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Fundamentals of optimized power production from CSP-PV hybrid plants

ATA Insights Webinar

Dr. Mike Wagner
Research Engineer

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NREL
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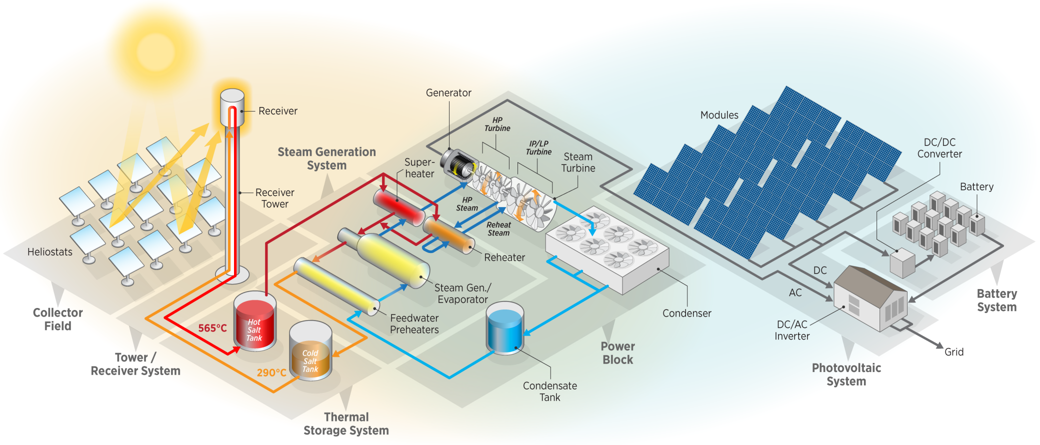
What is a CSP-PV hybrid?



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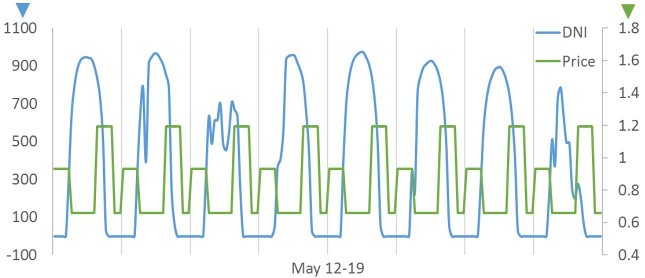
Requirements for hybrid production

- Two forms of solar energy generation with differing characteristics can be used to meet market demands



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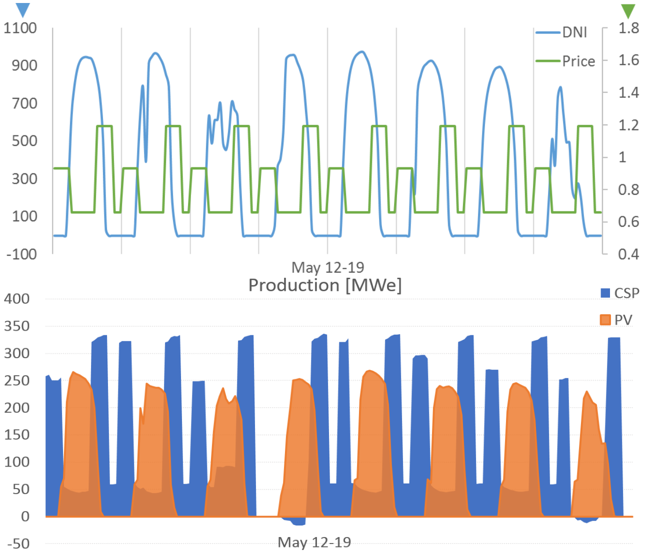

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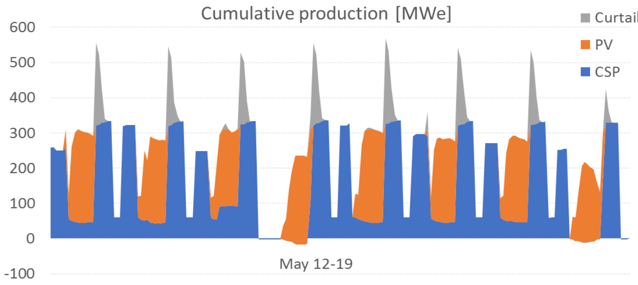
- Cumulative production of a paired plant exacerbates grid challenges
    - Likely to cause significant curtailment



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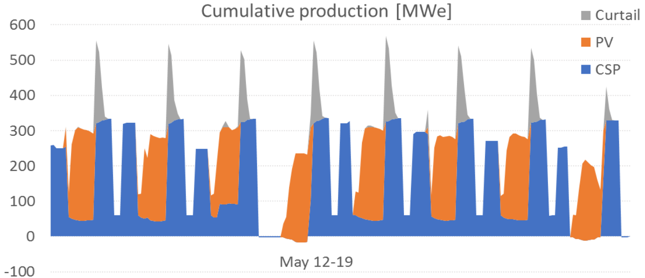
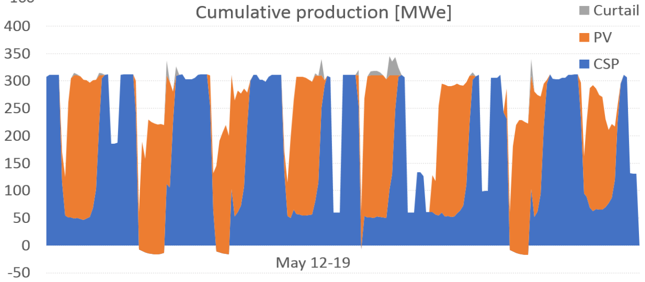
- Goal: Shift CSP production around inflexible PV





Modeling production – an approach for dispatch optimization

1. Develop a detailed, descriptive performance model (SAM)
2. Define an approximate and easily-solved model using a mixed-integer linear program (MILP)
3. Reduce problem size to ensure tractability (time decoupling, symmetry breaking, discounting of future decision details)
4. Solve MILP, maximizing revenue and minimizing O&M cost
5. Use solution as target production profile in detailed model
6. Repeat steps 4-5, progressing through annual simulation

<table>
<tr><th colspan="4">Day 1</th><th>Day 2</th><th></th></tr>
<tr><td>72 steps</td><td colspan="3">18 Time intervals</td><td>24 Time intervals</td><td>114</td></tr>
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Case study: CSP-PV-battery hybrid with grid constraint

Parameter	Units	Value
Cycle design thermal input ($\times$2)	MW_t	393
Cycle maximum gross output ($\times$2)	MW_e	163
Receiver design thermal output ($\times$2)	MW_t	565
Thermal energy storage capacity ($\times$2)	MWh_t	4716
PV field capacity	MW_{dc}	325
PV inverter maximum output	MW_{ac}	270
Battery capacity	MWh_e	150
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Maximum total power to grid	MW_e	310

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Location 1: N. Chile		
▷ Solar resource - DNI	$kWh/m^2/year$	2730
▷ Market price ratio†		1.6
Location 2: S. Nevada		
▷ Solar resource - DNI	$kWh/m^2/year$	2083
▷ Market price ratio		3.4

† *top 5%/bottom 5% of hourly prices*

Comparative results

Improvement in performance of hybrid systems compared to CSP-only baseline

Location	Metric	CSP only
N. Chile	*CF*	51.3 %
	LCOE	100.0 $/MW_h$
	PPA	94.9 $/MW_h$
S. Nevada	*CF*	32.0 %
	LCOE	156.0 $/MW_h$
	PPA	123.2 $/MW_h$

CF – capacity factor
LCOE – levelized cost of energy
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Comparative results

Improvement in performance of hybrid systems compared to CSP-only baseline

Location	Metric	CSP only	CSP-PV-Bat
N. Chile	*CF*	51.3 %	**+33.8 %pt**
	LCOE	100.0 $/MW$_h$	**-27.1 %**
	PPA	94.9 $/MW$_h$	**-20.2 %**
S. Nevada	*CF*	32.0 %	**+26.8 %pt**
	LCOE	156.0 $/MW$_h$	**-28.8 %**
	PPA	123.2 $/MW$_h$	**-14.0 %**

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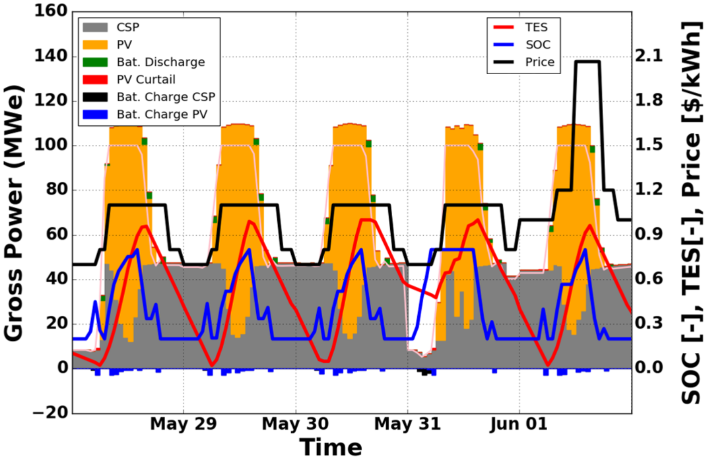
Detailed performance plots illustrate nuanced behavior



Results taken from different case study

- In a hybrid system, all forms of generation and storage are utilized

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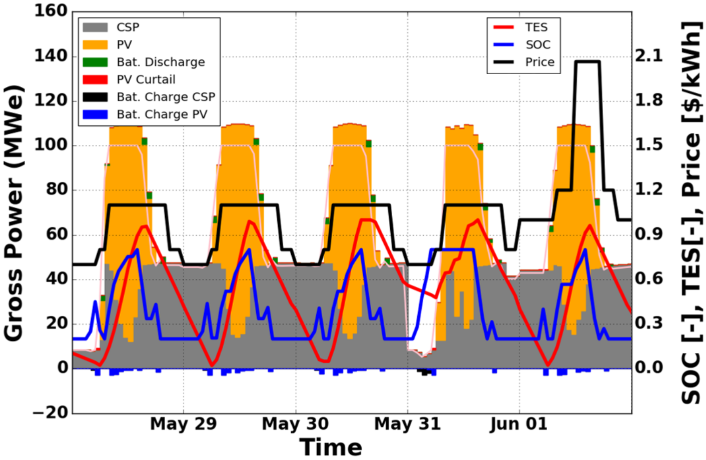

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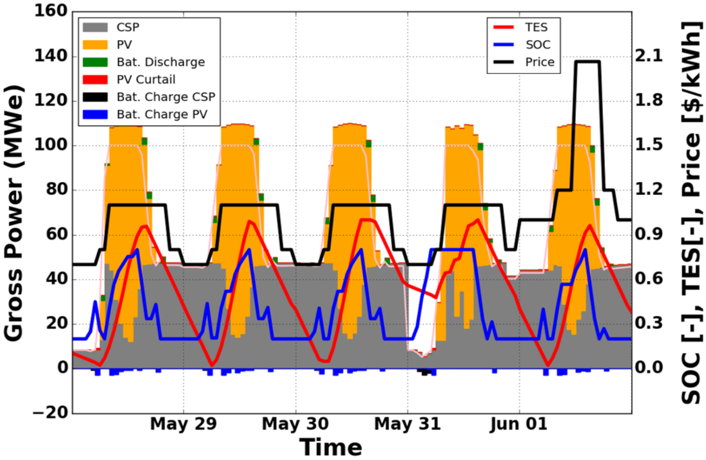

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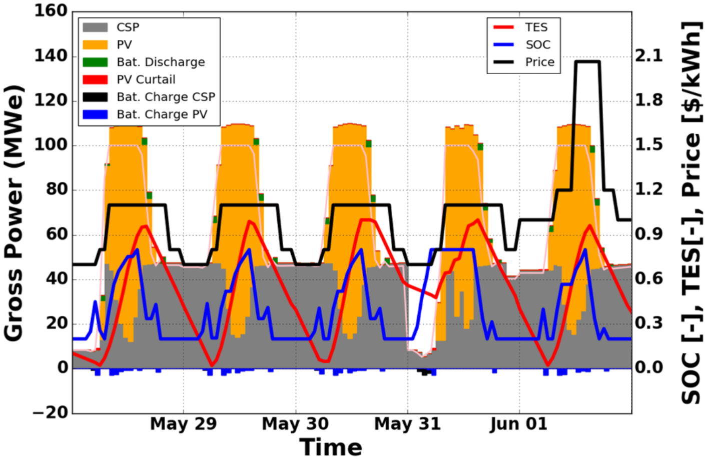

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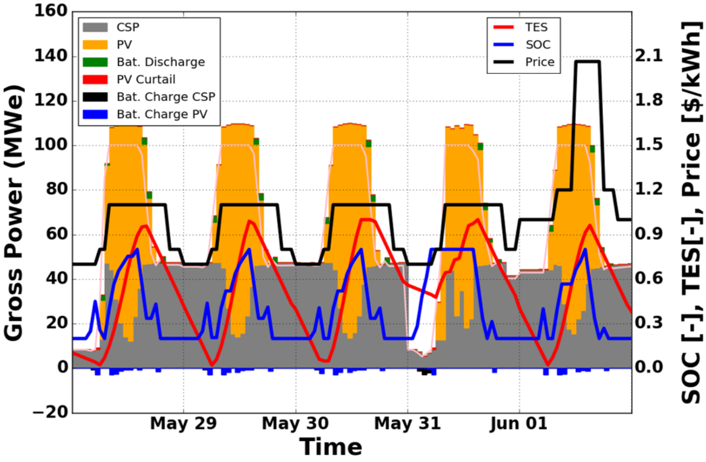

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- Battery discharge responds to rapid variations
- Time scale for battery discharge depends on long-term maintenance cost of power cycle ramping

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- Hybrids not viable when price is insensitive to capacity or time of day
- Robust dispatch optimization techniques are prerequisite

Acknowledgements

William Hamilton
Ph.D. Candidate
Colorado School of Mines

Thank you

Mike Wagner, Ph.D.
Thermal Sciences Group
National Renewable Energy Laboratory, Golden, CO
(303) 384-7430
mike.wagner@nrel.gov
www.nrel.gov/csp