ESIG Webinar Series

The Economics Of Flexible Solar For Electricity Markets In Transition

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ESIG
ENERGY SYSTEMS INTEGRATION GROUP

Webinar Presenters

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First Solar

First Solar

First Solar's Flexible Solar Technology

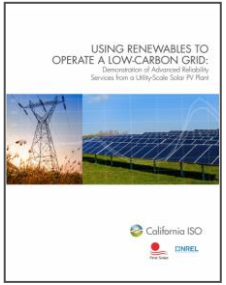
Mahesh Morjaria, PhD
(Formerly at First Solar)

RE PlantSolutions
Supported by First Solar.

Solar Plant Provides Essential Reliability Services

NERC: Essential reliability services

- Frequency Control
- Ramping capability or flexible capacity

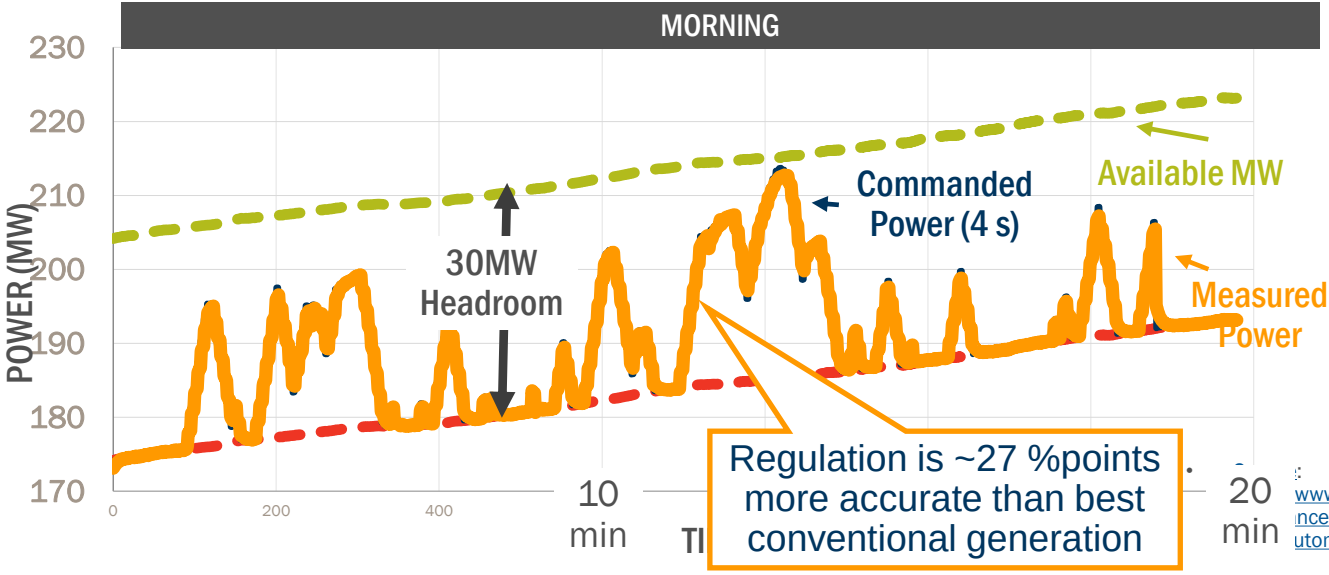


2018 Intersolar Outstanding Project Winner

2017 NARUC Award Winner

Power Regulation

- AGC
- Up-Regulation
- Down-Regulation
- Frequency Regulation
- Flexibility



Grid Reliability Services

www.caiso.com/Documents/TestsShowRenewablePlantsC
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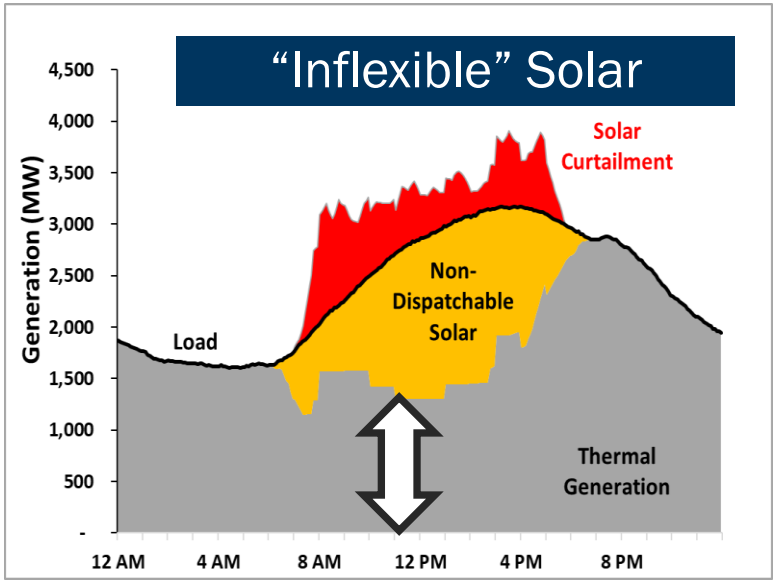
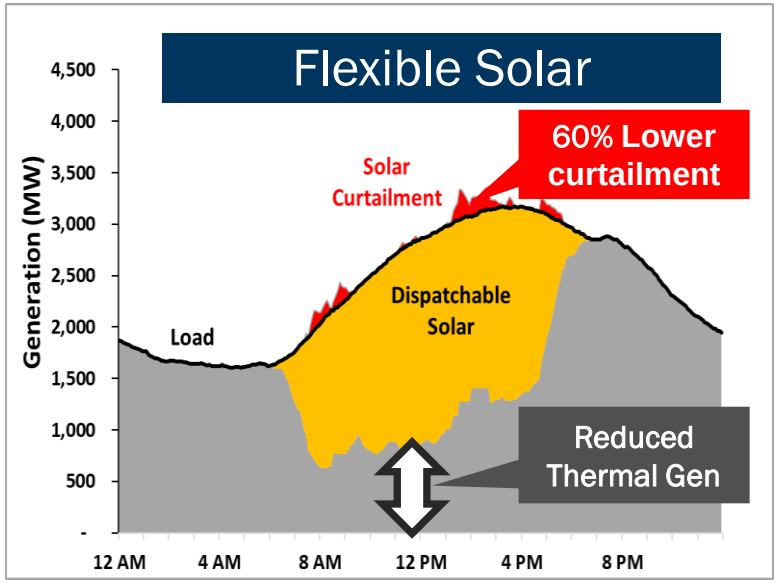
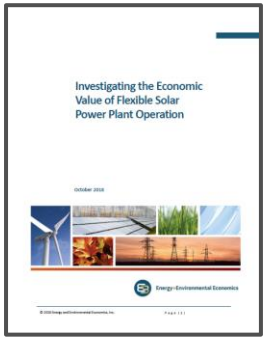
Solar Provides Flexibility



Solar Provides No Regulation Reserves



Flexible Solar: Provides regulation reserves.



Source: E3,TECO, First Solar Report "Investigating the Economic Value of Flexible Solar Power Plant Operation", https://www.ethree.com/wp-content/uploads/2018/10/Investigating-the-Economic-Value-of-Flexible-Solar-Power-Plant-Operation.pdf

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Energy+Environmental Economics

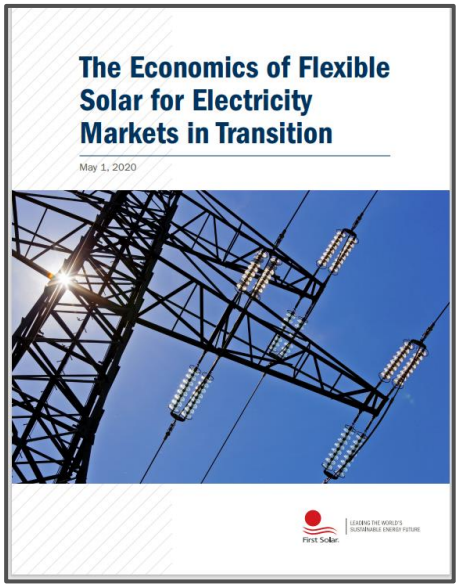
First Solar.

Research:
The Economics Of Flexible Solar For Electricity Markets In Transition

Steven Dahlke, PhD

Research Overview

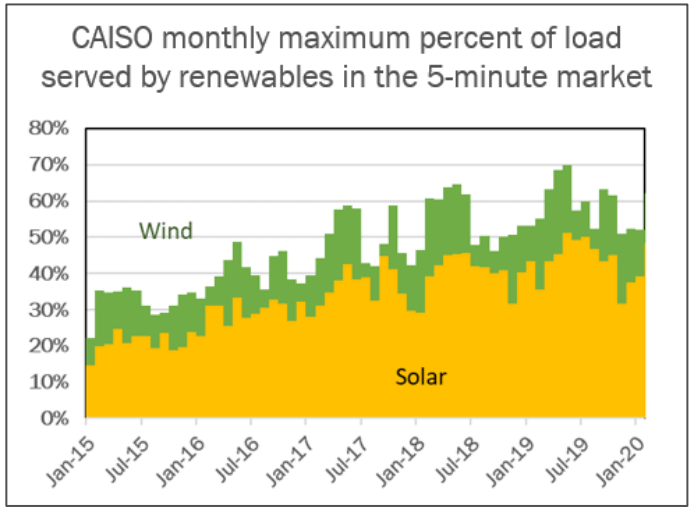
- Electric system flexibility needs grow with renewable penetration.
- Solar can be flexibly dispatched to provide system flexibility
- A model was built to study the economic impacts of flexible solar operation in the California electricity market.
- $100's of millions in annual system savings across region estimated from operating solar flexibly at 30% penetration, relative to non-flexible solar operation.
- Market design and contracting need to evolve to enable solar flexibility services.

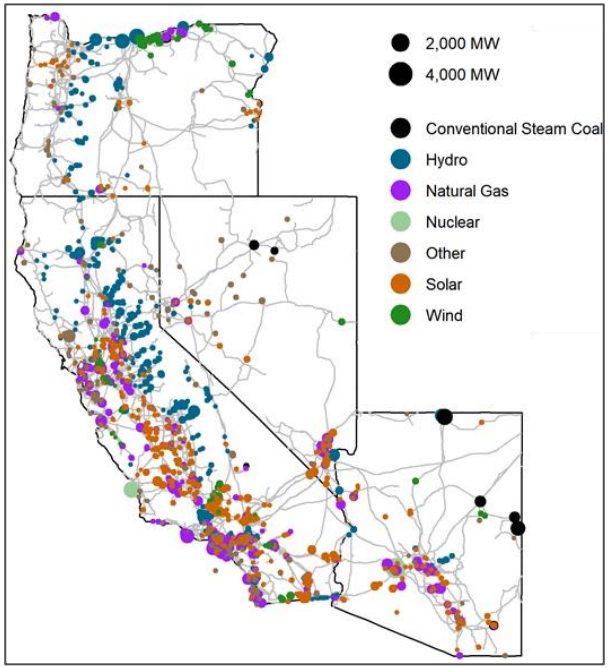


http://www.firstsolar.com/-/media/First-Solar/Documents/Grid-Evolution/The_Economics_of_Flexible_Solar_for_Electricity_Markets_in_Transition.ashx?la=en

Why Study California?

1. Large electricity market, (45-50GW peak demand).
2. High renewable penetrations that will continue to grow (SB-100)

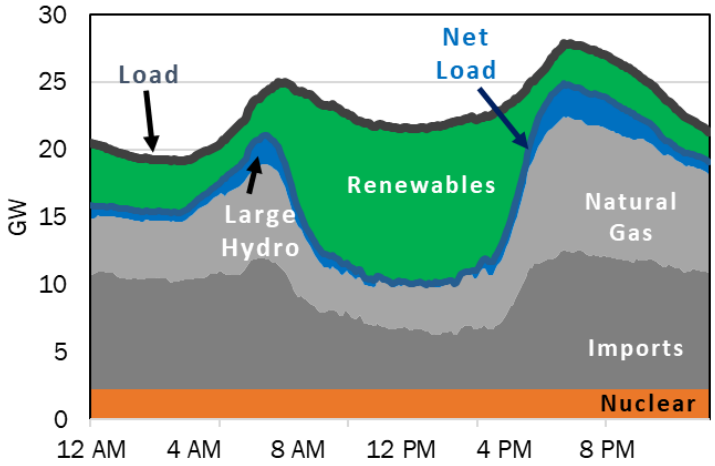




impacts of Growing Solar in California

1. Operational

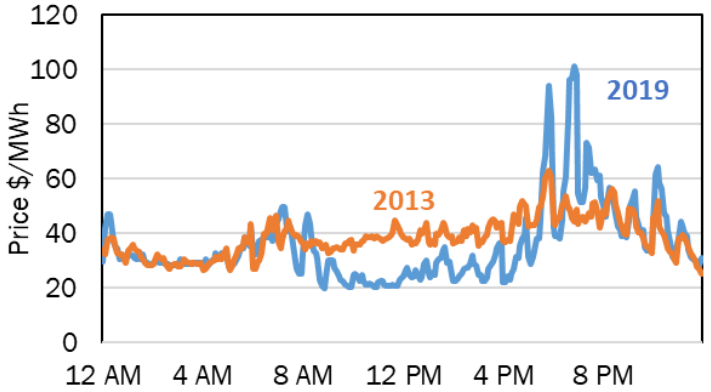
Large system ramps in the morning and evening.



CAISO supply mix, 2/24/2020

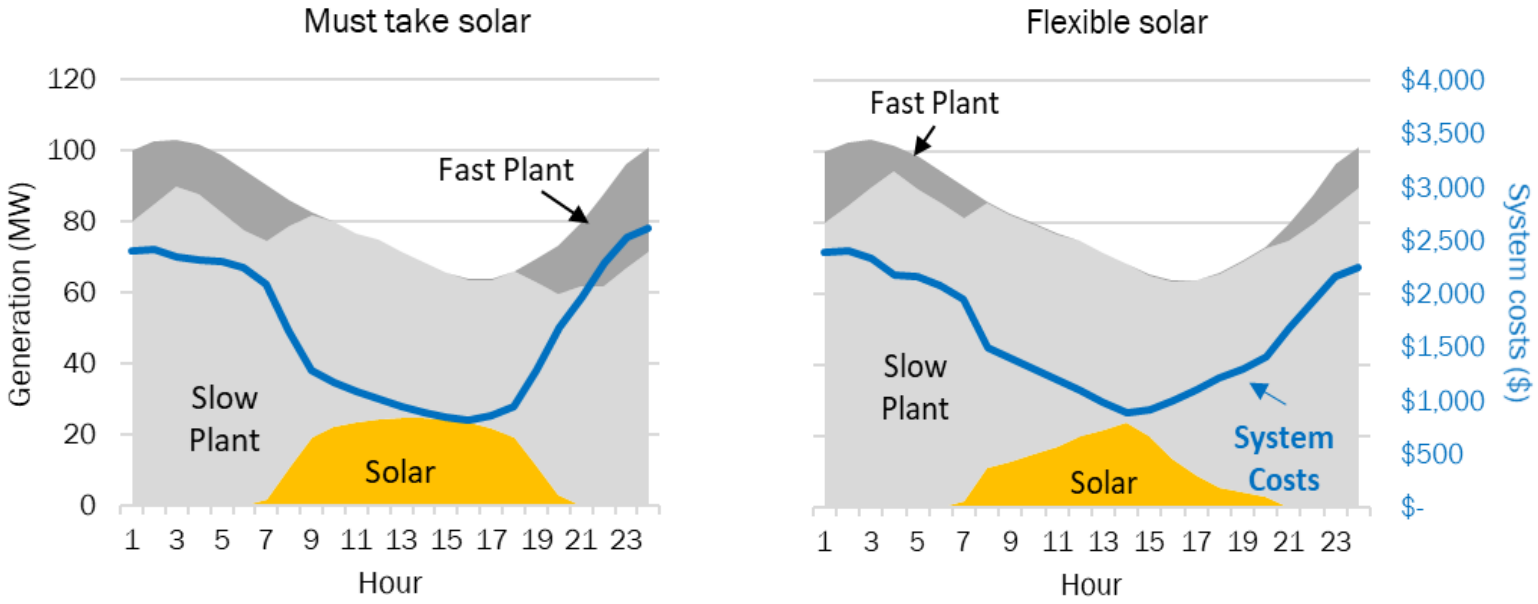
2. Economic

Low prices during the day, high prices in the evening.



CAISO average system prices by time of day for years 2013 and 2019

Cost Savings With Flexible Solar, Hypothetical Example

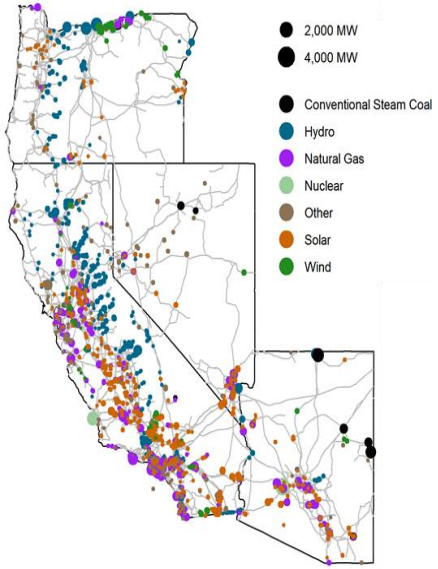


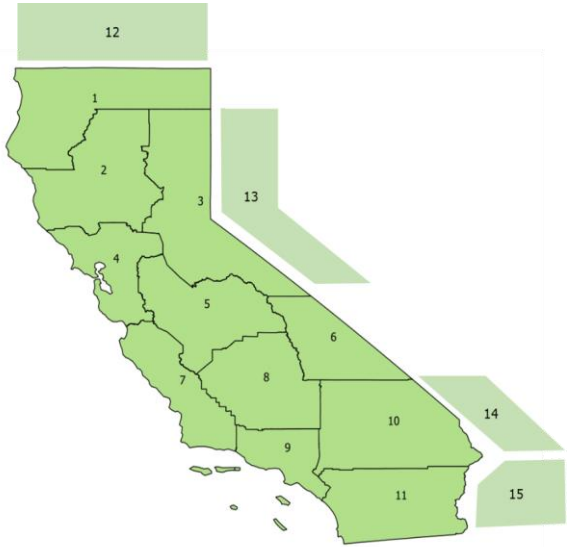
Reduced solar output reduces the need for the more expensive fast-ramping plant, lowering system costs.

Model Overview

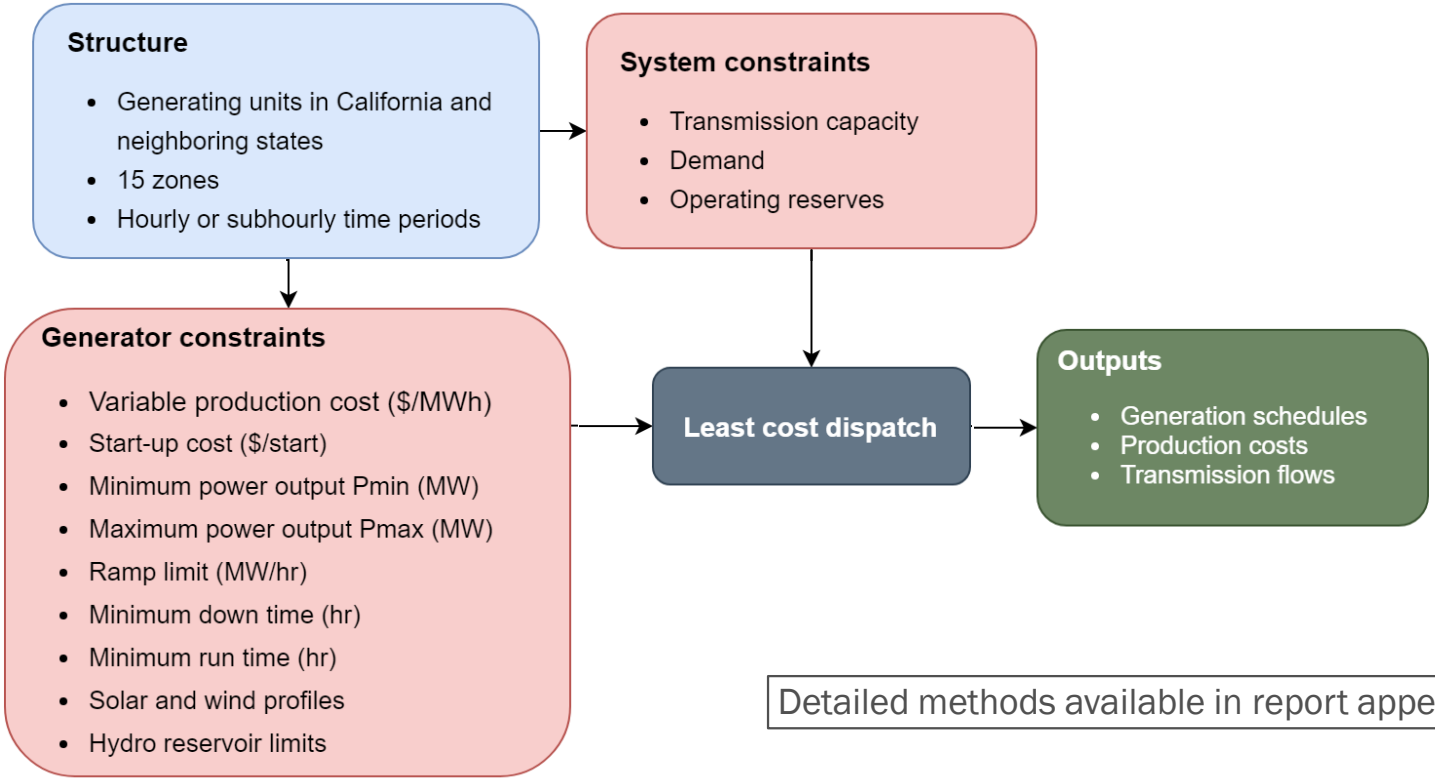
Structure

- Generating units in California and neighboring states
- 15 zones
- Hourly or subhourly time periods





Model Overview



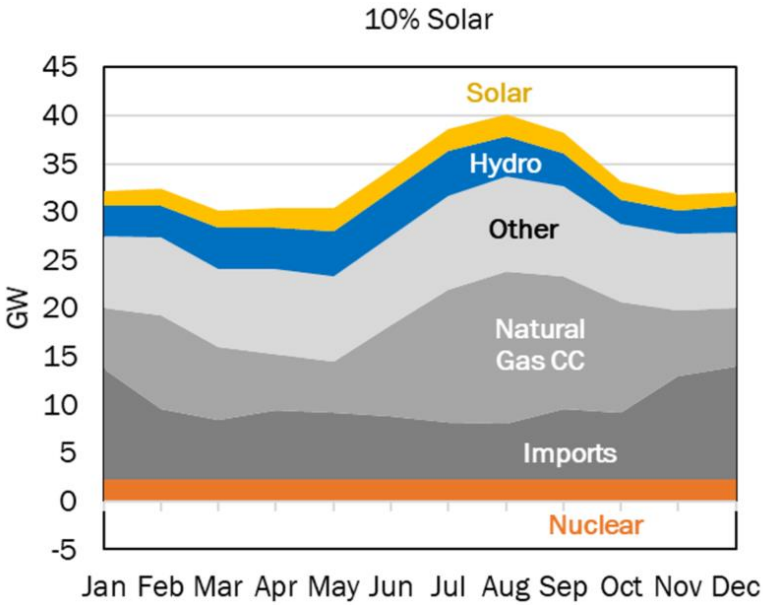
Detailed methods available in report appendix.

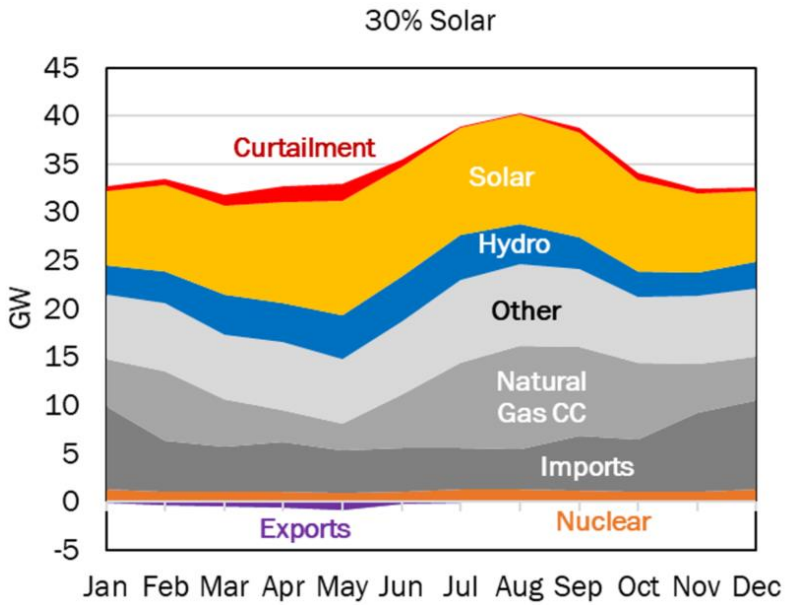
Baseline Model

- Several scenarios designed to study rising solar penetration.
- Solar penetrations are calculated before curtailment or dispatch down is applied in model.
- In baseline, solar curtailment only occurs for reliability. **Operator does not dispatch down solar when economic to do so.**

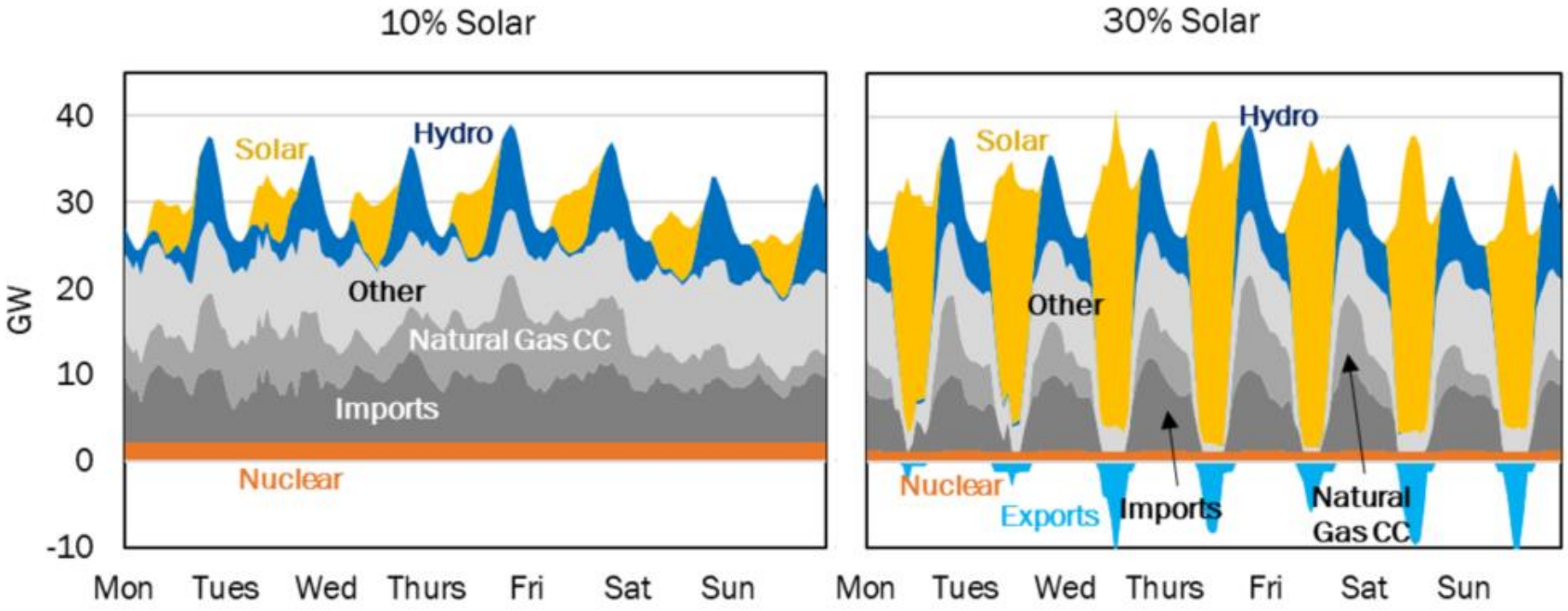
Scenario	Annual Penetration	Maximum Penetration
Base	10%	43%
High	30%	144%

Baseline model- Annual Supply



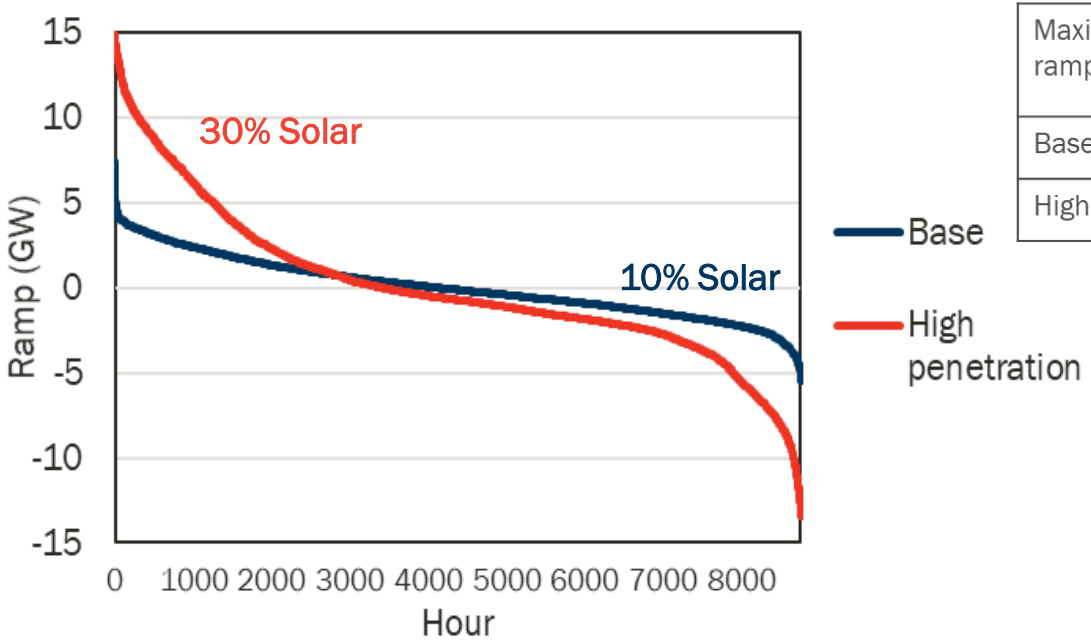


Baseline model – Daily Fuel mix



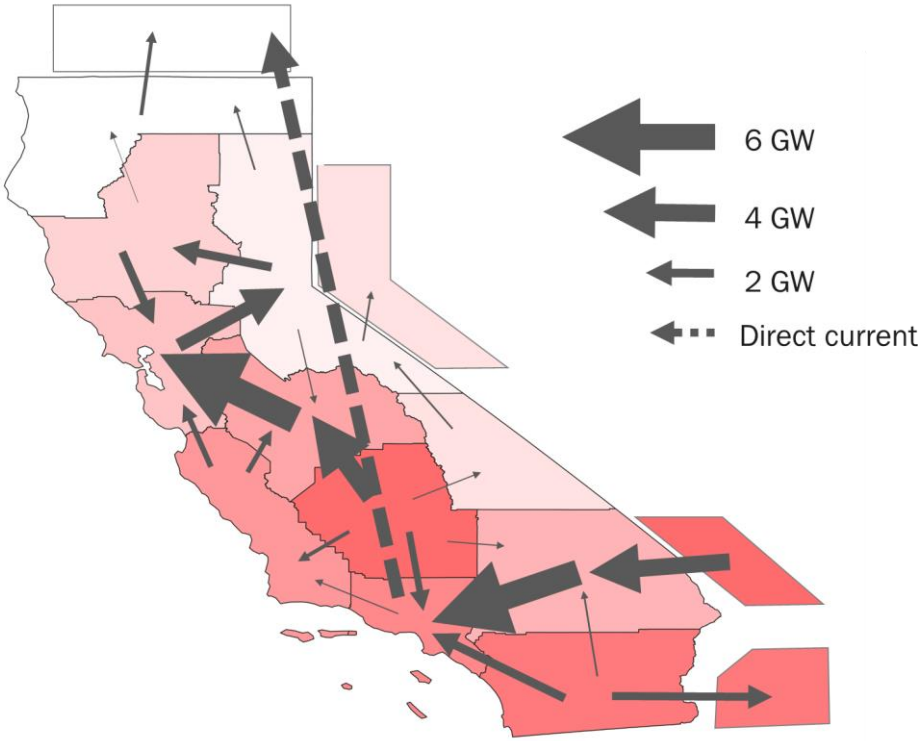
Single week in mid-April

Baseline Model – Net load Ramps



Maximum ramp (GW)	1-hr		3-hr	
	Up	Down	Up	Down
Base	7.4	-5.4	13.6	-14.4
High	14.8	-13.4	33.3	-29.1

Baseline model – Zonal Flows



Map shows midday transmission flows in spring for high solar scenario. Zones are shaded according to relative solar penetrations.

Historically, power flows come from the north and west. These partially reverse at high penetration.

Model – Flexible Solar

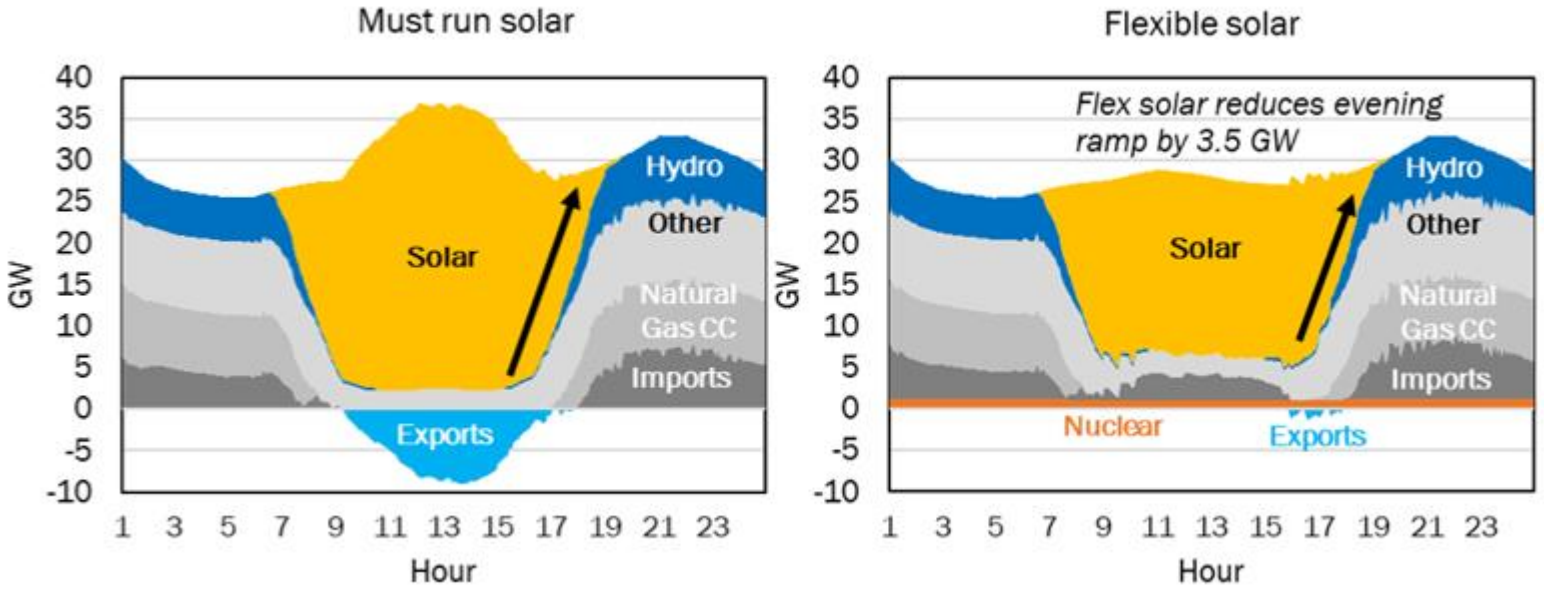
- In baseline model, the operator curtails solar for reliability, only when necessary to keep supply and demand balanced when no more generation and transmission are available.

- With flexible solar, the operator can dispatch solar down to lower system costs.

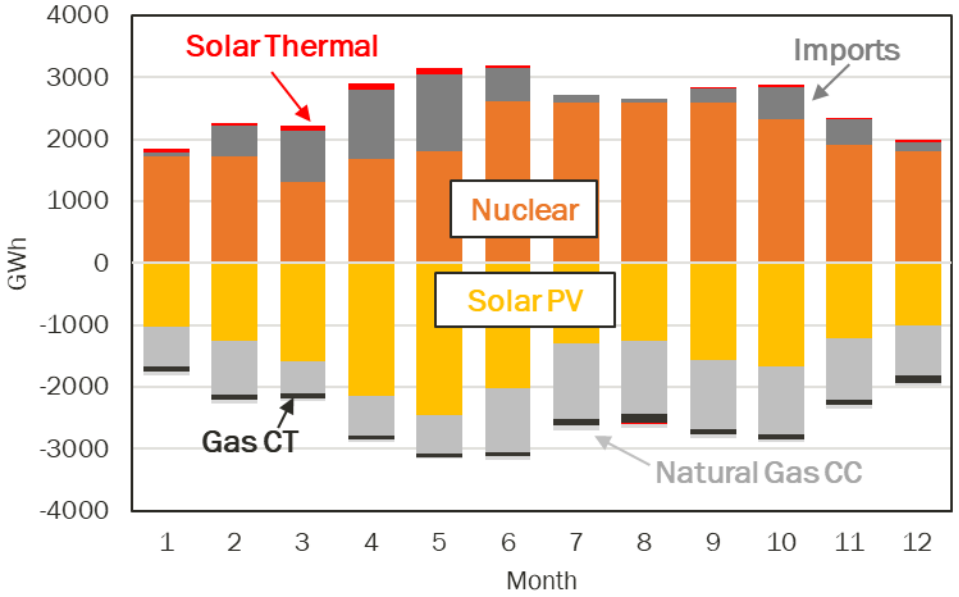
- Solar dispatch down during large system ramps enables lower cost ramp-constrained supply to replace higher cost units.

- System operator incorporates tradeoff with reduced low-cost solar energy in exchange for ramping support.

Baseline vs Flexible solar, Fall day



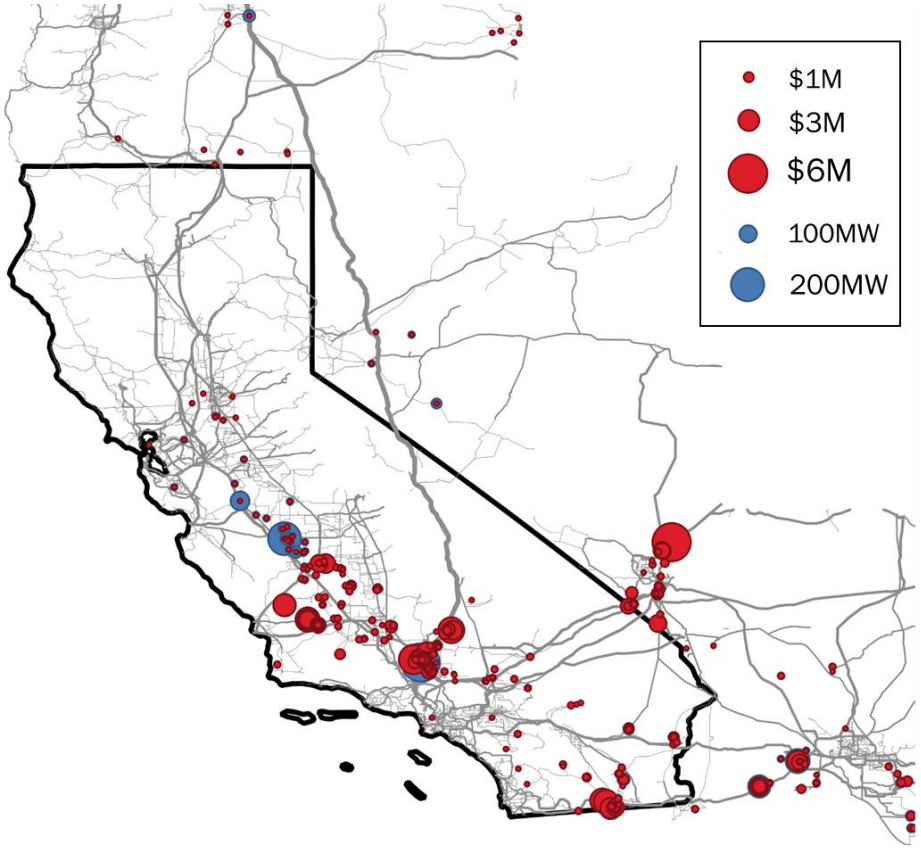
Change in Supply with flexible solar



- Solar is dispatched-down most during spring and least in summer
- Natural gas generation is reduced, lowering system costs.
- Replaced by nuclear, followed by imports and solar thermal.

Locational value of solar flexibility

- In baseline model, solar plants are constrained to must-run production, producing a flexibility shadow value for each plant.
- Most flexible solar value comes from large solar plants near Los Angeles and Las Vegas.
- Blue circles represent plant size and are placed behind red value circles. Where blue circles are visible, the solar plant is producing less flexibility value relative to its size



Impacts Of flexible solar

- Flexible solar reduces annual production costs in California by $172 million relative to the baseline.

- Including neighboring states increases total savings to $268 million

- Annual CO_2e emissions in California decline by 1.9 million metric tons (MMT), 5% of total electric emissions.

Market design for flexible solar

- Our model shows how dispatchable solar during system ramps can reduce the need for higher-cost fast ramping fossil units.

- If a solar plant can provide flexibility service at lower cost than the alternative, an efficient market would use flexible solar first.

- Technology neutrality is a core principal for market-based electric flexibility services. For example, dispatchable solar qualifying for regulation and flexible ramping in CAISO.

Conclusions

- System flexibility can be enhanced through a portfolio of measures, including flexible solar operation.
- All else equal, our model estimates flexible solar operation reduces California system costs by at least $172 million compared to must-run solar at 30% penetration.
- Savings come from solar dispatch down to reduce system ramping needs, decreasing energy from fast-ramping natural gas plants.
- Wholesale market redesign is needed to compensate solar for flexibility services.

Background Literature

- Several review studies on research system flexibility needs increase with growing penetrations of renewable energy.[1-5]
- Metrics have been developed to quantify system flexibility.[6-13]
- Operational and planning studies detail flexibility needs at high penetrations.[14-19]
- A portfolio of methods can enhance system flexibility, including market integration, storage, demand response, and operating existing plants flexibly. [20-26]
- Solar and wind can also be operated to provide system flexibility.[27-29]

Appendix: Background literature

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Appendix: Background literature

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Appendix: Background literature

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Appendix: Background literature

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