

21ST CENTURY ALCHEMY: TRANSITIONING FROM MINING TO SOLAR

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ABSTRACT

ASARCO LLC (Asarco) and its parent Grupo México, S.A.B. de C.V (Grupo Mexico) are of the view that a renewable energy project can be viable use of un-utilized mine lands and post-mining use of disturbed mined lands that have been reclaimed. This paper examines the drivers that make mining and solar energy development a good fit and, through a case study, discusses Asarco's experience in hosting the Avalon Solar Project, a 57-megawatt (MW) single-axis tracking solar power photovoltaic (PV) facility situated on approximately 500-acres tract of retired agricultural land, acquired for water rights purposes, in Pima County, Arizona near the Asarco's Mission Complex. The paper also discusses the reclamation of the San Xavier tailings storage facilities and waste rock deposition area, located within the boundaries of the San Xavier District (District) of the Tohono O'odham Nation where a portion of the Asarco Mission mining operations occur. These and other closed and reclaimed tailings storage facilities and possibly waste rock deposition areas could be suitable for siting future photovoltaic (PV) solar projects.

INTRODUCTION

ASARCO LLC (Asarco) was organized in 1899 as **American Smelting And Refining Company**. Originally a consolidation of several lead-silver smelting companies, it evolved over the years into an integrated producer of primary non-ferrous metals, including copper, lead and zinc and associated co-products. Grupo México, S.A.B. de C.V (Grupo Mexico) acquired Asarco in 1999. Today, Asarco is a vertically integrated producer of primary refined copper and associated co-products such as gold, silver, molybdenum, selenium, and tellurium. Asarco operates three open-pit mines and mills, two Leach, Solvent Extraction-Electrowinning (SX-EW) plants, a copper smelter in Arizona, and a copper refinery in Texas.

This paper is a companion to another paper by the co-authors entitled "Mining and Sustainable Development: An Oxymoron or R_x for a Bright Future? -- An Update," being presented at the Sustainable Industrial Processing Summit, 2017. This paper traces the evolution of and provides a detailed description of the Avalon Solar Project at Asarco's Mission Complex, and discusses the suitability of reclaimed tailings storage facilities and possibly, reclaimed waste rock deposition areas, for siting future solar facilities.

BACKGROUND

In mid-2009, Asarco started examining whether it makes sense to host renewable energy projects on lands owned by the company in Arizona, because of enquiries from solar power plant developers. This interest from solar developers was driven largely by renewable energy mandates for publicly owned utilities in various states including Arizona, as well as by federal and state tax incentives and subsidies that were available for renewable energy projects.

In 2006, the Arizona Corporation Commission approved the Renewable Energy Standard and Tariff (REST) rules, which require regulated electric utilities to generate 15% of their energy from renewable resources by 2025. Each year, Arizona's utility companies are required to file annual implementation plans describing how they will comply with the REST rules. There were three federal solar tax incentives and subsidies available during the 2009/10-timeframe: (1) Business Investment Tax Credit (ITC); (2) 1603 Program Payments for Specified Energy Properties in lieu of tax credits and (3) Modified Accelerated Cost Recovery Systems. There were also state incentives, such as the following provided by Arizona: (1) Solar Energy Equipment Sales Tax Exemption; (2) Renewable Energy Production Tax Credit and (3) Commercial/Industrial Solar Energy Tax Credit Program.

As an invited participant, one of the co-authors Krishna Parameswaran attended the U.S. Environmental Protection Agency (EPA) Re-Powering America's Land: Revitalizing Communities with Renewable Energy stakeholder meeting in Los Angeles on January 12, 2010. EPA's RE-Powering America's Land Initiative encourages renewable energy development on current and formerly contaminated lands, landfills, and mine sites when such development is aligned with the community's vision for the site. At this meeting, Parameswaran provided the industry perspective on siting renewable projects on lands owned by mining companies, making the case that siting renewable energy projects on disturbed lands could be a viable post-mining land use. Other presentations provided other landowner, energy developer, and utility perspectives. The utility perspective was provided by Carmine Tilghman of Tucson Electric Power (TEP).

At a webinar hosted by the Western Business Roundtable (WBRT, 2010) on May 12, 2010 titled "Mining to Solar Initiatives: Breathing New Life Into Old Lands," Krishna Parameswaran made a presentation entitled "Mining Companies and Solar Projects: Could be A Win-Win Scenario." The WBRT promotional material stated: "The nationwide push to deploy more renewable power systems is bringing into focus questions related to "where" best to install these systems. One innovative approach is to look at disturbed mining property as a host for new renewable installations. Three companies involved in such a project in Arizona will outline their plans and their experiences in this installment of our "Green Technologies: How They Work," webinar series. Our three guest speakers will discuss both the challenges and benefits of an approach that promises to minimize both landscape impacts, as well as breathe new life into "old" lands." Parameswaran argued that siting solar facilities on mining disturbed lands makes sense, and that collaboration between mining companies and renewable energy developers could be fruitful. The webinar discussions are summarized in an article by Adam Bruns entitled "Back from the Dead: The best places for renewable energy power plants may be the pits of the world." (Brun, 2010).

In the ensuing years, there were discussions with various solar developers, utilities and visits to local solar installations. Asarco signed a ground lease agreement with Avalon Solar Partners, LLC (Avalon), a wholly owned subsidiary of Equator Capital in May 2013. The lease agreement was for Avalon's development of a 35 MW Solar Photovoltaic (PV) power generating

facility to be sited on approximately 500 acres of land owned by Asarco adjacent to its Mission Complex in Sahuarita, Arizona. In January 2014, Equator sold the project to Clenera LLC (Clenera). The project was developed in two phases under long-term Power Purchase Agreements signed with Tucson Electric Power (TEP). Phase-1 is 35MW and commenced commercial operations during January 2015. Phase-2 is approximately 22 MW and commenced commercial operations during February 2016.

BENEFITS OF TRANSITIONING FROM MINING TO SOLAR

The reasons for considering the siting of renewable energy projects at mine sites are as follows:

- Fostering renewable energy projects enhances the sustainability credentials of a mining company, by reducing its carbon footprint through efforts to moving towards a more sustainable extractive industry.
- Mining companies have substantial land holdings, some of which are not utilized for operations. These include retired agricultural or ground water reservoir lands acquired for water rights purposes, as well as buffer lands. In addition, lands disturbed by mining such as waste rock deposition areas and tailings storage facilities are reclaimed after mining ceases. However, these reclaimed lands usually remain idle, and hosting a solar facility could be a suitable post-mining land use.
- Mining sites have the necessary infrastructure, including transmission lines, roads, and utilities. They also have heavy earth-moving equipment that can be used for building access roads, and certain non-mineralized mined materials that can be used for implementing stormwater controls.
- Mining operations represent large electricity loads and usually have medium/high voltage transmission/distribution infrastructure that can be used to transmit generated power from the solar power plant to the utility, thereby reducing interconnection costs.
- With the right regulatory framework, solar facilities developed next to mine loads could benefit from a “distributed generation” scheme, where some or even all the energy produced by the solar facility could be consumed on site, creating efficiencies for the grid as less energy should use public transmission and distribution infrastructure.

The benefits to a mining company in hosting renewable energy projects include the following:

- The cost of developing, constructing, operating and maintaining the solar facility is borne by the solar developer.
- Lease agreement with the developer for use of the land would be a source of revenue. In most cases, this kind of land would be idle or used for lower revenue generating uses such as grazing. If the solar facility is sited on reclaimed mine lands, the revenue could defray some of the post-closure costs such as maintenance of the cap, erosion controls, or storm water controls.
- In the future, new mine development and even operating mines could be process engineered or re-engineered to consume more electricity during the daytime and less during hours when there is no sunshine. Capacity factor would be reduced along with increasing capital costs due to equipment redundancy, but operating costs would also be reduced by cheaper solar electric energy costs.

As mentioned earlier, there are regulatory initiatives such as EPA’s “Re-Powering America’s Land: Renewable Energy on Potentially Contaminated Lands and Mine Sites,” aimed at promoting renewable energy projects on disturbed mine lands. The initiative has had limited success to date at mine sites, and one of EPA’s goals is to promote larger capacity utility-scale

projects. In addition, the U.S. Interior Department Bureau of Land Management (BLM) “Restoration Design Energy Project,” is aimed at examining the redevelopment potential of lands under its jurisdiction, funded by the American Recovery and Reinvestment Act (ARRA) of 2009.

Other benefits to a mining company include: (1) strengthening relationships with regulatory agencies. EPA has indicated that if a renewable project were to be sited on disturbed lands, that they would work closely with regulatory agencies having jurisdiction with respect to required mitigation/reclamation and permitting and (2) helping enhance its “good corporate citizen” credentials and build bridges with the local communities, and once again moving towards a more sustainable extractive industry.

Ultimately, it is important to build a business case for siting a renewable energy project at a mine site. This requires commencing a dialog with renewable energy developers to evaluate various technology options and system specifications. Another consideration is where the facility will be located— on unutilized land, reclaimed waste rock storage areas, or tailings storage facilities—and identifying constraints to renewable energy development. For example, consideration was being given to locating a solar installation on old tailings facilities at the Silver Bell mine. On further evaluation, it was determined that copper in the tailings could potentially be recovered by leaching. Once feasible projects have been identified dialog with utilities can commence. This is a very important step the electricity produced is usually sold to utilities through a long-term power purchase agreement (PPA).

AVALON SOLAR PROJECT-A CASE STUDY

This section discusses Asarco’s experience in hosting a solar farm on retired agricultural land that had been acquired for water rights purposes and was being used for grazing. It is an update of discussions in previous papers (Parameswaran, 2015; Parameswaran, 2016a).

The Pima Mine Road Solar Generating Facility, also known as the Avalon Solar Project, is a utility-scale 57-megawatt (MW) single-axis tracking solar power photovoltaic (PV) facility. The facility is hosted by Asarco on approximately 500-acres of disturbed land in Pima County, Arizona near the Mission Complex. As noted previously, it was born out of an EPA program established with the objective of siting renewable energy projects on disturbed lands, including mine sites.

The site conforms to TEP’s land use policies, and is ideally suited to host a solar generating station. The site is located outside of the Pima County Land Conservation System, and its flat topography and past agricultural use provide suitable terrain and soil conditions for constructing a solar facility. In addition, the site is in proximity to an existing TEP substation, which increases the efficiency and minimizes the additional transmission infrastructure required to deliver power generated to the electricity grid.

The General Contractor, Swinerton Renewable Energy, built the Solar Facility with help from many local and national subcontractors. Figures 1-8 are photographs taken during the construction phase of the project.



Figure 1 - Aerial View of Construction in Progress (9-14-2014)



Figure 2 - Installation of Substation and Tucson Electric Power (TEP) Dead End Structure



Figure 3 - Inverter Skid Installation in Progress



Figure 4 - Pile and Dead-End Structure Installation in Progress



Figure 5 - Torque Tube Installation in Progress



Figure 6 - Start of Stringing Wire Connections



Figure 7 - Rows with completed module installation and string wiring



Figure 8 - Racking and Module Installed

Panasonic Eco Solutions, one of the largest solar companies in the U.S., is overseeing the operations and maintenance of the project. Coronal Group, an alternative energy firm that finances and operates solar PV projects for institutions, municipalities, corporations and non-profit organizations throughout North America, is the operating manager of the asset. Clēnera, LLC (Clēnera), the Project Developer, brought all these parties together to design, engineer, and construct the project.

This unique collaboration between Asarco, Tucson Electric Power (TEP) and Clēnera, LLC (Clēnera) made the project a reality. Clēnera was responsible for constructing the facility, which provided 300 construction jobs. Electricity generated is sold to TEP under a 20-year power purchase agreement (PPA) helping the utility meet the Arizona's renewable energy mandate, requiring that 15 percent of its power production come from renewable sources by 2025.

Clēnera installed a small photovoltaic solar plant at the nearby Asarco Mineral Discovery Center (AMDC) using the same type of solar panels as used in the Avalon Solar Project (see Figure 9), which entirely powers AMDC. A video explaining the benefits of solar photovoltaic energy generation and the Avalon Solar Project plays at AMDC along with other videos explaining the copper production process. This adds yet another dimension to the Center's on-going efforts to provide the public with education on the copper mining industry.



Figure 9 - Solar Module Installation at Mineral Discovery Center

The solar farm commenced operation on December 23, 2014. The ribbon cutting ceremony took place on February 27, 2015. The project generates electricity to power 5,720 homes or over 50% of the homes in Sahuarita. It will avoid discharging 57,660 tons of carbon dioxide into the atmosphere. This is equivalent to taking 12,140 cars off the road. Aerial view of the Avalon Solar Project is shown in the photograph in Figure 10. Phase 2 of the project, which increased the generating capacity to 57 MW, began operation in February 2016, and the aerial view of the expanded Avalon Solar Project is shown in the photograph in Figure 11. The expanded facility will generate enough energy to power over 9,250 homes, or over 80% of the homes in Sahuarita. It will avoid discharging 93,000 tons of carbon dioxide into the atmosphere. This is equivalent to taking 19,600 cars off the road. In addition, the Avalon Solar Project should provide approximately \$4 million in property tax revenue to Pima County over the life of the project.



Figure 10 - Aerial View of the Avalon Solar Project



Figure 11 - Aerial View of the Expanded Avalon Solar Project

RECLAMATION OF SAN XAVIER TAILINGS STORAGE FACILITIES AND WASTE ROCK DEPOSITION AREAS

This section is based on prior discussions of San Xavier reclamation activities (Parameswaran, 2015; Parameswaran, 2016a) and the companion paper being presented at the Sustainable Industrial Processing Summit, 2017 referenced earlier. A portion of Asarco's Mission Complex is located within the boundaries of the San Xavier District (District) of the Tohono O'odham Nation. Asarco and the Nation entered into a lease agreement in 1959 to allow use of the Nation's property for copper mining and related activities.

In 2008, Asarco, the Tohono O’odham Nation, the San Xavier District, the San Xavier Allottees Association and the United States of America finalized a comprehensive Mining and Reclamation Plan (MARF) and established a \$33 million fund for reclamation construction and long-term maintenance activities. Reclamation activities commenced in 2009 and was completed in 2012.

The reclamation project scope involved capping with alluvium, rock armoring, construction of storm water controls and the revegetation of nearly 2200 acres of tailings storage facilities and waste rock deposition area. The reclamation plan incorporated sustainable desert vegetation goals, while minimizing the long-term maintenance and respecting the significant cultural and religious values associated with the land. Balancing these factors into a comprehensive reclamation plan in a very arid region was challenging.

Asarco and the Nation formed a six-member panel (Panel or MARF Panel) to oversee and administer the implementation of the reclamation design and construction phases of the project. Although the Panel included a diverse team of technical personnel, the panel also relied on independent consultants and governmental organizations to provide input and guidance. The U.S. Bureau of Indian Affairs, the U.S. Bureau of Land Management and the University of Arizona were instrumental in developing a very specialized re-vegetation matrix of reclamation seeds, trees and cactus. A portion of the grass seed mix grown locally by tribal industry generated a grass variety truly adapted to the reclamation area.

The surface of tailings storage facilities (TSF) was capped with a minimum of one foot of alluvium and seeded with a mix of native plant species. Steep slopes and benches graded to more stable 3:1 angle and covered with one foot of alluvium to reduce storm water infiltration and one foot of rock to minimize soil erosion.

The waste rock deposition areas consisted of overburden and alluvial soil stockpiles. Even though the rock deposition areas are much less susceptible to erosion than the tailings storage facilities, the reclamation goal for these areas also includes soil capping for the establishment of vegetation on the flat areas. Surface of waste rock deposition areas regraded to manage storm water, capped with a minimum one feet of alluvium. Native varieties of cacti, grasses, shrubs and wildflowers adapted to the desert used for revegetation.

A photograph of the top of the TSF prior to reclamation is shown in Figure 12. The success of revegetation on the tops of TSF in the third year after revegetation is shown in Figure 13. A photograph of the waste rock storage facility prior to reclamation is shown in Figure 14. The success of revegetation on the reclaimed waste rock deposition area after revegetation is shown in Figure 15.



Figure 12 - Tailing Storage Facilities (TSF) before reclamation



Figure 13 - Top of Tailing Storage Facility (TSF) after reclamation



Figure 14 - Waste Rock Deposition Facility before reclamation



Figure 15 - Reclaimed Waste Rock Deposition Facility

The success of this reclamation project has generated much interest from regulatory agencies and the mining industry throughout the U.S. and some foreign countries. The flat topography, availability of a suitable renewable energy resource, local water availability, and transmission access make reclaimed tailings storage facilities, and waste rock deposition areas make them ideal candidates for the siting of renewable energy projects.

SUITABILITY OF RECLAIMED TAILINGS STORAGE FACILITIES FOR SITING RENEWABLE ENERGY PROJECTS

EPA conducted a preliminary study at the request of the Tohono O’odham Nation (Nation) to evaluate renewable energy development opportunities for a 280-acre portion of reclaimed mine tailings area at the Asarco Mission mine. As noted in the previous section, the reclaimed mine tailings are located on lands within the San Xavier District of the Tohono O’odham Nation and leased to Asarco by the Nation for mining related activities. As part of the evaluation process, the Nation also participated in the BLM Restoration Design Energy Design Project for evaluating potential sites for renewable energy generation in Arizona. The purpose of this assessment was to determine if there are any potential environmental concerns that need to be considered when planning this type of redevelopment.

The footprint of the reclaimed tailings areas on San Xavier Reservation lands is approximately 1,400 acres. Of these, roughly 1,100 acres constitutes flat areas on the top of the tailings storage facility(TSF) and 300 acres comprise the tailings embankment. As noted in the prior section, the flat topography of the tops of the TSF, availability of a suitable renewable energy resource, local water availability and transmission access makes them suitable for solar energy development. The 280 acres of Nation-owned land identified by the San Xavier District for this pre-feasibility study are part of these tailings areas.

According to the EPA, “The ASARCO Mission Mine is located in an area that is highly suitable for solar power generation. According to the Department of Energy (DOE), National Renewable Energy Laboratory (NREL), this geographic area located south of Tucson has over 300 days of sunlight a year and average solar radiation estimated at greater than 6 kWh/m²/day), giving the reclaimed Asarco tailings excellent solar generation potential. Extensive infrastructure exists at the mine complex, including access points, transmission lines, substations, and a Union Pacific railroad connection. This existing infrastructure could significantly reduce capital costs for constructing a potential utility-scale, solar facility at the mine site. Sites like the Mission Mine can take advantage of local renewable resource attributes to generate electricity in a manner that increases energy efficiency, reduces the environmental impact of generation, and enhances energy diversity, while returning the land to productive reuse,” (EPA, 2011).

EPA concludes “ASARCO Mission Mine tailings area offers unique and potentially innovative opportunity to accommodate and potentially expand a utility-scale solar energy project at a single location. The tailings area has existing transmission capacity, roads, industrial zoning and other critical infrastructure in place for a utility-scale PV project,” with a caveat that “Additional geotechnical stability and settlement analysis, specifically of the Nation-owned section of the tailings, may be warranted prior to building any structures on top of the tailings areas and could help move a solar project forward,” (EPA, 2011).

In addition, EPA Region 9 in coordination with the U.S. Army Corps of Engineers, contracted Weston Solutions, Inc. (Weston) to conduct a Targeted Brownfields Assessment (TBA) for the Tohono O’odham Nation (TON) at the Asarco Mission Mine Tailings site to investigate the geotechnical make-up of the tailings. Weston conducted the field exploration program and Ricker Atkinson McBee, Morman & Associates (RAMM) conducted laboratory analysis and geotechnical engineering evaluation, analysis and recommendations.

To evaluate the geotechnical makeup of the tailings, subsurface soil samples were collected from various depths in five locations around the eastern half of TP1. Five soil borings were drilled utilizing hollow-stem auger drilling methods. Subsurface soil samples were collected with a split-spoon sampler and/or from the cuttings at various depths to provide the most geotechnical information possible in this phase of work. RAMM recommendations address foundation design, site development, material suitability and requirements, site preparation and grading procedures (RAMM, 2012).

Another study by Smith & Annala Engineering Company examined the geotechnical profile at the site to evaluate the sub-surface soils and their engineering properties. This information was used to develop geotechnical engineering recommendation for solar project design and construction. The study concluded that “the site may be developed as planned using deep foundation,” (SAECO, 2013)

These studies indicate that reclaimed TSFs could potentially be suitable for siting future renewable energy projects. Similarly, reclaimed waste rock deposition facilities could also be suitable for siting solar facilities, although additional geotechnical studies need to be conducted to determine the type of foundations necessary for installation of solar panels.

LOOKING TO THE FUTURE

In the United States to date there are limited numbers of renewable energy projects on or adjacent to mine lands, and to our knowledge only one—the Chevron Questa Project, is on reclaimed tailings storage facilities. Most of these have capacity less than 15 MW. Table 1 summarizes solar projects at mining company sites. Renewable energy projects on mine lands include:

**Table 1
Solar Energy Projects at Mining Company Sites**

<u>Facility Name</u>	<u>Location</u>	<u>Company</u>	<u>Energy Type</u>	<u>Capacity</u>	<u>Commenced Operation</u>
Ajo Solar Project	Ajo, AZ	FMI Inc.	Solar PV*	5 MW	2011
Bagdad Mine Solar	Bagdad, AZ	FMI Inc.	Solar PV	15 MW	2011
Chevron Questa Project	Questa, NM	Chevron	Solar CPV**	1 MW	2011
Avalon Solar Project	Sahuarita, AZ	Asarco	Solar PV	56 MW	2015/16

* Photovoltaic **Concentrated Photovoltaic

Source: (EPA, 2012; EPA, 2015; EPA, 2017, Recurrent Energy, Duke Energy)

A few tailings storage facilities on lands owned by Asarco will be closed in the next several years at the Mission Complex and Hayden Operations. Asarco intends to evaluate siting of a renewable energy project as a potential post-mining land use, building on studies already done by EPA on reclaimed tailings dams on tribal lands at Mission.

Asarco’s parent Grupo Mexico operates a 500 MW combined cycle plant that supplies electricity to the La Caridad and Buenavista del Cobre mines as well as the metallurgical complex all in Sonora, Mexico. New regulations require suppliers to acquire 5% of energy supplied as Clean

Energy Certificates (CECs). Grupo operates a 74 MW wind farm in Oaxaca that supplies energy to some underground mines and Cinemex, a third-party cinema chain in Mexico. More recently, some of the load from mining companies is shifted to more cinema theaters. In 2016, the Energy and Mines Congress presented Grupo Mexico the award for the “Best Use of Wind by a mining company.”

To meet some of the CEC’s and supplying renewable energy to underground mines, Grupo Mexico is developing the following solar projects:

- 11.5 MW solar plant at closed tailings dam at the Santa Barbara mine in Chihuahua;
- 7 MW solar plant at closed tailings dam at the Charcas mine in San Luis Potosi;
- 7 MW solar plant at closed tailings of the former copper refinery in San Luis Potosi;
- 8 MW wind plant near the Santa Eulalia mine in Chihuahua.

In addition, Grupo Mexico is planning over 200 MW solar plants in Sonora that will sell energy to the market and generate CEC’s.

Other mining companies in the United States have similar views regarding siting of solar projects on reclaimed mine lands. For example, “FMI considers siting of renewable energy facilities on former mine lands such as reclaimed tailings storage facilities a viable post-mining land use,” (Cobb, 2017) and “BHP believes that reclaimed storage facilities are well suited for solar installations. Repurposing a large amount of otherwise idle land to a desirable and beneficial post-mining land use and leave a positive legacy for the community, (Parker, 2017).

CONCLUSIONS

Asarco will continue to evaluate the technical and economic feasibility of locating a renewable energy project on a reclaimed tailings storage facility, as it closes tailings storage facilities at its mines in the next 5-7 years. Grupo Mexico is also planning on implementing solar projects both to acquire CECs as well as transitioning to the use of renewable energy for its mining operations and moving towards a more sustainable extractive industry. If some of the projects that are being contemplated by Asarco, Grupo and other mining companies come to fruition, Southern Tucson, Arizona has the potential to become the solar capital on the United States and along with Sonora, Mexico becoming the solar capital of the world.

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