Energy+Environmental Economics

Planning Transmission for Renewables:

Optimizing use of California's transmission system to deliver energy from renewable resources in the San Joaquin Valley

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Executive Summary

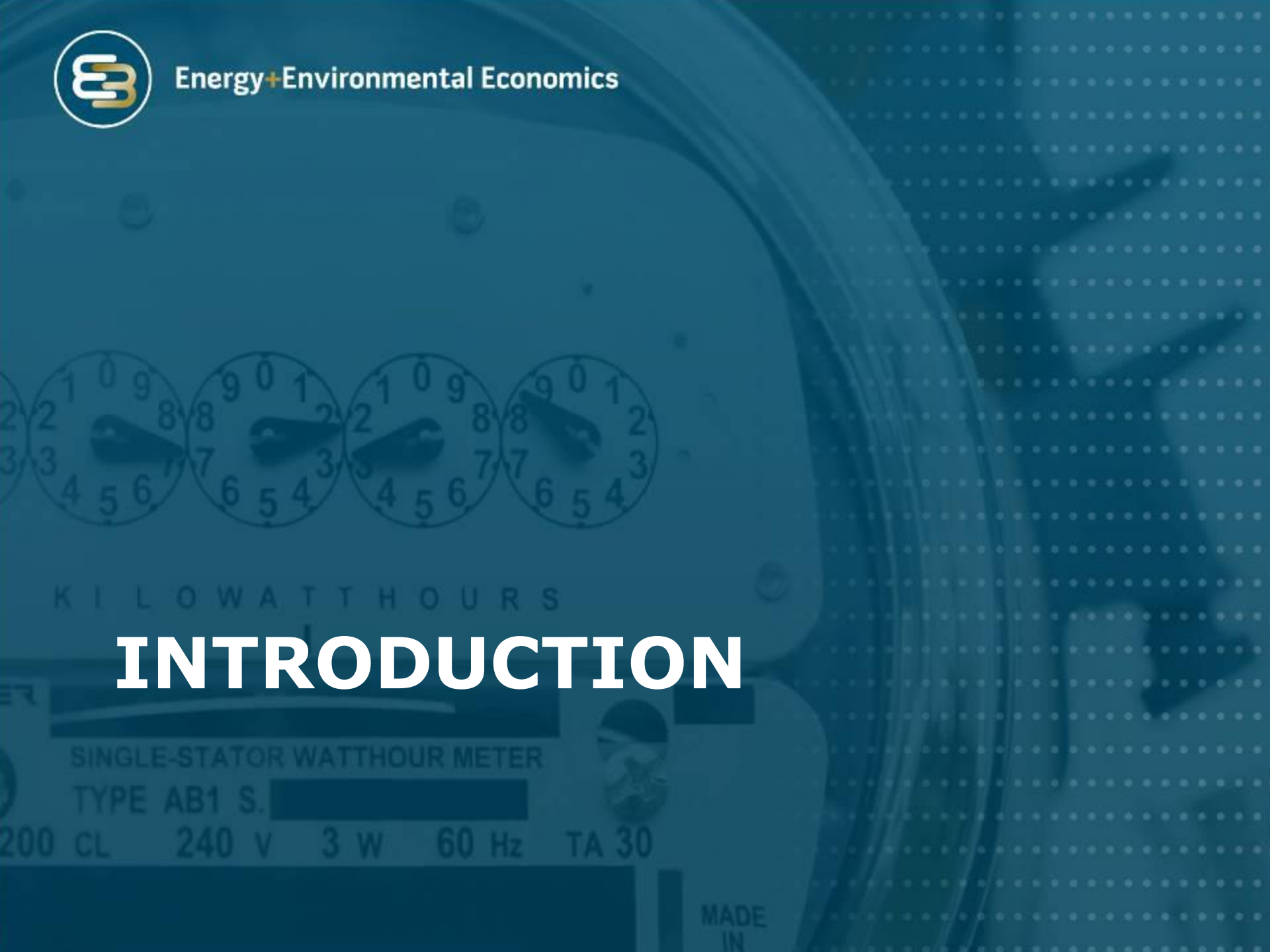
- Conventional transmission planning processes are not well suited for renewable energy because they focus on delivery capability during peak hours, rather than maximizing the delivery of renewable energy throughout the year
- This is hampering the development of renewable resources in transmission-constrained areas such as the San Joaquin Valley
- New transmission planning approaches that focus on renewable energy delivery can result in lower-cost renewable energy development

Executive Summary (cont'd)

- **The San Joaquin Valley (Westlands Renewable Energy Zone) provides a case study of the benefits of moving towards an "Energy Only" planning approach**
  - Significant additional solar resources could be developed with no new transmission in a region in which solar development has been limited due to transmission constraints
- **The San Joaquin Valley is also an ideal region for solar development from the perspective of low-conflict land use**
  - **Water stressed farmland with degraded soil** could be converted to solar, helping the region meet **groundwater sustainability targets** while bringing economic value to landowners

Outline

- **Introduction**
  - Study Motivation
  - Definitions
  - Study Questions
- **Transmission Planning in California**
- **Energy-Only Analysis**
- **Cost Analysis**
- **Conclusions**
- **Next Steps**



INTRODUCTION

Study Motivation

+ Purpose:

- Investigate the relative economics of developing renewable energy resources under varying levels of curtailment
- Investigate whether a new transmission planning framework focused on annual energy delivery rather than full resource delivery would result in more cost-effective solar development
- Demonstrate, at a high level, the impact of the new framework using the San Joaquin Valley as a case study

Study Motivation

San Joaquin Valley Context

- Experts estimate as much as 500,000 acres of agricultural land may come out of production in order to reduce consumptive water use and meet new groundwater sustainability targets
- Solar PV provides a low-water alternative land use that brings economic value to landowners, while contributing to state policy goals

RPS Policy and Planning Context

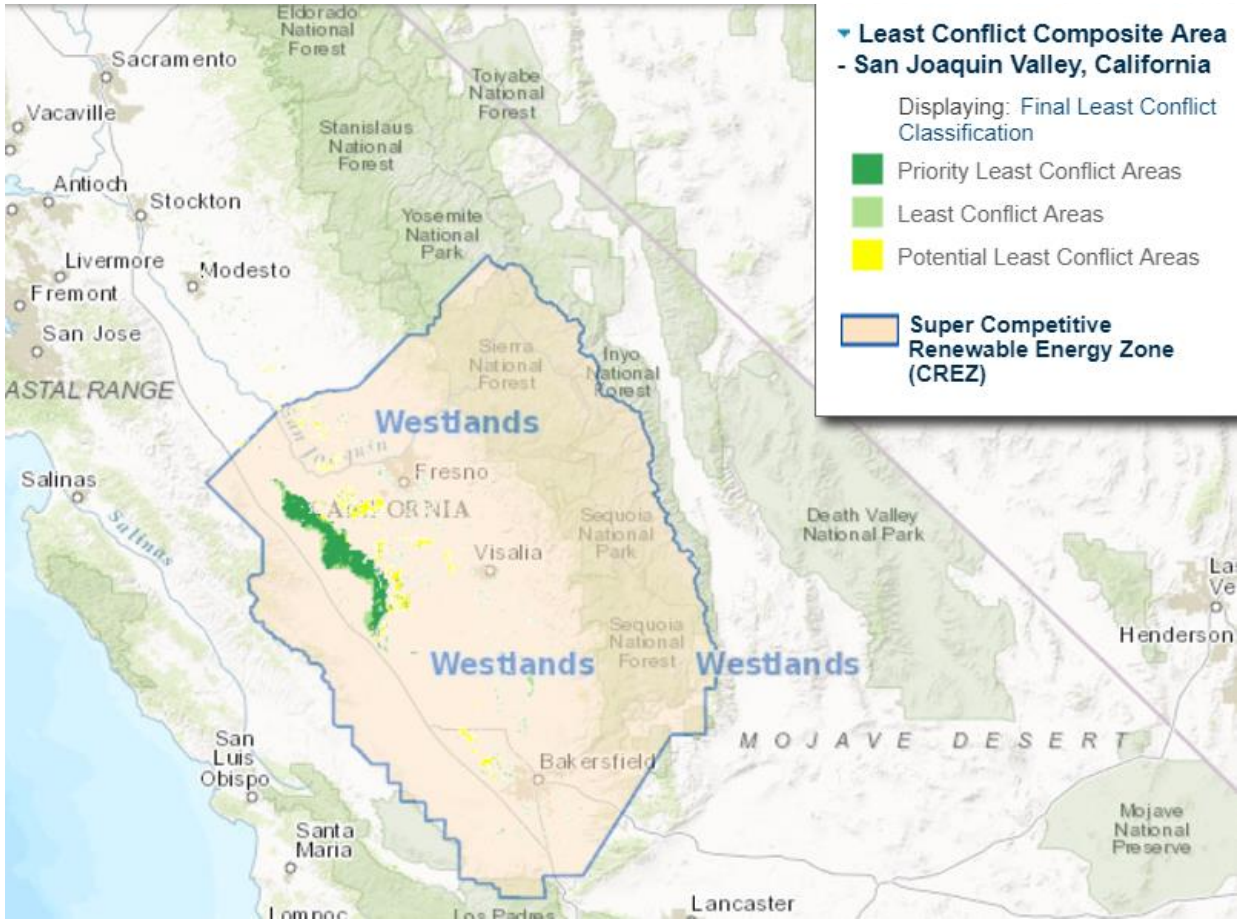
- California has aggressive goals for renewable energy development under its Renewables Portfolio Standard (RPS) program
- California Load-Serving Entities (LSEs) evaluate renewable contracts using a "Least-Cost, Best-Fit" framework which considers the resource cost and other factors including transmission cost and capacity value
- The value of the capacity credit provided by solar resources is declining due to saturation and California's currently high Planning Reserve Margin
- Planned curtailment offers a potential means of interconnecting new renewable resources without significant transmission investments

Study Motivation

- **A recent study identified abundant "Least Conflict Areas" in the San Joaquin Valley**
  - Areas for potential solar development which were identified as suitable for renewable resource development by environmental, agricultural, and solar stakeholder groups

- **"[P]articipants identified the lack of available transmission capacity as a major limiting factor in accommodating more renewable energy production from the Valley for use in other parts of the state." (p. 62)**

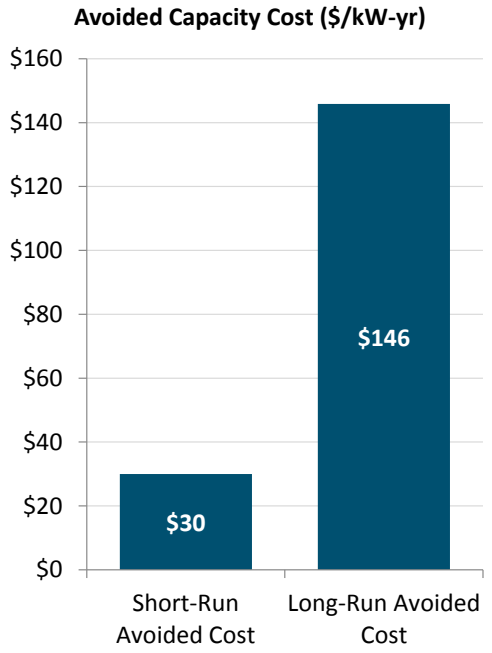
Link to the report: A Path Forward: Identifying Least-Conflict Solar PV Development in California's San Joaquin Valley (May 2016)

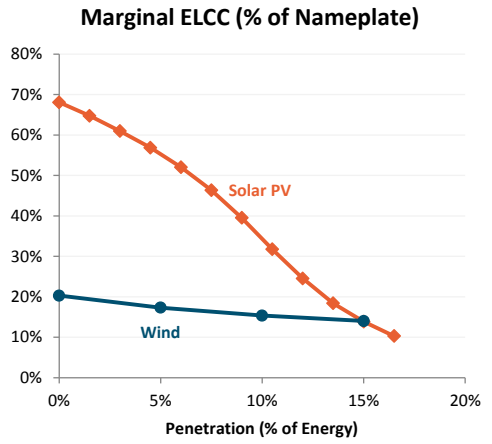


Source - https://databasin.org/maps/new#datasets=b64959db3e694254818d97e51e2e6f42

Resource Adequacy value of solar is low and declining

- **Due to a surplus of generation capacity, Resource Adequacy (RA) capacity value is currently very low**
  - Bilateral market prices: $10-30/kW-yr.
  - Long-run new resource cost: $150-180/kW-yr.
- **Capacity value of solar declines significantly at high penetration**
  - Increased solar production pushes net peak into evening hours when solar production is low
  - Marginal Effective Load-Carrying Capability (ELCC) of solar is currently less than 20% of nameplate capacity
- **Low capacity value reduces the benefit of planning transmission for full capacity delivery**





Key Definitions

+ Full Capacity Delivery Status (FCDS)

- A renewable energy procurement framework in which LSEs receive a credit against their resource adequacy requirements based on the Net Qualifying Capacity (NQC) rating of the renewable resource
- Qualifying for FCDS requires transmission to deliver the resource to load centers during peak demand hours, sometimes requiring new transmission construction

+ Energy-Only (EO)

- A renewable energy procurement framework in which full transmission deliverability is not required but LSEs receive no capacity credit for the renewable resources

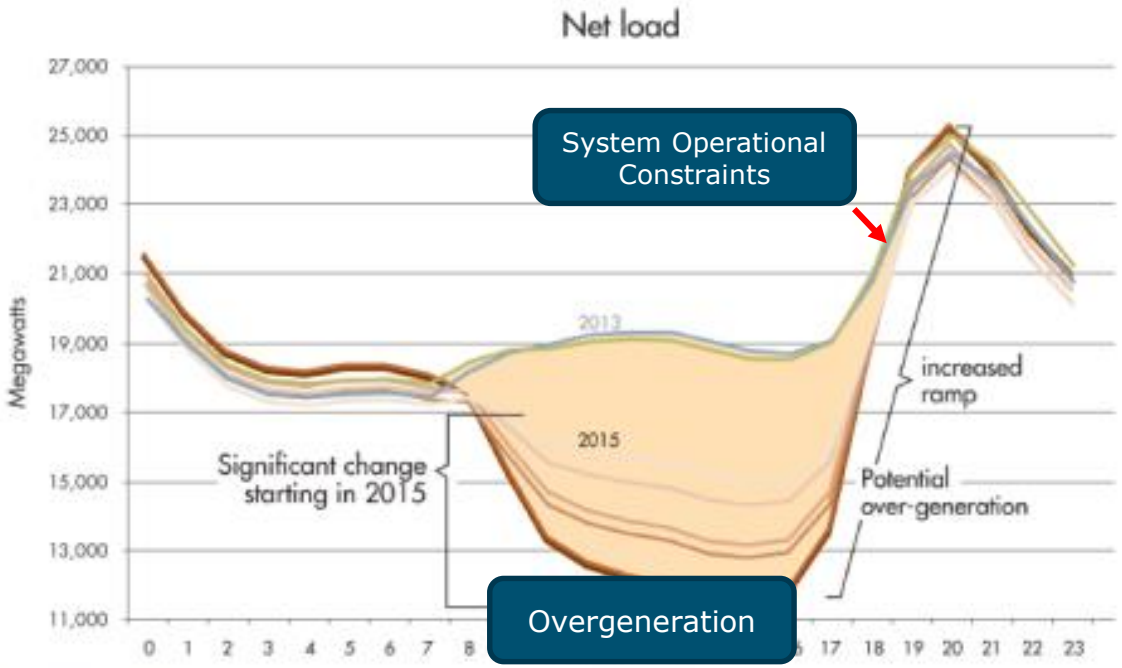
Key Definitions: Curtailment

- **EO procurement allows more solar to connect to the grid with less transmission investment**
  - Less transmission investment may result in curtailment of local solar resources due to lack of delivery capability
  - This study explores the cost-benefit tradeoffs of curtailment vs. transmission investment
- **This analysis focuses on incremental curtailment arising from transmission constraints only**
  - Investigates the effect of current transmission planning practices on California's ability to achieve high renewable penetration
  - Curtailment due to system-wide over-generation cannot be remedied with local transmission investment

Key Definitions: Curtailment

Curtailment of renewable resources can result from three primary causes

- **Overgeneration / system operational constraints**:
  - Supply exceeds demand (the "belly" of the duck curve)
  - Inability to integrate renewable generation (the "neck" of the duck curve)
- **Local transmission constraints**: Inability to deliver energy from generator to load
  - Seeing this already on Path 15. Limited transfer capacity between Southern and Northern CA at times



Study Questions

- How much more solar generation can be developed in the San Joaquin Valley under varying levels of allowed transmission-based curtailment?
- Can procurement based on planned curtailment help the state better utilize the existing transmission system to meet statewide greenhouse gas and renewable energy goals?
- What method might be used to assess the transmission system's ability to absorb renewable generation under a planned curtailment framework?
- How does planned curtailment affect the incremental cost to consumers of renewables development?

RESOURCE PROCUREMENT AND TRANSMISSION PLANNING IN CA

Portfolio Selection in California

- **Resource procurement in California is done under a "least-cost, best-fit" evaluation framework**
  - Prioritize development of renewable resources that minimize the total portfolio cost of meeting RPS requirements, taking into account
    - Transmission availability / needs
    - Energy / capacity value
    - Expected curtailment
- **CAISO is starting to consider how Energy-Only resources can fit into this LCBF framework**
  - "Special Studies" in 2015-2016 and 2016-2017 transmission planning processes examined the ability of the system to accept energy-only resources from around the state
  - The quantity of energy-only generation capacity that could be added to the transmission system was based on a rule of thumb rather than a rigorous calculation

Why consider Energy-Only resources?

+ Transmission planning in CA has historically relied on a full deliverability framework

- Deliverability for resource adequacy purposes considers a given resource's ability to serve load during times of peak system demand
- Makes sense in a capacity-scarce / heavily dispatchable system, to ensure that generators can deliver energy when called upon

+ Solar is expected to be CA's primary means of meeting RPS goals

- Capacity surplus means deliverable solar resources should no longer be the driving concern for system planners

+ RPS targets are based on energy delivered to the system

Total Resource Potential Reflected in CPUC IRP Assumptions	
Wind	2,331 MW
Solar	**122,210 MW**
Geothermal	1,463 MW
Biomass	1,106 MW

Source: RESOLVE Scenario Tool used in the IRP Process
ftp://ftp.cpuc.ca.gov/energy/electric/IRP%20Scenario%20Tool.zip

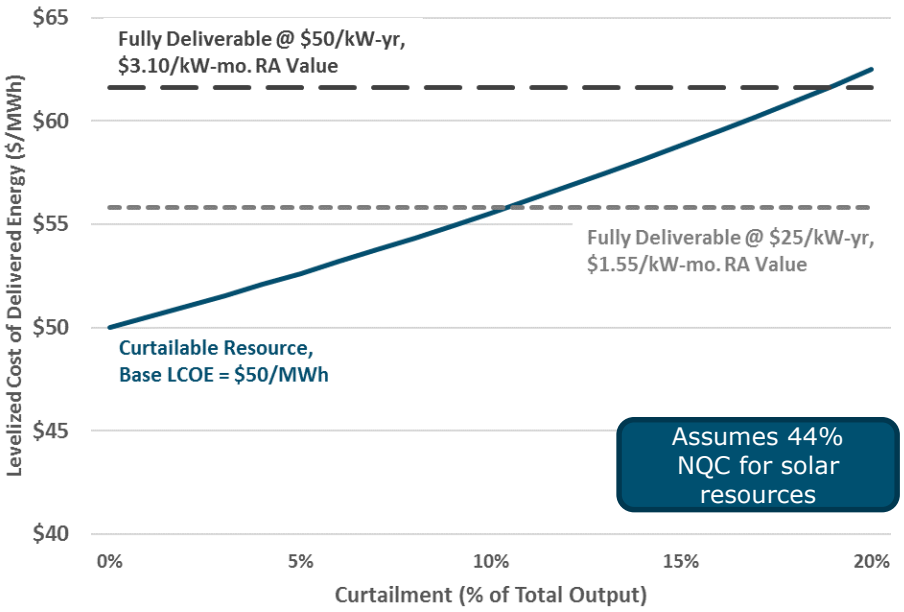
Energy-Only Resources can be procured at lower delivered cost

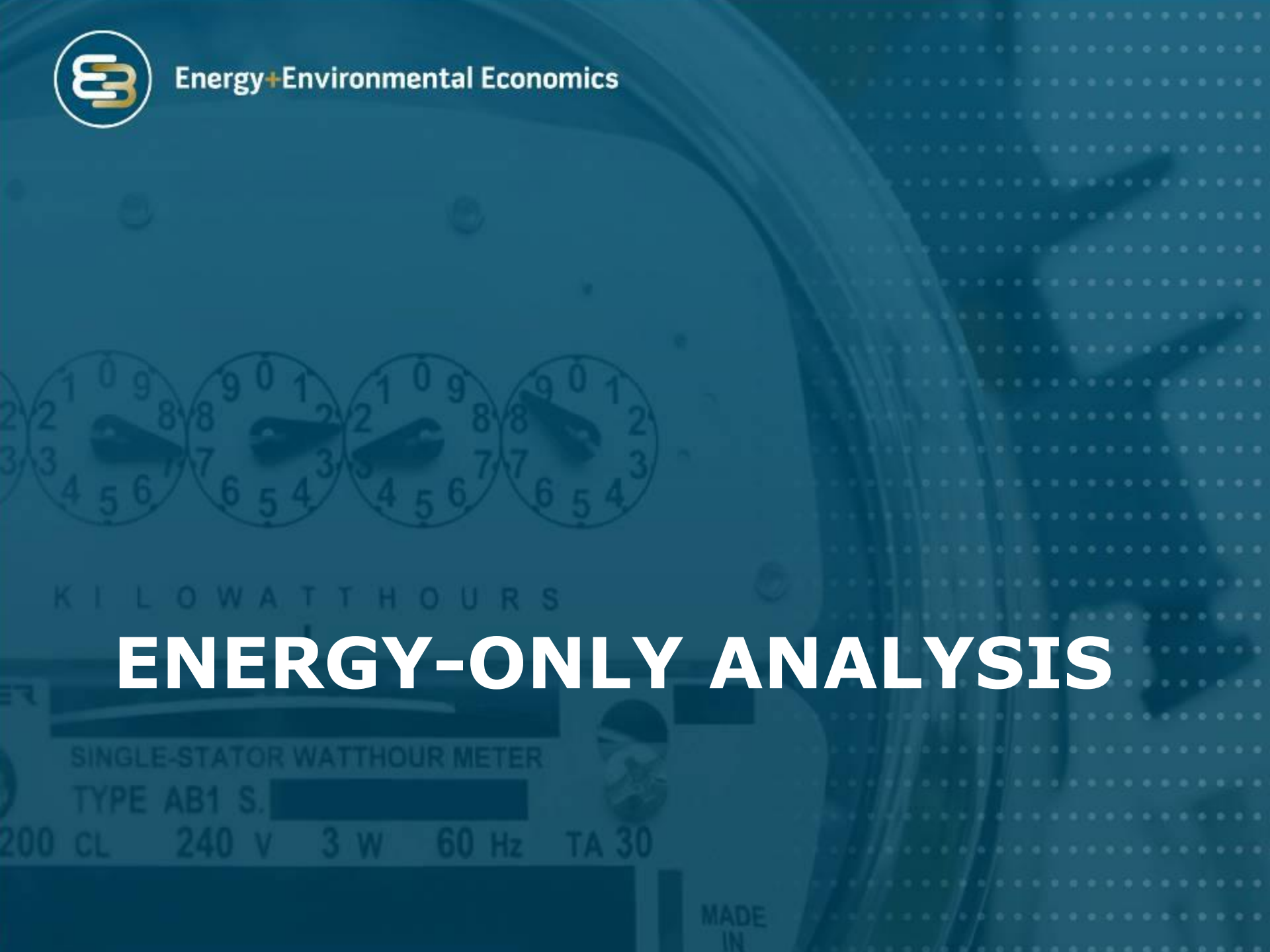
- **The following table shows that the delivered cost of a solar procured EO is lower than under FCDS under a reasonable range of transmission cost, capacity value and curtailment assumptions**

	Solar Resource Procured under Full-Capacity Deliverability Status ($/MWh)		Solar Resource Procured under Energy-Only Status ($/MWh)		Notes
	Low Value	High Value	Low Value	High Value	
Base LCOE	$50.00		$50.00		Sample value for comparison (33% CF)
Levelized Tx Cost	+$8.65	+$17.30	-	-	Assumes $25-50/kW-yr. cost of new Tx
Resource Adequacy Value	-$2.83	-$5.66	-	-	Assumes $1.55-3.10/ kW-mo. RA value, 44% NQC value for solar
Curtailment Penalty	-	-	-	+$5.56	Assumes 0-10% transmission-caused curtailment
Delivered Cost	**$55.82**	**$61.63**	**$50.00**	**$55.56**	

Energy-Only Resources can be procured at lower delivered cost

- **The total cost of resource procurement could be reduced by allowing planned curtailment to relieve transmission constraints rather than building new transmission**
- **Depending on the relative costs of solar and transmission, solar can offer cost savings even when subject to 10%+ curtailment**
- **Chart to the right compares:**
  - delivered cost of solar resource with varying levels of curtailment
  - delivered cost of solar (net of RA value) including transmission investments



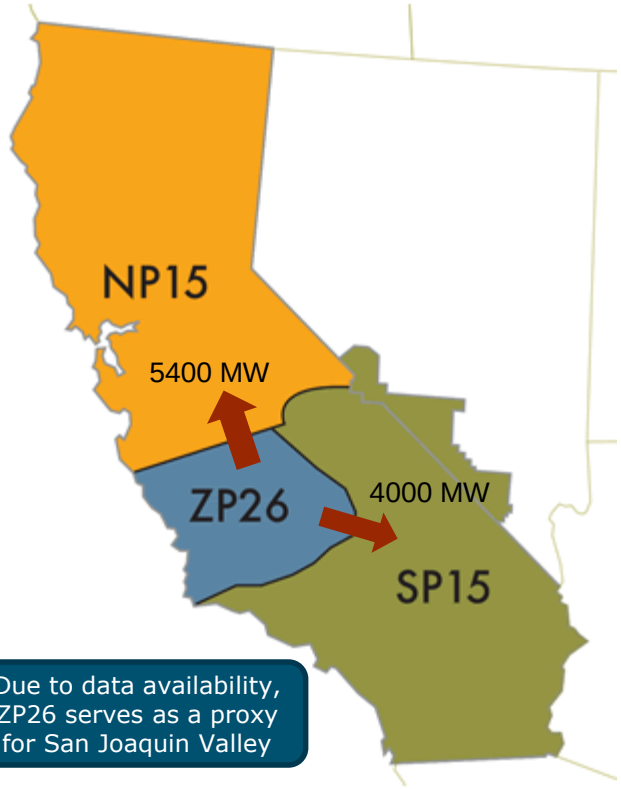


ENERGY-ONLY ANALYSIS

Methodology

- **High-level zonal model**
- **Based on annual hourly run of AuroraXMP model**
  - Describes load, generation, and power flows between zones
  - ZP26 serves as a proxy for the San Joaquin Valley (Westlands Renewable Energy Zone)
- **Solar capacity is added to the analysis zone until the model indicates that transfers out of that zone violate transfer criteria**
  - Solar is allowed to displace in-zone conventional resources and imports serving local load
  - Remaining solar is exported or curtailed (if allowed)

San Joaquin Valley System



Due to data availability, ZP26 serves as a proxy for San Joaquin Valley

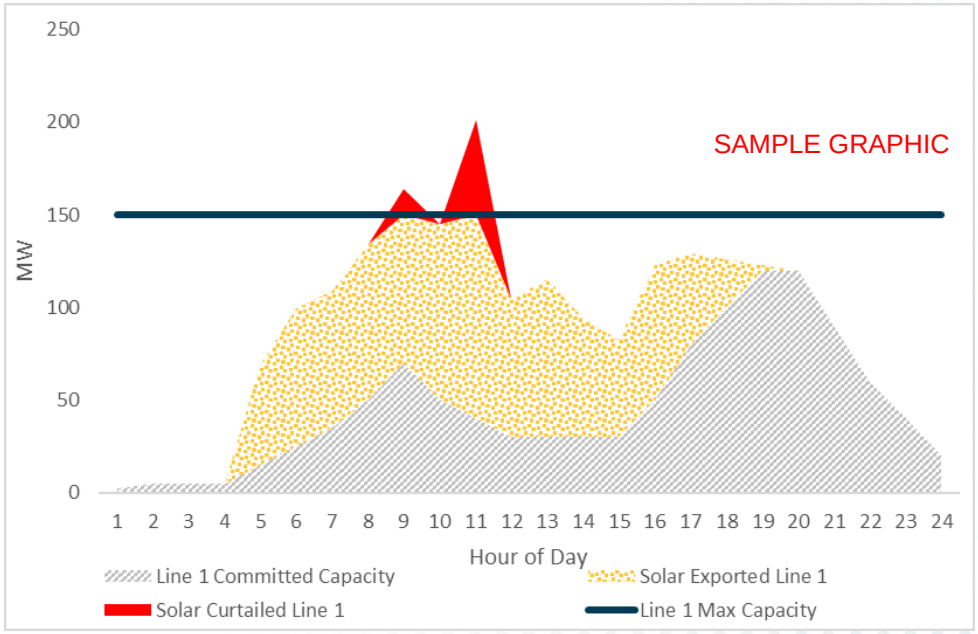
Source: CAISO OASIS

Excess solar power for export = Generated solar power – Local absorption capacity

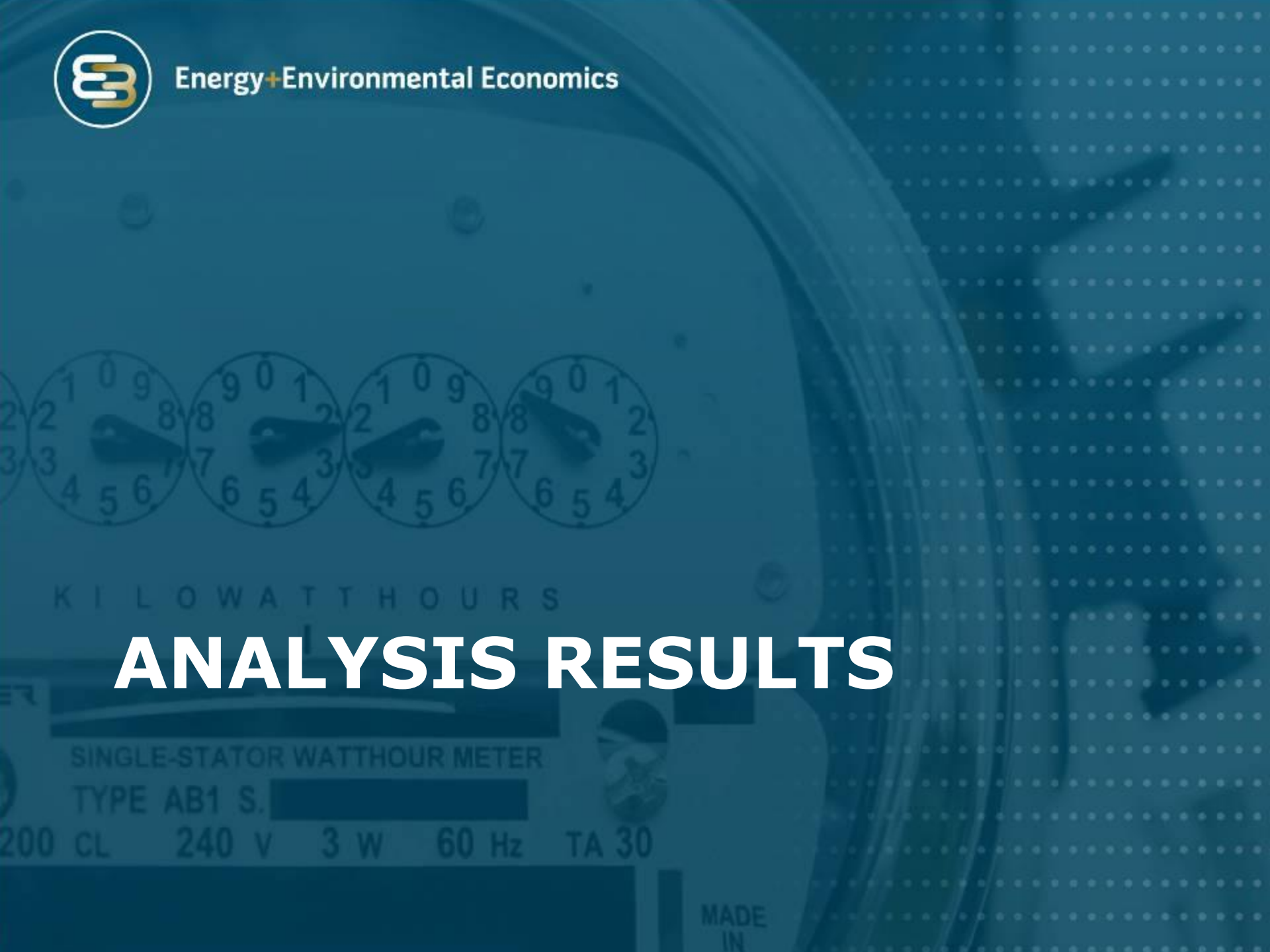
Local absorption capacity = ZP26 Imports + Local thermal generation

Analysis adds additional solar to the zone until next MW added would cause transmission-based curtailment to exceed specified limits (0-10%)

High-level demonstration of potential transmission utilization and cost impacts of moving to an alternate planning framework

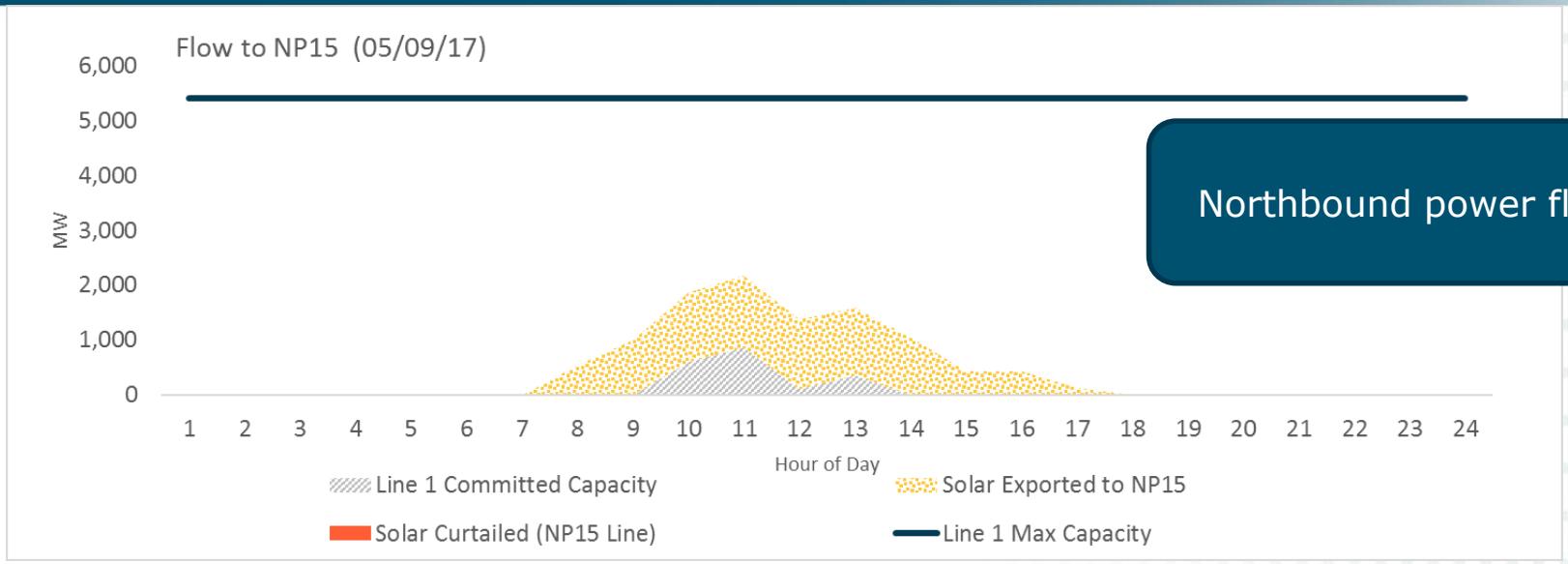


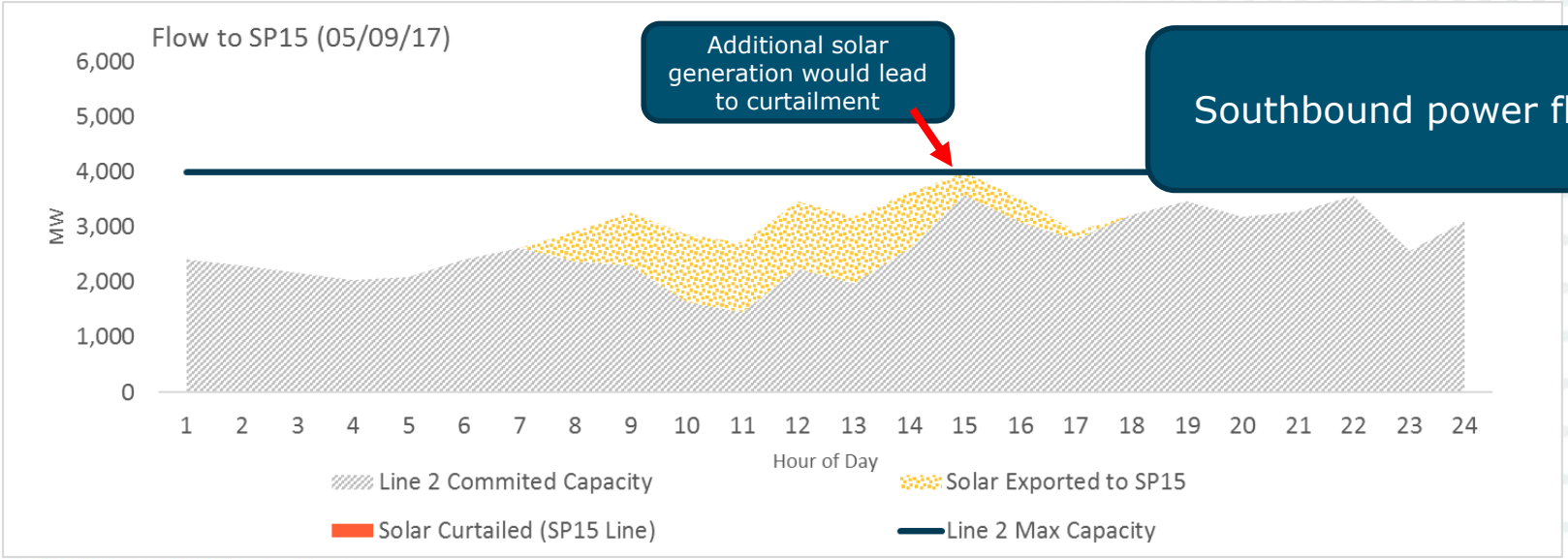
Goal: Identify maximum allowable PV capacity, given system characteristics, curtailment limits



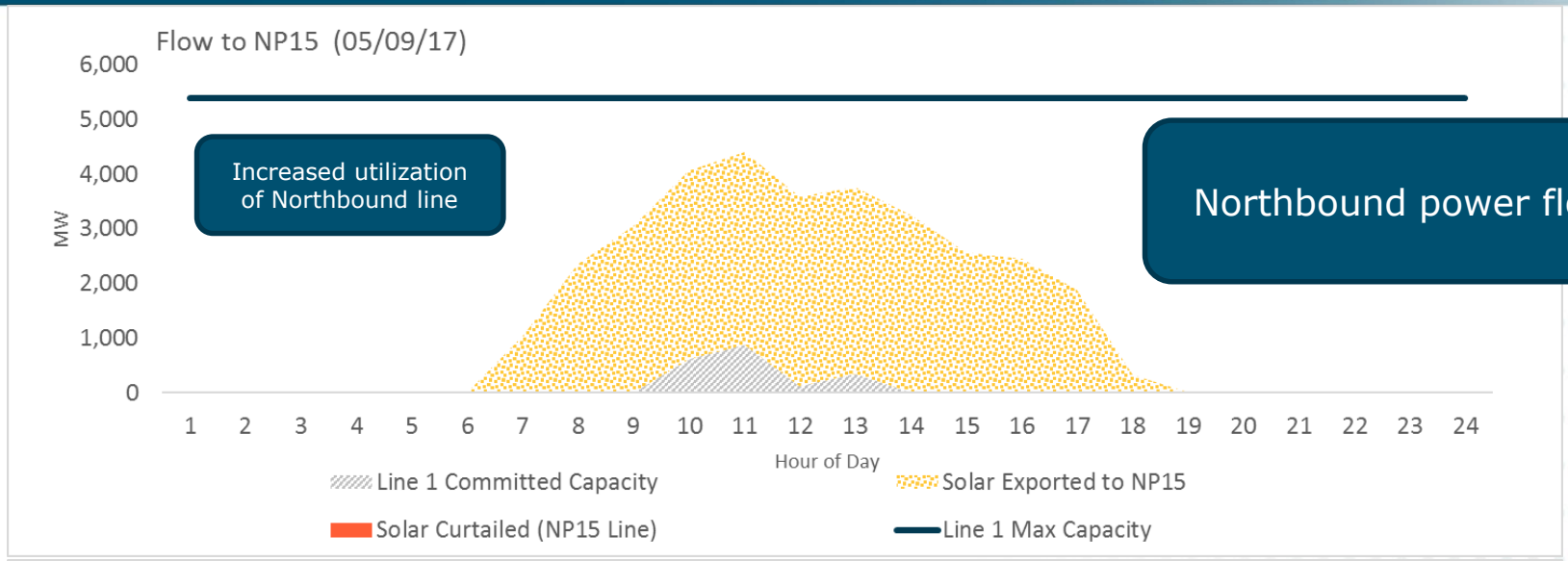
ANALYSIS RESULTS

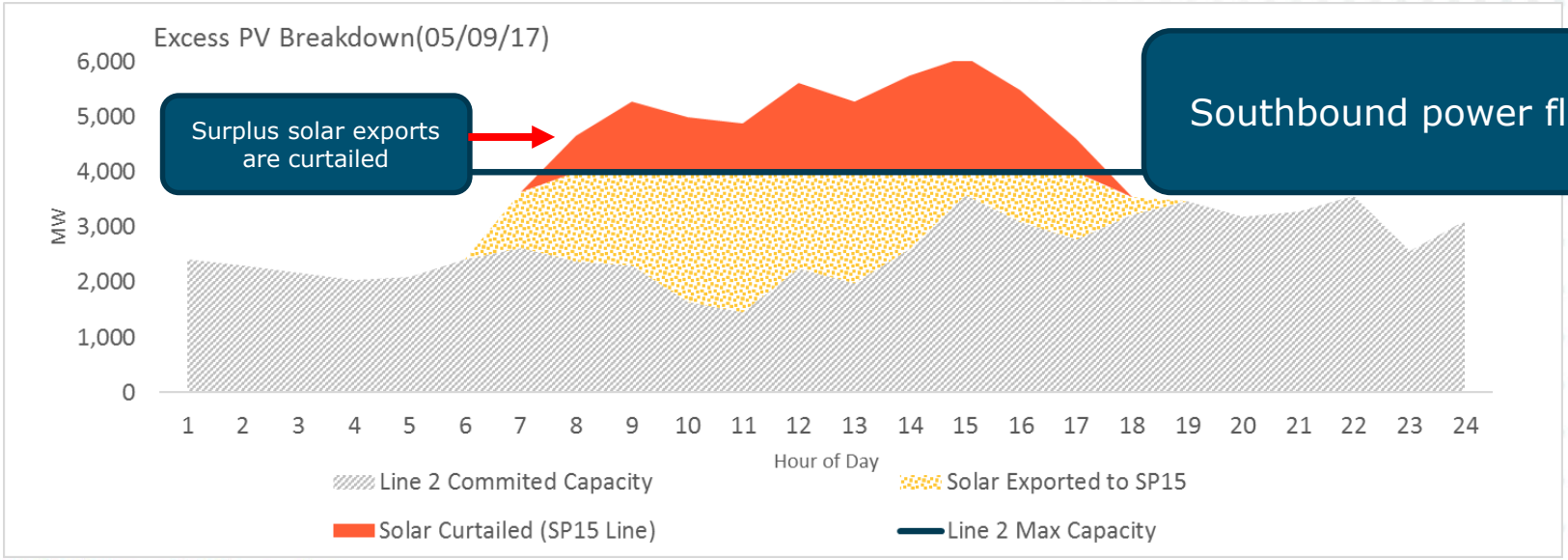
FCDS Power Flows Out of Zone (North and South), Capacity Limited Day



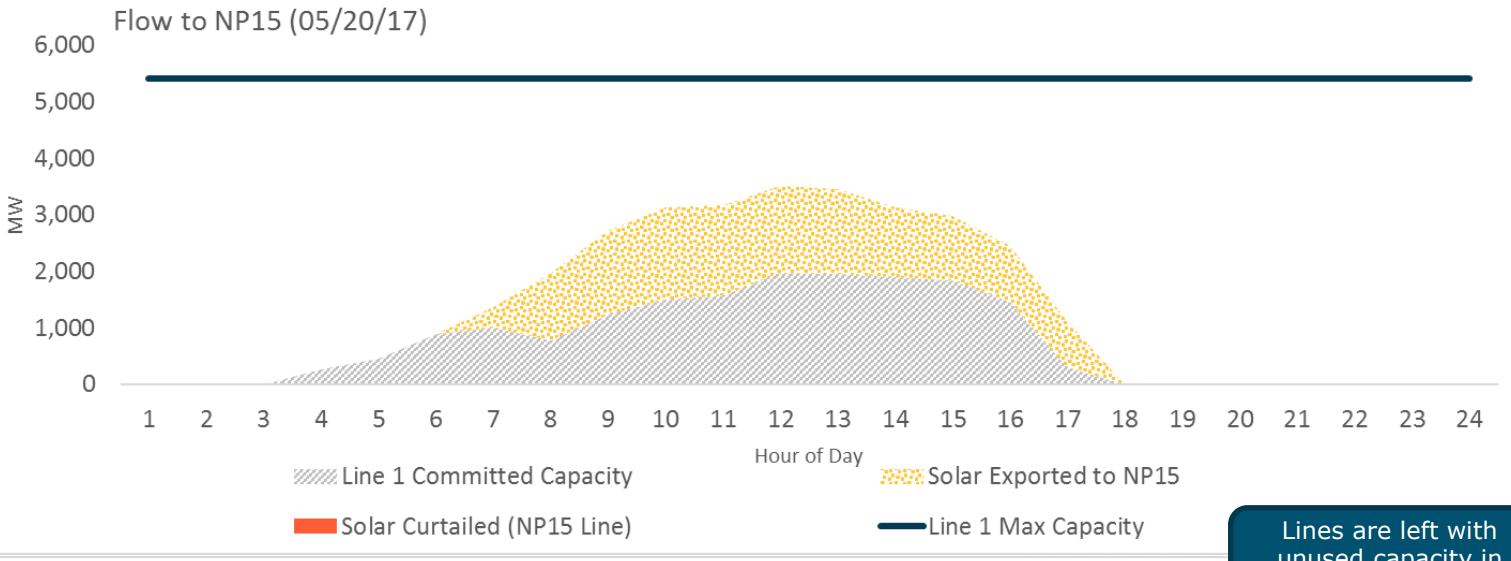


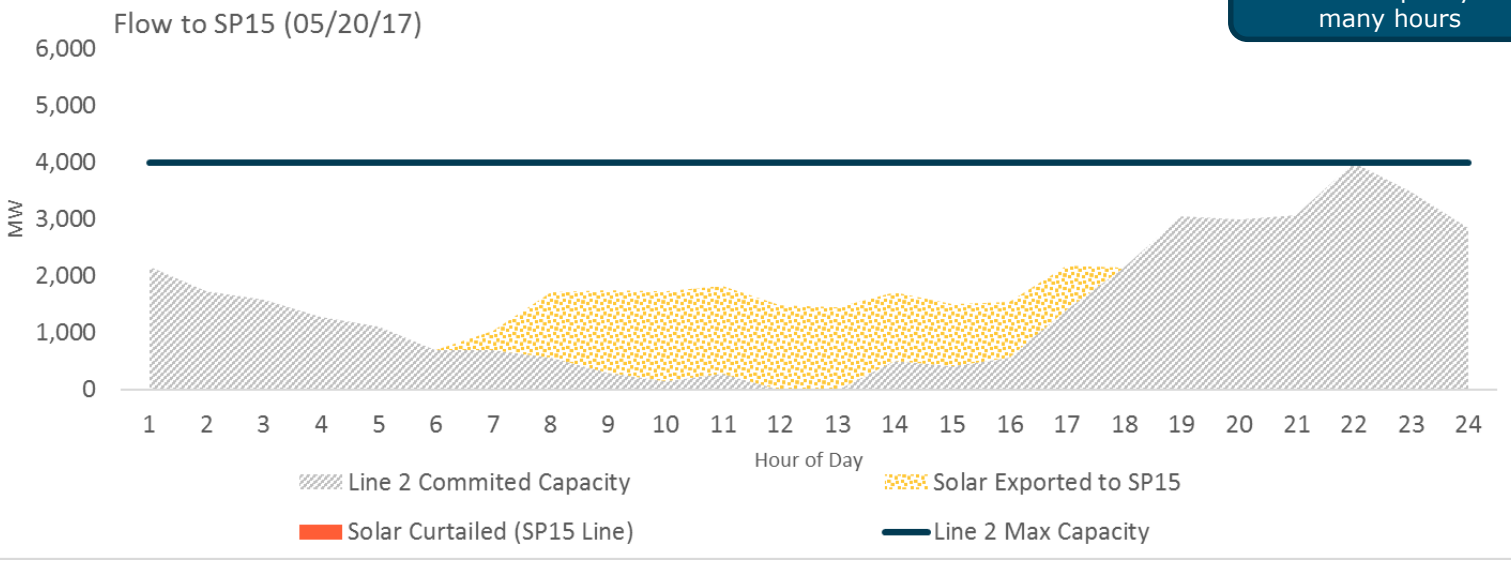
Planning For 5% Curtailment Results In Significant Curtailment on Capacity Limited Day





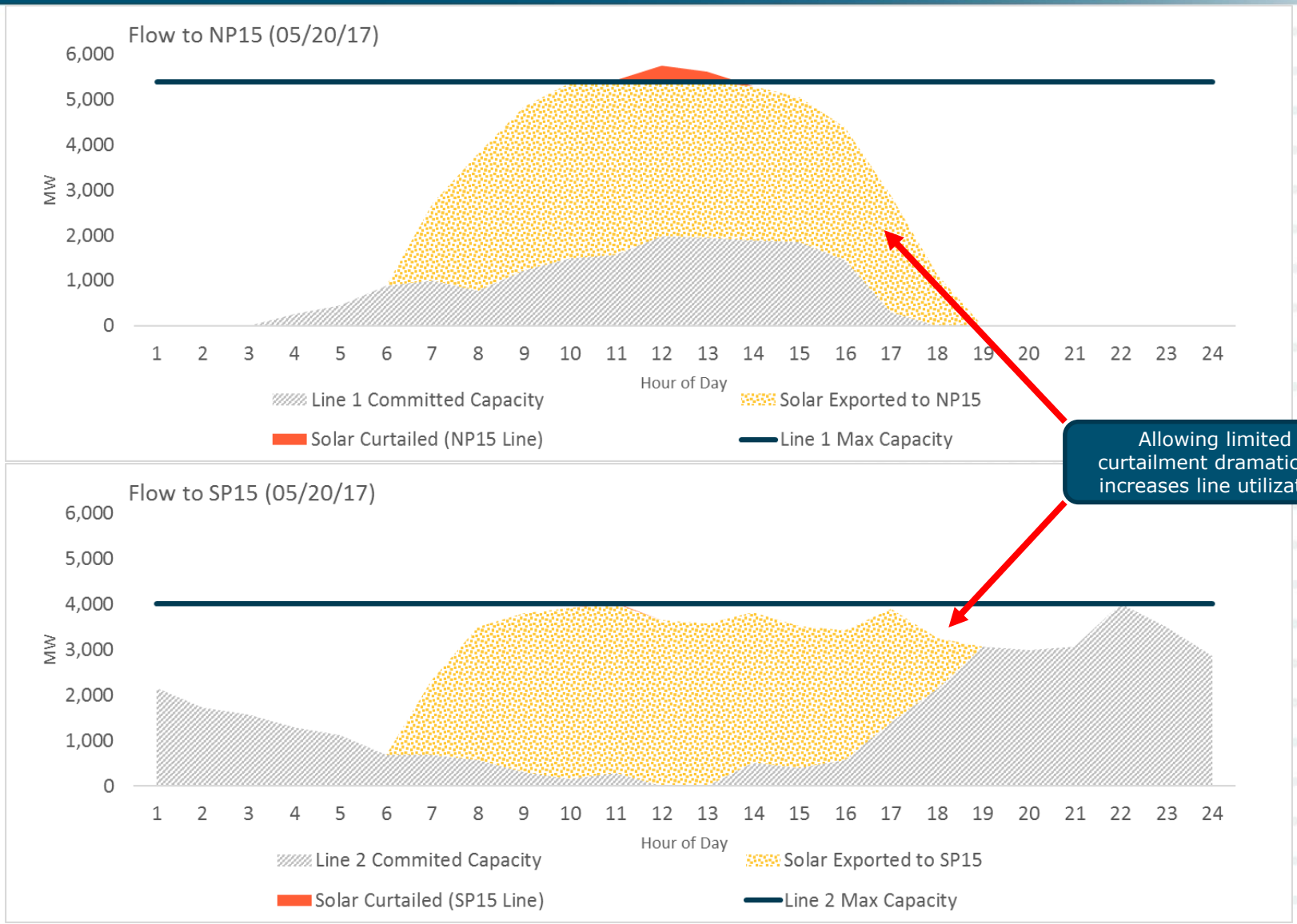
Capacity-Limited Results – Sample Day with Extra Transmission Capacity



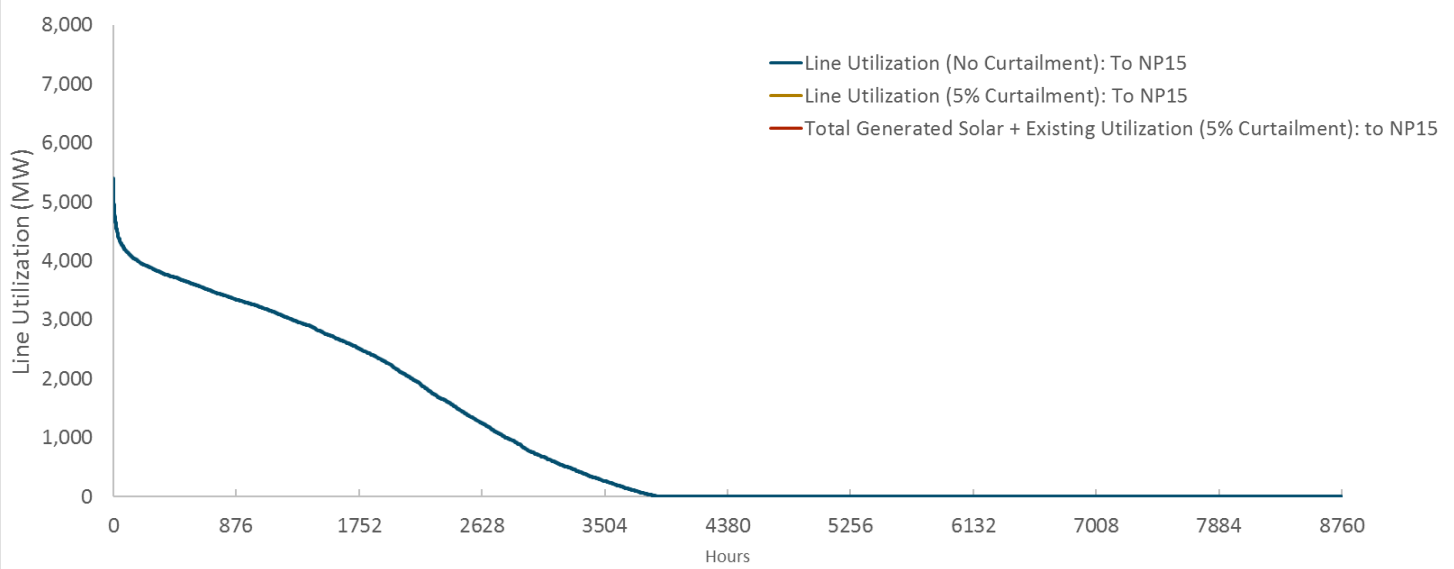


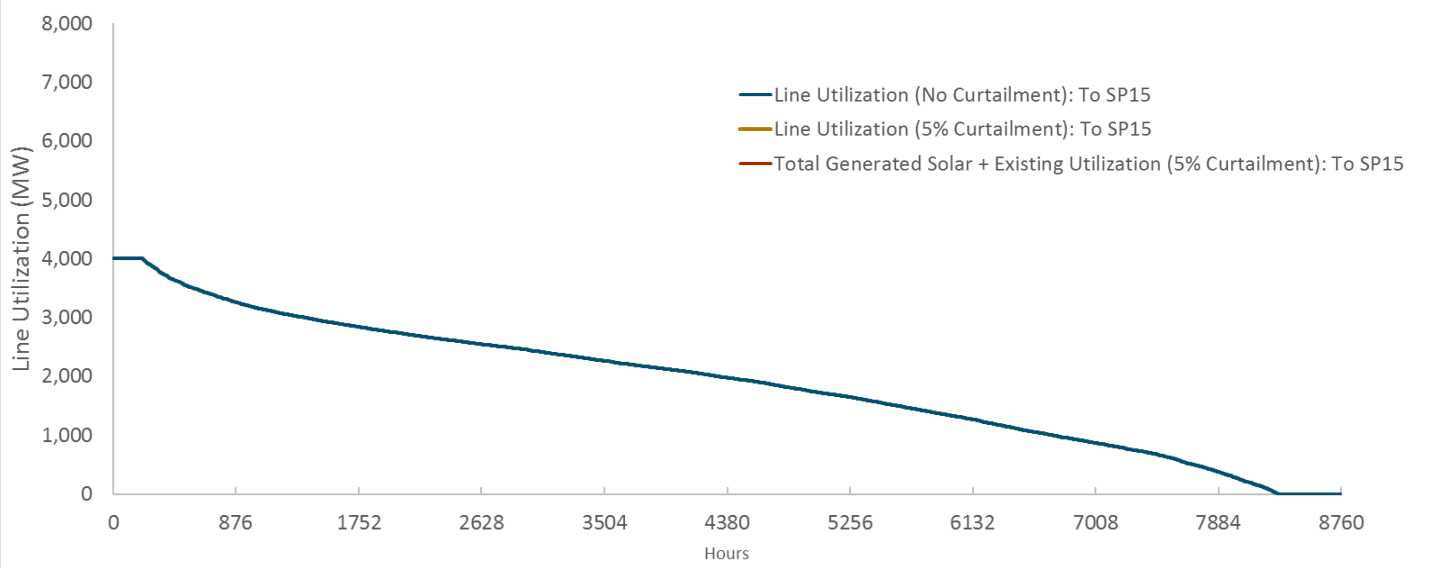
Lines are left with unused capacity in many hours

Planning for 5% Curtailment Increases Transmission Utilization on Most Days

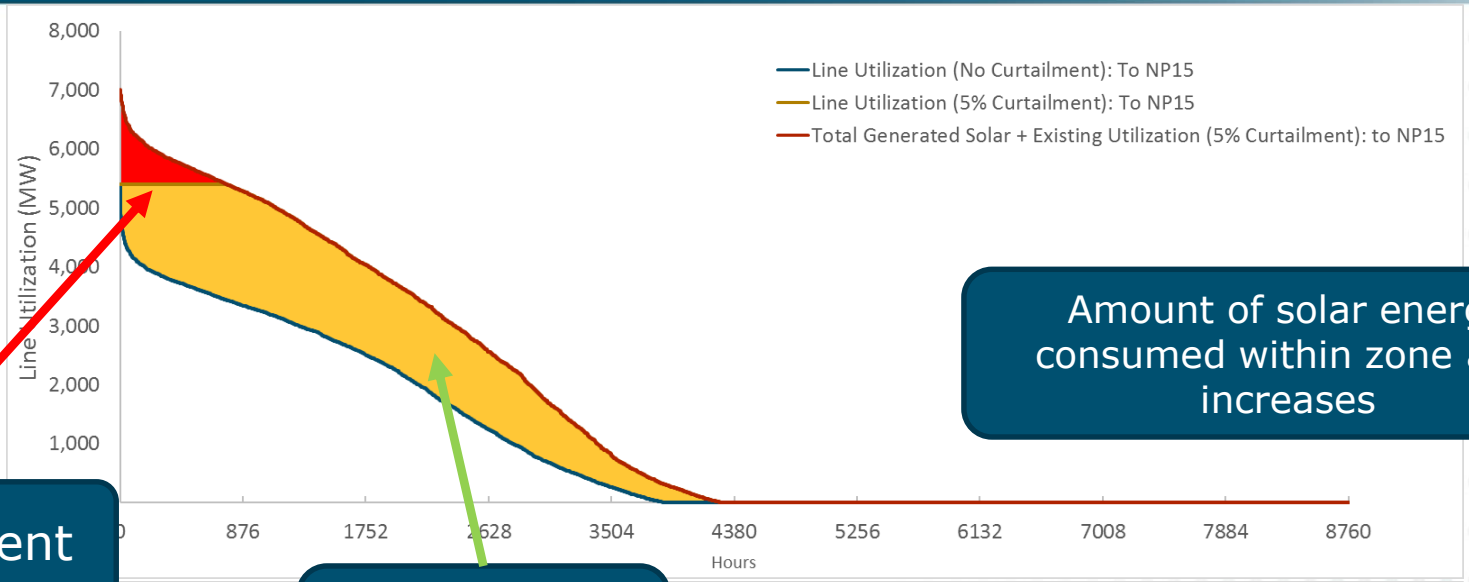


Line Utilization Across Year (No Curtailment)





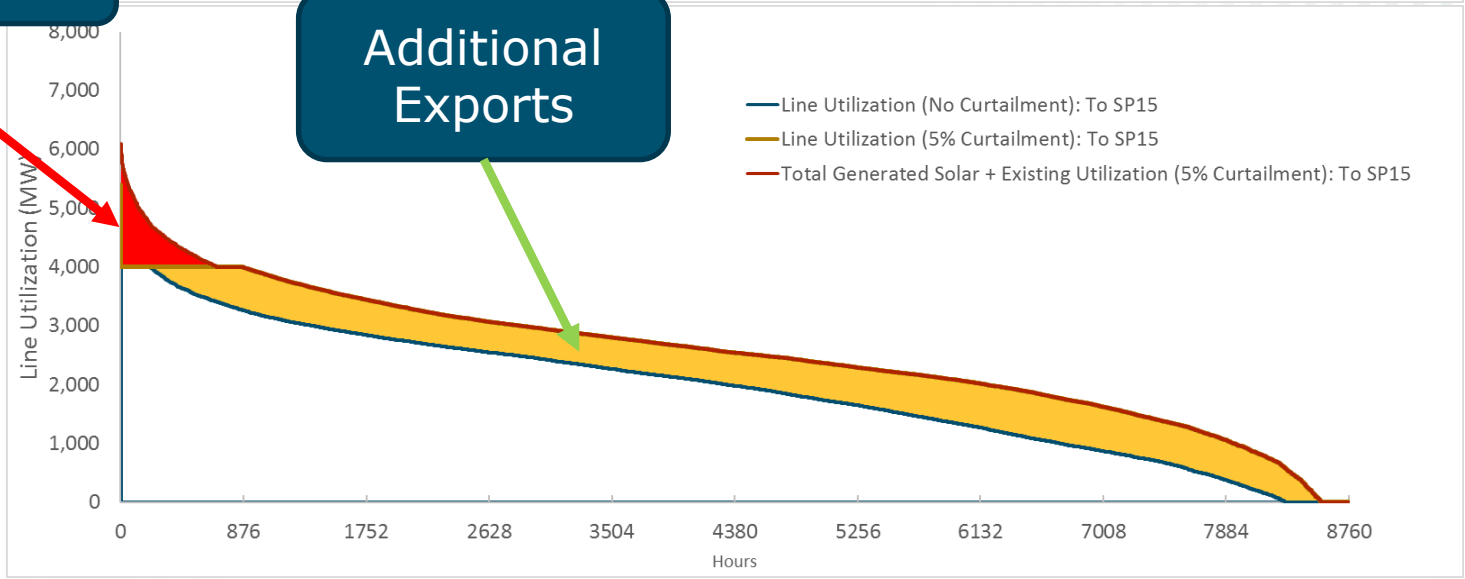
Planned Curtailment (5%) Increases Line Utilization

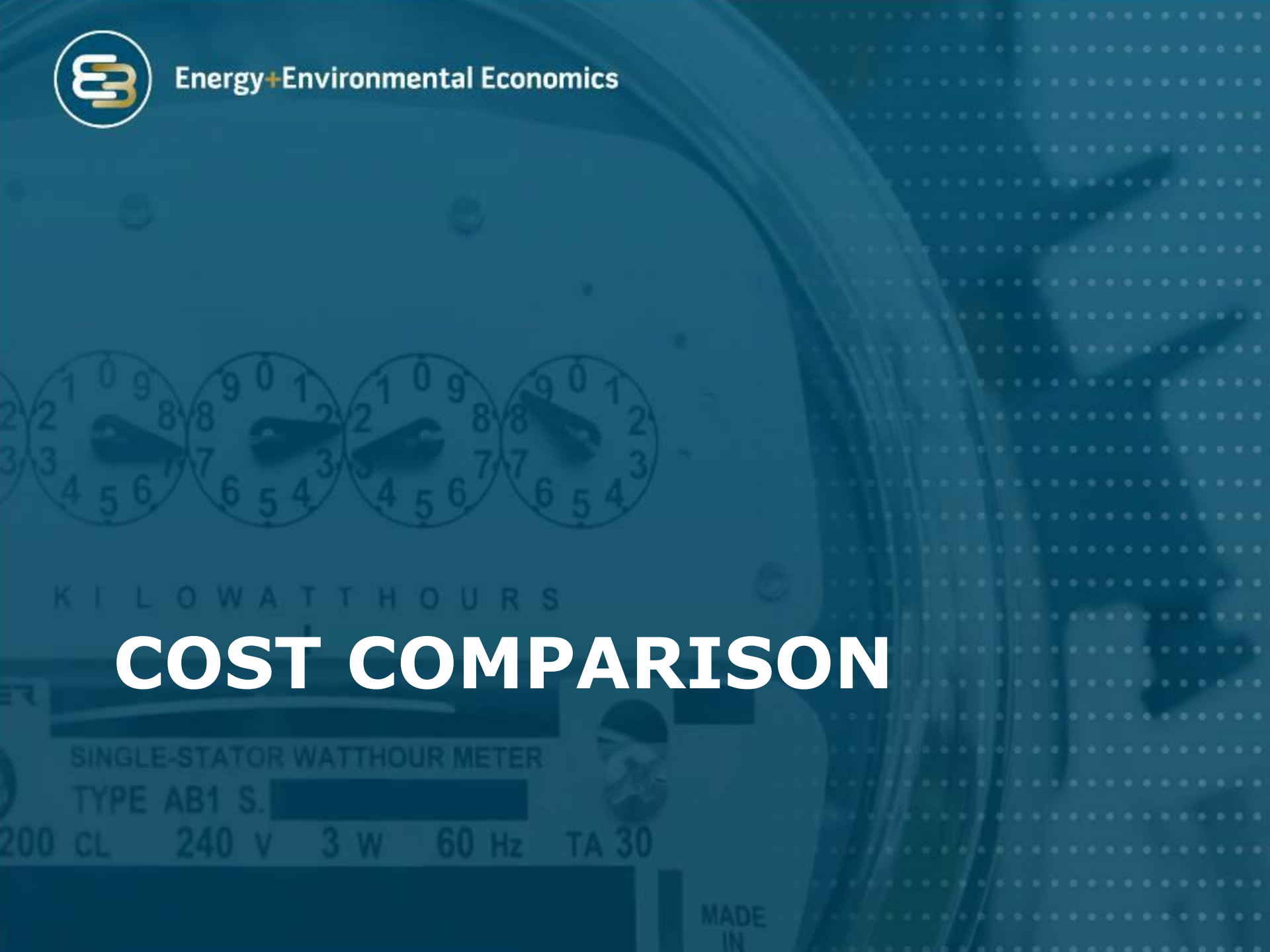


Amount of solar energy consumed within zone also increases

Curtailment

Additional Exports





COST COMPARISON

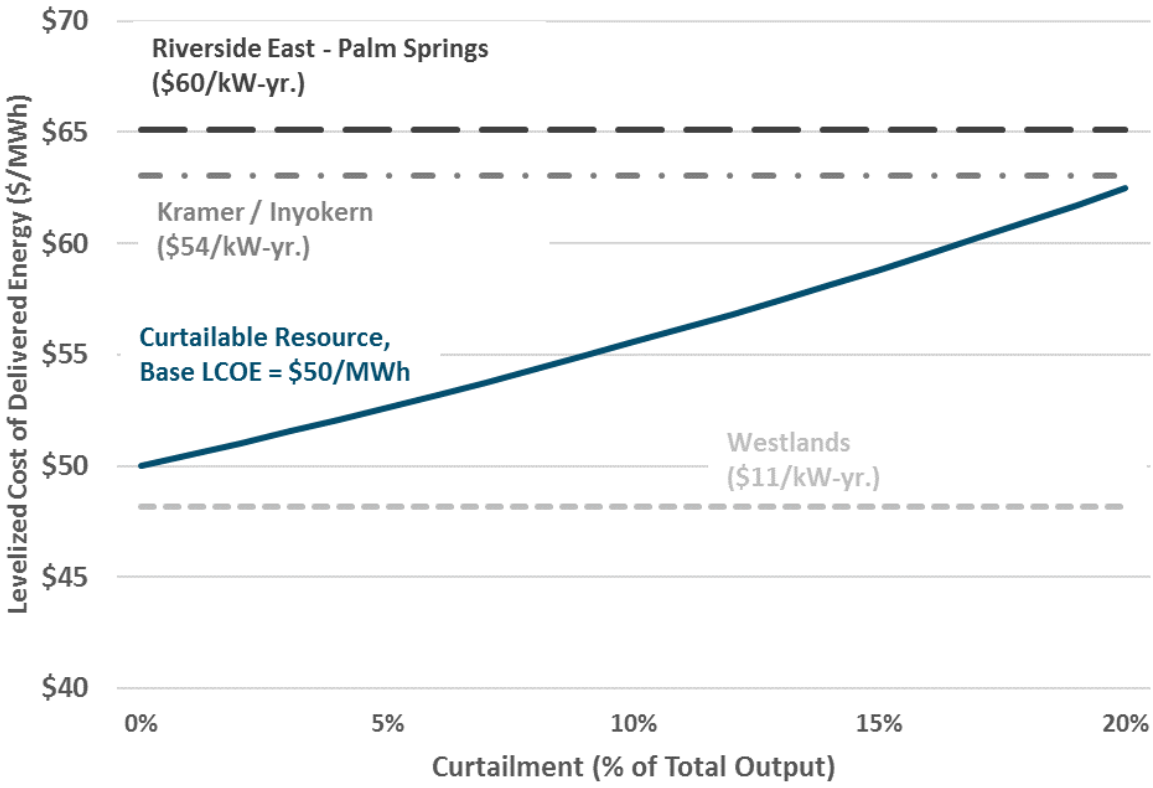
Cost Comparison – Curtailment or Transmission?

- **"Cost effective" curtailment for a given area depends on**
  - Cost of transmission upgrades
  - Levelized cost of solar energy
  - Capacity factor of solar resource
  - Value of resource adequacy (for deliverable resources only)
- **Cheaper / higher quality in-zone solar resources increase the amount of cost-effective curtailment**
- **Low-cost transmission upgrades and/or competitive out-of-zone solar resources limit economically justifiable curtailment**

Comparing Curtailment to Cost of New Transmission

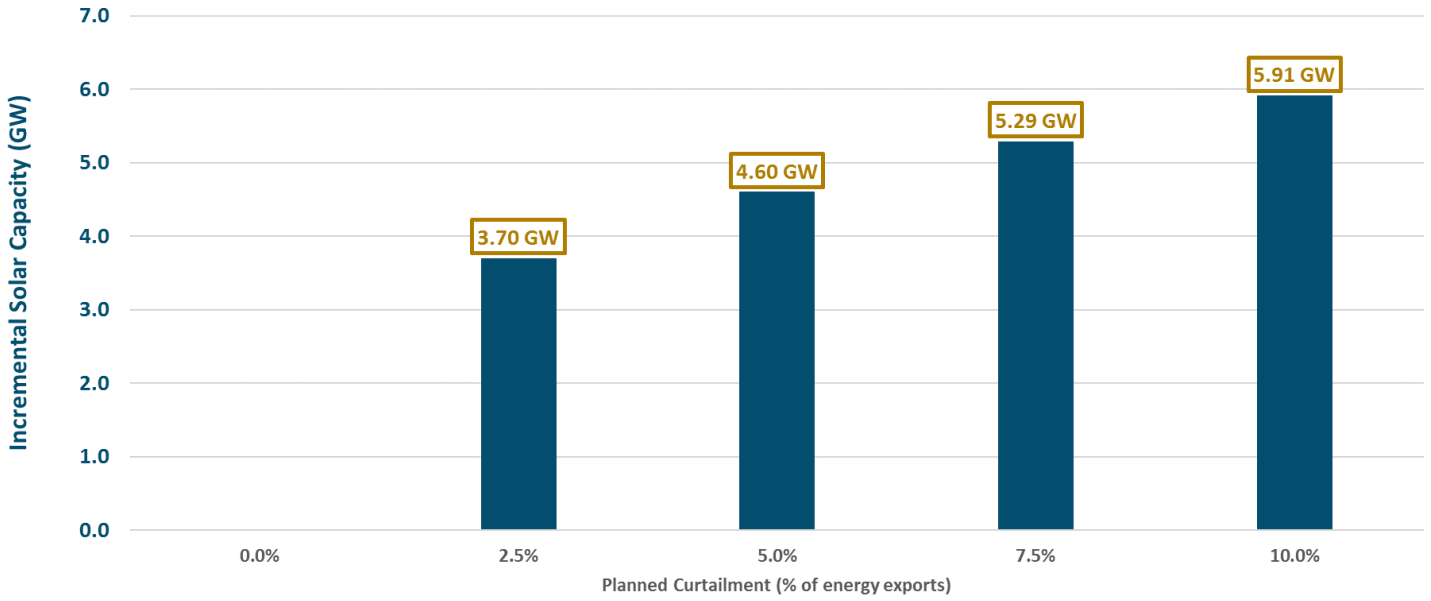
- **New Transmission Costs in the CPUC IRP Assumptions**
  - San Joaquin Valley - $11/kW-yr.
  - Kramer / Inyokern - $54/kW-yr.
  - Riverside East – Palm Springs - $60/kW-yr.
- **Incremental low cost transmission from San Joaquin Valley is likely to be limited**
- **Chart shows the delivered LCOE as a function of the % of total output curtailed**
  - Assumes **44% average NQC** for solar resources (based on 2017 CAISO values) and $3.10/kW-mo. RA Value

Curtailable EO Resources from San Joaquin Valley are more cost-effective than FCDS resources requiring new transmission from Riverside and Kramer areas

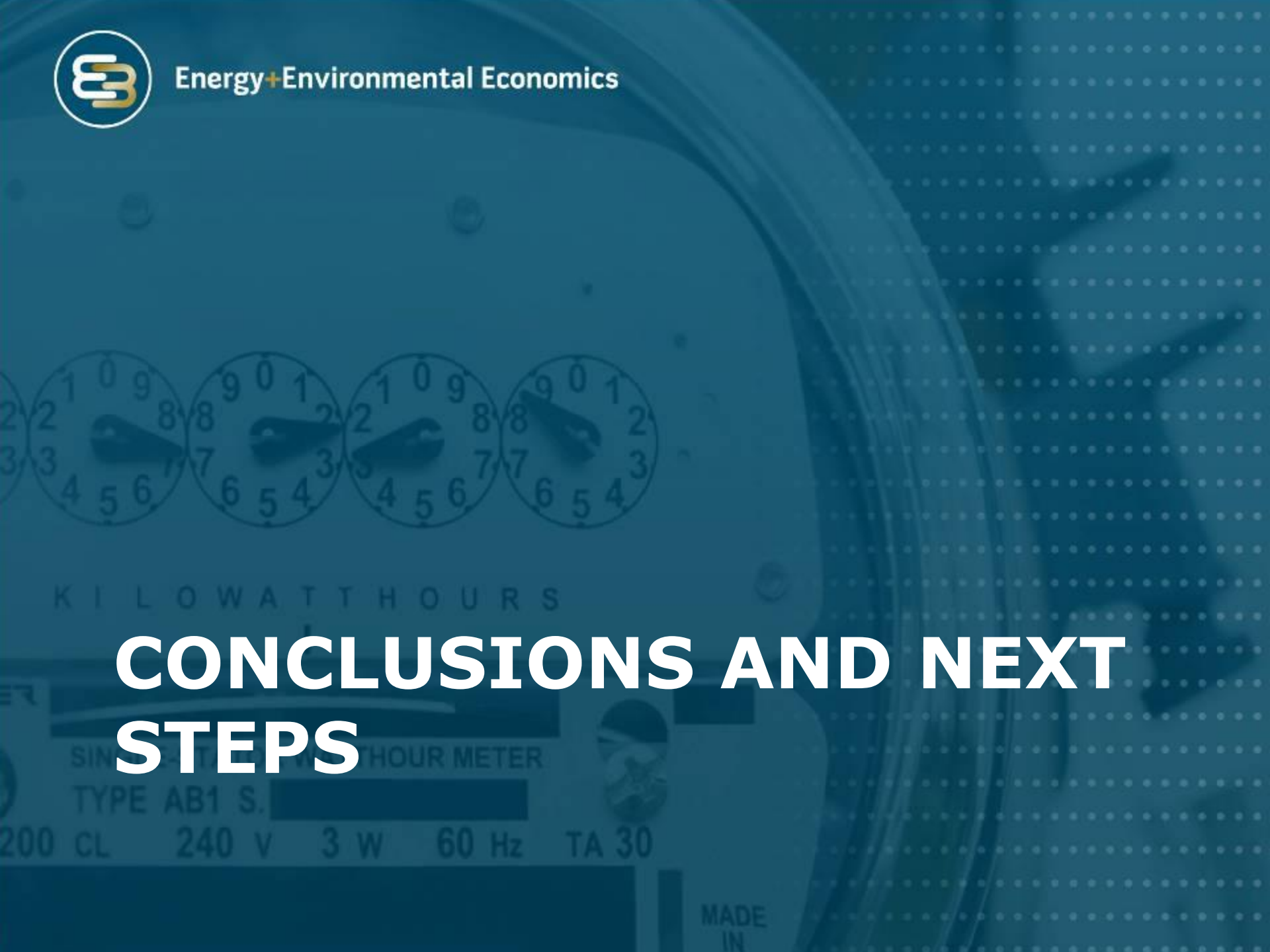


Results

- **High-level screening analysis suggests that an Energy-Only approach could allow almost 6,000 MW of additional solar development in the San Joaquin Valley (Westlands Renewable Energy Zone)**
- **Total additional generation (net of curtailment): up to 14,208 GWh**
- **Numbers are relative to a case that allows no transmission-based curtailment**



Note: Results shown here are dependent on data available for analysis and should be treated as illustrative



CONCLUSIONS AND NEXT STEPS

Conclusions

- **A high-level zonal analysis indicates that Energy-Only resource development could be more cost-effective than Full Capacity Delivery Status requiring new transmission**
  - Considering the potential for planned curtailment in transmission need assessments could allow the development of an additional 6,000 MW of solar in the San Joaquin Valley (Westlands Renewable Energy Zone)
  - May require local distribution upgrades / collector lines
- **Identifying planning procedures for resource additions would provide additional certainty to developers developing energy-only resources**
- **An Energy-Only planning framework can take advantage of "least conflict areas" while potentially saving cost to ratepayers relative to new transmission from other solar-rich zones**

Next Steps

- **California needs new transmission planning approaches that minimize the cost of meeting clean energy policy goals in the future by incorporating transmission needs for Energy-Only resources**
- **Evolving California's transmission planning process towards an Energy-Only framework would:**
  - Better utilize the existing transmission system to cost-effectively deploy more variable clean resources
  - Support progress towards meeting California's climate and RPS targets.

Energy-Only Transmission Planning Methodology

- **Methodology for assessing transmission needed for EO resources is very different from methodology for FCDS resources**
  - Assesses energy delivery throughout the year, rather than capacity delivery during a peak hour
  - Should consider multiple years of load, wind and solar data to provide a more accurate estimate of energy deliverability
  - Should consider the potential for and the economic impact of renewable energy curtailment caused by limited transmission deliverability
    - Most economic solution will likely have non-zero levels of transmission-caused economic curtailment of renewables
- **New transmission may still be warranted in an EO world**
  - Value of proposed transmission projects would need to reflect impact on existing curtailment and allowing deliverability of EO resources
  - These metrics could be incorporated into the Transmission Economic Assessment Methodology (TEAM)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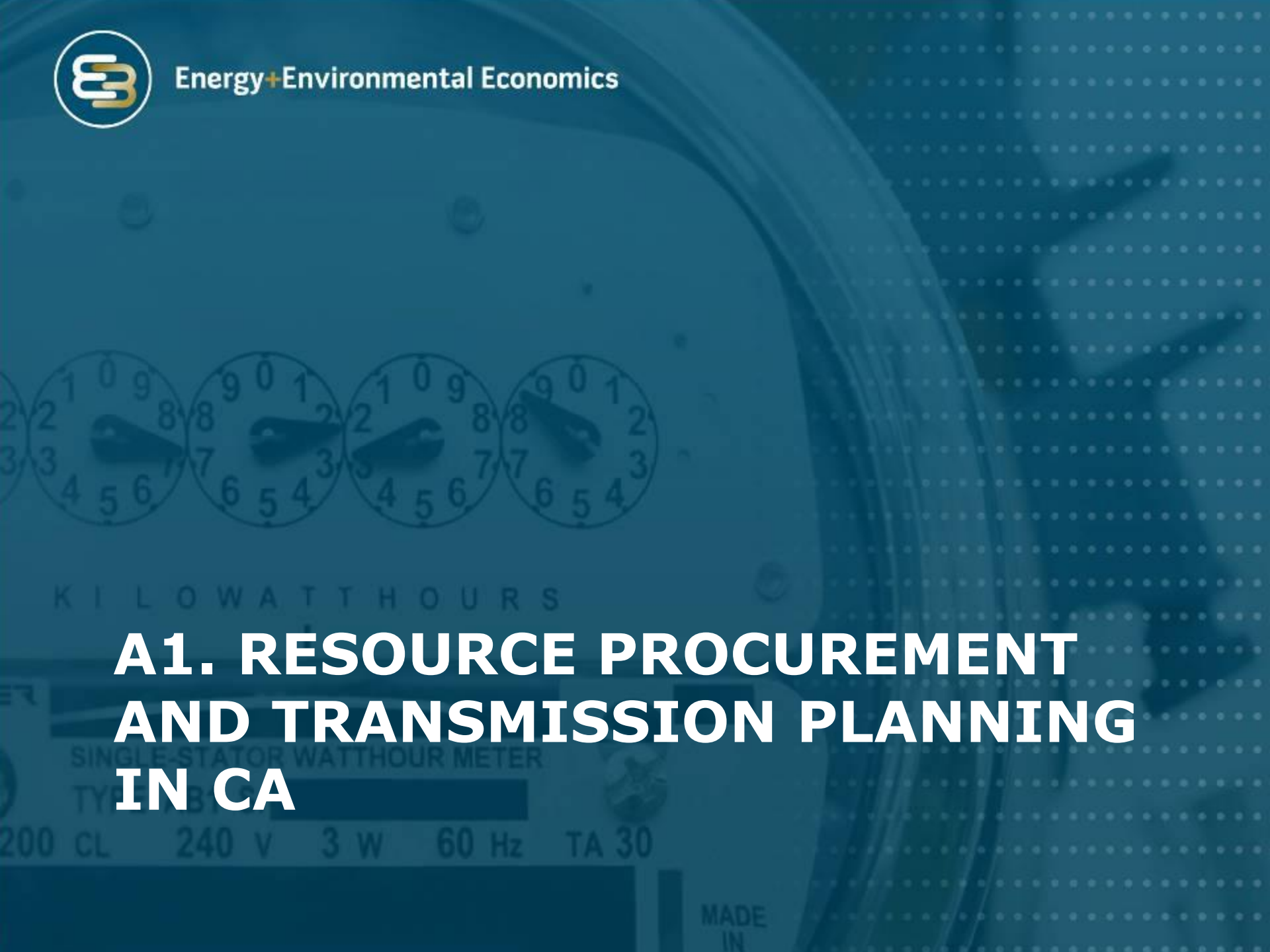
APPENDIX



A1. RESOURCE PROCUREMENT AND TRANSMISSION PLANNING IN CA

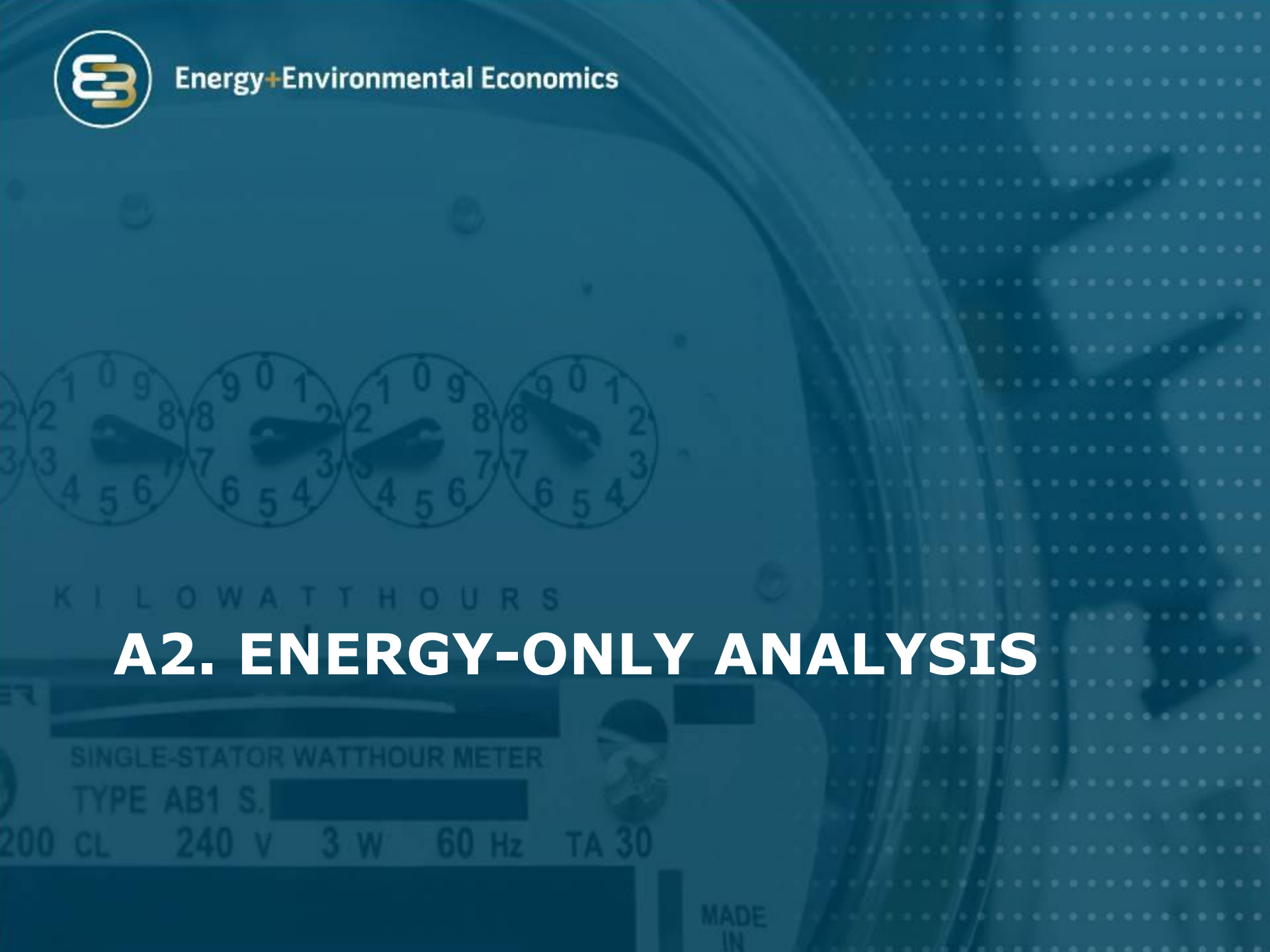
Energy-Only Resources in the CA Transmission Planning Process

- **In the 2015-2016 Transmission Plan, the CAISO estimated the amount of energy-only capacity from a variety of zones**
  - "The primary approach taken was for the ISO to estimate the reasonable amount of energy-only renewable generation the transmission system could accommodate with modest curtailment, the CPUC to provide 50 percent renewable generation portfolios relying on those estimates and utilizing the CPUC's RPS Calculator v6, and then in this study for the ISO test the validity of those assumptions through detailed modeling and system analysis."
- **Estimates of transmission capabilities for energy-only resource incorporated into RPS Calculator to generate new In- and Out-of-State portfolios**
  - Based on "experience modeling and studying the system, as well as considering past generator interconnection study results and production simulation modeling"
  - No documented methodology for determining capacity of the system to accept additional energy-only resources

Energy-Only Resources in the CA Transmission Planning Process

- **The 2016-2017 Transmission plan built upon the work started in the 2015-2016 Transmission Plan**
  - "[CAISO] and [California Public Utilities Commission] contemplated that a continued reliance on full capacity deliverability status (FCDS) for future renewable generation and alternatively, assessing transmission needs through an 'energy only' assumption would provide reasonable bookends on establishing transmission related needs to mitigate congestion and **deliver additional renewable resources to California's aggregate load**"
- **Compared 50% RPS portfolios on the basis of reliability, deliverability, and renewable curtailment (see p. 309)**
  - Westlands exhibited no reliability issues, and curtailment of the modeled resources arose primarily from system conditions rather than transmission constraints
  - Requirement for full deliverability of resources could limit development in the Westlands zone
    - Of the 2,000 MW of additional generation considered in the Westlands zone, only 1,600 MW could be added without creating a deliverability constraint
    - Meanwhile, Westlands has over 15,000 MW of available solar potential in the assumptions that feed into the IRP process

2016-2017 Transmission Plan can be found at https://www.caiso.com/Documents/Board-Approved_2016-2017TransmissionPlan.pdf



A2. ENERGY-ONLY ANALYSIS

Detailed Methodology: An iterative approach

Step 1: Calculate in-zone solar generation for given PV capacity

Step 2: Identify exportable solar energy

- Solar power available for Export = Total solar power - Westlands local absorption capability
- Assumes that solar generation within Westlands zone displaces local conventional generation and imports serving local load

Step 3: Compare desired power flow out of zone to available transmission capacity

- Assume weighted split between path to NP15 and SP15
- No demand for exports during systemwide curtailment

Step 4: Does resulting curtailment exceed criteria?

Step 5: Adjust PV capacity appropriately

Step 6: Repeat

System Operations

- **E3 used AuroraXMP to perform hourly zonal dispatch simulations based on expected system characteristics in 2018**
  - Dataset prepared by EPIS, refined by E3 to better match expected California solar resource procurement
  - Resources are economically dispatched on an hourly basis
  - Provides hourly zonal look at resources available within a given zone and expected net transfers between zones (given transmission capacity)

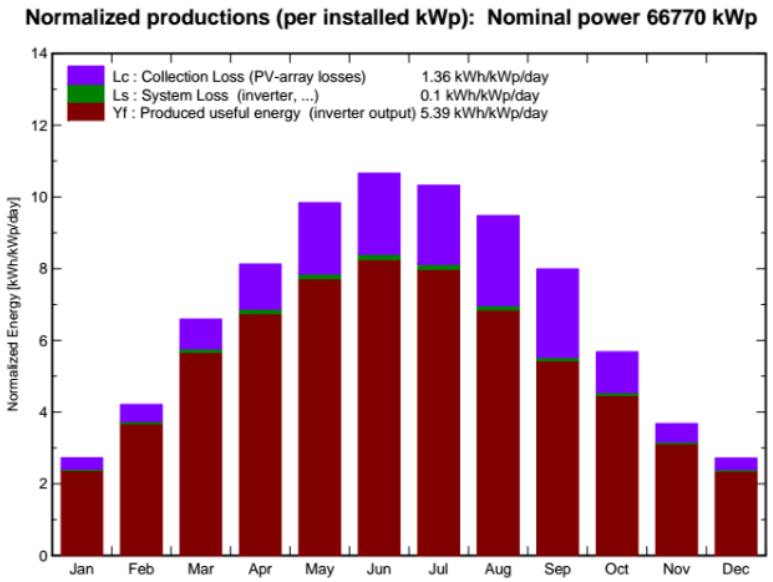
- **Key Assumptions:**
  - 3,400 MW of existing solar in ZP26 zone
  - 5,400 MW of transfer capability to NP15 zone
  - 4,000 MW of transfer capability to SP15 zone

Curtailment Limits

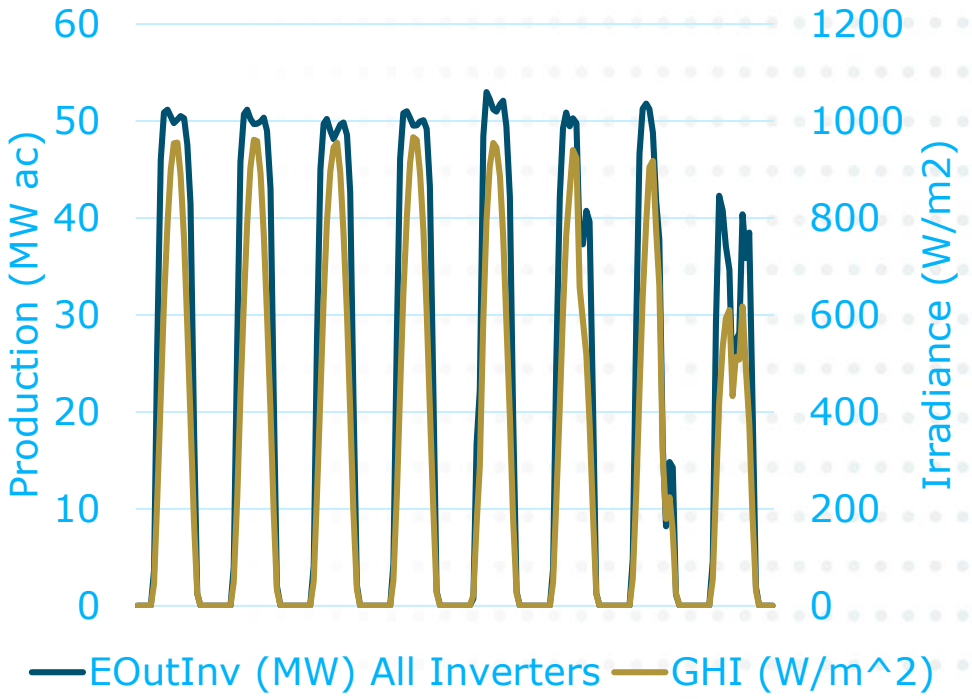
- **Analysis tested the ability to add solar resources under alternative assumptions about allowed curtailment:**
  - **No curtailment:** Solar PV capacity is added until an additional MW would trigger transmission-based curtailment
  - **Limited curtailment for reliability:** Solar PV capacity is added until a specified % of energy available for export is curtailed (annual basis)
    - Analysis tested curtailment of 2.5-10% of available energy for export
- **New PV is added in each case until specified limits are violated**
- **High-level demonstration of the potential effects of moving to this alternate planning framework**

San Joaquin Valley Solar Production Profile

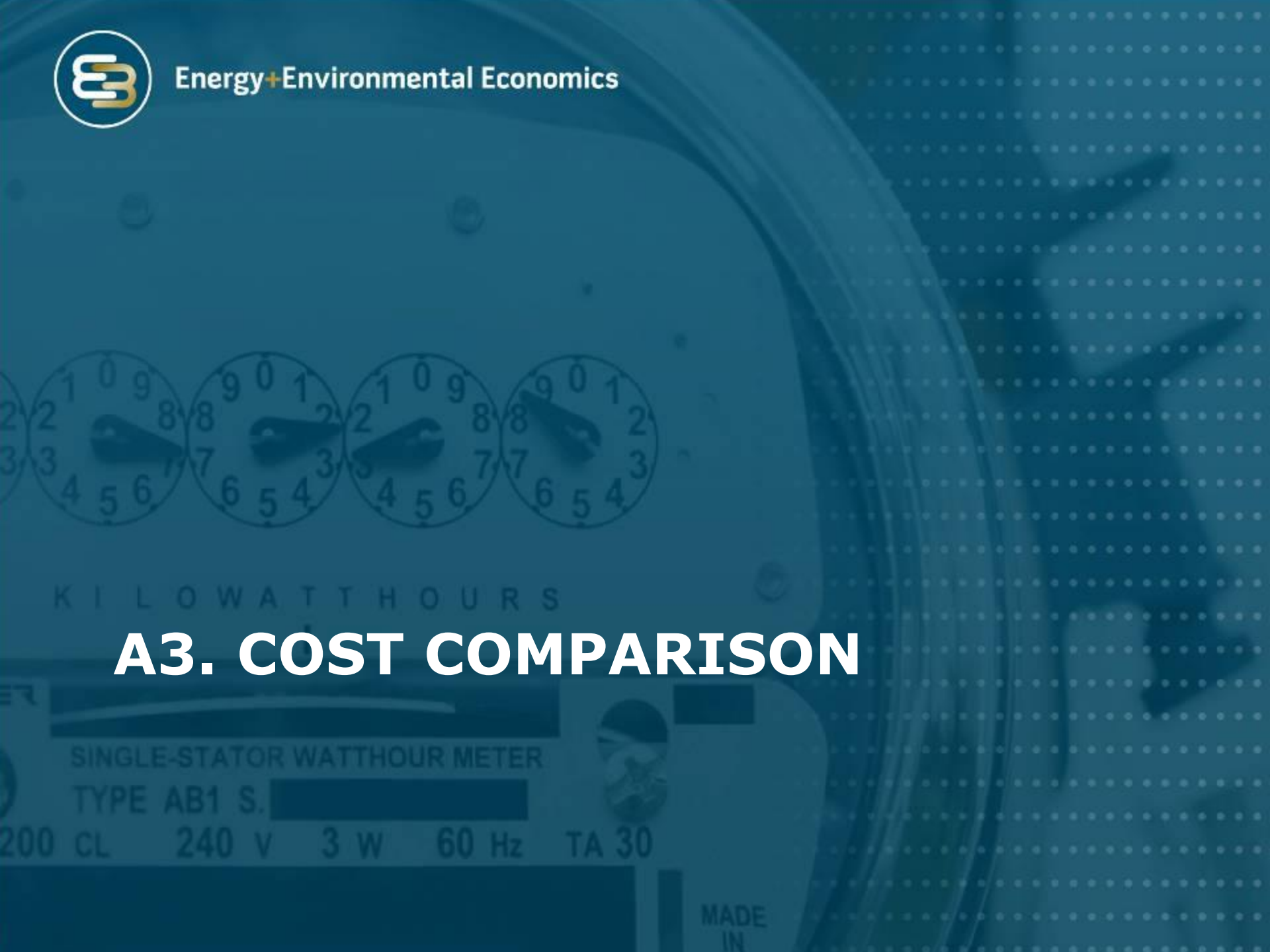
- **Solar shapes for added resources are taken from data prepared for the CPUC Integrated Resource Planning process**



Typical Meteorological Year



Typical Week in Springtime (May)



A3. COST COMPARISON

Cost of Delivered Resources

- **Comparing costs of fully delivered and curtailed resources requires thinking about the cost per *delivered* MWh**
- **Delivered cost of solar resource under curtailment increases, as costs are spread over fewer MWh of delivered generation**
  - $\text{Delivered LCOE} = \frac{Base\ LCOE}{(1 - Curtailment\%)}$
- **This delivered LCOE can be compared to the cost of fully delivered solar requiring new transmission**
  - Costs of curtailment are compared against the per-MWh cost of transmission
  - $\text{Delivered LCOE} = Base\ LCOE + \frac{Tx\ Cost - RA\ Value}{8.76 * CF}$

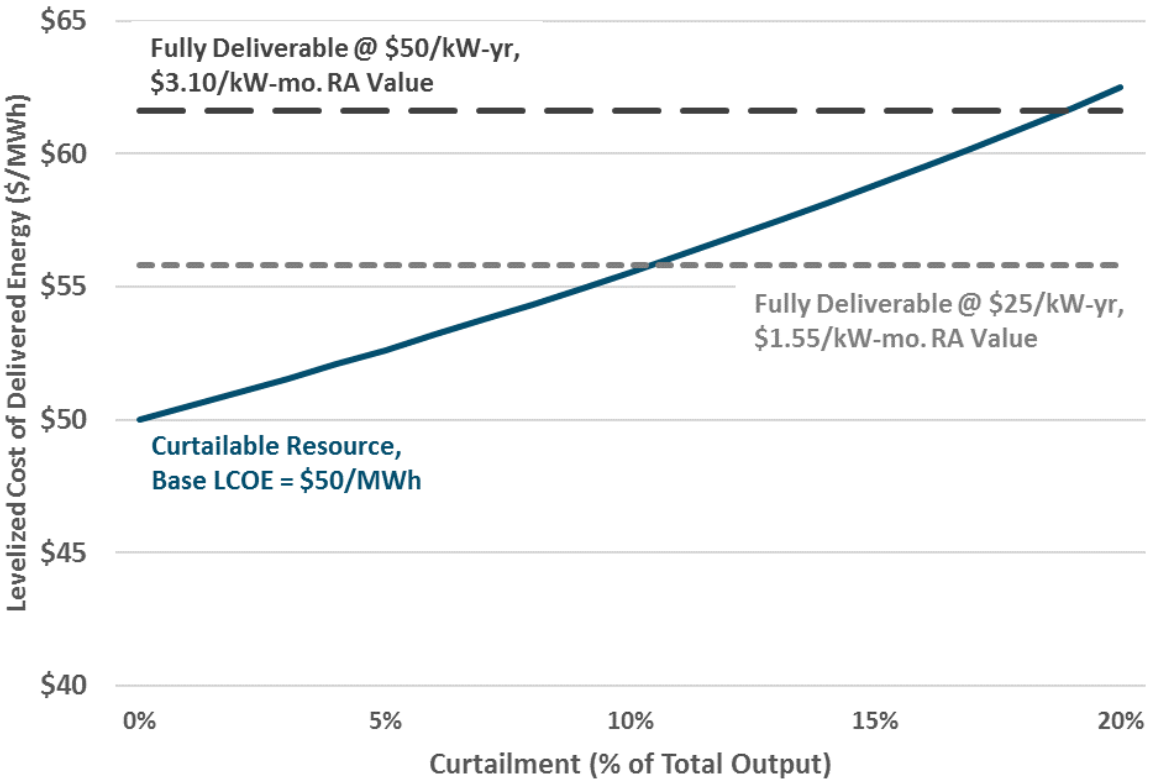
Levelized cost of new transmission ($/kW-yr.)

Value of deliverability ($/kW-yr.)

Comparing Curtailment to Cost of New Transmission

- **Sample chart shows the delivered LCOE as a function of the % of total output curtailed**
  - Assumes **44% average NQC** for solar resources (based on 2017 CAISO values)
  - **33% solar AC capacity factor** (Average for solar resources identified in CPUC IRP Assumptions)
- **Up to 10% curtailment results in lower LCOE than $25/kW-yr. transmission estimates**

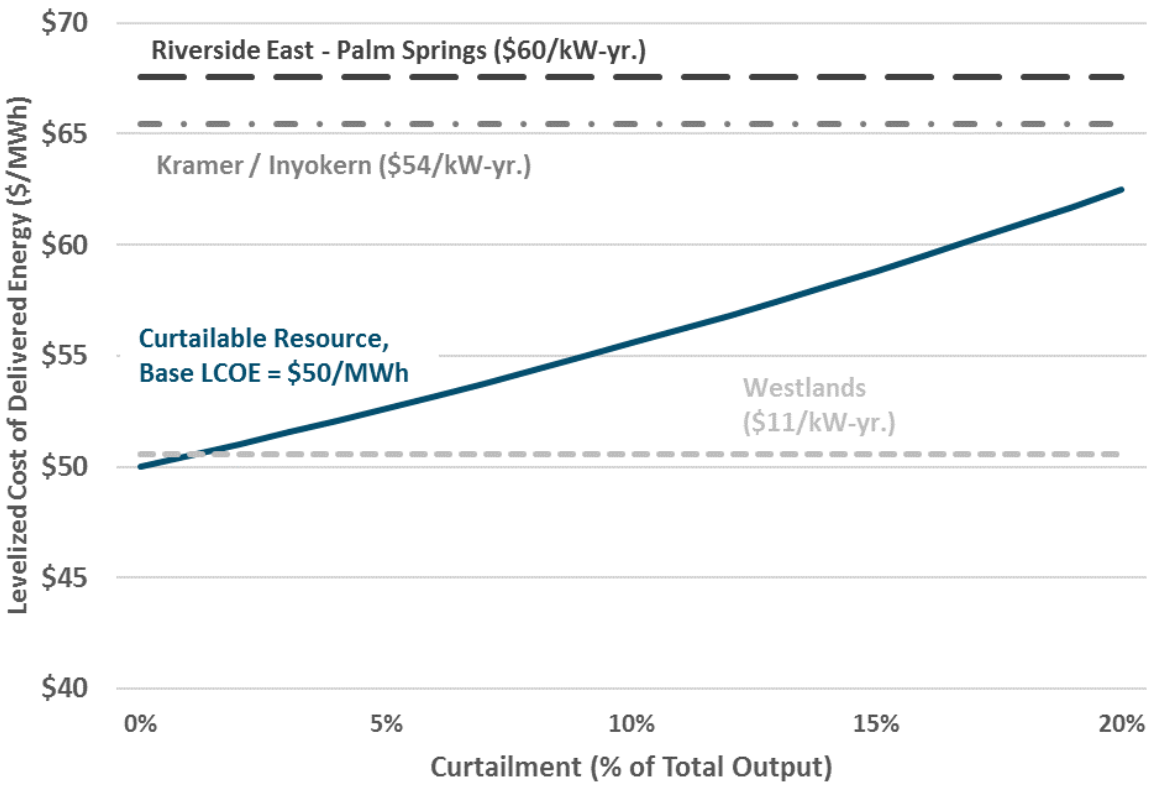
Curtailable EO Resources can be more cost-effective than FCDS resources that require new transmission



Comparing Curtailment to Cost of New Transmission

- **Curtailment becomes more attractive as the NQC of solar decreases**
  - Marginal solar resources already have very low NQCs, which will only decline as more solar capacity is added
- **Chart shows impact of Solar NQC falling to 25%**

As solar NQC declines due to saturation, the cost-effectiveness of curtailable EO resources improves relative to FCDS



Comparing Curtailment to Cost of New Transmission

- **Curtailment also becomes more attractive as the Base LCOE of solar decreases**
  - Lower costs lessen the impact of curtailment
- **Chart shows impact of Solar LCOE falling to $40 with 25% NQC**

As the cost of solar declines, the cost-effectiveness of curtailable EO resources improves relative to FCDS