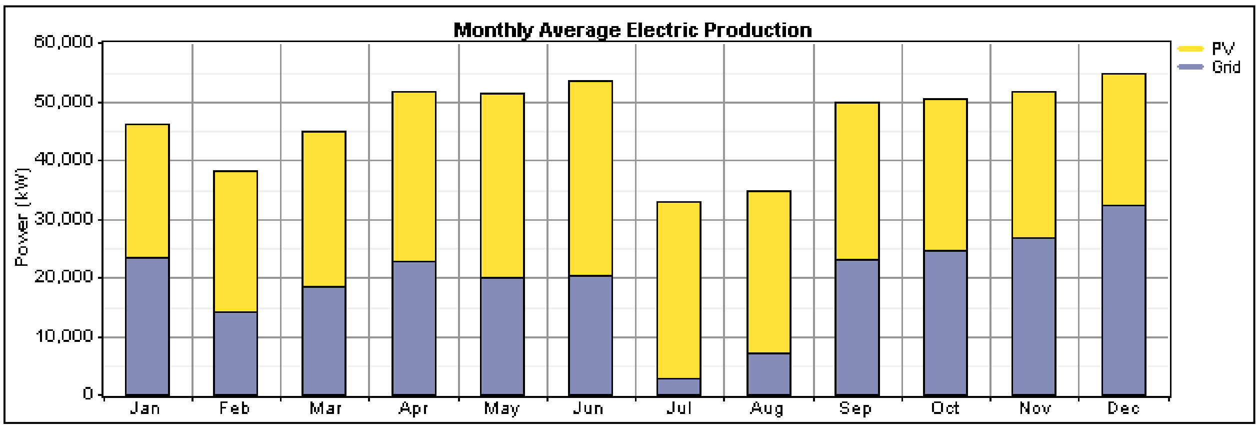

Figure 7-7. Monthly average electric production (100 MW system)

Figure 7-8 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 purple, 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 because the load is reduced significantly during this time. Due to the tracking algorithm used in HOMER, Figure 7-8 shows somewhat lower peak power production in the summer. Despite the lower peak, the actual monthly data in Figure 7-8 shows that the PV energy production is much higher in the summer.

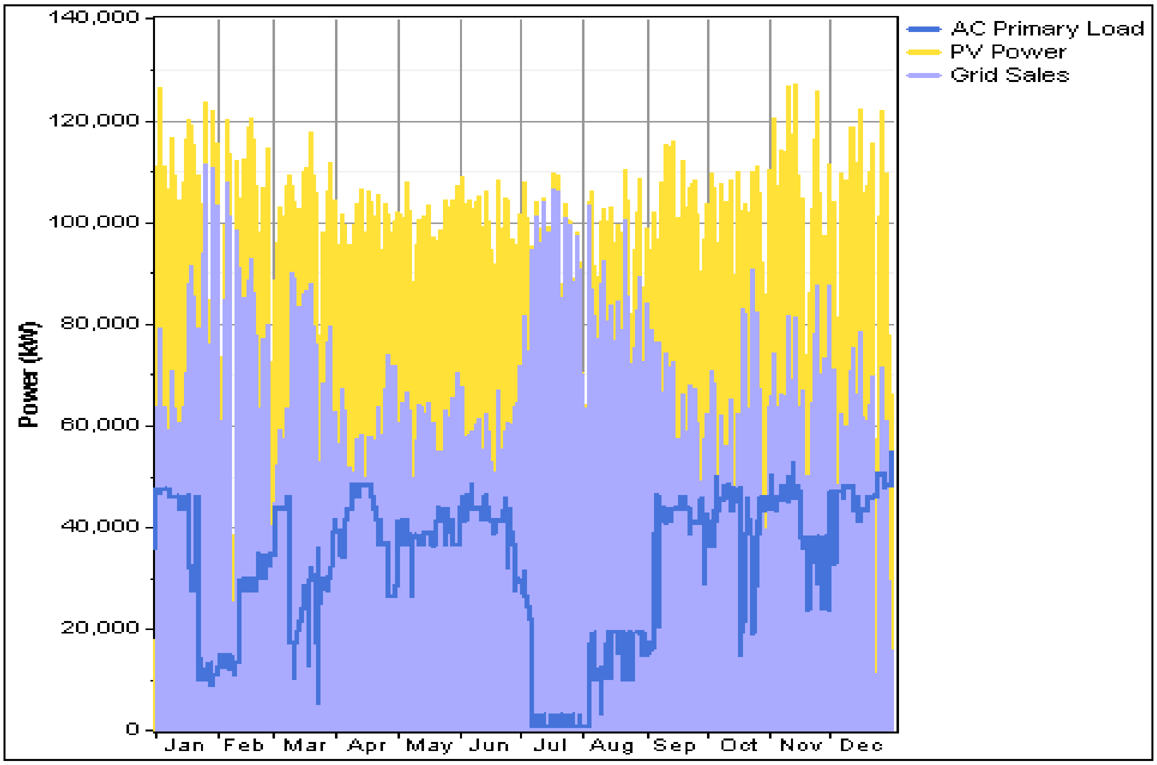

Figure 7-8. Annual hourly PV production at Hassayampa

7.2.2 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 7-2 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 approximately $5.8 million annually in excess power sold back.

Table 7-2. 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	10,089,448	128,977,008	0.035
1	20	60,000,000	8,202,507	164,855,568	0.044
2	50	141,000,000	4,298,754	195,952,512	0.049
3	100	286,000,000	-5,826,480	211,518,016	0.058

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 several grid power prices ranging from $0.035/kWh to $0.35/kWh. The assumed 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 PV becomes cost-effective when grid power prices rise above $0.09/kWh, with a 100 MW PV system being the most cost-effective solution when power prices are $0.11/kWh or greater. The graph in Figure 7-9 illustrates the optimal capacity size of the PV system (y-axis) as a function of the price of power (x-axis).

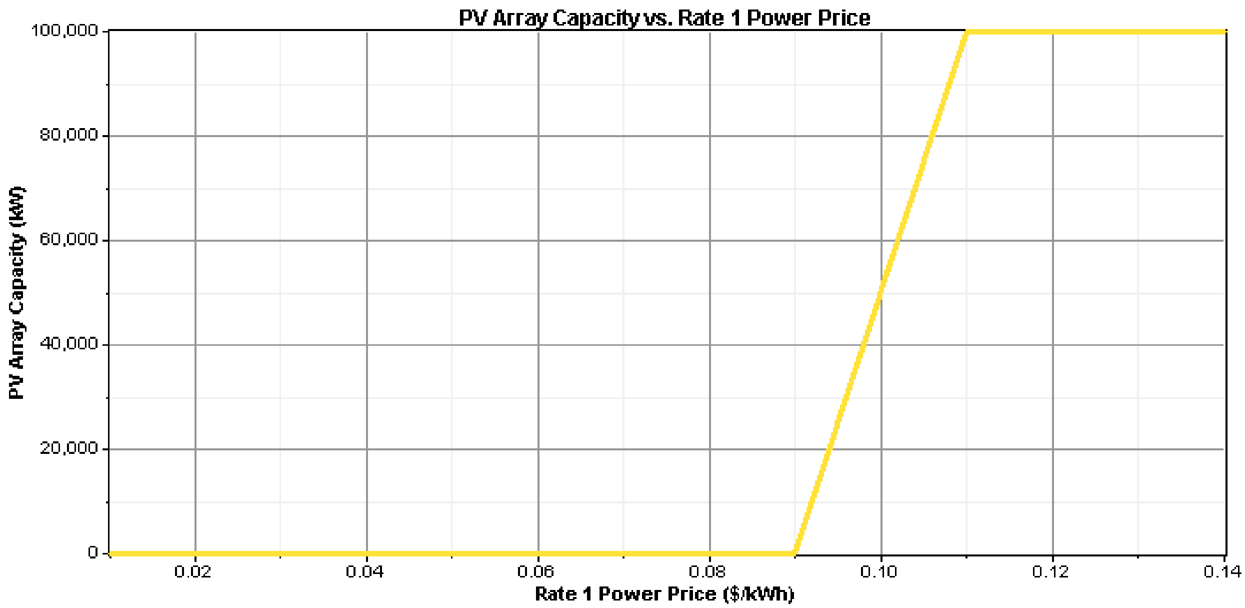

Figure 7-9. Sensitivity analysis on increase price of power

7.3 Technology Description

Most commercial CSP systems to date are parabolic trough systems that reflect and focus sunlight onto a linear receiver tube. The receiver contains a high-temperature fluid that is heated by sunlight and then used through a heat exchanger with water to produce superheated steam that drives the turbine generator. The parabolic trough CSP technology has been in commercial operation in southern California since 1981 (nine plants with a total of 350 MW). The latest CSP trough plant in southern Nevada, Nevada Solar One (64 MW), came on line in 2009.

Photovoltaics are semiconductor devices that convert sunlight directly into electricity. They do so without any moving parts and without generating any noise or pollution. They must be mounted in unshaded locations— rooftops, carports and ground-mounted arrays are common mounting locations. PV systems work well in the sunny Phoenix area.

The typical choices are south-facing (0° azimuth) rows of fixed panels tilted at latitude or single-axis modules oriented north-south that tilt from east to west during the day to track the sun. Single-axis tracking PV systems use 10% more land to mitigate adjacent panel shading; however, the cost increase over fixed panels is small (10%) and the system produces up to 35% more electrical energy.

Current private-sector development on BLM lands shows a major trend to pursue 50–200 MW PV plants as financial investors support the highly reliable technology where PV manufacturers provide 25-year module warranties.

Section 2 Solar Technology Overview provides more details on CSP and PV technology.

7.4 Preliminary Solar Plant Economics

Like most renewable technologies, there are market driving policies. The main driver has been state RPSs, where utility companies are mandated to increase power generation from renewable energy resources. State and utility financial incentives, and state and federal tax incentives are also allowing the utility-scale solar power cost of electrical generation to approach that of conventional fossil fuel-generation plants.

7.4.1 Federal and States Incentives

Federal incentives for corporate sector developed utility-scale solar projects include:

- Federal Investment Tax Credit: 30% of cost basis, expires 2016
- 5-year Accelerated Depreciation: no expiration

Arizona incentives for corporate sector-developed projects include:

- Renewable Energy Production Tax Credit, where:
    - Minimum size is 5 MW
    - Maximum incentive of $2 million per year
    - Program budget of $20 million per year on first come, first serve basis (timing is critical)
- Energy Equipment Property Tax Exemption: 100% of asset value
- Solar Equipment Sales Tax Exemption: 100% of sales tax on equipment

The financial and tax incentives for solar equipment for all states with Reclamation lands or facilities are provided at http://www.dsireusa.org/incentives/index.cfm?state=us&re=1&EE=1.

7.5 Modeling Preliminary Economic Feasibility

The NREL-developed System Advisor Model was used to identify the LCOE in ¢/kWh for assumed private sector owned and operated solar plants and delivery of electrical production through a 20–30 year PPA.

The following assumptions were established before running the model:

- All the tax and financial incentives above were applied
- 30-year financed debt service of 38% with 8% internal rate of return at 6% interest
- Debt service coverage ratio ≥ 1.3
- After-tax internal rate of return = 10%
- Assumed tax equity financial partner with tax appetite to leverage tax incentives
- Land lease = $0
- Sell price escalation rate = 2.5% (conservative)

- $3/W for large-scale PV systems (which is realistic based on recent large-scale project offers)
- PV system production degradation at 0.5% per year (NREL studies confirmed)
- $6.20/W for CSP systems (current market rates), which does not vary much by system size.

Models were run for:

1. 20 MW single-axis PV
2. 50 MW single-axis PV
3. 100 MW single-axis PV
4. 50 MW CSP trough–no storage
5. 60 MW CSP trough–no storage

The key results are summarized in Table 7-3.

Table 7-3. Preliminary Economic Feasibility Model Results

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

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 value listed under the LCOE in Table 7-3 for the project to be economically feasible.

This analysis used publicly available capital cost data. Informal discussions with developers indicate that current capital costs are lower than those used in the analysis. Thus actual LCOEs are likely to be less than shown in the analysis. Recent PPA prices for solar projects appear to be in the $0.07-$0.09/kWh range[29]. In terms of costs of energy, this site appears to be competitive for PV and perhaps power tower projects. The current market for solar projects is a bit uncertain. Many utilities have met their near- and mid-term renewable portfolio standard requirements for solar projects. Utility appetite for further solar projects will depend more upon cost of energy. Despite steadily dropping costs for solar energy projects, these projects still have a higher LOCE than do natural gas-fired plants.

7.6 Large-Scale Solar Project Development Issues

Development of large-scale renewable energy projects poses a significant challenge to attracting high-risk capital from developers and the financial industry. NREL uses a methodology referred to as SROPTTC (Site, Resource, Offtaker, Permits, Technology, Team, and Capital), which are

[29] Linden, S. "H2 2012 U.S. PPA Market Outlook." Presented on Oct. 24, 2012.

incremental actions to be taken to position the proposed project to attract private-sector interest. The elements are discussed below together with related federal agency actions.

Site—An assumption for economic modeling was a no-cost lease. This assumption should be verified. Alternatives could be an easement or license as no project on federal land could be financed without developer access to the site for O&M. There is a cost impact for requiring a lease. Typical lease rates are 2% of the project's direct cost. For example, the 20 MW PV project lease rate would be about $1.1M; however, the LCOE would increase to $.105/kWh for the next 30 years, and the first year cost to the offtaker would be over $50,000. Assuming a 2.5% escalation rate, the overall cost of electricity would increase to the offtaker by over $2 million.

Resource—The solar resource is a compelling factor as the Phoenix area has high quality solar insolation. However, another resource that needs to be considered is the high use of water for CSP thermal electric plants. A wet-cooled 50 MW CSP plant would consume 84 million gallons per year, including mirror washing. CSP plants can be dry cooled, reducing water consumption to 8 million gallons per year, mostly for mirror washing and boiler make-up water, leading to a 10% increase in capital cost and $.01/kWh increase in LCOE. By comparison, a 50 MW PV system would use 0.017 gallon/MWh or 2,009 gallons/year. Reduced water usage is another benefit of PV systems as compared to CSP systems.

Offtaker—As project development proceeds, it is essential to identify who would be the purchaser of the electricity produced. Project financing is not feasible without a confident source of revenue. This activity involves discussions with utilities or other large consumers that may have needs for renewable power (e.g., utility RPS goals) or that need reasonably priced peaking power with known projected LCOE.

Permits—This is a broad area of activity but primarily includes:

- National Environmental Policy Act compliance as development is a major action on federal land. This issue is always a major deterrent to private sector developers. If Reclamation can provide environmental analyses, surveys, assessments to identify impacts, and mitigation measures in advance, it would significantly attract industry interest.
- Interconnect Agreement. For any new generation plant in excess of 20 MW, the developer would need to contribute significant time and financial resources to conduct a large generation interconnect process. This involves three stages of studies (12–18 months and $500,000–$1,000,000) and is usually managed by the entity that owns or manages the transmission system for interconnection, often a utility like Arizona Public Service. This process is required before the developer could acquire an interconnection agreement, which is needed before a PPA could be executed by the proposed offtaker.
- Other Permits. These vary by state and regulatory bodies requiring permits before proceeding with construction and plant operations.

Technology—This is straightforward as Reclamation has a superior solar resource and is focused on solar power projects through PV or CSP.

Team—Development of any large-scale renewable energy project will require a dedicated team with mix of skills in contracting, real estate, legal, environmental, engineering and other disciplines, and consultants. The team will work collaboratively to address Reclamation's requirements along with the needs of the developer so that the federal team provides certainty that project development moves forward and mitigates delays.

Capital—There is clear evidence that the financial industry is interested in renewable resource investment. Recognizing that reduced uncertainty and commitment by Reclamation to support the developer and bringing resources (funding) for the project (e.g., National Environmental Policy Act) are key to attracting project capital from the private sector.

7.7 Utility-Scale Analysis—Next Steps

Conduct a Pre-Feasibility Interconnection Study to confirm the transmission lines near the project site have the capacity to accept the solar power generated. If transmission access is favorable, then:

1. Brief key Reclamation decision-makers on the potential for large-scale solar project development on Reclamation lands
2. Identify other stakeholders who will be impacted by project development
3. Prepare a detailed action plan with milestones for project development.

8 Yuma Utility-Scale Solar Assessment

8.1 Introduction

The Bureau of Reclamation is considering two Reclamation-owned parcels in and around Yuma, Arizona, as possible solar generation sites to make land that is not currently used more productive. One site is the Yuma Desalting Plant sludge disposal site (A22) near Yuma, Arizona, and the other is land located around the Brock Reservoir (Brock), along Interstate 8 in California, west of Yuma. The electric load at both sites is relatively small; therefore, the purpose of this analysis is for Reclamation to define opportunities using the identified underutilized land for solar energy generation and to identify the feasibility for solar developers to obtain use authorizations on the land. By identifying potential solar opportunities locally, these projects allow Reclamation's Lower Colorado Region to make progress toward meeting Department of the Interior goals for renewable energy while simultaneously creating economic development opportunities.

8.2 Site Descriptions

The two preferred sites for solar power projects on Bureau of Reclamation land near Yuma, Arizona, are Brock and A22. Brock is located approximately 22 miles west of Yuma, in Imperial County, California. The A22 site is located approximately 13 miles south of Yuma, in Yuma County, Arizona. Figure 8-1 and Figure 8-2 show the locations of the two sites.

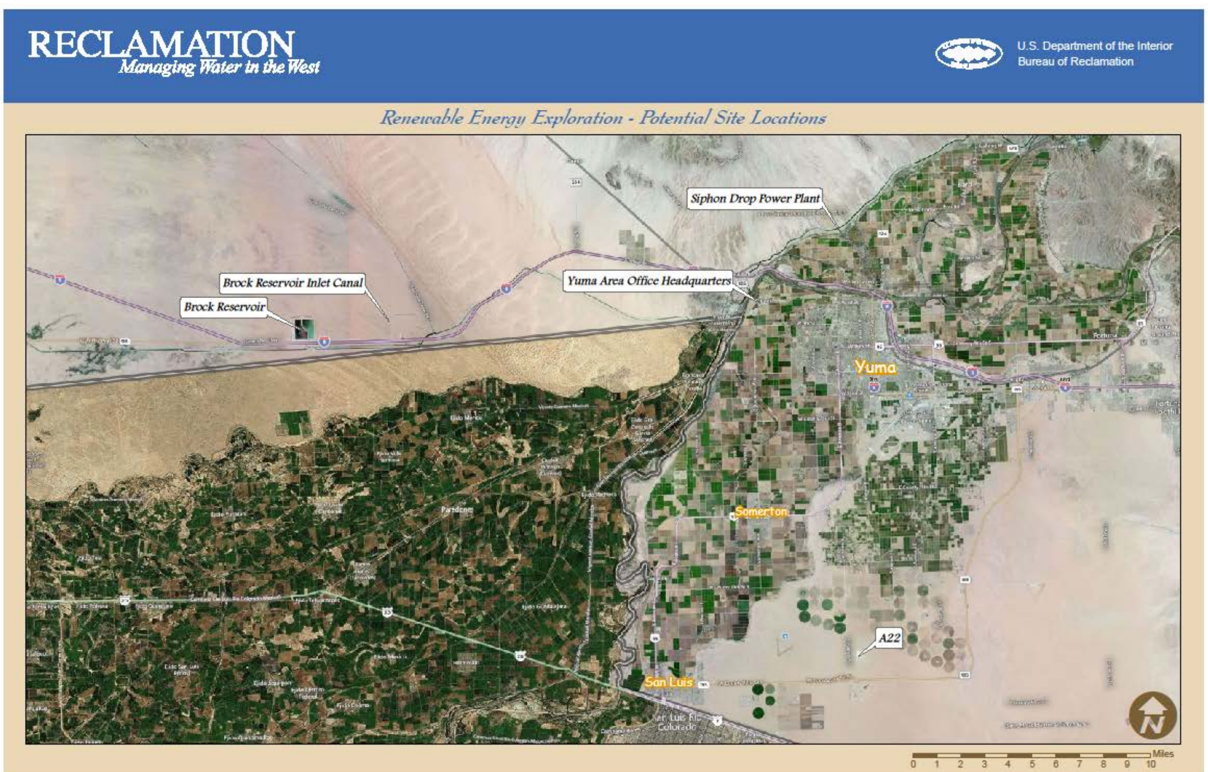

Figure 8-1. Proposed solar project locations

Source: Bureau of Reclamation

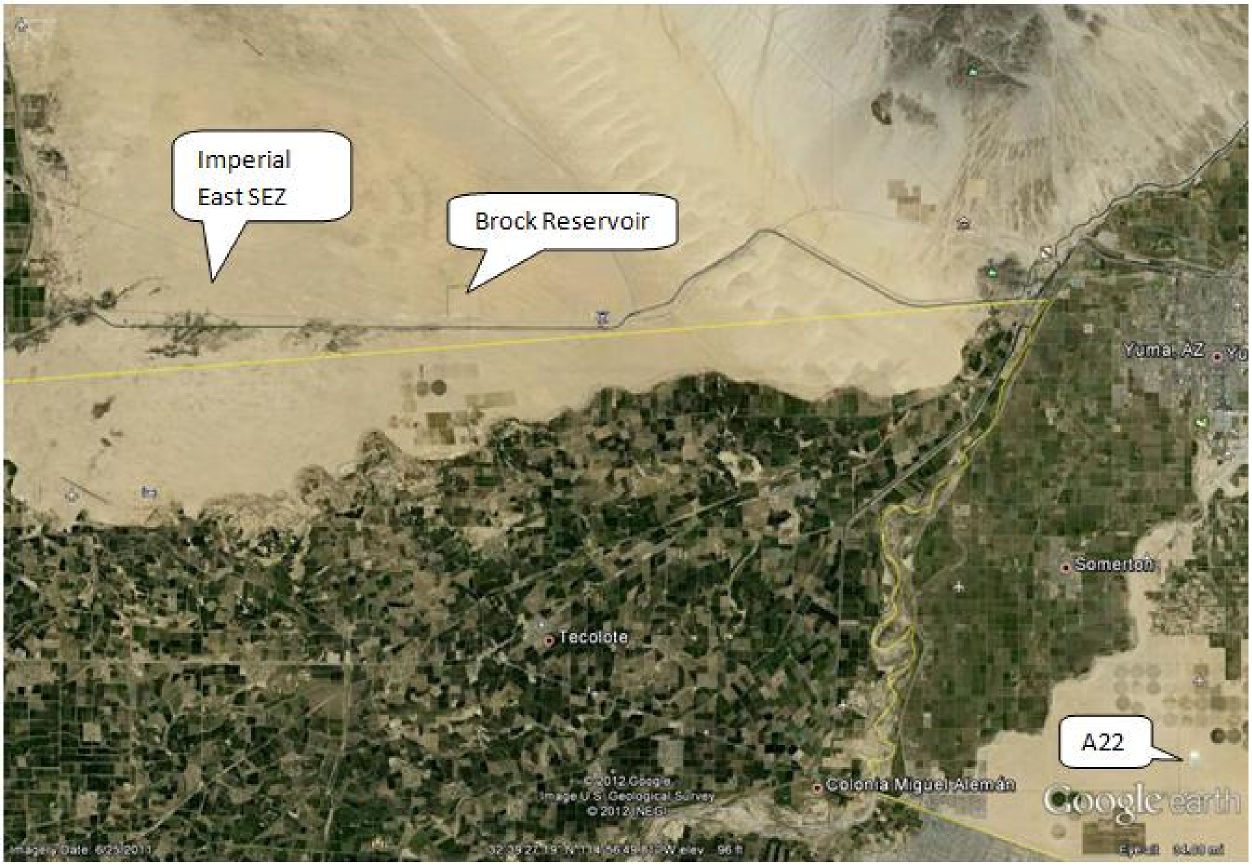

Figure 8-2. Proposed solar project locations

Source: Google Earth (modified by Blaise Stoltenberg, NREL)

8.2.1 Brock Reservoir

The proposed site at Brock Reservoir has approximately 2,083 acres available for solar generation. The site consists mainly of sandy hummocks and rough terrain, except directly west of Brock Reservoir Cell No. 2, which is mostly flat and clear. To the northeast of the site are large sand dunes. To the south of the site are Interstate 8, a transmission line corridor, and the Mexican border. Some of the land within the parcel has been previously disturbed. For this previously disturbed land, environmental analysis is complete and some of the lost habitat has already been mitigated. However, certain areas outside the inlet canal's right-of-way (ROW) would require action for National Environmental Policy Act (NEPA) compliance. Additionally, because the area is located within the Flat-Tailed Horned Lizard's (FTHL) East Mesa Management Area (MA), conservation measures would apply. These lands have been identified to be within the Desert Renewable Energy Conservation Plan (DRECP) boundaries. The west end of the site is approximately 2.3 miles from BLM's Imperial East Solar Energy Zone (SEZ), and most of the land area in this SEZ has been applied for by a single solar developer. The parcel available for solar development at this site is long and relatively narrow. This shape works fine for PV but is not viable for CSP technologies, which need more square or compact layouts to reduce thermal losses or to optimize heliostat fields. Figure 8-3 and Figure 8-4 give a close-up of the Brock site.

When looking at the site maps that follow, there is a land classification associated with each parcel:

- **Class 1**—Cleared land, NEPA covered, FTHL mitigation completed, no cultural issues
- **Class 2**—No prior clearing but NEPA covered, FTHL mitigation completed, no cultural issues
- **Class 3**—No prior clearing, no NEPA coverage, no FTHL mitigation issues, potential cultural issues
- **Class 4**—No prior clearing, no NEPA coverage, potential FTHL mitigation issues and cultural issues.

The definitions for the terms listed in the above classes are as follows:

- **Land clearing**—The project area was previously cleared of vegetation
- **NEPA coverage**—A prior NEPA document previously analyzed the project area
- **FTHL mitigation**—Either FTHL mitigation and compensation have been covered for project area, and/or FTHL mitigation consisting of fence requirements, biological surveys, providing biological monitoring during construction, and paying compensation for habitat loss may be required
- **Cultural**—The site was previously surveyed and cleared through the State Historic Preservation Office (SHPO) or a qualified archeologist.

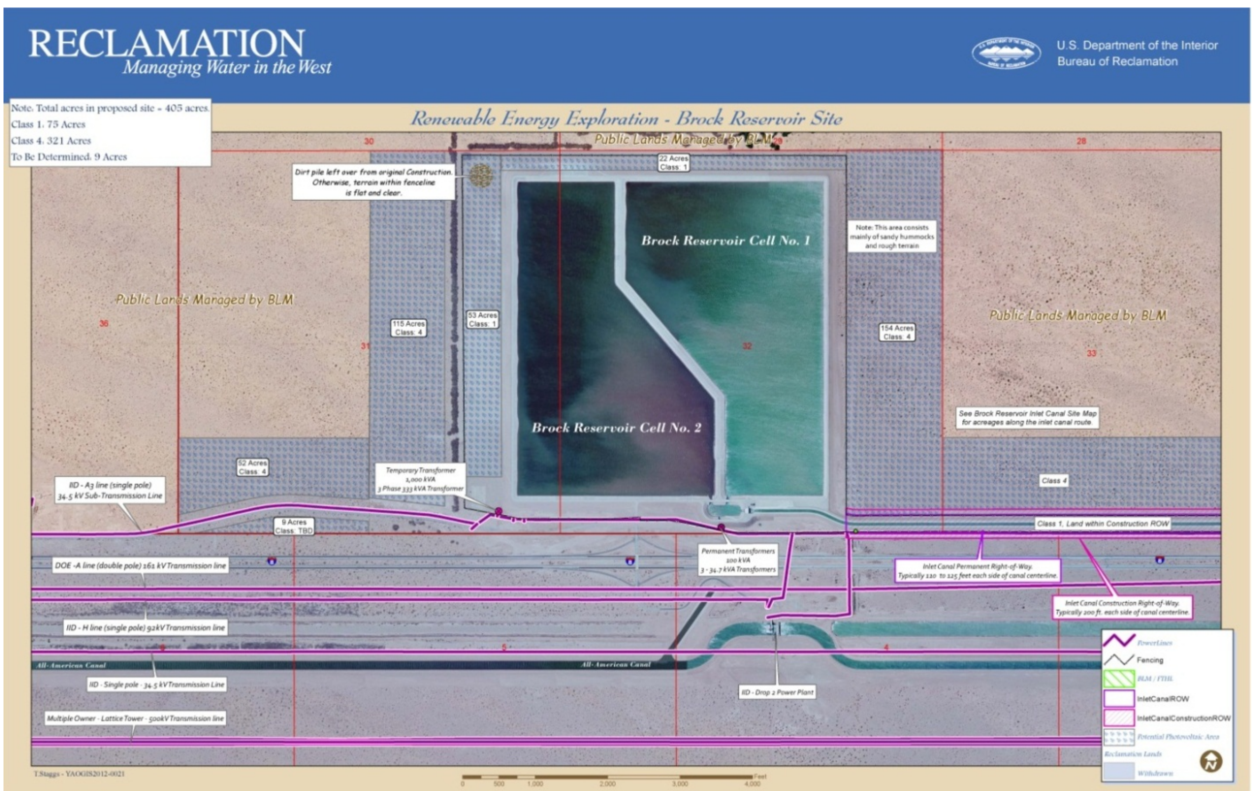

Figure 8-3. Proposed Brock Reservoir site (west)

Source: Bureau of Reclamation

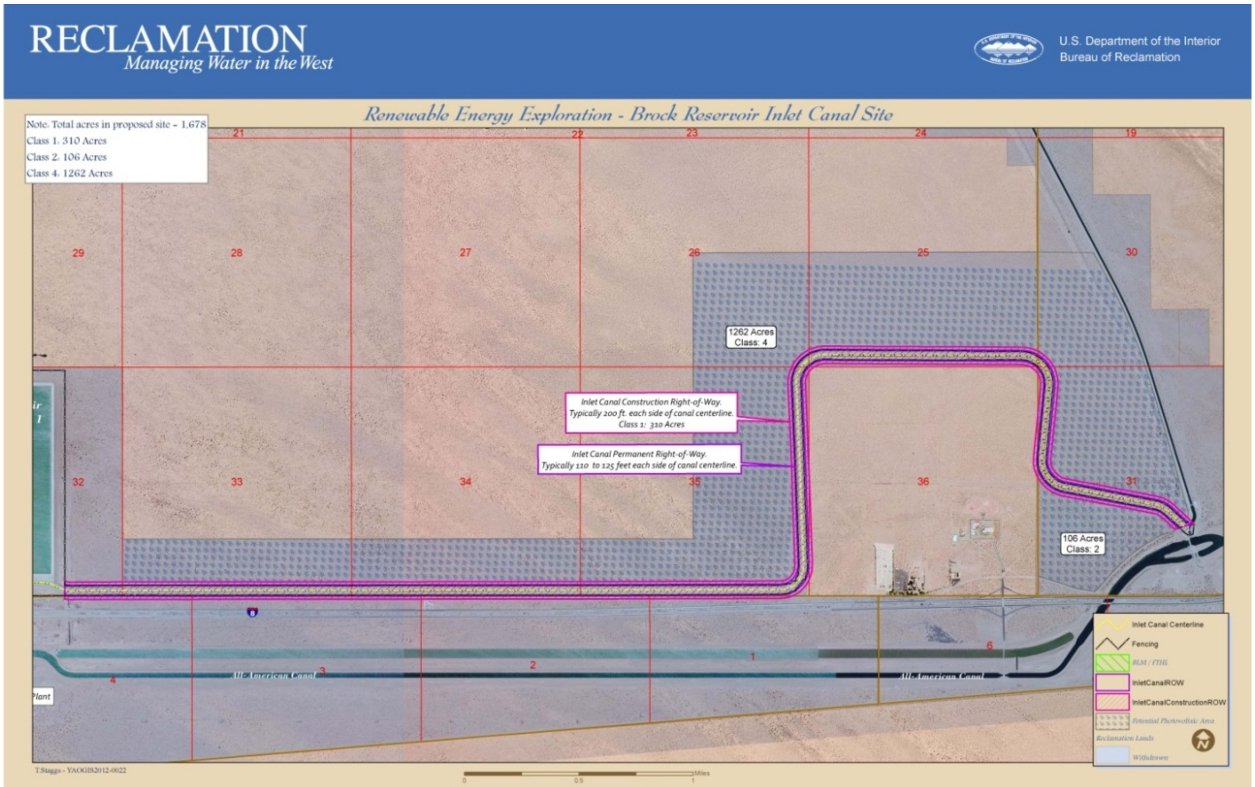

Figure 8-4. Proposed Brock Reservoir site (east)

Source: Bureau of Reclamation

8.2.2 Site A22

The proposed area at the A22 site has approximately 1,994 acres available for solar generation. The site appears to be relatively flat with scattered scrub brush. To the north is irrigated cropland, and to the south are County 23rd street and a state prison. An Arizona Public Service (APS) distribution line (12 kV) goes through the proposed area, and a substation exists approximately 4 miles to the west. A majority of the proposed site is undisturbed and would require action for NEPA compliance including biological and cultural consultation with the appropriate agencies. The site is located outside the FTHL's Yuma Desert MA but developing the site still may entail conservation measures based on the 2003 FTHL Rangewide Management Strategy, an interagency conservation agreement regarding the FTHL. This site could accommodate CSP technologies on the southern two sections of land but it probably is not practical on the northern half of the site. Figure 8-5 gives a close-up of A22.

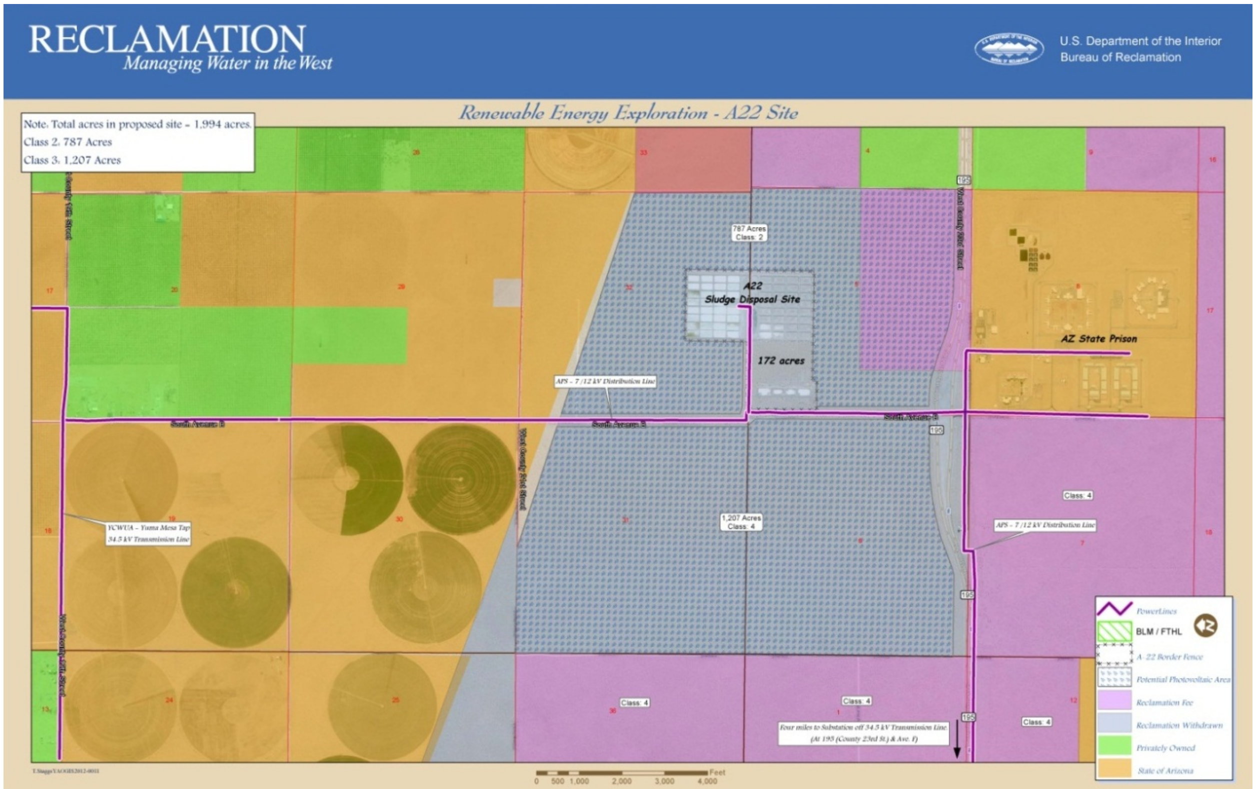

Figure 8-5. Proposed A22 site

Source: Bureau of Reclamation

8.3 Solar Resource

The solar resource in and around Yuma, Arizona, is excellent. The TMY3 weather file for Yuma International Airport indicates the global horizontal irradiance (GHI) resource is 1,977 kWh/m2/yr and the direct normal irradiance (DNI) resource is 2,319 kWh/m^2/yr. This resource is good for both PV and CSP and both can be considered. The Yuma TMY3 weather file was used by the SAM software to simulate solar generation systems and estimate energy production for this analysis. Solar Prospector[30] is a tool that displays higher resolution solar only data and indicates that the GHI could be 7% higher than the TMY3 and the DNI could be 13% higher. The difference is due to how the datasets are derived but the result is that the SAM-calculated energy production results are probably conservative estimates.

Solar resource maps are a quick way to assess the general solar resource of a site. Global solar radiation at latitude maps are a good indicator of solar resource for PV systems and are included below for both Arizona and California. The concentrating solar map is an indication of solar resource for CSP technologies and is included below for Arizona (A22 site). See Figure 8-6, Figure 8-7, and Figure 8-8.

[30] For more information on the Solar Prospector, see http://maps.nrel.gov/prospector.

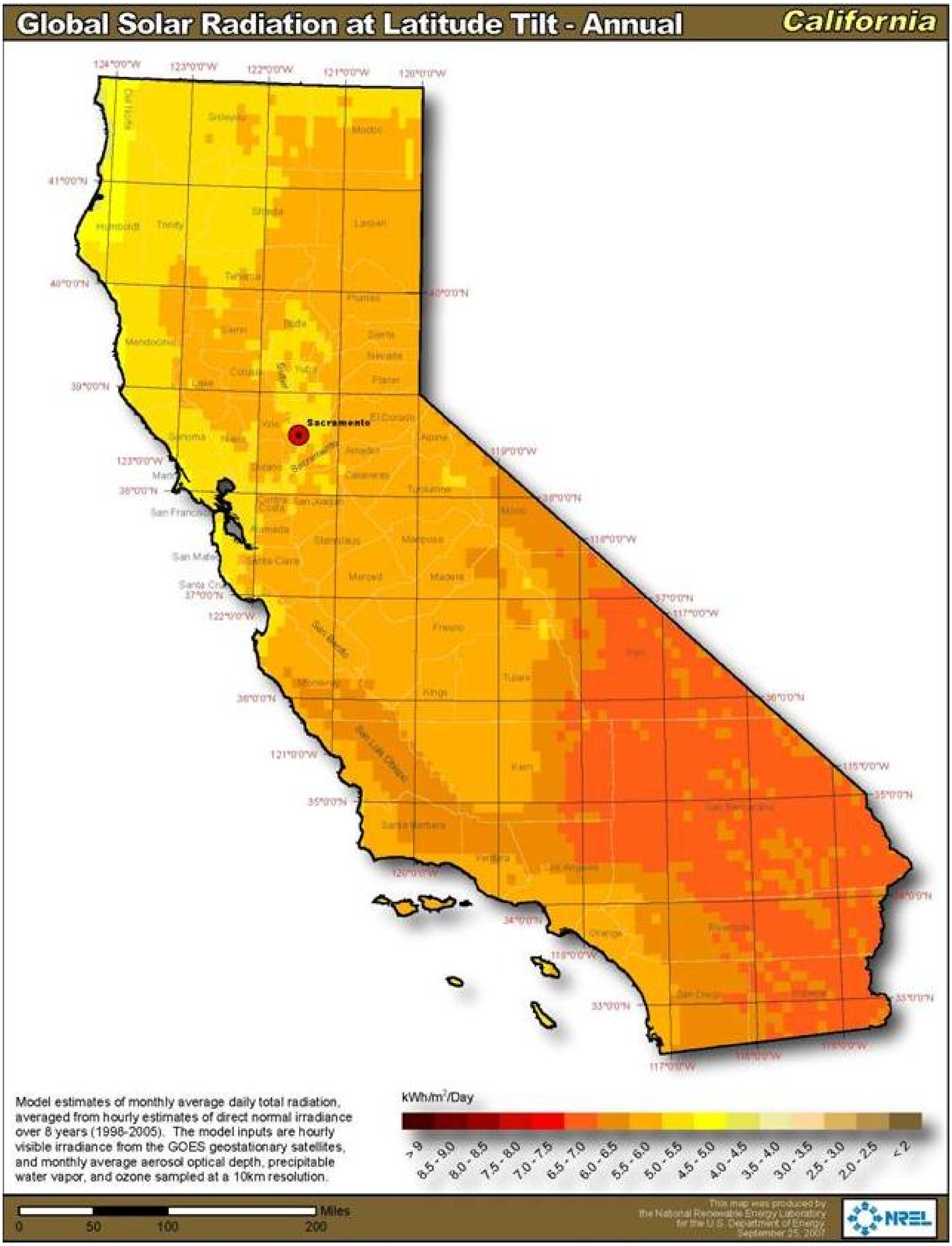

Figure 8-6. California global at latitude tilt solar resource (PV)

Source: NREL

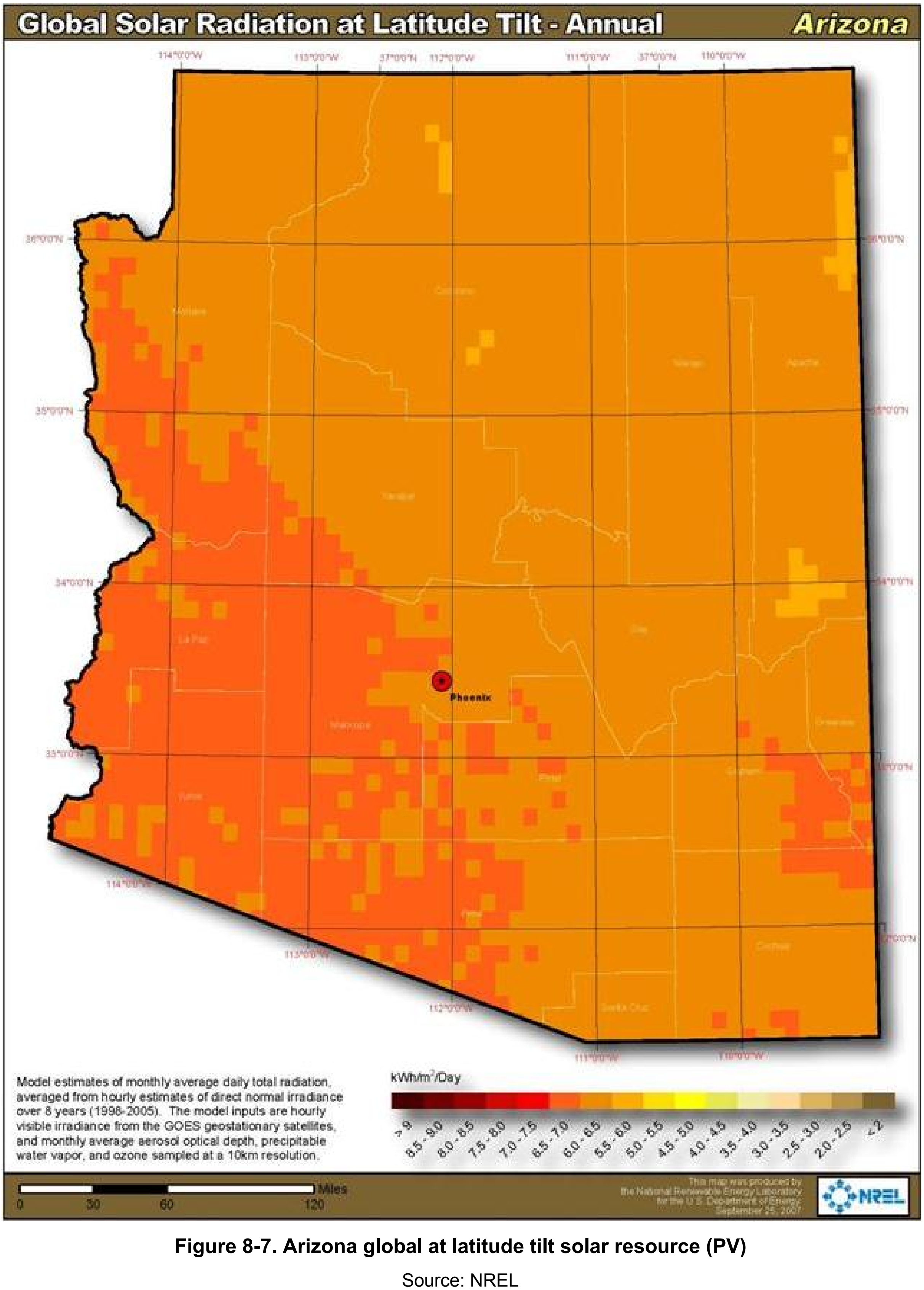

Figure 8-7. Arizona global at latitude tilt solar resource (PV)

Source: NREL

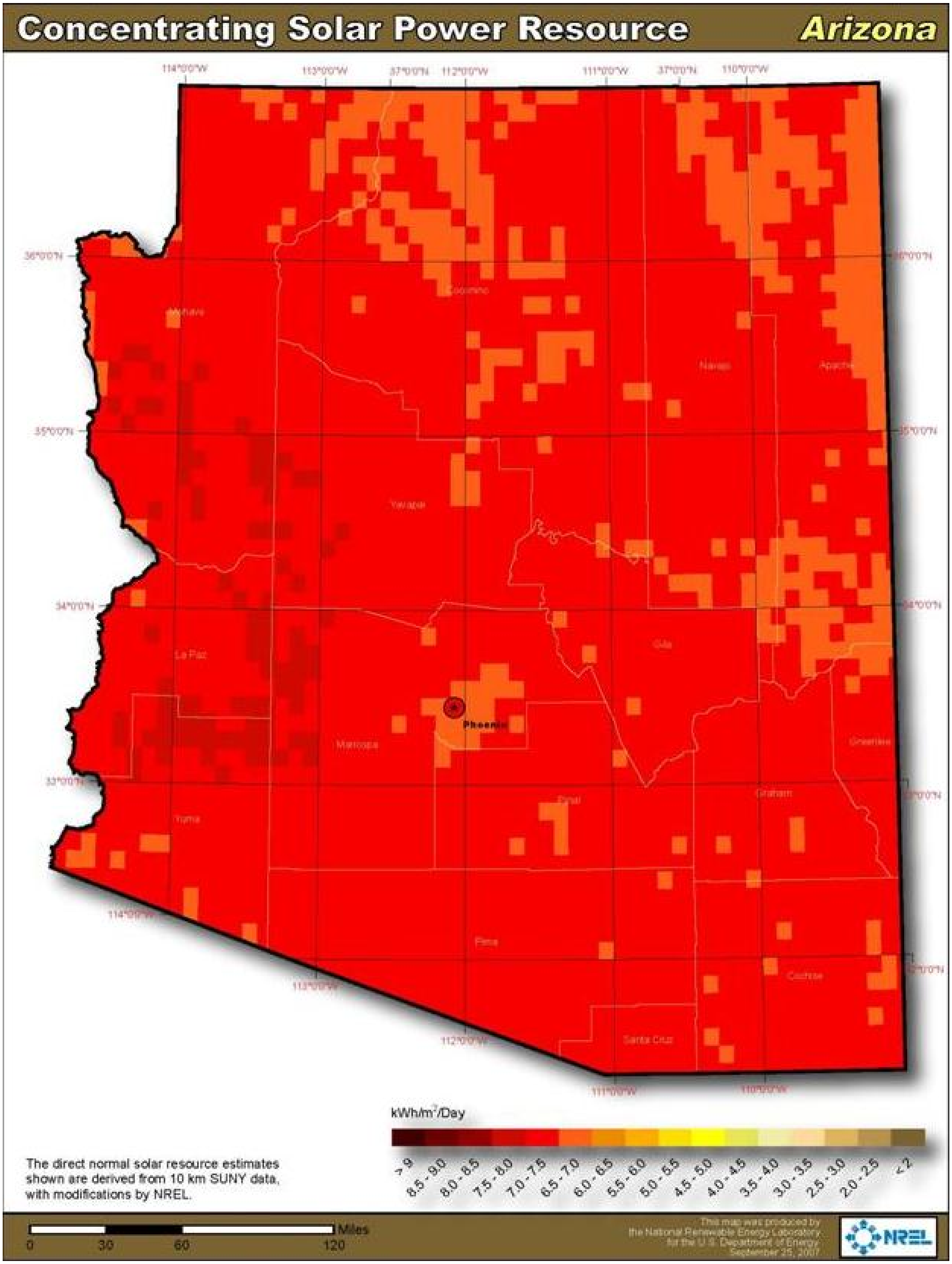

Figure 8-8. Arizona concentrating solar resource (CPV and CSP)

Source: NREL

8.4 Transmission Access

The Brock Reservoir site has a number of transmission and sub-transmission lines adjacent to the site. On the site itself is a 34.5 kV sub-transmission line. On the south side of Interstate 8 there are a 161 kV, a 92 kV, and a 500 kV transmission lines, and a 34.5 kV sub-transmission line. The available capacity on these transmission lines is currently unknown. For this site, the economic assumption is that a substation will need to be built to connect to adjacent transmission lines at an estimated cost of $4 million.

The Brock Reservoir site is ideally situated near the North Gila–Imperial Valley 500 kV line, and the completion of the Sunrise Project connecting Imperial Valley Substation into the San Diego Gas & Electric (SDGE) system will provide opportunity for PV projects in the near term. There are also a number of transmission projects in the early development stages, such as the second North Gila to Imperial Valley 500 kV line that may provide delivery capability for additional PV development in the future. There is much uncertainty about the timing of these transmission projects as several seem to be in competition for transmission customers. Some are still working through the California Independent System Operator (CAISO) approval process and may drop out as a result of the cost allocation for new transmission.

The sludge disposal site (A22) is approximately 4 miles away from the nearest substation. Assuming this is the best place for interconnection, an economic assumption of $4 million for transmission lines to the substation was included in the analysis.

8.5 Analysis Assumptions

The two sites were analyzed with NREL's SAM to estimate power production and economic feasibility. Table 8-1 lists the assumptions used in the model.

Table 8-1. Assumptions Used in Analysis

Property	Value	Source/Notes
Solar resource data	Yuma International Airport TMY3	SAM uses TMY weather files as input for solar generation simulations
Project life	30 years	
Financing terms	28-year loan at 6%	Industry standard is 1-2 years less than project life
Debt fraction	47%-48%	Adjusted to keep 1st year debt service coverage ratio (DSCR) near 1.3
Debt service coverage ratio	Near 1.3 (first year)	Industry standard
Equity internal rate of return (IRR)	15%	Common IRR in industry
Project incentives	30% investment tax credit (ITC) and 5-year modified accelerated cost-recovery system (MACRS)	DSIRE (www.dsireusa.org)
PPA escalation rate	2%	Common escalation rate
PV installed price	$2.79/W (fixed) & $3.37/W (1-axis tracking)	"Residential, Commercial, and Utility-Scale Photovoltaic (PV) System Prices in the United States: Current Drivers and Cost-Reduction Opportunities," pg. 33. (www.nrel.gov/docs/fy12osti/53347.pdf)
CSP parabolic trough installed price (no storage)	$3.96/W	SAM default based on industry contacts (no storage, 1.35 solar multiplier, and no capital land cost)
CSP power tower installed price (6 hours storage)	$5.90/W	SAM default based on industry contacts and no capital land cost
PV system degradation	0.5% per year	www.nrel.gov/docs/fy12osti/53713.pdf
PV O&M cost	$30/kW per year for years 1-15 $20/kW per year for years 16-30	First 15 years builds an escrow account for inverter replacement
CSP O&M cost	$65/kW and $3/MWh	SAM default based on industry contacts
Insurance	0.5% of installed cost per year	Industry standard
System capacity	5.75 acres per MW (fixed PV and CSP), 6.96 acres per MW (1-axis track PV)	Based on 4.0 W/ft^2 (fixed) and 3.3 W/ft^2 (1-axis) from EPA reports
Site lease costs (assumes BLM lease rate structure)	**BLM Lease Structure:** Two-part fee: Base + Capacity (Note: Capacity fee is phased in over 5 years) Brock: Base rent of $188.34/acre A22: Base rent of $313.88/acre **Brock and A22:** Capacity Fee: $5,256/MW (PV), $6,570/MW (CSP—no storage), $7,884/MW (CSP—3 hour or more storage)	Based on BLM 2010 rates: (http://www.blm.gov/wo/st/en/info/regulations/Instruction_Memos_and_Bulletins/national_instruction/2010/IM_2010-141.html)

8.6 Analysis

Table 8-2 and Table 8-3 below highlight the key results for the Brock Reservoir Site and A22 site, respectively. Results reflect BLM lease rates. The system technologies are listed in order of lowest to highest LCOE.

Table 8-2. Brock Reservoir Analysis Results

System Technology	System Size (MW)	Net Annual Energy (MWh)	LCOE Real ($/kWh)	PPA Price ($/kWh)	IRR	Capacity Factor	Annual Lease Payment ($)[a]
PV single-axis tracking	239	461,670	0.099	0.106	15%	22.1%	1,648,496
PV fixed tilt	290	451,467	0.105	0.112	15%	17.8%	1,916,552

[a] Lease payment based on BLM CY 2010 formula

Table 8-3. Yuma Desalting Plant Sludge Disposal Site Analysis Results

System Technology	System Size (MW)	Net Annual Energy (MWh)	LCOE Real ($/kWh)	PPA Price ($/kWh)	IRR	Capacity Factor	Annual Lease Payment ($)
PV single-axis tracking	229	442,353	0.097	0.104	15%	22.1%	1,829,501
PV fixed tilt	277	431,229	0.103	0.110	15%	17.8%	2,081,789
CSP molten salt power tower (6 hours)	116b	386,859	0.111	0.120	15%	37.9%	1,292,898b
CSP parabolic trough (no storage)	194b	338,699	0.154	0.165	15%	20.0%	1,653,434[a]

[a] CSP power plants using only the two southern sections of land (i.e., 1,207 acres), and listed power is net power after 8% parasitic losses.

The results of the SAM analysis show that PV with single-axis tracking results in the lowest real levelized cost of energy at $0.099 to $0.104 per kWh and also the lowest PPA price at $0.104 to $0.106 per kWh. The LCOE for both the Brock Reservoir Site and the Sludge Disposal Site are slightly different due to the different land lease payments. The Brock Reservoir Site has the potential to produce slightly more power because the location offers more room for solar generating equipment.

The PV technologies have a lower LCOE than the CSP technologies, which is likely due to the combination of lower capital costs and lower O&M costs for PV. PV with single-axis tracking offers a lower LCOE than PV with a fixed tilt due to a higher capacity factor, offering more production despite the slightly higher capital cost. CSP molten salt power tower with storage has the highest capacity factor, yet it is not high enough to offset the higher capital cost. The system size of CSP molten salt power tower was limited to 116 MW net to optimize the distance between the heliostats and the tower for the most favorable production and economics.

The results show both sites having similar economics and system production. It was assumed that land prep was the same for both sites. No property tax was assumed for the renewable generation technologies, and a difference in taxation between the sites could also change project economics.

This analysis used publicly available capital cost data. Informal discussions with developers indicate that current capital costs are lower than those used in the analysis. Thus actual LCOEs are likely to be less than shown in the analysis. Recent PPA prices for solar projects appear to be in the \$0.07-\$0.09/kWh range.[31] In terms of costs of energy, this site appears to be competitive for PV and perhaps power tower projects. The current market for solar projects is a bit uncertain. Many utilities have met their near- and mid-term renewable portfolio standard requirements for solar projects. Utility appetite for further solar projects will depend more upon cost of energy. Despite steadily dropping costs for solar energy projects, these projects still have a higher LOCE than do natural gas-fired plants.

8.7 Next Steps

Should Reclamation decide to move forward with preparing these sites for possible solar energy development, NREL recommends the following next steps:

- Get Brock Reservoir included as a development focus area in the Desert Renewable Energy Conservation Plan (see maps below, Figure 8-9 and Figure 8-10)
- Reclamation to confirm or amend, and finalize a draft Lease of Power Privilege (LOPP) D&S document
- Understand the nature of adjacent land, and the challenges and opportunities it might provide (e.g., tribal lands and cultural concerns or BLM lands that might allow for a bigger project).

[31] Linden, S. "H2 2012 U.S. PPA Market Outlook." Presented on Oct. 24, 2012.

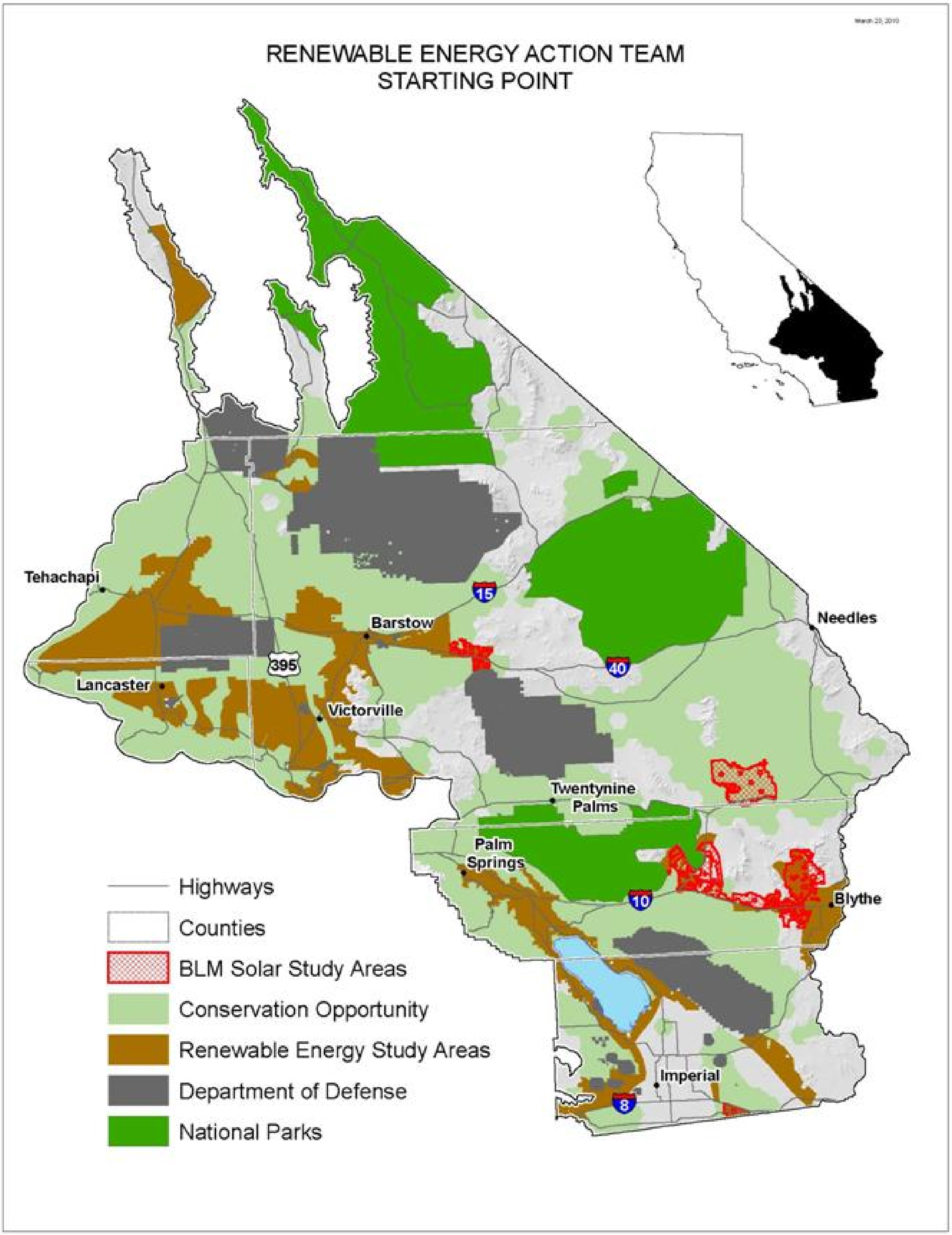

Figure 8-9. DRECP starting point map

Source: DRECP/CEC

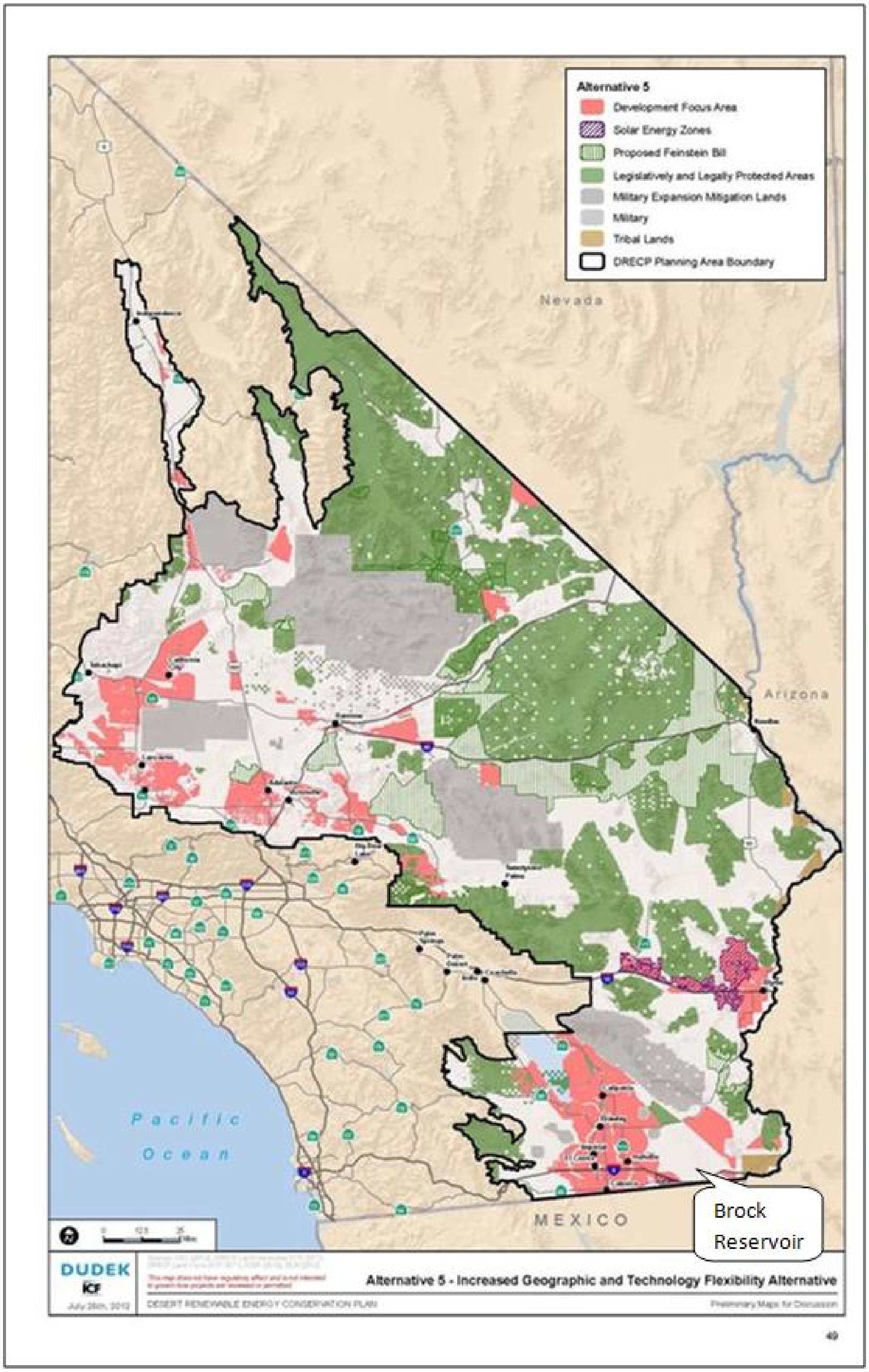

Figure 8-10. DRECP alternative 5 map

Source: DRECP/CEC

9 Utility-Scale Wind Assessment of North Platte Cluster

9.1 Introduction

On May 22, 2012, NREL conducted a site visit to the Reclamation North Platte cluster, located roughly 60 miles southwest of Casper, Wyoming, to assess the potential for wind development on the Reclamation-owned land in the area. George Neuberger, of the Wyoming Area Office, facilitated the site visit. The visit focused on the Morgan Creek area, Seminoe Reservoir/Dam, Kortes Reservoir/Dam, and Pathfinder Dam. The methodology used to assess the site is a standard high-level "fatal flaw" analysis that looks for key enablers that would encourage wind energy development, and also key barriers or "fatal flaws" that would inhibit or preclude wind energy development. The site visit looked at the following: wind resource, proximity to transmission lines and substations, available land/road access, environmental issues, and community receptiveness.

Figure 9-1 shows the location of the North Platte cluster in south central Wyoming. This area was selected for a site visit due to the large potential wind energy capacity of the Reclamation owned land, approximately 450 MW, even after applying a series of standard exclusions.

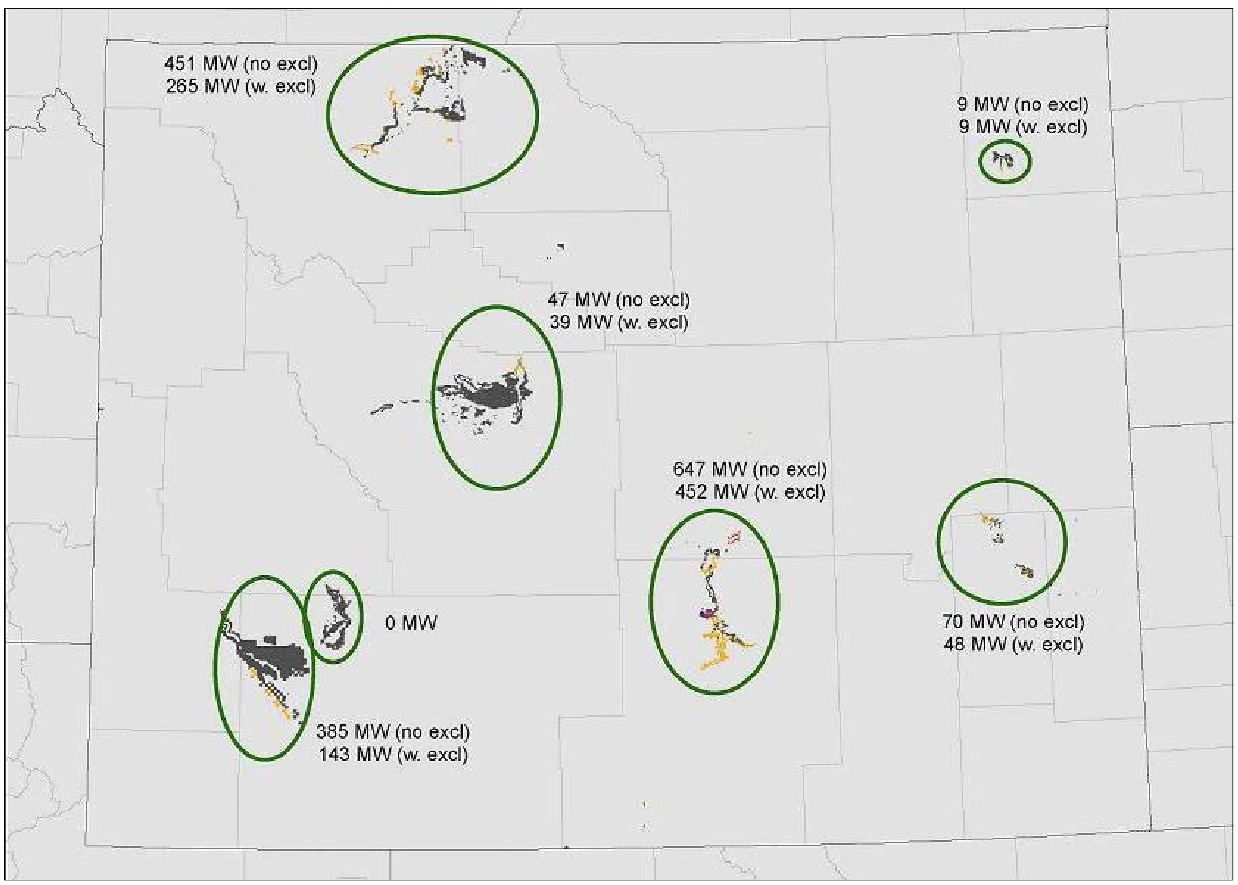

Figure 9-1. Reclamation North Platte cluster

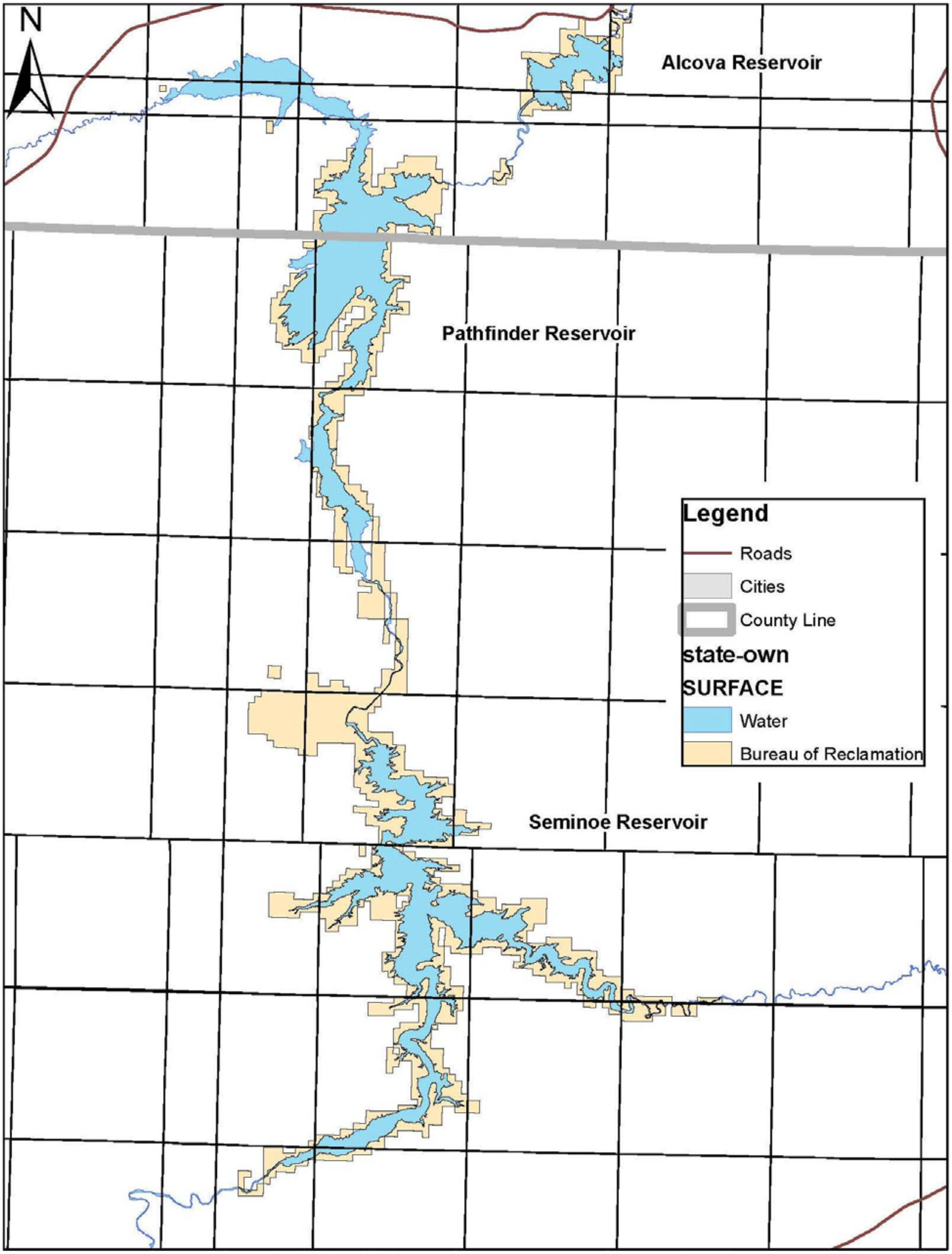

Figure 9-2. Reclamation North Platte cluster

Source: Bureau of Reclamation

9.2 Reclamation Land Description

The Reclamation North Platte cluster consists of land adjacent to four reservoirs along the North Platte River, which flows from south to north through the area shown in Figure 9-2. From south to north the reservoirs are Seminoe, Kortes, Pathfinder, and Alcova. The reservoirs are used for water supply, recreation, flood control, and electric power generation. Between the reservoirs, the North Platte flows through steep, rugged canyons. The area around the reservoirs is a mix of rugged terrain and flatter, more rolling terrain as shown in Figure 9-3.

The Reclamation-owned parcels generally consist of the land directly adjacent to the shoreline and along the river. This land is flat in some areas, such as along the northern part of Seminoe Reservoir, and rugged in other areas, with steep terrain extending down to the water line. In addition to the land adjacent to the water, the Reclamation-owned land includes the Morgan Creek area. This is a rugged parcel of terrain located just north of Seminoe Reservoir on the west side of the North Platte River. Reclamation-owned land around northern Seminoe Reservoir is used as a state park under an agreement with the State of Wyoming. The land adjacent to the Reclamation-owned parcels is a mix of public (mostly BLM) land and privately owned land.

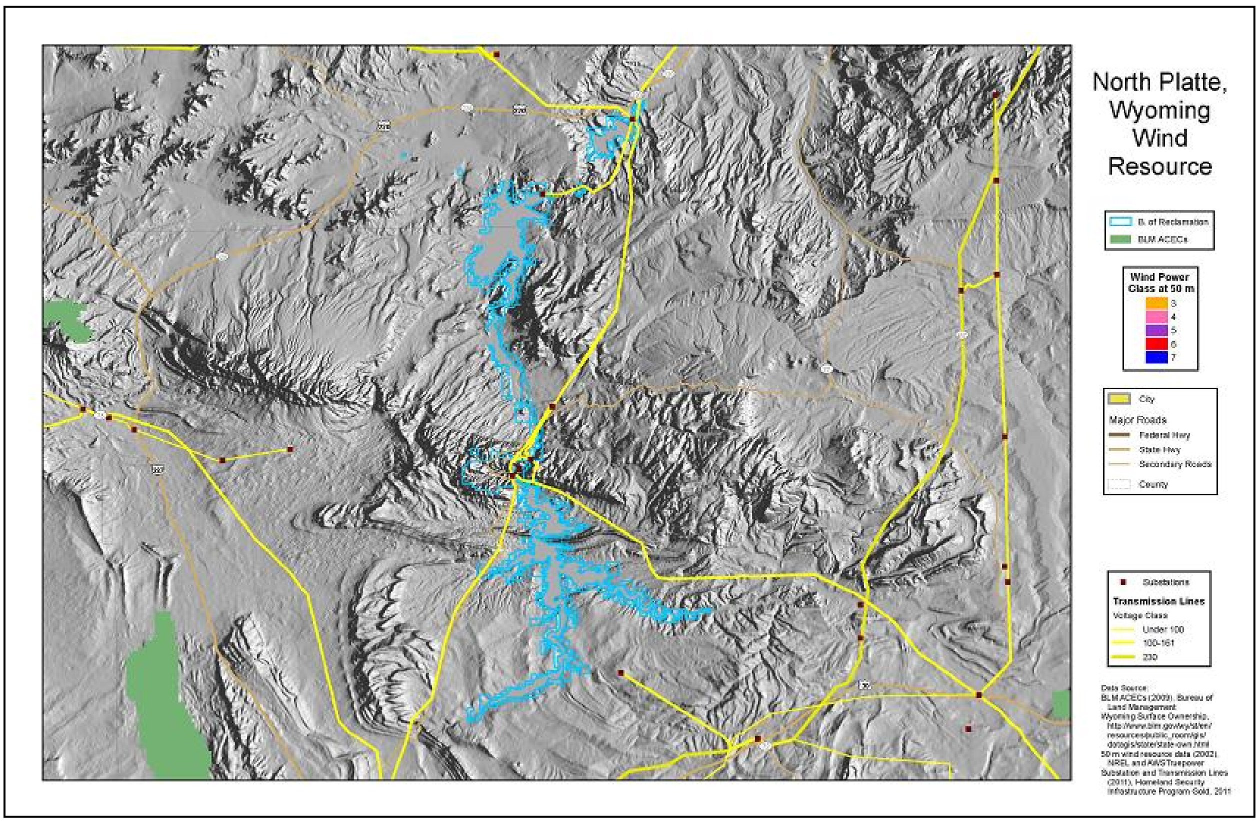

Figure 9-3. Relief map of the North Platte cluster

Source: Bureau of Land Management (using 50 m wind data from NREL)

9.3 Suitability Assessment

9.3.1 Wind Resource

Figure 9-4 shows the wind resource of the area prior to exclusions. The best wind resource within the North Platte cluster is along the ridge tops of the Morgan Creek area, which have a class IV and class V winds. Immediately adjacent to the reservoirs the wind resource is lower, mainly class III. Figure 9-5 gives close-up of the wind resource in the Morgan Creek area and northern end of Seminoe Reservoir. Figure 9-6 shows the wind rose for the area. As can be seen, the prevailing winds come from the west-southwest.

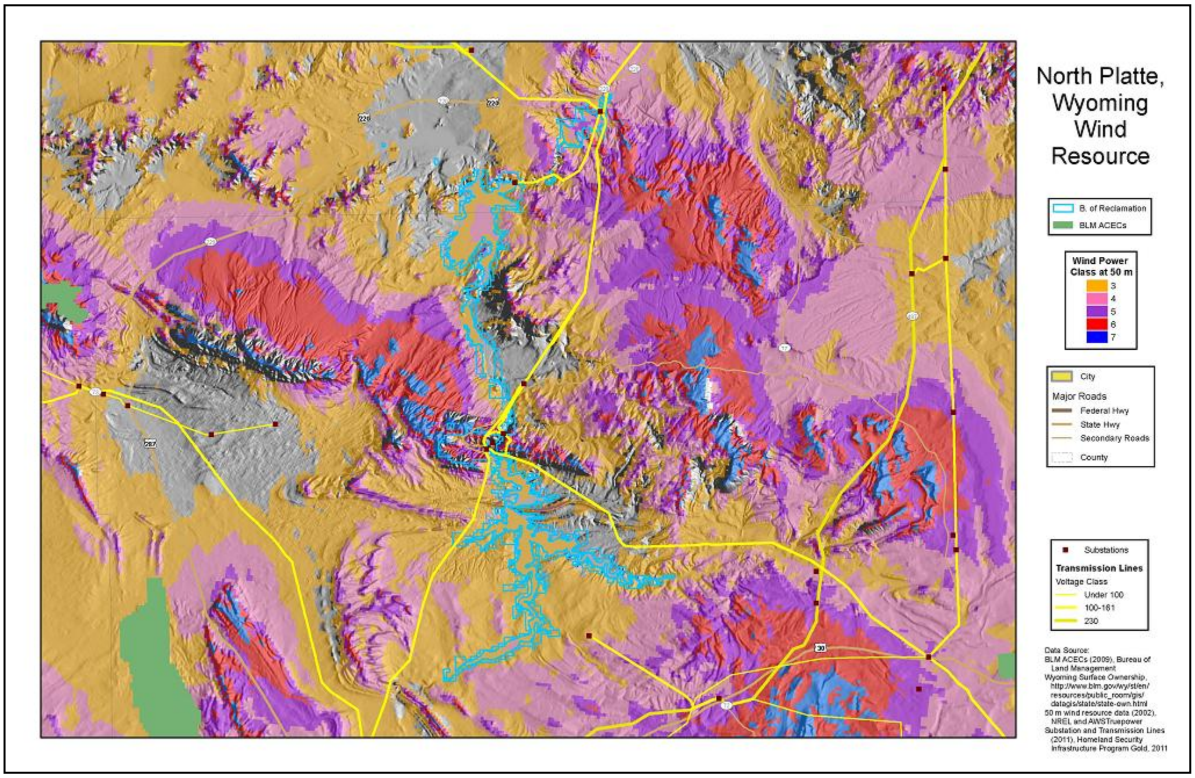

Figure 9-4. Reclamation North Platte cluster wind resource

Source: Bureau of Land Management (using 50 m wind data from NREL)

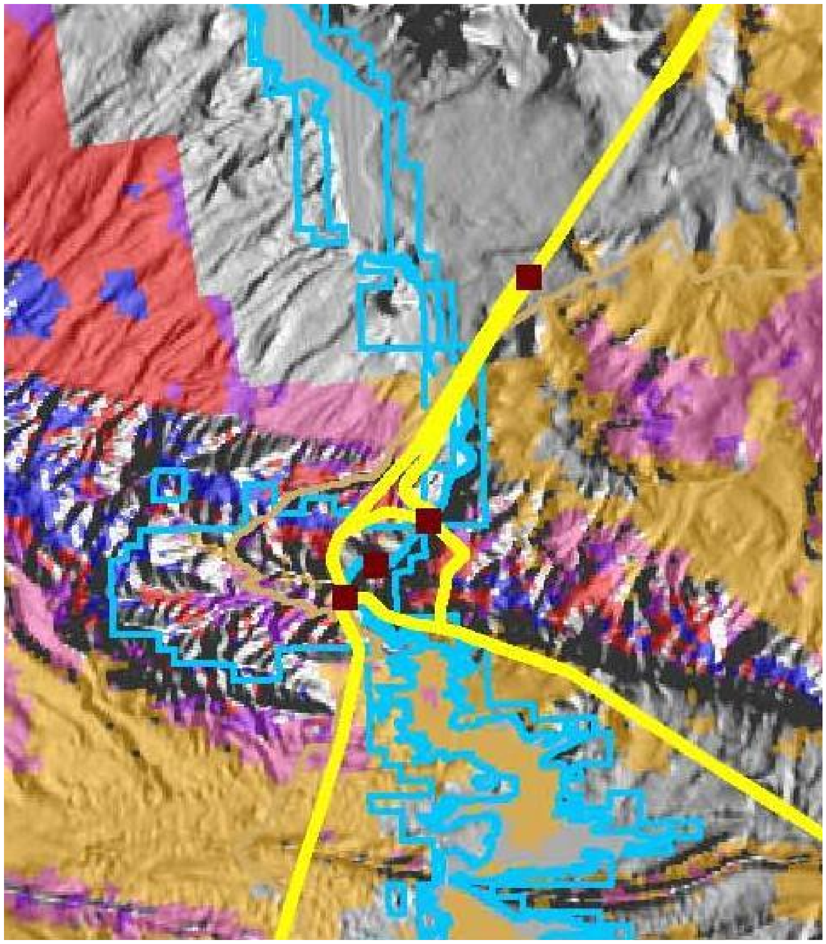

Figure 9-5. Morgan Creek area and northern Seminoe Reservoir wind resource (close up of Figure 9-4)

Source: Bureau of Land Management (using 50 m wind data from NREL)

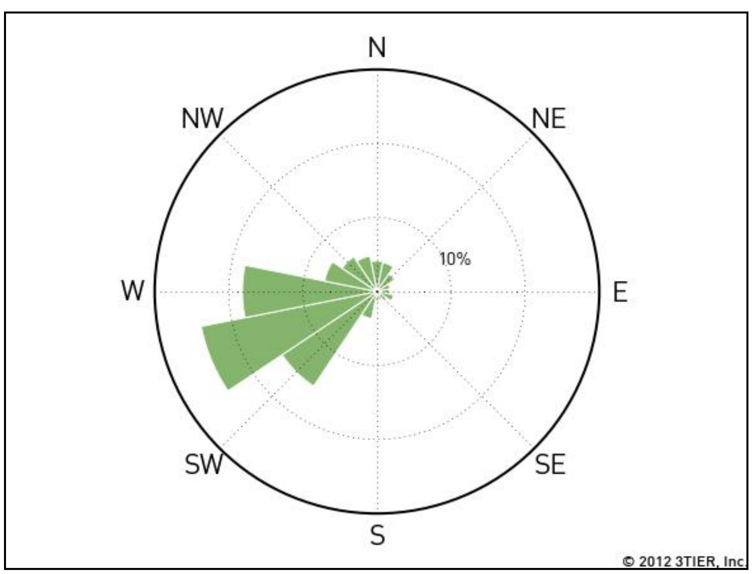

Figure 9-6. North Platte cluster wind rose

Source: 3Tier

9.3.2 Available Land/Road Access/Constructability

Overall road access to the general area is adequate. From the north, the area is accessible via paved/improved gravel road from Highway 220. From the south, the area is accessible from I-80 via a paved road. Access to the Morgan Creek area is problematic (Figure 10-7). Seminoe Road (an improved gravel road) is marginal, with steep sections and some switchbacks. Morgan Creek Road, which accesses some of the ridge tops, is basically a 4-wheel drive road, which is completely inadequate for oversized semi-trailers.

The Reclamation-owned land is awkward for wind development purposes. The Reclamation-owned parcels consist mainly of the shoreline around the reservoirs plus the Morgan Creek area. As discussed, access to Morgan Creek area is problematic. Some of the land around the reservoirs is flat and accessible but keeping a multiple-turbine installation within the Reclamation boundaries will require long cable runs between turbines, which will lead to prohibitive economics. Figure 9-8 shows a demonstrative layout of six 100-m diameter turbines on the Reclamation parcel at the north end of Seminoe Reservoir. The red lines show the rows, oriented perpendicular to the prevailing winds. The green squares show the turbine locations. Turbines within a row are spaced three turbine diameters apart (a typical spacing). The rows are six turbine diameters apart (about as close as good practice allows). This is the best possible scenario for siting turbine arrays on the Reclamation land in this area. The shape of the Reclamation owned parcels does not allow for the economical placement of large turbine arrays.

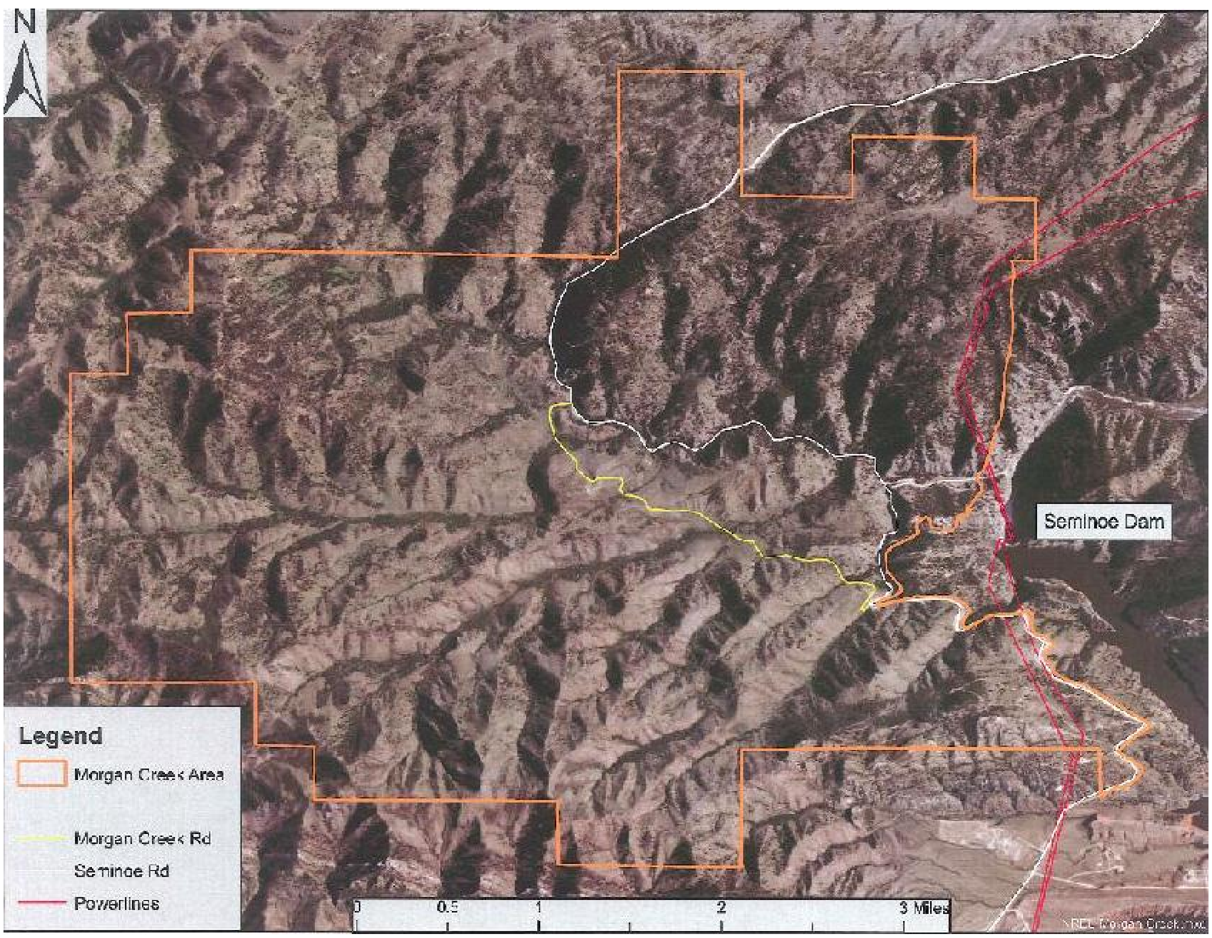

Figure 9-7. Morgan Creek area road access

Source: Bureau of Reclamation

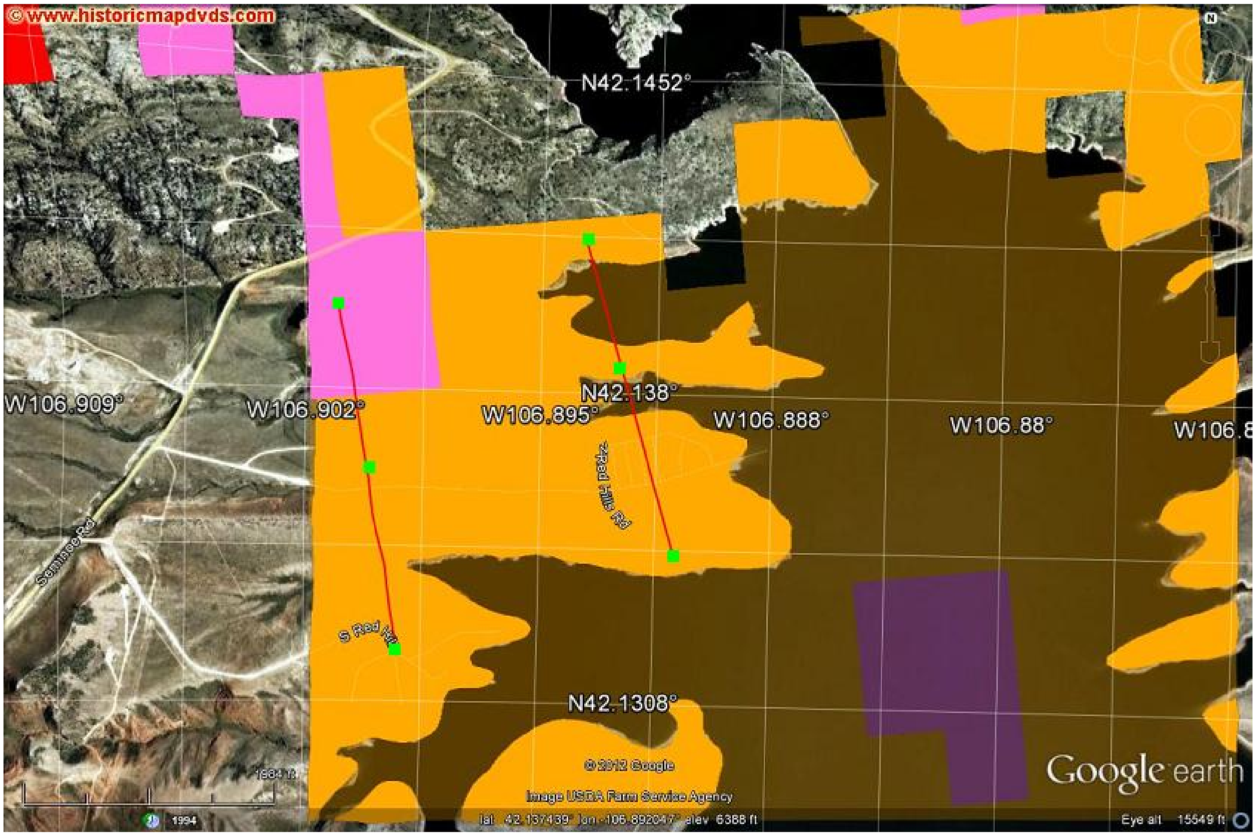

Figure 9-8. Hypothetical turbine layout on Reclamation parcel at northern end of Seminoe Reservoir

Source: Google Earth image overlaid with 50 m wind data from NREL (modified by Tony Jimenez)

9.3.3 Transmission Access

Figure 9-3, Figure 9-4, Figure 9-5, and Figure 9-7 show the power lines and substations that serve the area. Interconnection to the grid requires a substation (preferable) or a dedicated switch to the power line. The power lines in the area run from the dams. Most of the lines are 115 kV, but there is one 230 kV line. Given the voltage ratings of these lines, direct interconnection of single turbine would be prohibitively expensive. The six-turbine array shown in Figure 9-8 may be large enough to support a dedicated substation or interconnect.

Figure 9-5 shows the substations located on or near Reclamation-owned land. The figure shows three substations located along the North Platte River just downstream (north) of Seminoe River. An NREL team was able to visit two of these substations. Of the two substations visited, one is located at the base of Seminoe Dam, and the other is at the base of Kortes Dam. The main substation serving the area is the Western Area Power Administration (WAPA)-owned "Miracle Mile" substation located northeast of the Kortes Dam. This substation is not located on Reclamation land.

Access to the substations is difficult from the areas in which turbines can be built. For example, the flat area around the northern part of Seminoe Reservoir is separated from the substation at Seminoe Dam by a rugged canyon about two miles in length.

9.3.4 Environmental

As shown in Figure 9-9, much of the area is listed as sage grouse habitat. Consultation with the U.S. Fish & Wildlife Service (USFWS) would be needed for a project to move forward.

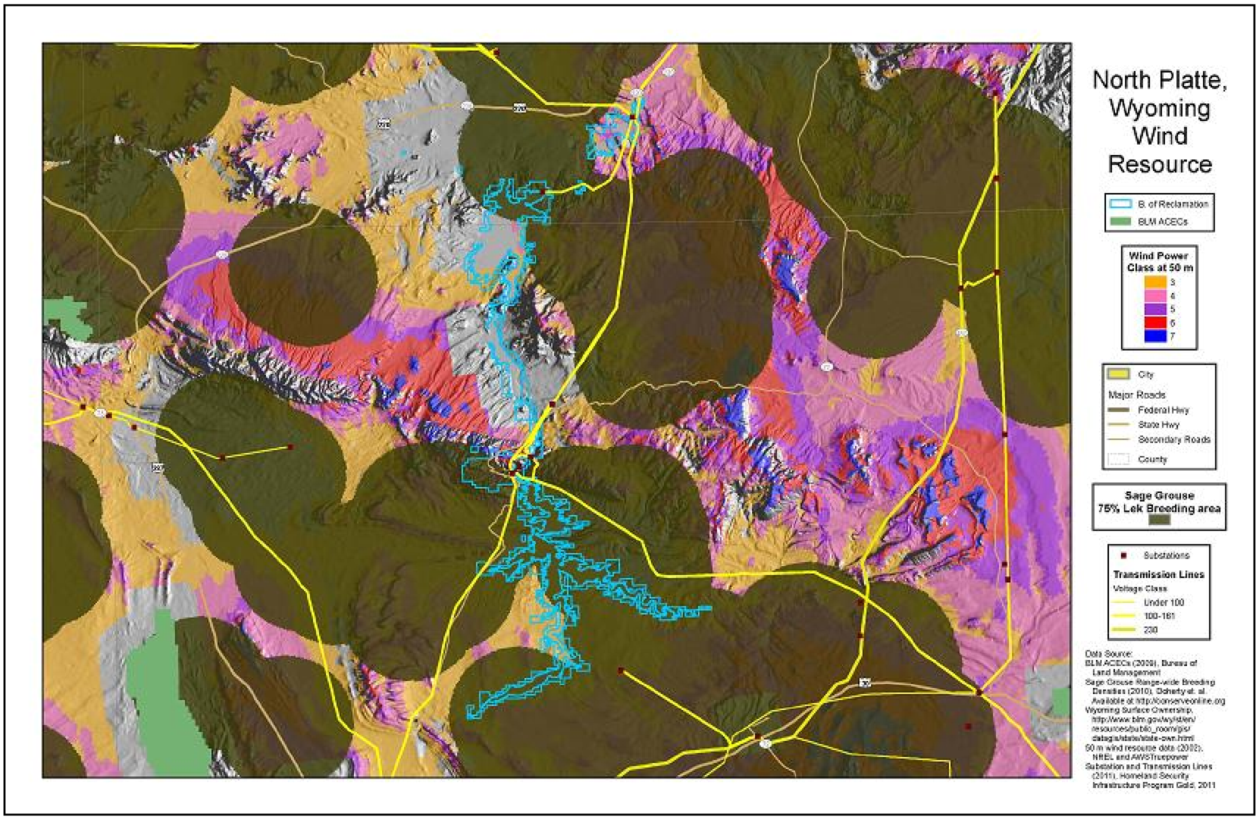

Figure 9-9. Sage grouse habitat in the North Platte cluster

Source: Bureau of Land Management (using 50 m wind data from NREL)

9.3.5 Community Receptiveness

The final consideration is the receptiveness of the local community to a wind project. The Reclamation parcel at the north end of Seminoe Reservoir is used as a state park. This was discussed with Mr. George Nueberger. While his sense is that most visitors that use the area for recreation would probably not object to a wind project, this certainly would need to be investigated further.

9.4 Ownership Structures

This section will briefly describe two potential business models for Reclamation to pursue—passive lease holder and Reclamation ownership. When evaluating these models it is important to understand a key difference between a hydro facility and a wind farm; unlike water, wind cannot be stored for when it is needed.

The first model is for Reclamation to be a passive leaseholder, collecting royalties for projects owned by others that are sited on Reclamation land. This has the advantage of being relatively easy. Reclamation would not have to learn all the details of wind farm development and would be spared the risks of development. The major disadvantage is that the scale of development is dependent on the decisions of others. There are steps Reclamation can take to encourage wind projects on Reclamation land but ultimately development is up to others. Should Reclamation decide to go this route, we recommend that Reclamation harmonize its processes with BLM to attract/allow development from adjacent BLM land. It appears that most Reclamation holdings have the same characteristics as the North Platte cluster. The holdings are relatively small and awkwardly arranged around bodies of water. This makes it hard to develop large projects solely on Reclamation land. However, Reclamation land is often adjacent to much large BLM land holdings. In certain locations a developer with a lease on BLM land may find it attractive to expand a project onto adjacent Reclamation land.

Reclamation owns many hydro facilities, and so is used to developing and owning large capital intensive projects. Reclamation may decide to develop a wind a wind farm. At this point, such a project would benefit from current very low federal government borrowing rates. However, there are significant disadvantages. Reclamation would take all the risks of ownership. A government-owned facility would not benefit from the production tax credit (PTC) or accelerated depreciation. Reclamation would have to find buyers of the energy either through PPAs or the spot market. Unlike hydro power, the wind cannot be stored. Electricity produced by the wind farm has to be sold as it is produced. Finally, the private sector has extensive experience in developing and operating wind farms. There doesn't appear to be a compelling need for large scale wind project development by the federal government.

9.5 Economic Analysis

This section gives an overview of an economic analysis of a hypothetical wind farm located at the northern end of Seminoe Reservoir.

Figure 9-10 shows the wind farm location on the 80 m wind map. The average wind speed [at 80 m above ground level (AGL)] for the location is shown as lying in the range of 7.0-7.5 m/s. This analysis assumes an average wind speed of 7.25 m/s and a Weibull K of 2.

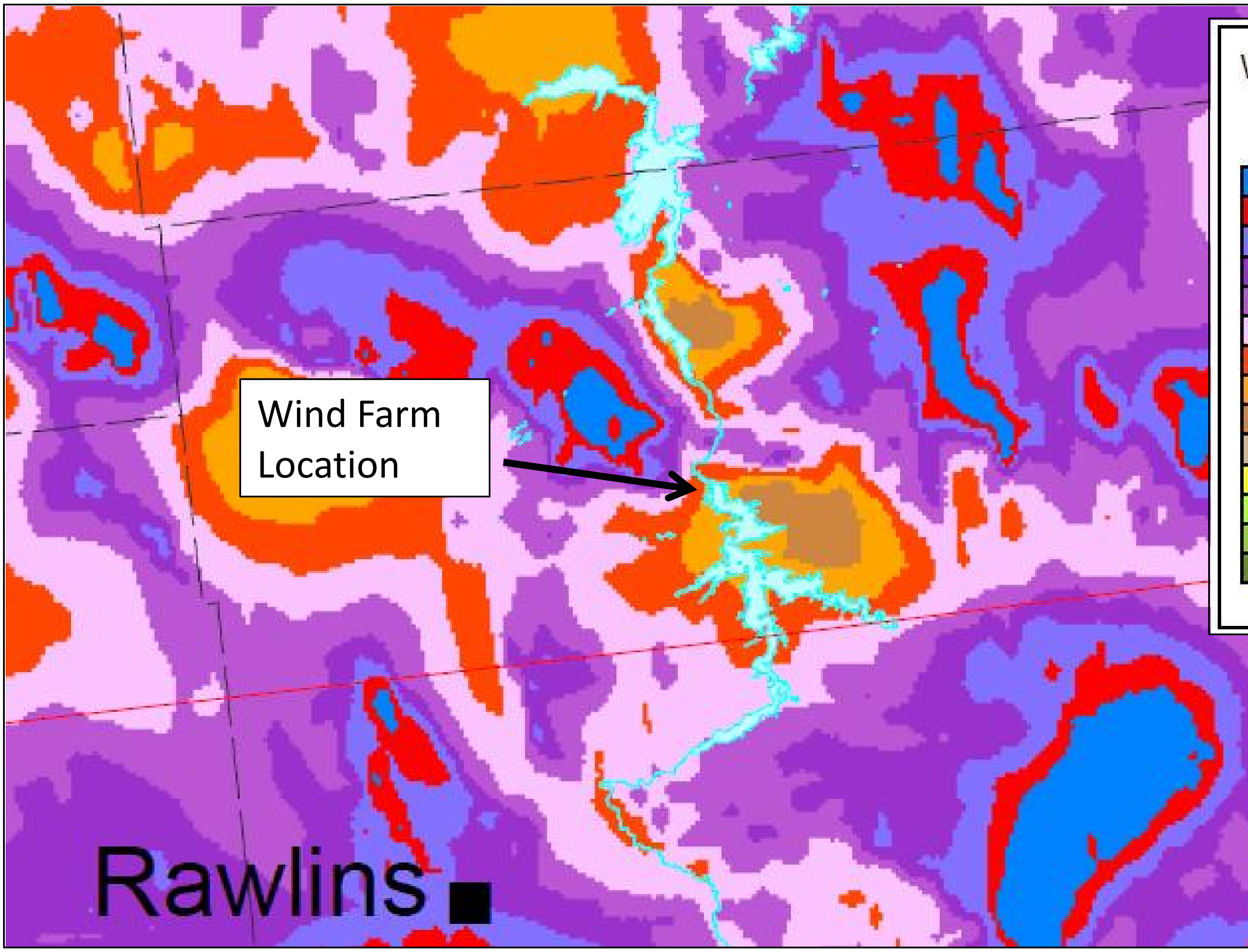

Figure 9-10. Wind farm location on 80 m wind map 80 m wind data

Source: EERE/DOE (modified by Tony Jimenez)

Table 9-1 lists the site and turbine assumptions. Table 9- 2 lists the economic and financial assumptions. The air density at the location is estimated to be 0.95 kg/m^3. The site has a lower air density due to its elevation. A turbine at this location will produce less energy (given the same wind resource) than a turbine at a lower elevation. The turbines used for this analysis are GE 1.6-100. This is a 1.6 MW Low Wind Speed Turbines (LWST) turbine with a 100 meter rotor. The LWST have extra-long rotors to enable greater energy capture in modest wind regimes. Use of this machine in the analysis may be optimistic. Due to the rugged surrounding terrain, the winds may be too turbulent to allow use of this machine. Table 9-1 shows the expected capacity factor for the GE 1.6-100 and the GE 1.6-82.5. The latter machine has a smaller rotor suitable for more turbulent winds than the GE 1.6-100. The wind farm consists of six turbines, laid out as shown in Figure 9-8 for a total rated capacity of 9.6 MW.

Table 9-1. Site and Turbine Assumptions

Site Assumptions	
Latitude	N 42.136
Longitude	W 106.896
Elevation	6420 ft (1950 m)
Air Density	0.95 kg/m^3
Average Wind Speed at 80 m AGL	7.25 m/s
Weibull k	2.00
Turbine Assumptions	
Turbine Loss Factor	15%
Net Capacity Factor (GE 1.6 100 m rotor)	35.7%
Net Capacity Factor (GE 1.6 82.5 m rotor)	31.5%
Wind Farm Rated Capacity	9.6 MW
Start Year	2014
Project Lifetime	20 years

The analysis examined two business models. The “cash-purchase” option assumes the wind farm is owned by Reclamation. The “third-party” lease assumes that a third party owns the wind farm, leasing the land from Reclamation.

Table 9-2 lists the economic and financial assumptions. The base-case scenario assumes a total installed cost of $2,300/kW. The 2011 Wind Technologies Market Report[32] lists an average installed cost of $2,300/kW. However, the report anticipates that project costs will drop as recent dramatic decreases in turbine hardware costs begin to be reflected in project costs. On the other hand, the LWSTs can be expected to have higher per kW costs due to the extra material in the blades. Also, a project at this location may have higher than normal interconnection costs. The use of $2,300/kW assumes these effects more or less cancel out. This analysis includes a sensitivity study over a range of installed costs to determine the effect of changes in the installed cost on the cost of energy.

The analysis assumes an O&M cost of $0.02/kWh (this value comes from the 2011 Wind Technologies Market Report). This covers all O&M, including periodic “capital repairs” of large components such as blades and gear boxes. After some discussion with Reclamation representatives, it was decided to use BLM lease rates for the third-party lease scenario. Per IM 2009-043, Wind Energy Development Policy, dated Dec. 19, 2009, the analysis used a site owner royalty of $4,155/MW/year. The IM has an expiration date of Sept. 30, 2010, but does not appear to have been updated.

[32] Wiser, R.; Bolinger, M. *2011 Wind Technologies Market Report*. Berkeley, CA: Lawrence Berkeley National Laboratory, 2012.

Table 9-2. Economic and Financial Assumptions

	Cash Purchase	Third Party Lease
Capital Costs		
Total Installed Unit Capital Costs ($/kW)	$2,300/kW	$2,300/kW
Total Installed Capital Cost ($)	$22,080,000	$22,080,000
Operating Expenses		
Variable O&M	$0.02/kWh	$0.021/kWh
Variable O&M Escalation Rate	0.9%/year	0.9%/year
Site Owner Royalty ($/MW/yr)	0	$4,155/MW/yr
Financing Assumptions		
Debt (% of capital cost)	0	40%
Schedule Type	N/A	Level Principle
Interest Rate	N/A	7%
Term	N/A	20 years
Tax Assumptions		
Marginal Federal Tax Rate	N/A	35%
Marginal State Tax Rate	N/A	0%
Incentive Amount (PTC)	N/A	$0.023/kWh
Incentive Length	N/A	10 years
Incentive Escalation Rate	N/A	0.9%/year
Economic Assumptions		
General Inflation Rate	0.9%/year	0.9%/year
Power Purchaser Discount Rate (Used for calculating LCOE)	3.9%/year	3.9%/year
Project Owner Discount Rate (Used for calculating NPV)	3.9%/year	12.9%/year
Minimum IRR	3.9%	10.9%
Energy Payment Escalation Rate	0	0

The inflation rate (0.9%) and discount rates (3.9% nominal) for the cash purchase option were determined using the guidelines published by the U.S. Department of Commerce in the annual publication, Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis–2011.[33] The 12.9% (nominal) project owner discount rate for the third-party lease scenario comes from discussions with project developers.

For the lease option, the analysis assumed a marginal federal tax rate of 35%. Wyoming does not have a commercial state income tax so the state tax rate was set at zero percent. However, Wyoming does levy a $0.001/kWh tax on commercial wind farms. For simplicity, this was added to the overall O&M cost.

The third-party lease scenario benefits from two incentives. The first is the PTC, which is a credit given for every kWh sold to an unrelated third party. The credit is available for the first ten years of a project and escalates with inflation. The current value (2012) of the credit is $0.022/kWh. The estimated value for the 2014 start date used in the analysis is $0.023/kWh. The PTC is scheduled to expire at the end of 2013. At the time of this writing, extension is uncertain.

[33] Rushing, A.; Lippiatt, B. *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis–2011*. U.S. Department of Commerce, 2011. Accessed July 2012: http://www1.eere.energy.gov/femp/pdfs/ashb11.pdf.

If the PTC is not extended, the LCOE of the third-party lease scenario will rise by approximately $0.01/kWh for projects that are started after the expiration date.

The other incentive available to the third-party lease scenario is accelerated depreciation. Under the Modified Accelerated Cost Recovery System (MACRS) a wind farm may be depreciated over a five-year period, with the bulk of the depreciation available in the first three years.

Overall assumptions represent the authors' best effort to develop a middle of the road scenario. However, significant uncertainties remain. The study includes a sensitivity analysis over initial capital cost and average wind speed to determine the effects of changes in these inputs on the levelized cost of energy.

9.6 Results Discussion

The economic analysis was conducted using the WindFinance[34] tool. Analysis results are given in Table 9-3 and Table 9-4. The results for the base case are shaded in light yellow. As can be seen, the LCOEs for the cash purchase option are lower than the LOCEs for the third-party lease option. For the base case, the respective LCOEs are $0.082/kWh for the cash purchase option and $0.092/kWh for the lease option. The full range of LCOEs is $0.065/kWh-$0.105/kWh for the cash purchase option and $0.070/kWh-$0.140/kWh for the lease option. The LCOE for the lease option is more sensitive to changes in the initial capital cost and changes in the average wind speed than the LCOE for the cash purchase option.

There are a couple of likely reasons for why the LCOEs are lower for the cash purchase option than for the lease option. The first reason is the current very low IRR that applies to government-owned projects compared to privately owned projects. The second reason is the modest wind resource reduces the value of the PTC. A greater wind resource enables greater energy production and thus increases the value of the PTC. Thus, the third-party lease option benefits more from a greater wind resource than does the cash purchase option.

[34] WindFinance is available at http://analysis.nrel.gov/windfinance/login.asp.

Table 9-3. Analysis Results–Cash Purchase Option

Cash Purchase	-20% Capital Cost	-10% Capital Cost	Base Capital Cost	+10% Capital Cost	+20% Capital Cost
Average Wind Speed = 7.75 m/s Nominal Levelized Cost of Energy (LCOE) (cents/kWh)	6.51	7.05	7.6	8.14	8.68
Real LCOE (start year cents/kWh)	5.98	6.48	6.98	7.48	7.98
Payback Period (years)	14	14	14	14	14
Annual Energy Production (MWh/year)	29,602	29,602	29,602	29,602	29,602
Average Wind Speed = 7.50 m/s Nominal Levelized Cost of Energy (LCOE) (cents/kWh)	6.74	7.32	7.89	8.46	9.04
Real LCOE (start year cents/kWh)	6.2	6.73	7.25	7.78	8.31
Payback Period (years)	14	14	14	14	14
Annual Energy Production (MWh/year)	28,088	28,088	28,088	28,088	28,088
Average Wind Speed = 7.25 m/s Nominal Levelized Cost of Energy (LCOE) (cents/kWh)	7.02	7.63	8.24	8.84	9.45
Real LCOE (start year cents/kWh)	6.45	7.01	7.57	8.13	8.69
Payback Period (years)	14	14	14	14	14
Annual Energy Production (MWh/year)	26,490	26,490	26,490	26,490	26,490
Average Wind Speed = 7.00 m/s Nominal Levelized Cost of Energy (LCOE) (cents/kWh)	7.33	7.98	8.63	9.27	9.92
Real LCOE (start year cents/kWh)	6.74	7.33	7.93	8.52	9.12
Payback Period (years)	14	14	14	14	14
Annual Energy Production (MWh/year)	24,892	24,892	24,892	24,892	24,892
Average Wind Speed = 6.75 m/s Nominal Levelized Cost of Energy (LCOE) (cents/kWh)	7.71	8.4	9.09	9.79	10.48
Real LCOE (start year cents/kWh)	7.08	7.72	8.36	9	9.64
Payback Period (years)	14	14	14	14	14
Annual Energy Production (MWh/year)	23,210	23,210	23,210	23,210	23,210

Table 9-4. Analysis Results–Third-Party Lease

Lease	-20% Capital Cost	-10% Capital Cost	Base Capital Cost	+10% Capital Cost	+20% Capital Cost
Average Wind Speed = 7.75 m/s Nominal Levelized Cost of Energy (LCOE) (cents/kWh)	7.04	7.98	8.92	9.86	10.8
Real LCOE (start year cents/kWh)	6.47	7.33	8.2	9.06	9.93
Payback Period (years)	5	5	6	6	6
Annual Energy Production (MWh/year)	29,602	29,602	29,602	29,602	29,602
Average Wind Speed = 7.50 m/s Nominal Levelized Cost of Energy (LCOE) (cents/kWh)	7.45	8.44	9.43	10.42	11.41
Real LCOE (start year cents/kWh)	6.85	7.76	8.67	9.58	10.49
Payback Period (years)	5	6	6	6	6
Annual Energy Production (MWh/year)	28,088	28,088	28,088	28,088	28,088
Average Wind Speed = 7.25 m/s Nominal Levelized Cost of Energy (LCOE) (cents/kWh)	7.94	8.94	10.04	11.09	12.14
Real LCOE (start year cents/kWh)	7.3	8.22	9.23	10.2	11.16
Payback Period (years)	5	6	6	6	6
Annual Energy Production (MWh/year)	26,490	26,490	26,490	26,490	26,490
Average Wind Speed = 7.00 m/s Nominal Levelized Cost of Energy (LCOE) (cents/kWh)	8.48	9.6	10.72	11.84	12.96
Real LCOE (start year cents/kWh)	7.8	8.83	9.86	10.89	11.92
Payback Period (years)	6	6	6	6	6
Annual Energy Production (MWh/year)	24,892	24,892	24,892	24,892	24,892
Average Wind Speed = 6.75 m/s Nominal Levelized Cost of Energy (LCOE) (cents/kWh)	9.15	10.3	11.55	12.75	13.95
Real LCOE (start year cents/kWh)	8.41	9.47	10.61	11.72	12.82
Payback Period (years)	6	6	6	6	6
Annual Energy Production (MWh/year)	23,210	23,210	23,210	23,210	23,210

Wind PPA prices have come down sharply from their 2008-2009 peak. Published data indicates that PPA prices for non-California, non-“Wind Belt” projects executed in 2011 were generally in the range of $0.04-$0.06 per kWh.[35] The estimated LCOEs for this site are higher than current PPA prices, indicating that this site is probably uncompetitive for a wind energy project at this time but may become more competitive in the future.

[35] Wiser, R.; Bolinger, M. *2011 Wind Technologies Market Report*. Berkeley, CA: Lawrence Berkeley National Laboratory, 2012.

9.7 Overall Conclusions and Recommendations

Wind development is problematic on the Reclamation-owned land in this area. All the potential sites have one or more issues. Parts of the Morgan Creek area appear to have a good wind resource but these locations are not very accessible. Some of the Reclamation land around Seminoe Reservoir is more accessible but it is separated from the substation at Seminoe Dam by rugged terrain. This location also suffers from the awkward shape of the Reclamation-owned land parcels, which makes compact siting of multiple turbines difficult. A small project may be feasible at the north end of Seminoe Reservoir, but overall, none of the sites investigated appear compelling. Even if at some future time the economics of a project at the northern end of Seminoe Reservoir become more competitive on an absolute basis, it is must be remembered that there are nearby non-Reclamation-owned parcels that are more favorable for wind energy development. A final possibility is development on BLM land. Due to the extensive BLM land holdings in the area, this would open up many new options.

10 Montana Reclamation Lands Wind Screening Assessment

10.1 Introduction

The Bureau of Reclamation is responsible for a number of reservoirs, canals, and sections of water drainages in Montana. As part of Reclamation's goals to meet agency renewable energy targets and/or make its stewardship of the land more productive, the following desktop study was completed to screen Reclamation-owned land in Montana for the possibility of installation of wind energy generation projects. The study identifies possible project locations. For each location, the study provides an estimated maximum project capacity (MW), wind class, transmission substation proximity, and other relevant site characteristics.

10.2 Methodology

The following is a description of the methodology used to determine the values entered into the site matrix and site summary.

NREL developed GIS maps for each of the Reclamation-owned sites in Montana that showed potential for wind development. These maps included the boundaries of Reclamation-owned land, transmission line location and voltage range, transmission substation location, major roads, wind class at 50 meters AGL, areas excluded from wind development, and sage grouse areas. These maps were used in conjunction with Google Earth to determine a high-level estimation of the appropriateness of Reclamation lands for wind development. The screening criteria used to determine if a site should be listed were:

- No obvious environmental show stoppers (a couple of areas have sage grouse habitat that may preclude development; these have been identified in the table)
- Terrain is not too rugged (determined subjectively)
- Site is not in the middle of a reservoir or active (wet) drainage area
- There appeared to be some road access near the site
- A minimum of three utility-scale wind turbines could be placed at the site.

If a site met these criteria, it was listed even if other considerations were less favorable.

Once a site was identified, an estimation of the number of turbines that could be placed was developed using the assumption that the prevailing winds come from the south/southwest. Based on a GE 1.6 MW turbine with an 80 m rotor, turbines were placed based on 0.15 miles separation between turbines in a row and 0.3 miles separation between rows of turbines.

For sites meeting the screening criteria, other metrics were determined as follows. The distance to a substation was taken from the edge of the site nearest the nearest substation to the substation (note: transmission lines to these substations may or may not have available capacity to accept wind energy from the site). Wind class at the site was taken from the NREL wind map. Road access was determined from Google Earth along with apparent topographical land characteristics. Sage grouse areas were based on NREL-produced GIS maps.

10.3 Sites Summary

The sites are summarized in Tables 10-1 through 10-3. Figures 10-1 through 10-6 show maps of the sites.

Neither Big Horn County nor Flathead County Reclamation lands meet the screening criteria (due to lack of suitable space) and, therefore, determined to have no opportunity for utility-scale wind generation.

Glacier County (Figure 10-1) has a site that is in a valley and meets the screening criteria. It also appears to have a substation on site with Highway 89 running through the middle of the site. Wind is estimated to be class 3, and there is room for an estimated 92 MW to 96 MW of wind turbines.

Chouteau County (Figure 10-2) has what appears to be a large, flat site in farming country. There are local roads all around the site. The site is approximately 2.8 miles from the nearest substation. An estimated project size on the flat land portion of the site is 339 MW. Wind resource is estimated as class 3.

Phillips County (Figure 10-3) has three geographically dispersed sites that meet the screening criteria and all have estimated class 3 wind resource. Site PH1 is adjacent to Lake Nelson and appears to have a substation and a highway on the site. Estimated generation capacity of the site is 67 MW. It has been identified as a sage grouse "75% Lek breeding area," which may preclude development. Site PH2 is about 17 miles south of Lake Nelson in a north-south oriented valley. It is approximately 14 miles to the nearest substation and looks to be accessed only by secondary roads. Estimated generation capacity of the site is 100 MW. It has been identified as a sage grouse "75% Lek breeding area." Site PH3 is a smaller site about 8 miles west of Malta and adjacent to a river system. Local roads access the site and a substation is 2.3 miles away. Estimated generation capacity of the site is 19 MW.

Hill County (Figure 10-4) has two sites that have challenges but may merit further analysis. They both have estimated class 3 wind resource and neither is identified as a sage grouse area. Site HC1 is composed of areas that are close to each other but not contiguous. They appear to be relatively flat drainage land in an agricultural area with local roads around the site. The nearest substation is 4 miles away and the estimated project size is 77 MW. Site HC2 is near the middle of Fresno Reservoir and appears to be a mesa overlooking the reservoir to the southwest. The site could accommodate about 28 MW of turbines and is approximately 9.4 miles from a substation. A challenge with this site is that it might require about 1.8 miles of road to access the site.

Teton County (Figure 10-5) has seven sites that meet the screening criteria. The sites have a class 3 to class 4 wind resource. Site T1 is just west of Power, Montana, and included three adjacent but not contiguous areas. There appears to be some flat mesa tops around some rugged drainages that might be suitable for wind. There are local roads around the site, it is 1.5 miles to the nearest substation, and has an estimated capacity of 64 MW. Site T2 is a small area west of Vaughn but appears to have a substation on or near the site and highway adjacent the site. The site appears to be on the edge of a mesa with about a 6 MW capacity. Site T3 is just south of Fairfield and includes two noncontiguous areas that are on the edge of a mesa top. There are local roads near the site, and the nearest substation appears to be 0.5 miles away. Estimated capacity for the two areas is 9 MW. Site T4 is 3.5 miles west of Fairfield and includes land that appears to be a ridge adjacent to rugged drainages. There are local roads around the site, and a substation is on or near the site. Site T5 is two noncontiguous areas 9 miles west of Fairfield that sit on an east-west ridge. There are local roads around the site, the nearest substation is 2.4 miles away, and the estimated wind generation capacity is 72 MW. Site T6 is two areas 4 miles northeast of Willow Creek Reservoir. There appears to be flat land with roads to the site and a substation on or adjacent to the site. Estimated wind generation capacity is 19 MW. Site T7 is a raised area on the northeast shore of Willow Creek Reservoir. There is a local road around the reservoir, and the nearest substation is 4 miles away. Estimated wind generation capacity is 16 MW.

Toole and Liberty Counties (Figure 10-6) have three sites that meet the screening criteria. These sites have fairly flat areas that overlook the river that drains Lake Elwell. The wind resource is primarily class 3 with a couple areas of class 4. Site TL1 is 10 miles southeast of Lake Elwell Dam with some secondary drainages that run through the site. There is a highway that runs through the site, and it is 2.6 miles to the nearest substation. Estimated site capacity is 27 MW. Site TL2 is 13.5 miles from the dam and about 30% of the site has estimated class 4 wind. Local roads access the site, and it is 5.3 miles to a substation. Estimated site capacity is 14 MW, which is lower than expected based on land area, but the orientation of the site and assumed prevailing wind direction reduced the capacity estimate. Site TL3 is 15 miles southeast of the dam and includes two nearly contiguous areas. It accessed by local roads and is 6.5 miles to a substation. Estimated site capacity is 27 MW.

10.4 General Notes, Conclusions, and Next Steps

This study identified Reclamation-owned parcels in Montana that are potential candidates for wind energy development. At first pass, the sites appear to have the necessary elements for wind energy development—adequate wind resource, transmission access, and road access. The sites appear to be free of major fatal flaws, with the possible exception of sage grouse at a couple of the locations. On an absolute basis the sites have development potential. However, with only a few exceptions, most of the Reclamation-owned parcels in Montana are too small to host large wind farms. Chouteau has space for about 340 MW while Glacier and Phillips could each host roughly 100 MW each. In most cases, Reclamation-owned parcels would need to be combined with non-Reclamation-owned land for there to be enough space for a large wind farm. Many of the Reclamation-owned sites in Montana are close to windier sites. The majority of Reclamation-owned parcels have a class 3 wind resource. Review of the maps in the section show that most of the Reclamation-owned parcels are near areas with a class 4 or greater wind resource. A few years ago this would have been a significant disadvantage. This is less true now. High wind speed turbines are less efficient and see higher loading. Many developers are starting to prefer somewhat less windy sites that allow for deployment of more efficient, lower wind speed turbines At first pass, some of the Reclamation-owned parcels appear to have development potential, but there does not appear to be a compelling reason to prefer the Reclamation-owned parcels over the nearby sites with a similar or greater wind resource.

Should Reclamation decide to continue with this analysis, the recommended next step would be to conduct a more in-depth evaluation of the top two or three clusters: Chouteau, Glacier, or Phillips.

Table 10-1. High-Level Wind Energy Potential Assessment for BOR Land in Montana (Part 1)[a]

Property	Est. Capacity (MW)	Distance to Substation (miles)	Wind Class	Road Access	Land Characteristics	Sage Grouse	Other Comments
Big Horn	0	3.2 miles to nearest nonexcluded site (not BOR land)	N/A	N/A	Rugged terrain around lake with some flat land to east of dam	None	All areas around substations are excluded
Flathead	0	N/A	N/A	N/A	Fairly rough terrain	None	Whole area is excluded
Glacier	92-96	0	3	Hwy 89 runs through area	Appears relatively flat down in a valley	None	
Chouteau	339	2.8	3	Roads all around site	Flat plain	None	
Phillips (adjacent to Lake Nelson)	67	0	3	Road through middle of site	Primarily flat with hills in west	75% Lek breeding area	Fragmented land areas
Philips (about 17 mi south of Lake Nelson)	100	14	3	From Earth looks like some secondary road access nearby	Valley between hills to the east and west	75% Lek breeding area	
Philips (about 8 mi west of Malta)	19	2.3	3	Road appear to be around the site	Adjacent river system; flat with hills to the south	None	Substation is on or adjacent to west end of site but river bed makes development up to substation questionable
Hill County (Fresno Reservoir-South end; two sites)	57 + 20	4	3	Roads around site	Flat land with agriculture surrounding site	None	Looks like a drainage and maybe a wetland some parts of the year (two sites)
Hill County (Fresno Reservoir-Middle)	28	9.4	3	Would require about 1.8 miles of new road	Flat mesa top	None	Nice, well-oriented site, but road and transmission access appear challenging

[a] Capacity is based on measurements of available land with turbine spacing of 3 diameters and row spacing of 6 diameters using a GE 1.6-80.

Table 10-2. High-Level Wind Energy Potential Assessment for BOR Land in Montana (Part 2)

Property	Est. Capacity (MW)	Distance to Substation (miles)	Wind Class	Road Access	Land Characteristics	Sage Grouse	Other Comments
Teton (just west of Power)	64	1.5	3	Roads around site(s)	Drainages	None	Appears to be some rugged drainage terrain with some flat mesa-type land
Teton (12.5 miles west of Vaughn)	6	On or adjacent to site	3	Hwy 89 adjacent to site	Mesa top with valley to south	None	
Teton (1.5 miles south of Fairfield)	9	0.5	3	Roads around site	Mesa top with valley to south	None	
Teton (3.5 miles west of Fairfield)	56	On or adjacent to site	3-4	Roads around site	Flat top ridge with sloping drainage to north and south	None	
Teton (9 miles west of Fairfield)	72	2.4	3-4	Roads around site	East-west low ridge	None	
Teton (4 miles NE of Willow Creek Reservoir)	19	On or adjacent to site	3	Road to site	Flat land	None	
Teton (NE shore of Willow Creek Reservoir)	16	4	3-4	Road around reservoir	Low hills	None	

Table 10-3. High-Level Wind Assessment for BOR Land in Montana (Part 3)[a]

Property	Est. Capacity (MW)	Distance to Substation (miles)	Wind Class	Road Access	Land Characteristics	Sage Grouse	Other Comments
Toole-Liberty (10 miles SE of Lake Elwell Dam)	27	2.6	3-4	Highway through site	Flat with shallow valley to south	None	
Toole-Liberty (13.5 miles SE of Lake Elwell Dam)	14	5.3	3-4	Country agricultural roads	Mesa top above river	None	Site oriented on NE to SW axis. Reduced number of turbines to 1/0.3 miles
Toole-Liberty (15 miles SE of Lake Elwell Dam)	27	6.5	3	Country agricultural roads	Mesa top above river	None	Site oriented on NE to SW axis. Reduced number of turbines to 1/0.3 miles

[a] Capacity is based on measurements of available land with turbine spacing of 3 diameters and row spacing of 6 diameters using a GE 1.6-80.

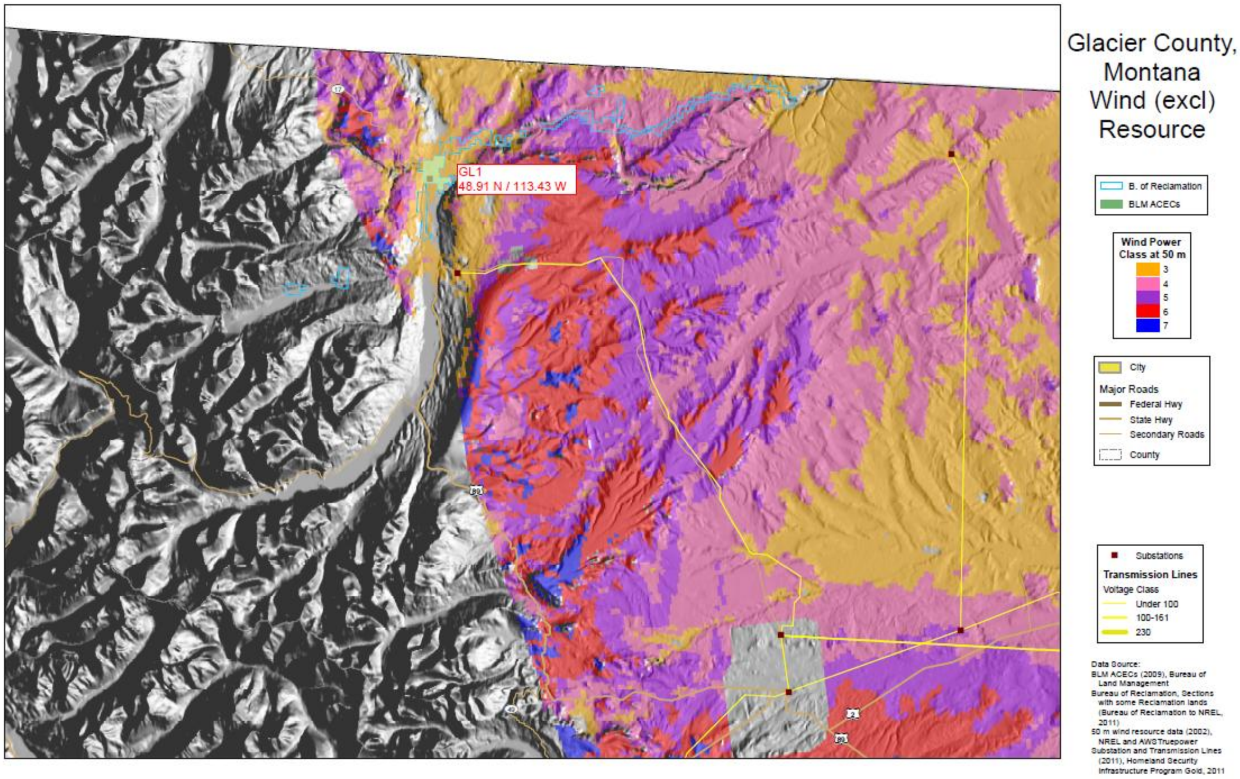

Figure 10-1. Glacier County Reclamation-owned land

Source: Bureau of Land Management (using 50 m wind data from NREL; modified by Blaise Stoltenberg)

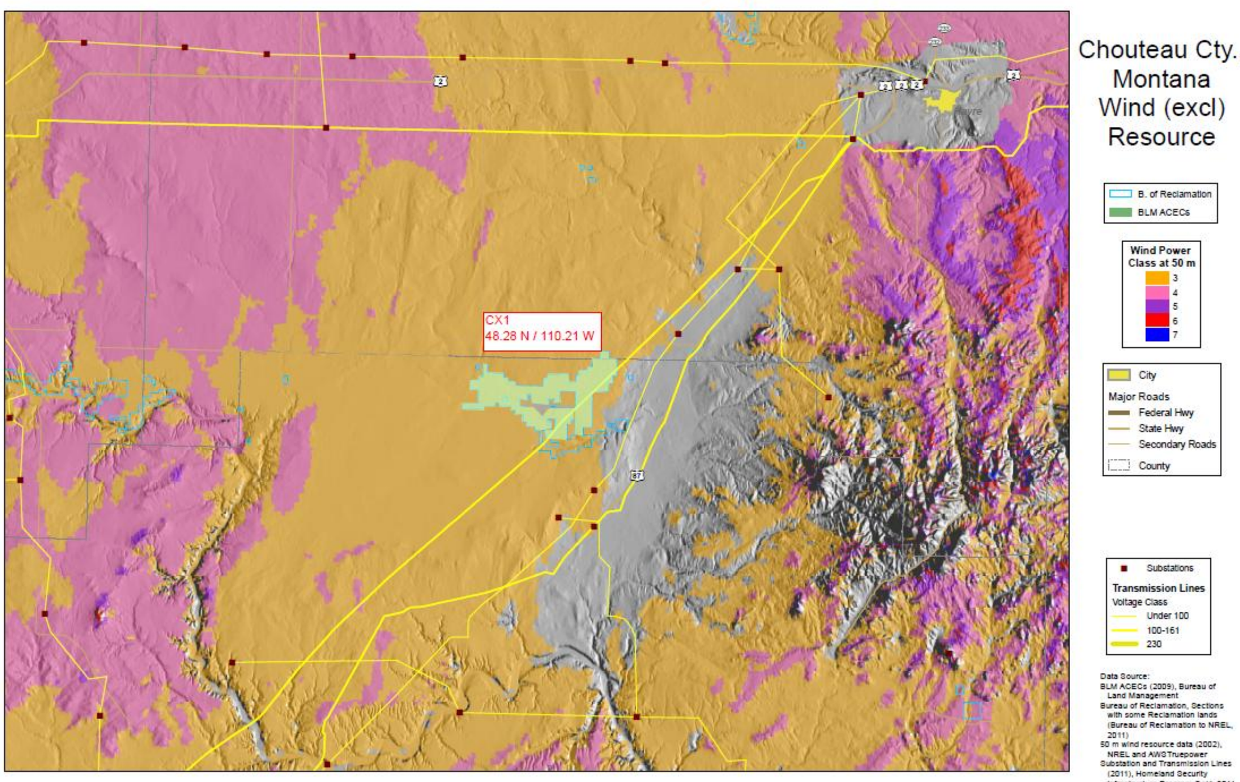

Figure 10-2. Chouteau County Reclamation-owned land

Source: Bureau of Land Management (using 50 m wind data from NREL; modified by Blaise Stoltenberg)

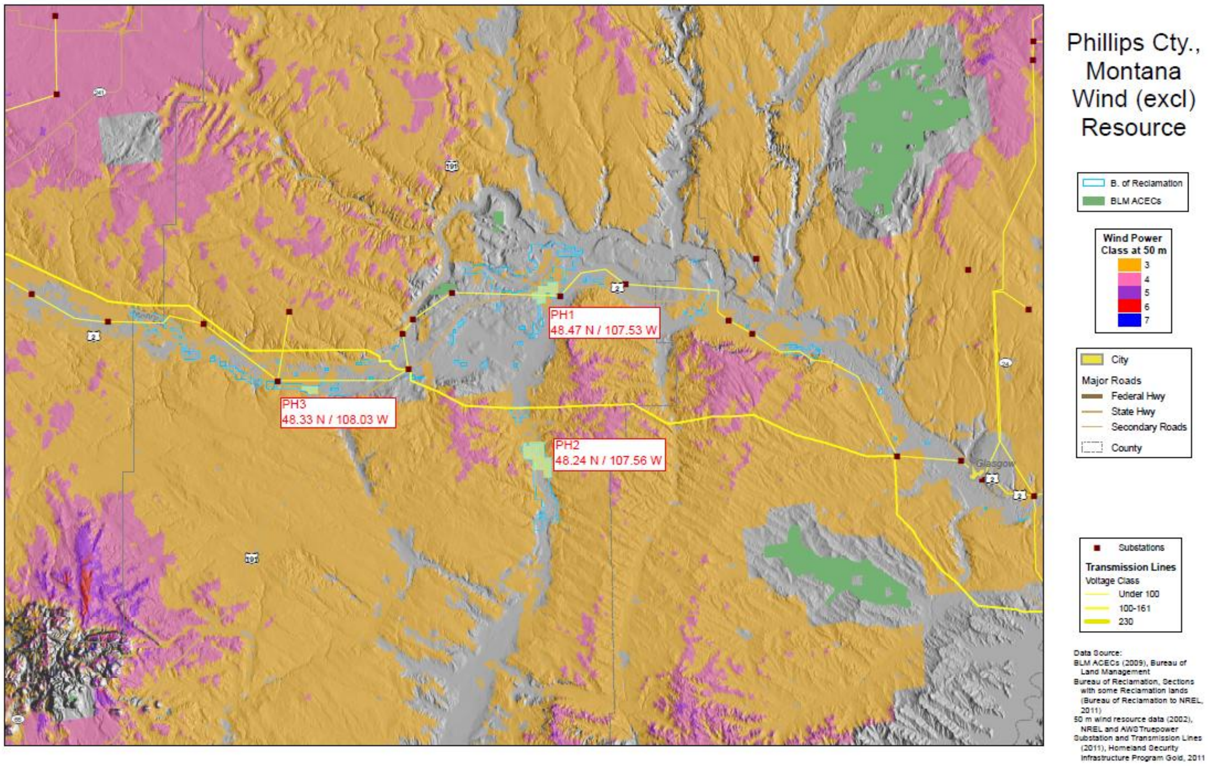

Figure 10-3. Phillips County Reclamation-owned land

Source: Bureau of Land Management (using 50 m wind data from NREL; modified by Blaise Stoltenberg)

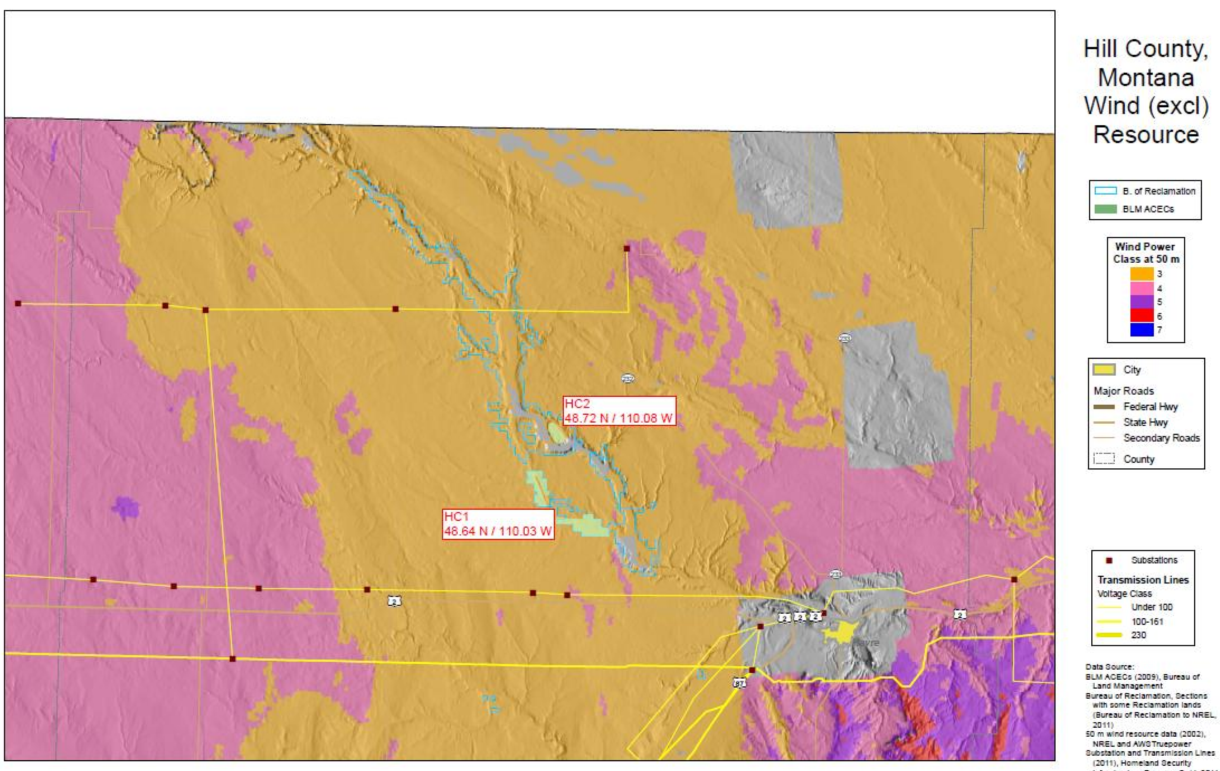

Figure 10-4. Hill County Reclamation-owned land

Source: Bureau of Land Management (using 50 m wind data from NREL; modified by Blaise Stoltenberg)

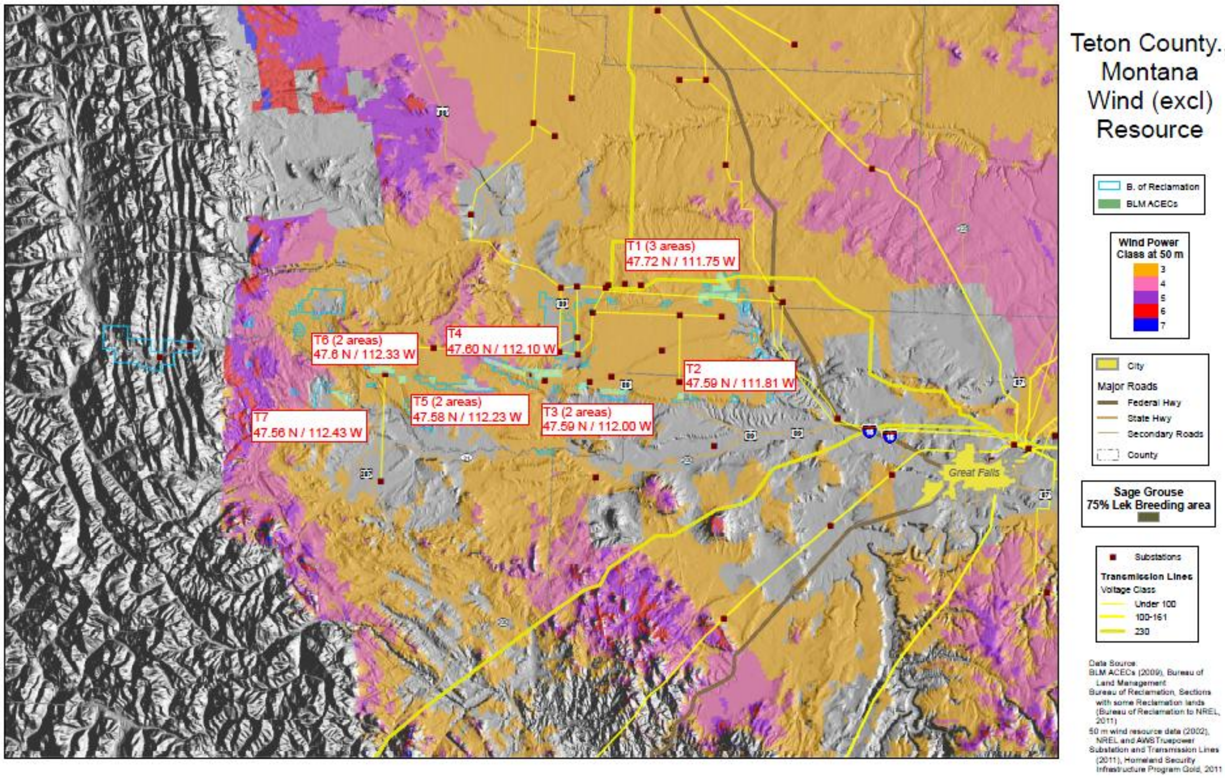

Figure 10-5. Teton County Reclamation-owned land

Source: Bureau of Land Management (using 50 m wind data from NREL; modified by Blaise Stoltenberg)

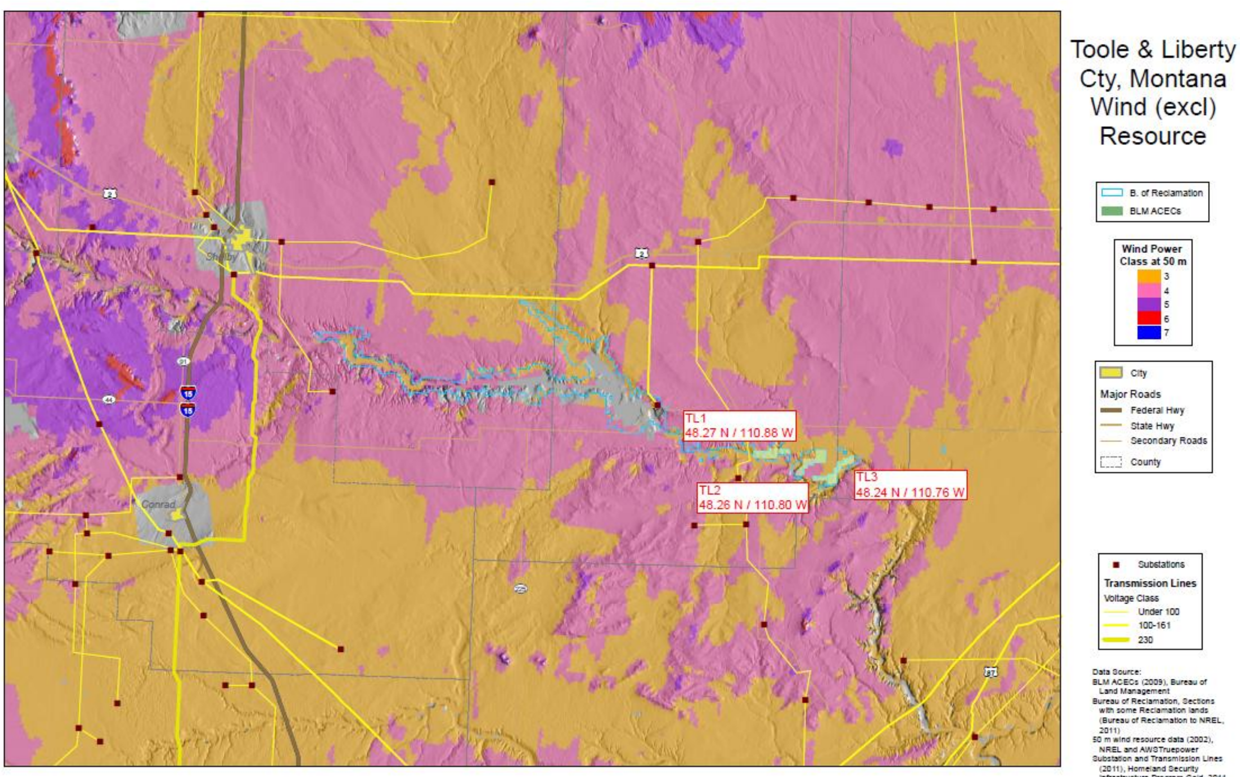

Figure 10-6. Teton and Liberty County Reclamation-Owned Land

Source: Bureau of Land Management (using 50 m wind data from NREL; modified by Blaise Stoltenberg)