Real-Time Reserve Requirements

Emily Barrett

Principal Market Design Specialist

Reserve Certainty Senior Task Force

September 26, 2025

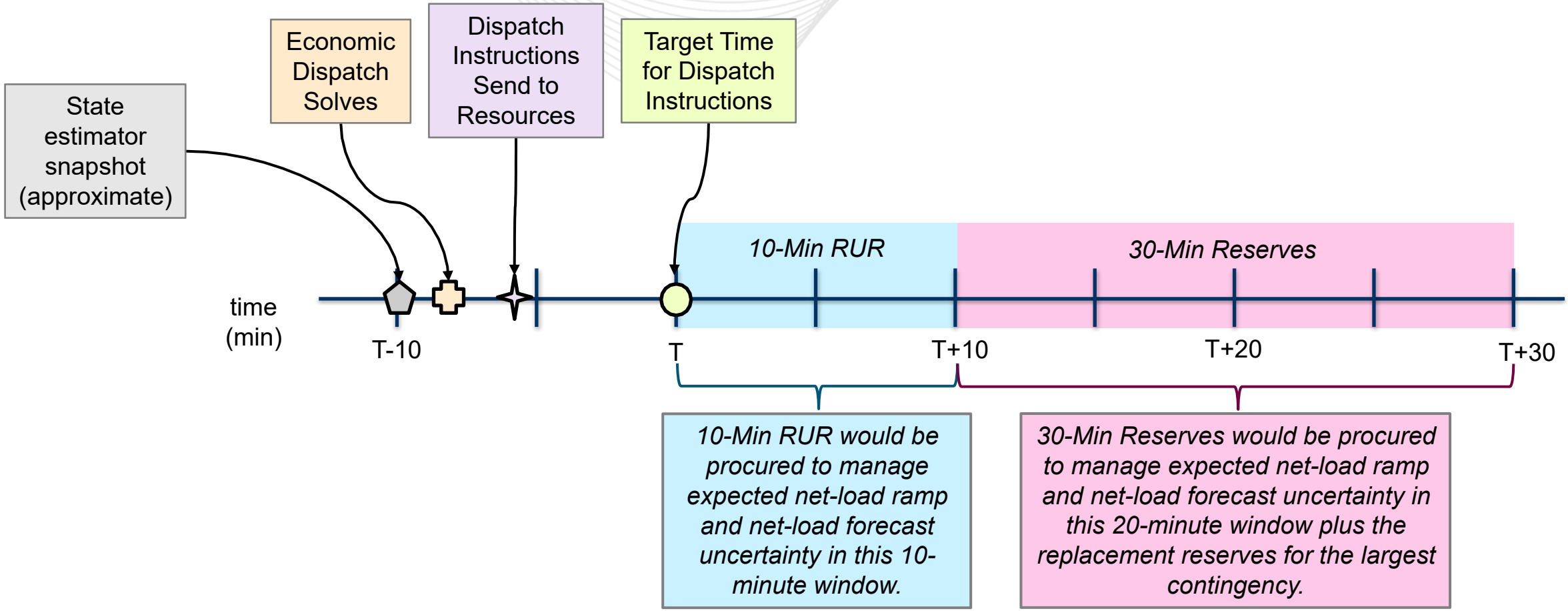
Reserve Design

30 Min. Reserves – Updated	**Used to ensure sufficient supply is available to manage net-load forecast uncertainty and to serve net-load in the next 30 minutes. Also to ensure sufficient reserves to backfill 10-minute contingency reserves and support system recovery following an event.**
10 Min Ramp/Uncertainty Reserves – Up and Down Reserves	**Used to ensure sufficient supply is available to manage net-load forecast uncertainty and to serve net-load in the 10 minutes following the target interval.**
Primary Reserves (PR) **Synchronized Reserves (SR)**	**Used to manage the risk of losing the largest unit and to meet NERC reliability requirements.**

Reserve Requirement Definitions

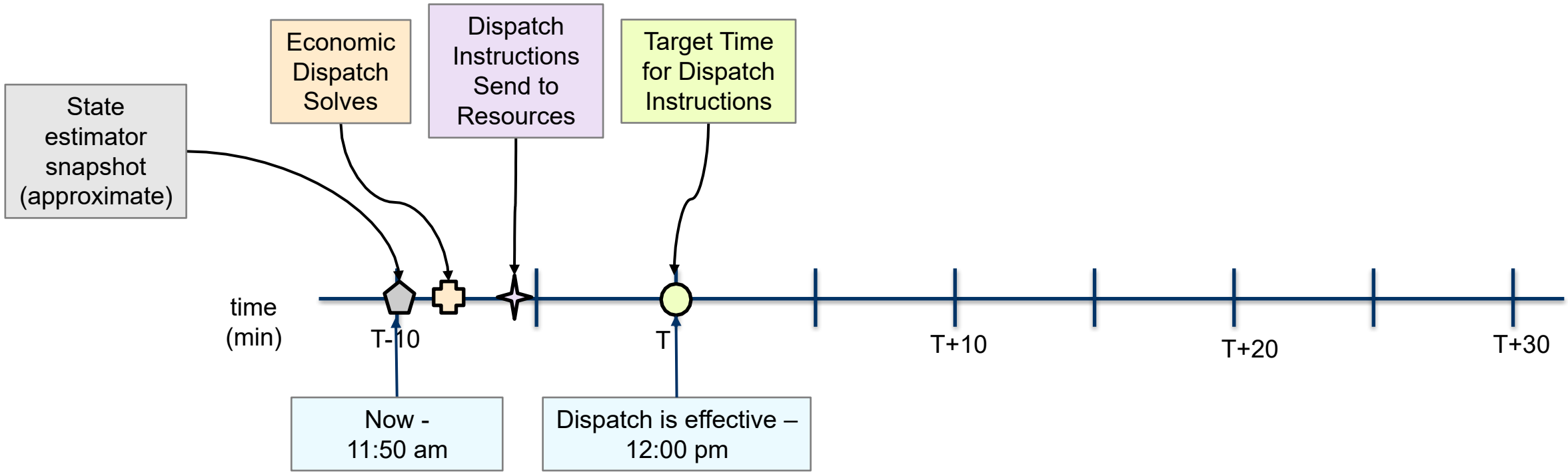
30 Min. Reserves – Updated	**20-Minute Net-Load Ramp beyond 10-Minute Net-Load Ramp + (30-Minute Uncertainty – 10-Minute Uncertainty) + Largest Single Active Contingency**
10 Min Ramp/Uncertainty Reserves – Up and Down Reserves	**10-Minute Net-Load Ramp + 10-Minute Uncertainty**
Primary Reserves (PR) **Synchronized Reserves (SR)**	**Primary Reserve: 1.5 x Synchronized Reserve (and inclusive of SR)** **Synchronized Reserve: Largest Single Active Contingency x Performance Adjustment**

Reserve Deployment and Forecast Timing



Example Set-Up

- It is 11:50 am September 17, 2025.
- Based on the 10-minute lookahead used in PJM's economic dispatch engine, dispatch instructions are calculated now for 12:00 pm.



Example Set-Up

- It is 11:50 am September 17, 2025.
- Below are the load, wind and solar forecasts *as evaluated at* 11:50 am *for effective times* 12:00 pm, 12:10 pm and 12:30 pm.

	Load Forecast	Wind Forecast	Solar Forecast	Forecast Lookahead
9/17/2025 12:00 pm	96,673 MW	114 MW	6,220 MW	10 minutes
9/17/2025 12:10 pm	97,111 MW	118 MW	6,239 MW	20 minutes
9/17/2025 12:30 pm	98,023 MW	128 MW	6,247 MW	40 minutes

10-Min Ramp/Uncertainty Reserves

Reserve Requirement Definitions

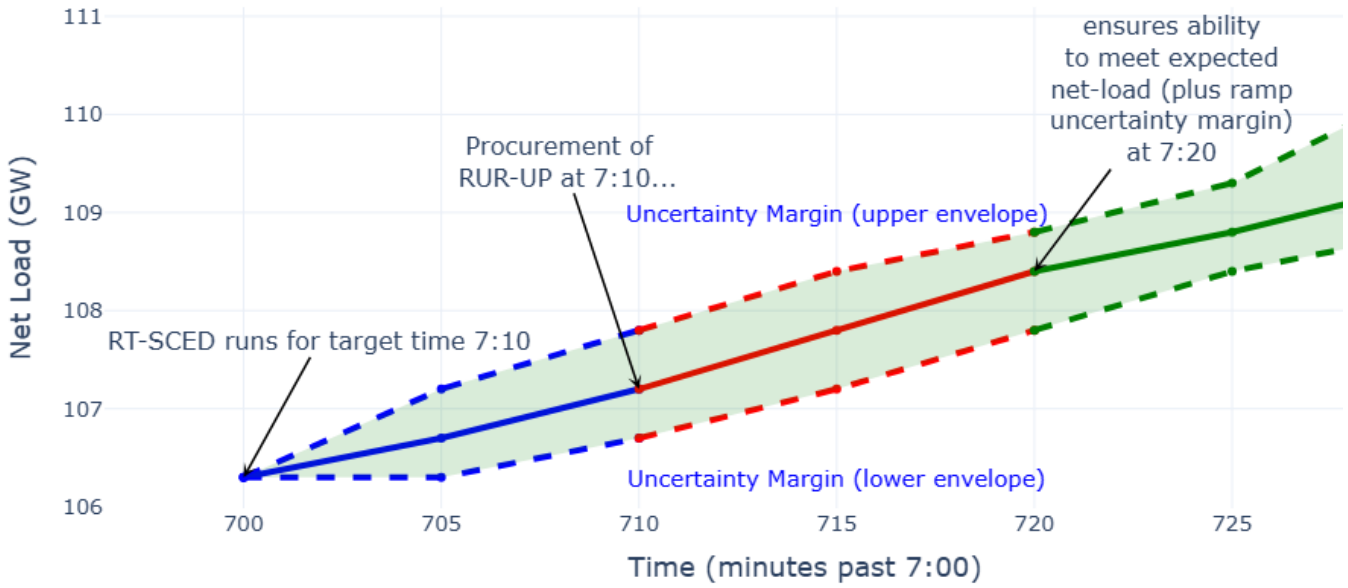
10 Min Ramp/ Uncertainty Reserves

10-Min Net-Load Ramp + 10-Minute Uncertainty

10-Min RUR Components

10-Min Net-Load Ramp

- The expected ramp component of the requirement ensures that we have sufficient flexibility to follow the forecasted net-load ramp. This is the red solid line from 7:10 to 7:20 in the figure to the right.



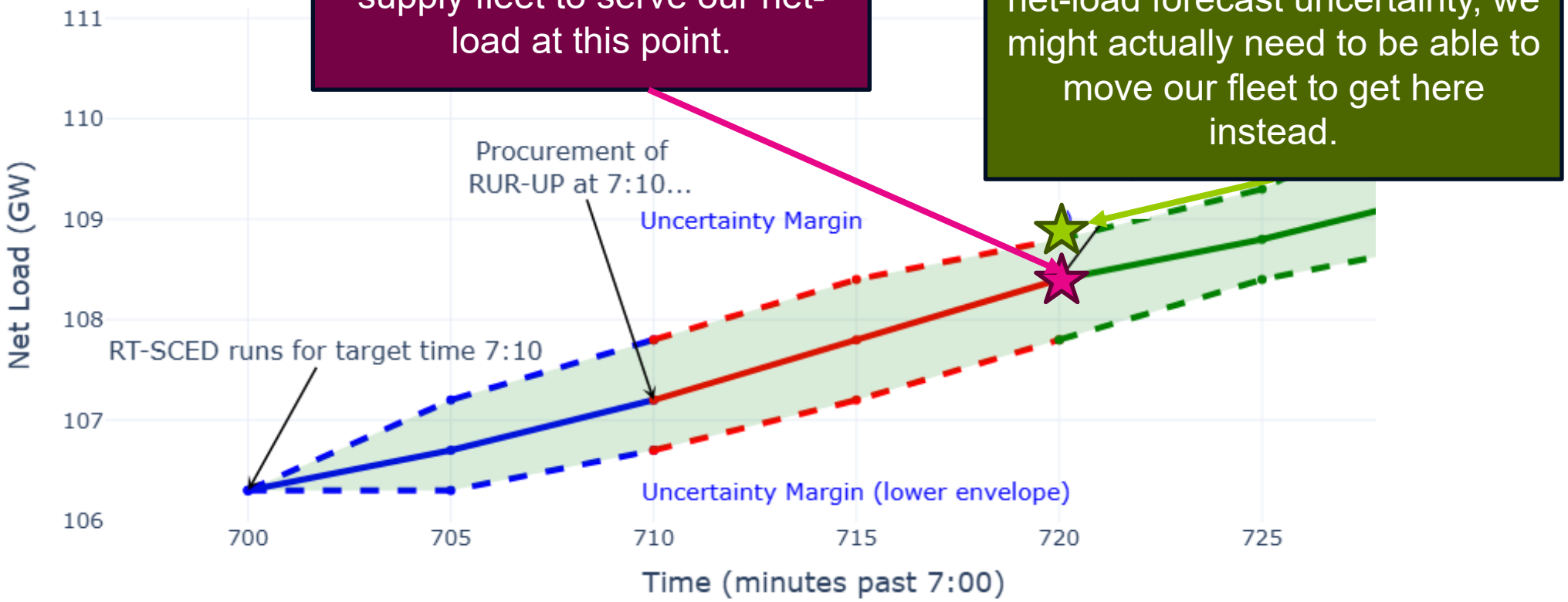
10-Min Uncertainty

- The uncertainty component recognizes that we have some net-load forecast uncertainty around that expected ramp, represented by the envelope around the net-load forecast annotated by green shading and the dotted red line from 7:10 to 7:20.

10-Min RUR Components

The expected ramp component accounts for the fact that we *expect* to need to move our supply fleet to serve our net-load at this point.

The uncertainty component recognizes that, because of our net-load forecast uncertainty, we might actually need to be able to move our fleet to get here instead.



10-Min RUR Expected Ramp Component

- The expected ramp component of the 10-Min RUR product would be calculated based on the expected (or forecasted) net-load ramp for the 10 minutes beyond the target time.
- In the September 17th example (as set-up in slides 5 and 6), that is the net-load ramp that occurs between 12:00pm and 12:10 pm *as evaluated at* 11:50 am, which is the 10-minute lookahead for economic dispatch.

	Load Forecast	Wind Forecast	Solar Forecast	Forecast Lookahead
9/17/2025 12:00 pm	96,673 MW	114 MW	6,220 MW	10 minutes
9/17/2025 12:10 pm	97,111 MW	118 MW	6,239 MW	20 minutes

10-Min RUR Expected Ramp Component

	Load Forecast	Wind Forecast	Solar Forecast	Forecast Lookahead
9/17/2025 12:00 pm	96,673 MW	114 MW	6,220 MW	10 minutes
9/17/2025 12:10 pm	97,111 MW	118 MW	6,239 MW	20 minutes

Net-Load Forecast = Load Forecast – Wind Forecast – Solar Forecast

As forecasted for 12:00 pm:

- Net-Load Forecast = 96,673 MW – 114 MW – 6,220 MW = 90,340 MW

As forecasted for 12:10 pm:

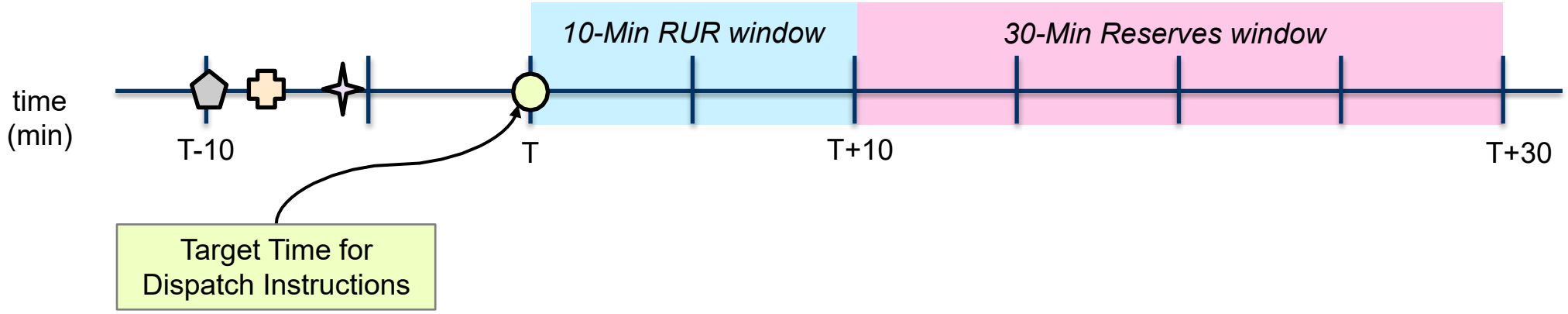
- Net-Load Forecast = 97,111 MW – 118 MW – 6,239 MW = 90,754 MW

Net-Load Ramp = Net-Load Forecast for 12:10pm – Net-Load Forecast for 12:00 pm

- Net-Load Ramp = 90,754 MW – 90,340 MW = **414 MW**

10-Min RUR Uncertainty Component

- The uncertainty component of the reserve requirement would be based on a historical analysis of the net-load forecast uncertainty in the relevant lookahead as described in the RCSTF presentation from September 17, 2025.
- For the 10-Min RUR product, the goal is to calculate how much the forecast for *effective time* T+10 changes between *when it is evaluated at* T-10, when the reserves are procured, and *when it is evaluated at* T, when the reserves could be dispatched by the economic dispatch engine.

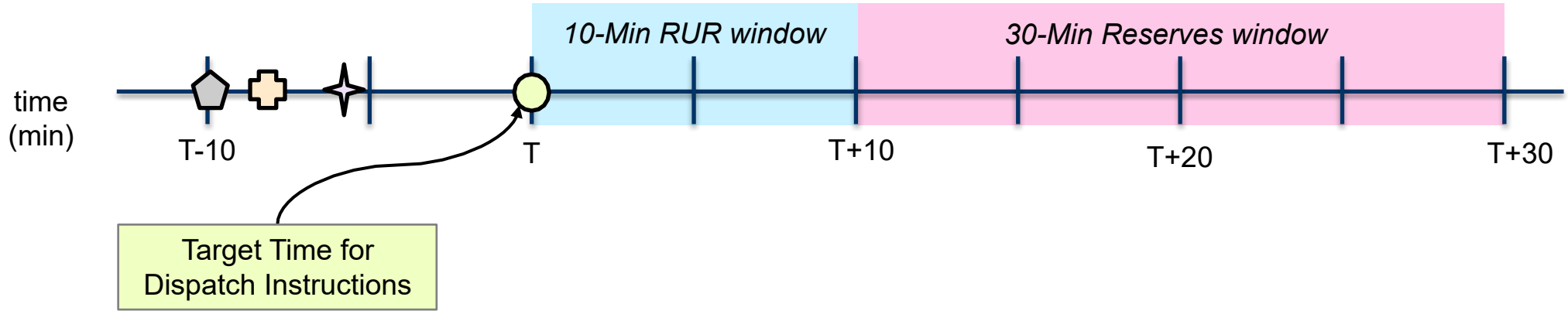


Reserve Forecast Timing for the 10-Min RUR Uncertainty Calculation

For every T+10 interval of the year, PJM calculated the net-load forecast uncertainty 10 minutes ahead, by comparing the forecast *effective* at T+10 *as evaluated* at 1) T and 2) T-10.

If the net-load forecast *for effective time* T+10 was greater *when evaluated at* T than *at* T-10, that represents a time when more flexibility was needed to manage uncertainty associated with under-forecasted net-load and would drive the procurement of “up” uncertainty reserves.

$$\text{Net-Load Forecast Uncertainty}_{T+10} = \text{Net-Load Forecast}_{T+10@T} - \text{Net-Load Forecast}_{T+10@T-10}$$



10-Min RUR Uncertainty Component

Assuming a percent-uncertainty-based approach like the one used in DASR (the second approach in the September 17, 2025 RCSTF presentation), the percent uncertainty values would be calculated separately for load, wind and solar, and then multiplied by each of the forecasts for the appropriate target time.

	Load Forecast	Wind Forecast	Solar Forecast
9/17/2025 12:10 pm	97,111 MW	118 MW	6,239 MW

	10-Min Ramp/Uncertainty Reserve		
Uncertainty Percentile	Load	Wind	Solar
95th	0.4%	1.9%	3.1%

10-Min RUR Uncertainty Component

Uncertainty Component =
% Load Forecast Uncertainty x Forecasted Load +
% Wind Forecast Uncertainty x Forecasted Wind +
% Solar Forecast Uncertainty x Forecasted Solar

Uncertainty = 97,111 MW x 0.004 + 118 MW x 0.019 + 6,239 MW x 0.031

Uncertainty = 388 MW + 2 MW + 193 MW

Uncertainty = **584 MW**

	Load Forecast	Wind Forecast	Solar Forecast
9/17/2025 12:10 pm	97,111 MW	118 MW	6,239 MW

	10-Min Ramp/Uncertainty Reserve		
Uncertainty Percentile	Load	Wind	Solar
95th	0.4%	1.9%	3.1%

10-Min RUR Requirement

- The total 10-Min RUR Requirement would be the sum of the expected net-load ramp component and the uncertainty component.
- In this example for 12:00 pm September 17, 2025, using the percent-error-based uncertainty approach that would be:

10-Min RUR Requirement = Net-Load Ramp + Net-Load Uncertainty

10-Min RUR Requirement = 414 MW + 584 MW = **998 MW**

30-Min Reserves

30-Min Reserve Requirement Definition

30 Min. Reserves – Updated

20-Minute Net-Load Ramp beyond 10-Minute Net-Load Ramp +

(30-Minute Uncertainty – 10-Minute Uncertainty) +

Largest Single Active Contingency

30-Min Reserve Expected Ramp Component

- The expected ramp component of the 30-Min Reserve product would be calculated based on the net-load ramp for the 20 minutes beyond the time covered by the 10-Min RUR product.
- For the same September 17, 2025, example, that is the net-load ramp that occurs between 12:10pm and 12:30 pm as forecasted at 11:50 am (the 10-minute look ahead for economic dispatch).

	Load Forecast	Wind Forecast	Solar Forecast	Forecast Lookahead
9/17/2025 12:10 pm	97,111 MW	118 MW	6,239 MW	20 minutes
9/17/2025 12:30 pm	98,023 MW	128 MW	6,247 MW	40 minutes

30-Min Reserve Expected Ramp Component

	Load Forecast	Wind Forecast	Solar Forecast	Forecast Lookahead
9/17/2025 12:10 pm	97,111 MW	118 MW	6,229 MW	20 minutes
9/17/2025 12:30 pm	98,023 MW	128 MW	6,246 MW	40 minutes

Net-Load Forecast = Load Forecast – Wind Forecast – Solar Forecast

As forecasted for 12:10 pm:

- Net-Load Forecast = 97,111 MW – 118 MW – 6,239 MW = 90,754 MW

As forecasted for 12:30 pm:

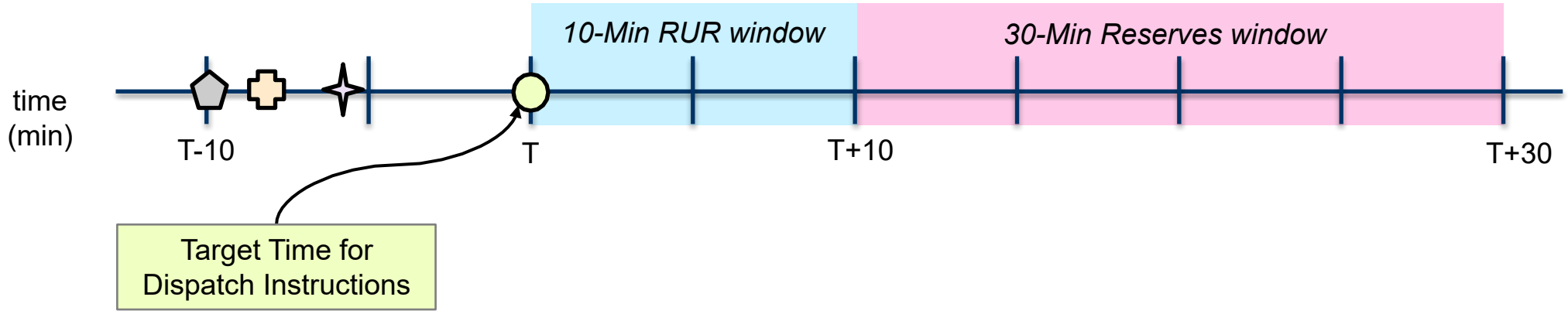
- Net-Load Forecast = 98,023 MW – 128 MW – 6,247 MW = 91,648 MW

Net-Load Ramp = Net-Load Forecast for 12:30pm – Net-Load Forecast for 12:10 pm

- Net-Load Ramp = 91,648 MW – 90,754 MW = **894 MW**

30-Min Reserve Uncertainty Component

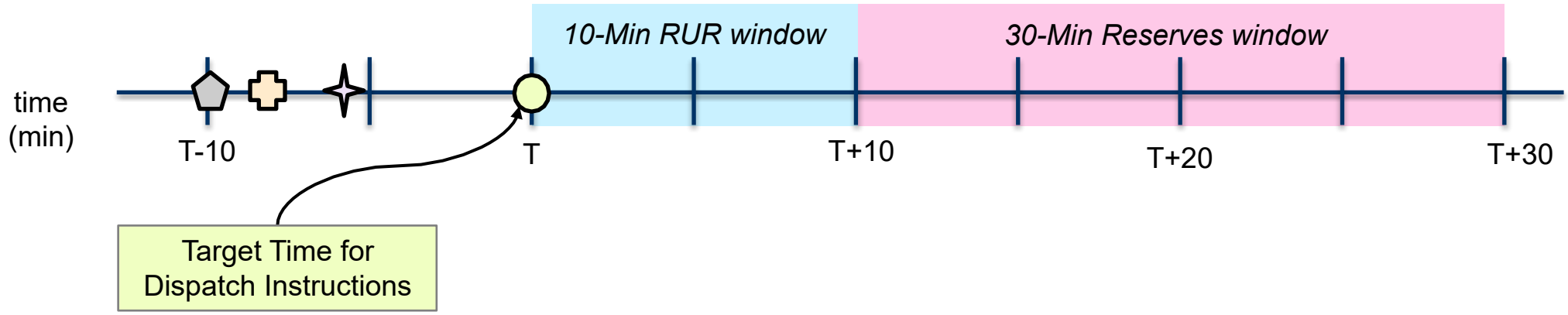
- The uncertainty component of the reserve requirement would be based on a historical analysis of the net-load forecast uncertainty for the relevant lookahead as described in the RCSTF presentation from September 17, 2025.
- For the 30-Min Reserve product, the goal is to calculate how much the forecast for *effective time* T+30 changes between *when it is evaluated at* T-10, when the reserves are procured, and *when it is evaluated at* T+10, which is the end of the window covered by the 10-Min RUR.



Reserve Forecast Timing for the 30-Min Reserve Uncertainty Calculation

For every T+30 interval of the year, PJM calculated the net-load forecast uncertainty for the 20 minutes beyond the 10-Min RUR window, by comparing the forecast *effective* at T+30 *as evaluated* at 1) T+10 and 2) T-10.

$$\text{Net-Load Forecast Uncertainty}_{T+30} = \text{Net-Load Forecast}_{T+30@T+10} - \text{Net-Load Forecast}_{T+30@T-10}$$



30-Min Reserve Uncertainty Component

Assuming a percent-uncertainty-based approach like the one used in DASR (the second approach in the September 17, 2025 RCSTF presentation), the percent uncertainty values would be calculated separately for load, wind and solar, and then multiplied by each of the forecasts for the appropriate target time.

	Load Forecast	Wind Forecast	Solar Forecast
9/17/2025 12:30 pm	98,023 MW	128 MW	6,247 MW

	30-Min Reserve		
Uncertainty Percentile	Load	Wind	Solar
95th	0.6%	2.7%	4.0%

30-Min Reserve Uncertainty Component

Uncertainty Component =
% Load Forecast Uncertainty x Forecasted Load +
% Wind Forecast Uncertainty x Forecasted Wind +
% Solar Forecast Uncertainty x Forecasted Solar

Uncertainty = 98,023 MW x 0.006 + 128 MW x 0.027 + 6,247 MW x 0.04

Uncertainty = 588 MW + 3 MW + 250 MW

Uncertainty = **841 MW**

	Load Forecast	Wind Forecast	Solar Forecast
9/17/2025 12:30 pm	98,023 MW	128 MW	6,247 MW

	30-Min Reserve		
Uncertainty Percentile	Load	Wind	Solar
95th	0.6%	2.7%	4.0%

30-Min Reserve MSSC Component

- The third component of the 30-Min Reserve requirement is the largest contingency component, which is based on the Most Severe Single Contingency (MSSC) on the system.
- The largest contingency at 12:00 pm on September 17, 2025 was 1,788 MW
- MSSC Component = **1,788 MW**

30-Min Reserve Requirement

- The total 30-Min Reserve Requirement would be the sum of the expected net-load ramp, uncertainty component and MSSC components.
- In this example for 12:00 pm September 17, 2025, that would be:

30-Min Req = Net-Load Ramp + Net-Load Uncertainty + MSSC

30-Min Req = 894 MW + 841 MW + 1,788 MW = **3,523 MW**

- Of this total requirement, the Net-Load Ramp and Net-Load Uncertainty components would need to be online.
  - 30-Min Online Req = 894 MW + 841 MW = **1,735 MW**

Synchronized and Primary Reserves

SR/ PR Reserve Requirement Definitions

Primary Reserves (PR)

Synchronized Reserves (SR)

Primary Reserve: 1.5 x Synchronized Reserve (and inclusive of SR)

Synchronized Reserve: Largest Single Active Contingency x Performance Adjustment

SR/PR Reserve Requirement

- The Synchronized Reserve Performance Adjustment is currently 30%
- The largest contingency at 12:00 pm on September 17, 2025 was 1,788 MW
- MSSC Component = 1,788 MW

Synchronized Reserve (SR) = Largest Single Active Contingency x Performance Adjustment

SR = 1,788 x 1.30 = 2,324 MW

Primary Reserve (PR) = 1.5 x Synchronized Reserve

PR = 2,324 x 1.5 = 3,487 MW

Note: *For simplicity, the 190 MW second step of the SR and PR ORDCs have not been included. Therefore, these requirements only represent the first step.*

Example Summary

The load, wind and solar forecasts for 12:00 pm September 17, 2025, as evaluated at 11:50 am were as follows:

	Load Forecast	Wind Forecast	Solar Forecast
9/17/2025 12:00 pm	96,673 MW	114 MW	6,220 MW
9/17/2025 12:10 pm	97,111 MW	118 MW	6,239 MW
9/17/2025 12:30 pm	98,023 MW	128 MW	6,247 MW

Total market clearing results for the 12:00 pm target time would have been:

Energy	96,673 MW
Synch Reserves*	2,324 MW
Primary Reserves*	3,487 MW
10-Min RUR	1,012 MW
30-Min Reserves	3,515 MW

**SR and PR are nested requirements, so PR is inclusive of SR.*

References and Data Sources

Five-Minute Forecast Data

- Load: https://dataminer2.pjm.com/feed/very_short_load_frcst/definition
- Wind: https://dataminer2.pjm.com/feed/five_min_wind_power_forecast/definition
- Solar: https://dataminer2.pjm.com/feed/five_min_solar_power_forecast/definition

More detail on the Uncertainty Quantification

- https://www.pjm.com/-/media/DotCom/committees-groups/task-forces/rcstf/2025/20250917/20250917-item-05---real-time-reserve-requirements.pdf

A companion spreadsheet has also been posted along with this meeting's materials that provides the calculations for the example used in this presentation.

Contact

Facilitator:
Lisa Morelli, Lisa.Morelli@pjm.com

Secretary:
Amanda Egan, Amanda.Egan@pjm.com

SME/Presenter:
Emily Barrett, Emily.Barrett@pjm.com

Real-Time Reserve Requirement Examples

Member Hotline

(610) 666 – 8980

(866) 400 – 8980

custsvc@pjm.com

Acronyms

Acronym	Term & Definition
SR	**Synchronized Reserves** are reserves provided by resources that are synchronized to the grid and can respond within 10 minutes.
PR	**Primary Reserves** are reserves provided by resources that are either synchronized or not synchronized to the grid and can respond within 10 minutes.
RUR	**Ramping/Uncertainty Reserves** are reserves that would be procured to manage forecasted ramp and uncertainty operational flexibility needs.
MW	A **Megawatt** is a unit of power equaling one million watts (1 MW = 1,000,000 watts) or one thousand kilowatts (1 MW = 1,000 KW).

PROTECT THE POWER GRID

THINK BEFORE YOU CLICK!

pjm

Be alert to malicious phishing emails.

Report suspicious email activity to PJM.

(610) 666-2244 / it_ops_ctr_shift@pjm.com

Appendix

Motivation: Simple 10-Min RUR Uncertainty Example

For this example, assume no uncertainty reserves are procured and PJM is only procuring reserves to manage the net-load ramp.

- At time T-10, PJM's economic dispatch engine sends energy and reserve instructions for target time T.
- The forecast for effective time T as forecasted at T-10 is 95 GW, meaning that energy instructions are sent out to dispatch the fleet to 95 GW.
- The forecast for effective time T+10 as forecasted at T-10 is 96 GW, and so PJM also sends reserve assignments for 1 GW of 10-Min RUR to ensure sufficient ramp is available to achieve 96 GW at T+10.
- However, 10 minutes later when time T occurs, the forecast for effective time T+10 increases from 96 GW to 98 GW, meaning that the 1 GW of ramp procured to manage the expected net-load ramp under-estimated the amount of ramp needed to serve net-load in the next 10 minutes, creating a potential reliability concern.
- It was impossible to know at time T-10 that the forecast for effective time T+10 was too low. Therefore, PJM is proposing to look at historical changes in the forecast as the effective time approaches to quantify its forecast uncertainty and inform reserve procurement quantities.