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# Fundamental Considerations Associated with Placing Solar Generation Structures at Central Arizona Project Canal

**Central Arizona Project, Arizona**
**Lower Colorado Region**


**U.S. Department of the Interior**
**Bureau of Reclamation**

**May 2016**

# Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

# Fundamental Considerations Associated with Placing Solar Generation Structures at Central Arizona Project Canal

## Central Arizona Project, Arizona
## Lower Colorado Region

*prepared by*

**Phoenix Area Office**

**U.S. Department of the Interior**
**Bureau of Reclamation**

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# Executive Summary

In 2014 the Bureau of Reclamation's (Reclamation) Science and Technology (S&T) program selected a proposal submitted by the Phoenix Area Office (PXAO) to develop a white paper evaluating placing solar panels at the Central Arizona Project (CAP) canal. The purpose of the white paper is to examine the fundamental considerations relevant to placing solar over or alongside the CAP canal system and its impacts. These considerations and impacts include operations and maintenance, structural, evaporation, costs (design, O&M, land vs over canal), authorities, and stakeholders.

This white paper specifically studies the CAP canal, which extends 336 miles through South west Arizona and ranges from 65-114 ft wide. This canal delivers water throughout Arizona and is a critical asset to Reclamation and its stakeholders in the area. The Central Arizona Water Conservancy District (CAWCD) operates and maintains this canal system on behalf of Reclamation. The focus is the implementation of PV technology o the canal supported by a truss system and alongside the canal mounted on piers. .

Currently, the State of Gujarat, India is the only project in the world that is similar. The 33 foot wide Narmada Canal was covered with ½ mile or 750 meters of PV using a steel truss system for the supporting structure. This is a significant steel structure which would need to be even more robust to span the 90 ft wide CAP canal. Impacts associated with a structure of this magnitude include impeding access to the CAP canal, interfering with operations and maintenance, and possibly compromising the integrity of the CAP canal foundation. There is limited information available on the India installation and the impacts experienced there.

Results indicate that the capital cost of placing PV panels over the CAP canal is approximately 24 percent more costly than placing PV panels next to the canal on either a Reclamation right-of-way, or more ideally, on an off-the-canal solar farm located elsewhere, perhaps on Bureau of Land Management's Solar Energy Zone near the CAP canal. The pier mounts on the ground are approximately 11 percent the cost of the steel truss system required to span the canal.

Covering the CAP canal with PV panels has the possible benefit of reducing evaporation because of the cooling associated with shading. However this savings is small, 6 acre-ft per year, relative to the costs associated with placing solar over the CAP canal.

Additionally, Reclamation owns the CAP, but CAWCD operates and maintains the CAP on Reclamation's behalf. Canal operators have expressed concerns regarding the impacts not only to O&M but the unknown costs associated with solar at the CAP and the potential impacts on the costs of water delivery.

Placing solar at the CAP is an extremely complex issue. This paper was designed to outline the fundamental considerations when placing solar over or alongside the CAP. Based on its findings, there are too many unknowns, especially regarding impacts to O&M and costs to proceed with a project of this nature at the CAP. Potential future research includes evaporation, costs for over the canal structural support, impacts to O&M costs, canal access and how these would affect the costs of water.

# Introduction

## Background

The President's National Energy Policy of 2001 and Section 211 of the Energy Policy Act of 2005 (P.L. 109-58) encourages the development of renewable energy resources, including solar and wind energy, as part of an overall strategy to develop a diverse portfolio of domestic energy supplies for the future.  Through Executive Orders (EO) 13423 and 13514 , President Obama established renewable energy as a priority and greenhouse gas reduction targets for federal agencies (Heimiller, Haase, & Melius, May 2012). In efforts to address the afore mentioned mandates and to offset the power use of the CAP canal, this white paper (written in 2014) will focus on solar renewable power generation.

The generation of solar energy is one of the most rapidly expanding forms of renewable energy in the U.S. and may be considered for installation on either land beside canals or over the canals.  The Federal Government has promoted the expansion of power production from non-hydro renewable energy sources.  The Bureau of Land Management (BLM), this nation's largest land manager, has led the advancement of making federal lands available for such production.

## Location

The Central Arizona Project (CAP) canal (Figure 1) carries water 336 miles, to lands in Maricopa, Pinal and Pima counties, as well as to several communities, including the metropolitan areas of Phoenix and Tucson. The CAP is the largest canal in Arizona, traversing the state through a variety of ecological environments.  The CAP gains nearly 2,900 vertical feet in elevation.


**Figure 1 - Central Arizona Project System Map**

# Purpose of the White Paper

In 2014 the Bureau of Reclamation's (Reclamation) Science and Technology (S&T) program selected a proposal submitted by the Phoenix Area Office (PXAO) to develop a white paper evaluating placing solar panels at the Central Arizona Project (CAP) canal. The purpose of the white paper is to examine the fundamental considerations relevant to placing solar over or alongside the CAP canal system and its impacts. These considerations and impacts include operations and maintenance, structural, evaporation, costs (design, O&M, land vs over canal), authorities, and stakeholders.

# Review of Related Literature

## Gujarat, India

The State of Gujarat in India has commissioned a one-megawatt solar plant on a 750 meter branch of the Narmada Canal near Chandrasan area of Anand Taluka. The State estimates that the PV panels are reducing evaporation by 7.3 acre-feet /year (Kumar). Note the top width of the canal is approximately 33 feet, a third of the width of the CAP canal.

As shown in Figure 2 and Figure 3, the structure is quite large for the 10.1 meter (33 feet wide) span. The average span necessary for the CAP will be about 2 to 2.5 times larger than what was constructed in India, and will vary along the length of the canal from 65 feet to 114 feet.


**Figure 2 - Gujarat India Solar Canal Project (Sardar Sarovar Narmada Nigam Limited)**

**Figure 3 - Gujarat India Solar Canal Project (Sardar Sarovar Narmada Nigam Limited)**

# CAP Power Demands

Conveying water through the CAP canal system from the Colorado River to the terminus near Tucson requires a cumulative pumping lift of approximately 2,900 vertical feet. This requires large amounts of electricity to run the system's 109 pumps to lift approximately 1.5 million acre-feet (MAF) of CAP water. These pumps are located in 15 separate pumping plants. The 4 largest western pumping plants, located along the initial 120 miles of aqueduct, contain the largest pumps and create the majority of CAP's electrical demand. The amount of energy needed for these pumps totals 2.8 million megawatt hours per year which is equivalent to 320 Megawatts (MW) of continuous generation capacity. One mile of solar panels over the canal provided during on-peak hours 65 megawatt hours annually which is roughly 0.002 percent of the CAP canal energy requirements.

The CAP is the largest single end-user of energy in Arizona, getting more than 90 percent of its power from the Navajo Generating Station (NGS) (CAP, 2016); a coal power plant near Page, Arizona. The remainder of the required power comes from market purchases, Hoover Dam, and New Waddell Dam.

CAP load demand is typically highest in the off-peak, non-summer period, averaging about 450 MW. During the May to August period, CAP load demand is typically reduced to approximately 200 MW due primarily to the associated economic benefits of marketing NGS peak power as “surplus power” during the peak summer demands. This excess power is marked to outside entitles on the open market. This demand cycle is the opposite of the solar radiation intensity (insolation). Insolation drives solar energy production in PV cells; more intense solar radiation produces more electricity which occurs in the late spring, summer and early fall periods.

# Types of Solar Installations

## Solar Power

Countries with extensive solar policies—such as Germany and Spain—lead the world in solar deployment. Similarly, the U.S. states with extensive solar incentives that led the United States in both cumulative and annual installations in 2013 were California, Arizona, New Jersey, North Carolina, and Massachusetts (Figure 4) (Solar Energy Industries Association/GTM Research, 2014).

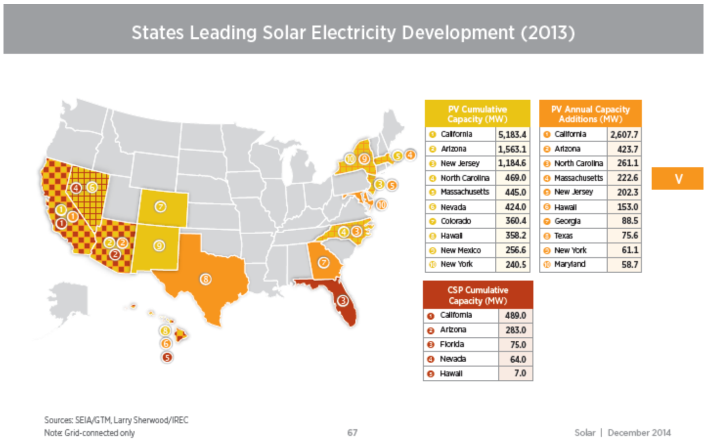
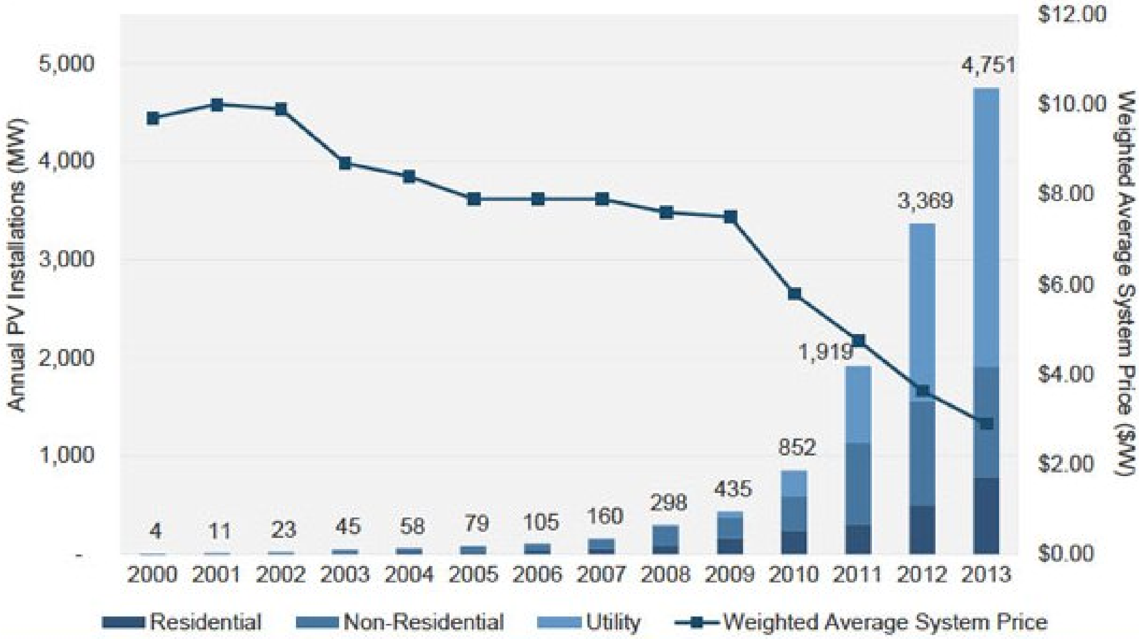



**Figure 4 - States Leading Solar Electric Development 2013 (NREL - 2013 Renewable Energy Data Book)**

## Solar Prices

Falling prices of solar power systems have made solar more affordable. Figure 5 illustrates how lower costs of solar power systems is related to the number of installs. Some of the reasons for this decline in solar power cost are listed below (GTM Research/Solar Energy Industries Association, 2014):

- The U.S. installed 4,751 MW of solar PV in 2013, up 41 percent from 2012 and nearly fifteen times the amount installed in 2008.
- The cost to install solar fell throughout 2013, ending the year 15 percent below the mark set at the end of 2012.
- At the end of 2013 there were more than 440,000 operating solar electric systems in the US with roughly 12,000 MW of PV.
- The US installed 2,106 MW in the fourth quarter alone, 44 percent of the annual total. This makes Q4 2013 by far the largest quarter in the history of the U.S. market, exceeding the next largest quarter by 60 percent.
- The market value of all PV installations completed in 2013 was $13.7 billion.
- Solar accounted for 29 percent of all new electricity generation capacity in 2013, up from 10 percent from 2012. This made solar the second-largest source of new generating capacity behind natural gas.




| Installations (MW) | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residential | 1 | 5 | 11 | 15 | 24 | 27 | 38 | 58 | 82 | 164 | 246 | 304 | 494 | 792 |
| Non-Residential | 2 | 3 | 9 | 27 | 32 | 51 | 67 | 93 | 200 | 213 | 339 | 831 | 1,072 | 1,112 |
| Utility | 0 | 3 | 2 | 3 | 2 | 1 | 0 | 9 | 16 | 58 | 267 | 784 | 1,803 | 2,847 |
| Total Installations | 4 | 11 | 23 | 45 | 58 | 79 | 105 | 160 | 298 | 435 | 852 | 1,919 | 3,369 | 4,751 |

**Figure 5 - U.S. PV Installation and Average System Price, 2000-2013 (Solar Energy Industries Association/GTM Research, 2014)**

# Design Types

## Photovoltaics

PV materials are semiconductor devices that convert sunlight directly into electricity. This is a process of converting photons to electrical voltage through the semiconducting materials. They do so without any moving parts and without generating any noise or pollution. They must be mounted in unshaded locations. PV systems work well in the sunny Arizona area (Heimiller, Haase, & Melius, May 2012).

Panels made of semiconductor material generate electricity when exposed to sun light. PV panels are not 100 percent efficient due to technological limitations, alignment with the sun, ambient heat, cleanliness of the panel and a number of other factors. In 2015, the PV industry was able to achieve 22.5 percent efficiency (MacDonald, 2015).

### *Thin film photovoltaics*

Thin film PV is a subset of the standard PV panels. They are lower weight than the standard PV panels. However, currently they are also less efficient. They are being used as an alternative building material. There have been discussions regarding their use in floating on the water surface of the canal. Floating solar panels are typically found on quiescent bodies of water using standard solar panels on floatation structures. If this were to be pursued, the corrosive water conditions would require additional study and protective construction/operation procedures.

# Solar at CAP Design and Costs

## Design Assumptions

The design assumptions in this white paper are not all inclusive and a more robust engineering design study is required. To calculate the cost per megawatt of capacity to cover the CAP canal with standard PV panels, the following basic assumptions were made:

- Steel trusses must span 100 feet with no center support.
- 39 steel trusses will be placed at a spacing of 25 feet.
- Canal banks are available for foundation installation for the trusses.
- Canal banks can be used to install underground electrical cabling and ductwork.
- Panels will be located in close proximity to the CAP transmission switchyard locations to reduce transmission losses.

## Additional Considerations

Public safety is an important part of Reclamation’s infrastructure related responsibilities, especially on its canals systems. Reclamation has safety requirements of buoy’s, escape ladders etc. Covering the canal surface could prevent escape or rescue. Furthermore, trusses across the canal could provide an attraction for individuals to cross, play or fish from the structures. This is a very dangerous situation as there are no handrails on solar installations, and falling into the canal would be a high risk possibly resulting in death.

The PV Panel array illustrated in Figure 6 shows a straight segment of the canal. (The figure shows only a portion of the arrays; a total of 39 rows would be required for 1 MW. The total length of the canal that would be covered is 975 feet, or 0.19 miles). No consideration is given for operations and maintenance (O&M) access for the panels or the canal, orif the canal bank would support the weight of the trusses and PV panels without negatively impacting the canal structure. All of these assumptions require additional study.

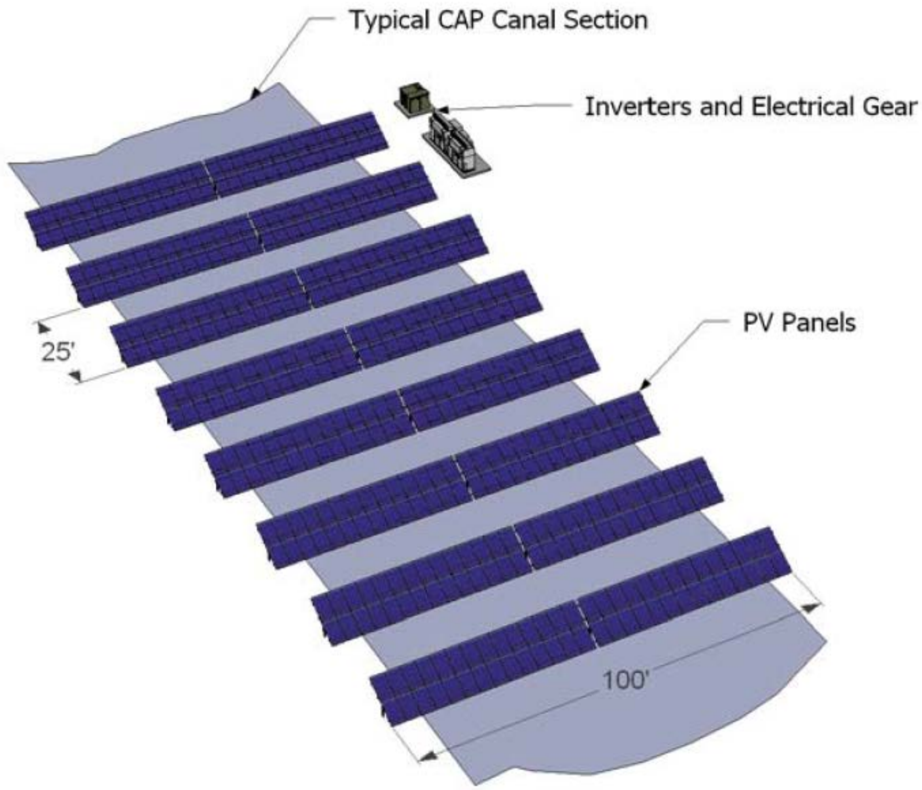



**Figure 6- Proposed CAP Canal PV Installation for One Megawatt Capacity (only a portion of the modules shown)**

Another consideration which needs to be evaluated is the angle of the canal in relationship to the angle of incidence, or the angle at which the sun's rays strike the earth. The structural panel supports may not work in many locations along the CAP without additional engineering considerations due to the bearing and sinuosity of the canal.

Other issues to consider are: longer truss spans, more materials, higher construction costs, canal embankment availability, canal embankment penetration, panel and truss removal and replacement for O&M on the canal lining or embankments, and increased loadings on the canal embankments. These details are not within the scope of this paper, however if a more detailed report is considered in the future these should be included.

A typical ground-mounted PV configuration is shown on Figure 7. This configuration will allow for proper alignment for optimum energy production. This configuration also allows for O&M access.

An important consideration is the distance from solar arrays to existing electrical substations, and ensuring the substation can accept the incoming power from the array.

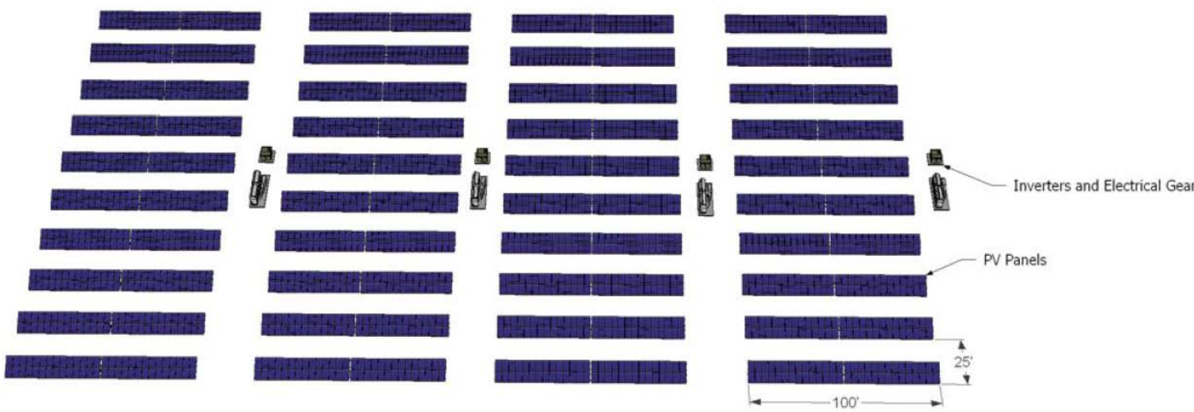



**Figure 7- Proposed Ground-Mounted PV Installation for One Megawatt Capacity**

## Costs

These costs only include basic design and construction costs for 1 MW of power. Using the above design assumptions (Pg. 12), the following conceptual level cost estimate was developed for Canal-Mounted (Table 1) and Ground-Mounted (Table 2) installations for one-megawatt of power on 975 feet of the CAP Canal. These cost estimates were developed in part from the National Renewable Energy Laboratory System Advisor Model (NREL-SAM) software in 2014. No costs for power transmission, O&M to the canal or panels, panel removal and replacement for O&M, or extra costs for panel installation over a canal are included in these estimates. Table 3 compares the 2014 capital costs developed in Tables 2 and 3.

**Table 1 – 2014 Conceptual Level Cost Estimate for Installing One Megawatt PV Capacity over 975 ft of the CAP Canal (NREL-SAM)**

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | AMOUNT |
|---|---|---|---|---|
| **Contract Costs - One Megawatt Capacity** | | | | |
| PV Modules | 1,000 | kWdc | $630.00 | $630,000 |
| Inverter | 1,000 | kWac | $260.00 | $260,000 |
| Remainder of Electrical Equipment | 1,000 | kWdc | $630.00 | $630,000 |
| Installation Labor | 1,000 | kWdc | $700.00 | $700,000 |
| Installation Inefficiencies Over Canal (10%) | 1 | | $700,000 | $70,000 |
| Installer Margin and Overhead | 1,000 | kWdc | $160.00 | $160,000 |
| Foundation – Concrete Piers | 78 | ea | $2,000.00 | $156,000 |
| Steel Truss System, Panel Connections, Walkway | 3,900 | lf | $150.00 | $585,000 |
| | | | | |

| DESCRIPTION | | QUANTITY | UNIT | UNIT | AMOUNT |
|---|---|---|---|---|---|
| Subtotal | | | | | $3,191,000 |
| | | | | | |
| Contingency | 25% | | | | $797,750 |
| | | | | | |
| Subtotal for One Megawatt - Capital Cost | | | | | $3,988,750 |
| | | | | | |
| **Non-Contract Cost** | | | | | |
| Permitting, Environmental Studies | | 1,000 | kWdc | $170.00 | $170,000 |
| Engineering | | 1,000 | kWdc | $180.00 | $180,000 |
| Grid Interconnection | | 1,000 | kWdc | $150.00 | $150,000 |
| | | | | | |
| Subtotal for Non-Contract Costs | | | | | $500,000 |
| | | | | | |
| **Total Cost for One Megawatt of capacity** | | | | | $4,488,750 |
| Total Installed Cost per Capacity ($/Watts direct current (Wdc)) | | | | | $4.49 |

The SAM model (NREL-SAM) calculated a levelized cost of energy (LCOE) of approximately $0.13/kWh for the one megawatt capacity over the CAP Canal. The LCOE is total cost of installing and operating a project expressed in dollars per kilowatt-hour of electricity generated by the system over its life. It accounts for:

- Installation costs
- Financing costs
- Taxes
- Operation and maintenance costs
- Salvage value
- Incentives
- Revenue requirements (for utility financing options only)
- Quantity of electricity the system generates over its life

**Table 2 – 2014 Conceptual Level Cost Estimate for Installing One Megawatt PV Capacity near CAP Pumping Stations on Federal Lands (NREL- SAM)**

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | AMOUNT |
|---|---|---|---|---|
| **Contract Costs - One Megawatt Capacity** | | | | |
| PV Modules | 1,000 | kWdc | $630.00 | $630,000 |
| Inverter | 1,000 | kWac | $260.00 | $260,000 |
| Remainder of Electrical Equipment | 1,000 | kWdc | $630.00 | $630,000 |
| Installation Labor | 1,000 | kWdc | $560.00 | $560,000 |
| Installer Margin and Overhead | 1,000 | kWdc | $160.00 | $160,000 |
| Foundation – Pier Mounts | 570 | Ea | $150.00 | $85,500 |
| | | | | |
| Subtotal | | | | $2,325,500 |

| DESCRIPTION | | QUANTITY | UNIT | UNIT | AMOUNT |
|---|---|---|---|---|---|
| | | | | | |
| Contingency | 25% | | | | $581,375 |
| | | | | | |
| Subtotal for One Megawatt - Capital Cost | | | | | $2,906,875 |
| | | | | | |
| **Non-Contract Cost** | | | | | |
| Permitting, Environmental Studies | | 1,000 | kWdc | $170.00 | $170,000 |
| Engineering | | 1,000 | kWdc | $180.00 | $180,000 |
| Grid Interconnection | | 1,000 | kWdc | $150.00 | $150,000 |
| | | | | | |
| Subtotal for Non-Contract Costs | | | | | $500,000 |
| | | | | | |
| **Total Cost for One Megawatt of capacity** | | | | | $3,406,875 |
| Total Installed Cost per Capacity ($/Wdc) | | | | | $3.41 |

**Table 3 – 2014 Support Structure Cost Comparison of 975 ft of Canal vs Ground Mounted PV System for One Megawatt Capacity**

| System | Support Structure | Total Support Cost | Capital Costs |
|---|---|---|---|
| Canal Mounted | Steel Truss/Concrete Piers | $741,000 | $4,488,750 |
| Ground Mounted | Pier Mounts | $85,500 | $3,406,875 |

These cost estimates are based on rules of thumb and are high level in nature. Their purpose is to provide a basic understanding of costs. From a practical perspective, these costs may be quite low.

# Impacts to Operation and Maintenance (O&M)

CAWCD is the operating entity of the CAP canal and in the past has expressed concerns regarding installation of solar panels. CAWCD is required to have access to all portions of the canal at all times in order to ensure that the primary mission of water delivery is accomplished. Installation of solar over the canal would impact regular inspection and corrective actions for settlement, lining cracks, embankment erosion, sediment removal, animal burrows, vegetation, and flow control structures.

One specific example of impacts to O&M includes a situation where repairs to canal lining and embankments occurred when seepage was observed. This was a critical repair as the canal lining and embankment fail recently near the pumping plant causing a very long and expensive outage. During this repair, another lining failure was noted by the helicopter aerial inspection and repair locations were expanded. Covering the canal surface and lining would severely impact the ability for these type of inspections and observations of the canal lining.

A key physical consideration for covering the length of the CAP canal with PV panels is the geometric configuration of the canal, with a typical top width of the canal between 80 and 90 feet (Figure 8). This is a critical dimension as this would be the unsupported distance the solar panels would need to span. A span supporting this distance and associated solar panel weight would require a massive and substantial structure along with a tight longitudinal spacing along the canal alignment.

**Figure 8 - Typical CAP canal cross section.**

Mid-span supports structure located within the canal prism will not be allowed since the existing concrete lining is not designed for those loads. Unsupported structures which will span distances of 90 feet and greater will necessitate significant structural components to carry the panel weights and live loads. The tight spacing for these structures and non-portability of the support infrastructure will hinder operational maintenance of the aqueduct. There may be some other types of supports, like cabling, that may be more cost effective, but these would require further study to evaluate cost and impacts to O&M.

While the focus of this white paper centers on the logistics and impacts of installing solar in the physical area immediately above the open channel canal, it is important to recognize that options for solar power have been explored using CAP right-of-way outside the canal. The entire right-of-way of Reclamation canals are typically fully utilized for alternate project uses such as access roads, flood detention, communication and control cables, and environmental mitigation commitments.

# Evaporation Savings Analysis

## Amount of Water Saved

Evaporative studies on shading water bodies with different materials have been examined throughout the world. According to an evaporation pan study conducted by the King Saud University (Alam & AlShaikh, 2013) in Saudi Arabia, using palm fronds as a shade, the amount of evaporative water savings is between 47 percent using one layer of palm fronds, up to 58 percent using two layers of fronds. Another evaporation pan study by the University of Southern Queensland Toowoomba (Craig, Green, Scobie, & Schmidt, 2005) in Australia used a NetPro shade cloth which resulted in a yearly evaporative savings of 68 percent.

Covering the CAP canal with PV panels has the possible benefit of reducing evaporation because of cooling associated with shading. Although actual evaporation is dependent on several factors studies indicate there may be potential to reduce evaporation by 50 percent by shading. Factors that may influence evaporation are: air temperature, water temperature, wind, shading efficiency, humidity, water depth, heat from the solar panels, etc. For the purpose of this study, yearly evaporation is estimated at 6 feet per year in the CAP canal. With 1 MW (or 975 ft) of solar and assuming a CAP canal with of 90 ft, the evaporation would normally be roughly 12.1 acre-feet (ac-ft) per year. If shading conserves 50 percent, 6 ac-ft may potentially be conserved per year from shading benefits. Additional evaporation studies conducted on the CAP canal would need to be conducted in order to better quantify actual evaporation savings from shading the canal with PV panels.

## Costs

As shown in Table 4, the cost to cover 975 ft of the CAP canal with solar panels outweighs the benefits of the value of water saved.

**Table 4 - Cost Comparison for Cost to Cover Canal with Solar versus Water Evaporation Savings to generate 1 MW over 975 feet of canal**

| Type of Cost | Unit Cost |
|---|---|
| Cost to Cover Canal with Solar to generate 1MW (975 ft) | $4,488,750 |
| Value of water saved by covering canal per acre-foot | $170 per acre-foot |
| Water saved by covering canal in acre-feet | 6 acre-feet |
| Value of water saved by covering 975 ft canal per year | $1,020 |

# Consideration for Future Study

## Bureau of Reclamation Land Availability

The Department of the Interior and Reclamation leadership have expressed interest regarding the feasibility of developing renewable power supplies on Reclamation Lands (Heimiller, Haase, & Melius, May 2012).

Reclamation, while primarily a water and hydropower management agency, holds title to lands that may be well suited to wind and/or solar power installations (typically, greater than 1 MW) insofar as these lands:

- are in parts of the West receiving abundant solar radiation and wind
- have good road access but restricted public access
- are often adjacent to power plants, substations, pumps, transmission lines, or other components of the energy grid

In addition, Reclamation has a number of facilities and structures, such as visitor centers, pumping plants, and other structures that may be suitable for deployment of renewable energy and energy efficiency technologies.

However, Reclamation lands are not ideally suited to support supplemental uses such as renewable energy development, primarily from the standpoint that Reclamation lands are typically geometrically linear in nature and are often encumbered by project operational or environmental mitigation (Department of the Interior's Treasured Landscape) requirements. These priority uses especially along the CAP limit the ability to consider overlapping uses such as energy development.

## Bureau of Land Management Land Availability

Based on an extensive public outreach process, the Arizona State Office of the United States Department of the Interior, Bureau of Land Management (BLM), also identified 64 previously disturbed sites on federal, state, municipal and private lands in their Restoration Design Energy Project Environmental Impact Statement, dated, October 2012, for renewable energy development." Section 7, "Nominated Site Profiles (Bureau of Land Management, October 2012). Eleven of these sites are located on or near short segments of the CAP canal, primarily outside CAP right-of-way, and could potentially be used to site solar power installations.

BLM's Solar Energy Zones (SEZ) land, predominantly off Reclamation's controlled right-of-ways, has been set aside for utility scale solar development and there are many advantages to using these Zones. (e.g., cost & timing of engineering & design, regulatory, construction, O&M, administrative, NEPA).

The BLM has focused particularly on solar energy having created 19 SEZs totaling about 285,000 acres of land available for utility scale solar energy production. If fully built out, projects in the designated areas could produce as much as 23,700 megawatts of solar energy, enough to power approximately 7 million homes. The program also keeps the door open, on a case-by-case basis, for the possibility of carefully sited solar projects outside solar energy zones on about 19 million acres in "variance" areas. SEZs have already had considerable environmental and other regulatory analysis performed that increases their cost effectiveness as well as decreasing the time necessary from a developer's concept to the generation of power.

The BLM intends to implement the following policies and procedures for projects in SEZs, and complete the rulemaking items and other initiatives described below, in an effort to encourage future utility-scale solar energy development in the SEZs. (Bureau of Land Management, 2015)

- Facilitate Faster and Easier Permitting in SEZs
- Improve and Facilitate Mitigation
- Facilitate the Permitting of Needed Transmission to SEZs
- Encourage Solar Energy Development on Suitable Lands Adjacent to SEZs
- Provide Economic Incentives for Development in SEZs

Figure 9 shows the location of all the BLM SEZs in relation to the CAP Pump Stations. The closest zone is Brenda, Arizona. It is approximately 20 miles from either the Little Haquahala or Bouse Hills pump stations. Transmission costs from this SEZ to either pump station would be substantial.

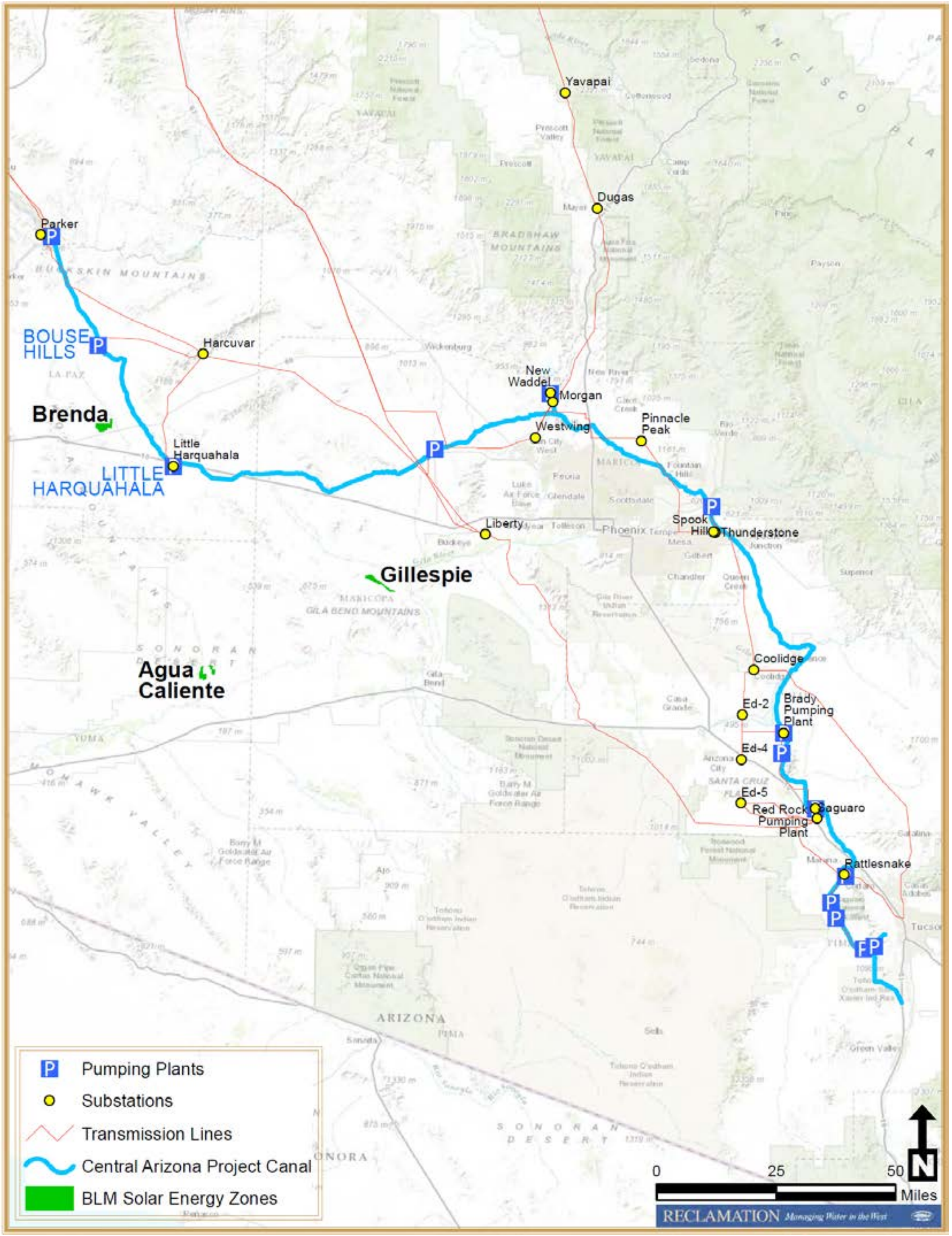



**Figure 9 - BLM Solar Energy Zones in Arizona**

## Authority

Reclamation has the authority to develop project specific hydropower and two thermal plants. For federal development, legislation would be required giving Reclamation the authority to develop solar. Otherwise, private development using the land lease authorities where the project meets authorized purposes and does not interfere with project operations or contractual requirements would be necessary.

# Conclusions

From a cost perspective the disadvantages outweigh the benefits of placing solar over the CAP canal. One main disadvantage is that a significant structure would be necessary to span the canal to support the panels. Concerns with such support structure include: cost, access restriction to the CAP canal, interference of O&M, limited panel orientation due to the canal positioning as well as the possibility of compromising the integrity of the CAP canal foundation. Covering the CAP canal with PV panels has the possible benefit of reducing evaporation because of cooling associated with shading. Assuming shading conserves 50 percent, 6 ac-ft may potentially be conserved per year from shading benefits.

The results of this white paper show that the cost of placing PV panels over the CAP canal is approximately 24 percent more costly than placing PV panels near the canal on Reclamation right-of-ways, or on BLM land.

Further study is required in order to recommend and proceed with solar installation at the CAP canal. Additional research that was identified include: improved structural cost estimates, improved O&M cost estimates, improved impacts to O&M, impacts to the canal and canal lining, evaporation studies including evaporation with shading, viability of solar power over small canals, and a robust design for solar panels to be installed in remote locations.

# Reference List


Alam, S., & AlShaikh, A. A. (2013). Use of palm fronds as shaded cover for evaporation reduction to improve water storage efficiency. *Journal of King Saud University – Engineering Sciences (2013) 25*, 55-58.

Bureau of Land Management. (2015, August 8). *Solar Eneergy Program Wester Solar Plan*. Retrieved September 25, 2015, from BLM Solar Energy Program: http://blmsolar.anl.gov/sez/policies/incentives/

Bureau of Land Management. (2015, August 8). *Solar Energy Program Wester Solar Plan*. Retrieved September 25, 2015, from BLM Solar Energy Program: http://blmsolar.anl.gov/sez/policies/incentives/

Bureau of Land Management. (October 2012). *Renewable Arizona: Restoration Design Energy Project - FINAL, Environmental Impact Statement Volume II of II.*

CAP. (2016, 06 02). *Navajo Generating Station*. Retrieved 06 02, 2016, from CAP-AZ: http://www.cap-az.com/public/navajo-generating-station

Central Arizona Project. (December 2010). *Solar Energy Alternatives.*

Chu, Y. (2011). *Review and Comparison of Different Solar Energy Technologies.* Global Energy Network Institute.

Craig, I., Green, A., Scobie, M., & Schmidt, E. (2005). *Controlling Evaporation Loss from Water Storages.* NCEA Publication No 1000580/1.

GTM Research/Solar Energy Industries Association. (2014, March 10). *2013 Solar Industry Report release*. Retrieved from Renewable Energy Focus.com: http://www.renewableenergyfocus.com/view/37374/gtm-research-solar-energy-industries-association-release-2013-solar-industry-report/

Heimiller, D., Haase, S., & Melius, J. (May 2012). *Renewable Energy Assessment for the Bureau of Reclamation.* Golden Colorado: NREL.

Kumar, K. (n.d.). Retrieved June 2014, from Nordic Folkecenter: http://www.folkecenter.net/mediafiles/folkecenter/pdf/SOLAR-ENERGY-IN-INDIA.pdf

MacDonald, F. (2015, 10 8). *Science Alert*. Retrieved from Panasonic has made the world's most efficient rooftop solar panel: http://www.sciencealert.com/panasonic-has-produced-the-world-s-most-efficient-rooftop-solar-panel-with-22-5-module-efficiency

Martinez Alvarez, V., Baille, A., Molina Martinez, J. M., & Gonzalez-Real, M. M. (2006). Efficiency of shading materials in reducing evaporation from free water surfaces. *Agricultural Water Management 84 February*, 229-239.

NREL-PVWatts. (n.d.). *PVWatts*. Retrieved July 2014, from http://pvwatts.nrel.gov/pvwatts.php

NREL-SAM. (n.d.). *System Advisor Model (SAM)*. Retrieved July 2014, from NREL: https://sam.nrel.gov/

Sardar Sarovar Narmada Nigam Limited. (n.d.). Retrieved July 24, 2014, from http://www.sardarsarovardam.org/Client/PictureDetail.aspx

Solar Energy Industries Association/GTM Research. (2014). *Solar Market Insight Report 2013 Year in Review.* http://www.seia.org/research-resources/solar-market-insight-report-2013-year-review.