The Value of Concentrating Solar Power (CSP) with Thermal Energy Storage

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BrightSource

BrightSource Overview

- **Leading solar thermal technology**
  - Our proprietary technology concentrates the sun's energy to produce high-value steam to power electricity, petroleum and industrial process markets worldwide
- **Founded in 2004**
- **Corporate Structure**
  - **Oakland:** Corporate headquarters
  - **London:** Business development, including JV structures for MENA and China
  - **Jerusalem:** Engineering and Product Supply entities; Corporate Accounting/IT
  - Local offices in Beijing, China and Johannesburg, South Africa
- **Technology Deployment**
  - **Ivanpah:** 377 MW commercial scale solar project located (Mojave Desert, CA)
  - Groundbreaking October, 2010. Dedication February, 2014
  - **Coalinga:** 29 MWth demonstration thermal EOR plant for Chevron (Coalinga, CA)
  - Operated October, 2011 though - December, 2014
  - **Solar Energy Development Center (SEDC):** Fully operational 6 MWth solar-to-steam demonstration facility (Israel)
  - Dedicated June, 2008.
- **Seasoned team of CSP industry pioneers**
  - Principal members of our technical team pioneered the first utility-scale solar energy plants about three decades ago by designing and developing 354 MW of solar thermal power systems, which remain in operation today.

BSE Shareholders and Office Locations

Shareholders

Venture Capital

- VantagePoint Venture Partners
- Draper Fisher Jurvetson
- Riverwood
- DBL Investors

Industrial

- GE
- Chevron
- BP alternativenergy
- StatoilHydro Venture

Financial Institution

- Morgan Stanley
- CalSTRS
- Goldman Sachs

Strategic Partners

International Business Development

- GE
- Shanghai Electric

(China JV)

Electricity Generation Customers

- Southern California Edison, An Edison International Company
- PG&E
- The Electricity Authority

Huanghe, a subsidiary of SPI

Project Equity Investors

- nrg
- Google
- GE
- NOY Infrastructure & Energy Investment Fund

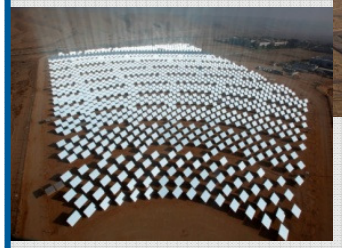
Huanghe, a subsidiary of SPI

- Shanghai Electric

The Past, Present and Future of BrightSource

2006 - today

- Technology Validation
- Green Field Development
- Project Owner/Developer
- Significant Equity Investment
- Utility Scale Power Plants



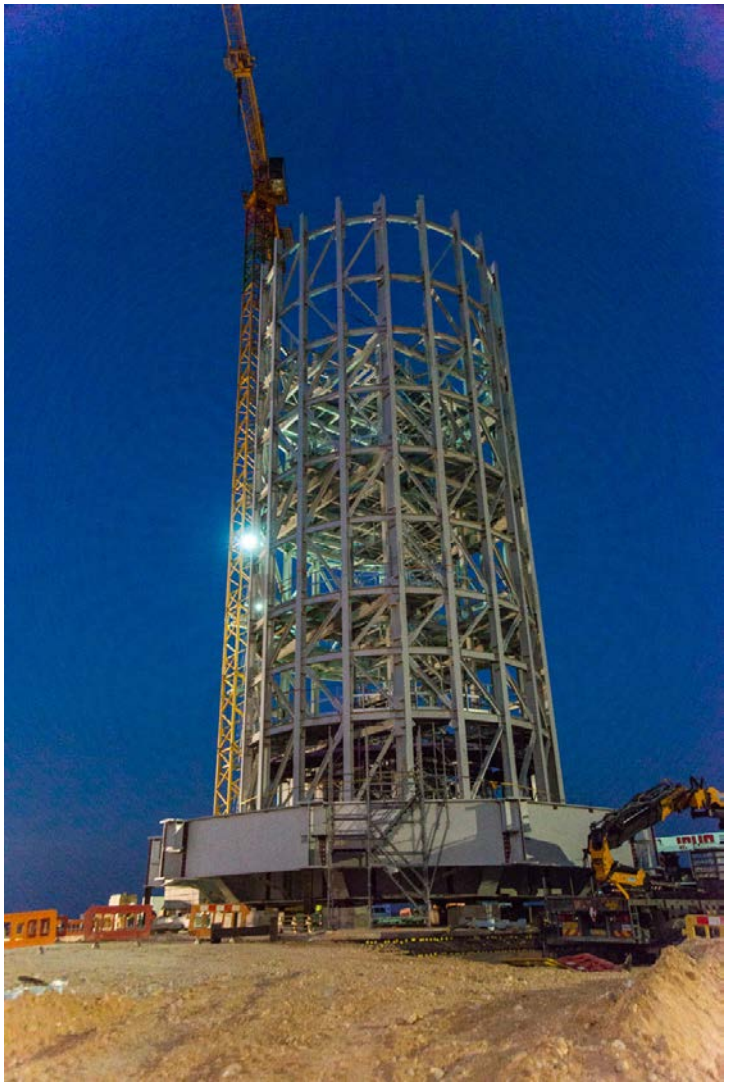

Future

- "Sun to Steam" Leader
- Focused on Software and Services
- Lead Storage Deployment
- International Business Development through Strategic JVs

Solar Energy Development Center	Chevron Coalinga Solar Thermal EOR Plant	Ivanpah Solar Electric Generating System	Ashalim Thermal Solar Power Station	Projects in Development
(6 MWth) Operating	(29 MWth) Operating	(377 MW) Operating	(121 MW) Under construction	China (Delingha/Huanghe) South Africa (Solis) MENA

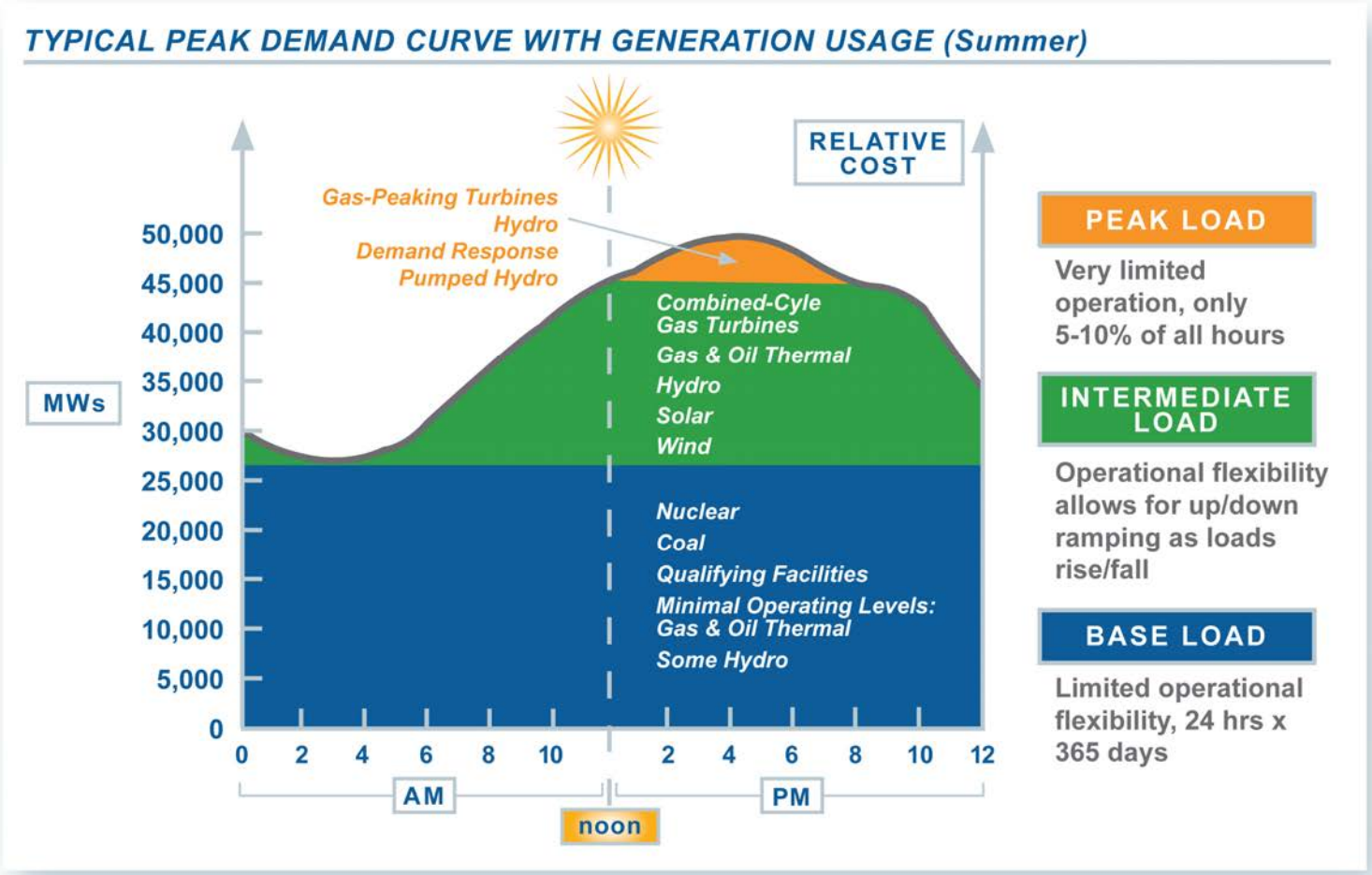
Key Enabling Technologies

1. Low-cost heliostat design
2. Receiver coatings
3. Solar field layout
4. Solar field control systems
5. Wireless solar field network (first implementation in Ashalim project)
6. Thermal Energy Storage



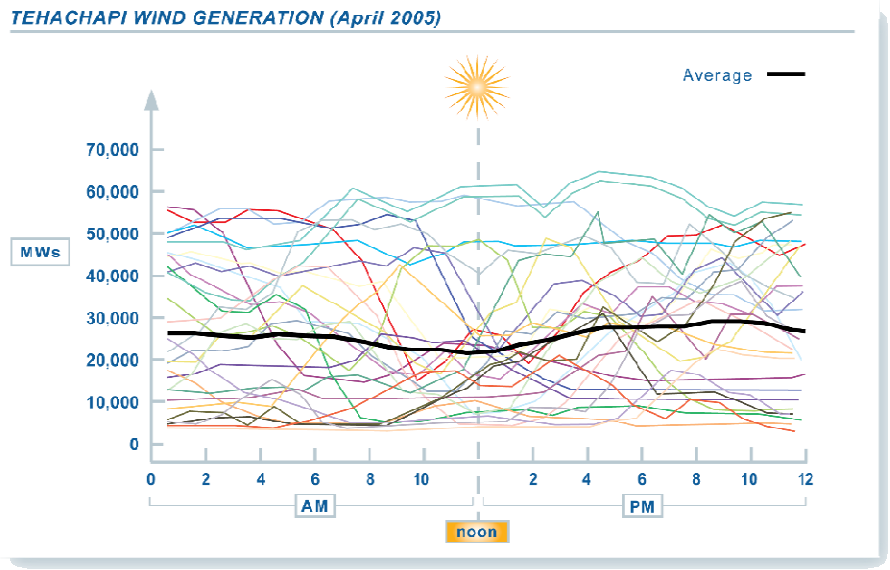
Ashalim: World's tallest power tower, 750 meters

Different Resources Serve Different Needs

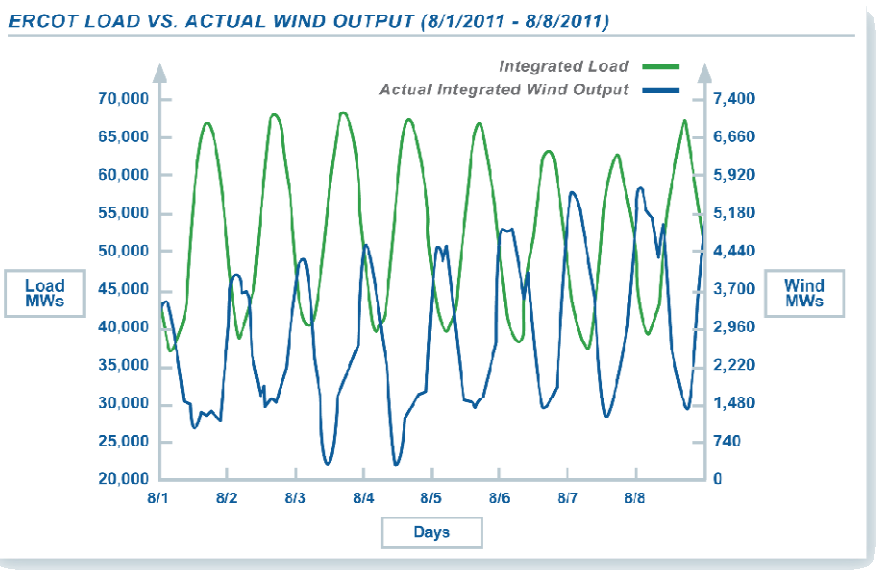


Source: California's Electricity System Supply and Demand Overview, presentation by Jeffrey Byron, Commissioner, State Energy Resources Conservation and Development Commission (energy commission), to the California State Assembly Utilities and Commerce Committee, Informational Hearing, March 29, 2007.
* According to the energy commission, 1 megawatt will provide electricity for approximately 750 homes.

Output Variability Impacts Grid Operations and Increases Costs …(wind example)



Forecast Uncertainty Day-to-Day

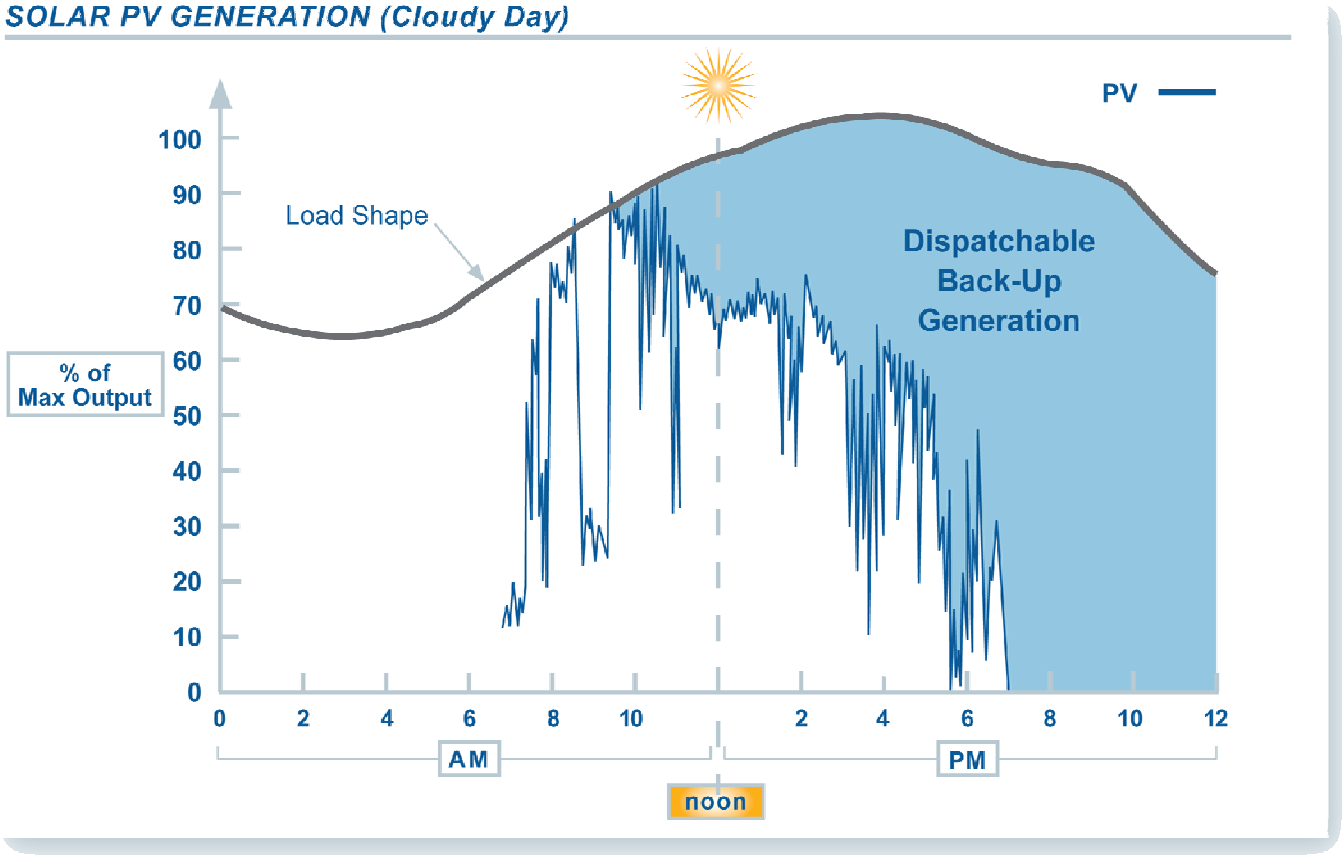


Non-Coincidence with Peak Demand

- Variable resources require changes in grid system operation resulting in integration costs
- Short-term variability increases the need for frequency regulation
- Increased variability requires greater flexibility and operating reserves, with more ramping capability to meet output changes

Tehachapi Source: Electric Power Research Institute, presented at REFF-West, September 2009
Ercot Load Chart Source: The Wind-Energy Myth by Robert Bryce, August 12, 2011, National Review

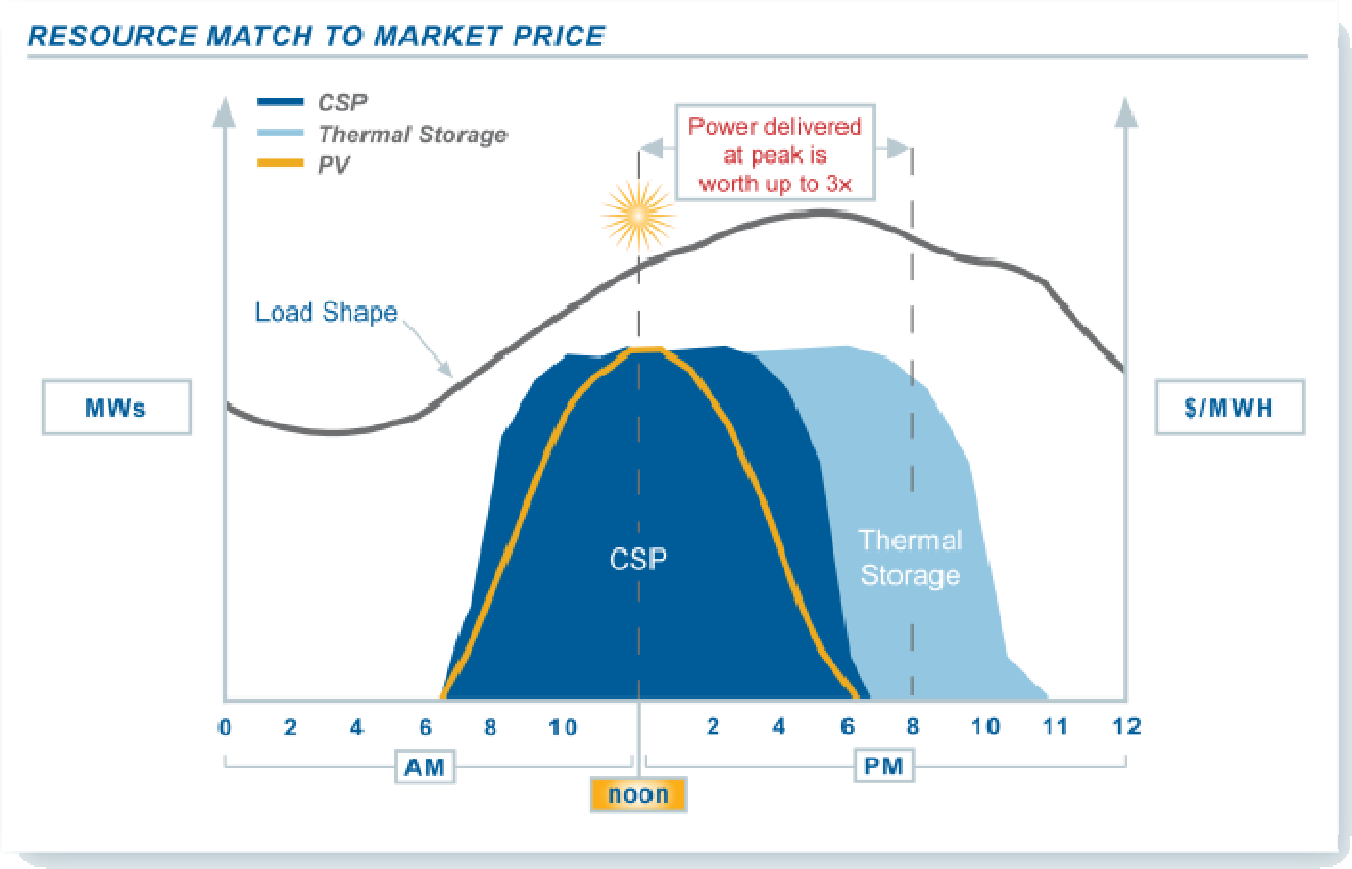
Output Variability Impacts Grid Operations and Increases Costs … (solar example)



PV Output Variability

… Requiring Dispatchable Generation to Maintain Reliability

Solar Thermal with Storage: Superior Alignment and More Energy Delivered at Higher Value



Energy storage increases asset utilization and transforms solar thermal into a high-value, flexible resource

Net System Cost is a Metric Used to Evaluate Cost Competitiveness Between Resource Alternatives

What it takes to construct the project	What it takes to generate electricity	What it takes to keep the lights on
Capital Cost	**Energy Cost**	**Net System Cost**
$ / W	Levelized Cost of Energy (LCOE)	Least-Cost, Best-Fit (LCBF)
Considers only installed cost	**Considers additional costs and energy produced**	**Considers utility value**
▪ Number of panels / mirrors / equipment ▪ Cost to make it ▪ Installed cost adds labor and materials	▪ Capital costs ▪ Capacity factor ▪ Degradation ▪ Operating costs ▪ Basic financing	▪ LCOE ▪ Integration costs ▪ Market value of energy (and ancillary services) ▪ Availability at peak demand

Unlike other methodologies, Net System Cost accounts for both costs and benefits

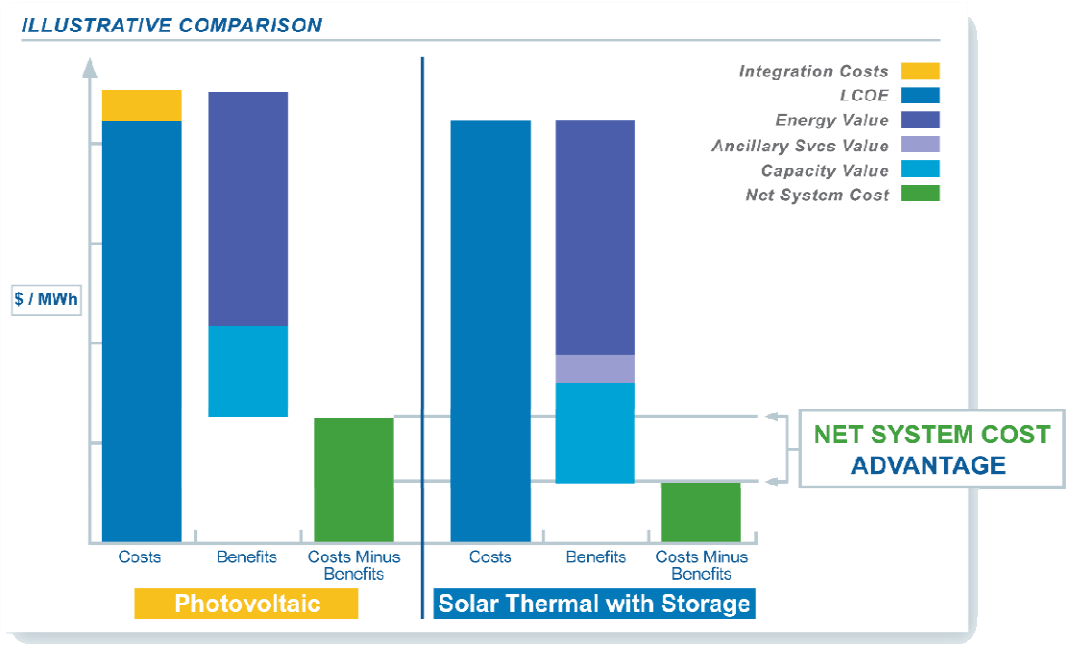
Net System Cost is a Metric Used to Compare Cost Competitiveness Between Resource Alternatives

COSTS — BENEFITS

LCOE + **INTEGRATION COSTS** − **ENERGY VALUE** − **CAPACITY VALUE** = **NET SYSTEM COST**

The method by which utilities procure resources to minimize the total cost of system operations.

Calculated by comparing total costs associated with a resource minus its benefits.



Evaluation based on Net System Cost is designed to achieve the lowest overall cost to ratepayers

The comparison of Net System Cost above is for illustrative purposes only and is not based on actual values.

Quantifying the Value of CSP with Thermal Energy Storage

The Economic and Reliability Benefits of CSP with Thermal Energy Storage: Literature Review and Research Needs, 2014

- Technical report incorporates the latest research on the economic and reliability benefits of CSP with thermal energy storage and serves as a comprehensive guide to understanding the design and operational attributes of CSP plants with thermal energy storage. (124 pages)

- The report is intended for utilities, regulators, grid operators and policy makers, and presents a framework for more informed decision-making in the evaluation of competing resources to achieve better outcomes for energy consumers.

http://www.brightsourceenergy.com/reports

Purpose of Report

- Provide a primer on valuation of CSP with thermal storage to help readers with different backgrounds understand the existing research literature
- Review research methods and results (primarily US)
- Encourage improved valuation in US utility procurement - and possibly elsewhere in the world
- Provide ideas for the technical and policy research agenda
- Note: Does not conduct a cost comparison of solar technologies or alternative renewable integration resources

Net cost is essentially the cost minus the benefits of a renewable project, where the benefits include any market products and operational attributes that can be quantitatively or qualitatively evaluated.

Report Organization

Part 1 - Background

1. Introduction
2. Design and Operational Attributes of CSP with Thermal Energy Storage
3. Utility or Market Services Offered by CSP with Thermal Energy Storage
4. Valuation of Renewable Resources – Definition of Net System Cost and Quantitative Methods
5. Valuation of Renewable Resources – Implication of Regulatory and Market Regimes
6. Looking to the Future: Simulating Power Systems under High Renewable Scenarios

Part 2 – Valuation Results

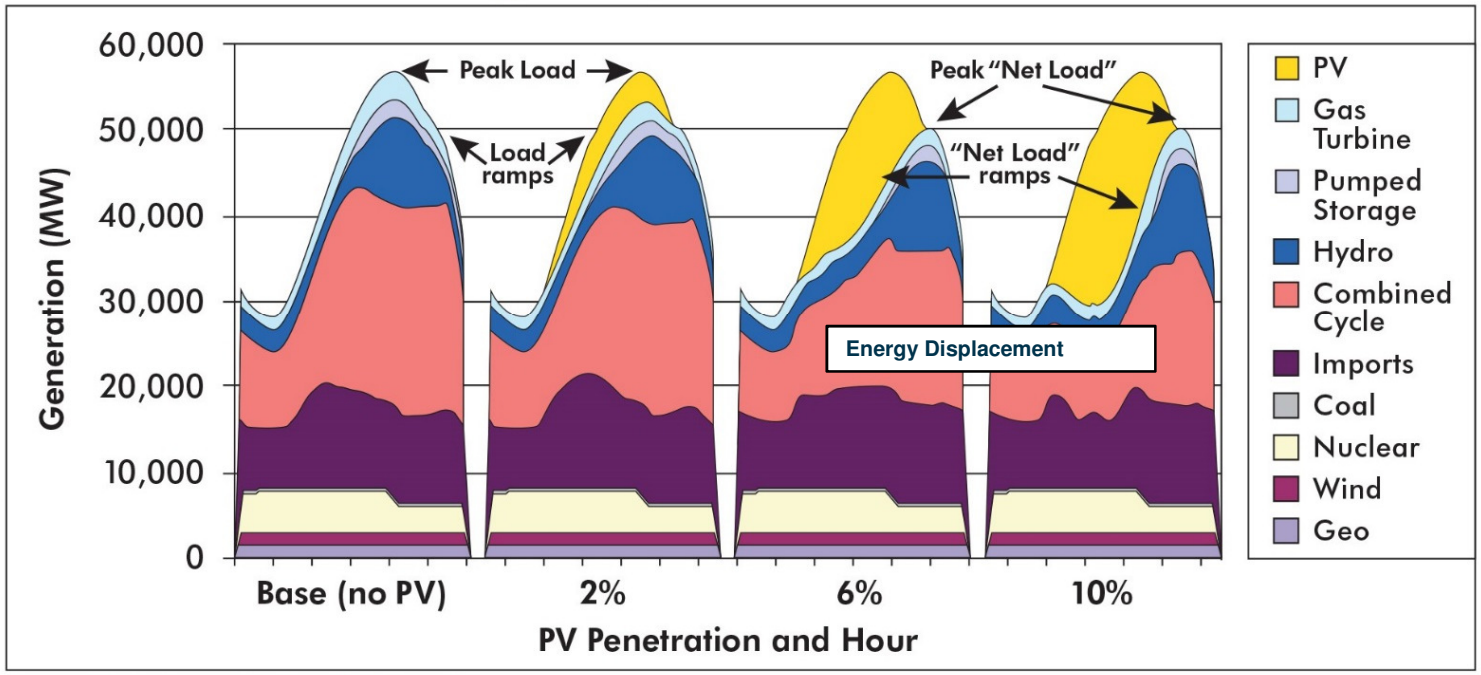
7. Energy and Ancillary Services
8. Resource Adequacy and Long-term Reliability
9. Integration and Curtailment Costs
10. The Total Economic Benefits of CSP with Thermal Storage
11. Incorporating Market and Reliability Valuation into CSP Plant Design
12. Conclusions and Next Steps

Appendix A: Methodologies for Calculating Capacity Value of CSP with Thermal Energy Storage

Appendix B: Simplified Calculation of Integration Costs in California under 33% RPS

Output Variability Impacts Grid Operations and Increases Costs …(solar PV example)

Figure 6-1: Simulated Dispatch in California for a Summer Day with PV Penetration from 0-10% Annual Energy – Comparison of Peak Load and Peak "Net Load"

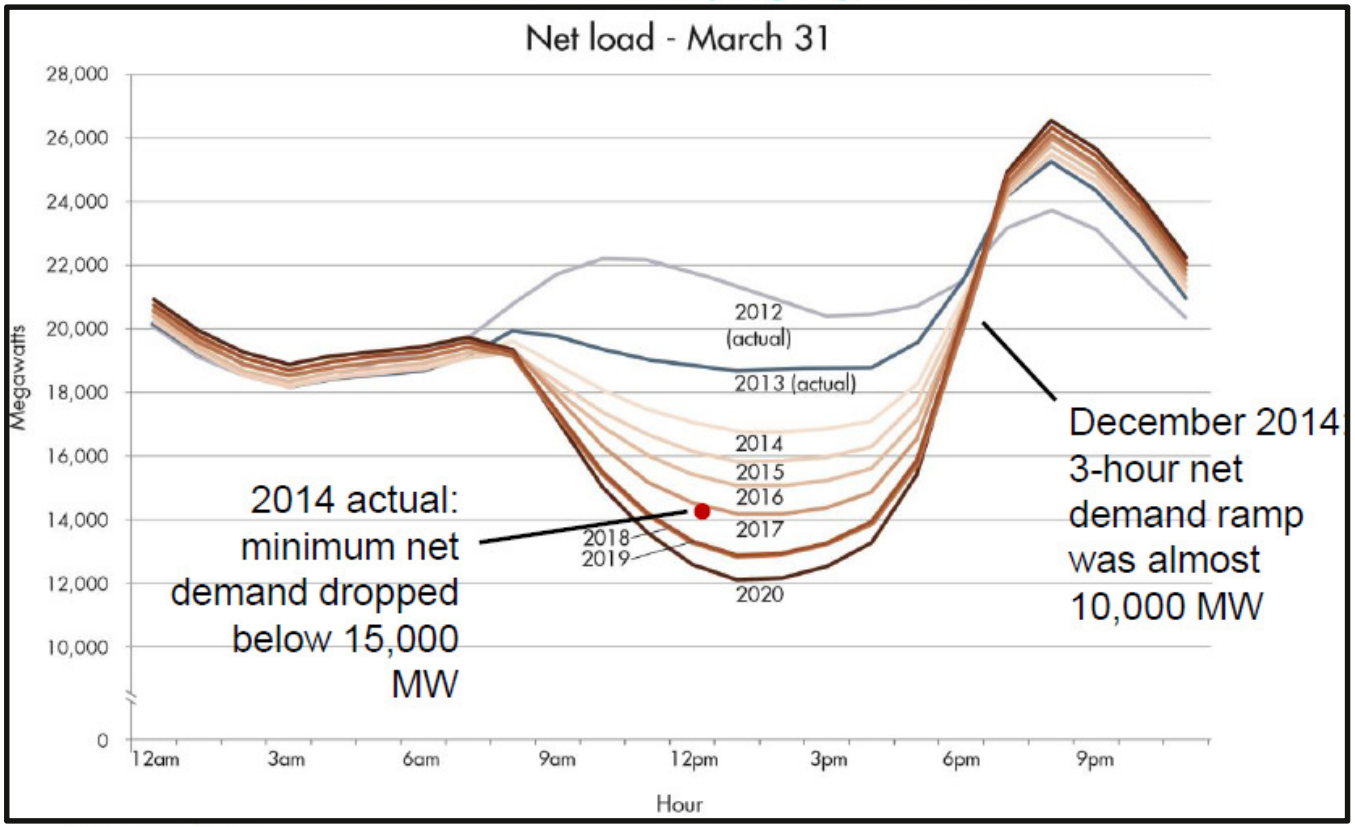


Source: Denholm and Mehos (2011), pg. 3.

Three primary drivers of changes in variable solar energy value: peak load, load ramps and energy displacement

California's Famous "Duck" Graph – Updated

Figure 6-3: Evolution of Hourly Net Load (Wind + Solar) Ramps in the California ISO for a Spring Day, 2012-2020

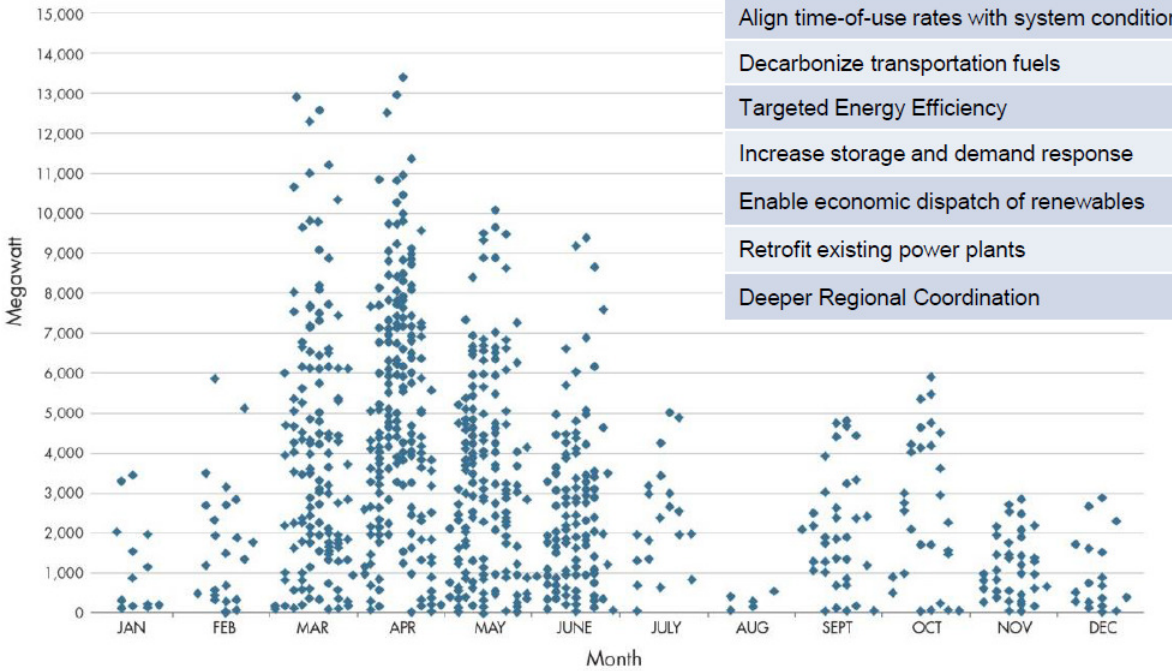


CSP technology is one of a range of operational solutions to address the supply variability introduced by rapidly expanding wind and PV production.

Over-generation - A Challenge in Renewable Integration*

Anticipated renewable curtailment - 40% RPS in 2024 scenario

Slide bkgrnd-header-board.jpg

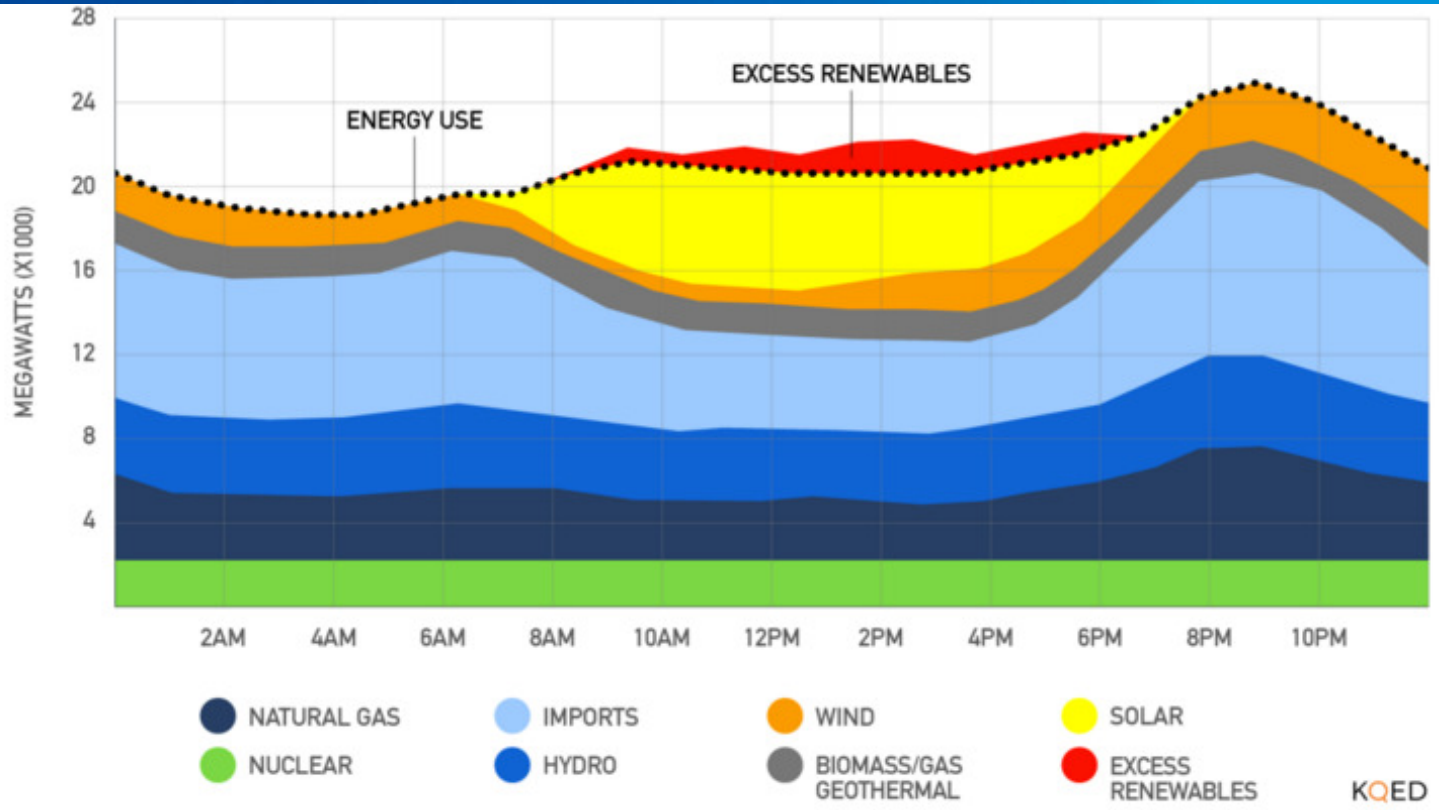


Solutions
Align time-of-use rates with system conditions
Decarbonize transportation fuels
Targeted Energy Efficiency
Increase storage and demand response
Enable economic dispatch of renewables
Retrofit existing power plants
Deeper Regional Coordination

40% RPS in 2024 Scenario													
Number of Hours	15	29	141	202	165	114	20	5	36	33	42	20	822
Max Curtailment (MW)	3,384	7,484	12,927	13,402	10,035	9,363	5,006	557	4,770	5,849	2,805	2,862	13,402
Generation (GWh)	5,537	5,825	7,156	7,165	7,717	8,046	8,058	7,084	6,751	6,482	5,802	5,575	81,198
Curtailment (GWh)	15	59	583	1,013	594	291	47	2	70	88	48	17	2,825
Percent	0.3%	1.0%	7.5%	12.4%	7.1%	3.5%	0.6%	0.0%	1.0%	1.3%	0.8%	0.3%	3.4%

*Source: CAISO DOE-CSP Stakeholder Meeting

CAISO Overgeneration: March 27, 2016



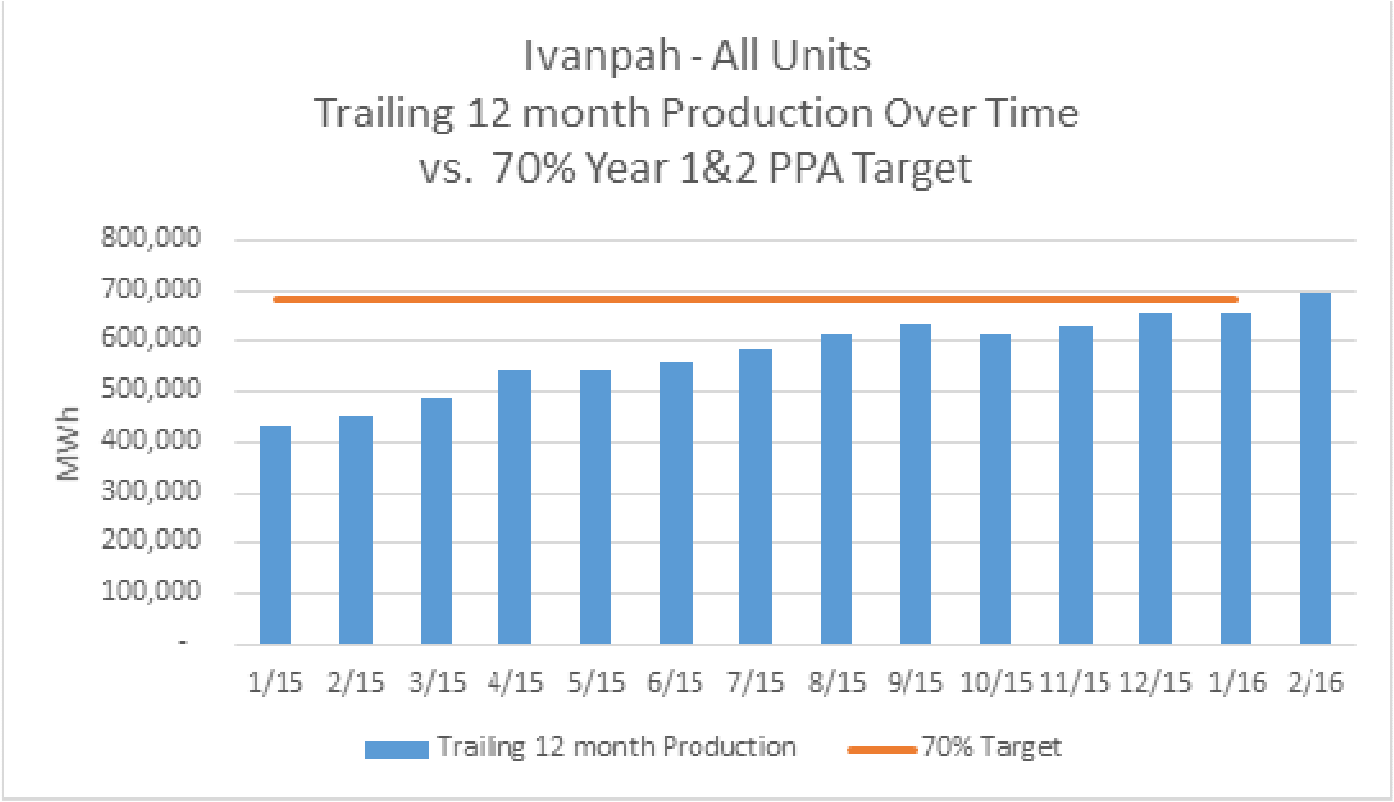
- The total MWh of wind and solar curtailed on March 27 was 6,252 MWh of which 5,953 MWh solar. The maximum hourly solar economically curtailed was 1,562 MW in hour ending 15.
- All this was managed via economic bids and not having to manually curtail. The cause appears to be driven by the combination of high renewable output and low loads as a result of weekend spring weekend conditions.

Key Findings on CSP Valuation

- At lower penetrations, all solar technologies have similar high capacity and energy benefits.
- At penetrations greater than 5-10% penetration by energy, solar capacity value declines significantly, with the exception of CSP-TES.
- Net costs include the long-term energy, ancillary service and capacity benefits and have been shown to provide an additional $30-60/MWh, or even higher, of benefits when compared to a PV plant with equal annual energy production in high renewable penetration scenarios.
- As renewable energy penetration increases, the operational flexibility offered by CSP with storage supports integration of wind and PV.
  - While some studies have pointed to the possibility of curtailment of renewable energy generation, this could be reduced by maintaining dispatchable resources in the portfolio.
- Institutional differences in market structures and regulatory regimes must be considered:
  - In countries with transparent wholesale markets, it is easier to value a plant's attributes, but historical prices do not necessarily help in forecasting future system conditions.
  - In regions without such markets, resource planning methods used by utilities can similarly use simulations to estimate the value (net system cost) of alternative renewable resources.

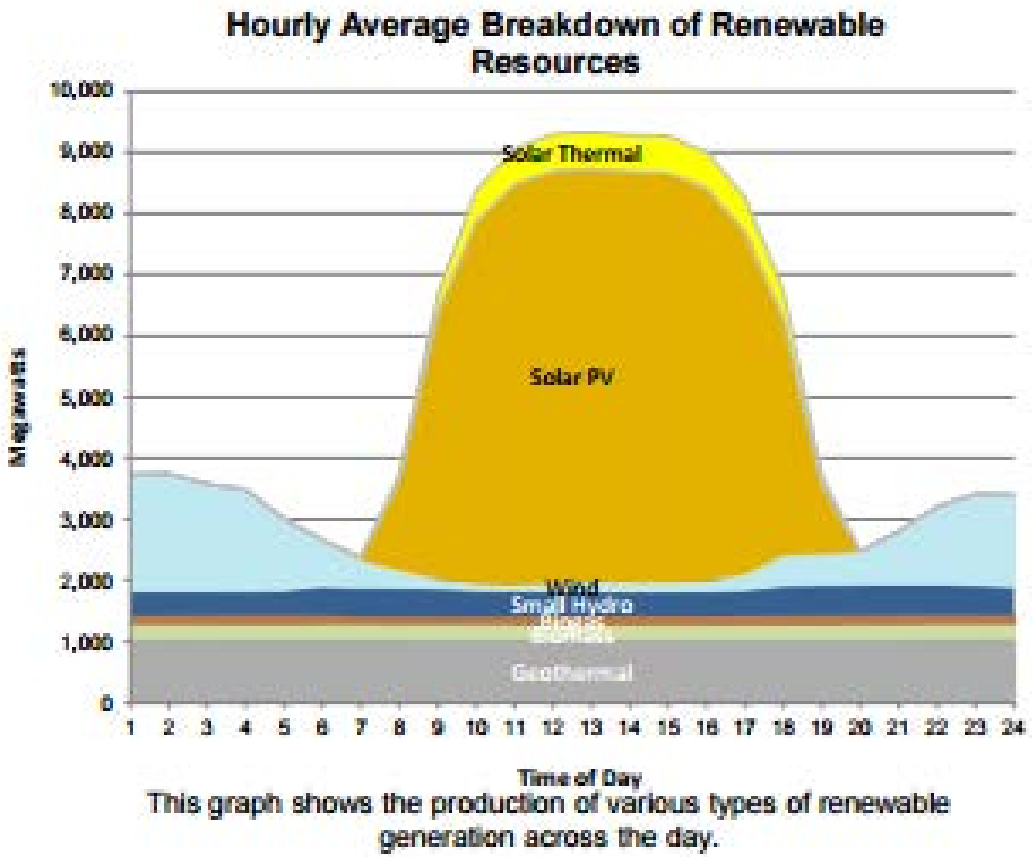
IVANPAH

Performance



- Ivanpah is not only a new plant, but the first of its kind at this scale. A multi-year performance "learning curve" has always been assumed since the earliest stages of planning and is typical for opening a major utility-scale thermal power plant of any kind. In fact, the annual expected generation was developed considering performance in the fourth year of operation.

CAISO Renewables Production: April 2, 2016



This graph shows the production of various types of renewable generation across the day.

- Ivanpah produced 3,672 MWh, representing approximately 65% of the 5,695 MWh for solar thermal produced on this day.

CAISO Daily Renewables Watch report for April 2, 2016. It is unverified raw data and is not intended to be used as the basis for operational or financial decisions.

Environmentally Responsible Design

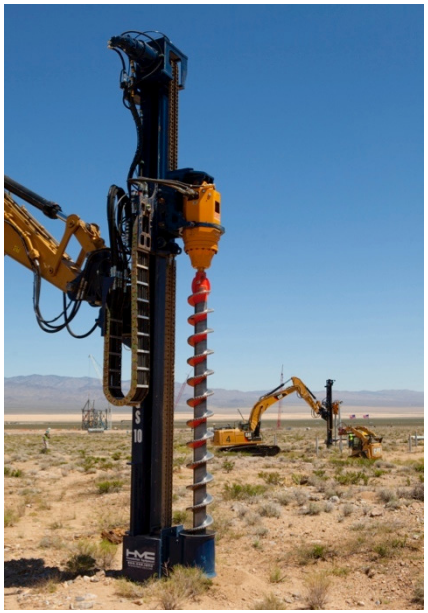


- Technology and systems
  - Designed to minimize impact on ecosystems and positively address all aspects of:
    - Site selection
    - Low-impact design
    - Water usage
    - Air quality
    - Species protection
    - Plant preservation

Sustain One

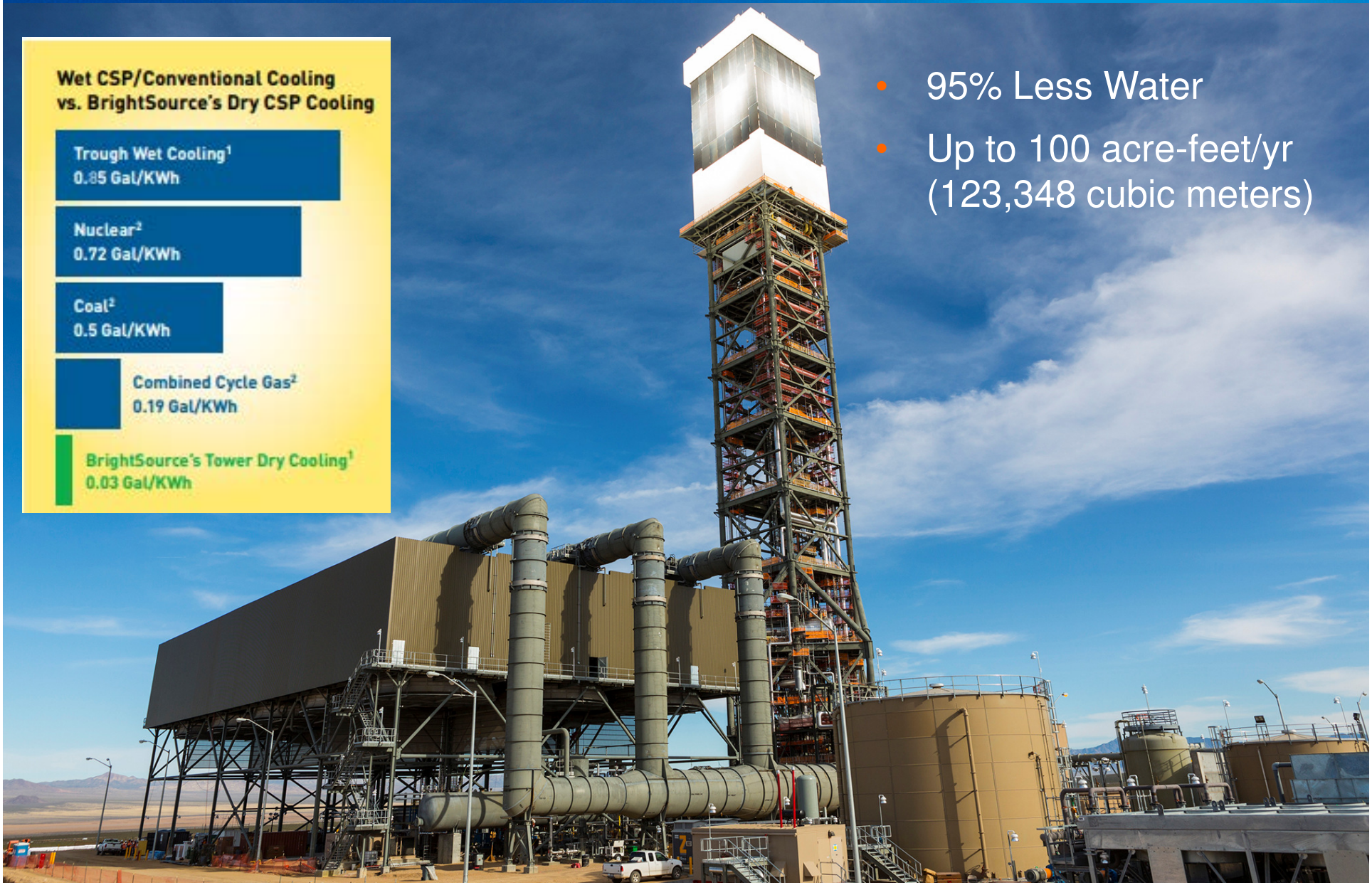
RESPECT. PROTECT. PRESERVE.

Sustainable Construction Practices



- Heliostat installation, placement
  - Pylons set into ground with low-impact “pylon driver”
    - Heliostats mounted on pylons
  - Process eliminates need for foundations, concrete pads
    - Vegetation co-exists beneath mirrors
    - Promotes natural draining and avoids corrosion
      - Preserves site’s natural hydrologic cycle to greatest extent possible

Low Water Use With Dry Cooling Technology



- 95% Less Water
- Up to 100 acre-feet/yr (123,348 cubic meters)

Land Use Comparison: Associated Infrastructure



- Eliminates impacts associated with conventional fuels used to power most electrical energy sources
  - Exploration, extraction, processing, transportation, fuel conversion
    - Fuel Storage: tanks, stockpiles, etc.
    - Non-renewable fuel disposal: coal ash containment areas
    - Transportation: rail-yards, pipelines, tanker fleets

Safeguarding Air Quality

- Renewable technology displaces electricity generation from dirtier sources
  - Coal, oil-fired power plants
- Reduces criteria air pollutants
  - Nitrogen oxides, sulfur dioxide, lead and mercury
- Avoids CO^2 emissions

Thank You!