Introduction

The Ivanpah Solar Electric Generating System is the largest concentrating solar thermal power plant in the world. At 377 megawatts nominal (392 MW gross), Ivanpah provides enough power annually for 140,000 homes in the Pacific Gas & Electric and Southern California Edison service territories. More than 13 million tons of carbon dioxide emissions will be avoided over the 30-year lifecycle of the project, the equivalent of taking 2.1 million cars off the road. The project has already provided significant economic benefits locally, regionally and stretching across a supply chain that spans 17 states.

Ivanpah has been highlighted as a model for renewable energy deployment by such public leaders as Presidents Barack Obama and Bill Clinton and former California Governor Arnold Schwarzenegger.

As the first solar thermal tower facility constructed at this scale, seeing the project through to completion presented a number of challenges – on permitting, financing, and engineering – that required innovative solutions and new ways of approaching power plant development. In each of these three areas, thoughtful, predictable policy, as well as a real commitment by all public and private stakeholders to work together to problem solve, helped ensure the success of this project.

This paper provides an overview of what it took to build this iconic infrastructure project and how BrightSource is using the lessons learned at Ivanpah to bring clean solar steam to power markets around the world.

BrightSource Technology

BrightSource Energy’s proven solar thermal tower technology produces electricity the same way as fossil fuel power plants – by creating high-temperature, high-pressure steam to turn a conventional turbine. However, instead of using fossil fuels to create the steam, BrightSource uses the sun.

At the heart of BrightSource’s proprietary solar thermal
system is a state-of-the-art solar field design, optimization software and a control system that allow for the creation of high-temperature steam. Thousands of software-controlled mirrors, called heliostats, track the sun in two dimensions and reflect the sunlight to a boiler that sits atop a tower. The solar field at Ivanpah is comprised of 173,500 heliostats that reflect sunlight onto the three 140 meter tall towers. When the concentrated sunlight strikes the boiler’s tubes, it heats the water to create superheated steam. The steam is piped from the boiler to a conventional steam turbine to produce electricity, where transmission lines carry the power to homes and businesses. In other applications, the steam is used in industrial processes such as thermal enhanced oil recovery or desalination.

By integrating conventional power block components, such as turbines, with our state-of-the-art solar field design, electric power plants using BrightSource technology can deliver cost-competitive, reliable and clean power when it’s needed most. The company can also integrate proven molten salt storage or hybridize with a fossil fuel plant, further increasing output and reliability, and significantly reducing energy costs.

Prior to Ivanpah, BrightSource’s technology had been tested and proven in the field at two facilities: in our R&D facility and at a 29 MWth project built for Chevron’s enhanced oil recovery operation near Coalinga, California. These facilities have been closely examined, tested and validated by leading independent engineering firms, including Parsons and RW Beck.

**Project Finance**

Large energy infrastructure projects of all kinds, including fossil fuel and renewable energy plants, generally utilize project finance to provide the funds they need for construction. Project finance is a well-established financing structure that leverages the debt and equity necessary to execute capital intensive ventures. The goal is to balance risks and rewards between project participants and to allocate risks consistent with capability, risk appetite, and credit capacity of the stakeholders. In order for a project financing structure to be successful, there must be a well conceived business plan that is both economically viable and technically feasible.

BrightSource employed the project financing model for the Ivanpah project. Consistent with that model, the U.S. Department of Energy’s loan guarantee program was instrumental in attracting the capital necessary to finance this innovative project at commercial scale. BrightSource was the project sponsor of Ivanpah, but is not the loan recipient. The borrower under the project’s $1.6 billion loan guarantee is the special purpose project company itself, which is owned by NRG Energy, Google, and BrightSource. The project company holds the long-term, fixed price power purchase agreement meaning that for a 20 or 25 year period it has purchasers for all of the energy it produces at a fixed price.

The project company also owns the infrastructure that produces that energy. The underlying loan is fully secured by all of the project company’s physical assets and contracts, and the borrower pays interest that will earn a return for the lender, in this case, the U.S. taxpayer. For Ivanpah, the project companies own the three power sales contracts, each with a major credit-worthy utility for a minimum of 20 years. This is analogous to building a new hotel and having its mortgage backed not only by the property, but by the income that will result from guaranteed, 100% occupancy for 20 or more years.
**Economic Impact**

Construction of any major infrastructure project provides economic benefits that accrue locally, regionally, and nationally. Ivanpah is no different. At the peak of construction, there were nearly 3,000 people employed on site at Ivanpah— including more than 2,100 craft workers. These jobs are family-wage, highly-skilled trade, manufacturing and engineering jobs created in an area with one of the nation’s highest unemployment rates. The project included training and deploying skilled pipefitters, electricians, engineers, welders, technicians, heavy equipment operators, mechanics, technicians, insulators and millwrights.

At completion, Ivanpah generated an estimated $250 million in earnings for these construction workers and over its 30 year life will produce $650 million in earnings for workers on the site, including the 90 permanent jobs required to operate the plant.

The project doesn’t simply create jobs at the site. Ivanpah created jobs throughout its 17-state manufacturing and supply chain. These are jobs that provided the equipment and materials needed for construction at Ivanpah. For example, one supplier was an 85-year old gear drive company, called ConeDrive Gearing Solutions, located in Traverse City, Michigan. To serve the Ivanpah project, they hired roughly 20 additional workers to their existing 163 member team.

In total, the Ivanpah supply chain totaled 42 million heliostat components, including 22 million rivets, more than 7,500 tons of steel, 2,000 kilometers of cable, and more than 27,000 cubic meters of concrete.

**IVANPAH SUPPLY CHAIN/DOWNSTREAM BENEFITS**

**A Commitment to Domestic Spending**

- Domestic suppliers make up the majority of Ivanpah’s supply chain, representing 18 states throughout the U.S.*
- Local building trades are staffing the Ivanpah project.
- More than 50% of ocean freight is shipped aboard US-flagged vessels.

* includes Maryland headquarters of Bechtel, Ivanpah’s engineering, procurement and construction (EPC) provider.
Environmental Sustainability

BrightSource has designed its proprietary technology to have as minimal environmental impact as possible. At Ivanpah, BrightSource incorporated features and strategies that both reduce environmental impacts and, at the same time, reduced project costs.

Land Use

CSP is more land efficient than competing solar technologies, as shown in a recent study performed by National Renewable Energy Lab (NREL). Moreover, the Ivanpah project was designed with a deep commitment to thoughtful land use and siting practices; when determining where to site our projects, BrightSource uses a stringent set of environmental and generation criterion:

- Areas with high direct natural solar insolation, which decreases the amount of land required
- Sites close to development or that have already had pre-existing human impact
- Access to pre-existing transmission infrastructure

Heliostat pylons were inserted directly into the ground, and did not require leveling the solar field or pouring concrete foundations. This allows the natural contours and vegetation at the site to remain in all but a fraction of the site, limiting grading and major earthwork primarily to the powerblock areas. BrightSource technology can be deployed on up to a 5 percent grade, eliminating the need for flat land and grading as required by PV or other solar thermal technologies.

Water Use

BrightSource’s solar technology uses water in two primary ways: to clean the heliostat mirrors and to produce steam for electricity generation or industrial processes. At Ivanpah, water is not lost during power generation. In order to conserve water, Ivanpah uses a dry cooling process to condense the steam back to liquid water, which is then cycled back to the boiler in a closed loop system.

In thermal steam systems, the super heated steam inside the boiler pipes must be cooled and condensed back into water in a closed loop system. Dry cooling uses an air-cooled condenser comprised of many large fans to circulate air over the pipes to cool and condense the steam. By comparison, a wet cooling system will circulate water across the pipes to cool and condense the steam. Dry cooling allows the project to reduce water usage by more than 90 percent relative to competing solar thermal technologies using conventional wet cooling systems. By using dry cooling, we are also able to eliminate the need for evaporation ponds and extensive water treatment facilities, which provide us with greater flexibility on where we can site our projects.

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<thead>
<tr>
<th>Wet CSP/Conventional Cooling</th>
<th>BrightSource’s Dry CSP Cooling</th>
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<tbody>
<tr>
<td><strong>Trough Wet Cooling</strong></td>
<td><strong>0.03 Gal/KWh</strong></td>
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<tr>
<td><strong>Nuclear</strong></td>
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<td><strong>Coal</strong></td>
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<tr>
<td><strong>Combined Cycle Gas</strong></td>
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1 Source: California Energy Commission

Our ability to produce and sell more electricity makes dry cooling an economically viable choice. It significantly reduces the cost implications of using a more expensive dry cooling system, and it also reduces the percentage of overall parasitic load.

The minimal amount of water consumed by a BrightSource project is used from the cleaning of heliostat mirrors, and even this water is made up of partially recycled boiler water. Total annual water consumed at Ivanpah is roughly 123 megaliters, equivalent to the use of 300 typical California homes. Put another way, Ivanpah uses less water than the amount required to maintain two holes of the adjacent 36-hole golf course.

BrightSource’s technology is designed to produce the highest temperature and pressure solar steam in the world. Ivanpah achieves temperatures of more than 550 degrees Celsius. Competing systems are limited by temperatures that the heat-transfer medium can reach. This technological advantage lets us use more of the steam’s heat energy to efficiently power a steam turbine-generator. As a result, BrightSource solar thermal power systems can produce more electricity than competing technologies.

### IVANPAH BY THE NUMBERS

- Located on 3500 acres (14.2 km²) of public desert land
- Three unit power tower system production: 377 MW (Net)/392 MW (Gross)
  - Ivanpah 1: 126 MW
  - Ivanpah 2: 133 MW
  - Ivanpah 3: 133 MW
- Tower Height: 459 feet (140 meters)
- Number of Heliostats: 173,500 (2 mirrors/heliostat)
- Reflective Area per Heliostat: 163 sq. ft (15.2 m²)
- Heliostat Solar-Field Aperture Area: 2,637,200 m²
- Average Homes Served Annually: 140,000
- Average Heliostat Installation Rate: 1/minute during construction period
- Heliostat Placement Accuracy: +/-10 cm of depth and 6 inches (15 cm) of leeway in location

- Boiler Type: Solar Receiver Steam Generator (SRSG)
- Heat-Transfer Fluid: Water
- Cooling Method: Dry (air cooled condenser)
- Water Consumption: 100 acre feet/year equivalent to 300 homes/year
- Avoided Emissions: More than 400,000 metric tons of carbon dioxide (CO₂) each year
- Construction Jobs Created: More than 2,100 craft workers/3000 total workers at peak construction
- Wages and Employee Earnings: Approximately $650 million, including construction and operation*
- State and Local Taxes Paid: Approximately $300 million*
- Owners: NRG Energy, Google and BrightSource Energy
- EPC Contractor: Bechtel

*Estimates based on the power plant’s 30 years of operation*