Regulation Market Overview

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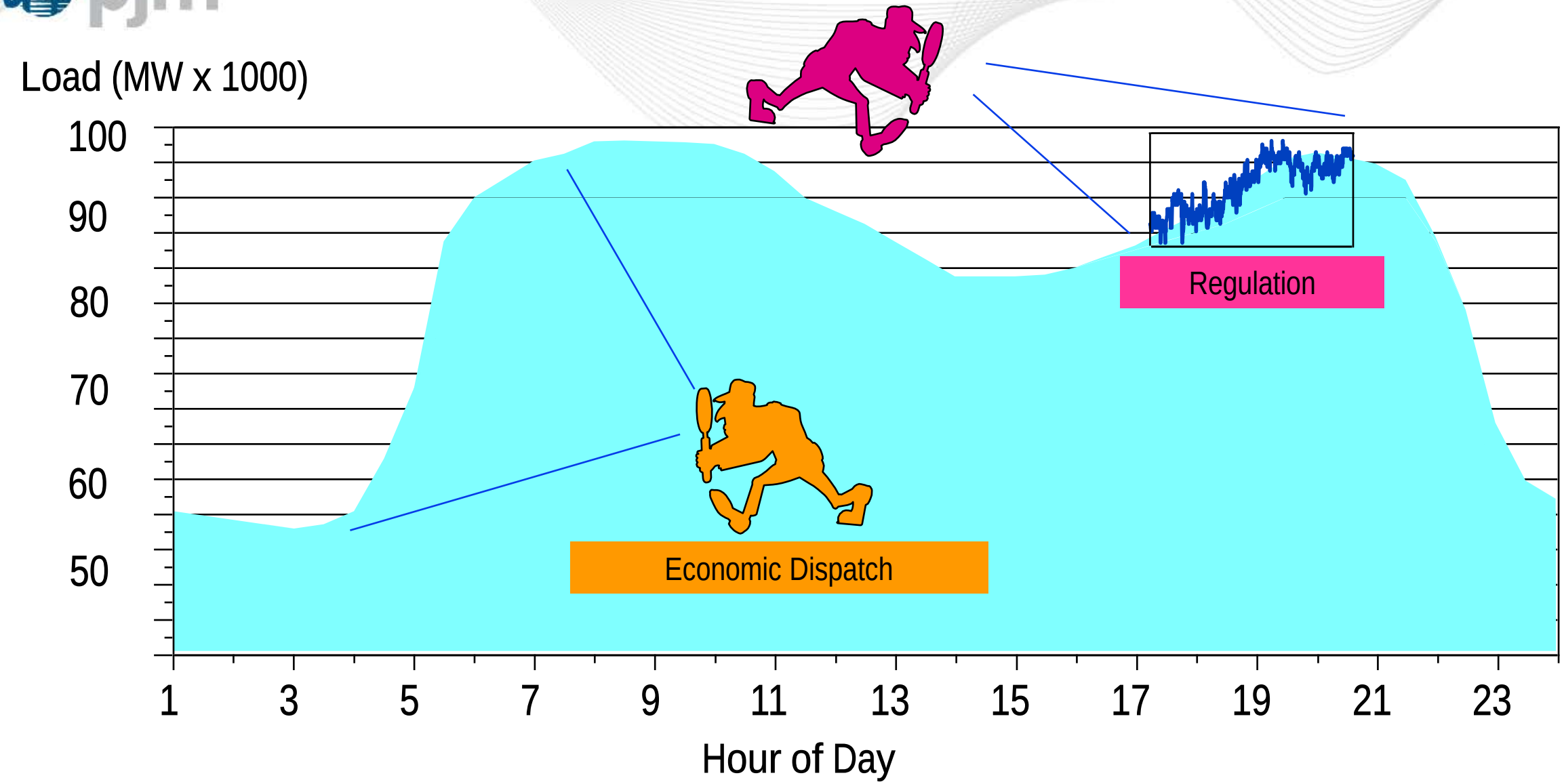
Regulation Overview

- Regulation is a product in the Ancillary Services Market that provides market-based compensation to resources that have the ability to adjust output or consumption in response to an automated signal
  - Helps to maintain interconnection frequency
  - Help to track moment-to-moment fluctuations in customer loads
  - To correct the unintended fluctuations in generation
  - Manage differences between actual and scheduled power flow between control areas
  - Match generation to load within a control area

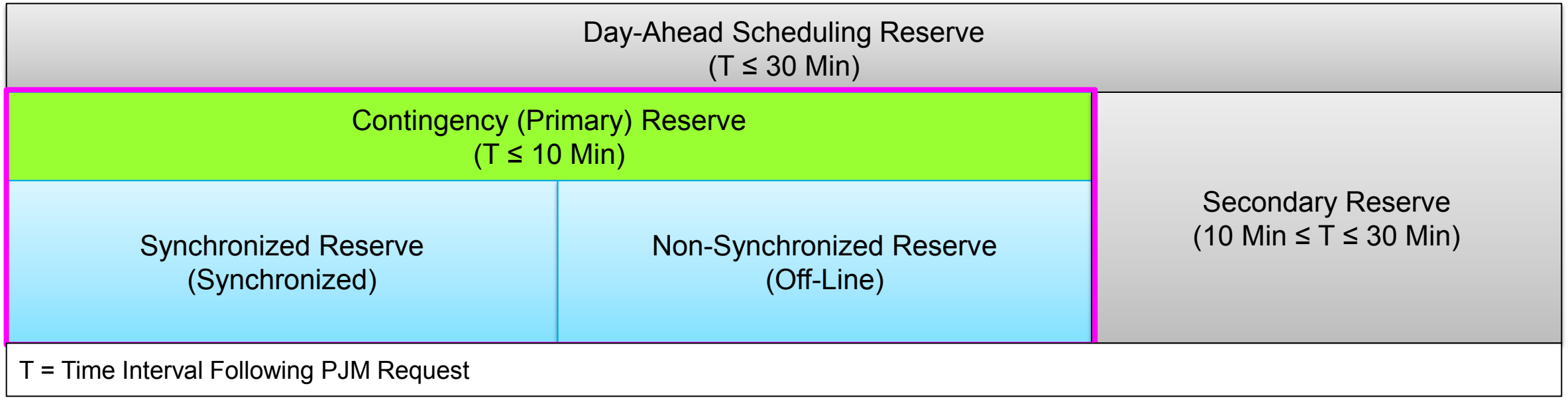
- The Regulation service is a reliability product

Regulation vs. Economic Dispatch



Reserves

Reserves are additional generation capacity above the expected load. Scheduling excess capacity protects the power system against the uncertain occurrence of future operating events, including the loss of energy or load forecasting errors.



Synchronized Reserves

- The main goal of this service is to recover the ACE back to it's pre-contingency level within the allotted timeframe after a resource loss, large tie errors, and under frequency conditions.
  - Outside of regulation
- This service provide a quick boost of generation (or load reduction) to the system to recover low ACE
  - Synchronized reserves cannot control over-frequency
  - Manual deployment

Non-Synchronized Reserves

- Non-Synchronized Reserve is reserve capability that can be fully converted into energy within 10 minutes of the request from the PJM dispatcher and is provided by equipment not electrically synchronized to the system

- Why do we procure NSR?
  - Reliability reason: NSR provides a backfill in case SR does not adequately respond to a spin event
  - Market reason: a non-zero NSR market clearing price (NSRMCP) is a good indication that the system is getting tight on reserves

Day-Ahead Scheduling Reserves

- PJM schedules reserves on a Day-Ahead basis
  - Ensures the difference between forecasted load and forced generator outages does not negatively impact reliable operations
  - DASR considers variables that negatively impact system reliability, specifically Underforecasted Load Forecast Error (LFE) and Generator Forced Outage Rates (FOR)
  - DASR = Underforecasted LFE + FOR
  - Percentage is calculated annually
  - Currently set at 5.93%
- Unlike Synchronized Reserves, DASR is not maintained in Real-Time
- There are no DASR events for resources to respond to

Regulation Resource Requirements

- Resources must be located electrically within the PJM RTO
- Generation resources must have a governor capable of AGC control.
- Resources must be able to receive an AGC signal.
- Resources must demonstrate minimum performance standards (must maintain 40% historic performance score), as set forth in the PJM Manual
- New resources must pass an initial performance test (minimum of 75% compliance required). PJM will rely on owner‘s data for initial qualification.
  - Resources that pass are enabled in the markets databases by PJM personnel
- Resources MW output must be telemetered

Qualified Regulation MW

Resource Type	REGA MW	REGD MW	Dual Qualified
Steam	3103	0	0
Hydro	970	420	420
CT	1194	80	20
Energy Storage	0	176	0
DSR	4	8	2
Total MW	**5271**	**684**	**442**

Regulation Qualification

To qualify for the regulation market resources must pass three (3) consecutive regulation tests with a performance score of 75% or greater

- Resources MW output must be telemetered and activated before testing
- One self test is allowed (Signal data is available to participants on PJM.com)

Resources must continue to demonstrate minimum performance requirements once in the Regulation Market

- Historical performance score must be greater than 40% (100 hour rolling average)
- Individual hour performance must be greater than 25% to be compensated

Manual 12 – Section 4.5

Performance Score Calculation

PJM scores resources on 3 components:

Accuracy: *the correlation or degree of relationship between control signal and response*

Delay: *the time delay between control signal and point of highest correlation*

Precision: *The instantaneous error between the control signal and the regulating unit's response*

A resource's performance score is calculated as:

$$\text{Perf\_Score} = \frac{1}{3}*\text{Accuracy} + \frac{1}{3}*\text{Delay} + \frac{1}{3}*\text{Precision}$$

Regulation Market Timeline

REGULATION MARKET

Throughout the operating day PJM clears the Regulation Market hourly and makes intra-hour adjustments as necessary.

REAL-TIME MARKET

Regulation offers due

Due a day ahead of the operating day by noon:

- Energy schedule for LOC calculation to qualify units

Due a day ahead by 6:00 p.m.:

- Cost based offer (capped at actual cost + $12 adder) *Required for clearing*
- Price based offer (optional – capped at $100/MWh)
- All other regulation data can be revised up till 60 minutes before the operating hour

Up to 1 hour prior to the operating hour:

- Regulating status (available, unavailable, SS)
- Regulating capability (MW above and below reg midpoint)
- Reg min and max
- Reg signal type (A or D)

Data submitted to eMKT

Performance Based Regulation Concepts

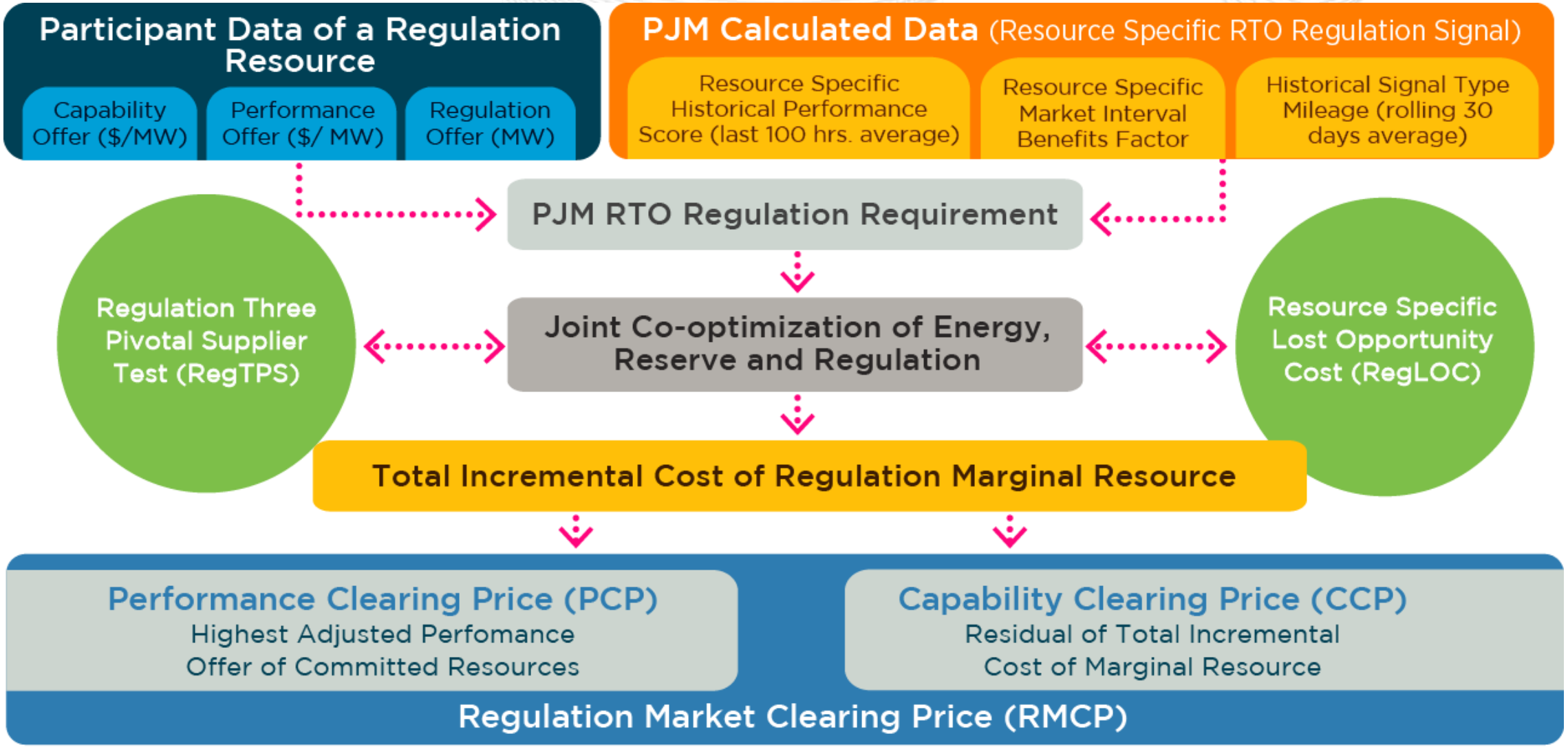
- Benefits Factor - translates a RegD MW into a RegA MW
  - All RegA resources have a BF = 1
  - Value ranges from 2.9 to 1 during excursion hours and 2.9 to 0 during non-excursion hours
    - Excursion hours: HE7, HE8, HE 18 – HE 21
    - Pending MRC endorsement from the RPI group
- Mileage - the absolute sum of movement of the regulation signal in a given time period. Resources following the dynamic signal (RegD) will likely move much more than those on the traditional signal (RegA)
- Performance Score – evaluation of how a regulating resource closely follows the regulation signal. Value ranges from 1 to 0.
  - Resources with an hourly performance score of <=.25 will not receive compensation
  - Resources with a historical performance score of <=.40 will be removed from the market

Effects of Performance Based Regulation

- Resource offers (capability and performance), and Lost Opportunity Cost are adjusted based on:
  - Resource specific Benefit Factor
  - Resource specific Historic Performance Score
  - System-wide Historic Mileage
- Good performing resources look less expensive and poor performing look more expensive to the Market Clearing Engine
  - Currently not true for self-scheduled resources.

$$Effective\ MW = RegMW * Performance\ Score * Benefits\ Factor$$

Regulation Market Clearing Process



Regulation Market Clearing

- Regulation is cleared every hour for one hour look-ahead
  - Pricing is done every 5 minutes along with energy LMP in real-time
  - Co-optimized with energy
- Regulation is cleared to meet the established requirements
  - 525 Effective MW for Off-peak (0000 – 0500)
  - 700 Effective MW On-Peak (0500 – 0000)
  - Clear the most economic mix of RegA and RegD resources
- One RTO Regulation market and therefore one uniform clearing price (RMCP)
  - Clearing is based on merit (cost, performance, and benefits to the system)
  - Clearing price separates into capability and performance clearing prices (CCP and PCP)
  - No clearing price based on signal type (RegA, RegD)
- The Area Control Error (ACE) is not a factor in the clearing process

Clearing (ASO) vs. Pricing (LPC)

ASO
Ancillary Services Optimizer

Runs one hour in advance of operating hour to procure least cost set of resources

Input:
Regulation Offers from eMKT
Historical Performance Score
Historical Mileage

Output:
MW assignment
Forecasted LMP (for LOC calculation)
Rank Price (not financially binding)

LPC
Locational Pricing Calculator

Runs every 5 minutes in Real-Time to price assigned resources

Input:
Assignment from ASO
Intra-hour commitments
Historical Performance Score
Actual Mileage

Output:
Actual 5 minute LMP (for LOC calculation)
Regulation Market Clearing Price (comprised of the Regulation Market Capability Clearing Price and the Regulation Market Performance Clearing Price) used in Settlements

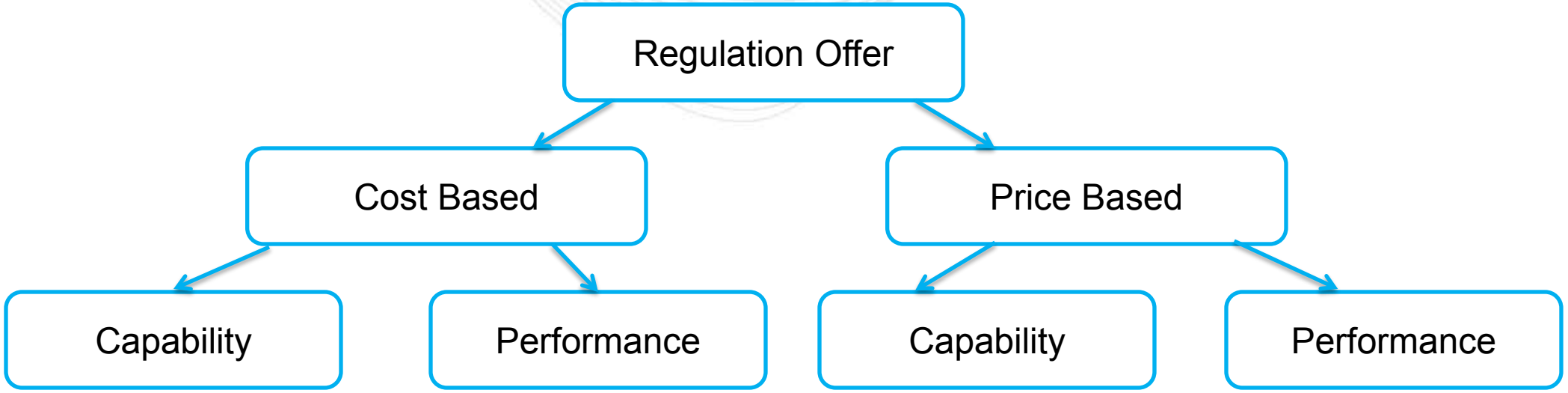
Regulation Market Clearing

Rank = Adjusted Capability Offer Cost
+ Adjusted Performance Offer Cost
+ Adjusted Lost Opportunity Cost

- Rank is used by ASO to stack resources in order to determine the least cost set of resources to meet the requirement
  - RegA and RegD resources are evaluated simultaneously
- Rank price is not financially binding
- The term “adjusted” means factoring in the PBR measures of Benefits Factor, Mileage, and Performance Score

Regulation Offers

Rank = Adjusted Capability Offer Cost + Adjusted Performance Offer Cost + Adjusted Lost Opportunity Cost



Clearing starts at:

Least of [(Capability Cost + Performance Cost), (Capability Price + Performance Price)]

The cheaper offer is used for Regulation TPS Test

- Regulation Three Pivotal Supplier (RegTPS) Test is used to mitigate market power
- If supplier PASSES, price based offer is used for remainder of clearing process

Cost Based Offer is required for clearing

Capability Offer Cost Example

Rank = Adjusted Capability Offer Cost + Adjusted Performance Offer Cost + Adjusted Lost Opportunity Cost

$$Adjusted\ Reg\ Capability\ Offer\ Cost\ (\$/MWh) = \frac{Capability\ offer\ (\$/MWh)}{Benefits\ Factor\ *\ Historic\ Performance\ Score}$$

Resource	Offer Type	Signal Type	Capability	Performance	Benefits Factor	Performance Score	Adjusted Capability Offer
A	Self-Scheduled	A	$1.00	$0.50	1	0.5	$0.00
B	Self-Scheduled	D	$2.00	$1.00	1.8	0.85	$0.00
C	Economic	A	$0.00	$0.00	1	0.6	$0.00
D	Economic	D	$0.00	$0.00	2	0.9	$0.00
E	Economic	A	$5.00	$0.50	1	0.75	5/(1*0.75) = $6.67
F	Economic	D	$1.00	$0.25	1.5	0.8	1/(1.5*0.8) = $0.83

Performance Offer Cost Example

Rank = Adjusted Capability Offer Cost + Adjusted Performance Offer Cost + Adjusted Lost Opportunity Cost

$$Adjusted\ Reg\ Performance\ Offer\ Cost\ (\$/MWh) = \frac{Performance\ offer\ (\$/MWh) * Historic\ Mileage}{Benefits\ Factor\ * Historic\ Performance\ Score}$$

Resource	Offer Type	Signal Type	Capability	Performance	Benefits Factor	Performance Score	Mileage	Adjusted Performance Offer
A	Self-Scheduled	A	$1.00	$0.50	1	0.5	5	$0.00
B	Self-Scheduled	D	$2.00	$1.00	1.8	0.85	15	$0.00
C	Economic	A	$0.00	$0.00	1	0.6	5	$0.00
D	Economic	D	$0.00	$0.00	2	0.9	15	$0.00
E	Economic	A	$5.00	$0.50	1	0.75	5	(0.5*5)/(1*0.75) = $0.67
F	Economic	D	$1.00	$0.25	1.5	0.8	15	(2*15)/(1.5*0.8) = $3.13

Historic mileage is used for clearing, actual mileage is used for pricing

Regulation Lost Opportunity Cost (RegLOC)

- RegLOC – is the foregone revenue or increase in costs relative to the energy market for providing regulation.
  - Calculated only for pool scheduled generators
  - Is $0 for DSR and self-scheduled generators
  - RegLOC is calculated relative to the cheaper of available priced-based energy schedule or the most expensive cost-based energy schedule

$$\text{RegLOC Schedule} = \text{Least}\left\{\begin{array}{l}\text{available priced-based energy schedule,}\\ \text{greatest(available cost-based energy schedule)}\end{array}\right\}$$

Regulation Lost Opportunity Cost (RegLOC)

- In the clearing process – RegLOC is calculated as the difference between forecasted LMP and price at the Reg base-point on RegLOC schedule

- In the pricing – RegLOC is calculated as the difference between Real-Time LMP and price at the Reg base-point on RegLOC schedule

Effects of Zero Offers on LOC

- Resource types determine the eligibility for LOC
  - Storage and DSR
    - Not eligible for LOC
    - Rank is zero
  - Generation Resources
    - Participate in Real-Time market
    - LOC component may be non-zero
    - Rank may be non-zero
- Self Scheduled Offers
  - Price taker
  - Not eligible for LOC
  - Rank is zero

Adjusted Lost Opportunity Cost Example

Rank = Adjusted Capability Offer Cost + Adjusted Performance Offer Cost + Adjusted Lost Opportunity Cost

$$\text{Adjusted RegLOC} = \left[\frac{|\text{LMP} - \text{MC}|}{\text{Resource BFactor} \times \text{Resource Historical Performance Score}} \right]$$

where MC is the price of Reg set point on the RegLOC schedule

Resource	Offer Type	Signal Type	Benefits Factor	Performance Score	Mileage	Adjusted Capability Offer	Adjusted Performance Offer	Adjusted LOC
A	Self-Scheduled	A	1	0.5	5	$0.00	$0.00	$0.00
B	Self-Scheduled	D	1.8	0.85	15	$0.00	$0.00	$0.00
C	Economic	A	1	0.6	5	$0.00	$0.00	$10.00
D	Economic	D	2	0.9	15	$0.00	$0.00	$0.00
E	Economic	A	1	0.75	5	$6.67	$0.67	$2.00
F	Economic	D	1.5	0.8	15	$0.83	$3.13	$0.00

Rank Example

Rank = Adjusted Capability Offer Cost + Adjusted Performance Offer Cost + Adjusted Lost Opportunity Cost

Example requirement = 90 MW

Rank Order Low to High

Resource	Offer Type	Signal Type	Adjusted Capability Offer	Adjusted Performance Offer	Adjusted LOC	Rank	Effective Offer MW	Cleared MW
C	Economic	A	$0.00	$0.00	$10.00	$10.00	20	0
E	Economic	A	$6.67	$0.67	$2.00	$9.34	20	10
F	Economic	D	$0.83	$3.13	$0.00	$3.96	20	20
A	Self-Scheduled	A	$0.00	$0.00	$0.00	$0.00	20	20
B	Self-Scheduled	D	$0.00	$0.00	$0.00	$0.00	20	20
D	Economic	D	$0.00	$0.00	$0.00	$0.00	20	20

Rank Price (ASO) vs. RMCP (LPC)

- Calculating the Rank in ASO and the RMCP in LPC
  - The same steps are performed except Reg TPS Test (only done in ASO)

- Real-Time conditions affect regulation pricing
  - System conditions change
    - Resources needed for constraint control
    - Impacts to LOC
  - Forecasted LMP vs. 5 minute LMP
  - Historical mileage vs. actual mileage

RMCP Example

Regulation Market Clearing Price = Regulation Market Capability Clearing Price + Regulation Market Performance Clearing Price
RMCP = RMCCP + RMPCP

Resource	Offer Type	Signal Type	Adjusted Capability Offer	Adjusted Performance Offer	Adjusted LOC	Rank	Effective Offer MW	Cleared MW
C	Economic	A	$0.00	$0.00	$15.00	$15.00	20	0
E	Economic	A	$6.67	$0.67	$20.00	**$27.34**	20	10
F	Economic	D	$0.83	**$3.13**	$0.00	$3.96	20	20
A	Self-Scheduled	A	$0.00	$0.00	$0.00	$0.00	20	20
B	Self-Scheduled	D	$0.00	$0.00	$0.00	$0.00	20	20
D	Economic	D	$0.00	$0.00	$0.00	$0.00	20	20

- Regulation Market Clearing Price (RMCP) = highest rank of cleared resources = $27.34
- Regulation Market Performance Clearing Price (RMPCP) = highest adjusted performance offer from cleared resources = $3.13
- Regulation Market Capability Clearing Price (RMCCP) = RMCP – RMPCP = $24.21

Regulation Settlements

- Capability Credit = Hourly-integrated Raw Regulation MW * Hourly Performance Score * Regulation Market Capability Clearing Price (RMCCP)
- Performance Credit = Hourly-integrated Raw Regulation MW * Hourly Performance Score * Mileage Ratio * Regulation Market Performance Clearing Price (RMPCP)

- 5 minute RMCCP and RMPCP are hourly integrated
- Hourly performance score must be above 0.25 to receive compensation
- Manual 28 Section 4