Investigation of the Solar Power Potential of Reclaimed Areas at the Black Mesa Coal Mine, Arizona, U.S.

Reclaimed land at the Black Mesa Coal Mine

A Report to Black Mesa Water Coalition and To Nizhoni Ani May 28, 2010

Power lines and other infrastructure in place at the Black Mesa Coal Mine

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Why has this Report been prepared?

This Report has been prepared to support Black Mesa Water Coalition and To Nizhoni Ani programs exploring the potential use of Black Mesa Coal Mine Reclaimed Land as solar power generation sites to provide sustainable, "green jobs-based" community development opportunities for mine area residents affected by job losses due to current and proposed mine closure. Black Mesa Water Coalition – www.blackmesawatercoalition.org - and To Nizhoni Ani are non-profit organizations established to protect natural resources and provide for a just socio-economic transition from coal mining to sustainable development in the Black Mesa Lease Area.

The focus of this investigation is the Reclaimed Lands within the Black Mesa lease site in recognition of the interest of Navajo residents of the Black Mesa Area:

- To retain ownership of customary use lands; and
- To provide a transition to a sustainable community economic base as substantial as that provided during coal mine operations on those lands.

For more information about Black Mesa, the solar potential of Black Mesa and the efforts towards a just transition from coal-based employment to sustainable development contact Black Mesa Water Coalition, To Nizhoni Ani, or the author.

What does the Report include?

The Report summarizes the solar power development potential of reclaimed land within the Black Mesa coal mine in Northeastern Arizona in the Southwestern United States. See Figure 1. The Figures in this Report are found following the **REFERENCES**.

The Report shows that the Reclaimed Areas of the Black Mesa Lease have many characteristics that are favorable for solar power development, and provides the basis for identification of specific parcels among the 12,805 acres of reclaimed land for site-specific assessments to investigate solar power facility feasibility.

Characteristics favorable to solar power development on Reclaimed Land at the Black Mesa include:

- Receives as much solar radiation as existing major solar power projects in the Southwestern U.S.;
- Ability to be managed in large parcels of 100 acres or more;
- Currently connected to the Southwest regional electrical transmission grid through existing power lines (a 230 kV power line), and on existing rights-of way;
- Includes an existing transportation network of roads on identified rights-of way, and other infrastructure;
- Will not require extensive Archaeological and Cultural Resource Clearances as land disturbed during mining has already been subject to resource clearances and resource removal; and

- Include water supply wells that are capable of provided the relatively small amounts of water needed by solar power facilities, compared to coal slurry activities or coal-fired power plant operations.

The report demonstrates that the Black Mesa area receives solar energy that is as strong, or stronger, than the solar energy reaching sites of existing and proposed solar power facilities in the southwest, based on National Renewable Energy Laboratory (NREL) data. (NREL 2007) See Figure 2.

The Report identifies specific attributes of the Black Mesa area that apply for solar facility site selection, providing a foundation for the performance of detailed assessments of sites within the reclaimed areas on the Black Mesa lease for specific solar power projects.

The reclaimed lands have been the site of both the extraction and reclamation phases of coal mining. Characterization of the legal and regulatory status for the reclamation efforts at each individual mine areas is beyond the scope of this report. Reclamation requirements for mine operations are established and enforced through a regulatory system current being implemented by the federal Office of Surface Mining and Reclamation Enforcement (OSMRE) of the Department of the Interior (DOI) through permits in place at the mine sites. Annual Reclamation Status Reports submitted to OSMRE by the leaseholder and mine operator – Peabody Western Coal Company – identify the specific reclamation status of leased lands disturbed by mine operations. Annual Reclamation Reports, Black Mesa Mine Environmental impact Statements, coal mine permits and applications, and contacts for additional information can be accessed through the OSMRE web site at www.wrcc.osmre.gov.

The Solar Power Potential for the Reclaimed Lands at Black Mesa

The solar resources reaching the earth at the Black Mesa lease site are comparable to the solar resources at existing solar power sites – such as the Nevada Solar One south of the Las Vegas which began producing electrical power in 2007 (Power Technology 2010), and at recently proposed solar power sites – such as the GA-Solar power facility near Santa Rosa, New Mexico announced in January 2010. Those sites are selected as reasonable comparisons for solar energy potential with the Black Mesa sites as real world examples of:

- Successful utility-scale solar power plant built and operating solar power facility in the case of Nevada Solar One (Power Technology 2010), and
- Recently announced utility-scale solar power facility proposal in the Southwest U.S. in the case of the GA Solar-Santa Rosa project (NM Independent 2010).

Estimates of the solar radiation reaching the Black Mesa area in Arizona and comparison sites in Nevada and New Mexico, are based on "Concentrating Solar Power (CSP) Prospect" data and maps available through the National Renewable Energy Laboratories (NREL) – www.nrel.gov - (NREL 2007).

The NREL Solar Power Resource Maps including the Arizona map shown in Figure 2, provide estimates of solar radiation and identify "concentrating solar power prospects" through facility siting criteria that exclude:

> "Potentially sensitive environmental lands, major urban areas, areas with slope >3% and remaining areas less than 1 sq. km. [250 acres] … to identify areas with the greatest potential for development." (NREL 2007)

The portions of the Black Mesa lease area meeting the NREL solar power prospect criteria are shown among the color-highlighted "concentrating solar power prospects" areas identified in Figure 2.

As presented in Figure 2, a comparison of NREL CSP maps with solar radiation shows that the solar energy reaching the Black Mesa area is very similar to, and as high or higher than solar radiation, the solar radiation reaching the Nevada Solar One and GA-Santa Rosa sites. (NREL 2007)

Solar Resources
Black Mesa Mine Area – 7.0 - 7.5 kwh/m^2/day
Las Vegas, NV – 7.0 - 7.5 kwh/m^2/day
Santa Rosa, NM – 6.5 - 7.0 kwh/m^2/day

Direct Normal Solar Radiation
Black Mesa Mine Area - 7.0 - 7.25 kwh/m^2/day
Las Vegas, NV – 7.25 - 7.5 kwh/m^2/day
Santa Rosa, NM - 6.75 - 7.0 kwh/m^2/day

The acreage required for the solar energy potential capacity at Black Mesa is based on ratio of acres of land to megawatts of electrical capacity as currently used at operating and proposed electrical generating capacity for Southwest U.S. sites with similar solar radiation characteristics, the Nevada Solar One and the GA-Solar Santa Rosa. For those sites:

- Nevada Solar One solar thermal power plant south of Las Vegas, NV – a 400-acre facility designed to generate 64 MW (Power Technology 2010), – a ratio of 6.25 Acres/MW – See Figure 3 and
- GA-Solar Santa Rosa solar energy project announced January 2010 as projected 2,500 acres generating 300 MW (NM Independent 2010) – a ratio of 8.33 Acres/MW – See Figure 4.

The Location and Extent of Reclaimed Areas on the Black Mesa Lease Lands

The reclaimed lands at the Black Mesa mine total 12,805 acres out of a total of 65,000 acres in three connected lease areas within the Navajo Nation and the Hopi Tribe Reservation. Within the 12,850 acres of reclaimed land, 2,520 acres are in parcels in reclamation for at least twenty years, since 1990. (OSMRE 2009) Figure 5 isslustrates the distribution of reclaimed land within the Black Mesa lease area.

Within the 12,805 acres of reclaimed land, 6,075 acres are located within the Navajo Nation north of the boundary of the former Joint Use Area. Of those 6,075 acres, 1,940 acres were in reclamation prior to 1990.

The location and status of reclaimed lands at the Black Mesa Mine Lease are based primarily on the 2008 and 1990 Environmental Impact Statements on the Black Mesa Mines – OSMRE 2009 - available at from the Office of Surface Mining and Reclamation Enforcement at http://www.wrcc.osmre.gov/WR/BM/bm.html.

The estimate of solar power potential of total area of Black Mesa Coal Mine Reclaimed Lands is derived by determining the land (acres) required for solar energy generation capacity (in megawatts) of these existing and proposed utility scale solar energy projects in the Southwest with similar solar radiation characteristics (6-8 acres/per megawatt) and applying it to the acreage of reclaimed land in the Black Mesa Leases. Table 1 presents the solar power generating potential of the Black Mesa Mine Reclaimed Area based on this ratio.

Within the lease area, the reclaimed lands at the mine are divided among 26 “mine areas” which range in size from 500 - 3,000 acres. Mine areas identified as in reclamation or reclaimed have under gone mining and reclamation activities at different times during the more than 40 years of coal mining on the Black Mesa leases.

Reclamation of mine areas include backfill, grading, and revegetation activities in compliance with existing permits and regulatory requirements, is under review for compliance with the complex reclamation requirements of the Black Mesa lease mines being implemented by the Federal Office of Surface Mining and Reclamation Enforcement (OSMRE). Location of the mine units within the Black Mesa lease highlighting mine areas in reclamation is shown in Figure 5.

Table 1
The Solar Power Potential of the Reclaimed Areas of the Black Mesa Lease
(Based on estimate of 6 - 8 acres per megawatt generating capacity)

Total Mined and Reclaimed Area in 2008 of 12,805 Acres provides
Solar Power Potential of 1,600 - 2,135 Megawatts

Total Mined and Reclaimed Area in 2008 north of former Joint Use Area of 6,075 Acres provides
Solar Power Potential of 760 - 1,012 Megawatts

Total Mined and Reclaimed Land ("Mined Out") in 1990 of 2,520 Acres provides
Solar Power Potential of 315 - 420 Megawatts

Total Mined and Reclaimed Land ("Mined Out") north of former JUA in 1990 of 1,940 Acres provides Solar Power Potential of 240 - 320 Megawatts

Total Acreage to be Mined and Reclaimed of 38,020 Acres (2008 EIS) provides
Solar Power Potential of 4,750 - 6,335 Megawatts
(for comparison, the Mohave Power Plant had a 1,640 Megawatt generating capacity)
Source: Black Mesa Mine Environmental Impact Statements available at
www.wrcc.osmre.gov/WR/BM/bm.html or through www.wrcc.osmre.gov

Table 2
Solar Power Potential of Reclaimed Lands in the Black Mesa Coal Mine
in Black Mesa Area Community Land Planning Sectors
(Based on estimate of 6 – 8 acres per megawatt generating capacity)

Figure 6A – Yellow Water Sector – All reclaimed land in Navajo Nation north of former JUA
Mine Areas N-1 and N-2 – 1,000 Acres Mined and Reclaimed Provides
Solar Power Potential of 125 - 165 Megawatts

Figure 6B – Mine Areas N-7 and N-8 – 940 Acres Mined and Reclaimed Provides
Solar Power Potential of 115 - 150 Megawatts

Figure 7 – Great Springs Sector – 80% of Mined and Reclaimed Area North of former JUA

Figure 8 – White Grass Sector – 50% of Mined and Reclaimed Area North of former JUA
Mine Area N-14 – 1,650 Acres Mined and Reclaimed Provides
Solar Power Potential of 205 - 275 Megawatts

Mine Area J-16 – 1,350 Acres Mined and Reclaimed Provides
Solar Power Potential of 165 - 225 Megawatts

Figure 9 – White House Sector – All Mined and Reclaimed Area in Navajo Partition Lands
Mine Area J-19 – 1,060 Acres Mined and Reclaimed Provides
Solar Power Potential of 130 - 175 Megawatts

Mine Area J-21 – 2,630 Acres Mined and Reclaimed Provides
Solar Power Potential of 325 - 435 Megawatts

Figure 10 – Owl Springs Sector – About 80% of Mined Area in Navajo Partition Lands
Mine Area J-7 – 1040 Acres Mined and Reclaimed Provides
Solar Power Potential of 130 - 170 Megawatts

Acreage and solar power potential for the mine units in reclamation is presented in Table 2, and illustrated in Figure 5. The mine units are grouped by sectors within the lease area to illustrate where the reclaimed mine units are located among the topographic features and remaining infrastructure on the Black Mesa lease. Detailed areas are shown in Figures 6 –10.

Post mining land use for mined lands and remaining infrastructure at the Black Mesa lease area is a major focus for area residents and community leaders. A Black Mesa–Kayenta Mines Leasehold Area Future Land Use and Community Development Plan ("Black Mesa Land Use Plan"), was conducted in 2005 for the Black Mesa Review Board, an organization composed of representatives of the Navajo communities in and around the Black Mesa leases to assist land use planning. Black Mesa Review Board has been reorganized as "Black Mesa United". The Black Mesa Land Use Plan (Black Mesa United 2005a and Black Mesa United 2005b) divides the lease area into six sectors and provides a narrative land use plan and projected future land use maps for those sectors.

Figures 6 - 10 combine the maps of proposed future land use for mine area and remaining infrastructure in the five Black Mesa Land Use Plan sectors, with significant acreage in reclamation from the Black Mesa Land Use Plan. Remote sensing imagery from Google Earth is included to show the location of reclaimed mine units, along with solar power potential and remaining infrastructure within the lease area.

In addition to resloped and revegetated mined lands, the lease area has an extensive network of road, electrical transmission, water well and pond, and coal handling plant facilities associated with mining activity. The Black Mesa Land Use Plan developed to assist Navajo communities in and around the mine identifies grazing and open space land uses, and an extensive infrastructure network for the lease area following completion of reclamation. (Black Mesa United 2005b) The extent of local infrastructure in place on the lease area is illustrated in the Future Land Use maps for the Black Mesa lease sector in Figures 6 – 10.

Figures 6 – 10 combine images from three sources, summarizing the solar power potential for the Black Mesa mine areas and land use sectors identified in the figures. The Figures include images from:

- Google Earth showing the appearance of the mine area to illustrate the condition of the land by remote aerial imagery;
- Black Mesa Coal Mine Environmental Impact Statements illustrating location and status of mining activity; and
- Black Mesa Land Use Plan and Associated Maps identifying future land use plans for mine sectors including proposed post-mining land use and the extent of remaining power line road, water and commercial infrastructure available for post-mining land use activities.

The existing power line infrastructure within the Black Mesa Lease Area is connected to the regional electrical transmission grid to provide the electrical power used to operate

the dragline excavators and other equipment and facilities associated with coal mining and handling operations. The power supply for the mine comes through a substation connected to a 230 kV transmission line between Page, Arizona and Four Corners Power Plant in New Mexico north of the Black Mesa Leases. (WRP 2008)

This electrical transmission connection is illustrated in Figure 11. Figure 11 (WRP 2008) identifies the existing electrical transmission infrastructure in the Southwestern US map modified to highlight the connection of the Black Mesa lease area to the regional electrical grid.

The existing transmission network to and within the Black Mesa lease, including the associated rights-of way, substations, and support service areas, will be valuable assets for any solar power development project using the Reclaimed Areas. (Black Mesa United 2005b)

Water Consumption Considerations for Solar Power Generating Facilities

Demand of water associated with solar power facilities is very low compared to conventional electrical power facilities. Water consumptions for any solar power facility is also very low compared to amount of water exported from the Black Mesa area as part of coal slurry transport operations.

Water consumption at solar power plants is primarily limited to cleaning of mirrors and reflective surfaces if dry cooling methods are installed. (Nuno 2008)

Water use requirements for solar power plants, whether solar-electric (photovoltaic systems), or solar-thermal (parabolic trough systems) consume only 5 - 6 % as much water as coal or oil fired power plants. (AWEA 2009 and Nuno 2008)

Water consumption at solar power plant requires 26 - 30 gallons per megawatt, while coal and oil-fired power plants require 430 - 490 gallons per megawatt. Estimated water consumption rates for solar power plants from AWEA 2009 and Nuno 2008 are summarized in Figure 12.

For a 100-megawatt solar power plant, the annual water consumption would be estimated to be 16.2 - 18.5 acre-feet per year – equivalent to 5.3 - 6 million gallons per year or 10.1 - 11.4 Gallons per minute.

For a 100-megawatt coal or oil-fired power plant, water consumption would reach 263.0 - 300 acre-feet per year – equivalent to 86 - 98 million gallons per year or 153.2 - 186.1 gallons per minute.

Archeological and Cultural Clearance Considerations

Land in the Navajo Nation, including the Black Mesa lease, is rich with cultural resources that hold immense and irreplaceable value for families who have lived on and used that land for generation upon generation. In addition, lands in the Navajo have extensive archeological resource value. Federal programs to preserve cultural resources and archeological resources require extensive survey, analysis and protection programs be completed before land uses that might disturb those resources are permitted for use through mineral or business lease.

Mined lands, such as the reclaimed lands at the Black Mesa leases, are among the very few areas of the Navajo Nation where cultural resource and archeological clearances have been issued, and land covered by those clearances disturbed. Due to the extensive nature of mining and reclamation few, if any, of the cultural and archaeological resources remain intact at the mine areas undergoing reclamation.

As a result of the completion of the cultural and archeological clearance process prior to mining, and the extensive disturbance of the mine areas due to mining that has occurred, the reclaimed lands are likely to need less extensive cultural and archeological survey and protection requirements than any undisturbed land in Navajo Country.

Because cultural and archeological clearance associated with large-scale developments like solar power facilities can be very costly and time-consuming, development at previously surveyed, cleared, and disturbed area may reduce or eliminate archeological and cultural clearance commitments.

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NREL 2007 — National Renewable Energy Laboratories (NREL), "Concentrating Solar Power Resource Maps", http://www.nrel.gov/csp/maps.html, accessed May 27, 2010.

Figure 2 incorporates "Concentrating Solar Prospects of Arizona", http://www.nrel.gov/csp/images/3pct_csp_az.jpg, July 2007, Accessed May 27, 2010.

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New Mexico data from "Concentrating Solar Prospects of New Mexico", http://www.nrel.gov/csp/images/3pct_csp_nm.jpg, July 2007, Accessed May 27, 2010.

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FIGURES

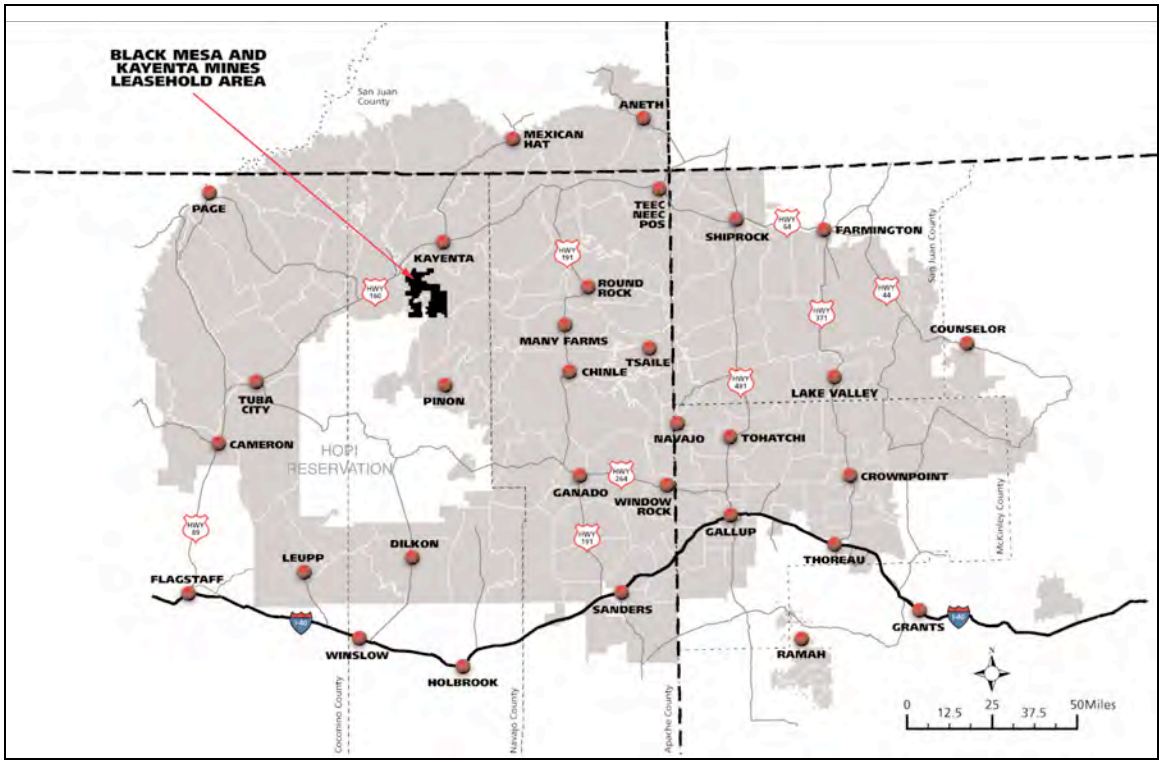

Figure 1 – Location of the Black Mesa Lease Area in Northeastern Arizona

Source: Black Mesa United, 2005b

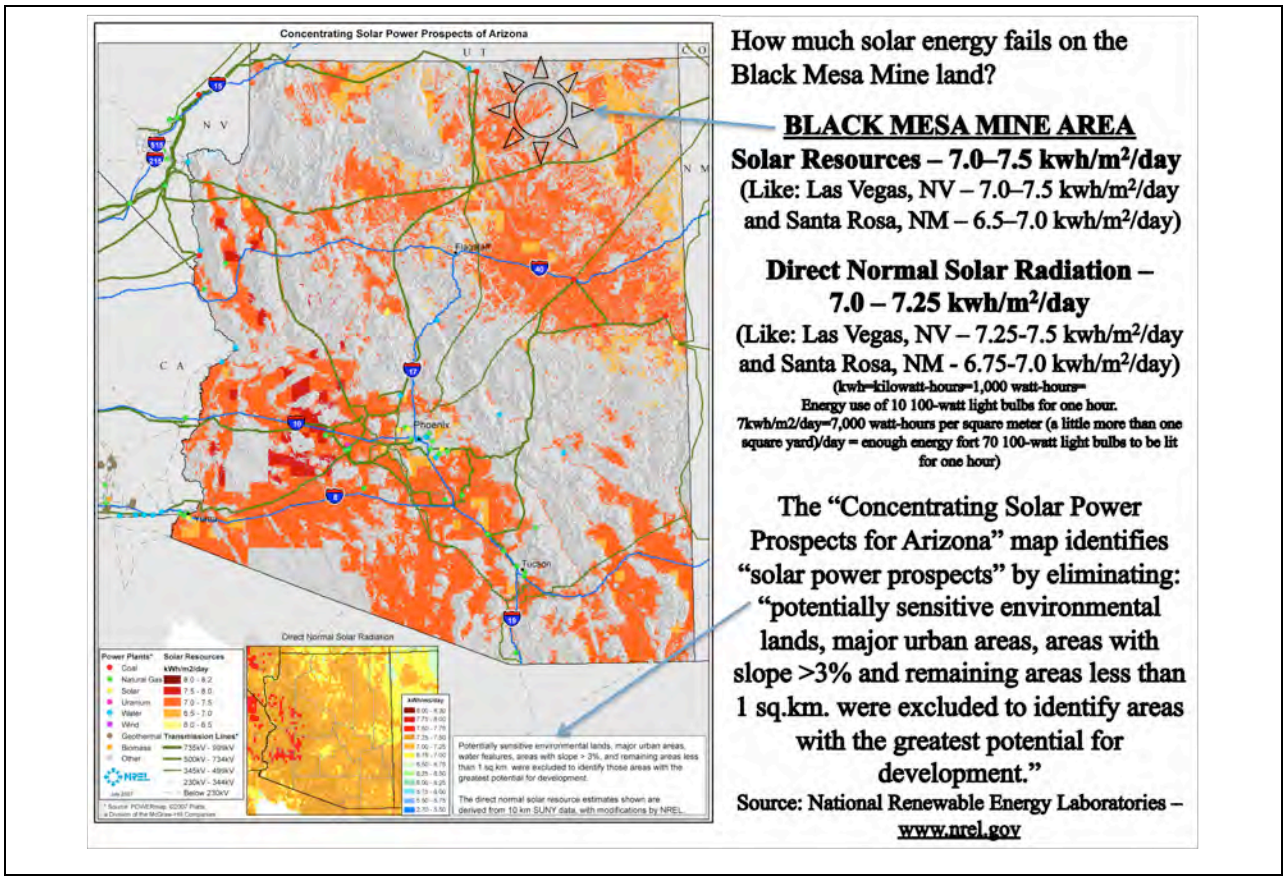

Figure 2 - Location of Black Mesa area on Arizona Concentrating Solar Power Prospect Map and comparison of Black Mesa solar resources with solar resource existing and proposed solar power sites. Source: NREL 2007

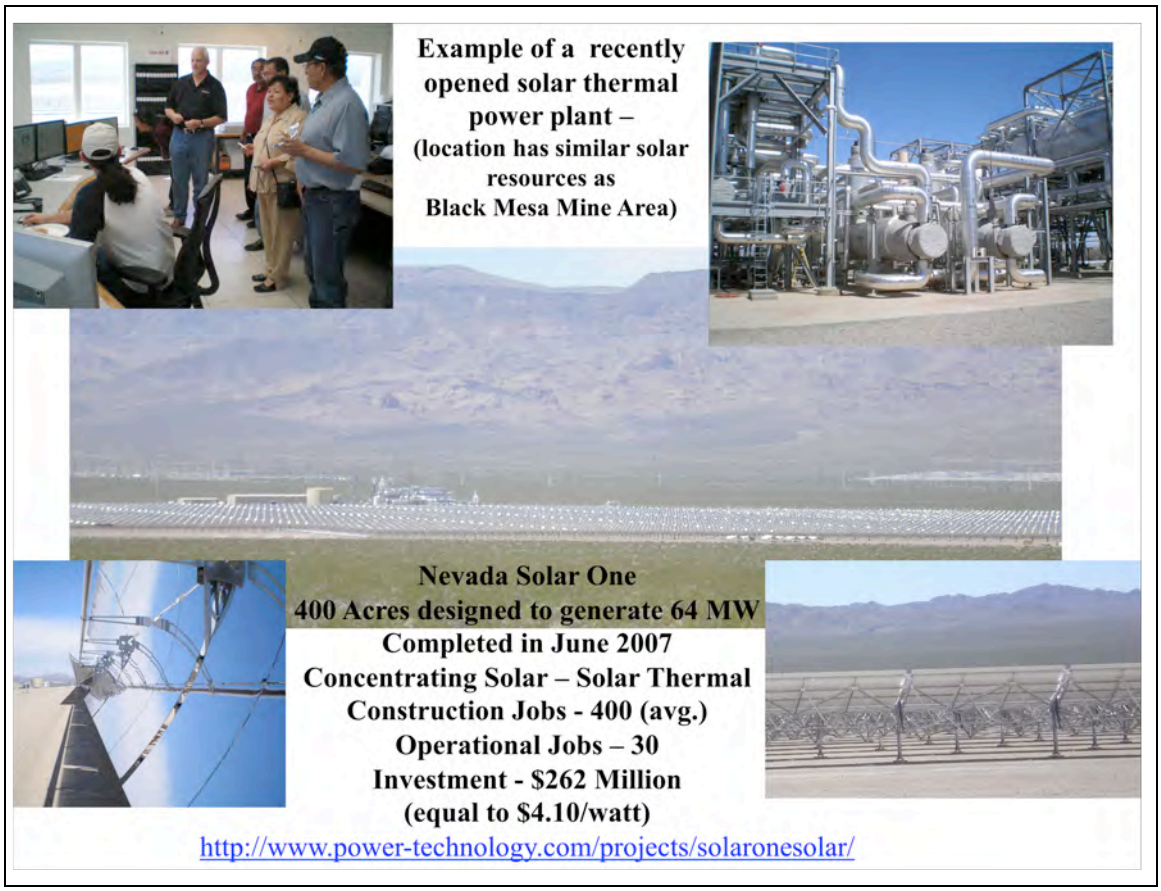

Figure 3 – Nevada Solar One – Illustrations and general information

Source: Power Technology 2010. Photos by Paul Robinson, 2008

Figure 4 – Illustrations of GA-Solar facility in Spain and information on GA-Solar project announced in New Mexico

Sources; NM Independent 2010 and www.ga-solar.com

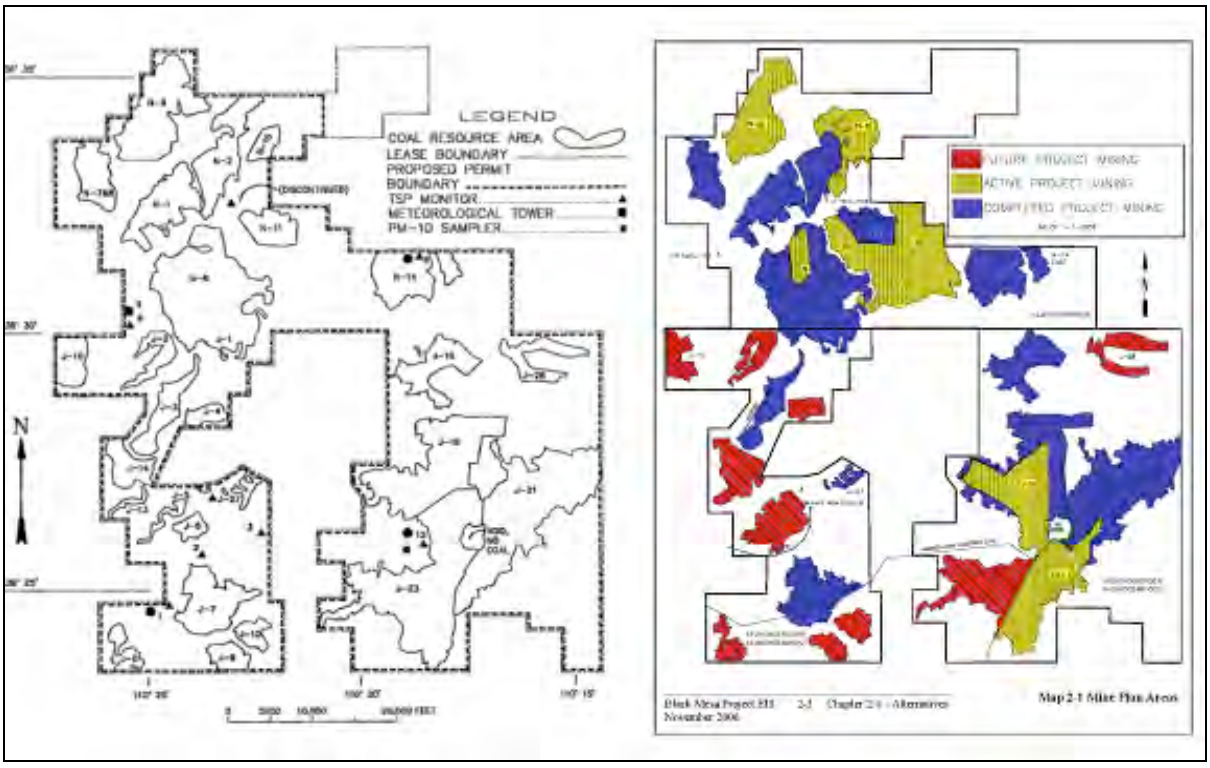

Figure 5 – Location and state of mining activity of mine areas in the Black Mesa lease area. Areas identified as “completed project mining” are considered “reclaimed areas’ in this report.

Source: OSMRE 2009

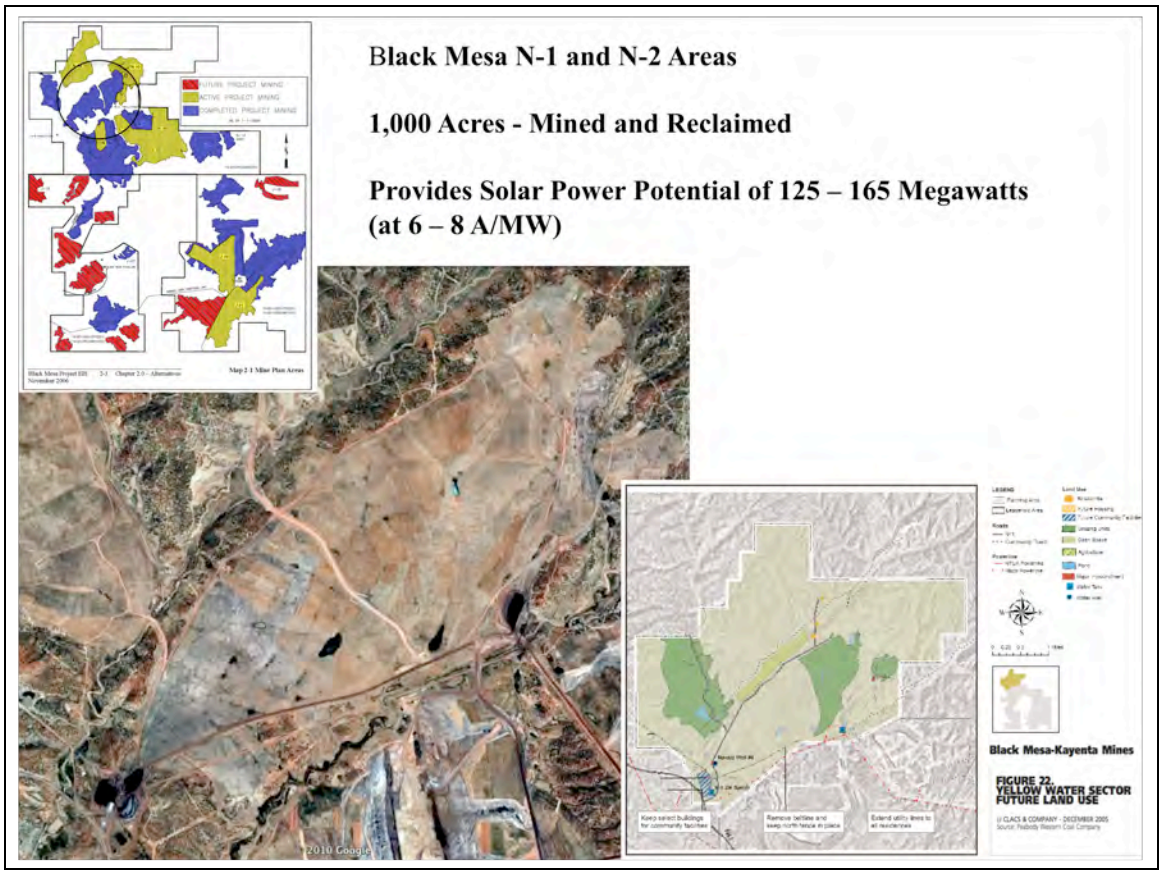

Figure 6A – Location and solar potential of reclaimed land in northern portion of Yellow Water Sector

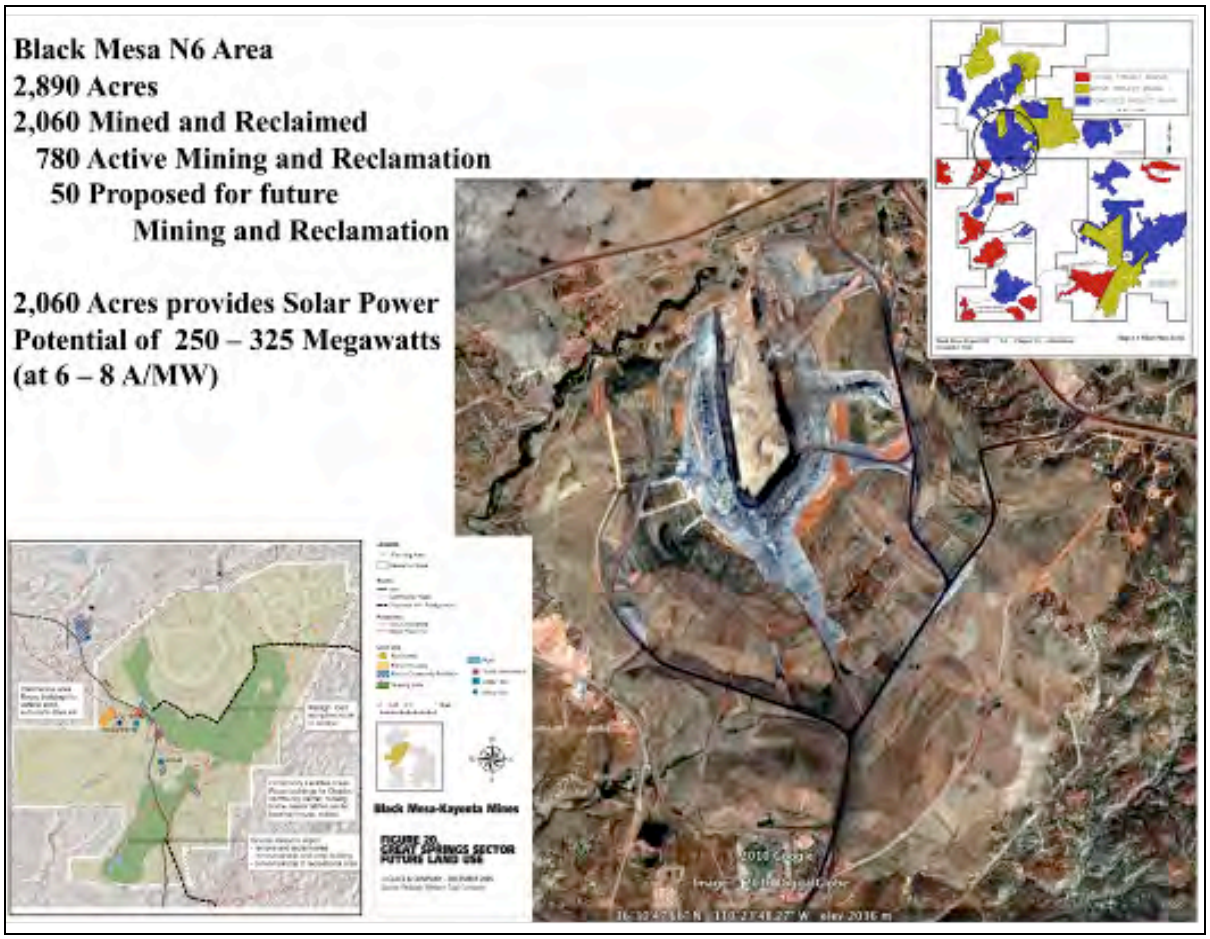

Figure 6B - Location and solar potential of reclaimed land in southern portion of Yellow Water Sector

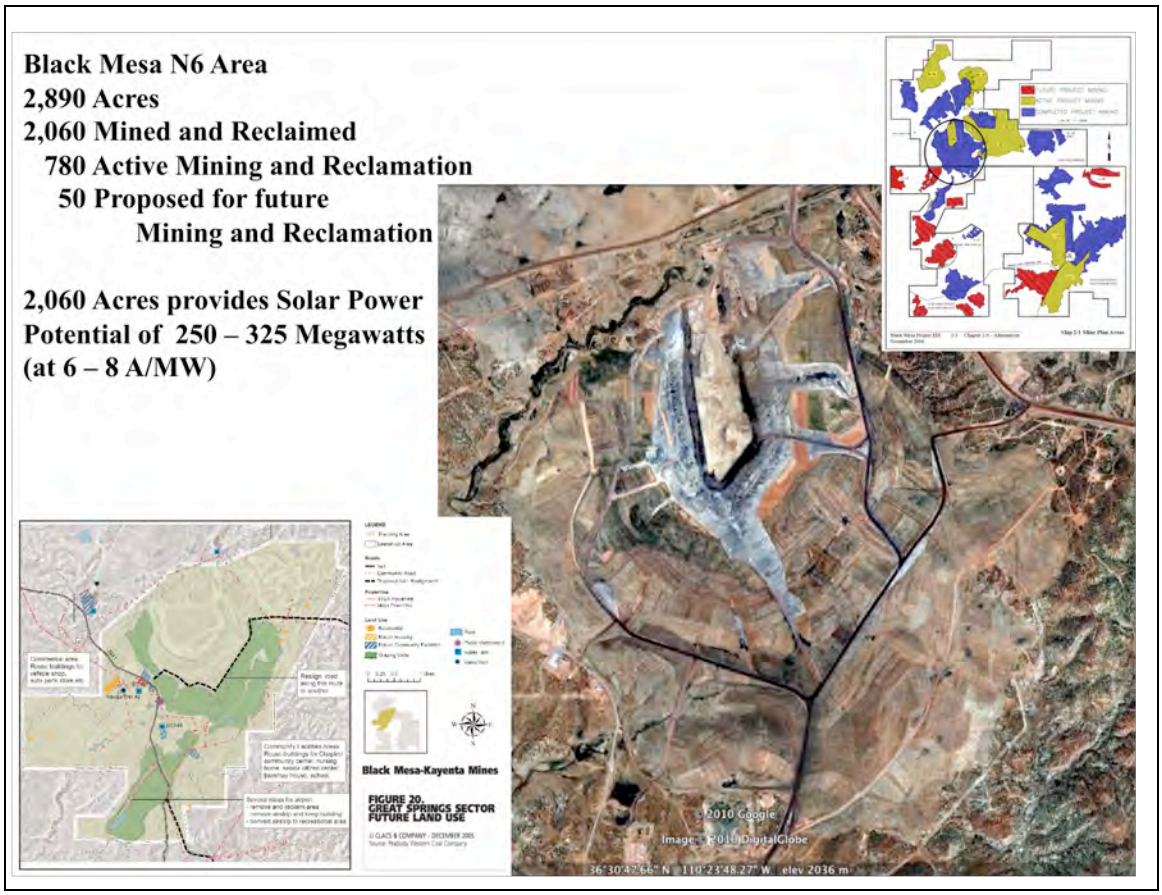

Figure 7 – Location and solar power potential of reclaimed land in Great Springs Sector

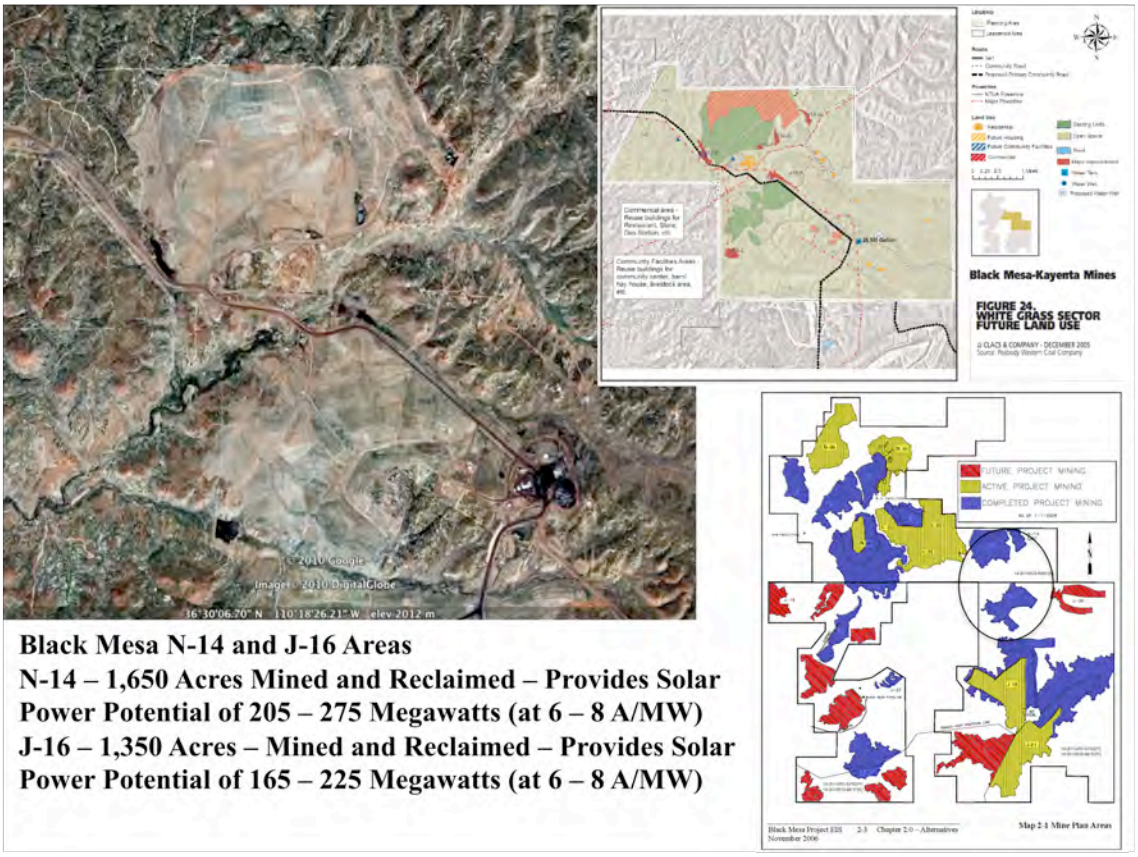

Figure 8 – Location and solar power potential of reclaimed land in White Grass Sector

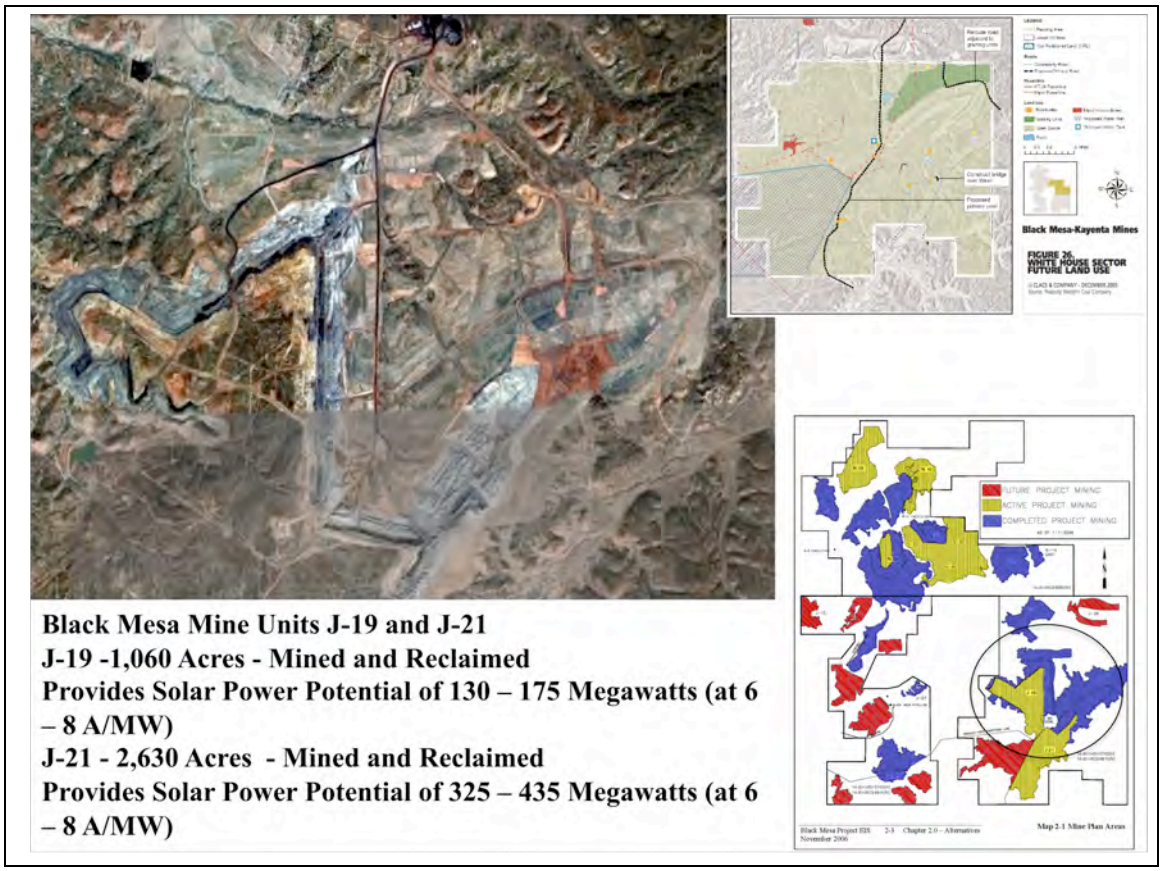

Figure 9 – Location and solar power potential of reclaimed land in White House Sector

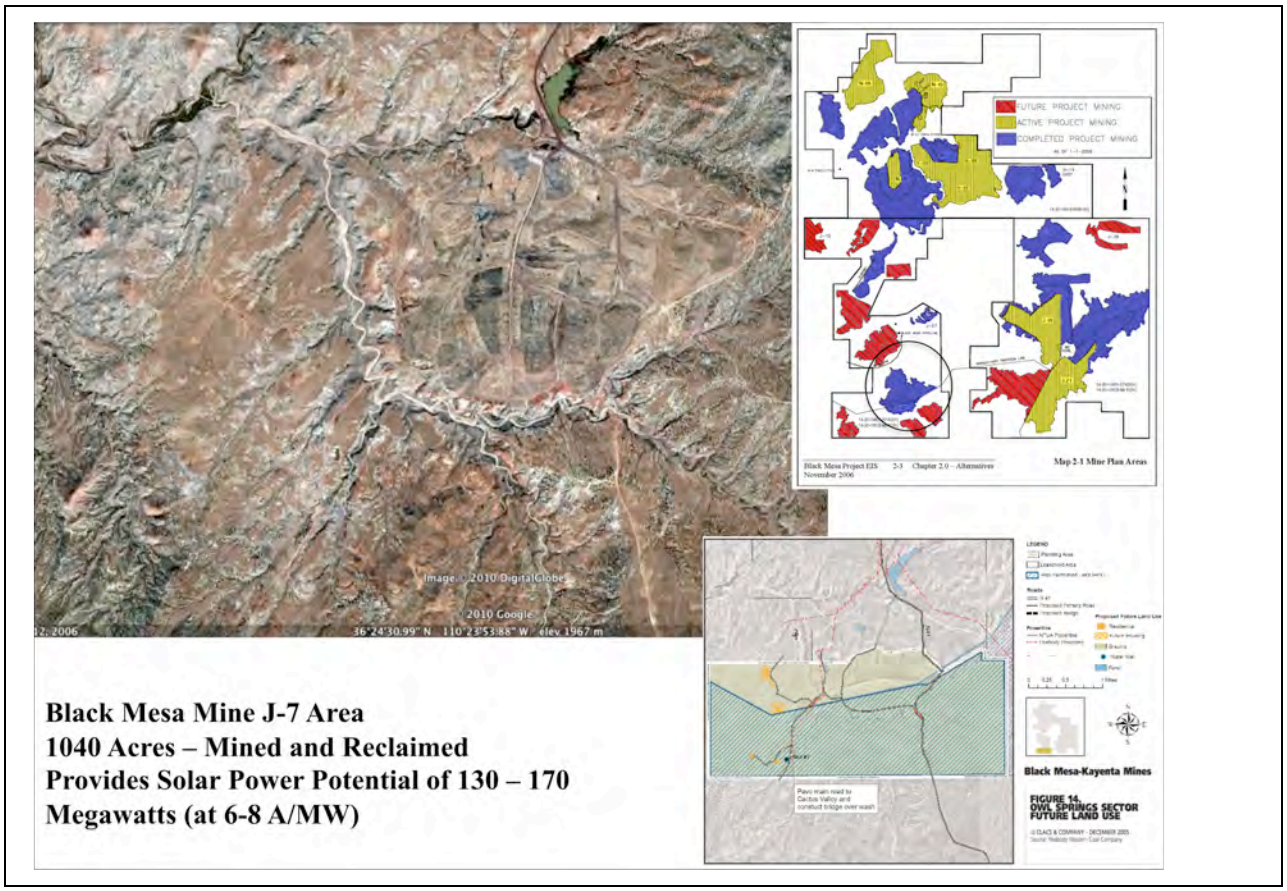

Figure 10 – Location and solar power potential of reclaimed land in Owl Springs Sector

Figure 11 – The Black Mesa Mine Area is connected to the Southwestern U.S. region electrical transmission grid.

Source: WRP 2008

Solar Power Plant Water Consumption

Water consumptions at solar power plants is primarily limited to cleaning of mirrors and reflective surfaces if dry cooling methods are installed.

Estimated Water Consumption Rates for 100 MW Solar Power Plants

Technology	Gallons/mwh	Gallons/kwh	Gallons/year	AF/yr	Gals/min
Photovoltaic	**30**	**0.03**	**6 million**	**18.4**	**11.4**
Solar Thermal	**26**	**0.026**	**5.3 million**	**16.2**	**10.1**
For Comparison:					
Nuclear	620	0.62	124 million	380.6	235.7
Coal	490	0.49	98 million	300	186.1
Oil	430	0.43	86 million	263	153.2
Wind	1	0.001	0.2 million	0.61	0.38

These calculations assumes that a 100 megawatt solar power plant generates electricity 2000 hours per year producing a total of 200,000 megawatt hours (mwh) of electrical power. For comparison, water consumption rates for the non-solar technologies also assume generation of 200,000 mwh/yr for 100 MW of capacity. One gallon per minute (gals/min or gpm) equals 1.612 acre feet per year (AF/yr).

Water consumption for solar power plants is about 5% of the water consumption of coal, oil or nuclear power plants and about 10% of the water consumption of combined cycle power plants for equal amounts of energy produced.

Sources: http://www.awea.org/faq/water.html
http://www.slideshare.net/fnuno/bulk-solar-generation-presentation

Figure 12 – Solar power plant water consumption rate with comparisons to water consumption rates for other power plant water consumption rates

Source: AWEA 2009 and Nuno 2008