United States Environmental Protection Agency

# Shining Light on a Bright Opportunity

## DEVELOPING SOLAR ENERGY ON ABANDONED MINE LANDS

U.S. Environmental Protection Agency
Office of Superfund Remediation and Technology Innovation (OSRTI)

# Shining Light on a Bright Opportunity - Developing Solar Energy on AMLs

*This report provides information about the development of solar energy at former mining sites for communities, including local governments, residents, and organizations, interested in creating renewable energy resources and new economic opportunities at these sites. The report describes the mechanics of solar energy, details the various solar technology options, explores solar energy's environmental, economic, and social impacts at mining sites, and provides case studies and next steps to help get projects in place.*

## Introduction

According to the U.S. General Accounting Office, there are between 80,000 and 250,000 abandoned mine lands (AMLs) across the United States. AMLs include abandoned mines and the areas adjacent to or affected by the mines. Because of safety or environmental concerns, the majority of these sites have never been considered for any type of reuse and have remained idle.

Solar energy projects hold the opportunity to change this situation. Solar energy is a renewable energy resource that does not generate pollution and has become an increasingly valuable way to diversify the nation's energy options. Spurred by technological advances, falling costs, and rising energy prices, solar energy projects are being developed across the country.[1]

**What is an AML**

Abandoned Mine Lands (AMLs) are those lands, waters, and surrounding watersheds where extraction, beneficiation, or processing of ores and minerals (excluding coal) has occurred. These lands also include include areas where mining or processing activity is temporarily inactive.

AML sites may be located in areas that may not be well-suited for more traditional commercial or industrial reuse opportunities. However, these sites can take advantage of local renewable resource attributes to generate electricity or produce power at these sites in a manner that increases energy efficiency, reduces the environmental impact of generation, and enhances energy diversity, while returning these lands to productive reuse. In addition, EPA has identified renewable energy development at mining sites as a priority for the Agency's reuse-related activities at contaminated sites.[2]

AMLs may serve as excellent locations for solar energy facilities, as the requirements for solar energy plants and the characteristics of AMLs are well suited to each other. First, solar energy requires one critical element: sunlight. Many mining sites are located in the western and southwestern United States, in areas that have abundant available sunlight (i.e., 300+ days a year). In addition, states like Pennsylvania are demonstrating the viability of solar energy plants on the East Coast. Second, utility-scale solar energy projects require access to large, open sites. The size of many AMLs means that large solar arrays can be accommodated at a single property.

Third, many AMLs are located near existing infrastructure, including roads and power transmission lines, due to prior mining activities. The availability of existing infrastructure can reduce project costs. Fourth, many AMLs are situated in remote areas with limited electricity infrastructure, making them well suited for the use of solar energy for on-site cleanup and reclamation activities (e.g., to power a ground water pump and treat system).

[1] At the end of 2008, over 750 megawatts (MW) of grid-connected solar energy had been installed in the United States, with another 6000 MW in the early planning or feasibility analysis stage. In addition, solar energy is being used widely off the grid for residential and commercial direct-use purposes, including at formerly contaminated properties, to power activities such as pumping stations.

[2] In September 2008, EPA, working with the Department of Energy's (DOE) National Renewable Energy Laboratory, unveiled a GIS-based catalogue of thousands of properties that could potentially host renewable energy production facilities. More information is available at http://www.epa.gov/renewableenergyland/

# What is Solar Energy

Solar energy is the light and radiant heat from the Sun that influences a range of systems and functions on Earth, from climate and weather to photosynthetic process in plants and sustaining life. Solar energy can be converted into other forms of energy, such as heat and electricity. In fact, for thousands of years, humans have harnessed solar energy for a range of uses, including lighting wood for fires and generating steam.

## *Why is it important*

While a majority of the country's current electricity supply is generated from fossil fuels such as coal, oil, and natural gas,[3] these traditional energy sources face a number of challenges including volatile prices, security concerns, and environmental impacts stemming from both the extraction and burning of fossil fuels. As these non-renewable energy sources are depleted, electricity may become more expensive.

The City of Brockton's 500-kW solar photovoltaic array was installed in 2004 at a cleaned up 27-acre brownfield site. (source: DOE)

As communities become more concerned about the environmental impacts of fossil fuels, renewable energy technologies are expected to play a greater role in meeting future electricity demand. Generating electricity through renewable energy sources, like solar, can help to reduce dependencies on fossil fuels as well as lower the amount of pollution associated with today's predominant power generation methods. For utilities, solar energy can provide important intermediate and peak load electricity. For communities, solar energy projects can facilitate site clean up activities and large-scale solar projects can generate significant local economic impacts from construction and operation.

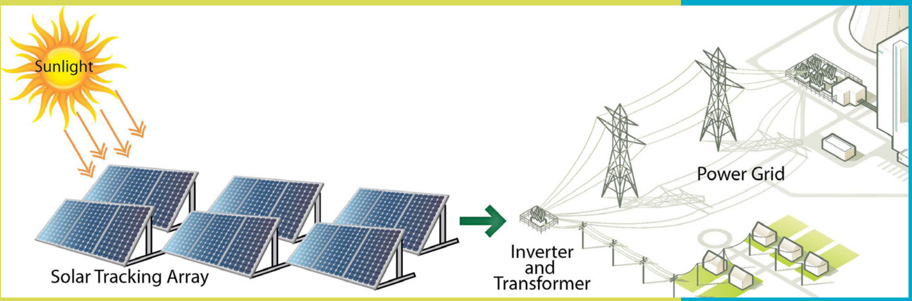
## *Solar Energy Technologies*

There are a variety of ways to capture or convert sunlight into useful energy. Solar technologies use the sun's energy to provide heat, light, hot water, electricity, and cooling, for homes, businesses, and industry. Solar technologies are broadly characterized as either "passive" or "active" depending on how they capture, convert, and distribute sunlight. Active solar activities and technologies use photovoltaic panels, pumps, and fans to convert sunlight into useful outputs, such as electricity. Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and aligning the position of a building to the sun.

[3] According to the Department of Energy, 70% of electricity in the US currently is from fossils fuels, 20% is from nuclear power, and 10% is from renewable sources - predominantly hydroelectric and wind.

The focus of this report is on active solar technologies. There are two primary active solar technologies that convert sunlight into electricity – photovoltaic devices and solar thermal plants.:

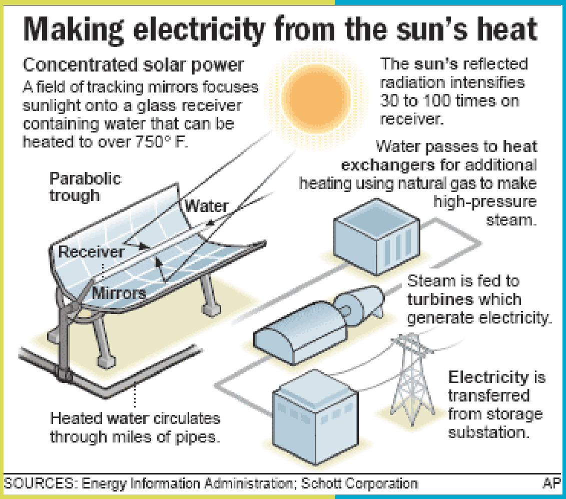
**Photovoltaic (PV) devices**, or “solar cells” make use of highly purified silicon that functions to convert sunlight directly into electricity. Solar cells are a familiar and widely used technology – calculators, toys, yard lights, roadside warning signs – all use solar cells to convert sunlight directly into electricity. In general, PV systems can be expensive to operate. Because of the high upfront cost, the cost per kWhour of PV systems can be significantly more expensive than conventional sources of electricity. However, PV systems are increasingly used in remote locations that are not connected to the electric grid because they offer more cost effective electricity.




**Solar Thermal Power Plants** indirectly generate electricity. Solar thermal collectors are used to heat a fluid (either water or a heat transfer fluid such as oil or brine) that produces steam that is used to power an engine or turbine. Solar thermal technologies (also called concentrating solar power, or CSP) produce electric power by converting the Sun’s energy into high-temperature heat using mirror configurations. A solar thermal plant, illustrated to the right, essentially consists of two parts: one part that collects solar energy and converts it to heat and the other that converts the heat energy to electricity.

Currently, concentrating solar power is the most efficient and cost-effective way to generate electricity from the sun. There are three principal concentrating solar technologies - parabolic trough, dish-Stirling engine, and power tower. A critical feature for most solar thermal technologies is their capacity for bulk power generation (i.e., electricity for the grid) while also being viable as smaller-scale energy plants. Additional information about these solar thermal technologies can be found in Appendix A.

**Parabolic troughs** are a proven technology in the U.S. Nine solar electric generating systems (SEGS), totaling 354 MW of generating capacity, were built during the 1980s in Southern California and a 64 MW parabolic trough plant came online in 2007 in Nevada with additional plants expected in the next few years. Highlights of this new Nevada CSP facility, which was built on a greenfield site, have been included in this report because the facility demonstrates the technical and financial implications of advanced solar thermal technology projects.



## Case: Utility-Scale Concentrating Solar Power Project

***Nevada Solar One***

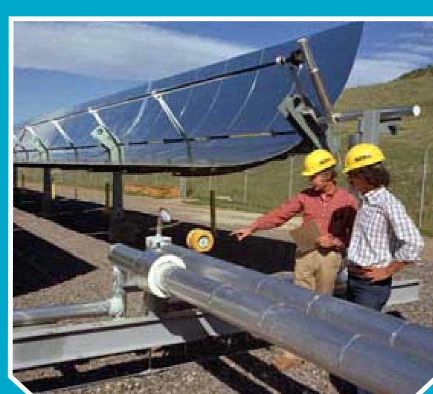
**Background:** Located in the shadow of Hoover Dam, Nevada Solar One (NSO) has been operating since June 2007. At the time of its construction, it was the largest concentrating solar power plant to be built in the U.S. in the last 17 years.

**Plant Details:** The NSO plant covers about 400 acres of the desert near Boulder City, Nevada, just south of Las Vegas. The plant uses a parabolic trough design that employs 182,000 trough-shaped mirrors that concentrate the desert sunlight and convert it into 750-degree F thermal energy, which is then used to create steam for electrical power generation. The footprint of the NSO plant is approximately 6.5 acres per MW of power. Running the plant does have high water demand, using 130 million gallons of water every year for cooling and other power production purposes.

**Technological Advances:** As opposed to the nine SEGS plants in California, which require a 25 percent natural gas-fired backup to keep the heat transfer fluid temperature from fluctuating during periods of low solar energy availability, Solar One has been designed to be more efficient in holding its temperature and requires a two percent natural gas backup.

**Financial Impacts:** Detailed project cost information is not publicly available, but construction costs for the plant have been estimated at over $260 million. The plant's construction created 800 construction jobs and 28 permanent positions. A 40-year lease for the land has been established with Boulder City at an annual cost of $550,000 with an option to lease another 650 acres in the future. In addition, the site is located adjacent to the existing El Dorado Energy natural gas power plant, which means that transmission lines were already in place and the plant has access to a large power distribution network.

The plant has an annual production output of >130,000 MWh of electricity and is estimated to produce electricity at $0.12-$0.16/kWh. Nevada Power Company and Sierra Pacific Power Company purchase all of the power generated by the plant under a 20-year power purchase agreement (PPA). The PPA is designed to ensure fixed costs for the electricity. Under this PPA, electricity from NSO will be purchased over 20 years. This electricity purchase will also help these utilities meet their obligations under Nevada's renewable portfolio standard and provide electricity price stability over the 20-year time horizon.



(source: Nevada Solar)

# Opportunities for Solar Energy Development on AMLs

There are a small but growing number of solar energy projects in operation at formerly contaminated sites, including mining sites, both in the United States and internationally. These projects include both utility-scale projects to generate electricity for the grid and smaller scale direct-use applications of solar energy technologies to provide power for remediation and reclamation activities at contaminated sites.

## *Large-Scale/ Grid-Connected Solar Energy Projects*

*(http://www.epa.gov/renewableenergyland/successstories.htm)*

Local communities, government agencies, and private developers have been building a range of utility-scale solar energy projects to meet state renewable portfolio standards, to help meet peak power demand, and to help state and local governments diversify their electricity-generating options. Specific examples of utility-scale solar energy projects at formerly contaminated properties include:

Tilted toward the south, each set of solar panels at the Nellis Air Force Base solar power plant rotates on a swivel to track the sun from east to west. (Source: US Air Force)

**Fort Carson:** A former landfill site at Fort Carson in Colorado got a new life in 2007 as a 2-MW solar energy plant covering nearly 15-acres. The plant generates approximately 3,200 megawatt-hours (MWh) of power annually, about 2.3 percent of Fort Carson's annual energy consumption. The energy produced by the photovoltaic array ties into a utility substation across the street from the site. Renewable energy credits[4] from the site are sold by the project developer to Xcel Energy and used by Xcel to meet the solar requirement of Colorado's renewable energy standard.

**Aerojet:** A public-private partnership between Aerojet, Solar Power, Inc. and the Sacramento Municipal Utility District has led to the development of a 6 MW solar farm on the Aerojet Superfund site near Sacramento. In 2008, Aerojet began planning to convert a portion of its facility into a solar farm to help power the site's ground water remediation program. The first solar arrays were installed in 2009; the final arrays were installed in April 2010. The electricity produced provides more than 20 percent of the energy needed to power the site's ground water remediation program. The Aerojet General Corporation Superfund site covers 5,900 acres near Rancho Cordova. Since 1953, Aerojet and its subsidiaries have manufactured rocket engines and formulated chemicals. Disposal and operation practices led to soil and ground water contamination. EPA listed the site on NPL in 1983.

**Nellis Air Force Base:** Under a public-private joint-venture between the U.S. Air Force, PowerLight, Nevada Power Company, and MWA Renewable Ventures, a 14-MW solar power plant operates 140 acres on the 14,000-acre Nellis Air Force Base in Southern Nevada. The 140 acres includes a 33-acre landfill that was capped in 1996. The PV array, built on land donated by the Air Force to MWA, is owned by MWA and was built and is operated by PowerLight. Nevada Power, which provides electricity to the base, must meet state renewable energy generation requirements through generation or buying renewable energy credits. MWA sells its power to the Air Force at a discount and sells its credits to Nevada Power. The solar plant, which includes more than 72,000 solar panels, generates 25,000 MWh of electricity per year. That's roughly 25 percent of electricity use at the base. By not burning fossil fuels to create this electricity, the base reduces CO2 emissions from electricity consumption by an estimated 24,000 tons per year.

[4] Renewable Energy Credits (REC) are tradable environmental commodities which represent proof that 1 megawatt-hour (MWh) of electricity was generated from an eligible renewable energy resource. More information on RECs can be found on page 15.

## Case: Leipziger Land Solar Power Plant Built at Former German Lignite Mine

**Background:** Situated on 49-acres of land that was a former lignite-mine ash deposit in Espenhain, Germany, the 5-MW photovoltaic power plant is made up of 33,500 solar modules that generate electricity that is fed directly into the German electricity grid. The project, which has operated since 2004, was initiated and developed by the energy company GEOSOL for $26.5 million.

**Innovative Solar Installation:** The solar modules were installed at the site using an innovative wood framing method that relied on a local material - the robinia tree . The tree's wood is almost indestructible and resistant to all kinds of weathering and was used to build the frames upon which the solar modules were mounted.

**Mining Land Reuse:** The Espenhain site, located near Leipzig, was a former settling area for lignite ash and dust - a type of brown coal. Based on this prior use and the amount of contamination at the settling area, the site did not offer many traditional reuse or redevelopment options. However, a solar energy plant was an option, but only after on-site contamination was addressed. At the Espenhain site, the lignite had to first be buried under a foot of soil before the specially designed wood frames that support the solar panels could be built.

**Photovoltaic arrays at Leipziger Land Solar Power Plant (source: GEOSOL)**

**Borna Solar Plant:** In 2005, GEOSOL installed an additional PV array near Espenhain at the Borna Solar Plant. The array has a maximum output of 3.4 MW, and utilizes a solar tracking system to track the sun. This plant has been built on the site of a former factory producing lignite briquettes. The Borna plant was installed for $28 million, and has an annual electricity output of 3.5 million kWh.

Former Borna briquette plant (source: GEOSOL)

Today, 3.4 MW PV array (source: GEOSOL)

## *Large-Scale/ Grid-Connected Solar Energy Projects continued*

A growing number of solar energy projects on contaminated properties, including mining sites, are in the early stages of planning or analysis.

**Questa Mine:** Chevron Mining Inc. (CMI, formerly Molycorp) is planning to build a one MW concentrating photovoltaic solar facility on the tailing site of CMI's molybdenum mine in Questa, New Mexico. Concentrating photovoltaic technology uses lenses to collect and focus direct sunlight onto layers of high efficiency cells. The facility will include approximately 175 solar panels placed on 20 acres of the Questa Mine's tailings site. The project will be implemented in conjunction with an evaluation of various soil cover depths for closure of the tailing facility at the end of mining operations. The electricity produced will be sold to Kit Carson Electric Cooperative through a power purchase agreement

**San Manuel Copper Mine:** Preliminary negotiations are underway to assess the feasibility of constructing a solar energy power plant on the tailings at the San Manuel copper mine in Pinal County, Arizona. Owned by BHP Billiton, the closed mine is currently undergoing one of the most comprehensive reclamation projects in U.S. history. The site's seven tailings impoundments cover 3,000 acres and are over 6 miles in length, 200 feet high in places, and situated up-gradient of the San Pedro River. The site has connectivity to the electricity grid, sits in proximity to a growing part of the state, and has tailing piles in need of new economic uses, making it a strong candidate for a large-scale solar energy project.

## *Small-Scale, Direct-Use Solar Energy Projects*

*(http://www.epa.gov/renewableenergyland/successstories.htm)*

As part of EPA's green remediation agenda and activities,[5] the use of solar energy for site cleanup and remediation is increasingly being implemented at contaminated sites - including brownfield, NPL, and mining sites – as a means to help increase the environmental, economic, and social benefits of contaminated site cleanup. Site-specific applications of solar energy to power site cleanup include:

**BP Paulsboro:** Located at a former refined petroleum and specialty chemical facility in Paulsboro, NJ, a 275 kW PV array provides electricity to power an extensive groundwater pumping system and a soil vapor extraction system. The PV array generates 350,000 kWh of electricity each year, meeting 25-30 percent of the system's energy requirements.

**New Rifle Uranium Mill Tailings:** Developed on top of a 130-acre former uranium mill tailings dump site, the 2.3MW PV array is part of the City of Rifle's (CO) planned Energy Innovation Center. The combined system provides 0.6 MW of power to a Colorado River water pumping station and 1.7 MW to the Rifle Regional Wastewater Reclamation Facility. Under an agreement with the City, SunEdison will finance, install, and maintain the PV systems, with an agreement that the city will purchase the electricity over a 20-year contract period, at which time the City has the right to take over the array.

**Apache Powder Company:** At the Apache Powder Superfund site in Arizona, an off-grid PV array provides energy to a centrifugal pump that circulates water through constructed wetlands at the site. The pumping system operated to re-circulate the contaminated water through the wetlands cells until the treated water reached the discharge cleanup standards. Because this cleanup application did not require continuous electricity to operate, connection to the utility grid was not needed.

[5] EPA defines green remediation as the practice of considering all environmental effects of remedy implementation and incorporating options to maximize net environmental benefit of cleanup. EPA is working with private and public partners to foster the use of best management practices for green remediation at contaminated sites across the United States.

**Altus Air Force Base**: To biodegrade a volatile organics hotspot located 10-18 feet below ground surface in a remote site location, Altus Air Force Base in Oklahoma relied exclusively on power from a 200-Watt PV array that recirculates ground water. The benefits provided by this system at this site include: incurred capital costs of only $2,300 for the pump/solar system, a low-maintenance alternative for the cleanup; an opportunity of re-using solar equipment (with a 20- to 30-year lifespan) at other locations or sites; significant cost reduction by not connecting to the electricity grid.

## Case: EPA's Cleanup - Clean Air Initiative at the Pemaco Superfund Site

**Background:** The Pemaco Superfund site in Maywood, CA, is a former chemical mixing facility located in a light industrial and residential area. Contamination was found in soils, shallow groundwater, and deep groundwater. EPA is using soil vapor extraction and a groundwater pump and treat to clean up the site's contamination.

**Solar Energy System:** The Pemaco site demonstrates the flexibility and capability of solar technology in helping to meet energy demands of treatment operations at contaminated sites. Four PV panels with 3-kW of total generating capacity were installed on an on-site building which houses a treatment system to clean up contamination in the soil and groundwater at the site.

**Impacts/Benefits:** The PV system contributes a total of 375 kWh of electricity to building operations each month, avoiding more than 4,300 pounds of CO2 emissions each year. Each year, the solar panel system is also expected to prevent emissions of four pounds of nitrogen oxide and three pounds of sulfur dioxide, both of which contribute to acid rain and smog. After the first nine months of operation, solar energy had generated enough power to cover one month of the building's total electricity expenses for system controls and routine operations.

**Financial Impacts:** The net cost of the system was $30,000, $21,000 after a rebate from California's Emerging Renewables Program. After one year of operation, the system had generated 6,172 kilowatt-hours of electricity for the year, resulting in electricity cost savings of $2,839

For more information visit: http://www.epa.gov/renewableenergyland/successstories.htm#pemaco

# Potential Impacts Of Solar Energy Development

All of these solar energy examples illustrate how the reuse of contaminated sites for renewable energy development can occur to meet a range of challenges and interests and provide opportunities for communities to return formerly contaminated sites to productive reuse. Highlighted, below, there are a range of beneficial environmental and economic impacts created by the reuse of contaminated properties for solar energy projects.

## *Ecological Impacts*

Potential ecological impacts and the benefits of solar energy production on AMLs include reduced emissions, reduced fossil fuel consumption, greenhouse gas emission benefits, site cleanup, and improved water quality.

**Facilitating site cleanup:** Plans to put a solar project on an AML may increase the priority to clean up the site. Overall, the cleanup of abandoned sites may remove or repair buildings and prevents them from becoming "attractive nuisances," making sites ready for reuse. As tailing piles are removed from a site to accommodate reuse, source contamination would be removed. Once a site is remediated, local ecosystem can be restored as well.

**Reduced Emissions:** Coal, natural gas and oil extraction and production release significant amounts of greenhouse gases, including carbon dioxide and methane, into the atmosphere. Solar energy plants do not emit criteria pollutants or greenhouse gases, primary contributors to global warming. Consequently, solar energy projects on mining sites could be an element of potential future policies related to climate change.

**Reduced fossil fuel use:** Utilizing solar energy relieves pressure on non-renewable, limited energy resources, such as natural gas, coal and oil. In addition, the process of extracting and refining coal and oil can negatively impact local ecosystems.

**Water quality:** Discharges from abandoned mines can severely impact streams, creeks, lakes, and reservoirs. Cleanup of tailings piles to make a site ready for a solar energy plant can help prevent contamination of drinking water sources. Cleanup of sites along rivers protects aquatic ecosystems from contaminant impacts.

**Large land footprint:** Utility-scale solar power plants need approximately one square kilometer for every 20-30 MW of generated electricity. This can pose a potential challenge if there are competing uses for a reclaimed mining site.

## *Economic Impacts – Local /State Impacts:*

Local economic impacts include job creation, energy cost stability, and potential property revitalization impacts. Economic impacts for state and local governments include economic development opportunities and potential new revenues.

**Job creation**: The construction and operation of a large solar energy project can have a positive impact on a local economy. Construction can use local sources or developed materials. Larger solar energy plants can be labor-intensive during both construction and operations, drawing labor from local markets or helping to transition labor from other sectors, such as mining.

> Recent analyses by DOE for California, Nevada, and New Mexico estimate that the construction and operation of a CSP facility can generate significant job creation impacts and enhance the gross state product for these states.

**Increased revenues:** A range of players involved in developing a solar project - energy companies, local employees, new assembling and manufacturing plants, and investors - can add to a state's tax stream. For any particular solar project, new revenue will depend on a project's geographic location, the quality of the resource, and access to markets for renewable energy credits.

**Revitalization of contaminated property:** Solar energy production on formerly contaminated lands can generate value to a community in a variety of ways. Utility-scale solar energy projects require a significant amount of land. Putting these formerly contaminated properties to use can take the strain off "greenfields" for this use and shift a negative perception associated with abandoned mining lands to one of a valuable asset to local communities.

**Local energy security:** Solar thermal energy installations can increasingly provide firm, dispatchable, peak-demand power when it is needed, providing a clean and reliable power source for local communities. Solar energy also can supplement energy needs during blackouts and disaster recovery.

**Economic development:** Fostering local solar energy production allows communities to meet their growing energy demands while facilitating local economic development opportunities. In addition to the jobs directly related to solar production, local energy investment allows local economies to benefit through that reinvestment.

## Economic Impacts – Private Sector Impacts:

Solar energy at former mine lands has a wide variety of anticipated economic impacts for a site owner, including revenues from leasing land and leveraging resources for site cleanup. Additionally, solar energy projects can provide impacts for utilities and energy service companies, including stabilizing energy transmission infrastructure and meeting renewable energy portfolio requirements.

### Potential Impacts/Benefits of Utility Scale Solar Facilities to Energy Utilities

- Solar electricity production aligns closely with periods of peak electricity demand, reducing the need to build additional fossil fuel (e.g., coal) power plants.
- Thermal storage or the hybridization of CSP systems with natural gas addresses the issue of solar intermittency and allows a plant to dispatch power when needed.
- The widespread availability of solar energy throughout the southwest provides utilities with flexibility in locating solar plants near existing or planned transmission lines.
- Once a solar plant is built, its energy costs are fixed. This stands in contrast to fossil fueled plants that have experienced large fluctuations in fuel prices during the last several years.

**Leveraged funding for site cleanup:** Where the potential benefits of reclaiming and reusing land exceed the costs of cleanup and redevelopment, state and local governments, industry, land developers, environmental groups, or private citizens may help to fund site cleanup activities (Note: additional funding may still be needed).

**Revenue from land lease agreements:** Compensation to a landowner of a site that will host a solar energy installation can be in the form of a fixed lease fee per acre, fixed fee per kWh generated, or a percentage of gross revenue attributable to the landowner's parcel.

**Stability for local and regional energy grids:** For utilities with an aging transmission and distribution infrastructure, off-grid solar projects can reduce grid infrastructure costs and offset expensive infrastructure upgrades.

**Meeting state renewable portfolio requirements:** Purchasing solar energy allows utility companies to meet state renewable energy requirements. Most western states now have renewable energy requirements in place, which require that a certain percentage of a state's energy come from renewable sources. In coming years, the federal government may develop greenhouse gas emission standards, which would be expected to place more pressure on utilities to rely on renewable energy sources.

# Potential Challenges for Solar Energy Development at Mining Sites

The cleanup and reuse of former mines for on-site renewable energy generation can be complicated by the technical challenges presented by a site, potential regulatory obstacles, the intermittent nature of solar energy, high upfront capital costs, and permitting challenges.

**Transmission access:** Access to nearby transmission lines is imperative to developing large-scale solar power projects. An interconnection study can help to assess the impact of a project and its electrical characteristics on a regional power grid; assess if modifications or upgrades are necessary; and identify the technical and financial requirements to do so.

**High up-front cost:** While costs continue to fall due to technological advances and economies of scale advances, some solar energy technologies continue to have higher upfront capital cost, higher current energy production costs (dollars per kWh produced), and higher potential costs of interconnecting to the grid. Future cost projections are contingent on future technological improvements and continued availability of public policy choices and incentives. However, it is expected that the cost of generating electricity from solar energy will continue to decline.

**Solar intermittence:** Utility-scale energy facilities need to be able to provide a dependable, consistent energy supply. To accommodate the intermittent nature of solar energy, solar facilities must be able to either store solar power or supplement their supply with another type of energy. Some solar plants utilize natural gas generators to supplement solar energy.

## Overcoming solar intermittence

- Hybrids: A solar energy project in Coalinga, California has proposed supplementing the solar plant with biomass to provide 107 MW of power. The hybrid plant, slated to open in 2011, will combine a 640-acre solar trough farm with a generator that burns orchard trimmings and agricultural waste.

- Storage: Storage allow for excess electricity to be generated after the sun goes down. various types of storage technologies are available: batteries, hydrogen, and pumped storage.

**Compatibility with remedy:** There are several important factors to consider when siting a solar facility on AMLs. At underground mine sites, openings, mine workings, and other subsurface passageways may lead to subsidence or other engineering challenges. Records kept by mining companies on subsurface activities at a site can provide valuable information. In addition, existing infrastructure – vacant buildings, underground gas pipes, overhead wiring, etc. – may need to be removed to make a site suitable for solar technology infrastructure.

**Increased Water Demand:** The availability of large amounts of water for a solar thermal facility is crucial to its success. The southwestern states, including California, Nevada, Arizona, New Mexico, Utah, and Colorado, have the most abundant solar resources in the world; they are also arid. Large-scale solar production facilities would create additional stress on a region's aquifer and ground water supplies. Dry cooling systems can reduce the water demand for CSP plants, but add to the cost of the plant and are currently less efficient at converting sunlight to energy.

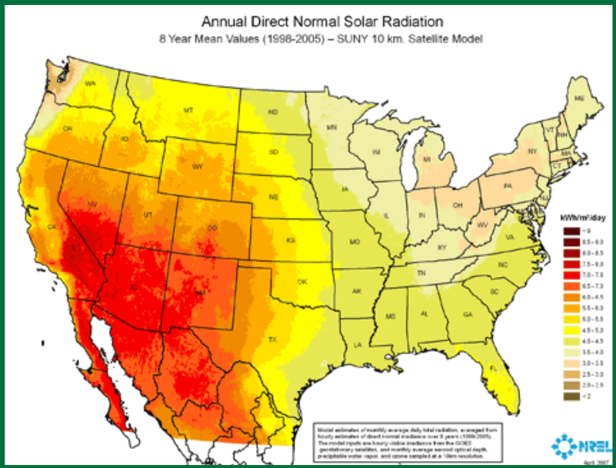
**Permitting:** Navigating the permitting process required to build a solar facility can pose one of the most challenging obstacles to utility-scale solar energy development. National, state, and regional permitting procedures are not typically coordinated and, as a consequence, permitting requirements can vary from state to state and from region to region. The number of agencies and the level of government involvement will depend on a number of factors particular to a project. These factors primarily include: applicable existing laws and regulations, location of the solar modules and associated facilities or equipment, need for transmission lines and access roads, size of the solar energy project, ownership of a project, and ownership of the land.

> For example, in California, a solar thermal power plant might require approvals from the state's Energy Commission and can be subject to reviews from EPA and the California Public Utilities Commission. Such a project would also require building permits from the California Independent System Operator, which controls power lines in the state.

Additionally, if a project is located in or requires access through federal lands, approval from that federal agency (e.g., the Bureau of Land Management) would be required.

# Getting Started – Does a Solar Energy Project Make Sense for My Mining Site?

Evaluating a site using several key steps can help interested parties determine whether a mining site is a good candidate for on-site solar energy development. While all criteria that follow may not apply to every site, the list can help quickly evaluate a mining site to determine if any initial information discovered about a site make use of solar energy on site on-site feasible or infeasible.




The arid region from southern California to west Texas has abundant energy resources. A study by DOE for the Western Governors' Association determined that the southwestern states (AZ, CA, CO, NV, NM, TX, and UT) have the solar resources and potentially suitable land to generate up to 7,000 GW of electricity. To put this number in perspective, the electric generating capacity of the entire country is presently 1,100 GW. (source: NREL)

## A. Assess a Site's Feasibility for Solar Energy

Solar energy resources are widely available throughout the United States. However, the quality of those resources is critical in determining a site's potential for utility-scale solar energy development or whether solar energy technologies can be used for on-site reclamation activities.

The Department of Energy provides resource maps to help identify the most suitable lands for renewable energy development. These maps can help with an initial assessment of a site's renewable energy potential. In addition, EPA has developed renewable energy maps that identify formerly contaminated lands and mining sites that present opportunities for renewable energy development. More information on these resources can be found in Appendix B.

## B. Determine the Solar Energy Technology to Use at a Site

According to DOE, to make the economics of a solar thermal facility feasible, the site must at a minimum:

- be at least 40 acres in size
- be less than three percent slope in terms of topography
- be located within 25 miles of existing transmission lines and roads
- have an average daily solar resource of at least 6.75 kWh/m2

Different active solar energy technologies (PV or solar thermal) have specific criteria (water use, minimum land area, amount of solar radiation needed) that must be met to determine its suitability to a mining site or other impaired property.

**Solar thermal** – Utility-scale concentrating solar power is used for grid-connected applications, so it will be best suited for mining sites that either have on-site transmission access or are located within a reasonable distance from existing transmission infrastructure. Because solar thermal facilities must be relatively large to be financially competitive, larger sites will be better suited for this technology.

**Photovoltaics** - On-site PV is an ideal candidate for mining site use due, in part, to its flexible installment options. Much of the United States has ample solar insolation levels for PV use. As a result, a decision to install a PV system at a mining site may depend more on the power requirements at a site and any site-specific financial and economic considerations (including renewable energy incentives) than the location of the site. On-site PV can provide an potentially viable financial alternative for remote mining site that are in an area where grid connection is not feasible because of distance or cost.

## C. Consider Community Involvement in Project

Community support can be crucial to the success of energy projects at AMLs. Building local support for a project relies on effective communication of a project's potential benefits – new jobs, increased tax revenues – to the community.

**Helpful Hint**

Understanding and communicating the economic, environmental, and societal benefits can be key to a project's long-term success. These benefits can include local revenue, applying non-emitting "green" technologies, and local community revitalization. Depending on a project's characteristics, community and stakeholder involvement can range from a series of public meetings, to hosting a targeted stakeholder group, to managing the process with a community- based committee with broad representation.

While there is no standard approach for community involvement, it is recommended that, at minimum, a project should seek input from a diverse range of stakeholders at several times during the project. Thoughtful community involvement in the process may be particularly important at AML sites, as redevelopment efforts may have a significant economic and social effect on nearby communities, many of which likely have strong historic ties to local mining sites.

## D. Clarify Site Ownership Issues

Ownership of a mining site can be a significant stumbling block to a site's redevelopment if the site is not wholly owned by one entity or if site ownership is unknown or unclear. If parts of the site are held by different parties with different interests, this can present problems in terms of common interests, decision-making delays, and limited forward progress throughout a project. Clear ownership of a site allows a community or developer to work with a known decision-maker rather than working with multiple or unclear stakeholders. This can also inform decisions regarding to whom a project should be marketed, and whether or not on-site energy generation will be practical or beneficial.

## E. Understand Local/ Regional Energy Markets

**Helpful Hint**

Initial questions to ask about site ownership include: Is the site abandoned? If not, is the site owner known? Is the site under the control of a single entity? Is the site in tax arrears?

For a utility-scale solar energy project, a project's technical feasibility and its financial viability may depend on a region's wholesale electricity market. Competitive market prices and the ability to secure attractive power purchase contracts for the energy from a project will depend on the costs of the existing mix of electric supply sources in the market and the ability of this supply to meet demand.

For utility-scale solar energy projects, there will be a need to work with the local utility and/or a region's power pool operator to determine the feasibility of connecting to a nearby transmission line. An otherwise fantastic site may ultimately not be viable for a utility-scale solar energy project due to the cost and/or difficulty of interconnecting to the grid.

## F. Understand Permitting Requirements

As highlighted above, there can be many facets to permitting a solar energy project. Each project's permitting requirements will be specific to the permitting jurisdiction, the characteristics and location of the site, and the specific details of a project.

It is advisable to develop good communication and a productive working relationship with state and local permitting and licensing authorities at the outset of a project. This will improve the chances that they will work effectively with a community or developer and clarify siting and permitting requirements and expectations in advance.

**Principles for a Successful Permitting Process**

Collective guidelines for more effective permitting process.

- Significant Public Involvement
- Understand Decision-Making Criteria
- Early Planning and Communication
- Coordinate with Regulatory Agencies
- Active Monitoring that Permit Conditions are Being Met

## G. Identify Project Developer Support

A large-scale solar energy project may need an energy developer to assist in designing and developing a solar installation. Developers may serve as a critical source of funding for the project and can serve as important third-party partners to accelerate the deployment of solar energy at a mining site. They can also assist with leveraging resources for cleanup and help to inform cleanup decisions to make them compatible with a solar array.

# Incentives and Policies for Solar Energy Development

A number of policies and incentives can be utilized to facilitate the development of renewable energy projects. Energy development incentives include both policy-based incentives (renewable portfolio standards) and financial incentives (tax credits and rebates).

Federal and state policies continue to play a major role in creating markets that are favorable for solar energy deployment. Solar energy's cost premium has declined in recent years due to technology improvements and an increase in the cost of fossil fuel based energy generation. At the same time, a growing nationwide public policy focus on carbon-free, renewable energy has created a wide range of financial incentives to lower costs even further. Six southwestern states (CA, NM, AZ, TX, CO, and NV) have established incentives to promote the use of renewable energy, including solar energy technologies. Chief among the state energy policies are renewable portfolio standards (RPS) that require that a specific portion of a state's electricity consumption be met by renewable energy by a certain date, tax incentives, and production incentives. EPA's Renewable Energy Page highlights many of these incentives.

Major financial and policy incentives are highlighted below. In addition, many states offer specific financial incentives for renewable energy development. The rules associated with many of these incentives are complex and it is recommended that a tax lawyer review their applicability to your project. Appendix B provides additional information on incentives.

## *Renewable Energy Policy Tools*

**Renewable Portfolio Standards (RPS)** – An RPS is a regulatory policy that requires the increased production of renewable energy sources such as wind or solar by a retail seller of electricity (e.g., a utility). A utility can satisfy this obligation by either (a) owning a renewable energy facility and producing its own power or (b) purchasing renewable electricity from another supplier. RPS policies are implemented by states, and vary considerably in their requirements with respect to time frames, eligibility, treatment of existing plants, enforcement and penalties, and whether they allow the trading of renewable energy credits.

**Helpful Hint**

It is important to note that unless a state RPS has a carve-out requirement for solar, utilities can be expected to pursue the most financially viable (e.g., least expensive) renewable energy projects. For many states, wind energy or biomass projects have been the most financially viable projects to date.

**Third Party Financing Models** - In the public sector, public entities are moving away from direct ownership of solar energy systems and toward the use of partnering with third-party owners. State and local governments see the third-party ownership model as a potential way to effectively monetize federal tax benefits, avoid paying the high up-front cost of solar, facilitate the use of otherwise marginal lands owned or controlled by a local government, more efficiently allocate public funds, and accelerate the deployment of solar projects. Instead of owning a solar system, a public entity hosts a system that is paid for and owned by a taxable entity. The public entity enters into a long-term contract (power purchaser agreement) with a third party to purchase the electricity generated on its property. The Nellis Air Force Base and Fort Carson PV projects detailed in this report are examples of this approach.

## *Renewable Energy Policy Incentives*

**Renewable Energy Credits (RECs)** - RECs are tradable commodities, separate from the electricity produced, that bundle the "attributes" of renewable electricity generation. Because they are unbundled from electricity, RECs are not subject to transmission constraints. RECs have become a dominant mechanism for compliance with renewable portfolio standard (RPS) policies in many states and voluntary green power purchases. There are two primary REC markets - mandatory and voluntary. Mandatory (or compliance) markets exist because of policy decisions, such as a state RPS, and tend to have higher prices per REC. Voluntary markets differ in that they provide consumers with the option to purchase or support renewable energy for a portion or all of their electricity needs. Voluntary REC prices depend on several factors, but are typically lower than mandatory market prices.

**Business Energy Tax Credits** (also known as Investment Tax Credits (ITCs)) - ITCs are tax incentives designed to encourage both individuals and businesses to make investments in solar energy. For commercial entities, the federal government currently offers a 30% investment tax credit to partially offset the up-front installed cost of a solar system. Investment tax credits have a major impact on the economic feasibility of a renewable energy power plant. For example, the SEGS plants in California benefited from the federal investment tax credits as well as a 25 percent solar energy state tax credit.

**Clean Renewable Energy Bonds (CREBs)** - Originally created by the 2005 Energy Tax Incentives Act, CREBs provide a federal tax credit for the bond owner in lieu of interest payments from the issuer. The Emergency Economic Stabilization Act of 2008 authorized $800 million of new renewable energy bonds to finance facilities that generate electricity from renewable resources, including solar. The legislation allows state and local governments, public power providers and electric cooperatives to issue CREBs to finance new renewable electric power facilities, including solar installations, through December 31, 2009.

**Renewable Energy Production Incentive (REPI)** - Authorized under the Energy Policy Act of 1992 and amended under the 2005 Energy Policy Act, REPI is a production-based incentive program that provides financial incentive payments as renewable electricity is generated. Given that REPI payouts are production based, the amount can be significant for large producers of electricity. However, for solar projects, the REPI payout is very modest. The average allocation for the 25 solar projects that received REPI funds in 2007 was less than $1,000. In addition, REPI payouts are subject to annual federal appropriations and therefore uncertain every year. Consequently, while REPI payouts may not be significant drivers for financing new solar energy projects, they can impact the overall economic picture of a solar project.

# Conclusion

With thousands of potentially viable AMLs in the Southwest alone, the potential impact from solar energy development on these sites are significant. Communities can harness the emerging need for secure and carbon-free energy to promote the remediation and restoration of many of these sites and to facilitate economic development.

However, uncertainties remain. Not all former mining sites will be suitable candidates for solar energy projects. Regional solar energy variation, availability of financing and financial incentives, and site-specific conditions will impact the feasibility of developing and exploiting the solar energy resources available at many of these mine lands. With these considerations in mind, public and private organizations are exploring how solar energy development can play an important role in local and regional economic development and community revitalization. Whether generating electricity for the grid or powering cleanup activities, solar energy projects can provide multiple beneficial impacts that can restore and return degraded and underutilized landscapes to productive use.

## Contact Information

For additional information on solar energy development opportunities at former mining lands, contact the following resources:

- EPA's RE-Powering America's Lands Initiative identifies Brownfields, RCRA, Superfund and mining sites for their wind, solar, and biomass development potential and provides other useful resources for communities, developers, industry, state and local governments or anyone interested in reusing these sites for renewable energy development. **http://www.epa.gov/renewableenergyland/index.htm**

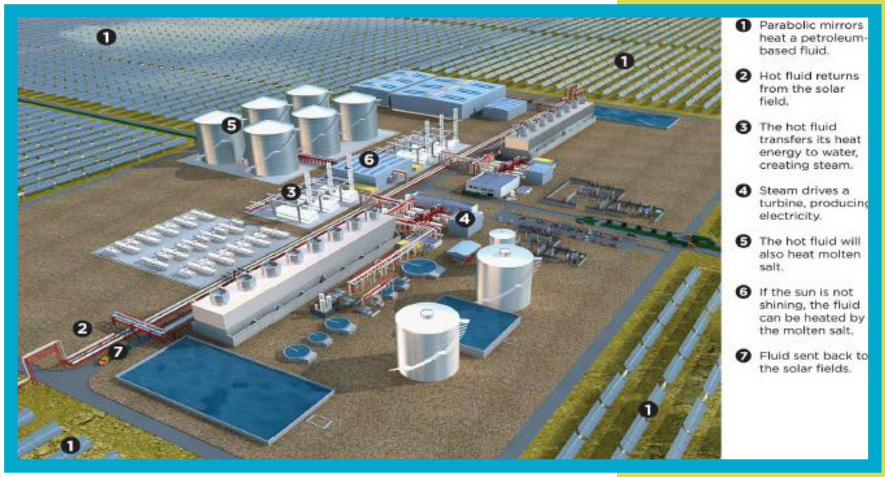
- EPA supports the reuse of former mind lands through the Superfund Redevelopment Initiative (SRI). Additional information about SRI can be found at **http://www.epa.gov/superfund/programs/recycle/**. The SRI website provides tools, case studies, and other technical and informational resources on cleaning up and reusing Superfund sites, including mining lands.

- EPA's Abandoned Mine Land (AML) Team provides communities with technical support and resources as they explore reuse opportunities available at former mine lands. EPA's AML Team works in partnership with communities to clarify EPA's interests at former mine lands and address potential obstacles to innovative reuse of these sites. For more information, please refer to the AML Team's website at **http://www.epa.gov/aml**.

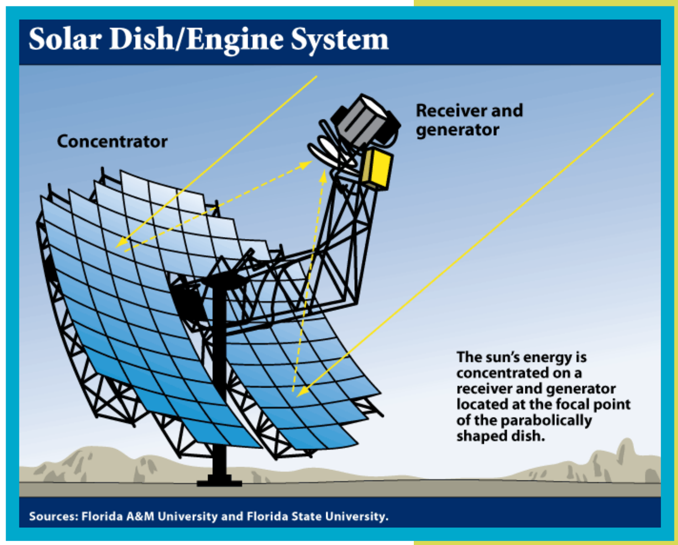
- EPA's Office of Brownfields and Land Revitalization provides financial and technical support that help clean up and reuse brownfields and other contaminated properties. For more information, please refer to the EPA Brownfields website at **http://www.epa.gov/brownfields/**.

# Appendix A: Solar Thermal Technologies

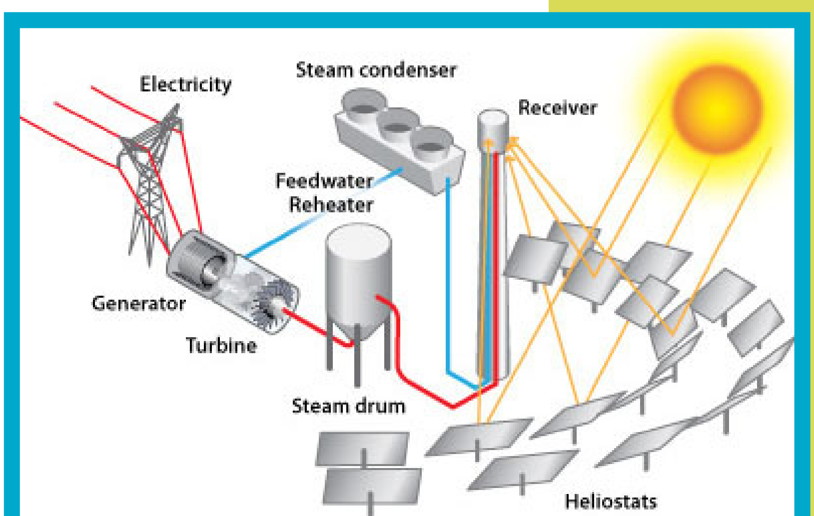
There are a variety of solar thermal power system options for deployment in the US.




**Parabolic Trough:** The predominant solar thermal systems currently in operation are linear concentrators using parabolic trough collectors. In such a system, the receiver tube is positioned along each parabola-shaped reflector. The tube is fixed to the mirror structure and the heated fluid—either a heat-transfer fluid or water—flows through and out of the field of solar mirrors to where it is used to create steam that spins a turbine that drives a generator to produce electricity. Trough designs can also incorporate thermal storage to be used in the evening or during cloudy weather to produce electricity. Parabolic trough plants can also be designed as hybrids, meaning they use fossil fuel to supplement the solar output during periods of low solar radiation.




**Dish/Engine:** A solar concentrator gathers the solar energy coming directly from the sun. The resulting beam of concentrated sunlight is reflected onto a thermal receiver that collects the solar heat and transfers the heat to a generator for electricity. The dish is mounted on a structure that tracks the sun continuously throughout the day to reflect the highest percentage of sunlight possible onto the thermal receiver. The dish/engine system is a technology that produces relatively small amounts of electricity compared to other CSP technologies.




**Power Tower:** For power towers, numerous large, flat, sun-tracking mirrors, known as heliostats, focus sunlight onto a receiver at the top of a tower. A heat-transfer fluid heated in the receiver is used to generate steam, which, is used in a conventional turbine generator to produce electricity. Some power towers use water/steam as the heat-transfer fluid. Other advanced designs are experimenting with molten nitrate salt because of its superior heat-transfer and energy-storage capabilities. Individual commercial plants can be sized to produce up to 200 MW of electricity.

# Appendix B: Solar Resources

## Department of Energy Resources

| | |
|---|---|
| **DOE Solar Energy Technologies Program** | http://www1.eere.energy.gov/solar/ |
| **National Renewable Energy Lab (NREL) Solar Research** | http://www.nrel.gov/solar/ |
| **NREL Job and Economic Development Impact (JEDI) model** | http://www.nrel.gov/analysis/jedi/ |
| **NREL Renewable Energy Resource Maps** | http://www.nrel.gov/renewable_resources/ |
| **NREL In My Backyard (IMBY) Tool** | http://www.nrel.gov/eis/imby/ |
| **DOE Solar Resource Maps** | http://www.nrel.gov/csp/maps.html |
| **NREL Troughnet** | http://www.nrel.gov/csp/troughnet/ |
| **NREL GIS and Mapping Resources** | http://www.nrel.gov/gis/ |
| **Southwest Concentrating Solar Power 1000-MW Initiative** | http://www.nrel.gov/csp/1000mw_initiative.html |
| **NREL Energy Project Planning Support** | http://www.nrel.gov/applying_technologies/project_planning.html |
| **PV Watts Calculator** | http://www.nrel.gov/rredc/pvwatts/ |
| **Report: "Financing Solar Energy Systems: A Federal Overview"** | http://www.nrel.gov/docs/fy99osti/26242.pdf |
| **DOE - Solar Energy Development Programmatic Environmental Impact Statement** | http://solareis.anl.gov/index.cfm |

# Appendix B: Solar Resources Continued

## EPA Resources

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|---|---|
| **EPA Renewable Energy Maps** | http://www.epa.gov/renewableenergyland/ |
| **EPA Abandoned Minelands Team Reference Notebook** | http://www.epa.gov/superfund/programs/aml/tech/refntbk.htm |
| **EPA Guide to Purchasing Green Power** | http://www.epa.gov/greenpower/documents/purchasing_guide_for_web.pdf |
| **Report: "Identification and Evaluation of Community Involvement Activities in Abandoned Mine Land Communities"** | http://www.epa.gov/aml/downloads/aml_comm_involvement.pdf |
| **Mine-Scarred Lands Initiative Tool Kit** | http://www.epa.gov/aml/revital/msl/index.htm |
| **Report: "Anatomy of Brownfields Redevelopment"** | http://www.epa.gov/brownfields/overview/anat_bf_redev_101106.pdf |
| **Renewable Energy Assessment for Iron King Mine - Humboldt Smelter Superfund Site** | http://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/3dc283e6c5d6056f88257426007417a2/defa7016a01e05cc8825782d0055fe4f/$FILE/Reuse%20Assessment%20June%202010.pdf |
| **Solar Power Purchase Agreements** | http://www.epa.gov/greenpower/buygp/solarpower.htm |
| **Sustainable Management Approaches and Revitalization Tool (SMARTe)** | http://www.smarte.org/smarte/home/index.xml |
| **CLU-In Green Remediation Overview** | http://www.clu-in.org/greenremediation/ |
| **Renewable Energy Certificates** | http://www.epa.gov/greenpower/gpmarket/rec.htm<br>http://www.epa.gov/greenpower/documents/gpp_basics-recs.pdf |

# Appendix B: Solar Resources Continued

## Other Solar Energy Resources

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|---|---|
| Solar Energy Industries Association | http://www.seia.org/ |
| Western Governors Association – Clean and Diversified Energy Initiative | http://www.westgov.org/energy |
| Department of Interior – Bureau of Land Management Solar Information | http://www.blm.gov/wo/st/en/prog/energy/solar_energy.html |
| Solar Energy International | http://www.solarenergy.org/index.html |
| American Solar Energy Society | http://www.ases.org/ |
| Interstate Renewable Energy Council | http://www.irecusa.org/ |
| Solar Electric Power Association | http://www.solarelectricpower.org/ |

## Funding and Financial Incentive Resources

| | |
|---|---|
| Database of State Incentives for Renewables & Efficiency (DSIRE) | http://www.dsireusa.org/ |
| DOE Office of Energy Efficiency and Renewable Energy Financial Opportunities | http://www1.eere.energy.gov/financing/ |
| SMARTe Financial Resources | http://www.smarte.org/smarte/tools/FinancingResources/index.xml?mode=ui&topic=financialresources |
| EPA Renewable Energy Incentive Fact Sheets | http://www.epa.gov/renewableenergyland/incentives.htm |

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# Shining Light on a Bright Opportunity

**DEVELOPING SOLAR ENERGY ON ABANDONED MINE LANDS**

EPA
United States
Environmental Protection
Agency

OSRTI
Abandoned Minelands Team

December 2011