Challenges with Operating Hydro Resources in EIM Market

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Challenges In Operating Hydro Resources in EIM Market

- **Summarize challenges and lessons learned from participants who currently operate hydro resources in EIM market**
- **How can we Maximize Value of Hydro Resources in EIM Market?**
- **Discuss how Flexible Hydro Resources can be the ideal tool for balancing VER resources (Wind & Solar) in the Western Market.**
- **Provide recommendations as to what can be done to extract more benefits from hydro resources**

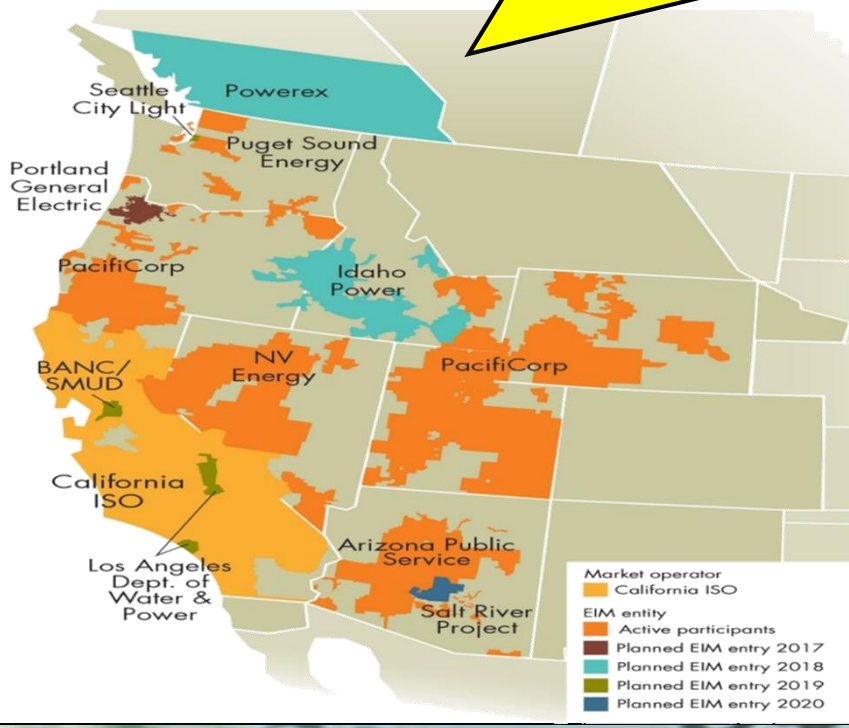
Hydro Resources in Western EIM Footprint

- **CAISO launched the MRTU market in April 2009 and the EIM market in November 2014.**

- **Many CAISO participants (PAC, PGE, PSE, PG&E, SCE) operate large hydro resources:**
  - **Cascaded pondage-hydro resources (Baker River, Big Creek, Mid Columbia)**
  - **Pump-Storage hydro resources (Helms, Eastwood)**

- **CAISO participants (APS, NVE, PAC, PSE, SCE, PG&E, SDG&E) also operate lots of wind & solar resources**

Western EIM Players
-- PacifiCorp (Nov 1, 2014)
-- NVE (Dec 1, 2015)
-- Puget Sound Energy (Oct 1, 2016)
-- APS (Oct 1, 2016)
-- PGE (Oct 1, 2017)
-- IPC (2018)
-- Powerex (2018)
-- SCL (2019)
-- LADWP (2019)
-- SMUD (2019)
-- SRP (2020)



How does Real-Time EIM Market Work?

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T - 75 minutes
- EIM Participating Resource submits hourly base schedule to CAISO
- EIM Participating Resource submits Energy Bids & Resource Plan to CAISO

T - 55 minutes
- EIM Participating Resource submits updated base schedule to CAISO

T - 45 minutes
- CAISO evaluates whether resource plan is feasible

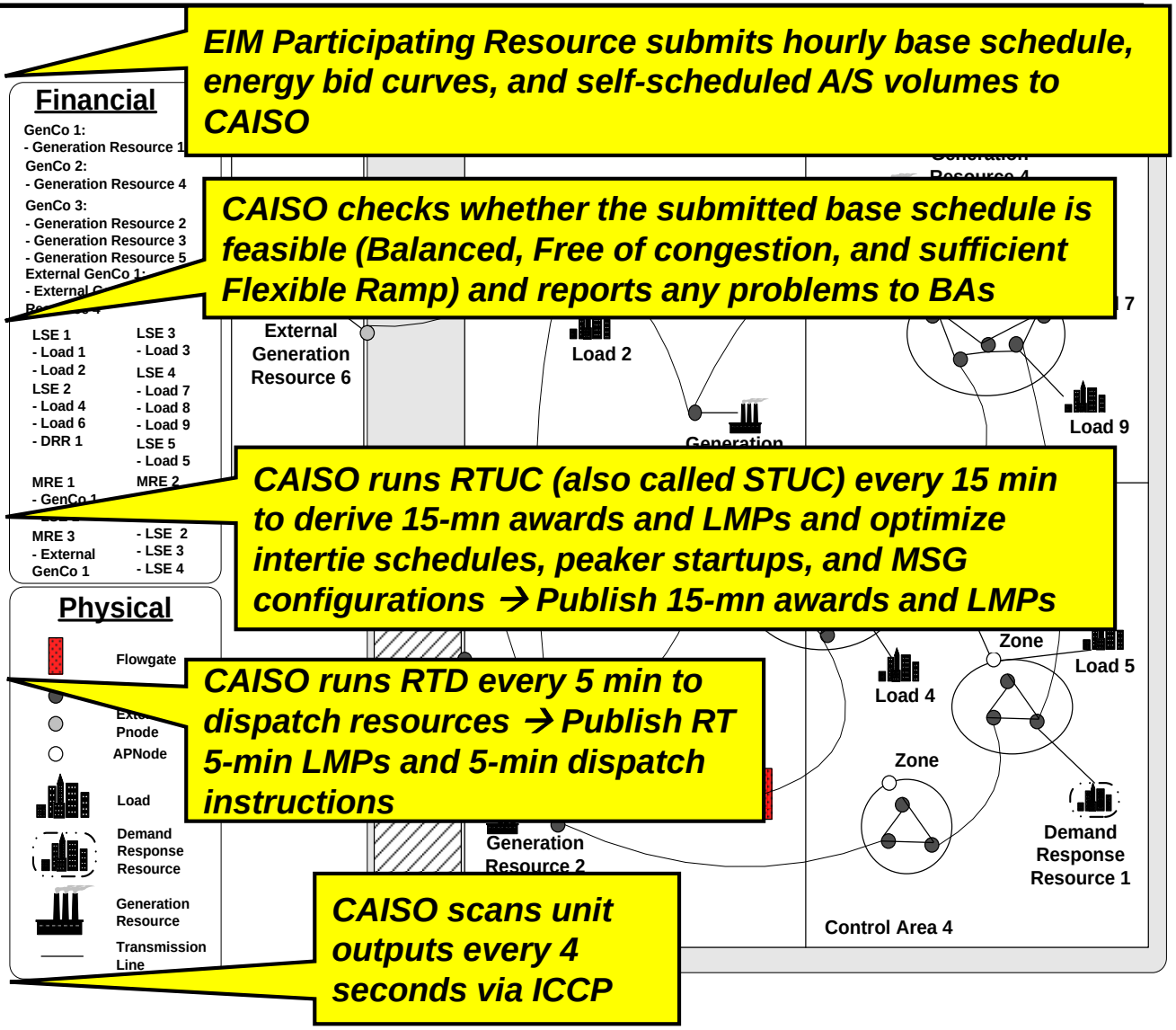
T -40 minutes:
- If resource plan is not feasible, BA can submit adjusted base schedule

T -20 minutes:
- ISO forecast loads for next 15 mn
- ISO runs RTUC to derive 15-mn schedules and LMPs and optimize intertie schedules

T – 7.5 minutes:
- ISO forecasts Loads for next 5 Min
- ISO runs RTD
- ISO sends 5-mn Dispatch Instructions & 5-mn LMPs to resources

T to T + 5 minutes:
- CAISO sends updated NSI to all BAs every 4 secs via ICCP
- Market participants ramp units to meet dispatch instructions

At the end of hour:
- Collect 5-mn Meter Data
- RT Energy Settlement is performed on a 15-mn basis for resources & interties and a 5-mn basis for resources and loads



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Strengths and Weaknesses of CAISO RT Optimization Engine

- **Strengths of CAISO RT Optimization Engine:**
  - **Use Full-Network Model to Produce 15-minute and 5-minute dispatch solutions that meet transmission constraints and n-1 criterion**
  - **Produce lowest cost solution to serve loads in EIM footprint**
  - **Use latest 15-mn and 5-mn forecasts for VER resources (Wind & Solar)**

- **Weaknesses of CAISO RT Optimization Engine:**
  - **Do not model operation of cascaded hydro plants**
  - **Do not recognize hydro topology and constraints**

CAISO RT Optimization Engine Delivers Significant Benefits (255 M$ from Nov 2014-September 2017)

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Benefits for Western EIM Market

- **EIM Market provides significant benefits for both EIM and MRTU players. Total Benefits reported for Western EIM Market = 255 M$ (Nov 2014 – Sept 2017)**
  - **More Efficient Dispatch, due to both Inter-Regional and Intra-Regional Dispatch, using automated 15-mn and 5-mn dispatch (70-75 % of total EIM benefits).**
  - **Increased utilization or less curtailment of variable energy resources (VER) (15-20 % of total EIM benefits)**
  - **Lower Flexible-Reserve Requirements (426-482 MW in upward direction and 504-521 MW in downward direction) by aggregating load, wind, solar variability, and load-forecast errors (3-5 % of total EIM benefits)**
  - **Enhance reliability for large multi-state EIM footprint by using full-network model and SCED engine to manage congestion for EIM footprint**

Actual EIM Benefits = 255 M$ from Nov 2014-September 2017 (6.7 M$/month)

Region	July	August	September	Total
APS	$2.52	$4.92	$3.64	$11.08
ISO	$2.01	$4.59	$1.03	$7.63
NV Energy	$2.28	$3.41	$2.86	$8.55
PacifiCorp	$2.79	$4.52	$3.00	$10.31
PSE	$0.97	$1.13	$0.88	$2.98
Total	$10.57	$18.57	$11.41	$40.55

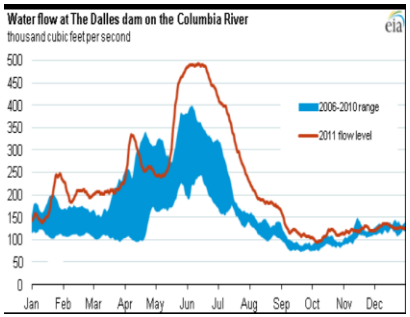
Table 1: Third quarter 2017 benefits in millions USD

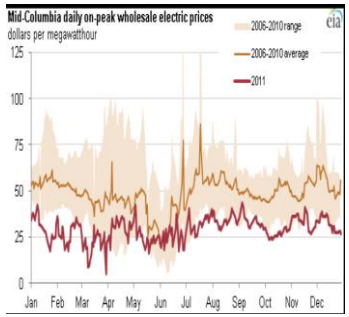
Optimizing Hydro Resources Before EIM Market

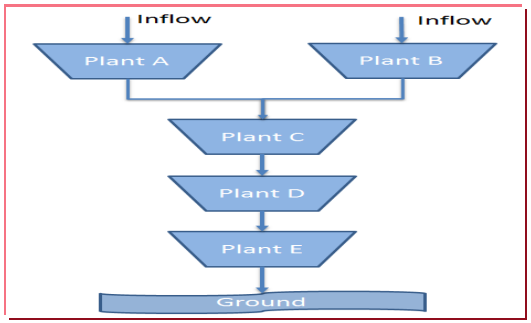
- **Hydro Optimization is a very complex process:**
  - **Long-Term Optimization (1-5 years) → Produce Annual hydro targets (Firm)**
  - **Annual Optimization → Produce monthly targets (Firm)**
  - **Monthly Optimization → Produce weekly targets (Firm)**
  - **Weekly Optimization → Produce daily targets (Firm or Flexible)**
  - **Daily Optimization → Produce hourly targets (Firm or Flexible)**

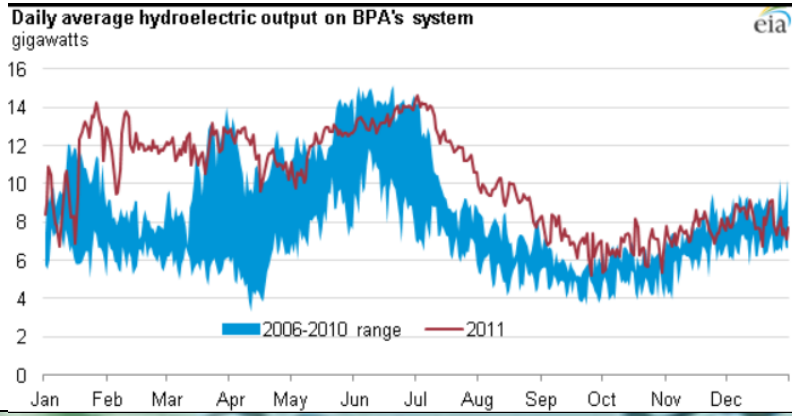
- **Key inputs for Hydro Optimization are:**
  - **Hydro inflows**
  - **Forward market prices**

- **Key outputs from Hydro Optimization are:**
  - **Hourly & Weekly & Monthly & Annual Hydro Generation & Pond Levels & Shadow Prices for Hydro Resources**









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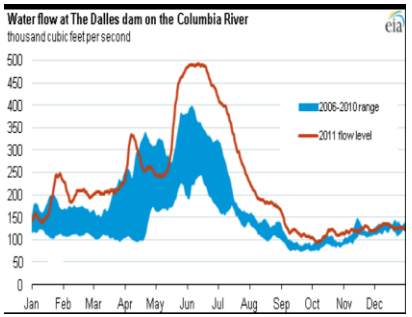
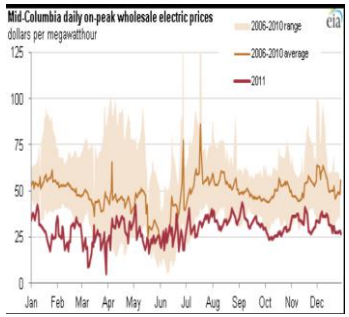
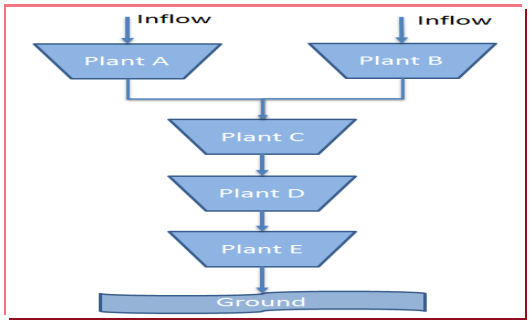
Optimizing Hydro Resources in EIM Market

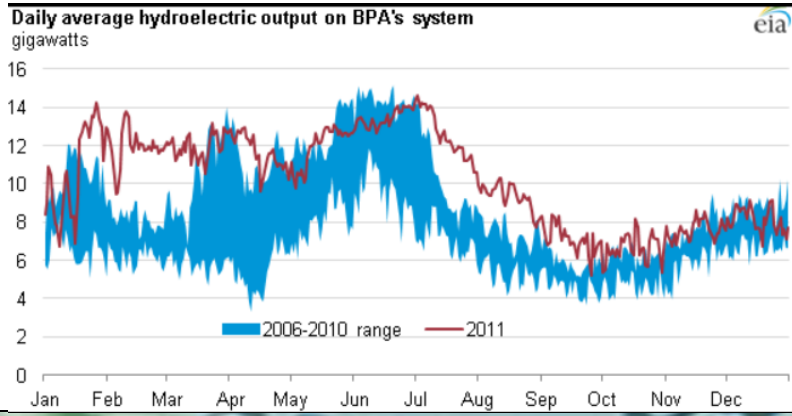
- **Key challenge to optimize hydro plants in EIM market is: "How do we Operate our Hydro Resources to maximize EIM benefits while meeting our daily & weekly & monthly & annual pond targets?"**

- **Hydro Optimization is a very complex process**
  - **Long-Term Optimization (1-5 years) → Produce Annual hydro targets (Firm)**
  - **Annual Optimization → Produce monthly targets (Firm)**
  - **Monthly Optimization → Produce weekly targets (Firm)**
  - **Weekly Optimization → Produce daily targets (Firm or Flexible)**
  - **Daily Optimization → Produce hourly targets (Firm or Flexible)**
  - **Hourly Optimization (EIM) → Optimize 15-mn and 5-mn dispatch for hydro resources (Flexible)**









How are Hydro Resources Paid in EIM market?

- **In EIM market, hydro resources are paid to provide:**
  - **Energy: Roughly 95 % of EIM Payments that hydro resources receive reflect Energy and Bid-Cost Recovery Payments (CC 64600, 64700, 64750, and 66200)**
  - **Flexible Reserves: Roughly 5 % of EIM Payments reflect Payments for Flexible Reserves (CC 7024, 7050, 7070, 7071, 7077, 7078, 7081, 7087, and 7088)**

Parameters for Optimizing Operation of Hydro Resources in EIM Market

- **Optimizing hydro resources in EIM market is a complex balancing act. To optimize operations of hydro resources in EIM market, market participants can control 3 parameters:**
  - **Baseline Schedule (MWh): Best schedule for operating hydro resource without EIM Market**
  - **Bid Curve ($/MWh): Shadow Price for Operating Hydro Resource at Base Schedule or Price that resource will receive for deviating from base schedule**
  - **Self-Scheduling Volume (MWh): Must-Run Volume**
  - **PMax (MW): Maximum capability of hydro resource**
  - **PMin (MW): Minimum capability of hydro resource**
  - **Ramp Rate (MW/min): Determine how fast hydro resource can move**

200-MW Hydro Resource	
Base schedule (MWh)	150
Shadow price ($/MWh)	30
PMin (MW)	100
PMax (MW)	200
Ramp Rate (MW/Min)	10

Bid Curve MW	Price $/MWh
100	25
149	30
151	35
200	35

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Numerical Example Illustrating Potential EIM Benefits for Hydro Resource

Key principle illustrated in this simple example is – Hydro resources can make money in EIM market as long as they are flexible, ie resources can operate above base schedule when RT LMPs (FMM & RTD) are higher than their shadow prices and below base schedule when RT LMPs are below their shadow prices

200-MW Hydro Resource		Interval	Base Schedule (MWh)	15-mn LMP ($/MWh)	15-mn Dispatch (MWh)	5-mn LMP ($/MWh)	5-mn Dispatch (MWh)	5-mn Meter (MWh)	15-mn Set (CC 64600)	5-mn Instructed Imbalance Set (CC 64700)	5-mn Uninstructed Imbalance Set (CC 64750)	EIM Charge or Credit ($)	Hydro Production Cost Savings ($)	EIM P&L ($)
Base schedule (MWh)	150	1	150	$20.00	100	$20.00	100	100	$83.33	$0.00	$0.00	$83.33	$125.00	$41.67
Shadow price ($/MWh)	30	2	150	$20.00	100	$20.00	100	100	$83.33	$0.00	$0.00	$83.33	$125.00	$41.67
PMin (MW)	100	3	150	$20.00	100	$20.00	100	100	$83.33	$0.00	$0.00	$83.33	$125.00	$41.67
PMax (MW)	200	4	150	$25.00	100	$20.00	100	100	$104.17	$0.00	$0.00	$104.17	$125.00	$20.83
Ramp Rate (MW/Min)	10	5	150	$25.00	100	$20.00	100	100	$104.17	$0.00	$0.00	$104.17	$125.00	$20.83
		6	150	$25.00	100	$30.00	150	150	$104.17	-$125.00	$0.00	-$20.83	$0.00	$20.83
Bid Curve	Price	7	150	$30.00	150	$30.00	150	150	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
MW	$/MWh	8	150	$30.00	150	$40.00	200	200	$0.00	-$166.67	$0.00	-$166.67	-$125.00	$41.67
100	25	9	150	$30.00	150	$40.00	200	200	$0.00	-$166.67	$0.00	-$166.67	-$125.00	$41.67
149	30	10	150	$40.00	200	$40.00	200	200	-$166.67	$0.00	$0.00	-$166.67	-$125.00	$41.67
151	35	11	150	$40.00	200	$40.00	200	200	-$166.67	$0.00	$0.00	-$166.67	-$125.00	$41.67
200	35	12	150	$40.00	200	$40.00	200	200	-$166.67	$0.00	$0.00	-$166.67	-$125.00	$41.67
		Hour	150	$28.75	137.5	$30.00	150	150	$62.50	-$458.33	$0.00	-$395.83	$0.00	$395.83
		Year (Assume that Hydro Resource is Flexible 10 % of the time)										-$346,750.00	$0.00	$346,750.00

Lessons Learned for Operating for Hydro Resources in EIM Market

- **To maximize EIM benefits, you would like to offer maximum hourly flexibility to the CAISO RT solver while meeting your near-term (daily & weekly & monthly) hydro constraints.**
- **Your base schedule should reflect your hydro hourly target before the EIM market.**
- **Flexibility of hydro resources is measured by:**
  - **Bid Curves ($/MWh): How much do you want be paid when your hydro resources are requested to deviate from your hourly target?**
  - **PMin & PMax (MW): How much are you willing to deviate from your hourly target?**
  - **Ramp rates (MW/min): How fast can your hydro resources ramp up and down to chase Load & VER deviations?**

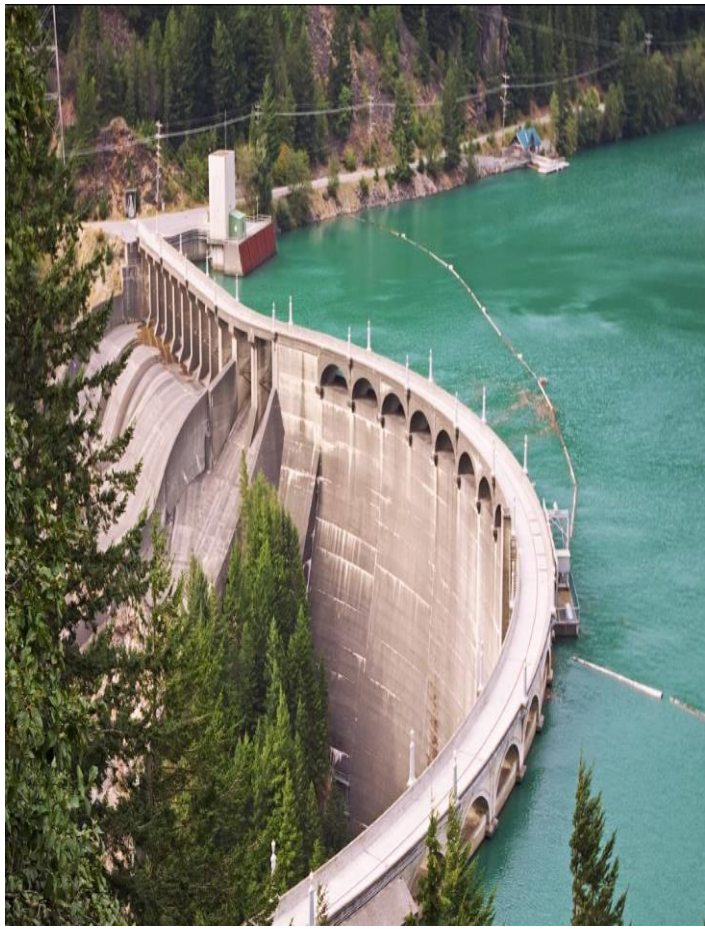
Key challenge for price-based optimization is participants will need to update bid curves & base schedule & self-scheduling volume for hydro resources on an hourly basis to maximize EIM benefits while meeting daily & weekly hydro targets.

200-MW Hydro Resource	
Base schedule (MWh)	150
Shadow price ($/MWh)	30
PMin (MW)	100
PMax (MW)	200
Ramp Rate (MW/Min)	10

Bid Curve MW	Price $/MWh
100	25
149	30
151	35
200	35

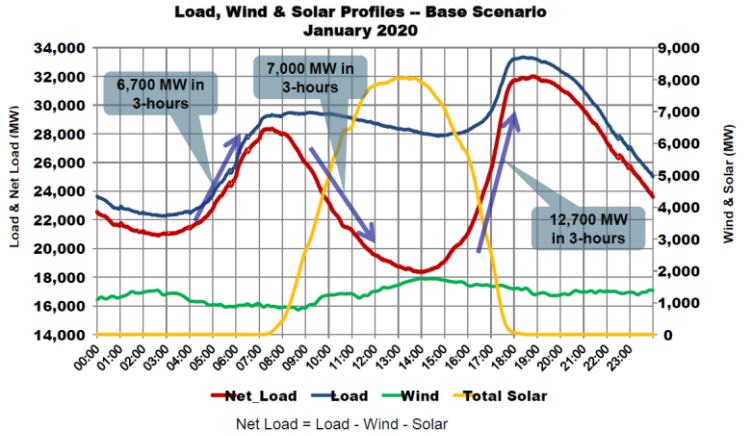
Key Factors Limiting Flexibility of Hydro Resources

- **Technical Factors**
  - Hydro resources operate in must-run mode due to high water inflows and small pond reservoirs
  - Hydro resources cannot ramp due to Forbidden zones or old Control Equipment which limits ramp capability
- **Regulatory Factors**
  - Maintain proper pond levels for recreation
  - Curtail hydro generation due to fish protection
- **Operating Philosophy**
  - Only use hydro resources to serve native customers, not for EIM market

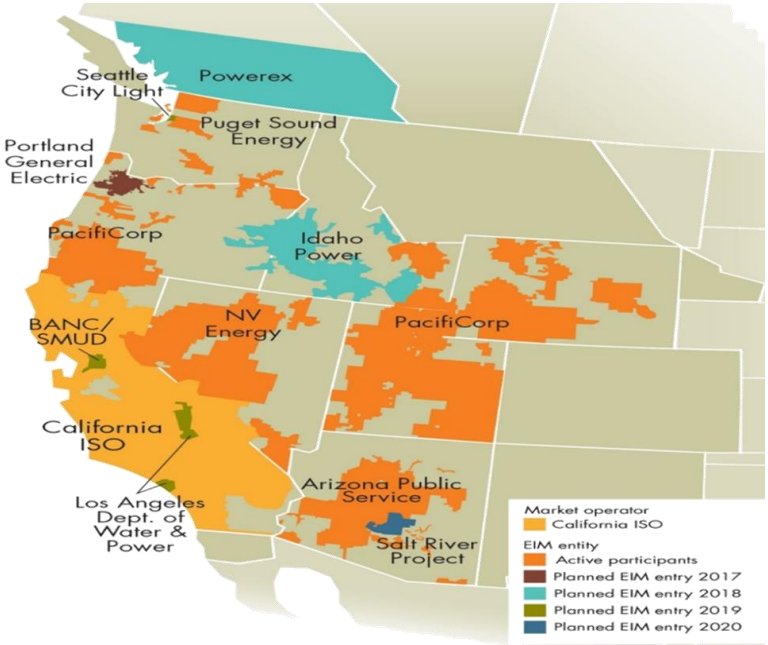


How should we Operate Pondage-Hydro Resources after joining EIM market?

- **Before joining EIM market, the best way to operate hydro resources is to perform a volumetric optimization and run hydro resources to shave the peak loads for your BA while meeting hydro & regulatory constraints**



- **After joining EIM market, the best method is to perform a price-based optimization in RT market and allow CAISO to operate hydro resources based on bid curves, self-schedule volumes, Pmin/Pmax, and ramp rates while meeting hydro & regulatory constraints**



Using Hydro Resources to Balance VER resources

- There is significant value in using hydro resources to meet last-minute load deviations and balance the output of VER (wind & solar) resources
  - When RT LMPs are low (Low loads or Lots of wind & solar plants operating), operate hydro resources below base schedules
  - When RT LMPs are high (High loads or Wind & solar plants operating at low levels), operate hydro resources above base schedules
- Value of flexible hydro resources will increase as we increase the mix of intermittent VER resources in Western market.

Hydro Resources can also be Paid for Providing Flexible-Ramp Reserves

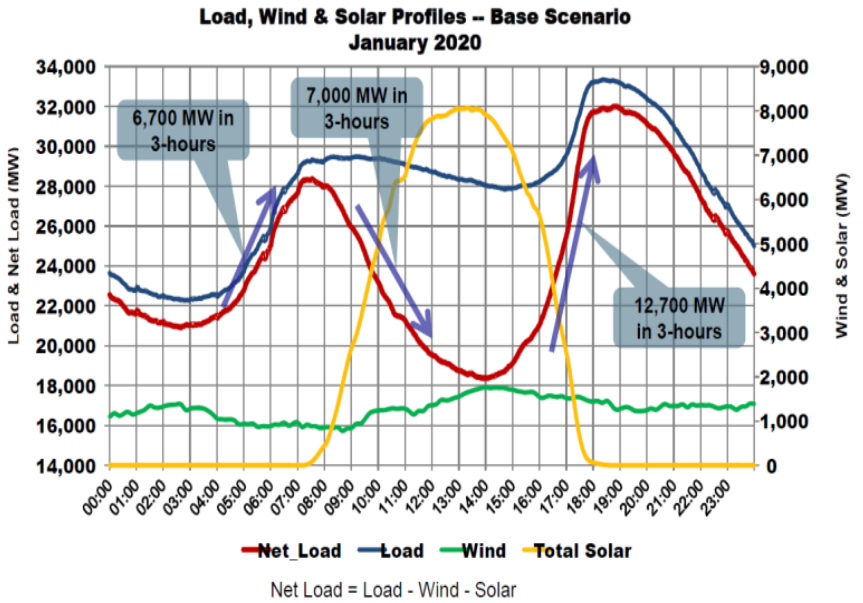
- **CAISO procures flexible-ramp capacity in FMM & RTD markets to deal with uncertainties (wind & solar & load) in RT operations.**

- **All resources that clear flexible reserves (Up & Down) in FMM & RTD markets are paid for providing reserves.**

- **Today, flexible-reserve payments are small – roughly 5 % of Energy Payments.**

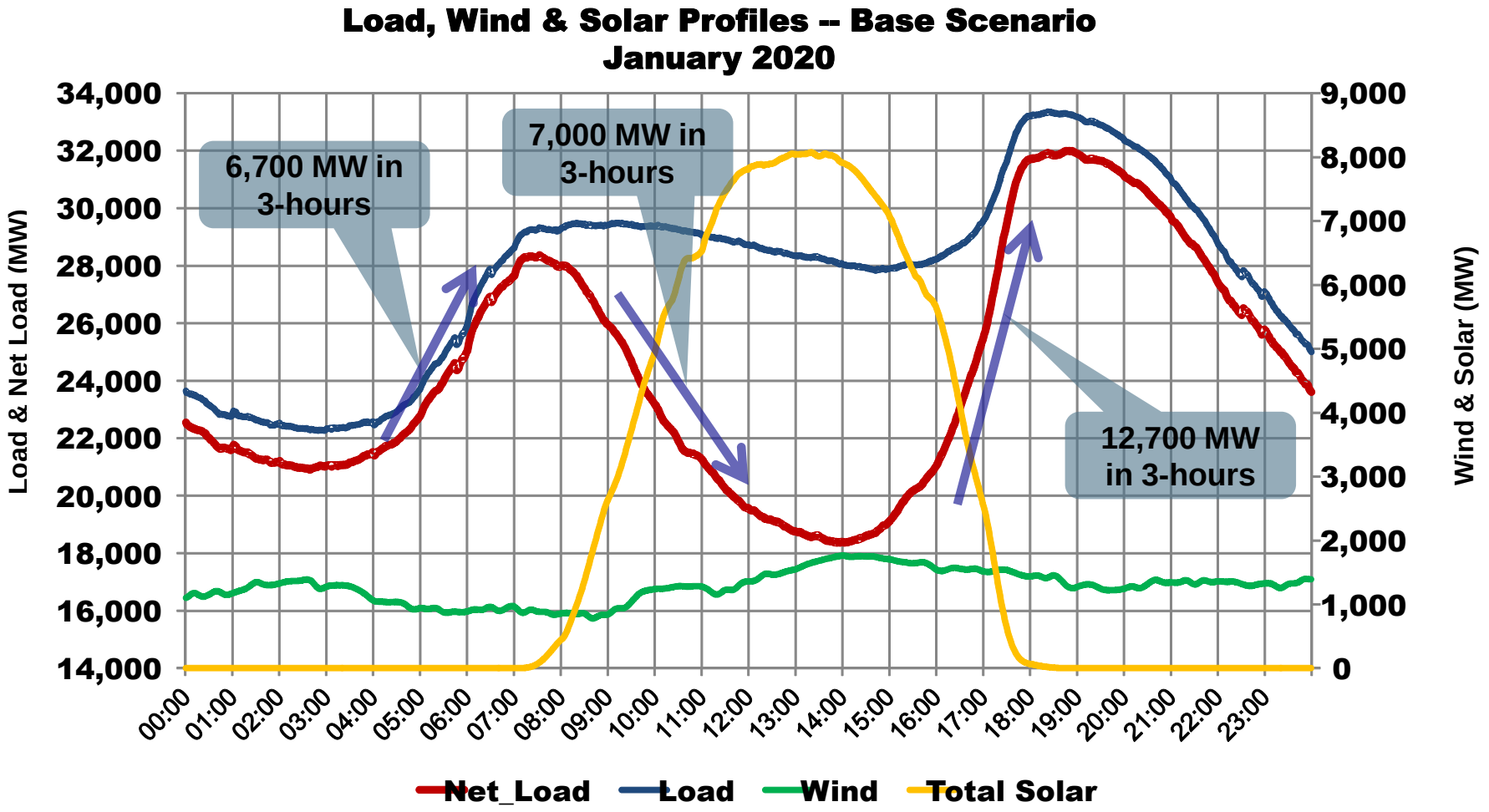
2017	June	AZPS	up	23	243
		CISO	up	171	1,000
		NEVP	up	17	221
		PACE	up	80	300
		PACW	up	8	150
		PSEI	up	16	135
		ALL EIM	up	10	1,800
		AZPS	down	7	228
		CISO	down	200	1,000
		NEVP	down	0	228
		PACE	down	63	300
		PACW	down	33	175
		PSEI	down	18	135
		ALL EIM	down	91	1,200

Table 4: Flexible ramping requirements



Net Load = Load - Wind - Solar

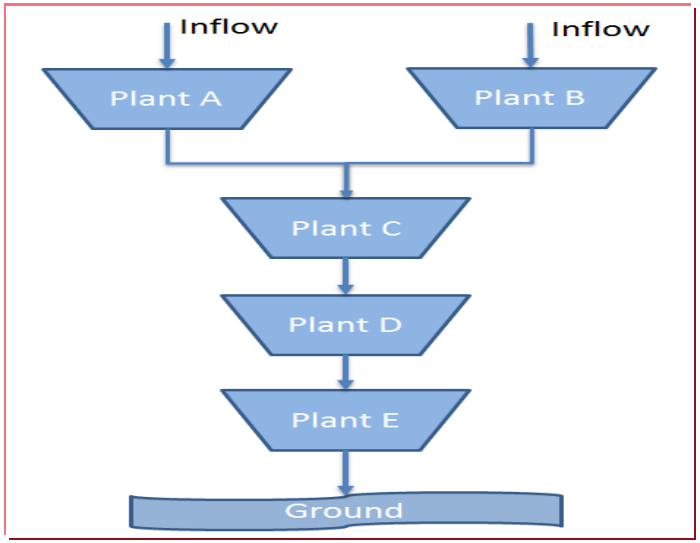
Need for Flexible-Ramp Capacity Will Increase in Future with Larger Wind & Solar Penetration



Net Load = Load - Wind - Solar

Feedback from EIM Participants with Experience with Operating Hydro Plants in EIM Market

- **PCI Questions**
  - **Q1: Do you gain any market benefits for operating hydro resources as participating resources in EIM Market?**
  - **Q1: Answer for Q1 is "Yes" for all EIM participants**
  - **Q2: With the current tools that you have, how well can you optimize your hydro resources in EIM market?**
  - **Q2: Answer for Q2 is "There is lots of room for improving hydro dispatch in EIM Market"**



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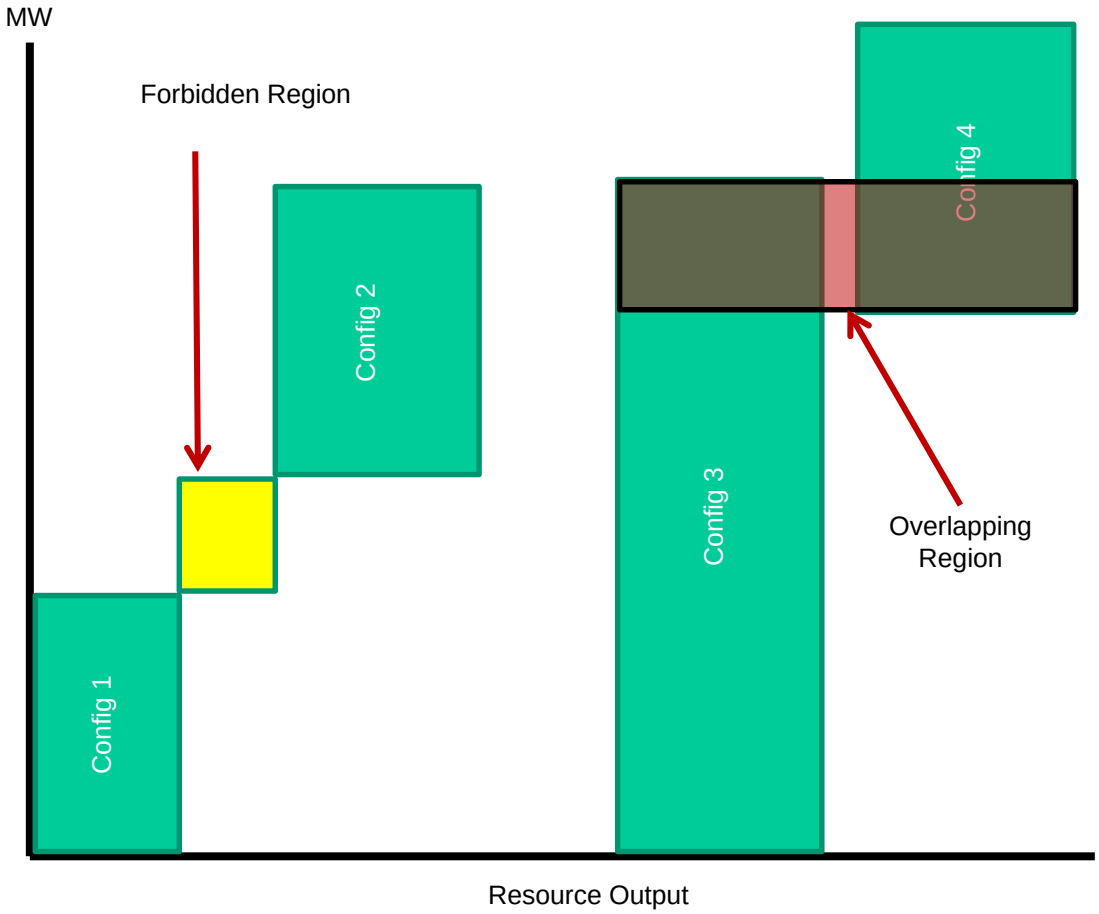
How are Hydro Resources Modelled in EIM Market?

- **Hydro resources can be modeled as regular resources or MSG (Multi-State Generating) resources. MSG model can be used to model:**
  - **Complex Hydro Resources with different characteristics**
  - **Hydro Resources with forbidden operating regions**

- **Pros and cons for using MSG Model:**
  - **Pro: Provide lots of options to model hydro constraints**
  - **Con: Complexity**



Prooposed MSG Enhancements to Better Model Hydro Resources

- **Several participants mentioned that they could not model hydro resources using MSG model because some MSG parameters can only be updated 2-3 times a month in the master file:**
  - **Transition Matrix**
  - **Forbidden zones**
  - **Ramp Rates**

- **Hydro resources have very dynamic characteristics. Hydro plant managers would need to update these hydro parameters on an hourly basis.**

From Configuration	To Configuration	Transition Cost ($)	Transition Ramp Time (minutes)	Notification Time (minutes)	Max Daily Transitions
Off-line	MSGGN_1_C1	2,000	900		1
MSGGN_1_C1	MSGGN_1_C2	3,000	30	40	5
MSGGN_1_C2	MSGGN_1_C3	4,000	30	40	5
MSGGN_1_C3	MSGGN_1_C4	5,000	30	40	5
MSGGN_1_C4	MSGGN_1_C3	0	30	40	5
MSGGN_1_C3	MSGGN_1_C2	0	30	40	5
MSGGN_1_C2	MSGGN_1_C1	0	60	40	5

Concluding Remarks

- **Dispatching hydro resources to meet last-minute load deviations and balance VER resources (Wind & Solar) is a win-win solution for everybody in Western EIM Market.**

- **Better optimization of hydro resources (especially pondage-hydro and pump-storage resources) can yield significant benefits for EIM market participants.**

- **We need to enhance CAISO RT optimization solver and market rules to get the most benefits from hydro resources:**
  - **EIM Solver: Enhance MSG model to better model pondage-hydro and pump-storage resources**
  - **EIM settlement rules: CAISO will need to increase flexible-reserve payments to provide greater incentives for hydro resources to increase flexibility and clear for flexible reserves**