Potential Role of Availability Incentives in Resource Adequacy

Sina Sharifi
Ph.D. Student, Dept. Electrical & Computer Engineering, JHU

Mahdi Mehrtash
Assistant Professor, Dept. Electrical Engineering, University Nevada-Reno
Assistant Research Professor, JHU

Benjamin F. Hobbs
Global Director, NSF EPICS Center
Deputy Chair for Engineering, Dept. Environmental Health & Engineering, JHU
Chair, CAISO Market Surveillance Committee

ESIG 2025 Forecasting & Markets Workshop, Nashville, June 2025

In revision for *Sustainable Energy Technologies & Assessments*. Supported by the U.S. DOE Office of Energy Efficiency & Renewable Energy through a subcontract with Argonne National Laboratory, and NSF Grant 2330450. Thanks to Juan Pablo Carvallo and Paul Spitsen (DOE), Todd Levin (ANL), Erik Ela (EPRI), Parviz Alivand and Matthew White (ISO-NE), and Anthony Giacomoni (PJM) for suggestions. Usual caveat applies

Energy at Hopkins | U.S. DEPARTMENT OF ENERGY | Argonne NATIONAL LABORATORY | JOHNS HOPKINS RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

Agenda

http://www.caltech.edu/news/why-do-people-choke-when-stakes-are-high-4199

Questions:

1. How much do short-run RA availability/performance incentive mechanisms (SR-RAIM) incentivize SR availability & long-run (LR) investment?

2. What do incentives & equilibria look like for an ISO NE-type system, where resources can:
   - *Either **accept*** an RA obligation (get fixed annual RA $ + some SR-RAIM $)
   - *Or **reject*** it (get more SR-RAIM$, but no annual $)

I. US SR-RAIMs
Structure & historical data

II. Theory
Quantify SR & LR incentives under various conditions

III. Simulations
Numerical experiments for ISO NE-like system

I. Motivation for SR-RAIM

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

Several revenue streams help cover resource fixed costs

- **Spot market** energy & ancillary services margins
- **Bilaterals**
- Capacity (**"RA"**) payments
- *Our focus:* Payments or penalties from **"SR-RAIM"**
  - **Reveneu** if exceed obligation for capacity availability or performance
  - **Charged** if fall short, due to unplanned or planned mechanical outages, unexpected weather conditions, fuel interruption, etc..

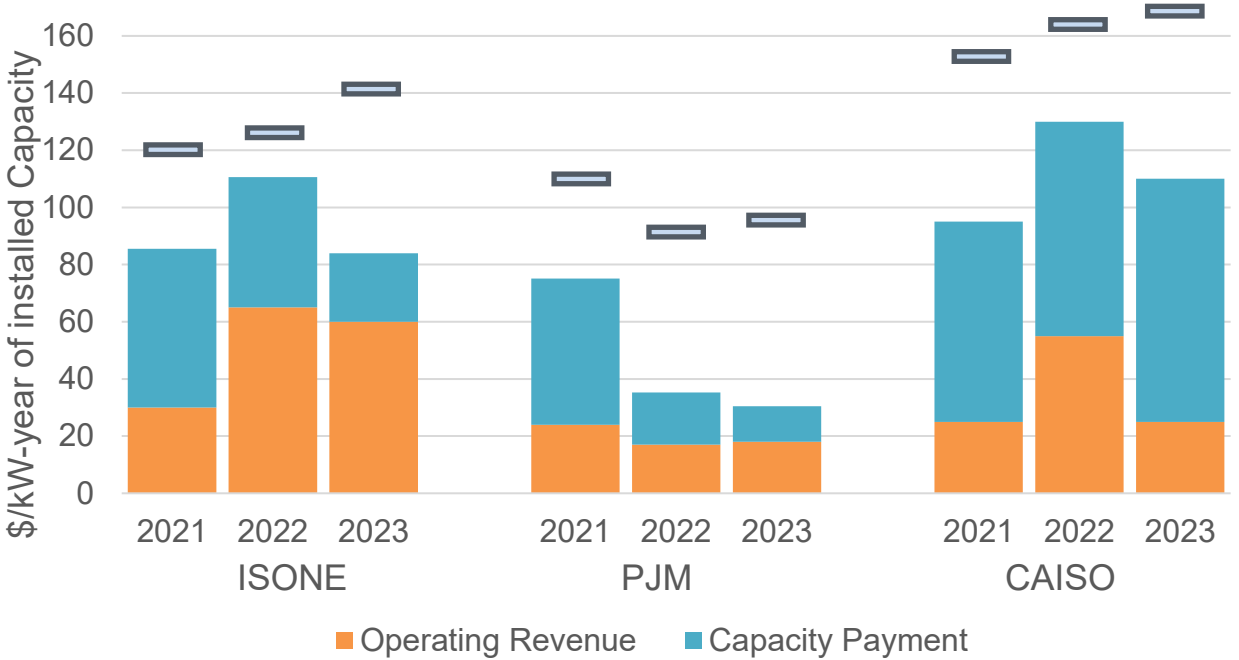
Goal: align SR incentives with when system needs resources

- Without having consumer spot prices exceed price/bid caps
- While moving gross margins closer to CONE

Have historical revenues covered CONE?

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

Gross margins from spot market and RA for CT units, compared to CT CONE



PJM data from RPM Auction Info 2022/2023, 2023/2024
ISONE data from 2022-2023 IMM report
CAISO data from 2023 Annual Report on Market Issues and Performance

Overview of SR-RAIMs within US

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

Capacity incentive mechanism types:

- *performance*-based (actually provides energy/ancillary services to market)
- *availability*-based (market offer & physical availability)

Summary of Performance Incentives

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

ISO-NE:

- Incentivizes resources that perform during "Capacity Shortage Conditions", charging those that don't
  - Meant to be revenue neutral
- "Performance Payment Rate" (p_2) now $5455/MWh (=f(CONE, RA prices))
- Resources can participate in SR-RAIM either as RA or non-RA.
  - RA contracted annually. SR-RAIM adjusts capacity obligation of RA by system-wide "balancing ratio" (*BR*); **payment** if perform above obligation, and **charged** if below.
  - Non-RA resources paid if perform. So more SR-RAIM revenues than RA, but no annual RA revenue

PJM:

- Similar structure to ISO-NE (but see Board 2023 proposal to limit SR-RAIM payments to RA resources)
- Rate based on zonal net CONE, subject to "stop loss" cap on annual payment (1.5xRA price)

CAISO:

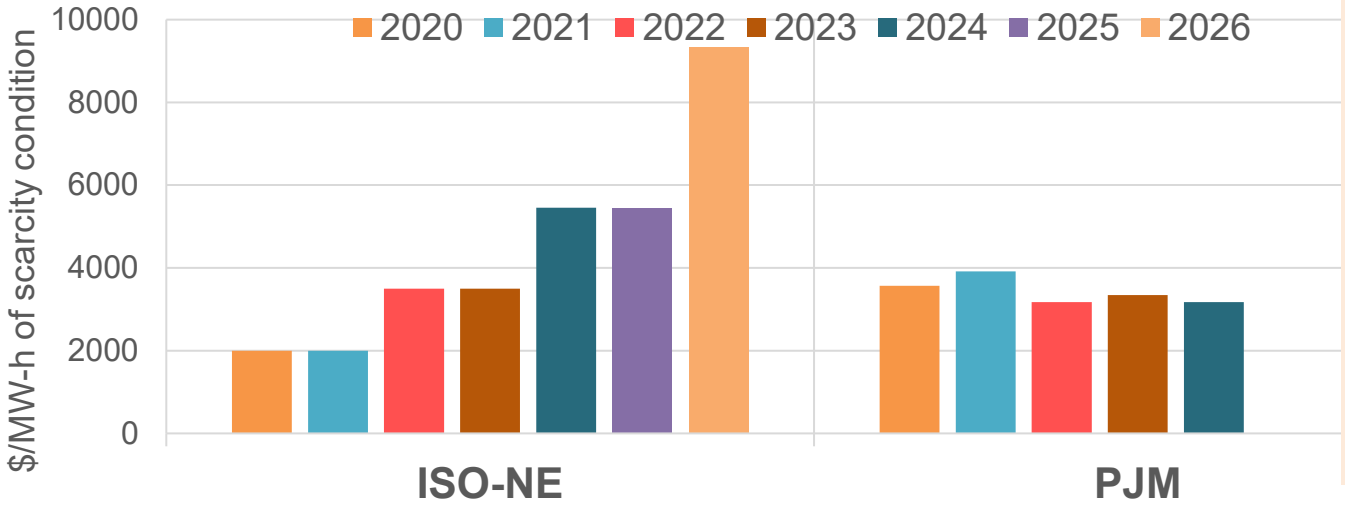
- Availability Assessment Hours based on annual load forecasts
- Resources charged if avg **availability <94.5%** during month's AAHs; those **>98.5%** are paid
- Penalty rates set at $4200/MW-month, 60% of net CONE

98.5%
Dead Band
94.5%

Incentive Rate Comparison

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

- For *Performance*-payment systems (ISO-NE, PJM):
  - For non-RA, full performance payment paid for all available capacity
  - For RA, only last (*Availability - Balancing Ratio*) fraction of capacity paid (e.g., 30% if BR=0.7)
    - *NB:* marginal increase in availability gets full payment
- Cf. CAISO: if a 1 MW RA unit is 96.5% available, total payment = $63/MW/mo
  - Yet 1 MW Marginal increase in availability earns $4200/MW/mo (if outside deadband)



Thus:

- *SR-RAIM incentive for investment is modest (ISO-NE/PJM) or ~nil (CAISO).*
- *But it can be strong for improving short-run availability (depending on shortage hrs/yr in ISO-NE/PJM)*

How often do scarcity conditions happen, & what costs result?

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

- **ISO-NE:** Five CSCs have occurred (2018, 2022, 2023, 2024 (2))
  - From 25-160 min per CSC
  - $11M-$50M of credits per CSC

  Our 2030 simulations show that LOLE = 1 day/10 yr → a few to up to 76 CSC hrs/yr

- **PJM:**
  - Storm Elliott alone resulted in $1.8B in non-performance charges (19 - 72 hrs reported)
  - 7/23, PJM redefined "Emergency Action", determining when shortage intervals occur

- **CAISO:**
  - Availability Assessment Hour definition:
    - Base ramping flexible resources have ~18 AAHs per day during all weekdays (~4500 hr/y)
    - Generic resources have ~5 AAHs/day
    - Lack of dependence on system conditions criticized as diluting incentive
  - Amounts 2024:
    - $46M nonavailability charges (double 2023's)
    - $19M incentive payments (50% higher than 2023)

I. US SR-RAIMs

Structure & historical data

II. Theory

Simple quantification of SR & LR incentives under various conditions

III. Simulations

Numerical experiments for ISO NE-like system

II. Example Performance Incentives for non-RA capacity (ISO NE-like)

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

- Assume a 1 MW unit under 2 different levels of CSC hours:
  - 1.5 hr/yr (2022 ISO-NE),
  - 30 h/yr (~our typical ISO-NE value if LOLE = 1 in 10; ~also for PJM in 2022)

- Assume ***rejects*** RA obligation, and SR-RAIM has payment rate of $5455/MWh

- Assume 100% available:
  - @1.5 CSC hr/yr: The payment would be 5455 * 1 * 1.5 = $8183/yr
  - @30 CSC hr/yr: The payment would be 5455 * 1 * 30 = $163,650/yr

Cf. Performance Incentives for RA capacity (ISO-NE)

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

- Same CSC assumptions
- Assume:
  - Unit has ***accepted*** RA obligation
  - RA price is $24,000/MW-year, SR-RAIM has payment rate of $5455/MWh
  - Unit is 100% available
  - Balancing ratio is ~0.7
- The unit will get a RA capacity payment of $24,000 /yr
  - @1.5 hr/yr: The payment would be 5455 * (1 – 0.7) * 1.5 = $2454/yr
  - @30 hr/yr: The payment would be 5455 * (1 – 0.7) * 30 = $49,095/yr
- ***What is best:*** Accept RA Obligation? vs. Reject RA Obligation (SR-RAIM only)?
  - @1.5 hr/yr: $26,454/y vs. $8183/y → *RA best*
  - @30 hr/yr: $73,095/y vs. $163,650/y → *Non-RA best*

Summary: Marginal Incentive to Build New Capacity in ISO-NE

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

What revenue/incentive does the investment (100% available) get from *capacity market + SR-RAIM*?

- ***Non-RA Option:*** With N hr/yr of scarcity, a new 1 MW unit gets SR-RAIM payment =

$$5455 \times N\$/year$$

- ***RA Option:*** If the unit's capacity is sold as RA @$24,000/MW/yr, assuming a balancing ratio ~ 0.7, then total revenue =

$$24{,}000 + 1636.5 \times N\ \$/year$$

- The unit will choose between these options, depending on the anticipated frequency of scarcity, BR, and RA clearing price.
  - 3 possible equilibria; depends on RA demand curve, SR-RAIM parameters, system mix
    1. *Non-RA most profitable for all resources of a given type*
    2. *RA most profitable*
    3. *Breakeven→ Mix*
  - We have precisely derived these relationships mathematically to use in calculating market equilibria

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

I. US SR-RAIMs

Structure & historical data

II. Theory

Quantify SR & LR incentives under various conditions

III. Simulations

Numerical experiments for ISO NE-like system: choosing RA or non-RA

III. SR market simulations (ISO NE-like 2030 system) in which resources can choose between being RA or Non-RA

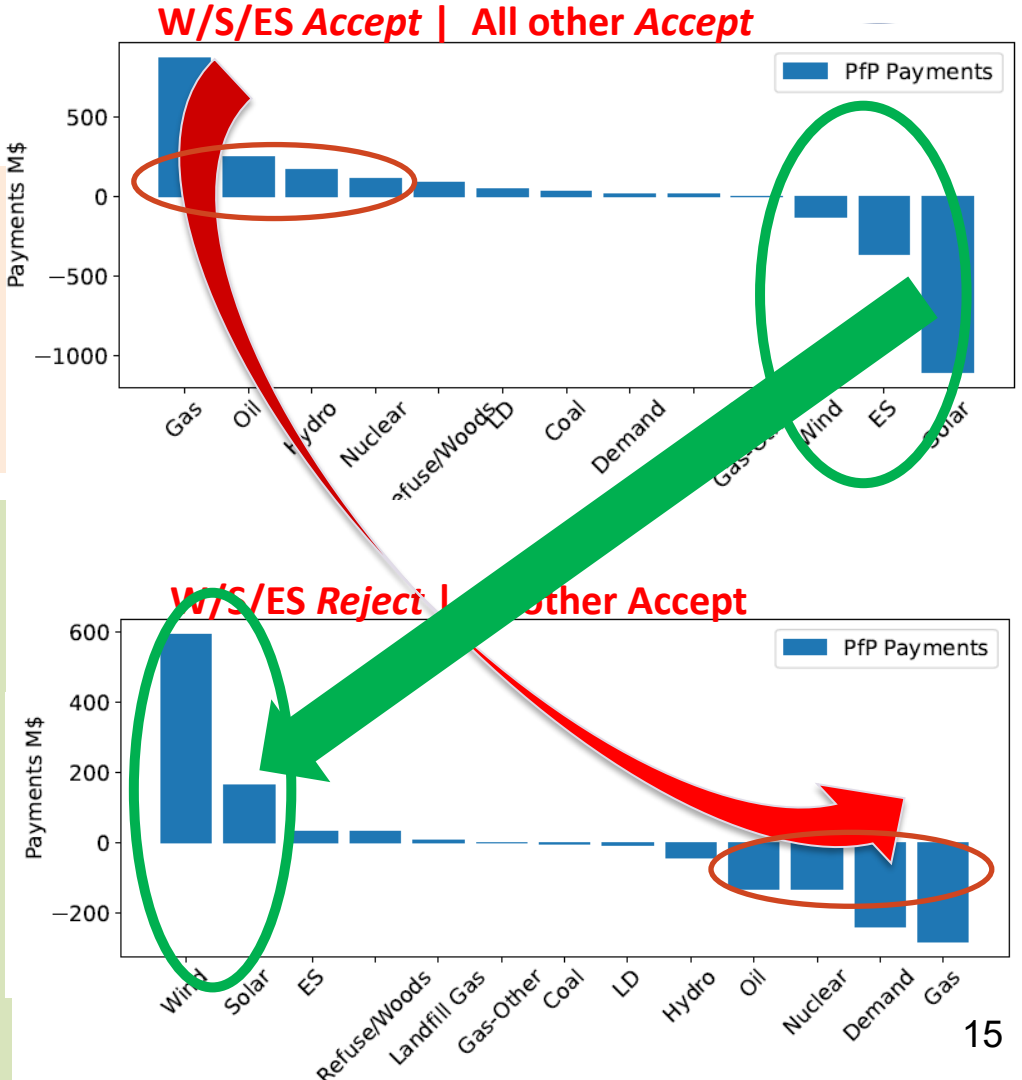
JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

- Characteristic of ISO-NE & PJM designs
- Resource can:
  1. **Accept RA obligation** (and get annual payment), subject to pay-for-performance charge in each CSC:
     = p_2 x (RA obligation — adjusted scheduled MW)
  2. Or: **Not accept RA obligation.** During each CSC hour, receives PfP payment:
     = p_2 x all scheduled MW
- "Adjustment" is by a "balancing ratio" BR → results in revenue neutrality:
  - I.e., Σ PfP charges for RA capacity shortfalls = Σ PfP payments to surplus capacity resources
  - *BR(t) = [Load(t)+Reserve Req(t)] / Total RA*
    So that: Resource *PfP Revenue* = p_2 * *[Actual Available* MW— *BR(t)*Obligation MW]*
  - *Thus,*
    - *Total RA<need → BR>1 → SR-RAIM revenue increased*
    - *Total RA>need → BR<1 → SR-RAIM revenue decreased*
- **Case study assumes:**
  - 2030 load, 50% variable renewables, 5 y sample of load & renewable output
  - RA demand curve
  - Fixed capacity, adjusted to target: (i) VRE penetration (50%) & (ii) 1 day-10 y LOLE (→ 56 CSC hr/yr)

III.1. SR Equilibrium among Strategies (choosing--or not--to be RA)

- **Two cases:** Wind/Solar/ES either:
  1. ***Accept*** annual RA obligation & payments; subject to PfP for obligated MW *minus* adjusted scheduled MW, or
  2. ***Reject*** RA obligation, & receive PfP payment on *all* scheduled MW

- **Results:**
  - If W/S/ES **accept** RA obligation: Their high PfP charges fully wipe out RA revenue
    - Revenue neutrality results in low BR → net positive PfP for most thermal resources
  - But to avoid losses, Wind/Solar/ES will instead **reject** RA obligation, and receive PfP payment on all scheduled MW
    - Revenue neutrality results in high BR → net negative PfP for most thermal resources, though accepting (high!) RA payments is more profitable for thermals than rejecting RA
    - → Nash equilibrium for RA designation: W/S/ES prefer reject, other resources prefer accept



III.2. PJM vs ISO NE Balancing Ratio (BR) Formulation, and Payment Level (p_2)

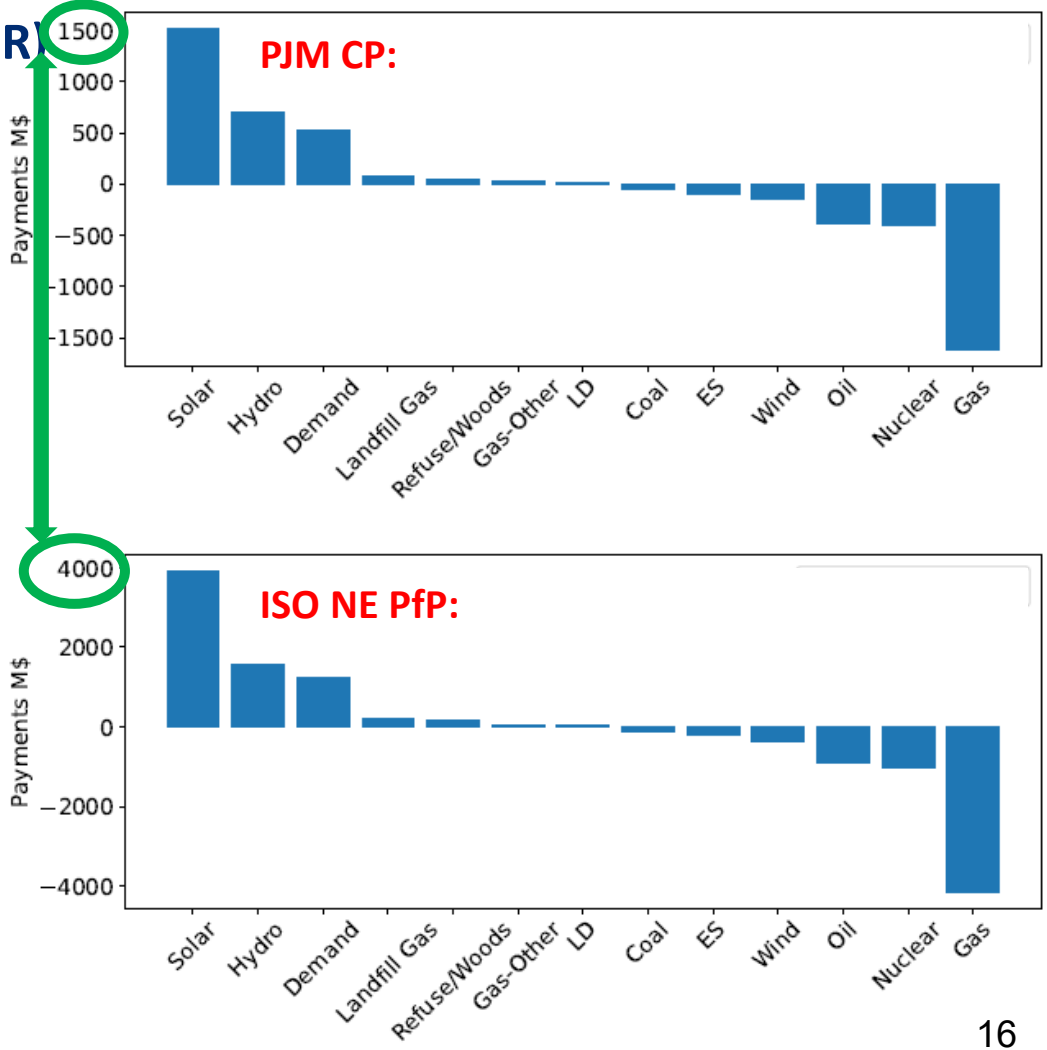
- **Assume:**
  - Solar rejects, others accept RA obligation
  - ***Balancing Ratio:***

    BR(t) = [Load(t)+Reserve Req(t)] / Total RA

    So that:

    *Revenue = p_2 * [Actual Available* MW *– BR(t)*Obligation MW]*
  - **PJM "Capacity Performance (CP)"** caps *BR(t)* ≤1.0; but **ISO NE "Pay for Performance (PfP)"** allows *BR(t)*>1.

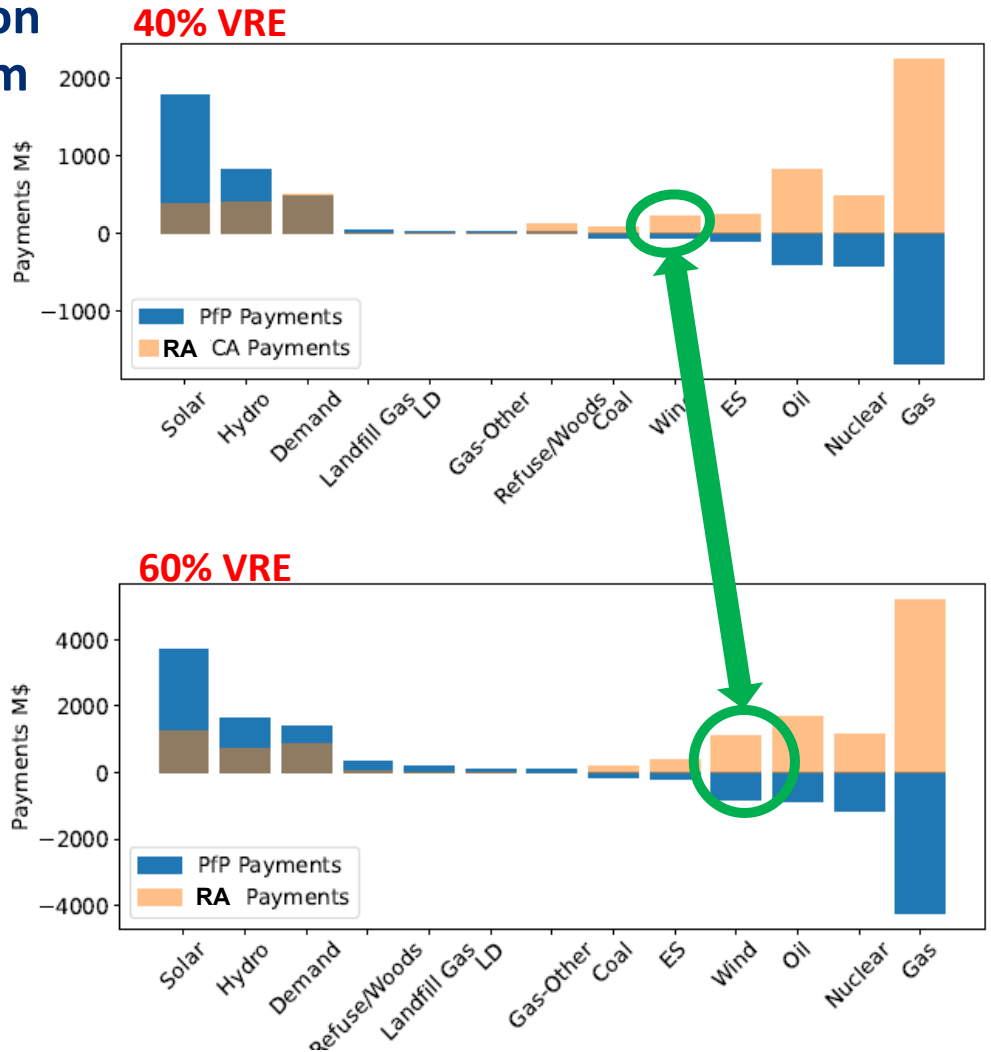
- **Result: Two offsetting effects:**
  - PJM's lower *BR(t)* increases PfP revenues. But its lower payment rate p_2 decreases payments far more



III.3. Sensitivity: Effect of VRE penetration on 2030 ISO NE-like RA & SR-RAIM system

- **VRE Penetration effect on CSC frequency:**
  With increase of VRE energy share: 40% → 60%....
  ….then CSC increases:
  20 → 64 hr/y (avg. over 5 yr sample)

- **Result:**
  - Higher CSC frequency & lower energy prices → ~doubled PfP payments & capacity prices
  - Wind, demand benefit disproportionally. Oil peakers (relatively) hurt



Conclusions: SR-RAIM effects

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

- SR-RAIM incentives for improving short run availability can be strong
  - But not for investment
  - CAISO system dilutes incentive with +/- 2% deadband, by not tying incentives to shortages, & low $ incentives (my opinion; usual caveat applies)

- Experience:
  - CAISO experiencing higher FORs, might signal that incentives are weak (resources accept charge rather than spend $ to increase availability) (A. Gilbert, CAISO RA Design Meeting, March 4, 2025)
  - PJM reports that "*Performance incentives work: Resource owners have installed dual fuel, adjusted gas scheduling practices, and made other changes to improve resource performance & reduce penalty risk*" (W. Graf, CAISO RA Design Meeting , March 4, 2025)
    - But concern expressed that rarity of shortages decreases "saliency"

- With both RA demand curves & SR-RAIM incentives, number of parameters to be tuned (and thus complexity!) increases
  - Having "flavors" (local RA, flexible RA) makes it even more so
  - Tuning to ensure sufficient investment incentive may conflict with desire for predictable prices for forward contracting

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

Thanks for your attention!

Questions?