

# Parabolic Trough Organic Rankine Cycle Solar Power Plant

S. Canada, G. Cohen, R. Cable, D. Brosseau, and H. Price

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# Parabolic Trough Organic Rankine Cycle Power Plant

S. Canada, Arizona Public Service, Phoenix, Arizona ([Scott.Canada@aps.com](mailto:Scott.Canada@aps.com))

G. Cohen and R. Cable, Solargenix Energy, Raleigh, North Carolina

D. Brosseau, Sandia National Laboratories, Albuquerque, New Mexico

H. Price, National Renewable Energy Laboratory, Golden, Colorado

## ABSTRACT

Arizona Public Service (APS) is required to generate a portion of its electricity from solar resources in order to satisfy its obligation under the Arizona Environmental Portfolio Standard (EPS). In recent years, APS has installed and operates over 4.5 MWe of fixed, tracking, and concentrating photovoltaic systems to help meet the solar portion of this obligation and to develop an understanding of which solar technologies provide the best cost and performance to meet utility needs.

During FY04, APS began construction of a 1-MWe parabolic trough concentrating solar power plant. This plant represents the first parabolic trough plant to begin construction since 1991. The plant will also be the first commercial deployment of the Solargenix parabolic trough collector technology developed under contract to the National Renewable Energy Laboratory (NREL). The plant will use an organic Rankine cycle (ORC) power plant, provided by Ormat. The ORC power plant is much simpler than a conventional steam Rankine cycle power plant and allows unattended operation of the facility.

### 1. Objectives

The primary objective of the parabolic trough ORC plant is to generate electricity to satisfy the APS solar obligation under the Arizona EPS. However, a secondary objective is to evaluate the cost and performance of this technology in comparison to the other solar technologies that APS is implementing. The DOE Solar Technology Program's objective is to use this project to help baseline the cost and performance of the current generation of parabolic trough technology.

### 2. Technical Approach

APS is a leader in the development and demonstration of new and emerging solar power technologies. APS has an extensive portfolio of fixed, tracking, and concentrating photovoltaic systems, which are currently operating in many locations across Arizona. The APS STAR facility is a world-class solar research facility dedicated to understanding how these technologies perform for utility and customer applications.

APS also has an extensive history supporting the development of concentrating solar power (CSP) technologies. Recent advances in parabolic trough solar technology and organic Rankine power cycle technology have made the possibility of a small parabolic trough plant economically feasible. Because of this, APS decided to competitively procure a 1-MWe parabolic trough plant. APS

selected the team of Solargenix Energy, Inc., of Raleigh, North Carolina, and Ormat International of Reno, Nevada, to develop the plant. Solargenix is the system integrator and provider of the parabolic trough solar field and Ormat is the provider of the ORC power plant. APS has partnered with SunLab<sup>1</sup> for technical support and to offer the project as a potential test bed for evaluation of parabolic trough technologies. The APS/SunLab team will use the plant to:

- Assess the cost and performance of small megawatt-scale trough plants
- Evaluate the first commercial deployment of the new Solargenix parabolic trough concentrator developed under a DOE cost-shared R&D contract
- Evaluate the integration of a modern organic Rankine power cycle with a parabolic trough solar field technology,
- Demonstrate unattended operation of a commercial parabolic trough power plant, and
- Demonstrate the cost, performance, and operating characteristics of a thermochemical thermal energy storage system.

### 3. Results and Accomplishments

In April 2002, APS issued a request for proposal for a 1-MWe parabolic trough plant. The Solargenix/Ormat team was selected and notified of award in August 2002. Construction began in June 2004 with grading of the site, installation of a security fence and installation of a water line from the existing Saguaro power plant. Construction of the solar field and installation of the power plant will begin in Fall 2004. Construction will be completed and initial operation should begin in Spring 2005.

The plant is located next to the existing APS Saguaro power plant facility approximately 30 miles northwest of Tucson, Arizona. The plant will initially have 10,340 square meters of parabolic trough solar field supplied by Solargenix. The power plant will be nominally a 1-MWe organic Rankine cycle system with wet cooling supplied by Ormat. Table 1 shows the main design characteristics of the plant. Note that the plant is being designed with the possibility of being expanded at some point in the future. Table 1 shows design information and key metrics for parabolic trough technology from the multi-year technology plan for both the initial base and the expanded system designs.

This is the first commercial parabolic trough power plant built by Solargenix Energy. However, Solargenix also plans to begin construction on a 50-MWe parabolic trough plant in

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<sup>1</sup> SunLab is a collaboration between NREL and Sandia National Laboratories in support of the U.S. DOE Solar Technology Programs work on concentrating solar power technologies.

Nevada prior to completion of this project. As a result, this project provides an excellent opportunity for Solargenix to ramp up capabilities in preparation for the larger plant.

### 3.1 SunLab Technical Support.

Prior to this project, APS staff had limited experience with parabolic trough solar technology. APS choose to partner with SunLab to help tap into the extensive parabolic trough knowledgebase that exists in the labs and industry. APS included SunLab in the project design review process. The lab contributions, in particular, helped validate the general process design being proposed, and provided some assurance that the plant should achieve the projected design point and annual performance.

### 3.2 Solargenix Concentrator.

Solargenix is using a new parabolic trough concentrator design developed under DOE's USA Trough Initiative. The APS project will be the first commercial deployment of the new Solargenix concentrator. The project provides the opportunity to evaluate the design in a commercial operating system.

### 3.3 Organic Rankine Power Cycle.

The Ormat power plant is a relatively standard organic Rankine cycle adapted from geothermal applications using n-pentane working fluid. The decision to use wet cooling resulted in a significant improvement in power-cycle efficiency during the Tucson summer.

### 3.4 O&M Database.

The success or failure of this project could depend on the eventual cost of operating and maintaining the plant. SunLab is modifying an existing PV database developed by Sandia that APS has used to track O&M costs of PV systems

### 3.5 Thermal Energy Storage.

Although the plant will initially be constructed without thermal energy storage (TES), APS is very interested in looking at the possibility of adding TES to the plant to improve the dispatchability of the plant. This allows solar output to be shifted to better match the peak power demand of the utility. The output from the 1-MWe plant is in itself insignificant in terms of the overall APS system load. However, the project provides an opportunity to see whether or not a solar thermal electric power plant with storage can actually dispatch solar electricity in a reliable enough manner to be considered a firm peak power source.

A team including APS, Solargenix, SunLab, and Nexant has developed a preliminary TES design for the plant. The design uses a direct thermocline storage system where the same fluid is used in the solar field and storage system. The thermocline uses a single storage tank that is filled with packed bed-filler media to reduce the volume of storage fluid required. The thermocline TES system reduces the cost by over 50% from a more conventional two-tank TES system. The primary disadvantage of a thermocline storage system is that the tank's thermocline zone, the region between hot and cold fluid, has an impact on both the solar plant and power plant operation. The APS project would allow these interactions to be better understood in a commercial plant operating environment.

## 4. Conclusions

The APS parabolic trough power plant is currently under construction and on-schedule for completion in early 2005. This is the first new parabolic trough plant to be built in 13 years, and the first to be owned by a utility. The collaboration between APS, Solargenix, and SunLab on this project has been positive and is likely to result in a more successful and valuable demonstration of the technology for all participants.

The development of the 1-MWe-trough plant has proven to be a good learning experience for APS. The current project has generated significant interest within the APS power generation group. As a result, the power generation group is looking for existing facilities within the APS system that could be re-powered with solar.

The APS project is proving to be a valuable opportunity for Solargenix. The 1-MWe project will use 24 of their new concentrators. This offers a reasonable scale-up in manufacturing and preparation for the 50-MWe project in Nevada, which will include 640 collectors.

For the DOE Solar Technology Program, the collaboration with APS provides an opportunity to get first-hand experience with the next generation of parabolic trough solar technology. The project also offers a low-cost and low-risk opportunity for field-testing new thermal energy storage technology in a commercial solar plant, yet at a small enough size that the costs for a demonstration are not excessive.

**Table 1. APS Plant Characteristics**

Plant Location:	Saguaro, AZ	
Direct Normal Solar	2636 kW/m <sup>2</sup> -yr	
Plant Size (nominal)	1.0 MWe	
ORC Turbine gross output	1.16 MWe	
Solar Field Heat Transfer Fluid	Xceltherm 600	
Inlet Temperature	120°C	
Outlet Temperature	300°C	
ORC Working Fluid	n-pentane	
ORC Inlet Temperature	204°C	
ORC Inlet Pressure	22.3 Bara	
ORC Design Point Efficiency	20.7%	
	Base	Expanded
Solar Field Size	10,340 m <sup>2</sup>	17,233 m <sup>2</sup>
Land Area	40,000 m <sup>2</sup>	64,000 m <sup>2</sup>
Thermal Energy Storage		
Design	none	thermocline
Capacity	0 hrs	6 hrs
Annual Capacity Factor	23%	40%
Solar to Electric Efficiency		
Design Point	12.1%	12.1%
Annual	7.5%	7.9%

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