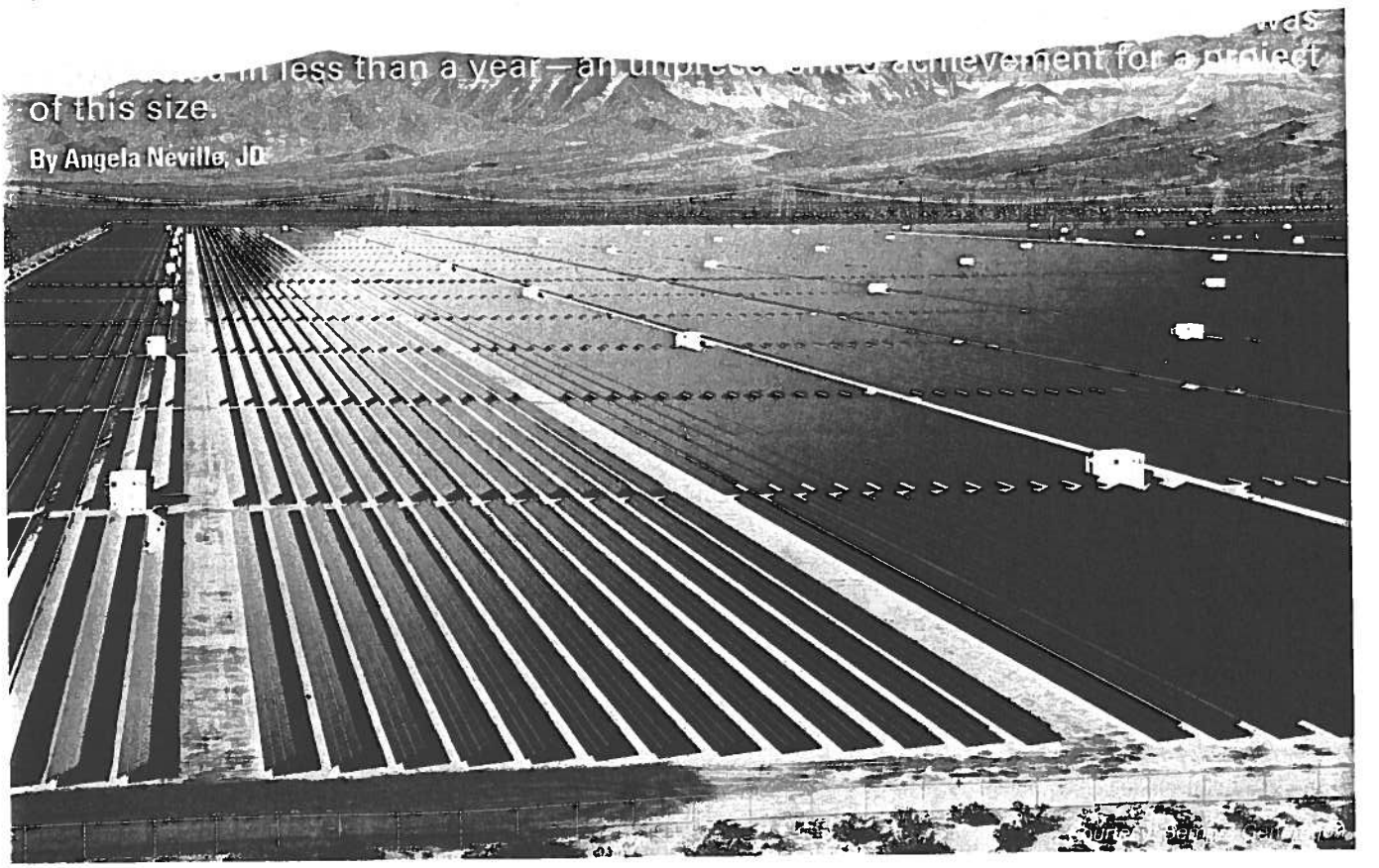
Copper Mountain Solar 1, Boulder City, Nevada

Owner/operator: Sempra Generation



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By Angela Neville, JD

Nevada is a sparsely populated state that contains large expanses of desert dotted with sagebrush and tumbleweeds. Because the southern Nevada desert offers intense year-round sunshine, there are few places in the world better suited for solar energy development.

The ample solar resource in southern Nevada was a main reason that Sempra Generation chose to build the Copper Mountain Solar 1 plant on a 380-acre tract in Boulder City, which is about 20 miles southeast of Las Vegas (Figure 1). Additional factors that made this location optimal for solar development were expansive available land and close proximity to major transmission lines that provide access to major markets, Scott Crider, director of external affairs, Sempra Generation, told *POWER* in October. (Boulder City sits between the Hoover Dam Powerplant and Las Vegas.)

When the facility entered service in December 2010, it was the largest photovoltaic (PV) plant in the U.S. The 48-MW installation produces an estimated 100 GWh of emission-free electricity on an annual basis. The new plant is located adjacent to Sempra Generation's 10-MW El Dorado Solar installation (a 2009 *POWER* Top Plant). Power generated from the project is sold to Pacific Gas & Electric under a 20-year contract.

On March 18, Nevada Governor Brian Sandoval, Boulder City Mayor Roger Tobler, Sempra Generation President and CEO Jeffrey W. Martin, and other dignitaries gathered to officially dedicate the new solar plant.

In his comments, Governor Sandoval praised Sempra Generation for its commitment to Nevada and for creating hundreds of local construction jobs during building of the solar facility: "This project exemplifies my goal of making Nevada into the renewable energy capital of the country. Projects of this magnitude provide hundreds of jobs and invest millions of dollars in our state."

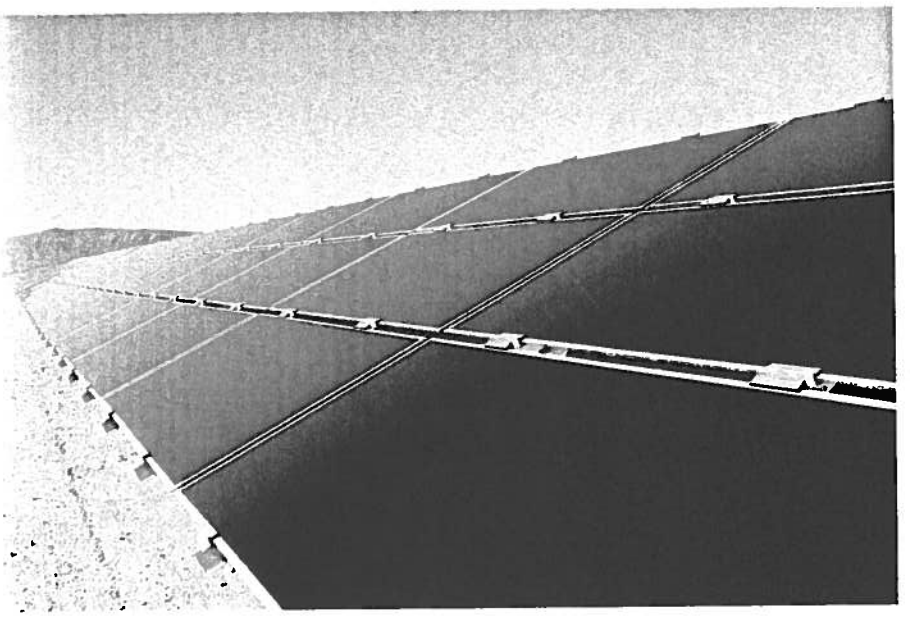
Copper Mountain Solar 1 was named "Solar Project of the Year" by *Renewable Energy Magazine.*

Operations Overview

"The landmark solar installation was built in less than a year, which required an innovative approach to development in order to achieve this scale and construction efficiency," said Crider.

First Solar supplied the thin-film PV solar panels and served as the engineering, procurement, and construction contractor for Copper Mountain Solar 1.

1. Hitting the jackpot. The 48-MW Copper Mountain Solar 1 is located in Boulder City, approximately 20 miles southeast of Las Vegas. The facility is currently the largest photovoltaic (PV) solar plant in the U.S. Its PV modules do not require the use of water to produce emissions-free electricity. *Courtesy: Sempra Generation*



First Solar's PV modules have a number of key design features:

- The front (superstrate) and back (cover) glass laminated sheets are heat-strengthened to withstand handling and thermally induced stresses, while avoiding breakage over the 25-plus-year module life.
- The semiconductor stable cadmium telluride (CdTe) compound semiconductor material, applied in a very thin layer, forms the active photovoltaic cells, which convert sunlight into electricity.
- Laminate material is used to bond the cover glass to the substrate and thereby seal the PV device from the environment.

The PV module specifications are as follows:

- Length: 1,200 mm (47.24 inches)
- Width: 600 mm
- Weight: 12.0 kg (26.45 pounds)
- Thickness: 6.8 mm

Crider pointed out that Copper Mountain Solar 1 is the first renewable power plant to operate under a unique California Independent System Operator (CAISO) "pseudo-tie" pilot program. The "pseudo-tie" transmission arrangement allows an out-of-state renewable resource generating plant to deliver electricity as if the generator were located in, or directly connected to, CAISO. He emphasized that "the pilot program is providing critical data to help CAISO test and validate its systems and procedures for the management of out-of-state variable resources."

In support of CAISO's new interconnection initiatives for renewable power generators, Copper Mountain Solar 1 was also among the first solar power plants to implement a customized plant control system that allows active power management, Crider explained. This functionality allows the plant operations team to quickly respond to system requirements—such as limiting power output—from a consolidated control center, rather than manually shutting down individual units distributed throughout the facility.

Boosting the Nevada Economy

Sempra Generation received federal and state tax incentives for the development of Copper Mountain Solar 1. These incentives play a critical role in the ongoing development of utility-scale solar projects in the U.S., according to Crider. However, this project is a net revenue generator for taxpayers. Crider noted that "for every $1 in tax incentives received, Copper Mountain Solar 1 will generate $2 in new land lease and tax incentives for federal, state, and local governments." Additionally, the project created hundreds of new construction jobs and is helping move Nevada's clean energy economy forward. Eight full-time maintenance and operations employees currently operate the plant.

"Over the life of the project, the facility will generate about $135 million in new revenue for state, local, and federal governments," Crider said. "For example, Boulder City, Nev., is using the land lease revenue from the project to fund essential city services like police, fire, and park maintenance."

Looking Ahead: Copper Mountain Solar 2

"Copper Mountain Solar 1 represents Sempra Generation's commitment to developing world-class alternative energy projects that generate a new source of clean power and create jobs," said Sempra's Martin. "But the success of Copper Mountain Solar 1 can be directly attributed to the vision and support of Boulder City, Pacific Gas & Electric, and many state and federal officials in Nevada. Their leadership is accelerating our country's transition to a more sustainable energy future."

In keeping with its goal of promoting solar energy, Sempra Generation is now planning a major expansion of its landmark solar installation in Boulder City. "The new facility will be called Copper Mountain Solar 2, and it will further solidify Sempra Generation and Boulder City as sustainable energy leaders," Crider said.

Construction on the 1,100-acre site is expected to begin in early 2012. Power generated at the new 150-MW solar plant will be sold to Pacific Gas & Electric under a 25-year contract.

The first 92 MW of solar panels at Copper Mountain Solar 2 will be installed by 2013; the remaining 58 MW are expected to be completed by 2015. The new facility will deliver the following benefits:

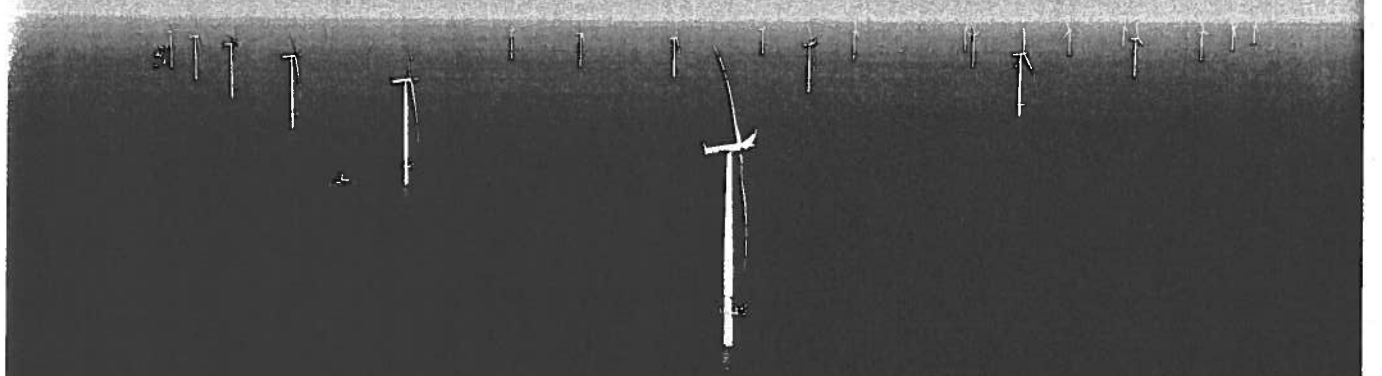
- Create about 175 construction jobs, plus five positions to operate the facility.
- Generate approximately $150 million in new revenue for state and local governments over the life of the project.
- Require no water to generate electricity.
- Produce a new source of clean, emissions-free electricity.
- Be located near existing power plants and transmission lines.

In addition to Copper Mountain Solar 2, Sempra Generation is expanding its renewable energy portfolio throughout other parts of the U.S. Southwest. It recently broke ground on a massive new solar facility in Arizona called Mesquite Solar, which could produce up to 700 MW of electricity at full build-out. The company also is pursuing additional solar installations in California. Sempra Generation has a solar development pipeline that could ultimately exceed 1,300 MW. ■

—Angela Neville, JD, is POWER's senior editor.

EnBW Baltic 1, Darss-Zingst Peninsula, Mecklenburg Province, Germany

Owner/operator: EnBW Energie Baden-Württemberg AG/EnBW Renewables GmbH



Germany's first commercial offshore wind farm—the 48.3-MW EnBW Baltic 1—consists of 21 Siemens wind turbines, each with a capacity of 2.3 MW and a rotor diameter of 93 meters. Siemens constructed the facility in an area covering about 7 square kilometers in the Baltic Sea.

By Angela Neville, JD

Courtesy: Siemens

Providing a reliable power supply from offshore wind turbines can be daunting because, typically, winds at sea are much stronger than onshore winds. Consequently, the logistics of installing ocean wind energy facilities and connecting them to the grid are much more challenging than carrying out similar operations on land. Despite such hurdles, Siemens recently completed successful installation of EnBW Baltic 1, an offshore wind farm located in the Baltic Sea approximately 16 kilometers (km or 9.94 miles) north of the Darss-Zingst peninsula.

The project, owned by EnBW Energie Baden Württemberg (EnBW), the third-largest energy company in Germany, was officially put into operation in May 2011. (A 60-MW offshore "pilot" project went into operation in late 2009. See our Feb. 2010 Global Monitor for coverage.) The wind farm's electricity is transformed at the project's transformer platform from 33 kV to 150 kV; the transformer is connected to the land grid by the company 50Hertz Offshore GmbH. With a projected output of approximately 185 GWh a year, the project will supply more than 50,000 German households with clean energy.

"This is an important milestone in the use of German offshore wind power. Onshore, Germany was a pioneer in wind power—and now it's important to rapidly tap the huge offshore potential," said René Umlauft, CEO of the Renewable Energy Division at Siemens, in May. He projected that by 2030, wind farms with total capacity between 20,000 MW and 25,000 MW will be operating off Germany's coasts and delivering electricity to German customers.

He added, "We'll soon be introducing a new wind turbine with a capacity of six megawatts." The new turbine will be gearless and well-suited for offshore wind farms.

The German Energy Sector

It's not surprising that Germany is a world leader in the use of wind power. In recent years, the country has aggressively promoted the use of renewable energy through its governmental policies. For example, on December 5, 2007, the German government unveiled its Integrated Energy and Climate Program, which aims to set a global example in the fields of energy and climate policy and is suited to the needs and capabilities of a modern national economy, according to the German Federal Ministry of Economics and Technology. The launch was timed to coincide with the kick-off of the United Nations Climate Change Conference in Bali, which was held in December 2007.

The program is based on the conviction that energy must be used with much greater efficiency than is currently the case and that much higher priority must be placed on the use of low-carbon energy.

The adopted measures aim to prove that climate protection is both affordable and compatible with economic growth.

For this reason, the German government is pursuing policies that deliver favorable results in keeping carbon dioxide (CO_2) emissions low but that are also as cost-effective as possible. The German government's goal is to achieve positive environmental outcomes without having a negative impact on consumers or German business competitiveness.

Experts in the German Energy Agency believe that new wind farms with an installed capacity of between 20 GW and 25 GW will need to be built in the North Sea and the Baltic Sea over the next 20 years to help meet the country's demand. Moreover, an additional 850 km of new high-voltage power lines need to be built, and 400 km need upgrading in order to transport the wind power to households, even in remote regions, according to a 2005 grid study produced by the agency.

But improving the grid is just one aspect of the government's policy. In the future, it will also be important to network residential customers, large industrial consumers, and urban and rural areas with differing power generation capacities in an intelligent manner, using "smart grid" technologies.

Triumphing over Construction Challenges

Each of the 21 wind turbine units at the EnBW Baltic 1 wind farm measures approximately 125 meters (m, 410 feet) from the foundation to the blade tip (Figure 1). In order to anchor these giant wind power units in the sea and connect them to the grid, suppliers, logisticians, technicians, and engineers had to work hand-in-hand—on land and water. Production, transport, installation, and other operations involved in building the wind farm had to be coordinated under challenging conditions. When difficult weather conditions developed, construction had to be stopped.

The wind farm's components were produced in several places: substation platform in Bremerhaven, Germany; monopiles (foundations) for the platform and wind turbine units in Rostock, Germany; transition pieces in Aarlborg, Denmark; cable rolls in Cologne; and wind power units in Denmark.

At the beginning of the offshore project, the construction team probed the ground at the site and then determined the positions of the individual wind energy units. Next, engineers dealt with the scour protection, which consisted of two layers of stones placed around each foundation base to protect it against washing caused by waves and currents. Then the monopiles were driven into the ground with a gigantic ram on a special ship. It took approximately 3,000 impacts to drive the approximately 37-m-long steel pipe about 20 m into the seabed.

Next, the transition pieces, the monopiles, and the wind power units were connected with each other and placed over the monopiles. The steel towers of the wind turbines were then placed on the transition pieces with huge cranes. The heavy cars with the generator, drives, and massive rotor blades were mounted next. Once these units are put in place, neither wind nor waves can move them.

After installation of the wind turbines, the approximately 61-km-long deep sea cable was laid and connected to the grid onshore.

The substation platform was also fixed to the ground using monopiles. The 450–metric ton heavy steel platform rests on just one monopile; when fully equipped, it weighs almost double that. The foundation of the monopile and transition piece with a total weight of 1,415 metric tons is therefore three times as heavy as the foundation of the wind power units. The structure is protected against drifting ice by an ice cone.

Underwater currents can cause continual changes to the seabed. Therefore, to make sure that no sand drifted away, causing destabilization of the foundations, another stone ring was deposited around the base of the foundations to protect against washing. This scour protection also holds the cables, which are connected to the deep sea cable of the internal electricity grid.

On the Horizon: EnBW Baltic 2

Siemens has orders for four more offshore wind power plants in German waters: EnBW Baltic 2 (288 MW), Borkum Riffgat (108 MW), DanTysk (288 MW), and Borkum Riffgrund 1 (320 MW).

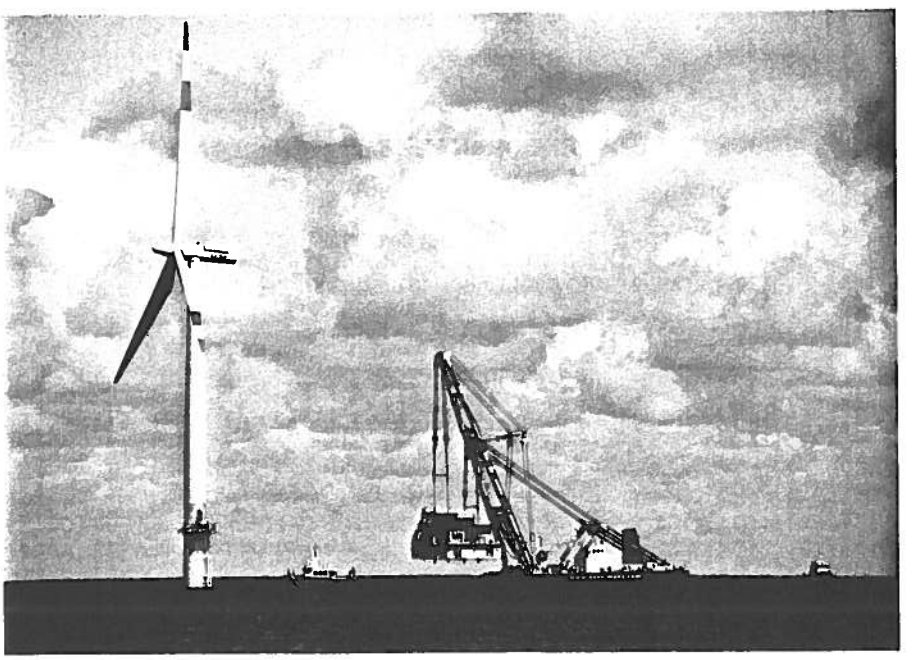
In June 2010, EnBW and Siemens Energy entered into an agreement requiring Siemens to supply 80 wind turbines, each with a capacity of 3.6 MW and a rotor diameter of 120 meters, for the EnBW Baltic 2 project (previously Kriegers Flak).

"EnBW Baltic 2 is a wind park with dimensions that clearly exceed EnBW Baltic 1," said Stefan Kansy, EnBW project manager of offshore wind energy. "A great distance to the shore, great water depths, and a varying construction soil need an experienced team. We have such an experienced team, which implements this project with great commitment—this is the best guarantee for success."

EnBW Baltic 2 will be located approximately 32 km north of the island of Rügen in the western Baltic Sea and will cover an area of approximately 27 square km. Projected to commence as early as 2012, the project will generate 1,200 GWh of electricity annually for approximately 340,000 households and reduce CO_2 emissions by 900,000 metric tons. The new offshore wind farm is scheduled to come online in 2013. ■

*—**Angela Neville, JD**, is POWER's senior editor.*

1. Doing the heavy lifting. The floating crane Matador brings the 900-ton transformer substation to the construction site of the 48.3-MW EnBW Baltic 1 offshore wind farm, which is located in the Baltic Sea north of Germany. *Courtesy: Siemens*

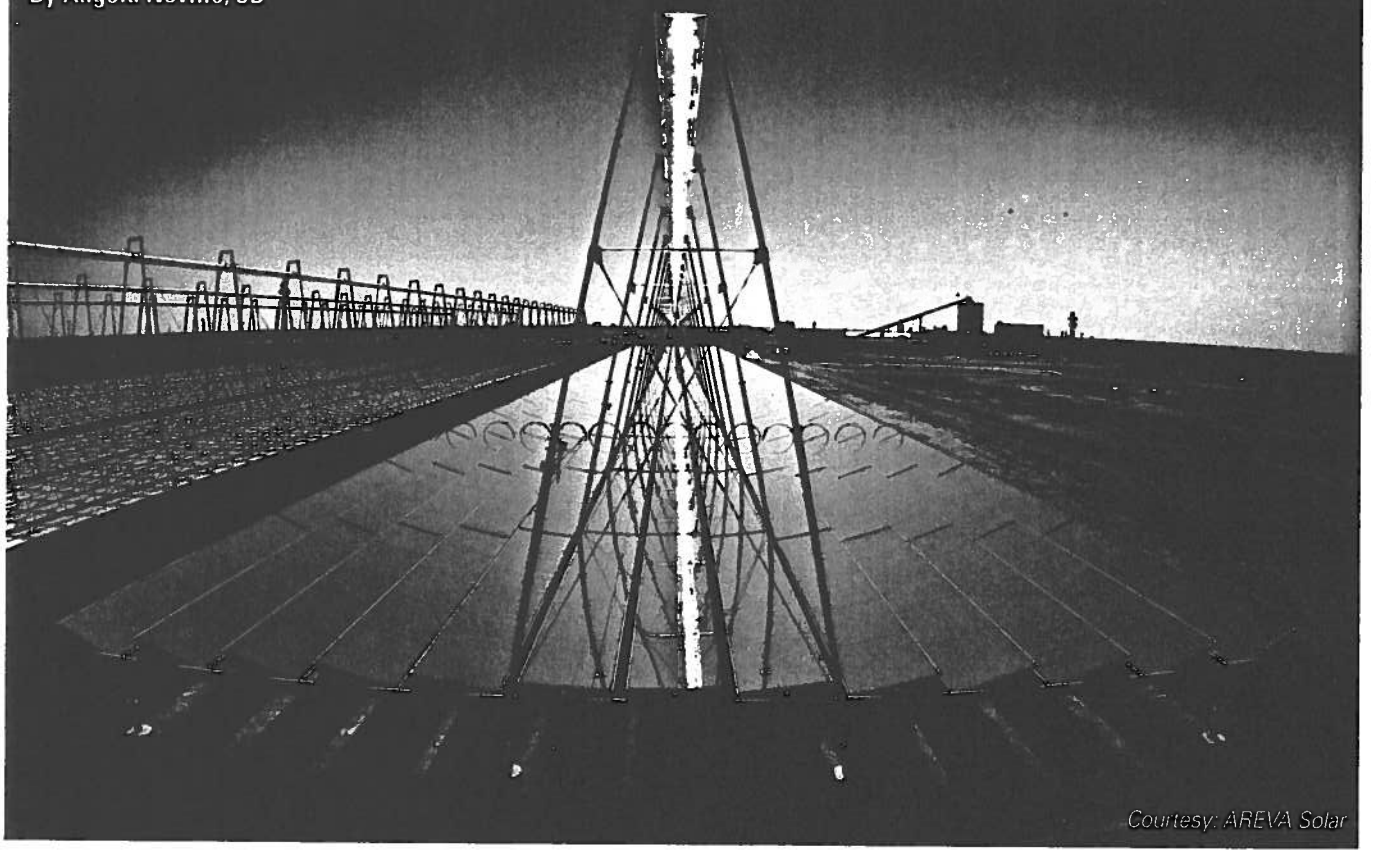


Kimberlina Solar Thermal Energy Plant, Bakersfield, California

Owner/operator: AREVA Solar

The 5-MW Kimberlina Solar Thermal Energy Station is the first to use compact linear Fresnel reflector technology developed to generate continuous superheated steam, a key element for higher-efficiency power generation and integration with new and existing plants. The facility's innovative technology helps deliver power even during periods of transient cloud cover.

By Angela Neville, JD



Courtesy: AREVA Solar

Situated in central California's breadbasket region, Bakersfield is a key agricultural center and a center for petroleum extraction and refining. Now this area is harvesting another abundant resource: the sun's energy.

The Kimberlina Solar Thermal Energy Plant, (initially developed by Ausra, which was purchased by AREVA Solar in February 2010), began operation in 2008 with its first three solar steam generators (SSGs), which used saturated steam boilers. Since 2009, the plant has operated with approximately 96% availability. In 2010, AREVA Solar constructed, commissioned, and began operating its fourth solar steam generator (SSG4) at the 5-MW Kimberlina facility in Bakersfield (Figure 1), which is the first to use direct steam compact linear Fresnel reflector (CLFR) technology, a type of concentrating solar power (CSP).

"It uses the most advanced CLFR technology in the world," Katherine Potter, vice president of communications for AREVA Solar, told *POWER* in October. The result is lower costs for stand-alone CLFR plants and easier integration of solar resources with fossil-fired power plants for solar augmentation and solar/hybrid power applications.

AREVA Solar was able to achieve direct steam generation through a proprietary model predictive control system that overcame the challenge associated with parabolic trough systems of temperature gradients in the absorber tubes and controllability of the two-phase water/steam flow.

At full capacity, Kimberlina's solar steam generators can generate up to 25 MW of thermal energy or up to 5 MW of electricity—enough power to supply 3,500 central California households, according to Potter. Field trials during September 2010 consistently demonstrated steam flow exceeding predictions during steady and transient conditions, while maintaining exit steam conditions at 60 ±3 bar and 370 ±20C. The SSG4 is expected to generate up to 450C superheated steam by year-end.

Kimberlina's SSG4 proved that AREVA Solar's CLFR technology can help deliver power even during periods of transient cloud cover. During "lights out" testing, SSG4 had sufficient solar thermal inertia to supply more than 18 minutes of superheated steam.

Kimberlina is designed to help meet California peak demand and has operated with high availability since it entered commercial operation. Its peak production comes during Central California's peak demand times, when fossil-fired electricity is most expensive. A key benefit of solar energy is that the cost of its fuel—solar radiation—will remain consistent while the price of fossil fuels will remain volatile.

Technical Innovations

In order to generate solar power, CLFR technology uses long, thin segments of mirrors, or reflectors, to focus sunlight onto a fixed receiver. These rows of reflectors can concentrate the sun's energy up to approximately 50 times. With AREVA Solar's technology, concentrated energy is transferred through boiler tubes in the receiver, ultimately generating high-pressure superheated steam. Unlike some solar thermal technologies, AREVA Solar's CLFR uses water as a working fluid, thus eliminating the need for costly synthetic oils and heat exchangers. And to maximize water conservation, CLFR uses a closed-loop system. Once heated, the superheated steam powers a steam turbine.

1. Solar light and heat. The Kimberlina facility in Bakersfield features the first once-through, direct steam compact linear Fresnel reflector (CLFR) superheated solar steam generator. This major technology advancement drives down costs for stand-alone CLFR plants and improves the integration of solar resources with fossil-fired power plants for solar augmentation and solar/hybrid power applications. *Courtesy: AREVA Solar*

A key benefit of solar energy is that the cost of its fuel—solar radiation—will remain consistent, while the price of fossil fuels will remain volatile.

The SSG4 delivers sustained, superheated steam in a quick and cost-saving manner, Potter explained. The design improves steam production performance by eliminating steam separation and recirculatory systems. Once-through direct steam generation greatly simplifies the overall system design by eliminating vessels, tanks, pumps, heat exchangers, and ancillary equipment. The tube bundle incorporates multiple passes, with superheater tubes arranged in the high flux regions and economizer/evaporator tubes arranged in lower flux regions. This ensures sufficient heat flux to sustain superheated steam temperatures throughout the operating day and reduces the average bundle temperature to reduce radiant heat losses. By eliminating the recirculatory systems, the once-through SSG reduces cost and startup time substantially, while enhancing performance.

"Kimberlina served as the testing ground for AREVA Solar being named the first solar steam power boiler manufacturer to receive the American Society of Mechanical Engineers' (ASME) 'S' Stamp Certificate of Authorization," Potter said. "An ASME 'S' Stamp is considered the industry hallmark of acceptance and certification."

Plant Profile

The reflectors and receiver tubers used at Kimberlina were manufactured at AREVA Solar's Las Vegas manufacturing facility. Construction management was provided in-house. Subcontractors were engaged for civil, structural, mechanical, and electrical activities, and the SSG4 boiler assembly was performed by AREVA Solar.

"Kimberlina's SSG4 demonstrated the rapid erection of AREVA Solar's CLFR design. Construction was accomplished over a six-week period within budget," Potter said.

Unique for field-erected boilers, the SSG4 tube bundle was welded at grade. After being inspected, the receiver and tube bundle support structure was placed over the bundles, secured, and then the entire receiver structure, with boiler tubes, was hoisted to its operating position, 60 feet above grade. One of the most significant successes of the project was the scheduling and sequencing of commissioning activities. Overall—from permits, procurement, preparation and issuance of contract documents to construction and commissioning—the entire project took just six months.

Overcoming Obstacles

Although Bakersfield has a good solar resource during the peak summer demand period, it experiences less-favorable and less-consistent solar conditions in the fall and winter, Potter explained. This challenge provided AREVA Solar with a good opportunity to test superheated steam production during interim cloud-coverage.

Unlike PV facilities, whose output is immediately interrupted by cloud cover, Kimberlina was able to sustain up to 18 minutes of superheated steam production during a period of cloud cover—demonstrating the benefits of solar thermal power and AREVA Solar's CLFR technological advancement, according to Potter.

The environmental and visual impacts of power project development can often be of concern to the local community. Potter emphasized that "AREVA Solar designed its CLFR to minimize its environmental footprint." The technology uses water as its working fluid, which eliminates the use of flammable synthetic fuels or expensive molten salts used in other CSP technologies. Its closed-loop system helps ensure maximum water conservation. CLFR is also the most land-efficient solar technology, using up to 2.6 times less land compared with other solar technologies. And, unlike fossil-fired power plants, solar power has no emissions.

Bright Future for CLFR Technology

AREVA Solar's success at Kimberlina is leading to other commercial ventures. For example, the company is constructing a solar power augmentation project at the Kogan Creek coal-fired power plant in Australia and has been chosen as the preferred solar thermal provider for the Solar Dawn project in Australia. Potter said the company also is exploring product development advancements that would use CLFR for enhanced oil recovery applications. ■

—Angela Neville, JD, is POWER's senior editor.

Martin Next Generation Solar Energy Center, Indiantown, Martin County, Florida

Owner/operator: NextEra Energy Inc., a subsidiary Florida Power & Light Co.

The 75-MW Martin Next Generation Solar Energy Center is the first hybrid solar facility in the world to combine a solar thermal array with a combined cycle natural gas power plant. Because the facility uses a steam turbine, transmission lines, and other infrastructure from an existing combined cycle unit, financial savings of approximately 20% were achieved compared to what a similar stand-alone solar plant would have cost.

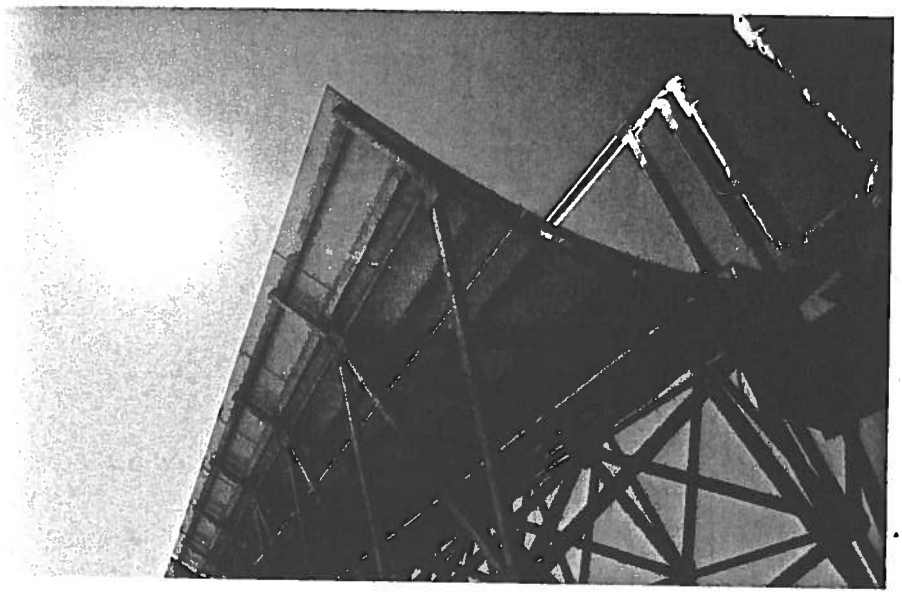
By Angela Neville, JD

Located in a region that has abundant wetlands, wildlife, and bald cypress trees, the new 75-MW Martin Next Generation Solar Energy Center is protecting the environment by harnessing the power of the sun to generate zero-emission electricity. By using solar energy to supplement the power production of an adjacent gas plant, the plant's innovative technology helps reduce Florida's carbon footprint. The plant will decrease fossil fuel usage by more than approximately 41 billion cubic feet of natural gas over the project's lifetime. The mirrors used in the parabolic trough arrays require no fuel or additional cooling water and produce no waste.

The Florida Power & Light (FPL) facility was completed on schedule and more than $75 million under budget. It entered commercial operation in December 2010 and is projected to produce 155,000 MWh per year, which is enough to serve almost 11,000 homes or 26,000 people.

"The solar trough technology FPL is using at the new Martin facility is an advanced version of the proven technology being used by NextEra Energy's other major subsidiary, NextEra Energy Resources, at the Solar Energy Generating Systems (SEGS) in California's Mojave Desert," Timothy Bryant, Martin Next Generation Solar Energy Center production manager, told *POWER* in October. "SEGS is the largest solar thermal site in the world, and the new Martin facility is the largest in the eastern United States."

1. Catching rays. The new Martin Next Generation Solar Energy Center consists of more than 190,000 mirrors arranged in solar troughs. Centered in the 284 rows of assemblies totaling almost 53 miles are heat-collection elements—20,000 vacuum-sealed, stainless steel tubes, each more than 13 feet long. Inside the tubes are nearly 800,000 gallons of a highly specialized heat-transfer fluid that runs between the solar field and the steam plant within more than 18 miles of carbon steel piping. *Courtesy: Florida Power & Light Co.*



Facility Overview

Bryant explained how the solar and combined cycle technologies are tied together so that "when the sun is shining, plant operators can effectively take their foot off the gas and allow the sun to help generate power."

Spanning more than 500 acres on the company's 11,300-acre Martin Plant site, the new solar facility consists of more than 190,000 mirrors carefully placed in trough alignments to capture the sun, similar to the way a magnifying glass operates (Figure 1).

The mirrors are arranged in 6,816 solar collection assemblies (SCAs) consisting of 28 mirrors per assembly, he said. Advanced tracking technology maximizes the efficiency of the troughs as the sun moves across the sky over the course of a day.

Centered in the 284 rows of assemblies totaling almost 53 linear miles are heat-collection elements—20,000 vacuum-sealed, stainless steel tubes, each more than 13 feet long. Inside the tubes are nearly 800,000 gallons of a highly specialized heat transfer fluid that moves from the field to the steam plant and back again within more than 18 miles of carbon steel piping.

The fluid is heated by the sun to approximately 740F and then pumped over to a heat exchanger at a steam plant. There, energy from the heat transfer fluid is extracted to create steam that is then integrated into a steam cycle at one of the natural gas–fired, combined cycle generation units at the site.

Of the approximately 300 contracts awarded on the project, more than half went to Florida companies, Bryant said. Materials managers purchased recycled aluminum from a company in St. Augustine, steel pylons from an Orlando firm, road material from a quarry in Port Mayaca, and lumber from Indiantown. The primary construction contractor was Lauren Engineers and Constructors, Inc., of Abilene, Texas.

When the section of the site where the solar arrays are located was originally licensed in 1989, it was intended to be used for a coal-powered generation unit. The wetlands easement license made sure that all impacted areas were properly mitigated and created a 1,130-acre conservation easement and preserved 291 acres of surrounding area. FPL has protected the easement and preservation areas for more than two decades. Now the area is being used for clean, renewable solar energy instead of coal-fired generation.

Technical Challenges

"Differences between conditions in the California desert, where the large SEGS facility is located, and those in Florida led FPL to adopt a number of structural innovations during construction of the Martin facility," Bryant said.

The arrays, which stand nearly 30 feet tall, were developed to withstand 130-mph winds by anchoring them with foundations larger than those used at the SEGS facility. The more than 6,800 frames that support the mirrors and heat-collection elements are complex trussed structures. Due to the potential for high winds, the SCA frames were designed and constructed to be much more rigid than desert-based frames, minimizing wind-related distortion and the likelihood of breakage.

Costs

The most recent estimated cost of the solar generation component for the Martin Next Generation Solar Energy facility is approximately 27 cents per kWh, which is higher than the 11 cents per kWh cost of generation from a new combined cycle gas fired unit, according to Bruce Kullman, Martin Next Generation Solar Energy Center senior operations specialist.

The Martin solar plant qualified for a federal investment tax credit of about $120 million, which will be passed on directly to customers to help lower the construction costs of the project.

Regional Economic Growth

At a time when Florida is suffering from the aftermath of the worst economic downturn in decades and has an unemployment rate in the double digits, the Martin Next Generation Solar Energy Center is having a significant positive economic impact on customers and local economies.

Approximately 1,100 jobs were created during the construction phase of the project, and FPL matched the skills of local workers with project needs as much as possible. As a result, more than half of the construction jobs were filled by workers from Martin County and nearby Okeechobee and St. Lucie counties. Six permanent employees now work at the Martin solar site. Other employees have been added to the Martin crews to handle solar field operational and maintenance activities, which include 52 preventive maintenance procedures, 16 new operating procedures, six operational reliability checks, and 26 major maintenance work packages. Additional contractors have been hired to perform other tasks, including mirror washing, grass cutting, and weeding.

It is estimated that the investment of approximately $400 million in capital spending on the project will generate tax revenues for Martin County schools and other public services of approximately $78 million over the plant's lifetime.

Future Goals

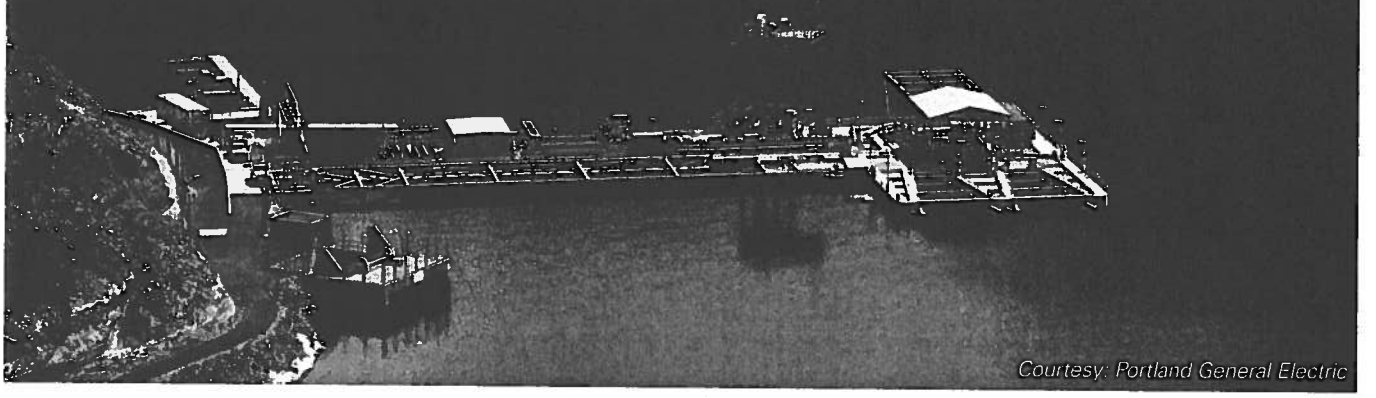
Not content with their past successes, employees at the Martin Solar Energy Center are focused on increasing the plant's energy production, improving operational performance, and demonstrating to the electric power industry that this first-of-its-kind facility in the world can be a more cost-effective way to produce solar power.

"We continue to learn how to optimize the performance of the facility and its technological infrastructure to ensure that we are capturing the most energy possible from Florida's plentiful sunshine," Kullman said. ■

—Angela Neville, JD, is POWER's senior editor.

Pelton Round Butte Hydroelectric Project's Selective Water Withdrawal Project, Oregon

Owners: Portland General Electric and the Confederated Tribes of the Warm Springs Reservation of Oregon
Operator: Portland General Electric



Courtesy: Portland General Electric

In December 2009, construction of an underwater tower and fish collection structure was successfully completed at the 465-MW Pelton Round Butte Hydroelectric Project. The first-of-its-kind fish bypass and intake structure returns temperatures in the lower Deschutes River to historic patterns and restores downstream passage of Chinook, steelhead, and sockeye salmon while maintaining existing generating capacity.

By Angela Neville, JD

Resting in a high desert setting in Central Oregon, Lake Billy Chinook is surrounded by high basalt cliffs and hillsides covered with sagebrush and juniper. The lake was formed by the construction of Round Butte Dam in 1964 and is fed by the Deschutes, Metolius, and Crooked Rivers. With its scenic views and large populations of bull trout and other fish species, the lake for years has attracted large numbers of anglers, boaters, hikers, and sightseers.

The new bypass and intake structure for the Pelton Round Butte Hydroelectric Project was one of the main components of a historic 50-year relicensing agreement signed in 2004 by co-owners Portland General Electric (PGE) and the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWS), Steve Corson, spokesman for PGE, told *POWER* in October. A license with the U.S. Federal Energy Regulatory Commission (FERC) for the project was issued in 2005, incorporating the agreement. Officially known as the Selective Water Withdrawal Project (SWW), the structure is the world's only known floating surface fish collection facility coupled with power generation (Figure 1). It was designed to reflect the latest scientific data about fish migration patterns. Construction wrapped up in 2009, and the project was certified as complete in early 2010.

Challenges with Original Fish Passage System

When the Round Butte dam was built in 1964, it had negative impacts on certain fish species in the area, even though it incorporated a juvenile and adult fish passage system. The original system included a downstream juvenile skimmer (capture facility) in the forebay of Round Butte Dam, an adult capture facility with associated upstream fish ladders, and a gondola that transported adult fish upstream over Round Butte Dam.

Unfortunately, the passage system failed, primarily due to downstream migration problems in Lake Billy Chinook, the reservoir behind Round Butte Dam. In 1966, when it was apparent that fish passage for downstream juvenile fish wasn't functioning well, the system was abandoned. As a result of the failed fish passage system, Chinook, steelhead, and sockeye salmon were unable to make their migration to the Pacific Ocean, and their populations dwindled. Consequently, kokanee (landlocked sockeye salmon) and other nonmigratory fish species ended up populating the reservoir.

A Unique Collaboration

The Pelton Round Butte Hydroelectric Project is the only U.S. hydroelectric project jointly owned by a Native American tribe and a utility. Currently, the project is two-thirds owned by PGE and one-third owned by the CTWS, through Warm Springs Power Enterprises. The uppermost dam is Round Butte; Pelton,

the middle dam, forms Lake Simtustus; the lowermost dam, the re-regulating dam used to balance river flows to meet peak power demands, is owned by CTWS. The three-dam project has a total net capacity of 465 MW.

CTWS purchased their first interest in the hydroelectric project from PGE effective Jan. 1, 2002. They have the option to purchase additional interests up to a maximum of 50.01% as early as the year 2029, according to the ownership agreement. The re-regulating dam powerhouse remains wholly owned by the tribes.

While PGE and the CTWS had great confidence that the science behind the SWW project was sound, it required a significant commitment to environmental stewardship. At a cost of $108 million, and with no historical precedent to confirm that the system would successfully resolve migration problems, moving forward with the SWW represented a leap of faith.

As complicated and difficult as the engineering challenges of this project were, PGE and the CTWS faced an equally daunting task: obtaining support for this project from more than 22 stakeholder organizations and agencies with a diverse and sometimes competing range of objectives, including the National Marine Fisheries Service, the Oregon Department of Environmental Quality, the Oregon Department of Fish and Wildlife, and the U.S. Department of the Interior.

An Innovative Solution

Following issuance of the new license by FERC, the next challenge was for CH2M HILL, the company selected to handle the unprecedented engineering project, to take a concept to design, and ultimately to operation. The SWW and associated fish facilities at Round Butte Dam had to be designed to attract and capture migrating salmon, steelhead, and sockeye salmon. The fish then needed to be transported safely downstream.

In order for the SWW to achieve these goals, the project's engineering team had to meet the following major objectives:

- Reorient the subtle surface currents toward the dam to allow downstream-migrating fish to find their way to the SWW.
- Safely capture downstream-migrating salmonids attempting to leave the reservoir using the SWW structure while excluding fish from the turbine intakes.
- Provide for the safe and efficient sorting, enumeration, tag detection, marking, and loading of downstream migrants for transport below the dam.
- Manage the downstream water quality during late summer and fall by mixing surface and deep waters to control the discharge temperature and dissolved oxygen levels mandated by the federal Clean Water Act.
- Meet seismic standards, as well as wind, wave, and hydraulic loading that an underwater structure is subject to.
- Achieve all of the above while maintaining hydroelectric generating capacity.

The size of the structure was driven by the location of the original powerhouse intake structure nearly 270 feet below the surface of the reservoir. This structure needed to be connected to the original intake structure to supply water for power generation while attracting fish and withdrawing water from the upper 40 feet of the reservoir. Adding to the challenge was the fact that the reservoir could not be drawn down to allow construction in a dry area and thereby required the assembly of components on site in a size-constrained construction area.

Construction of the 273-foot tall SWW tower was completed in December 2009. The bottom structure of the tower is coupled to the historic deep intake. The vertical flow conduit and top structure rises out of the bottom structure about 700 feet upstream of Round Butte Dam. It is capped with a rectangular-shaped intake structure that draws in generation water and fish.

Once the SWW tower became operational, it began collecting migrating fish. The fish are collected in two V-screens located on either side of the two intakes. The fish are then pumped to a fish-handling facility before being transported downstream of the project, where they can continue their migration to the Pacific Ocean. Water from the tower passes separately through turbines at the base of the dam to generate electricity.

1. Award-winning design. The first-of-its-kind fish bypass and intake structure at the Pelton Round Butte Hydroelectric Project is shown while under construction. The Selective Water Withdrawal Project, which was designed and constructed by CH2M HILL, won the 2011 American Council of Engineering Companies' national Grand Award. *Courtesy: Portland General Electric*

Successful Results

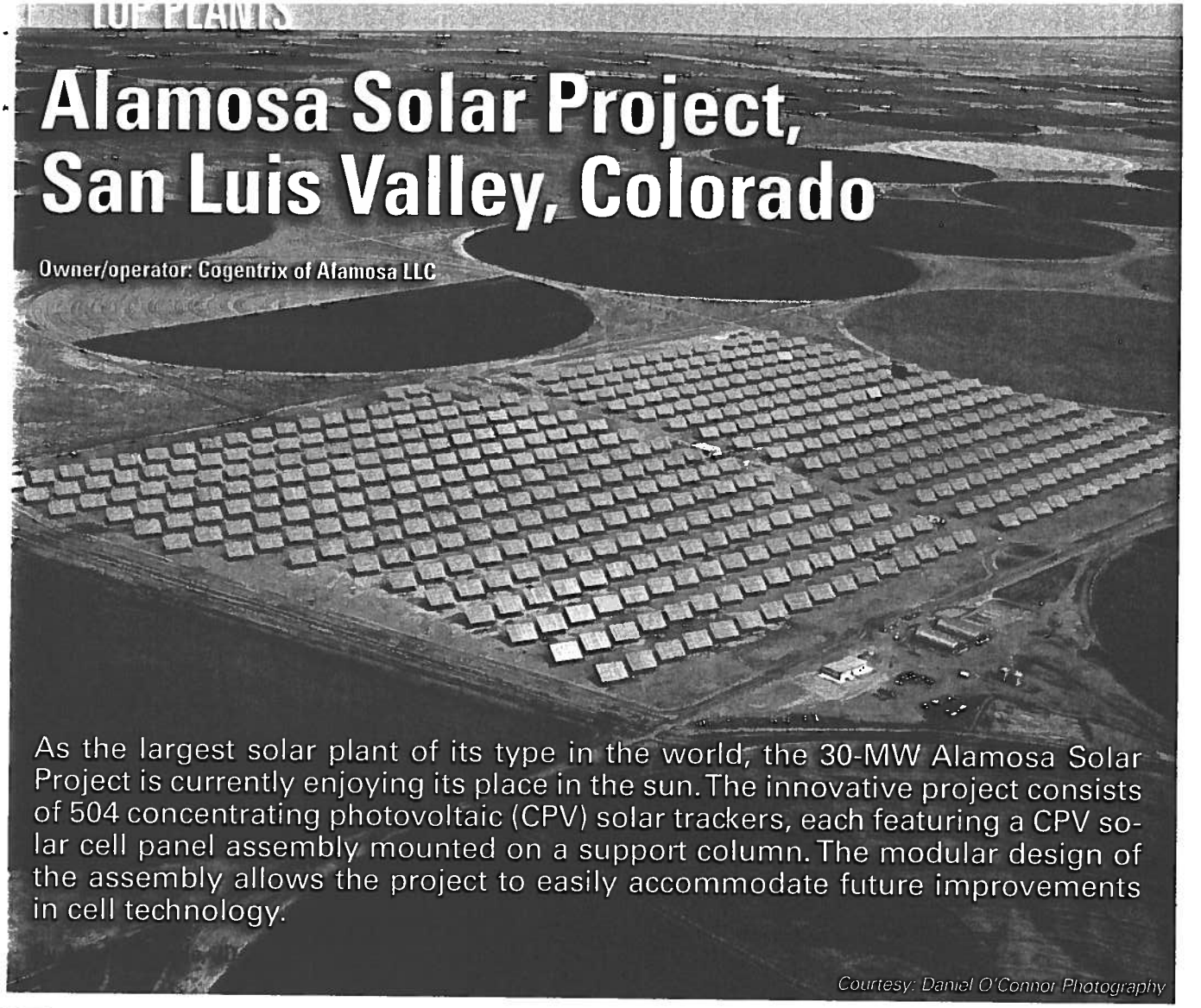
Biologists predicted that, in the long term, at least 96% of the juvenile fish collected at the water withdrawal tower would be safely transported downstream of the project and, to date, those numbers have already been exceeded. In 2011, the first few adult salmon and steelhead began their return trip from the Pacific Ocean, up the Columbia and Deschutes Rivers.

The tower's draw of warmer water off the surface of Lake Billy Chinook helps to keep the reservoir cooler in the summer, creating a healthier environment for fish. The tower has an intake near its bottom, so it can draw cold water during summer and fall to mix with warmer surface water. This helps maintain appropriate downstream temperatures in the lower Deschutes River. The modified reservoir environment provides a better habitat for bull trout, kokanee, and the rearing of juvenile sockeye salmon. ■

—Angela Neville, JD, is POWER's senior editor.

Alamosa Solar Project, San Luis Valley, Colorado

Owner/operator: Cogentrix of Alamosa LLC



As the largest solar plant of its type in the world, the 30-MW Alamosa Solar Project is currently enjoying its place in the sun. The innovative project consists of 504 concentrating photovoltaic (CPV) solar trackers, each featuring a CPV solar cell panel assembly mounted on a support column. The modular design of the assembly allows the project to easily accommodate future improvements in cell technology.

Courtesy: Daniel O'Connor Photography

The Alamosa Solar Project's site on 225 acres in southern Colorado's San Luis Valley was chosen specifically for its outstanding sunlight characteristics, which are necessary for concentrating photovoltaic (CPV) technologies. Among the positive attributes of the location are its high elevation (7,800 feet above sea level)—which means there is less atmosphere for the rays to pass through and, hence, greater insolation—and the presence of an existing 115-kV transmission line for interconnection.

The Alamosa Solar Project consists of 504 dual-axis, pedestal-mounted trackers supporting modules that produce approximately 60 kW each, providing enough power for about 6,500 Colorado homes. The facility, commissioned in May, provides electricity to customers of Xcel Energy's subsidiary, Public Service Company of Colorado.

The project is projected to generate approximately 76,000 MWh per year, which displaces approximately 249 million cubic feet of natural gas that would have been used by a comparable conventional natural gas–fired power plant. This eliminates the generation of approximately 43,250 tons per year of carbon dioxide (CO_2) emissions, based on the U.S. Environmental Protection Agency's estimate of 1,135 pounds of CO_2 generated per MWh. In addition, the CPV facility has very minimal water needs.

Facility Overview

J.E. (Jef) Freeman, Jr., vice president of development at Cogentrix Energy Power Management, the project's developer, told *POWER* in September that a hydraulic system rotates and tilts the assemblies throughout the day so the surface of each panel maintains an optimal angle with the sun.

"Another functional benefit of this design is that the CPV system makes efficient use of the available land," Freeman said. "One MW of rated capacity is installed on 7 acres, compared to the approximately 8 to 10 acres typically needed for other solar technologies. The CPV technology is also easier to permit and install, with no special grading, water use, or other site treatment, minimizing the impact on the local natural environment."

The CPV solar trackers are Amonix 7700 models, each featuring the company's proprietary module assembly mounted on a support column, Each tracker assembly is 70 feet wide by 50 feet high and contains 7,560 Fresnel lenses that concentrate sunlight approximately 500 times onto multi-junction solar cells manufactured by Boeing-Spectrolab. A hydraulic system supplied by Hawe Hydraulics North America rotates and tilts the assembly throughout the day so the surface of each panel maintains an optimal angle with the sun. Each tracker has its own inverter (manufactured by Solectria Renewables) that converts DC power output from the solar cells to AC power. As an added bonus, the assembly's modular design will easily accommodate future cell technology updates.

Major contractors for the project were Mortenson Construction (general contractor/construction manager), Stantec (lead design firm), and Ampirical Solutions (electrical switchyard engineering, procurement, and construction contractor).

The Alamosa Solar Project has a number of interesting design features, according to Freeman:

- Each 70-foot by 50-foot tracker assembly moves around a pivot point that is approximately 20 feet above site grade (Figure 1).
- Approximately 16,000 cubic feet of concrete, requiring more than 1,800 batch trucks, was used for site construction.
- The facility has more than 28 miles of grounding cable throughout the site and more than 52 miles of underground electric cable for transferring power from the field to the transmission grid.
- The advanced Ethernet network on site connects more than 2,500 unique devices, utilizing over 20 miles of fiber optic cable and 548 network switches.

Currently, the Alamosa Solar Project has a site staff of five; an additional lens-cleaning staff of typically four workers is under contract and employed when needed.

Dealing with Project Obstacles

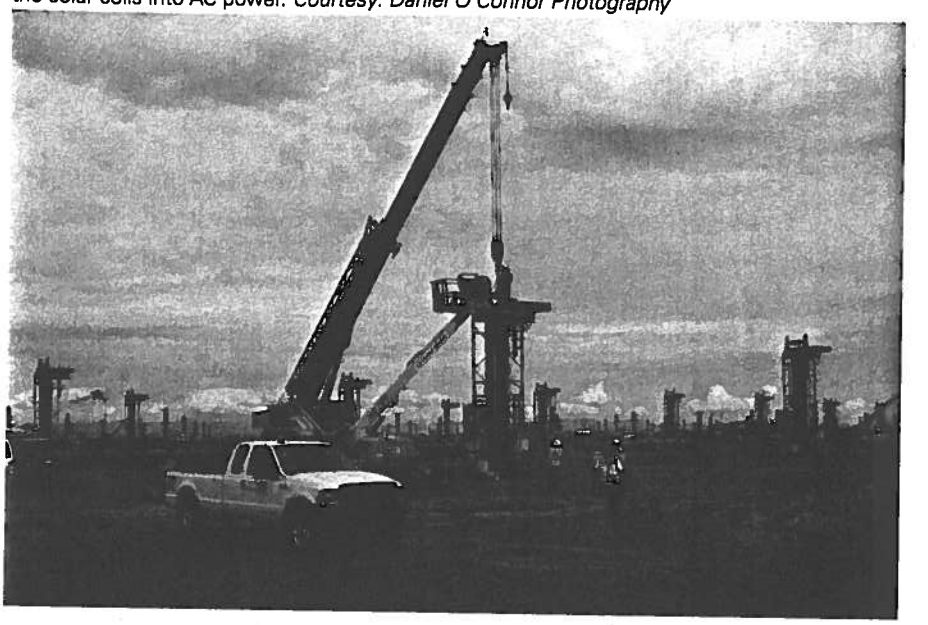
"The biggest challenge was the project scale itself," Freeman said. "Each tracker assembly contains 7,560 Fresnel lenses and multi-junction solar cells. For the total project, this equates to approximately 3.8 million of each of these components."

An additional hurdle for the project was the physical location. The high desert plateau required the engineering designers to account for extreme temperature variations (from –45F to over 95F), a frost line of 42 inches below the site grade, a relatively high water table, and the presence of invasive rodents. Freeman said that "overcoming these challenges required that the selection of materials and equipment met the functional needs of the project while also tolerating extreme conditions."

The project also had to take into account strong seasonal winds that scour the San Luis Valley floor, Freeman said. Winds have historically blown from the San Juan Mountains to the west, across the valley floor, and up against the Sangre de Cristo Mountains to the east. The Great Sand Dunes National Park and Reserve is along the eastern range and largely results from the valley sediment being deposited there.

To protect the equipment from wind damage, each tracker assembly has its own anemometer to measure wind speed to enable the assemblies to be moved into a flat, face-up, stowed position when winds are over 28 mph, Freeman explained. Additionally, a centralized control system provides backup wind speed measurements from three meteorological stations on site and will put the entire field into stow position when wind speeds exceed 30 mph.

1. Preparing for sunny days. The Alamosa Solar Project consists of 504 concentrating photovoltaic solar trackers. A solar panel support column is shown with the drive assembly being positioned at the top. Each tracker has its own inverter that converts DC power output from the solar cells into AC power. *Courtesy: Daniel O'Connor Photography*



The project encountered some challenges related to obtaining state and Alamosa County variances and permits. For example, to obtain the necessary water rights for potable and lens-cleaning water, the project team had to work closely with county conservancy officials to develop a program of water augmentation for the San Luis Valley groundwater system.

"Another challenge was due to the fact that the project's solar tracker assemblies have a maximum height of over 50 feet, which exceeds county height limitations," Freeman said. "Once again the project team worked with the county, through the state-delegated 1041 Permit process, to successfully secure all needed permits for construction, inclusive of a height variance to enable the project to move forward."

Securing Financial Backing

"The Alamosa project will be vital to the eventual commercialization of CPV technology by representing the first utility-scale implementation," Freeman said. The first hurdle for the project team was to find financing. Because the project is the first of its kind, conventional financing was not available. Traditional financial institutions required at least two years of operating performance data in order to adequately gauge the risk profile of the project before they would offer financing terms for review.

The project team ultimately secured a low-interest loan from the Federal Finance Bank under the U.S. Department of Energy's Loan Guarantee Program. In order to meet commercial operation deadlines, the project went into construction well in advance of securing the loan, which required significant upfront equity from the project developer until it was refunded from loan proceeds once financing finally closed. Construction was completed in approximately 12 months, and the facility successfully achieved commercial operation in April.

A Model for Future Solar Energy Projects

The ultimate success of the Alamosa Solar Project may have a significant impact on the financing of similar projects in the future. In order for the conventional commercial lending community to get comfortable with risks associated with innovative projects, an operating track record is needed. Freeman added that "the Alamosa Solar project is well on its way to establishing such an operating track record."

By their very nature, pioneering projects such as the Alamosa Solar Project often encounter equipment supply, construction, and operational obstacles. Each occurred at some point during construction and startup of the Alamosa project. It was imperative to have "quality ownership, engineering, construction, and operational personnel involved to ensure the project's ultimate success," Freeman explained.

"The combination of engineering talent at Cogentrix with the complementary talent at Stantec and Mortenson enabled the Alamosa Solar Project to address all challenges and become what is now the largest facility of its type in the world, " Freeman said. "As a result, it is the ideal role model for similar projects going forward." ■

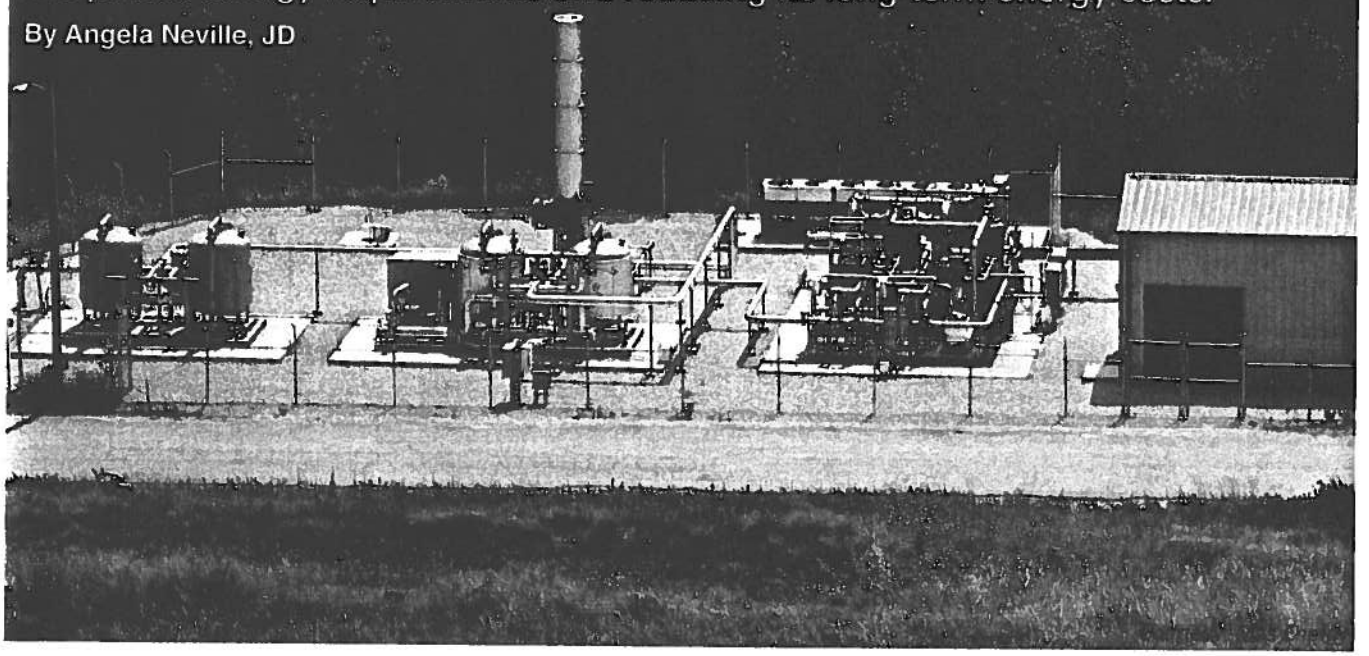
—Angela Neville, JD is POWER's senior editor.

Coca-Cola/Mas Energy Trigeneration Facility, Atlanta, Georgia

Owner/operator: Mas Energy

By taking a waste product and converting it into a fuel source, the 6.5-MW Coca-Cola/Mas Energy Facility became the first U.S. operational trigeneration project fueled by landfill gas. Since March, the new system has provided electricity, steam, and chilled water to the adjacent Coca-Cola Syrup Plant, satisfying most of the plant's energy requirements and reducing its long-term energy costs.

By Angela Neville, JD



It's the real thing. The Coca-Cola/Mas Energy Trigeneration Facility in Atlanta is a genuine renewable energy leader that uses treated landfill gas as an energy source for its operations. Using a trigeneration or CCHP (combined cooling, heat, and power) system, the new facility is projected to generate at least 48 million kWh of on-site renewable energy annually. The project also provides Coca-Cola (the "offtaker" or energy user) with the additional economic benefit of leveling its energy costs over an extended period of time.

Landfill gas from Republic Services' Hickory Ridge Landfill in nearby Conley, Ga., is the primary fuel source for the trigeneration plant. "We anticipate that the plant will use landfill gas as its primary fuel source for the life of the project," Jason Byars, vice president of business & project development at Mas Energy, told *POWER* in October. "The plant also was designed and installed with the ability to blend natural gas or use it as a backup fuel when landfill gas is interrupted to ensure relatively constant fuel input to the plant."

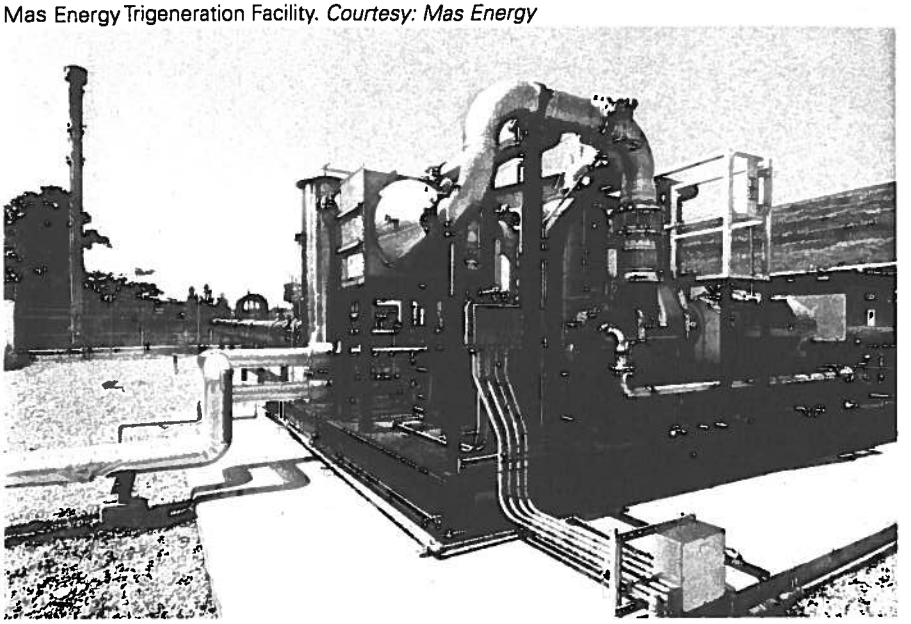
The new facility is gaining attention. For example, the U.S. Environmental Protection Agency's Green Power Partnership recently recognized the Coca-Cola Co. as the third-largest on-site green power generator in the U.S., and the trigeneration facility was a key factor in that ranking.

Operational Overview

The system achieved commercial operation on March 31, 2012, after approximately 15 months of construction and related activities. "This is the first trigen plant built at the offtaker's site. A significant challenge during the construction phase was coordinating all the construction activities so as not to interfere with or interrupt the offtaker's existing operations. Coordination of tie-ins to existing site utilities and the controls modifications required to integrate new systems into the existing schemes had to be done with careful attention to detail," Byars said.

The trigeneration plant has three GE Jenbacher J616 reciprocating engine generators, each rated at 2,175 kW for a gross output of 6,525 kW. The engines use selective catalytic reduction (urea) and selective noncatalytic reduction control technologies to mitigate the plant's total emissions and thereby keep them below major source thresholds. Fuel gas conditioning equipment (used at the landfill site) was provided by Venture Engineering for removal of siloxane (a chemical potentially harmful to the engines and post-combustion emissions control devices), as were polishing skids. Unison Solutions provided the compression and dehydration equipment. The si-

1. The big squeeze. The gas-conditioning skid dehumidifies and compresses the landfill gas prior to removal of siloxanes. The treated landfill gas is then used as fuel at the Coca-Cola/Mas Energy Trigeneration Facility. *Courtesy: Mas Energy*



loxane regeneration skid was purchased from Abutec.

The engines exhaust into individual heat recovery steam generators (HRSGs) that can each produce up to 3,500 lb/hr of steam at 125 psig, for a total rated steam output of 10,500 lb/hr. The HRSGs have bypass dampers that enable full electrical output to be achieved even when the offtaker's thermal requirements are relatively low. When in full steam-generation mode, the HRSGs' steam is dispatched to the offtaker's facility, where it is primarily used to drive a 1,065-ton steam turbine–driven York YST MaxE chiller. The steam can also be used to offset steam production from the offtaker's facility boilers via a 125-to-15 psig reducing station. The condensed steam (condensate) produced from each point of use is sent to the facility's existing feedwater deaerator before being returned to the HRSGs.

Byars explained that the project is unique because it involves landfill treatment and combustion at two different sites interconnected via a dedicated 6-mile pipeline. He said that "this project configuration added significant complexity to the scheme required to automate, monitor, and control the system." Approximately 2,200 scfm of landfill gas is first processed at the landfill via dehydration, compression, and siloxane removal equipment (Figure 1). Then it is transported to the offtaker's facility via the pipeline operated and maintained by AGL Resources.

"The trigeneration plant's generators operate in parallel with the Georgia Power distribution grid. And because the project has obtained 'Qualifying Facility' status, the offtaker is able sell any excess electricity generated by the trigeneration plant and not consumed by the offtaker's facility back to Georgia Power at avoided cost or better. As a result, Georgia Power gets the benefit of including some incremental renewable generation in their system fleet," Byars said.

Preparing Landfill Gas for Fuel Use

In order to protect the integrity of the post-combustion environmental controls installed at the offtaker's site, it was necessary to design and install landfill gas conditioning and cleaning systems at the landfill. Prior to development of this project, all of the gas produced at the landfill (approximately 2,200 scfm) was combusted via an open flare. Now it is delivered from the landfill's collection system to the treatment system at the landfill. The landfill's existing flare has remained in service and is available for use when operation of the trigeneration plant is upset or curtailed.

After it is collected in the landfill collection system, the landfill gas is cooled in a heat exchanger to prevent condensation in the oil system. The gas is then compressed to approximately 50 psig and cooled in a gas-to-air heat exchanger. It then flows through a glycol chiller and is cooled to 40F. Next, it passes through a moisture knock-out pot and reenters a regenerative heat exchanger, where it is reheated to 80F. At this point, the landfill gas passes to a siloxane removal skid.

The siloxane removal skid comprises two trains of siloxane removal beds and carbon polishers, each train capable of processing 100% of the landfill gas flow. Only one train operates at any given time while the other side is either in regeneration or standby mode. An auxiliary flare was permitted and installed to accommodate the siloxane removal skid regeneration process. The siloxane removal skid is generally in regeneration mode for six hours each day, during which it regenerates the off-line bed.

Byars explained that during regeneration, a blower and electric heater mix approximately 1,000 scfm of heated ambient air with a slipstream of approximately 120 scfm of landfill gas, which flows in reverse through the regenerating bed before being routed to the auxiliary flare. The two siloxane removal beds operate on an alternating 24-hour adsorption/desorption cycle.

After being in the siloxane removal bed, the gas then flows through a carbon polisher that further removes trace levels of siloxane. The siloxane removal skid's outlet connects to the inlet of the dedicated landfill gas pipeline, which transports the gas to the trigeneration plant site at the Coca-Cola facility.

Lining up Project Funding

"Mas Energy used a combination of debt and equity to fund construction of the project. One related challenge was the sourcing of debt for a relatively small project such as this. Ultimately, project financing was provided via a bond issuance through the Fulton County Development Authority," Byars said.

During the planning phase, Mas Energy—which develops, owns, and operates energy systems around the world—spent several weeks analyzing its air permitting options for the trigeneration plant. From one perspective, the permitting process could have taken several months given that the new plant would be a major source of air emissions and the greater Atlanta region is a "severe non-attainment" area for ozone. From another perspective, the project stood to benefit substantially from the U.S. Treasury's Section 1603 grant program as more fully described in the American Recovery and Reinvestment Act of 2009, provided that it achieved commercial operation prior to the end of 2011 (a deadline since extended by an act of Congress).

To expedite the permitting process and give the project the best chance of achieving commercial operation prior to the deadline, Mas Energy elected to install post-combustion treatment at the plant and permit the project as a synthetic minor source. "By working collaboratively with regulators, we were able to shorten what could have been a 'several months' process to one that took approximately 100 days from the date of the air permit application by Mas Energy to the date of air permit issuance by the Georgia Environmental Protection Division," Byars said. ■

*—**Angela Neville, JD** is POWER's senior editor.*

Gujarat Solar Park, State of Gujarat, India

Owners/operators: Multiple companies

Set up by the Gujarat government, the Gujarat Solar Park is actually a group of solar parks that provide dedicated common infrastructure for photovoltaic-powered projects owned and operated by numerous individual companies. When construction at all the parks is completed by the end of 2013, the Gujarat Solar Park is projected to reach a combined capacity of almost 1,000 MW, which will make it the world's largest solar energy generation installation.

By Angela Neville, JD

Courtesy: IANS/Daily News

"This project has the ability to tackle both energy security and water security, thus leaving behind a green footprint for future generations," said Gujarat Chief Minister Narendra Modi in April at the dedication of the 214-MW Charanka Solar Park, one of the solar parks that is part of the Gujarat Solar Park group. The new Charanka park is larger than the 200-MW Golmud Solar Park in China, which previously had been classified as Asia's largest solar energy facility.

In April, several Gujarat Solar Park facilities that were already operational and had a combined total of 605 MW received certificates of completion. In June, the project's solar parks reached a combined total of 689.8 MW. The entire group of solar parks is predicted to avoid 8 million tons of carbon dioxide emissions and save 900,000 tons of natural gas annually, according to the Gujarat government.

India's Electric Power Sector

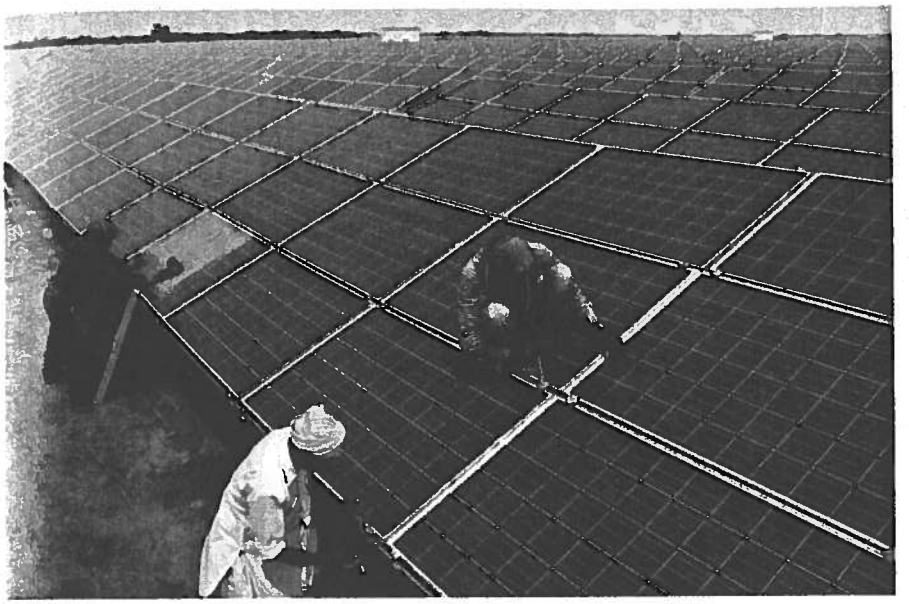
With a population of approximately 1.2 billion (July 2012 estimate), India is the second most populous nation in the world, behind China. India's electric power sector had an installed capacity of 207.85 GW as of September 2012, the world's fifth largest, according to a recent report issued by the Central Electricity Authority, Ministry of Power, Government of India. Captive power plants (those used for in-house power generation, typically by industrial entities) generate an additional 31.5 GW. Thermal power plants constitute 66% of the installed capacity, hydroelectric about 19%, and the rest is a combination of wind, small hydro, biomass, waste-to-electricity, nuclear, and solar. India generated 855 TWh of electricity during the 2011–2012 fiscal year.

The world's fourth-largest energy consumer after the U.S., China, and Russia, India currently suffers from a major electricity generation shortage. The International Energy Agency (IEA) estimates that the country needs to invest at least $135 billion to provide its population with universal electrical access. In December 2011, more than 300 million Indian citizens had no access to electricity. More than one-third of India's rural population lacked electricity, as did 6% of the urban population. Of those who did have access to electricity, the supply was often intermittent and unreliable—sometimes subject to blackouts such as the massive grid collapses that occurred in July. Fortunately, Gujarat, which actually enjoys an electricity surplus, was reinforced by the Western Grid and escaped those summer blackouts.

At an energy summit held in India in March, IEA Executive Director Maria van der Hoeven said, "Sufficient power provision is key to sustaining economic growth and development. The rapid growth of emerging economies like India therefore require significant power demand increases. According to our analysis, in India, electricity demand is projected to more than triple to over 3,200 TWh by 2035. This would imply that over 650 GW of new capacity will have to be built." The technologies and fuel sources that India adopts as it adds this additional capacity may significantly impact global resource usage and have potentially negative environmental effects, according to the IEA.

Van der Hoeven made the following predictions for India's electric power sector between 2012 and 2035:

1. Going for a record. Known as one the most business-friendly states in India, Gujarat has launched the Gujarat Solar Park project, which is destined to be world's largest solar-powered generation installation when it is completed in 2013. The park provides dedicated common infrastructure for PV-powered projects owned and operated by individual companies. *Courtesy: IANS/Daily News*



- Natural gas is expected to be the second-largest source of fuel for power generation, but still modest compared to coal.
- Coal use in the power sector will almost triple over the forecast period.
- Nuclear power generation will grow almost 10-fold.
- The most impressive increase will take place with renewable energy sources as their contribution increases 20-fold over the projection period.

Achieving such growth rates will not be easy, according to the IEA. Indeed, while coal will remain India's generation backbone during the whole period, coal's ability to keep pace with such enormous power demand increases is uncertain. This is largely due to logistical challenges and constraints on domestic coal production and the rising price of imported coal. Diversifying into gas and other alternatives is therefore not merely a matter of protecting the environment but also of promoting energy security.

Gujarat's Policies Promoting Solar Energy

India has solar irradiation that ranges from 4 to 7 kWh/square meter/day across the country, with western and southern regions having higher insolation. (For comparison, the average Phoenix, Ariz., insolation ranges from 6 to 7 kWh/square meter/day during the summer.) Located in India's western part, Gujarat is one of the most industrialized Indian states. It has annual power generation capacity of more than 14,000 MW with 2,000 MW of surplus power, according to government sources. It's not surprising that Gujarat, with its plentiful solar resources, is heavily promoting solar park development (Figure 1).

As part of the national solar energy initiative, the Gujarat government launched its Solar Power Policy in 2009. The state utility, Gujarat Urja Vikas Nigam Ltd., entered into long-term power purchase agreements with 84 solar power project investors to commission approximately 968.5 MW of generation capacity by the end of 2013, with the possibility of signing on additional companies in the future. The solar parks are being placed in sparsely populated flat areas in the northern part of the state.

The projects range in size from 1 MW to 40 MW. For example, the Charanka Solar Park consists of a group of 17 thin-film photovoltaic (PV) power systems located on a 4,900-acre site in Patan, a Gujarat district. A total of 17 national and international companies contributed power systems to the grid-connected park. When fully built out by the end of 2014, the park will host 500 MW of solar power systems. The Charanka park, estimated to cost approximately $280 million, was built in 16 months—faster than a conventional fossil-fueled plant.

The governmental development of solar parks has at least two main advantages:

- It streamlines the project development timeline by letting government agencies undertake land acquisition and necessary permits.
- It provides dedicated common infrastructure for setting up solar power generation plants funded by individual companies.

This approach has promoted the accelerated installation of private-sector solar power generation capacity and thereby cut many costs that would be faced by stand-alone projects. Common solar park infrastructure includes site preparation and leveling, water availability, access roads, and security services.

In parallel with the central government's initiative, the Gujarat Electricity Regulatory Commission announced a feed-in tariff to mainstream solar power generation, which will be applied to solar power generation plants in the park. Gujarat Power Corp. Ltd. is the agency that has been responsible for developing the Gujarat Solar Park and leasing land to project developers. Gujarat Energy Transmission Corp. Ltd. is responsible for developing the transmission capabilities for the park. The Asian Development Bank has provided some support for the project.

Renewable Energy Education Initiatives

"While we want to make Gujarat a solar hub, we also want our youth to conduct pioneering research and provide effective energy solutions for future generations," Modi said in April at the Charanka Solar Park dedication ceremony. In 2008, Pandit Deendayal Petroleum University, located in Gujarat, launched its School of Solar Energy, which was a first-of-its-kind training facility in India. The government also is actively supporting research by Gujarat Energy Research & Management Institute and other solar energy groups.

"Will we be able to manage so many solar power plants without having a skilled local workforce? Absolutely not!" Modi said. "Major training initiatives through industrial training institutes (ITIs) will take research and training in this field to another level. Six solar photovoltaic ITI labs have been established and students are already signing up to learn."

Sunny Forecast for Solar Energy

Under its Solar Power Policy, the state government has signed memoranda of understanding for future projects to be developed in Anand, Banaskantha, Jamnangar, Junagadh, Kutch, Porbandar, Rajkot, Surat, and Surendranagar.

By 2013, India aims for solar power to account for 3% of total national capacity, according to Gujarat Solar Park sources. In addition, the nation wants renewable sources of energy to rise from the current 6% of all capacity to a whopping 15% by 2020. ■

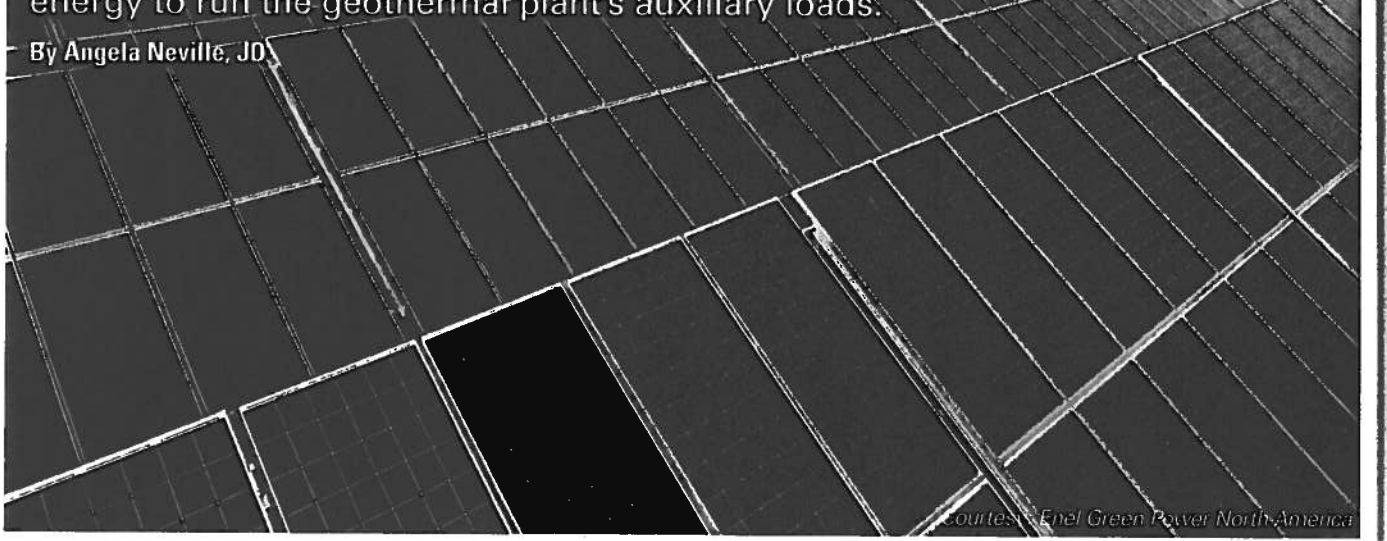
*—**Angela Neville, JD** is POWER's senior editor.*

Stillwater Solar-Geothermal Hybrid Plant, Churchill County, Nevada

Owner/operator: Enel Green Power North America

The Stillwater hybrid facility is the world's first renewable energy project that pairs geothermal power's baseload generation capacity with solar power's peak capacity. Inaugurated in May, the 26-MW solar plant is integrated with the adjacent 33-MW geothermal plant, which began operations in 2009, and provides energy to run the geothermal plant's auxiliary loads.

By Angela Neville, JD



Courtesy: Enel Green Power North America

Combining the best of two renewable energy technologies, the Stillwater hybrid facility balances the continuous generation capacity of geothermal energy with the peak capacity of solar energy. The new solar plant's photovoltaic (PV) panels cover 240 acres next to a geothermal plant in Churchill County, Nevada.

The Stillwater geothermal project, which received $40 million in tax support under the American Recovery and Reinvestment Act of 2009, harnessed innovative technologies to add solar energy to the facility and now provides 59 MW of combined capacity to power about 45,000 local homes. NV Energy has a contract to buy all the power generated by the plant.

"As the first of its kind in the world, this project demonstrates how we can tap renewable energy sources to provide clean power for American families and businesses and deploy every available source of American energy," Steven Chu, secretary of the U.S. Department of Energy, said in May. "Supported in part by the Recovery Act, the Fallon facility is expanding domestic renewable energy sources and helping to build the infrastructure we need to stay competitive in the global race for clean energy technologies."

How Geothermal Power Works

Geothermal energy is the only nonhydro renewable energy source able to provide baseload power because it relies on the continuous flow of heat from underground water sources rather than depending on the availability of wind or sun. In many geothermal reservoirs, however, the water temperatures are moderate (below 400F) and not hot enough to produce steam with the force needed to efficiently turn a turbine. Nonetheless, such moderate temperature reservoirs can generate electricity using a binary system.

Francesco Venturini, Enel Green Power North America's (EGP NA) president and CEO, told *POWER* in October about the Stillwater geothermal plant's medium enthalpy binary system. He explained that the facility uses the system because of the moderate temperature of the nearby geothermal reservoir. The plant's binary system uses two fluids: hot water from underground wells heats isobutane and causes it to flash into vapor, which then turns the turbines to generate electricity.

In addition, the facility uses proprietary technology that increases efficiency by minimizing the parasitic load—energy losses that occur from operating the various pumps and fans required in the power generation cycle. The plant has a closed-loop system that continually replenishes the geothermal resource. Once the geothermal fluid has passed through the plant, it is pumped back into the ground. Therefore, there are zero intentional emissions from the process and virtually nothing is emitted to the atmosphere.

Venturini added that his company has strong expertise in the geothermal energy sector. "EGP NA is the first company in the world to produce electricity from geothermal sources dating back to 1904 in Larderello, Italy. The company has over 700 MW of geothermal capacity in full operation and uses innovative operational and drilling techniques to optimize its projects' output," he said.

An Electric Combination: Geothermal and Solar Technologies

Adding the solar component to the Stillwa-

ter facility was something that occurred to EGP NA management after building the geothermal component, Venturini said. He also explained his company's goals related to developing new synergies between geothermal and solar energy.

"Having succeeded in proving the concept in a commercial-scale application, EGP NA Green Power's Stillwater Solar project paves the way to address key drawbacks for both geothermal and solar technologies: resource risk/parasitic load and generation intermittency, respectively," Venturini said. The geothermal plant also provides auxiliary power to the solar plant when there is no sunlight, "thus eliminating the need for backfeeding power from the utility," according to Venturini.

Currently, a number of utilities use renewable energy sources like solar power during hours of peak consumer demand and combine it with a baseload coal or natural gas plant to ensure a steady power supply. In contrast, the Stillwater facility combines two renewable energy technologies to produce electricity at the same location and thereby increases the generation of zero-emission electricity.

Combining geothermal and solar energy at the Stillwater plant also makes it possible to use the same infrastructure, further reducing environmental impacts. That integration includes the control system, electrical protection and island mode capability, fire detection/protection schemes, electrical interconnection, and the use of a common operations and maintenance staff.

"It has to be said that since this geothermal-solar project is a first of its kind, it met the regular challenges of everything new in terms of combining two advanced technologies, as well as challenges of a regulatory and administrative nature," Venturini said.

This innovative hybrid power plant demonstrates that the strengths of these different renewable technologies combine to create a better whole. Together, they:

- Enhance the thermal efficiency in the geothermal unit when it is lowest, typically during the hottest and sunniest times of the day or year.
- Stabilize production during the day, enabling a more load-following production profile.
- Reduce investment risk due to the uncertainty of the geothermal resource and compensate for geothermal reservoir temperature depletion without reducing production.

Plant Profile

The solar power component at the Stillwater facility consists of more than 89,000 polycrystalline premium photovoltaic (PV) CNPV-295P modules on fixed mounts (Figure 1). They were manufactured by CNPV Solar Power SA, an integrated manufacturer of solar PV products. Las Vegas–based Bombard Renewable Energy was the general contractor for the solar project.

The benefit of adding solar to the Stillwater facility's production capacity has been confirmed in generation measurements to date. "Average daily generation in the peak hours is significantly enhanced by the PV system, while the geothermal plant begins to reach optimal generation levels when solar generation ramps down," Venturini explained.

"From a source point of view, there were no development difficulties, as the geothermal plant (operational since 2009) was already positioned in an area with good solar irradiation levels, so EGP NA just had to install the PV facility and connect it to the grid," Venturini said. "It also helped that Enel Green Power was finishing construction of its pilot project in Italy integrating a solar thermal system to boost efficiency of a combined cycle natural gas power plant."

EGP NA employs approximately 50 staff members in the state of Nevada. The company has roughly 30 employees who operate and maintain the Stillwater Solar Geothermal Hybrid Plant and EGP NA's Salt Wells Geothermal Plant (which also became operational in Nevada in 2009).

Venturini noted that the project's success derives from a number of factors:

- The hard work and commitment of the engineers and staff at EGP NA.
- The collaboration with and support of NV Energy, state and local government agencies, and the local communities—all of which were essential in completing the project.
- Federal and state energy policies supporting renewable energy that were critical in EGP NA's decision to commit to this successful investment.

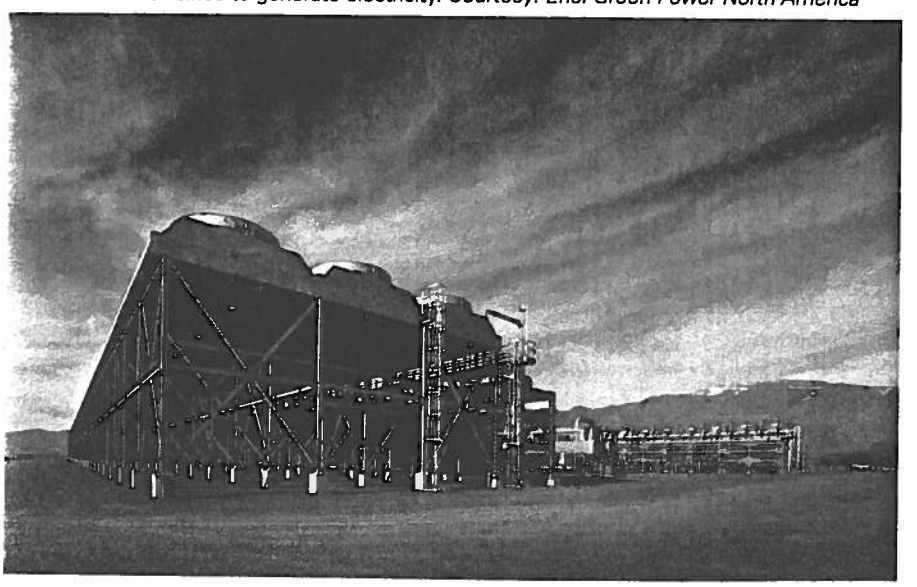
Looking Ahead

The Stillwater hybrid plant is already being recognized as a trendsetter in the renewable energy sector that will probably encourage future hybrid projects. On June 28, 2012, the Geothermal Energy Association (GEA) recognized the Stillwater Solar-Geothermal Hybrid Project for advancing geothermal technology. The GEA singled out the Stillwater facility for being the first hybrid power plant of its kind. The association pointed out that "this technology may help to allow future projects that would otherwise have been unfeasible as stand-alone geothermal or solar projects to be more economically and technologically viable."

In his remarks at the dedication ceremony for the Stillwater Solar Plant in May, Nevada Governor Brian Sandoval praised EGP NA for its innovation and leadership and looked forward to future growth in the Nevada renewable energy sector. "Clean energy is a key sector for Nevada. It provides energy from local sources, drives innovation, and most importantly, brings high-quality jobs and economic growth to the local communities. Enel Green Power's first-of-a-kind solar geothermal hybrid project is a living example of these benefits and I support the further growth of this industry in Nevada," Sandoval said. ■

—Angela Neville, JD is POWER's senior editor.

1. Some like it hot. The Stillwater facility integrates 26 MW of photovoltaic solar generating capacity with 33 MW of baseload geothermal power. In the geothermal plant's binary system, hot water from underground wells heats isobutane and causes it to flash into vapor, which then turns the turbines to generate electricity. *Courtesy: Enel Green Power North America*

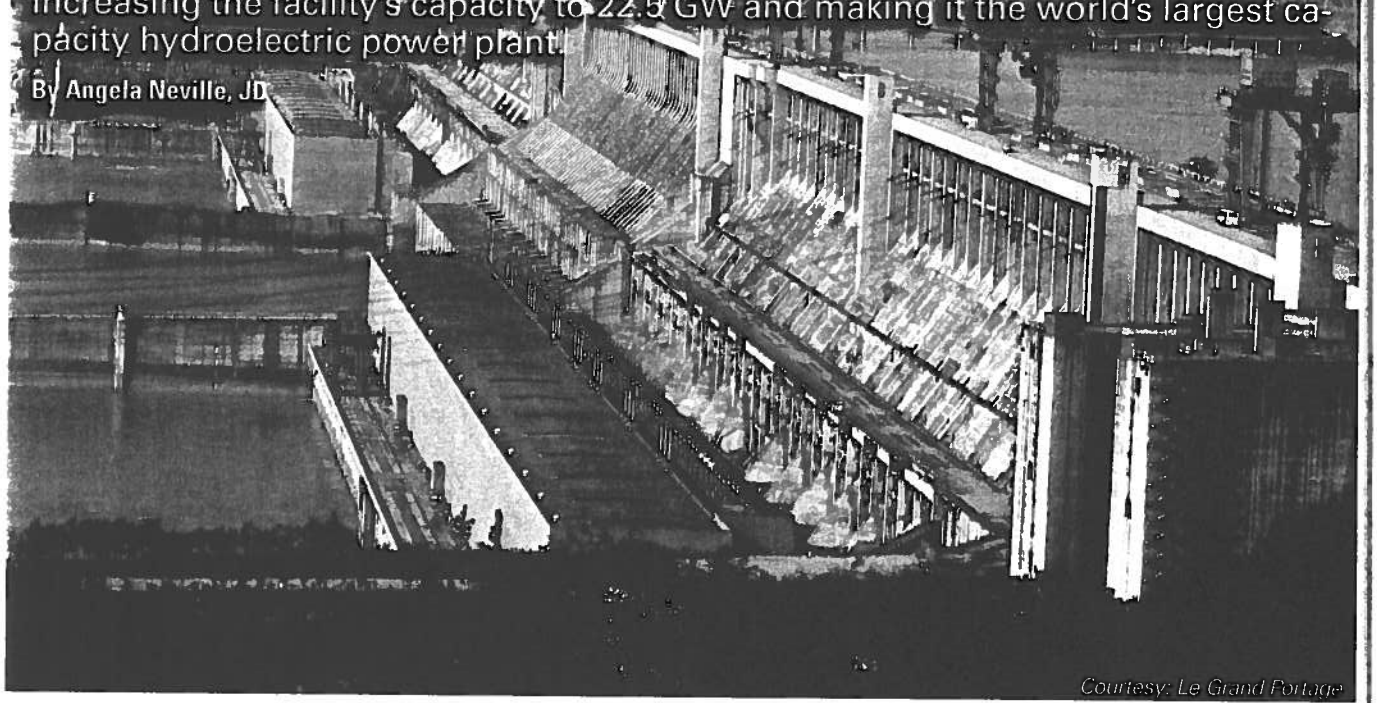


Three Gorges Dam, Yangtze River, Hubei Province, China

Owner/operator: China Yangtze Power Co., Ltd.

After nine years of construction, installation, and testing, the Three Gorges Dam is now complete. On May 23, 2012, the last main generator finished its final test, increasing the facility's capacity to 22.5 GW and making it the world's largest capacity hydroelectric power plant.

By Angela Neville, JD



Courtesy: Le Grand Portage

It's fitting that the Three Gorges Dam (TGD) achieved full commercial operation in 2012, the Year of the Dragon, based on the Chinese zodiac. The dragon sign represents accelerated risk-taking and breaking through outmoded paradigms. Through hard work and tenacity, the pioneering TGD developers and their staff overcame many obstacles to create an immense hydroelectric facility. Since the TGD was started almost a decade ago, it has set several world records in hydropower construction and achieved a series of technology breakthroughs, thanks to continuous scientific and technical advances.

Located in the Xilingxia Gorge area, one of the three gorges of the Yangtze River, the dam controls a drainage area of 1 million square kilometers (km^2), with an average annual runoff of 451 billion cubic meters (m^3). The TGD is made of 14.86 million m^3 of concrete, is the biggest structure of its type in the world, and is visible to astronauts in the International Space Station.

The Project's Construction History

As the legal entity in charge of the TGD, the China Three Gorges Corp. (CTGC) has had full responsibility for the TGD's financing, construction, and operation, according to CTGC sources. The CTGC was set up as a state-authorized investment institution, which was allowed to use Chinese state funding for the project. In September 2002, the CTGC established the subsidiary China Yangtze Power Co., Ltd. (CYPC), which was assigned to manage both the TGD and the Gezhouba hydropower plants. The $30 billion cost of the TGD project will be repaid by revenues received from the sale of electricity.

On Dec. 14, 1994, TGD construction formally started. On Nov. 8, 1997, the river closure was completed as part of Phase 1. In 1998, Phase II construction of the TGD went in full swing, and six years later, on June 1, 2003, the TGD's reservoir started storing water. Next, on June 16, 2003, the TGD's double-lane five-step shiplock was put into service. Then on July 10, 2003, the first 700-MW generator was connected to the grid and began to generate electricity. The last unit entered service in May 2011.

Facility Highlights

Now fully operational, the TGD has a total of 34 generators: 32 main generators, each with a capacity of 700 MW, and two plant power generators, each with capacity of 50 MW, for a total capacity of 22.5 GW. Of those 32 main generators, 14 are installed in the north side of the dam, 12 in the south side, and the remaining six in the underground power plant in a mountain south of the dam.

The first units were manufactured through two joint ventures (JVs) followed by units manufactured by Chinese companies based on extensive technology transfer requirements. The first JV consists of Alstom, ABB Group, Kvaerner (which supplied eight units), and the Chinese company Harbin Electric Machinery Co. Ltd. (HEC). The other JV includes Voith, General Electric, and Siemens (abbreviated as VGS and which supplied six units) plus the Chinese company Dongfang Electrical Machinery Co. Ltd. The technology transfer agreements were signed together with the equipment supply contracts. For example, as part of their agreement, HEC produced 14 units in all (eight

on the project's left bank, four on right bank, and two underground), with the final two units produced almost completely in China. CTGC later contracted with Alstom for the supply of four additional units.

The TGD uses Francis turbines with a diameter that is 9.7 m or 10.4 m (VGS design/Alstom design) and a rotation speed of 75 revolutions per minute. The turbine generators' rated power is 778 MVA, with a maximum of 840 MVA and a power factor of 0.9. Most of the TGD's generators are water-cooled. Some newer ones are air-cooled, which are simpler in design and easier to maintain.

Several technology breakthroughs were made during generator installations: automatic welding on the large stator assembly, lamination stacking of a large stator in the field, welding and measurement of rotor roundness, and controlling the roundness of rotor rim and plate.

The speed of the units' installation was impressive. For example, in 2003, the project team installed and put into operation six 700-MW units, which set a new world record for yearly installation of large-size turbine generators. Monitoring data showed that all the units that had been put into operation worked steadily and met the design requirement of various technical parameters.

During the annual dry season that occurs from November to May, power output is limited by the river's flow rate. On the flip side, when there is enough water flow, power output is limited by plant generating capacity. The TGD reached its design-maximum reservoir water level of 175 m for the first time on Oct. 26, 2010, when generation capacity of 84.7 TWh was realized.

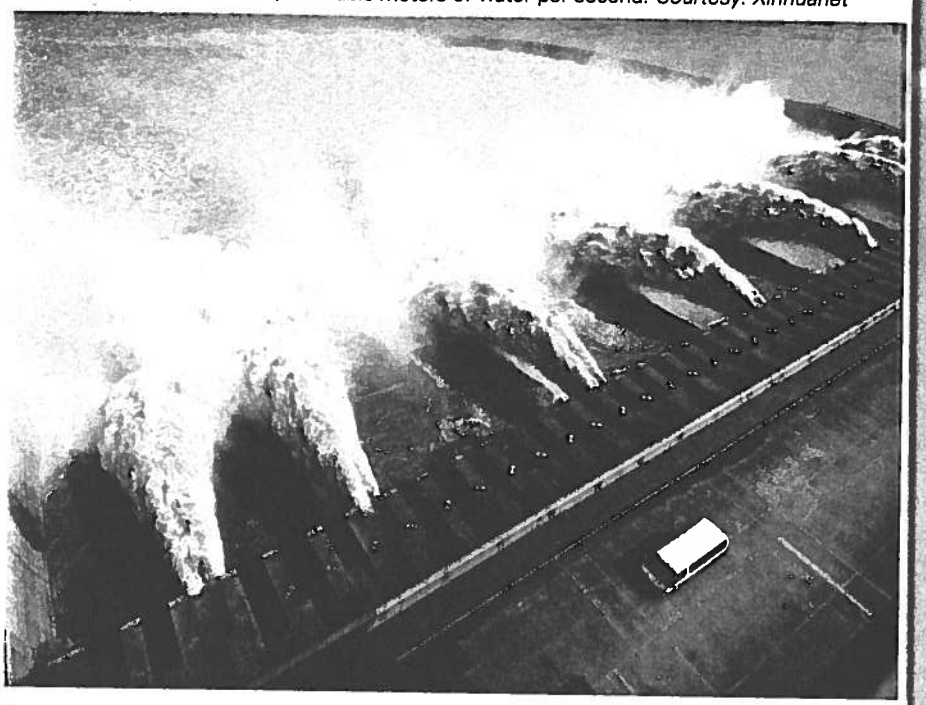
By Aug. 16, 2011, the plant had generated approximately 500 TWh of electricity. Now that the TGD is fully operational, annual generation is projected to be more than 100 TWh. Currently, the facility's electricity is sent to Central China, East China, Guangdong, and Chongqing with a maximum transmission range of 1,000 km. Nine provinces and two cities consume power generated by the TGD (Figure 1).

Originally, the TGD was intended to meet 10% of China's power needs. However, demand has increased more quickly than the Chinese government initially projected. For example, the TGD supported only about 1.7% of the country's electricity demand in 2011, when demand reached 4,692.8 TWh.

Environmental Effects

Compared to coal-fired power stations producing the equivalent level of generation, the TGD will avoid creating the following pollutant amounts, according to CTGC sources:

1. Dealing with a deluge. On July 24, 2012, flood water was released from the Three Gorges Dam, the 22.5-GW hydropower project on the Yangtze River in central China. Because of heavy rains in the upper reaches of the river, the facility experienced its largest flood peak during 2012 with a peak flow of 70,000 cubic meters of water per second. *Courtesy: Xinhuanet*



- 100 million tons of carbon dioxide
- Two million tons of sulfur dioxide
- 0.37 million tons of nitrogen oxide
- Large quantities of wastewater and solid waste such as coal ash

The TGD will improve China's air quality by not creating contaminants that cause acid rain and greenhouse effects in East and Central China. In addition, hydropower saves the energy needed to mine, wash, and transport coal from northern China.

Despite such accomplishments, some critics assert that the huge hydroelectric facility is having the following negative impacts on the environment:

- *Wastewater collection increased.* More than one billion tons of wastewater are released annually into the Yangtze River, which in the past was moved downstream before the river was dammed and the reservoir was created. Now the water in the reservoir appears stagnant and polluted.
- *Decrease in forest cover.* The Three Gorges, especially in the Yangtze Basin upstream from the Three Gorges Dam, currently has 10% forestation, down from 20% in the 1950s.
- *Loss of wildlife.* The region provides habitats for hundreds of freshwater and terrestrial animal species. Some of the species that have been negatively impacted by the TGD include Chinese (Baiji) river dolphins, Siberian cranes, and Yangtze sturgeon. Freshwater fish are especially affected by dams due to changes in the water temperature and flow regime. Many fish are injured in the turbine blades of hydroelectric plants as well.
- *Increased erosion and sedimentation.* At current levels, 80% of the land in the area is experiencing erosion, depositing about 40 million tons of sediment into the Yangtze River annually because the flow is slower above the dam. Much of the sediment will now settle there instead of flowing downstream, and there will be less sediment downstream.

Controlling Floods

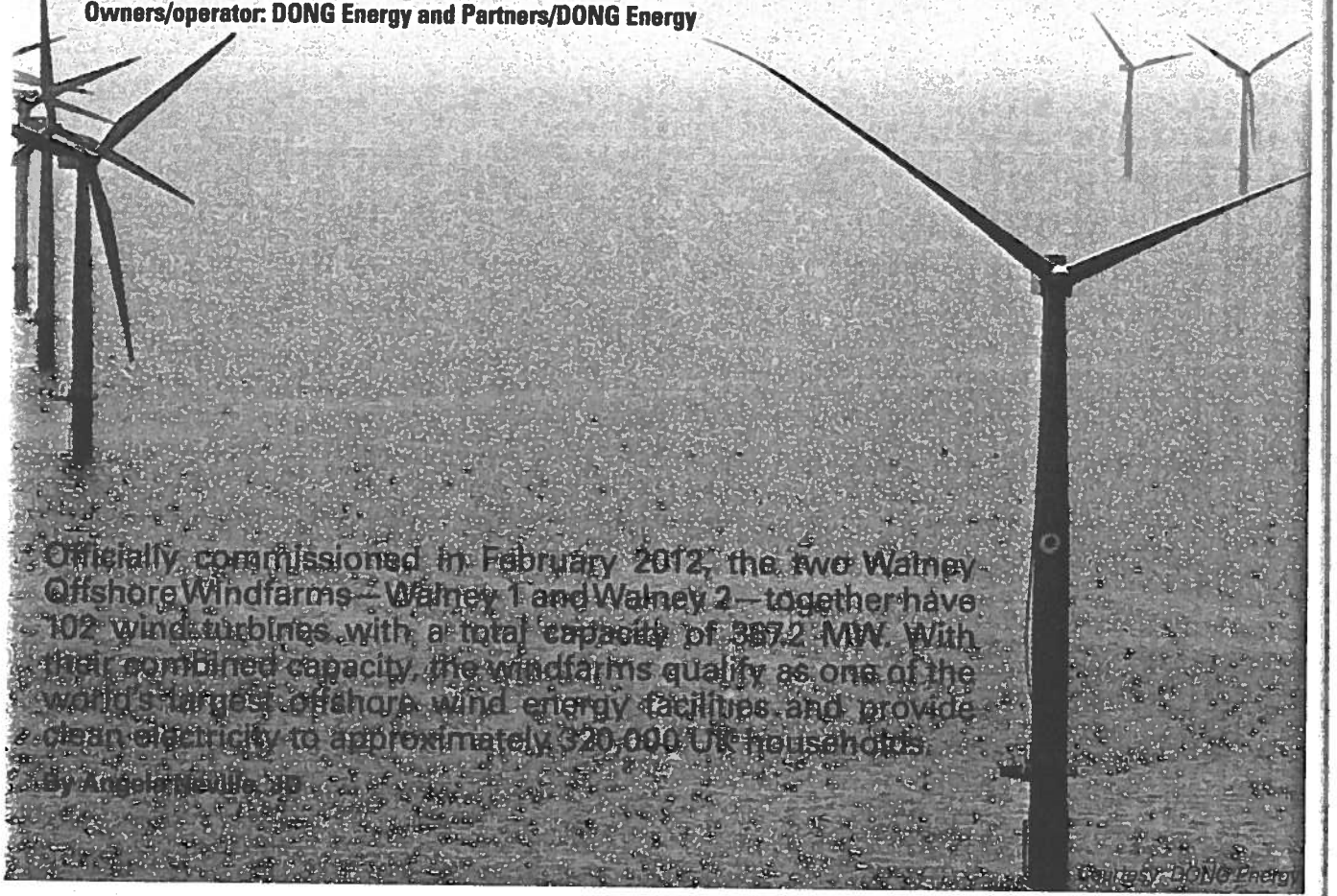
The Three Gorges Dam project is designed to adjust the Yangtze River's upstream flood, which will ensure successful flood control of the Jingjiang section, CTGC sources say. The project's goal is to prevent 10-year floods and control 100-year floods of the Yangtze River. Even in the rare case of a 1,000-year flood, mass damages or injuries can be prevented, according to the CTGC.

At the same time, serious problems—such as environmental degradation and disease epidemics related to floods or flood diversion—will also be avoided. Thus, the project will protect 1.5 million hectares of farmland and towns and 15 million people from flood damage in the Jianghan Plain and the Dongting Lake area. ■

—Angela Neville, JD is POWER's senior editor.

Walney Offshore Windfarms, Irish Sea, UK

Owners/operator: DONG Energy and Partners/DONG Energy



Officially commissioned in February 2012, the two Walney Offshore Windfarms—Walney 1 and Walney 2—together have 102 wind turbines with a total capacity of 367.2 MW. With their combined capacity, the windfarms qualify as one of the world's largest offshore wind energy facilities and provide clean electricity to approximately 320,000 UK households.

Courtesy: DONG Energy

Long a seafaring nation, the United Kingdom (UK) is now in the forefront of nations embracing offshore wind power. In fact, the scale of offshore wind power currently being planned by the UK renewable energy industry is larger than in any other country.

When commissioned in February 2012, the 367-MW Walney Offshore Windfarms (Walney 1 and Walney 2) became the world's largest offshore wind energy installation. Then in September 2012, construction of the even larger 500-MW Greater Gabbard Offshore Wind Farm off the Suffolk Coast was completed. Upping the ante, the 630-MW London Array offshore wind project is currently under construction. Looking farther down the road, other UK offshore wind farms in the pipeline will be even larger; these include Dogger Bank at 9,000 MW, Norfolk Bank at 7,200 MW, and Irish Sea at 4,200 MW.

Constructed in two phases during 2010 and 2011, the Walney Offshore Windfarms are located approximately 15 kilometers (km) off Walney Island in the Irish Sea. DONG Energy (50.1%), Scottish and Southern Energy (25.1%), and OPW (24.8%), a company jointly owned by Dutch pension administrator PGGM and Ampère Equity Fund (managed by Triodos Investment Management), are behind Walney (UK) Offshore Windfarms Ltd. DONG Energy served as the lead partner in the Walney Offshore Windfarms' construction phase and is also the operator.

Construction Overview

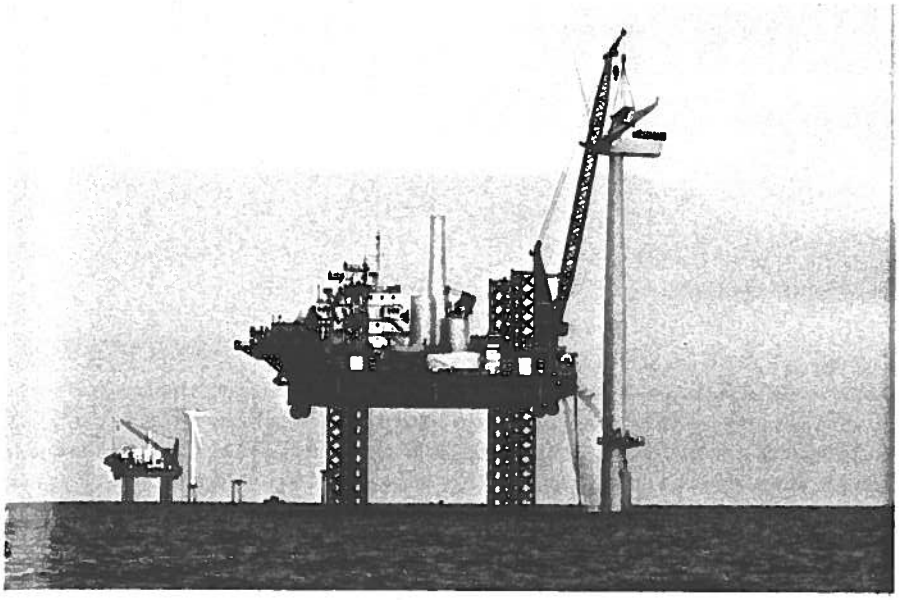
The Walney facility was constructed according to the multi-contract model, working in close cooperation with all the contractors and suppliers, Jens Hansen, project manager with DONG Energy, told *POWER* in September. The project also optimized the installation time through parallel installation (Figure 1).

"We installed the largest wind turbine foundations ever made—almost 70 meters (m) long and weighing more than 800 tonnes. In addition, our project was one of the first wind farms to use the new Siemens 120-m rotor diameter turbine with blade improvements," Hansen said. "The entire Walney facility has a combined total of 102 3.6-MW Siemens wind turbines."

"The offshore logistics for Walney 2 was a big challenge, but due to good planning it was all done according to the plan," said Hansen. He explained that by approaching the Walney project via a multi-contracting strategy, project managers were able to mitigate and handle risks and uncertainties quickly. Consequently, project management had a high awareness of the dangers and potential upsides in the project and thereby increased their ability to do parallel installation with controlled risk exposure.

DONG Energy coordinated all the activities in the multi-contracting project. A

1. Uplifting work. During construction of the Walney Offshore Windfarms, which was handled in two phases—Walney 1 and Walney 2—crane barges, jack-up vessels, and tugs worked out of ports in the East Irish Sea, primarily Barrow and Mostyn Harbors. *Courtesy: DONG Energy*



number of subcontractors performed the following duties:

- Seajacks from the UK installed the wind turbines.
- Geosea and Ballast Nedam handled the foundation installation.
- VSMC and Prysmian installed the cables.
- Scaldis installed the offshore substation.
- Tideway handled the scour protection.

Facility Operations

The Walney Offshore Windfarms are located in the Irish Sea, which is characterized by high tides and waves, and windy weather. The difference between high tide and low tide is approximately 8 m. The wind speed is estimated to average approximately 9.3 m/s at 80 m. Even though the wind farms cover an area of roughly 73 km², they are located far enough from the coast that their visual impact is minimal.

Each of the 102 turbines generates electricity at a voltage of 33 kV. Offshore substations collect electricity from the wind turbines and step up the voltage to 132 kV for the local grid. "The Walney 1 offshore substation is connected to the national grid by a 44-km-long buried export cable at the substation in Heysham, whereas the Walney 2 offshore substation is connected to the national grid at Cleveleys near Blackpool, via a 43-km-long buried export cable," Hansen explained.

The Operation and Maintenance (O&M) Base in the new purpose-built premises at Barrow's Ramsden Docks consists of an office for administration, welfare, and catering for personnel and a warehouse for storing equipment for maintenance of the offshore wind farms. Two new purpose-built service vessels and a new service pontoon are in place to enable the transport of service technicians to and from the wind farms. From the O&M Base, turbine operations can be monitored 24 hours a day and a local crew of approximately 60 people will ensure that the Walney Offshore Windfarms are in operation for the next 25 years, according to Hansen.

"The wind conditions are very good and the area also has very good grid connection possibilities; hence, we have other wind farms in the area and therefore gain a certain synergy," Hansen said. "When we have more activities in the area, DONG Energy as a company gains a better opportunity to work with the local community (like we have done with the Walney Fun Run) and to be an attractive employer for the skilled labor in the area."

Monitoring for Possible Environmental Impacts

The marine environment and bird life in and around the facility were carefully studied before the wind farms' construction was authorized. During the two years of construction, additional work was done to ensure that construction activities remained within acceptable limits for noise and other disturbances, according to Mike Robson, senior environmental advisor on the Walney facility team. In fact, as Hansen explained, "During the Walney Offshore Windfarms' construction, we were not allowed to install the monopole foundation during the period from February until April 7 due to the spawning season for the sole."

Wind farm personnel are now conducting post-construction environmental surveys. "Now that the wind farms are completed, a series of surveys will be carried out during the next few years to keep an eye on any possible impact the wind farms may have," Robson said. "Only minor impacts are expected on the seabed sediments and the marine fauna, including fish and shellfish, encountered in and around the wind farms."

Starting in late April 2012, survey vessels began taking samples to study marine organisms in and on the seabed, and a specially chartered fishing vessel is taking trial catches of fish using a scientific beam trawl. Also in 2012, a series of bird surveys will be made from a boat to count birds in and around the wind farms.

The surveys' results will be presented to scientific advisors at the Centre for Environment, Fisheries, and Aquaculture Science, an executive agency of the UK's Department for Environment, Food, and Rural Affairs. "The surveys will help to improve our knowledge of the sea and its resources in the Walney Offshore Windfarms' area," Robson said.

Powering the Future

With their projected annual production of approximately 1,400 GWh, the Walney Offshore Windfarms are set up to benefit from the UK Renewables Obligation Certificate regime, which will create value for the facility owners, explained Hansen.

He noted that the wind farms also benefit the local economy: "They will create jobs and business opportunities. A lot of persons have had direct and, maybe more importantly, indirect benefits from the wind farms' construction activities and will also benefit for many years to come from their operations."

Currently, the UK offshore wind energy sector appears to have the wind at its back. In 2011, Renewable UK, a leading UK renewable energy association, conducted a study of deployment trends that analyzed the existing pipeline of future UK offshore wind projects. The study projects that by 2016 there will be about 8 GW of installed capacity and a total of approximately 18 GW by 2020.

In terms of its contribution to net UK electricity production, offshore wind energy supplied around 1.5% in 2011. This amount will grow to between 7% and 8% by 2016 and to approximately 17% by 2020, according to Renewable UK. ■

—Angela Neville, JD is POWER's senior editor.