U.S. DEPARTMENT OF ENERGY
LOAN PROGRAMS OFFICE
October 2016
INVESTING *in* AMERICAN ENERGY

# POWERING NEW MARKETS: ENERGY STORAGE POISED FOR GROWTH

## NOTE FROM THE EXECUTIVE DIRECTOR

The Department of Energy's Loan Programs Office (LPO) helped launch the first commercial-scale concentrating solar power (CSP) plants with thermal energy storage in the United States.

CSP plants use the sun's heat to create thermal energy to generate electricity. This heat can be stored to allow CSP plants to continue operating during cloud cover or even after the sun sets, helping provide energy on demand.

Between 2010 and 2011, LPO financed five of the world's largest CSP projects. By integrating thermal energy storage, two of these projects brought the first utility-scale "nighttime solar" to the United States.

These pioneering projects have the potential to become valuable sources of clean energy and in the areas where their energy is being used, they are helping to better integrate renewable energy into the electric grid. As first-of-a-kind projects, the lessons learned from these projects will help provide valuable insights for future deployments in how to finance, construct, and operate the technology at commercial scale.

Thermal energy storage is just one storage technology poised for commercial deployment. With its remaining loan guarantee authority, LPO could play a role in helping to launch new energy storage markets.

MARK A. McCALL
**Executive Director**

*October 2016*

LPO issued loan guarantees to the first U.S. CSP projects with thermal energy storage – a key technology for enabling greater integration of renewables to the electric grid.

## HOW SOLAR THERMAL ENERGY STORAGE WORKS

Unlike photovoltaic (PV) solar panels that absorb the sun's rays to directly generate electricity, CSP creates thermal energy by using mirrors to reflect the sun's rays onto a focal point that heats up a heat transfer fluid. The heat transfer fluid heats water to create steam to power a turbine that generates electricity, just like a conventional fossil fuel power plant.

A benefit of thermal energy is that heat can be stored for later use, similar to how a thermos keeps coffee hot.

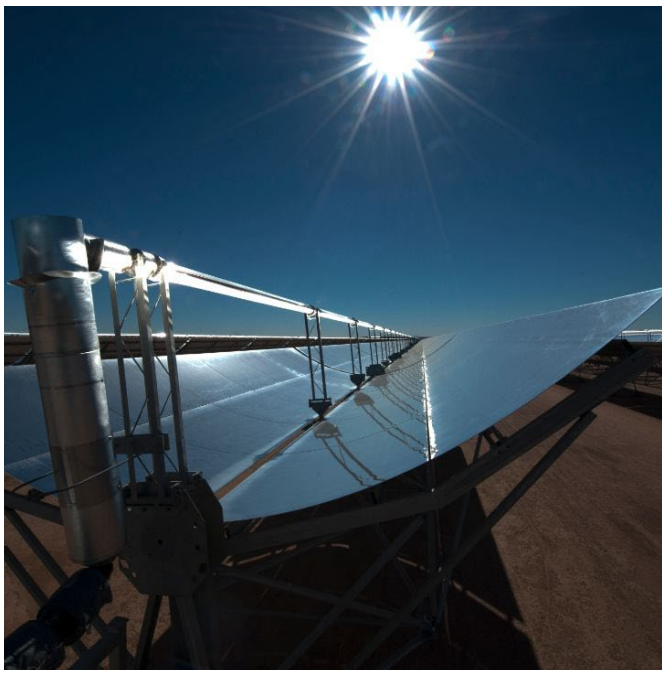
By integrating a thermal energy storage system, a CSP plant can generate electricity for extended periods of time when its solar resource is not available, depending on the size of the storage facility. This allows CSP to deliver electricity to the grid when it is needed – not just when the sun is shining.

Currently, there are two primary CSP technologies in commercial use, each of which can utilize storage: power towers and parabolic troughs.

Thermal energy storage technology allows solar power to perform up to full capacity even when the sun is not shining.

Credit: SolarReserve

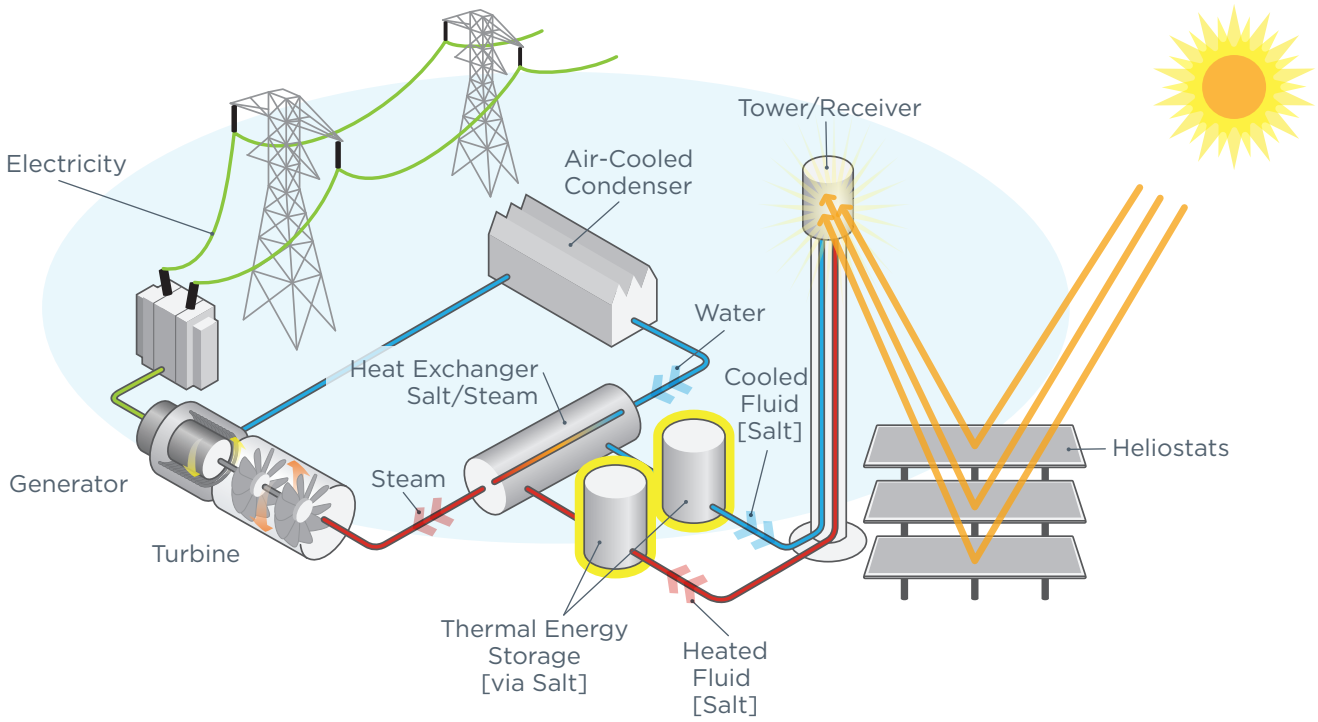
**Crescent Dunes, a power tower CSP plant with thermal storage in Nye County, Nevada**



Credit: Atlantica Yield

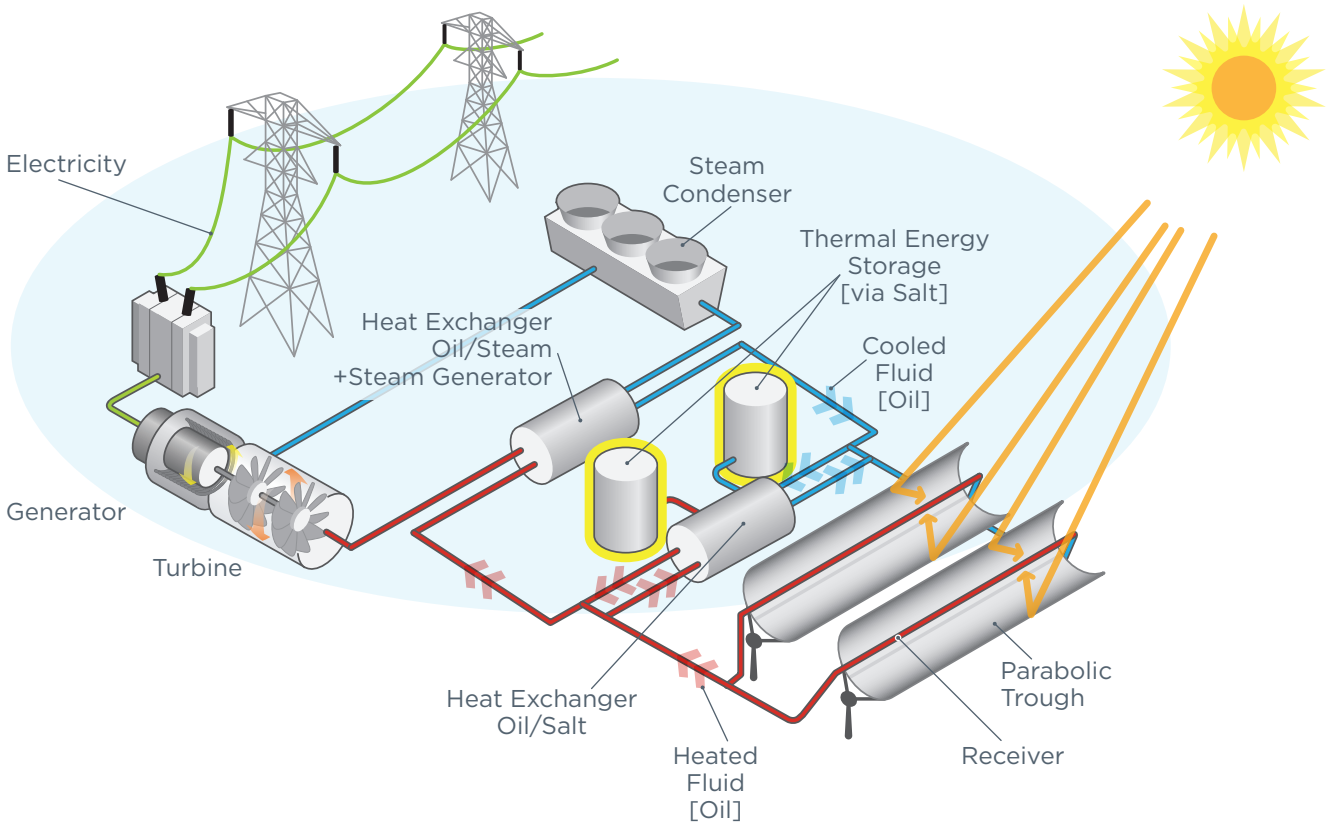
**Solana, a parabolic trough CSP plant with thermal storage in Gila Bend, Arizona**

# POWER TOWER CSP WITH THERMAL ENERGY STORAGE




In power tower CSP systems, numerous large, flat, sun-tracking mirrors—known as heliostats—focus sunlight onto a receiver at the top of a tall tower. At present, power tower CSP technology can use molten salt as the heat transfer fluid. Lower temperature molten salt is pumped from a storage tank up the tower to the receiver, where it is heated by the sun, then flows to a hot storage tank. The hot salt heats water to produce the steam that spins the turbine. This hot molten salt retains its heat so well that it can be stored and used to generate electricity at later times.

# PARABOLIC TROUGH CSP WITH THERMAL ENERGY STORAGE




In parabolic trough CSP systems, giant "U" shaped mirrors are used to capture the sun's energy. Synthetic oil can be used as the heat transfer fluid that heats water to create steam and also heats molten salt stored in tanks near the power block. When the sun goes down, the hot molten salt transfers its heat back to the heat transfer fluid which then heats water to generate steam that drives a turbine to produce electricity.

## BENEFITS OF CSP WITH ENERGY STORAGE: PROVIDING "SOLAR ON DEMAND"

CSP with thermal energy storage benefits both electric utilities and electric grid operators because it can generate electricity on demand, making it a "dispatchable" energy source. Dispatchability is key to meeting times of peak demand — the time of day that historically requires sustained periods of electricity supply — or changes in demand for electricity.

To handle peak demand and short-term spikes in demand, fossil fuel "peaker" power plants have been built to operate only during these times.

These peaker plants often sacrifice efficiency for lower capital costs since they do not operate full time. Lower efficiency can increase the costs and the emissions of greenhouse gases and other air pollutants. And because they only operate at times of high demand or system supply shortages, they sell electricity at a much higher price.

Because CSP achieves its maximum output during the middle of the day when solar energy is at its highest, it can store some or all of that thermal energy and dispatch it at times of peak demand or times when the grid needs energy supply the most — reducing the need for expensive and polluting peaker plants.

As a dispatchable energy source, CSP with thermal energy storage also allows greater use of intermittent resources without storage like PV solar and wind at full capacity when their resources are highest, such as the middle of the day for solar. This reduces the potential for over-generation and the need to curtail intermittent renewables, which means operating them at less than full capacity. Operating powerplants using cost-free fuel sources like the sun or wind closer to full capacity increases their value.

The role of CSP with thermal energy storage is particularly important as renewable energy has become the fastest growing source of new electricity generation in the United States. As renewables continue to grow, CSP with thermal energy storage may become even more valuable. A National Renewable Energy Laboratory (NREL) study of increasing renewable deployment scenarios in California found that the value of CSP with thermal energy storage increases by 5 to 6 cents per kilowatt-hour as non-dispatchable renewable resources are increasingly added to the grid.

With storage, CSP facilities can save some or all of their thermal energy for when the grid needs it most.

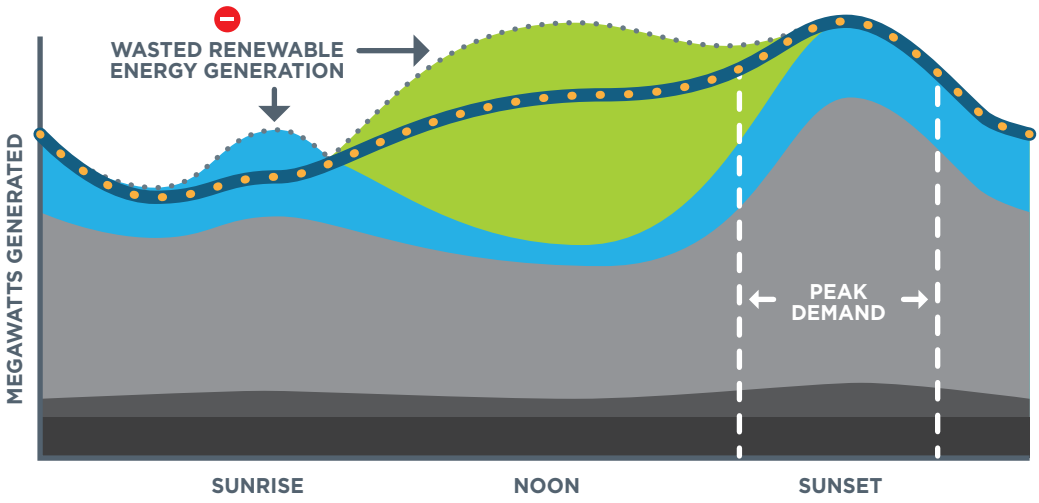
# ADDING VALUE TO OTHER RENEWABLES

PEAK ELECTRICITY GENERATION FROM RENEWABLES DOES NOT ALWAYS MATCH PEAK ELECTRICITY DEMAND.

Storage technologies can store energy from solar and wind systems, for example, so that it can be dispatched to meet peak demand, making renewable energy more reliable and competitive.

## WITHOUT ENERGY STORAGE

Excess renewable energy generation is wasted and may not be available during peak demand when fossil fuel peaker plants are used.



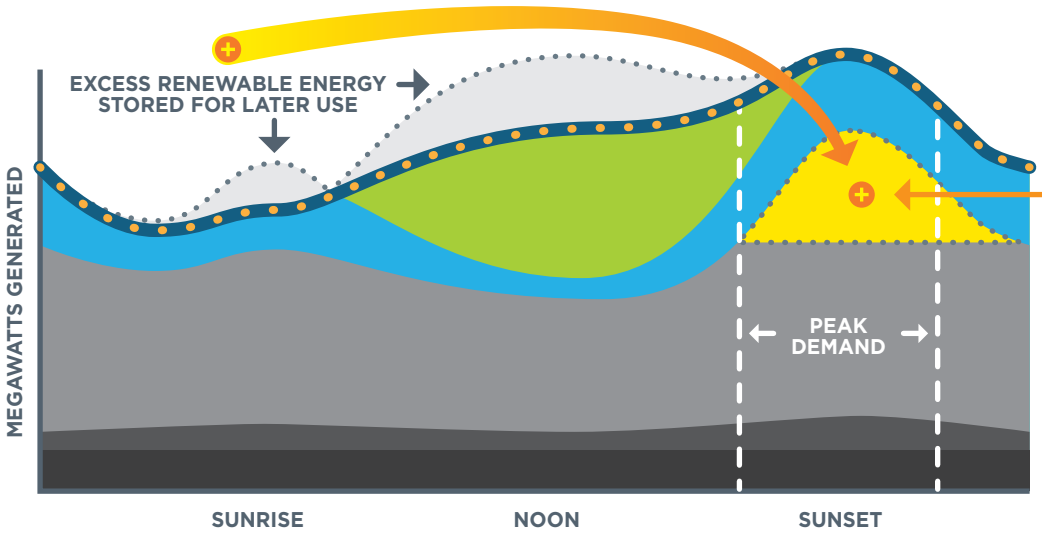

ELECTRICITY DEMAND

ELECTRICITY SUPPLY

- SOLAR
- WIND
- FOSSIL
- HYDRO
- NUCLEAR
- STORED

## WITH ENERGY STORAGE

Intermittent renewable supply can better meet energy demands even when the renewable resource is not available.




ENERGY SUPPLIED FROM FOSSIL FUEL PEAKER PLANTS IS REDUCED.

## LAUNCHING THERMAL ENERGY STORAGE IN THE UNITED STATES

The ability of CSP, and especially CSP with thermal energy storage, to provide solar on demand and improve grid integration for renewables has created demand for this technology. A Bloomberg New Energy Finance analysis of electric utilities' clean energy procurement plans found significant interest in storage technologies.

Despite these benefits, developers faced challenges several years ago securing financing to build large CSP projects because facilities at that scale had not been deployed in the United States in thirty years and CSP power towers had never been deployed in the country. Additionally, CSP with thermal energy storage had never been deployed at commercial scale in the United States. Commercial lenders are often unwilling or unable to take on the risk of supporting the deployment of a newer technology at large scale until it has a solid history of commercial operation.

LPO guaranteed $5.84 billion in loans for five CSP projects, two of which included thermal energy storage.


Credit: Atlantica Yield

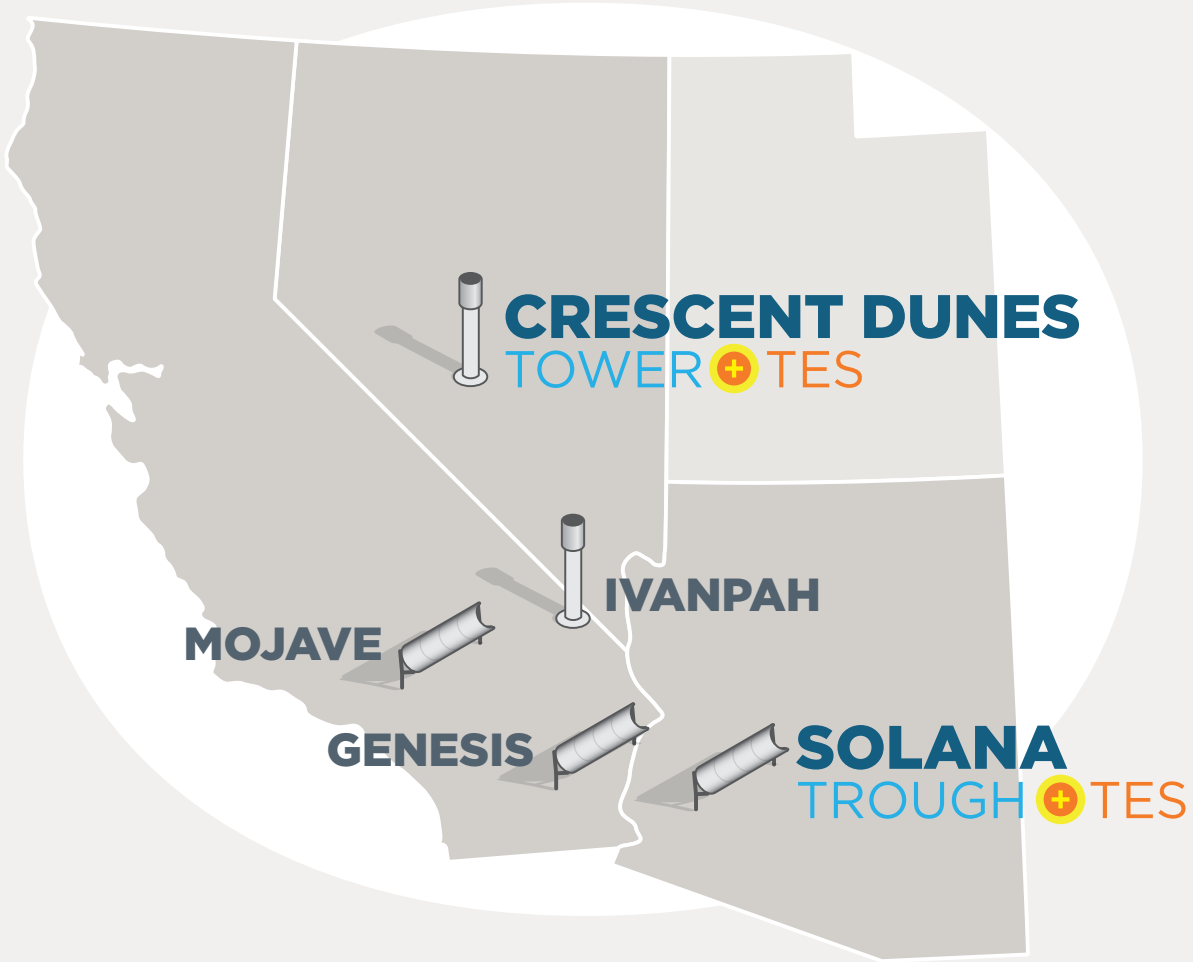
LPO played a crucial role in bridging this financing gap by issuing $5.84 billion in loan guarantees between December 2010 and September 2011 for five CSP projects available under Title XVII – specifically the Section 1705 program authorized by the American Recovery and Reinvestment Act.

This financing helped enable construction of the largest CSP plant in the world and first CSP power tower in the country (Ivanpah in California), the first CSP plant with thermal energy storage in the country (Solana in Arizona) and the world's largest CSP power tower with thermal energy storage (Crescent Dunes in Nevada). All five projects are now generating electricity.

Learn more about LPO CSP projects at: energy.gov/lpo/csp

## FIRST UTILITY-SCALE THERMAL ENERGY STORAGE IN U.S.

### LPO-FINANCED CSP PROJECTS



## VALUABLE LESSONS LEARNED FROM FIRST-OF-A-KIND PROJECTS

In addition to increasing the nation's clean energy capacity, the lessons learned by actually financing, building, commissioning, and operating these plants at commercial scale has the potential to help catalyze future innovation and larger commercial deployment.

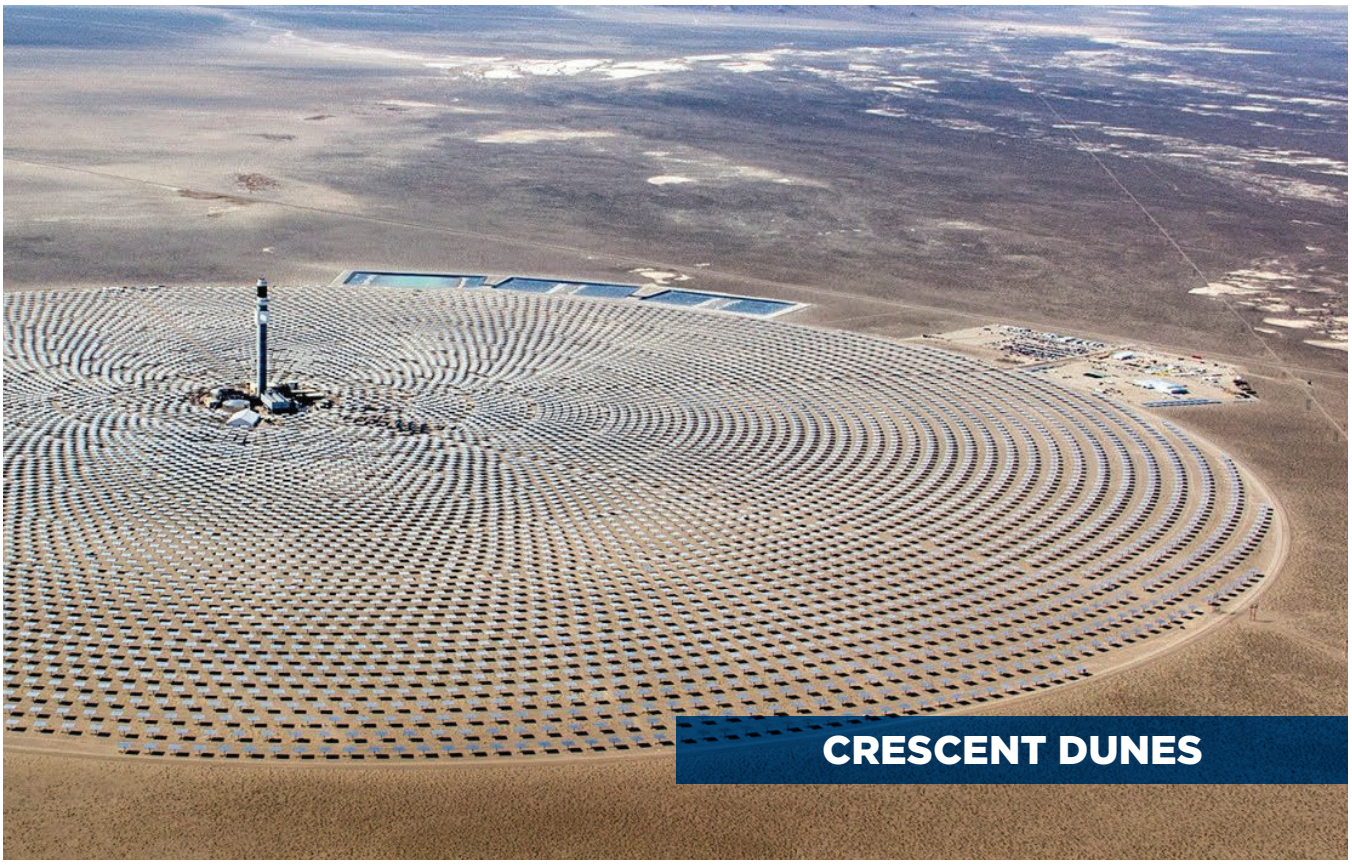
By working with LPO, developers have access to the Department of Energy's team of financial, technical, environmental and legal professionals to help establish a framework for financing future projects.

Additionally, project developers learn important lessons during the construction and commissioning phases. Processes that work can be replicated or refined. Challenges that arise can be addressed and mitigated for future projects. These lessons can allow the next generation of projects to be built more efficiently and with lower cost.

Once projects are operational at commercial scale, the plant operators can observe how the technology functions in ways that cannot be seen at demonstration scale. Unforeseen issues can arise and the lessons learned in solving these challenges are vital for improving the technology and lowering costs in future deployments.

First-of-a-kind projects also help to develop a history of commercial operation for the technology, thus reducing the risk for commercial lenders to finance future deployments without the Department's loan guarantees.

First commercial-scale deployments help catalyze future innovation and larger commercial deployment.




Credit: SolarReserve

## NEXT-GENERATION STORAGE TECHNOLOGY

The lessons learned at the five CSP projects financed by LPO will play an important role in U.S. global leadership in the CSP and energy storage markets.

California-based SolarReserve is now exporting the technology used at Crescent Dunes to other promising global markets. Energy-intensive mining operations in Chile present one opportunity and SolarReserve is in negotiations to construct solar projects that include both CSP with thermal energy storage and PV. South Africa, which has been largely dependent on coal power plants, is also making a major push to increase its usage of CSP. The South African Department of Energy has given approval for a 100-MW CSP plant with thermal energy storage using the technology from Crescent Dunes.

Expanding upon its experience at Ivanpah, California-based BrightSource is now offering thermal storage in future projects. China represents another promising market and BrightSource has signed a joint venture with Shanghai Electric Group to bid on proposals for CSP plants with thermal energy storage.

The increased deployment of storage technologies has the potential to drive down costs and attract private lenders, similar to what has occurred with utility-scale PV and wind. A number of other storage technologies are poised for commercial-scale deployment in addition to thermal energy storage, including batteries, flywheels, compressed air storage, and pumped hydro. LPO can help finance the first commercial deployments of innovative storage technologies with up to $4.5 billion of loan guarantees for Renewable Energy and Efficient Energy Projects and $8.5 billion for Advanced Fossil Energy Projects.

Technology pioneered as part of LPO- financed projects can play an important role in launching new markets.

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