Question	Answer
Is there any compensation available for solar energy providers providing the flexibility to offset the lost revenue from energy sales?	Most existing PPA (Power Purchase Agreements) do not comprehend lost revenue from energy sales. However, it is getting more common in newer PPAs to expect certain amount of curtailment. In that case the flexibilty can provide additonal value that can be realized by the owner or the off-taker.
did you do any accounting for impacts on wider system costs (i.e. if exports are reduced, that would affect system costs for the importing region)	We accounted for system costs across the full model-defined geography, including the impacts of changing trade flows on generator production costs both in California and neighboring states.
Is it more reasonable to invest in flexible solar than in demand response solutions for power balancing? (edited)	In general, during normal operation the option that is most cost-effective should be exercised. If foregone solar is worth 3c/kWh and the demand response cost is lower than it may be a better option all other things being equal
The ITC makes headroom feasible for solar facility, but wind with PTC has no incentive. Should PTC change to give "credit" for operating headroom from wind?	This is more of a policy question. However, even without ITC or PTC consideration, there has to be a higher incentive for solar or wind to keep headroom. If they are being curtailed for other reasons, then it is no brainer for sure.
Can you comment on the rolling blackouts in CA this week?	During summer peak demand periods where supply is in short supply the system operator will be less likely to dispatch solar below its maximum output. We find the value of solar flexibility is concentrated in the spring and fall months where demand is lower relative to solar production, and the remaining supply is turned off or set to minimum operating levels.
Do you think variable energy resources such as solar should have a cost to provide downward ancillary services vs. curtailment?	Foregoing zero marginal cost electricity has opportunity cost associated with it. Whether it is for downward services or curtailment it is the same.
@ Mahesh: There a is significant change in solar utilization w/ reg. Can you provide a bit more info.1) how much reg req. was enforced 2) any ramp assumptions?	Please refer to the TECO paper for more details on how much regulation was enforced on solar. 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 .
"peak power " is being advertised as the perfect solution for accommodating intermittent nature of renewable. Can flexible solar replace peak power?	I am not familiar with that term in this context.

How would different levels of carbon pricing impact the optimization?	Carbon prices would raise the costs of natural gas generation in California and incent greater reliance on non-carbon emitting flexibility solutions, including flexible solar.
What is "flexible solar" and how it differs from typical solar?	Flexible solar can be controlled in real time or near real time to meet operating needs.
Does cloud cover impact the ability for solar plants to follow agc? the base dispatch seems to lack any variability due to the intermittent source.	The way headroom was created was based on the possible power at each instant from the plant. Cloud cover reduces available power and hence the base dispatch is pushed down too. See the report for more details. www.caiso.com/Documents/TestsShowRenewablePlantsCanBalanceLow-CarbonGrid.pdf. AGC: Automated Generator Control
What offer costs did you use for solar resources in your dispatch/cost minimization model?	Solar offers into the model with $0/MWh variable production cost.
Not everyone has access to run a system IRP model to see true system value, how do you recommend moving towards more accurate metrics?	This type of model produces the most accurate picture of system-wide value. The security-constrained unit commitment and economic dispatch models utilized by RTOs to determine dispatch schedules are more detailed and accurate than what we built for this research, and are in a good position to determine the value trade-offs between flexible solar production and total system value.. We built our modelas open-sourced and the documentation, code, and data are accessible to everyone online at the Open Science Framework repository: https://osf.io/y7dcx/
What are the barriers for flexible solar to be eligible for CAISO's new DA ramping reserves product?	It does not appear solar is eligible for revenue through any of CAISO ramping products as they are currently conceived.
What are your thoughts on Hybryd (PV+Wind) Projects for Energy Flexibility? Do you have any literature on this topic you can share?	A good idea. With storage hybrid the flexibiltiy is greatly enhanced. We recommend Lawrence Berkeley Laboratory's recent research as a starting point in the literature: https://emp.lbl.gov/news/hybrid-power-plants-are-growing-rapidly-are
In your opinion, is there a possibility of a future autonomous power grid where there is no place for market, because the system itself self optimizes?	While certain aspects of grid operation are becoming more automated, the fundamental unknowns determining energy supply and demand, along with the economic benefits of competition suggest to me that there will always be a place for an organized market where humans will buy and sell energy from each other, with computers and robots playing a supporting role.

Great picture of the plant under variable resource conditions -- do you have examples of performance under those conditions? What interactions occur?	Please refer to the TECO paper for more details. 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 .
What is the cause of the large CAISO price swings within the span of 1-2 hours (slide 9)?	Prices rise rapidly in the evening when the system operator dispatches high-cost backup generation to meet balance the net-load ramp as solar goes offline.
How could/would this proposal potentially help with the current feeder rotation going on in CA?	See #6
Isn't this simply a matter of having a clearing price for Reg and Contingency Reserves that is higher than the make-whole price for lost solar production?	Flexible solar can provide these ancillary services. The ramping support described in this model is a different service as frequency regulation is for short-term balancing needs and contingency reserves are held for unexpected outages.
What fraction of solar plants in California are currently treated as must run versus allowed to curtail in response to system needs/market prices?	I believe all wholesale solar plants in California are subject to curtailment by the operator if needed for system reliability. I am not aware of any plants in California that adjust dispatch in response to market prices and for ramping support.
At a given level of annual energy penetration (eg 30%) what is the difference in capex to overbuild the PV. Or put another way what is the ROI for flex solar? (edited)	Solar plants with modern controls can operate flexibly without additional capital expenditure. The ROI for new solar plants at growing penetrations was not contemplated in this research.
Isn't CA eliminating nuclear even if flexible solar reduces ramping constraints that kill it in your base case? How do your results change without nucs?	We ran a sensitivity case that included the Diablo Canyon nuclear shut down. In this case, flexible solar delivered positive net benefits that were somewhat reduced, more details are in the report.
You mention hourly and sub-hr modeling - can you talk more about this? Seems like much of the real-world flexible ops would happen at ~minute scale	We ran a sensitivity model with a 5-minute dispatch, and this showed higher benefits than what was captured in the hourly model. See the report for more details. This was a sensitivity because solving a year of 5-minute dispatch for the full region with the model we constructed was not practical on our computer.
Due to the solar generation's uncertainty and variability, the solar generation and flexibility is not firm, i.e, not 100% reliable. Can you address it?	Implications of uncertainty were addressed in the webinar Q&A, see the recording for more details

When PV is managed and responding to commanded power level, what are the potential positive impact on the need for inertia on the grid?	If held in reserve, solar could provide a fast frequency response to a large event that may reduce the need for inertia to help arrest rapid frequency drop. May not be a cost-effective approach since you will be holding back solar unnecessarily for a long time for an infrequent event.
How does $172M system value at 30% energy penetration compare with the value of additionally curtailed energy over and above the base case?	At 30% penetrations and higher there are many days when solar production exceeds local demand and without storage this energy has low or zero value.
Is using flexible solar for reducing ramping done due to the system running into physical limits of ramping capability, or is it done to reduce production costs	Both.
Are all the savings generated by more efficient commitment of gas CCs as opposed to less efficient but more flexible peaker units? Is flexibility in DA or RT?	Savings are generated by reduced need for energy from both gas peaker and CC's during periods of high ramping needs, depending on the particular day. Generally, offers and purchases in the day ahead market determine unit commitment while the real-time market enables short-term adjustments to schedule deviations. Both constructs are important in supporting system flexibility.
Would some version of a Flexi-ramp product solve the lost revenue to solar when it is dispatched down?	Yes.