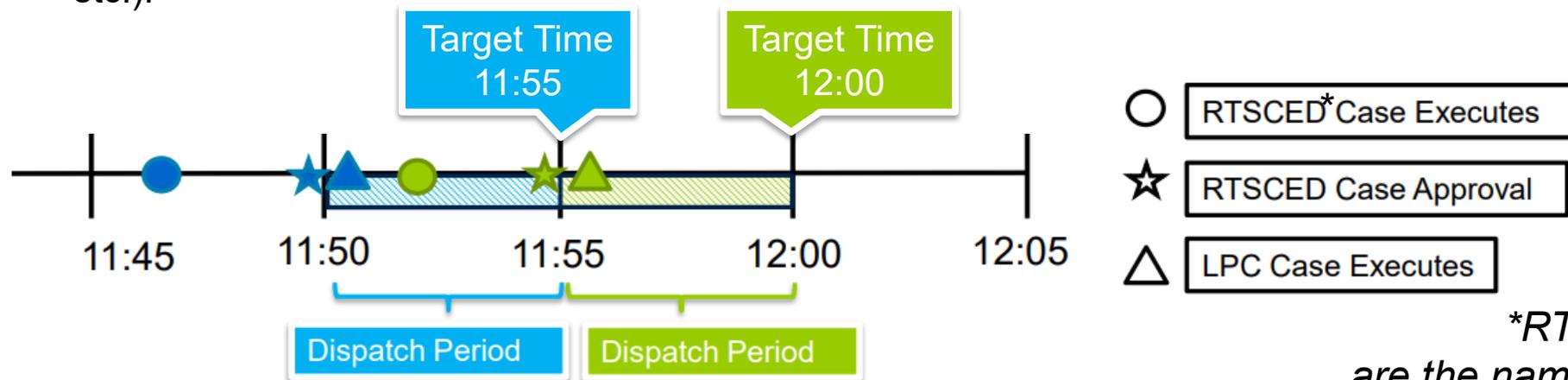


# Energy Market Practices for Intermittent Resources

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- The real time energy market is a location-based auction for electrical energy that is run every ~5 minutes. It is constrained to honor power limits of transmission facilities (and some other constraints).
  - The demand for real time energy is the measured real time load (including scheduled exports, etc.).
  - In general, the real time energy market auction covers the 5-minute interval that starts at the upcoming 5-minute mark (e.g., 1:20, 1:25, etc.). See diagram below.
- The day-ahead energy market is a forward auction for the real time energy market for each clock hour. All 24 hours of the next day are auctioned at once.
  - The demand for day-ahead energy is the bid-in demand of load serving entities (plus exporting buyers, reserves, etc.).



*\*RTSCED and LPC together are the name of the real-time auction*

- Offers to sell into an energy auction have three key pieces:
  - **Economic Minimum (ECOMIN)**—the least power the generator can provide.
  - **Economic Maximum (ECOMAX)**—the most power the generator can provide while online.
  - The **offer price**—the price at which the generator is willing to sell electricity in the target interval. This can be higher prices for higher quantities (an “offer curve”).
- Some sellers simply schedule their generation without otherwise participating in the real-time auctions. These are non-dispatchable.
  - There are various ways for a supplier to enter this status in real time and day ahead, but in effect, the Economic Minimum is equal to the Economic Maximum which are equal to their scheduled quantity, and their offer price is such that it always clears.
    - The Fixed Gen flag also accomplishes this in real time.
  - Most wind and solar resources are not in this category (that is, they are dispatchable).

- There are many other energy market parameters, e.g.:
  - Ramp rate
  - Start up cost
  - Minimum run time
  - No load
- These parameters are most relevant to the limited physical flexibility of steam and gas turbine generators.
  - E.g., at noon on a sunny day, a 100 MW solar resource can go from 100 MW to 0 MW (or vice versa) immediately via inverter controls.
- Under certain circumstances, certain types of resources are obligated to use PJM-established parameters unless they have received approval of an alternate value.

## What do Intermittent Resource Offers Look Like?

- **Intermittent Resource offers look the same as any offers from any other supplier.**
- The physical minimum power capability of an Intermittent Resource is often 0 MW.
  - In order to maximum profits under a variety of prices, an offered **ECOMIN of 0 MW would make sense** to reflect the physical capabilities.
  - The bid-in ECOMIN of a wind generator cannot be above their Capacity Interconnection Rights. In case of local transmission system overload, this allows the energy market to automatically clear a lower output level for the wind generator vs. if it had a higher ECOMIN.
- The maximum power capability in a given 5-minute interval is limited by the expected incoming wind or solar energy at the generator. That is, the forecasted output for the next 5-minute interval.
  - The owner of an Intermittent Resource can update their offered **ECOMAX in real time to reflect ongoing changes in their forecasted output in the next 5-minute interval.**
- It generally makes sense for Intermittent Resources to **offer at a price of around \$0 or less** to reflect short-run marginal costs. (Some subsidies or PPA arrangements mean the provider is willing to sell for less than \$0.)
  - Under certain circumstances, offer prices are limited to “Cost based offer” rules.

- Energy-only wind, solar, hydro (and any other type) resources may offer into the day ahead energy market for a variety of reasons (hedging, bilateral transactions, etc).
- Intermittent Resources that have a Capacity market obligation must offer into the day ahead energy market.
  - Such resources should make all of their physical capability available to PJM in the day ahead energy market. For wind and solar resources, this means their forecasted hourly output for the next day.
  - PJM makes a forecast for each wind and solar unit, and makes that forecast available to the provider in Markets Gateway for those units for use in day ahead offers.
- After the day ahead auction, providers are given a schedule of cleared quantities for each hour. The results include prices for each hour.



# Simplistic Illustration of Dispatchable Intermittent Resources\*

Assume an Intermittent Resource with a 0 MW ECOMIN, a \$0 offer price, and an ECOMAX that varies every 5 minutes to match the changing output forecast. Assume unlimited ramp rate. Assume no transmission losses.

- When the RTO (or even regional) LMP is positive, and there is no local congestion, the resource will likely clear the auction at their ECOMAX. Their “dispatch point” (i.e., their auction clearing quantity) will be at their ECOMAX.
  - Their actual output will probably be pretty close to the dispatch point, since dispatch is equal to ECOMAX, and ECOMAX is derived from forecast, and the t+5minute forecast is pretty good.
  - ECOMAX, dispatch, and output bounce up and down as resource availability varies.
- In the event that the local transmission system cannot accommodate all of the output of the resource, it will generally be dispatched down. If it is the only generator in this constrained pocket, it will generally set the local price at its offer of \$0.
  - LMPs are generated in the pricing run (“LPC”), while dispatch (of which SCED curtailment is a type) is generated in the earlier dispatch run (“SCED”).
- In the event RTO (or regional) LMP is below \$0, the resource will generally be dispatched to 0 MW.
- When a wind resource is dispatched downward, the “curtail flag” is set and communicated to the resource owner to clearly establish the need to reduce output.

*\*Actual auction outcomes are a product of complex and detailed circumstances and so may not match this simple scenario in all cases.*

- The Market Seller of any dispatchable generation type (including thermal generation and also Intermittent Resources) are charged Balancing Operating Reserves (BOR) charges when the actual metered output for an interval deviates from dispatch for that interval, as per Tariff Attachment K-Appendix Section 3.2.3 subsection (o).
  - Note that BOR charges are used to fund the cost of real time uplift, not synchronized reserves or any other reserve.
- Charges may apply when % off dispatch is  $> 10\%$  for any 5-minute interval.
  - If a resource has a sum of the absolute value of generator deviations for an hour that is less than 5 MWh, there are no charges for that hour.

- Intermittent Resources can be eligible for uplift compensation, especially lost opportunity cost payments, in case PJM needs them to produce at a lower level than indicated by the LMP at their bus relative to their offer price.
  - In that case, the resource is losing out on the profit they would make by generating at the higher level and earning LMP. This is the “lost opportunity cost”, roughly the gap between LMP and the offer price across the relevant quantities of the offer curve.
- For wind resources, the quantity used in the lost opportunity cost calculation is based on a wind backcast (rather than on ECOMAX and other offer parameters).
- A typical scenario for lost opportunity cost is overly high voltage on the local transmission network, which can only be addressed by reducing real power output. Since SCED cannot generally control for this condition, it is difficult to capture in LMP. Therefore, LMP remains high, but dispatch requires the unit to reduce output.
  - Other uplift scenarios are possible.

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## Energy Market Practices for Intermittent Resources



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