The Value of CSP with Thermal Energy Storage

带储热的光热发电的价值

Joseph Desmond
Senior Vice President, Marketing & Government Affairs
乔戴斯蒙德，亮源市场和政府事务高级副总裁

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量化带储热CSP的价值
Quantifying the Value of CSP with Thermal Energy Storage

带储热CSP的经济和可靠性价值：文献回顾和研究需要

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

- 技术报告包括关于带储热CSP的经济和可靠性价值的最新研究，可作为综合指南帮助理解配置储热CSP电厂的设计和运行特质

  Technical report incorporates the latest research on the economic and reliability benefit 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)

- 读者对象为电厂、监管机构、电网运营商和政策制定者，帮助其做好各类资源竞争上网的评价，为电力消费者带来福音

  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.

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报告目的
Purpose of Report

- 关于带储热CSP价值的读物，帮助初读者了解不同背景和现有研究文献
- 回顾研究方法和结果（主要针对美国）
- 鼓励对美国（或世界其他地方）购电时做的价值评估进行改进
- 就技术和政策研究日程提出想法

- 备注：未就太阳能技术或可替代可再生能源并网发电的成本进行对比

- 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

净成本指成本减去可再生能源项目附加收益的值，附加收益包括任何从数量和质量上可被评价的市场产品和运行优势

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.

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输配电成本为衡量各类发电方式成本竞争力的标尺

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

施工阶段 **What it takes to construct the project**	发电阶段 **What it takes to generate electricity**	配电阶段 **What it takes to keep the lights on**
建设成本 **Capital Cost** $ / W	发电成本 **Energy Cost** Levelized Cost of Energy (LCOE)	输配电成本 **Net System Cost** Least-Cost, Best-Fit (LCBF)
仅考虑建设成本 **Considers only installed cost**	考虑发电的额外成本 **Considers additional costs and energy produced**	考虑电厂价值 **Considers utility value**
▪ 水冷壁和镜子数量/设备 Number of panels / mirrors / equipment ▪ 生产成本Cost to make it ▪ 安装成本加劳动力和材料 Installed cost adds labor and materials	▪ 建设成本Capital costs ▪ 容量系数Capacity factor ▪ 电厂衰减Degradation ▪ 运行成本Operating costs ▪ 基本融资Basic financing	▪ 发电成本LCOE ▪ 并网成本Integration costs ▪ 电的市场价值（加辅助服务）Market value of energy (and ancillary services) ▪ 高峰负荷时发电的能力 Availability at peak demand

与其他方法不同 的是，这种输配电成本既包括成本，也包括额外价值
Unlike other methodologies, Net System Cost accounts for both costs and benefits

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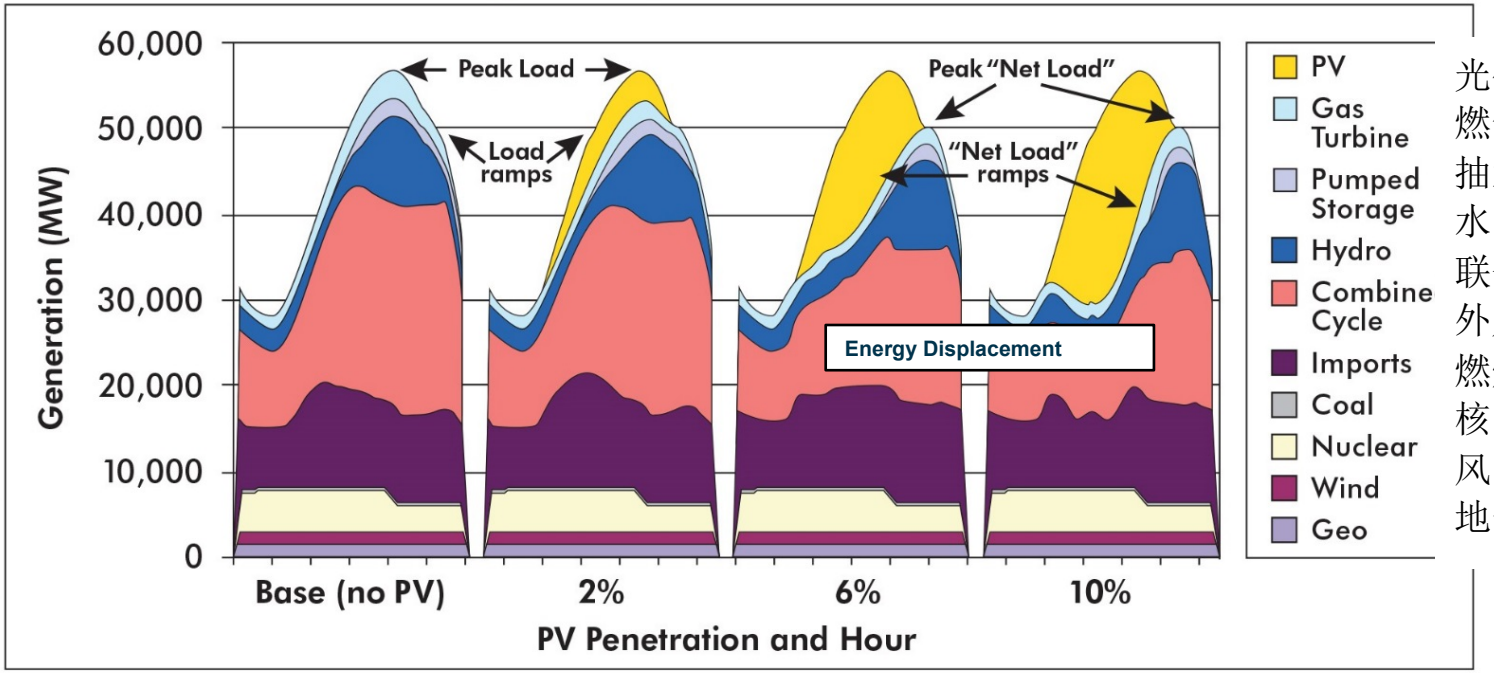
出力多样性影响电网运行和增加成本（以光伏为例）

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

图6-1：模拟夏天加州电网分别接纳0-10%光伏时的调度情况——对比高峰负荷和高峰“净负荷”

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”



光伏
燃气轮机
抽水蓄能
水电
联合循环
外购电
燃煤
核电
风电
地热

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

改变各种太阳能价值的三大驱动：高峰负荷、负荷斜增和电力位移Three primary drivers of changes in variable solar energy value: peak load, load ramps and energy displacement

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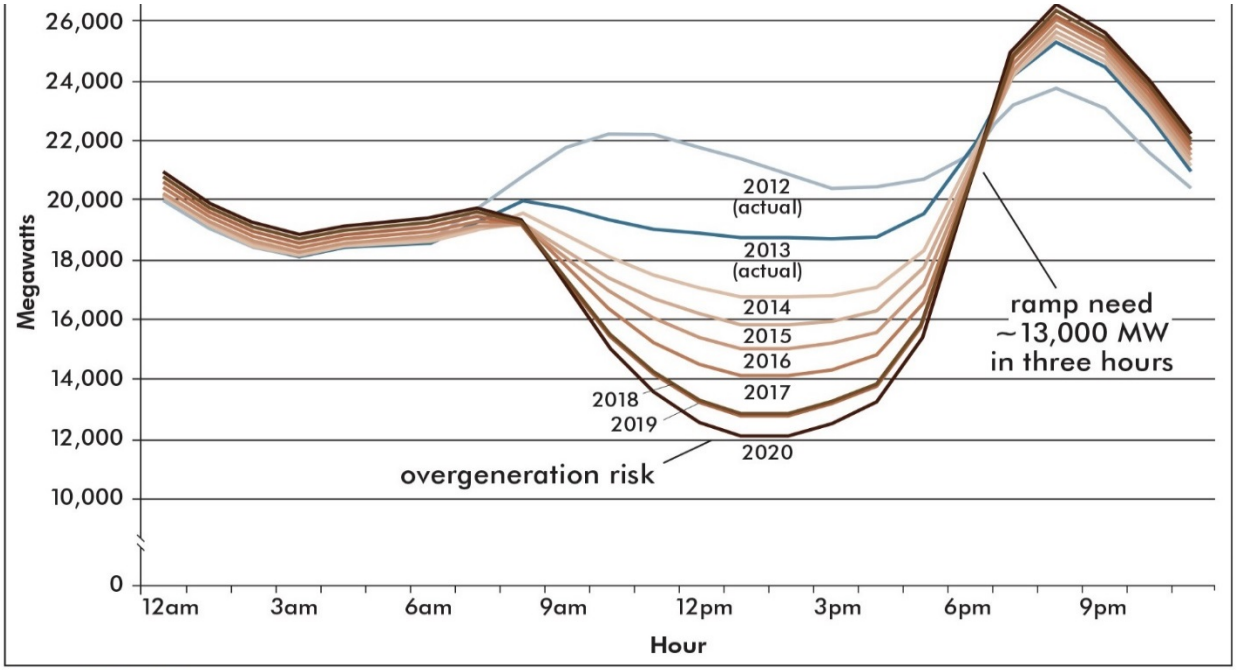
出力多样性影响电网运行
Output Variability Impacts Grid Operations

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

图6-3：2012-2020加州独立系统运营商春日每小时净负荷（风+太阳能）斜增演变



Source: CAISO, 2013a.

光热是解决风电和光伏快速扩张所带来的供电多样性问题的一系列运行解决方案之一

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

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BrightSource Opportunity – US China Renewable Energy Collaboration
亮源机遇 – 中美可再生能源合作

US-China Cooperation Framework
中美能源合作框架

China NEA
中国能源局

US DOE
美国能源部

First Commercial Scale Project
示范项目

CPI/ Huanghe
中电投/ 黄河

BrightSource

上海电气 SHANGHAI ELECTRIC

Assist and Complete China National CSP Handbook
协助编制国家光热手册

水电水利规划设计总院

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Research on CSP 's value and contribution to Grid
研究光热发电
对电网的价值和贡献

国家电网公司 STATE GRID

NREL

Qinghai Delingha 6 x 135MW Solar Thermal Tower Project

规划德令哈6 x 135 MW光热项目
第一期: 2 x 135 MW

Help shape the future of China CSP market

为中国光热市场的未来创造条件

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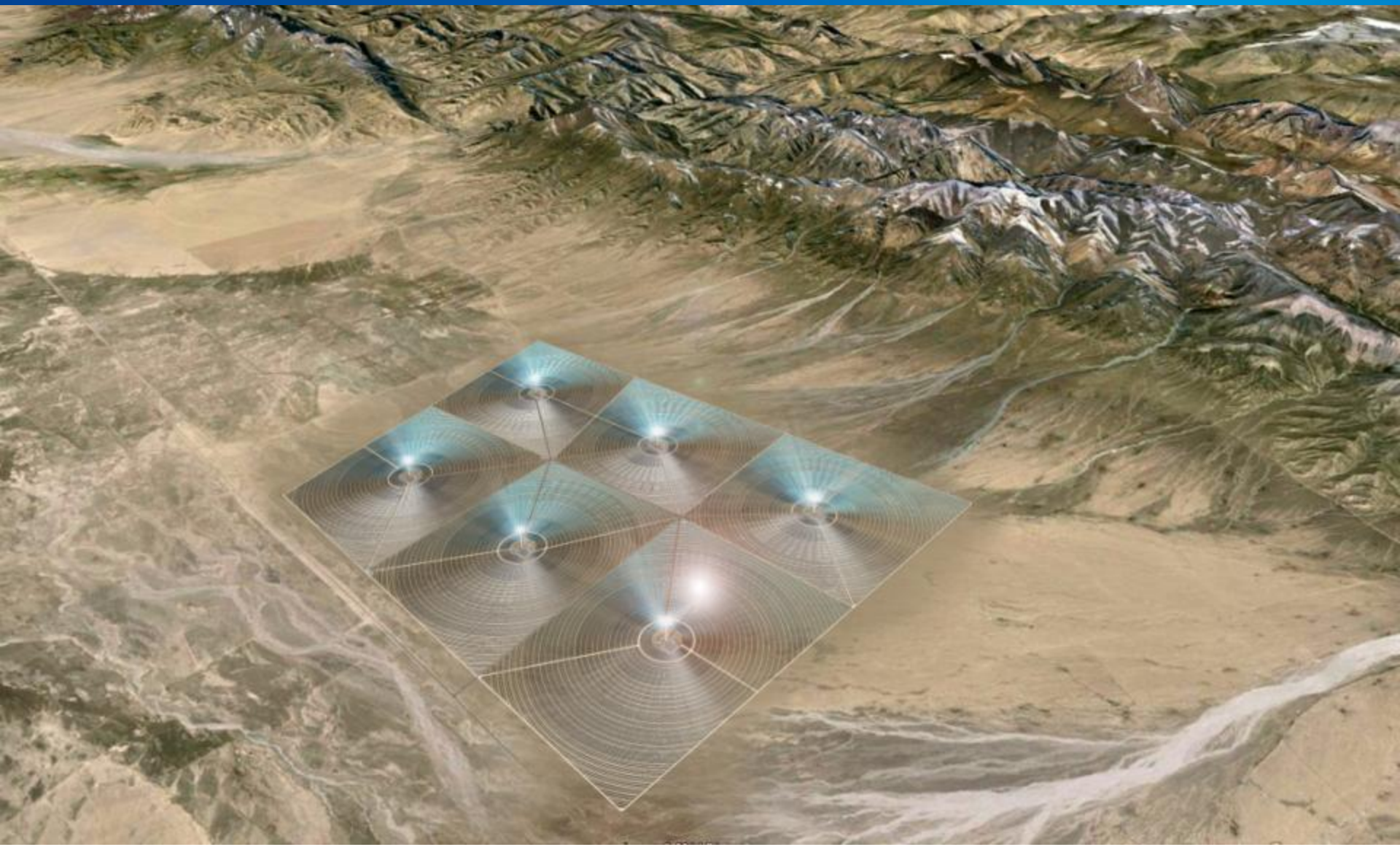
Delingha Project Rendering Art
德令哈项目示意图



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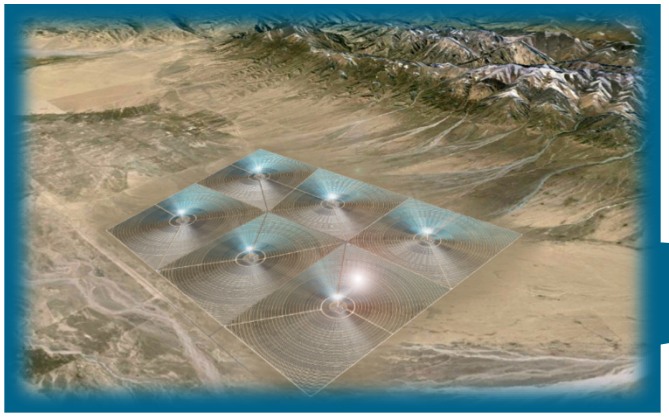
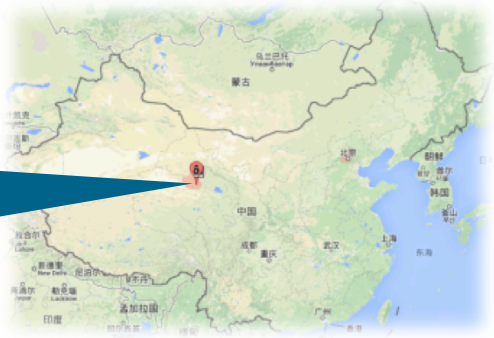
Huanghe Delingha CSP Power Project Plan
黄河德令哈光热发电项目总规划

The Project located at Delingha City, Haxi Prefecture, Qinghai Province
项目位于青海省海西州德令哈市

Site Location
厂址





Project Size
项目规模

Project construction split in phases, total 6 x 135 MW

Phase 1: 2 x 135 MW

Molten Salt Storage Hours: 3.5 hours

Annual gross output: ~690,000 MWh, ~2694 full load equivalent operating hours

项目规划总装机容量6 x 135 兆瓦，分阶段建设

一期：2 x 135 兆瓦

熔盐储热：时长3.5小时

年总发电量6.9亿度，满负荷等效运行约2694小时

Power Tariff
电价

Expected Tariff: Around RMB 1.2/kWh
预测电价：1.2元/度左右

为中国带来经济价值评估方法
Valuation Methodologies for China

Methods for Analyzing the Economic Value of Concentrating Solar Power with Thermal Energy Storage

P. Denholm, J. Jorgenson, M. Miller, and E. Zhou
National Renewable Energy Laboratory

C. Wang

State Grid Energy Research Institute

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用热能储存技术进行聚光太阳能发电的经济价值分析方法

P. Denholm、J. Jorgenson、M. Miller 和 E. Zhou
国家可再生能源实验室

C. Wang

国家电网能源研究院

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