Intertemporal ORDC

EPFSTF

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Monitoring Analytics

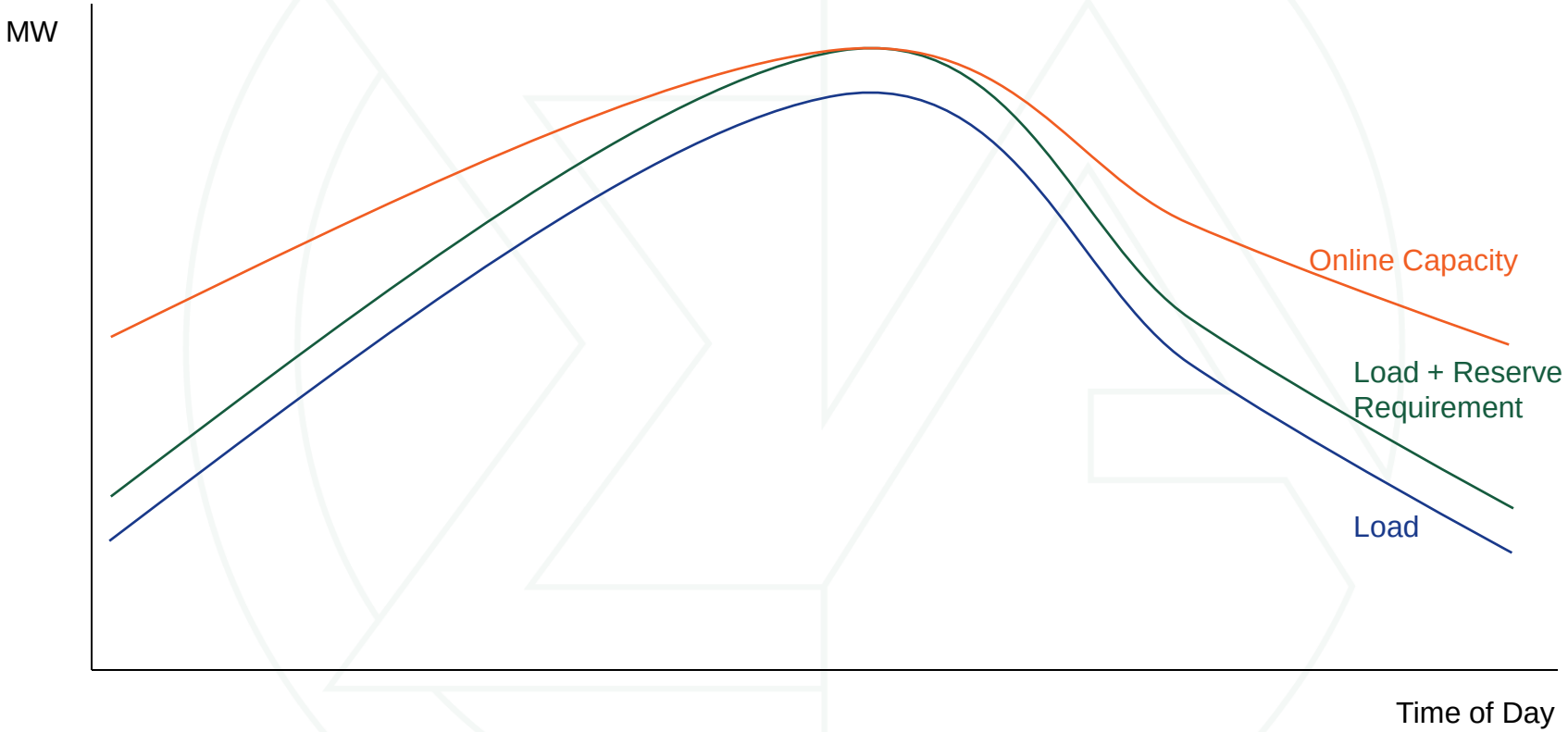
Price Formation and Scarcity Pricing

- **Underlying issue EPFSTF set out to address is the appropriateness of falling prices when load rises**
- **Real time unit commitments to meet increasing load or declining reserves can lower price when more capacity is brought online**
- **Capture some of the intertemporal dynamics of the market in the reserve demand curves (ORDCs)**
- **Support prices at times when additional reserves provide a more economic commitment though not necessary to meet the concurrent reserve requirement**

Daily Reserve Pattern

- **Reserve levels vary over the course of an operating day.**
  - **Ample reserves when load is low**
  - **Closer to reserve requirement when load peaks**
- **When load is low, reserves exceed requirement because the most economic commitment to meet load includes long minimum run time (baseload) units.**
- **The market commits the additional reserves for energy needs, not to meet concurrent reserve requirement.**

Daily Reserve Pattern



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Fluctuations in Supply and Demand

- **Suppose the total amount of reserves falls due to fluctuations in supply and demand.**
- **Possible outcomes:**
  1. **No impact because plenty of reserves**
  2. **Reserves fall below requirement**
  3. **No concurrent shortage, but market is tighter and more reserves are expected to be needed at some point**
- **Current ORDC addresses 1 and 2.**
- **Outcome 3. creates a demand for reserves that may lead to a real time unit commitment.**

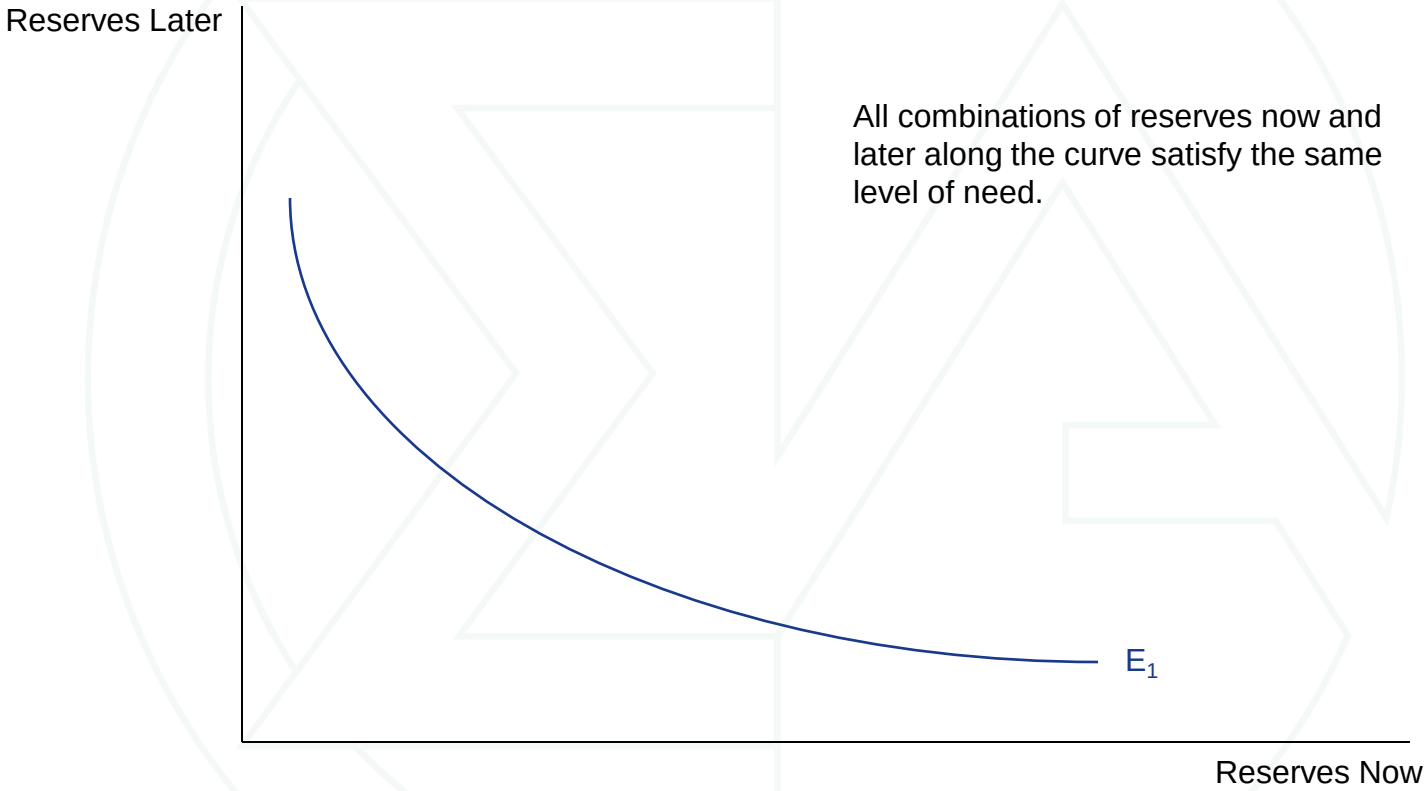
Demand for Additional Reserves

- Operator anticipates persistent falling reserves
- Need to bring more capacity online to maintain energy and reserves through the next peak period
- Can purchase more reserves now or later
- An economic approach to the decisions depends on
  - The relative effectiveness of reserves brought online now or closer to the peak period
  - The relative cost of reserves brought online now or closer to the peak period
- Demand is the expected cost savings of purchasing more now to avoid a higher cost later.

Effectiveness of Reserves Now and Later

- **Reserves purchased hours ahead of time may no longer be online later.**
- **Reserves purchased too close to when needed may not come online quickly enough.**
- **One MW of reserve purchased later, during the daily peak, provides one full MW of peak reserves.**
- **One MW of reserve purchased now may provide less than one MW of peak reserves.**
- **Reserve effectiveness is the probability that a MW of reserves now will meet the peak reserve requirement.**

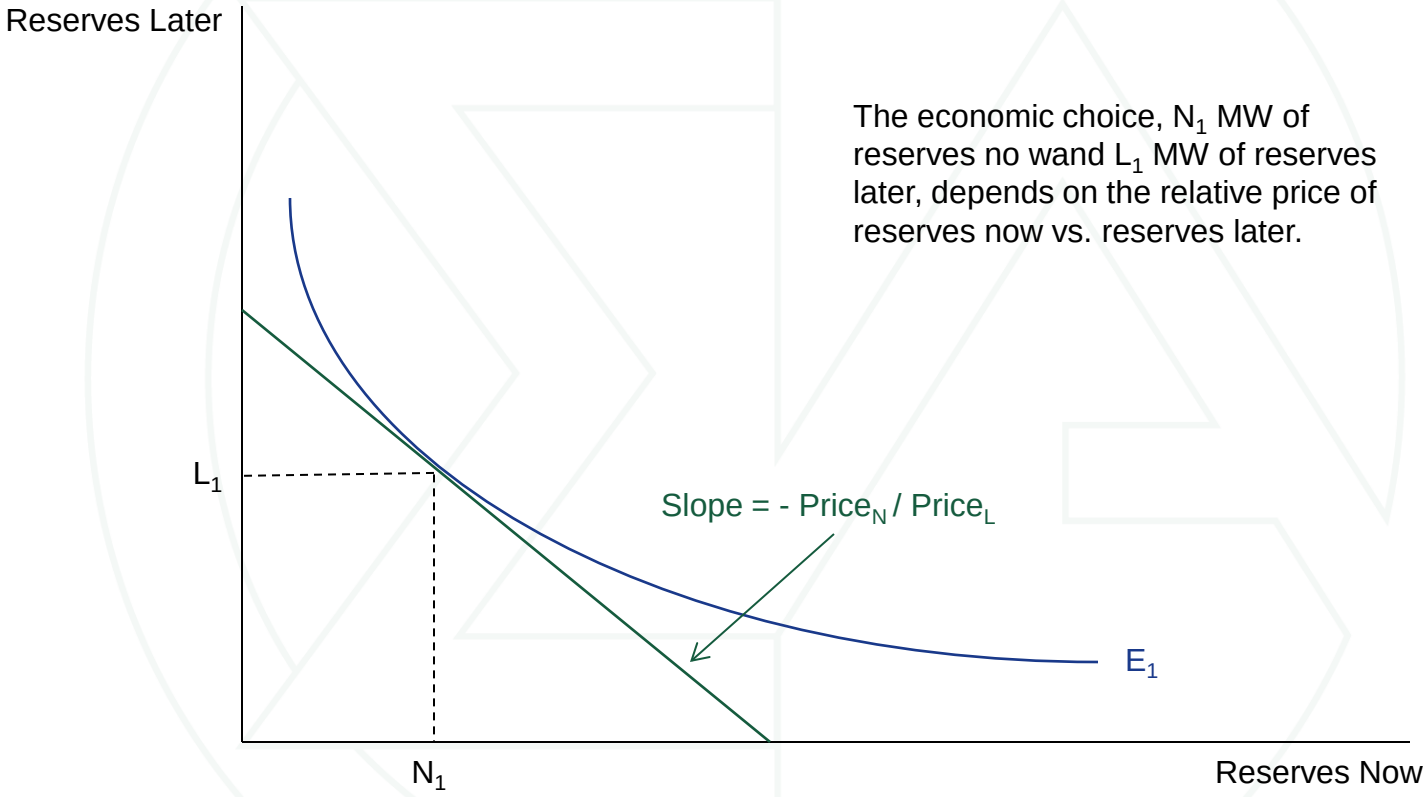
Effectiveness of Reserves Now and Later



Cost of Reserves Now and Later

- **The need for more reserves occurs later, during the peak period, when prices are higher.**
- **Prices are currently lower.**
- **As the relative price of reserves now versus later falls, purchase more now.**

Choice of Reserves Now and Later



The economic choice, N_1 MW of reserves no wand L_1 MW of reserves later, depends on the relative price of reserves now vs. reserves later.

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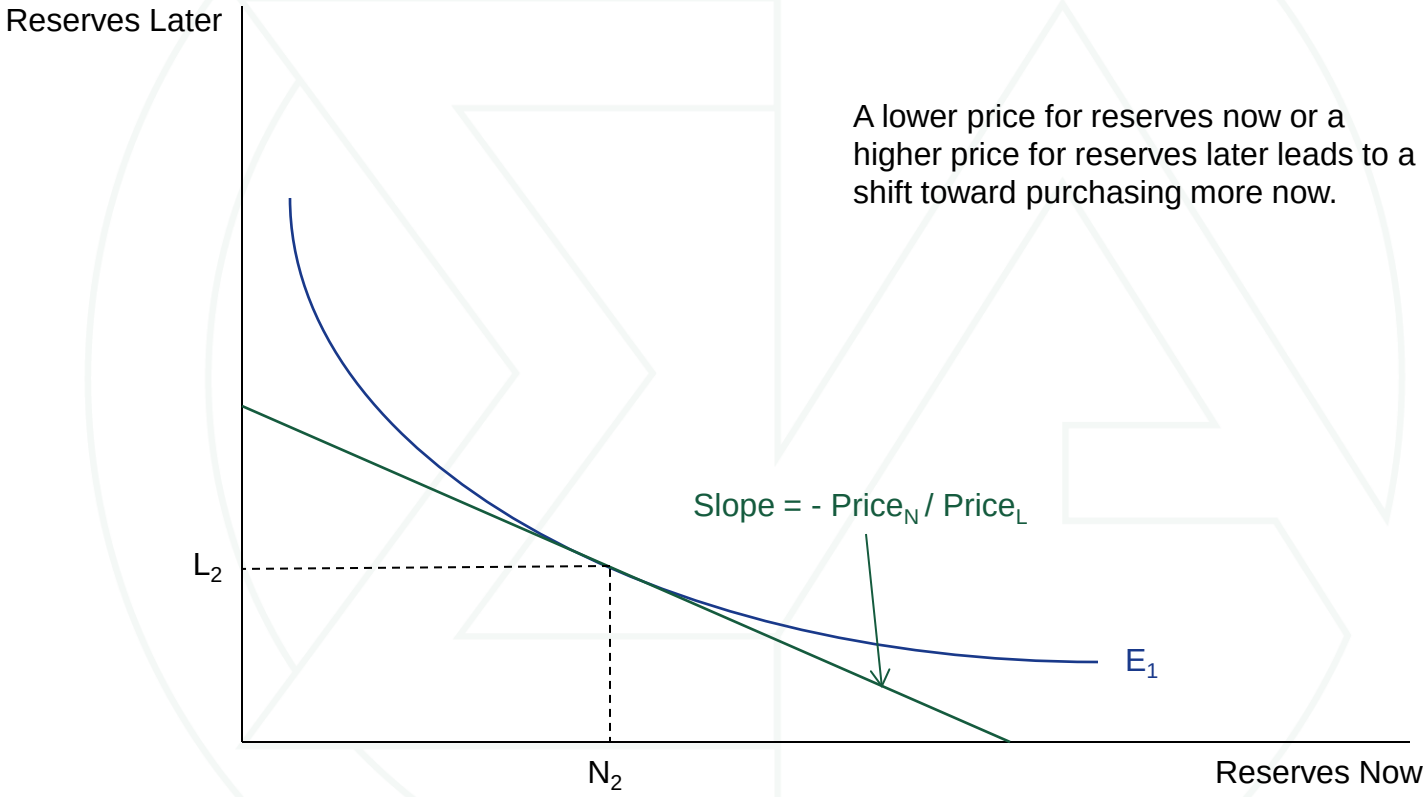
Choice of Reserves Now versus Later

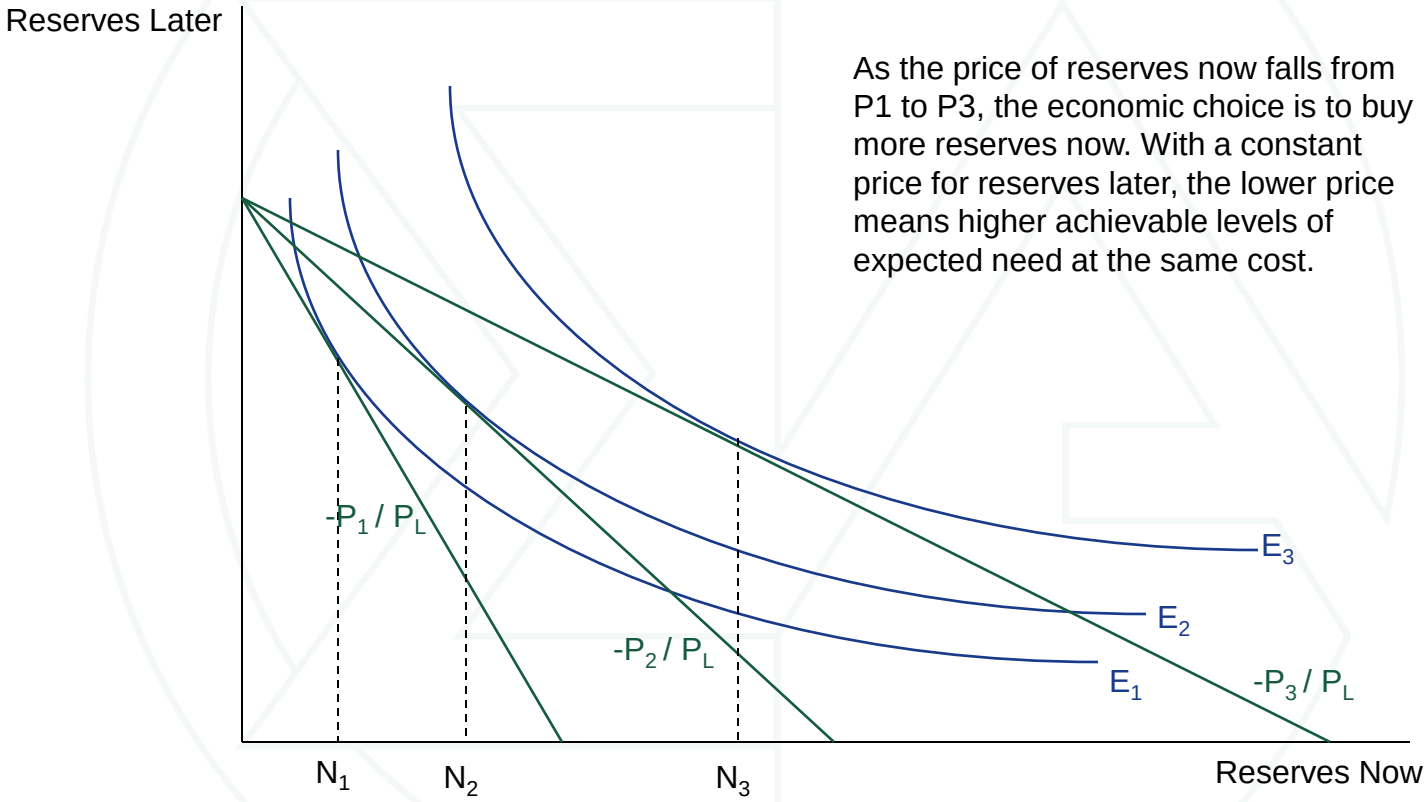


Deriving Demand for Reserves Now and Later

- **The relationship between the increasing economic purchase of reserves now and the falling price of reserves now is the demand curve for additional reserves now.**
- **The demand curve equates the relative effectiveness per dollar of reserves now to the relative effectiveness per dollar of reserves later.**

$$\frac{Effectiveness\ Now}{Price\ Now} = \frac{Effectiveness\ Later}{Price\ Later}$$

Deriving Demand for Reserves Now and Later



As the price of reserves now falls from P1 to P3, the economic choice is to buy more reserves now. With a constant price for reserves later, the lower price means higher achievable levels of expected need at the same cost.

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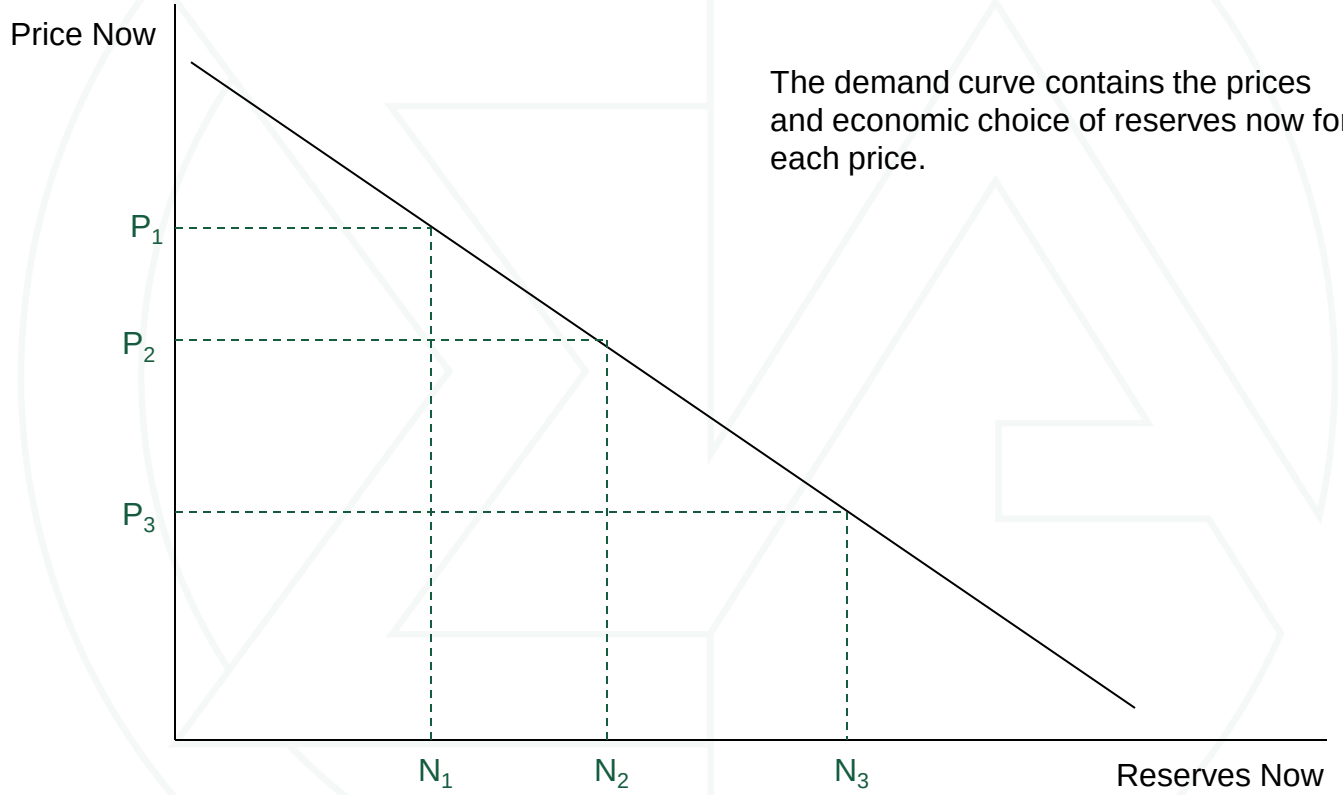
Deriving Demand for Reserves Now and Later



The demand curve contains the prices and economic choice of reserves now for each price.

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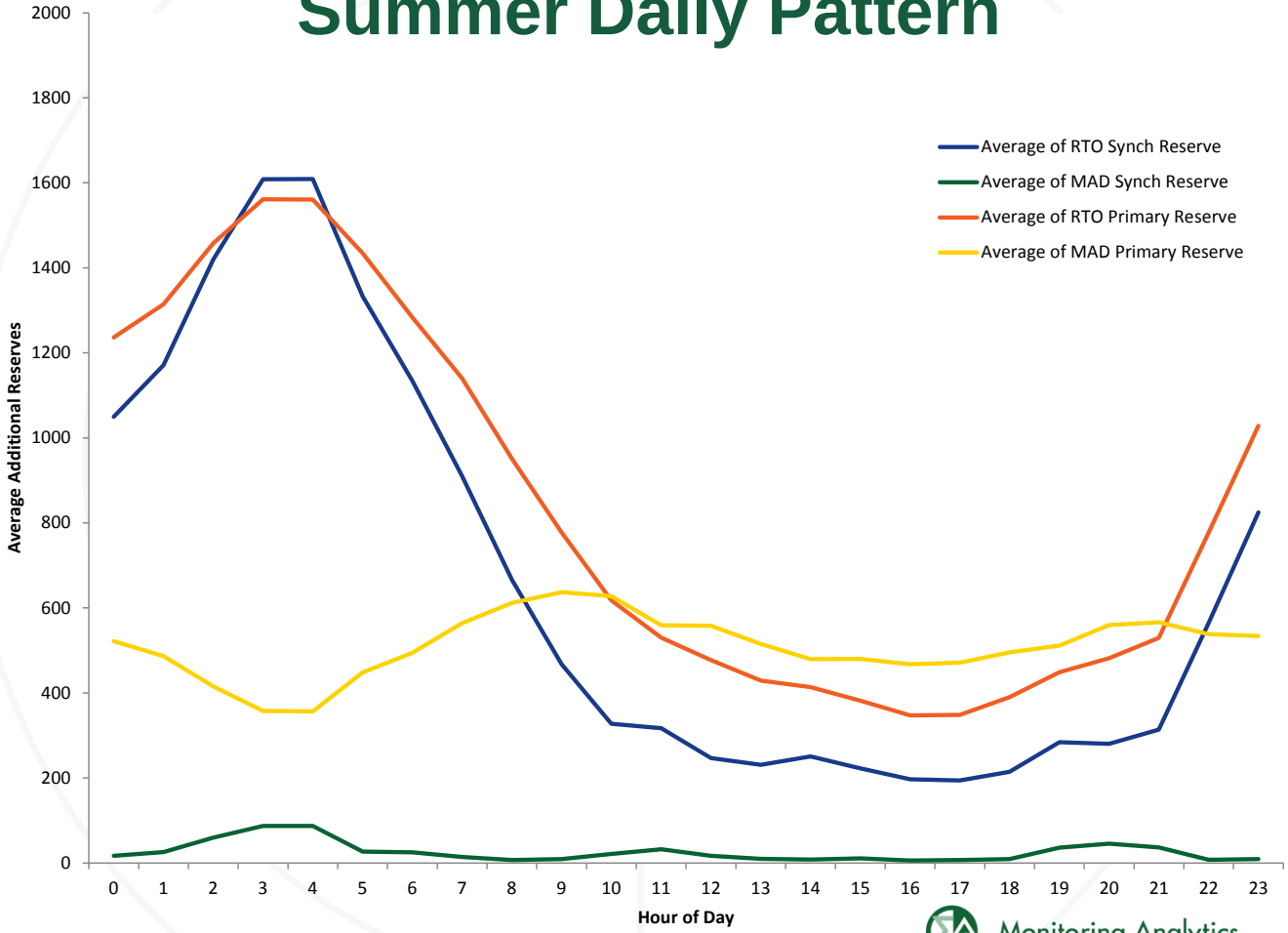
Historical PJM Reserves

- **IMM analyzed historic five minute reserves for 2015, 2016, and 2017.**
- **Average hourly reserves varied from small shortages to more than 1,600 MW above the requirement.**
- **Daily reserve patterns vary by season.**

Summer Daily Pattern



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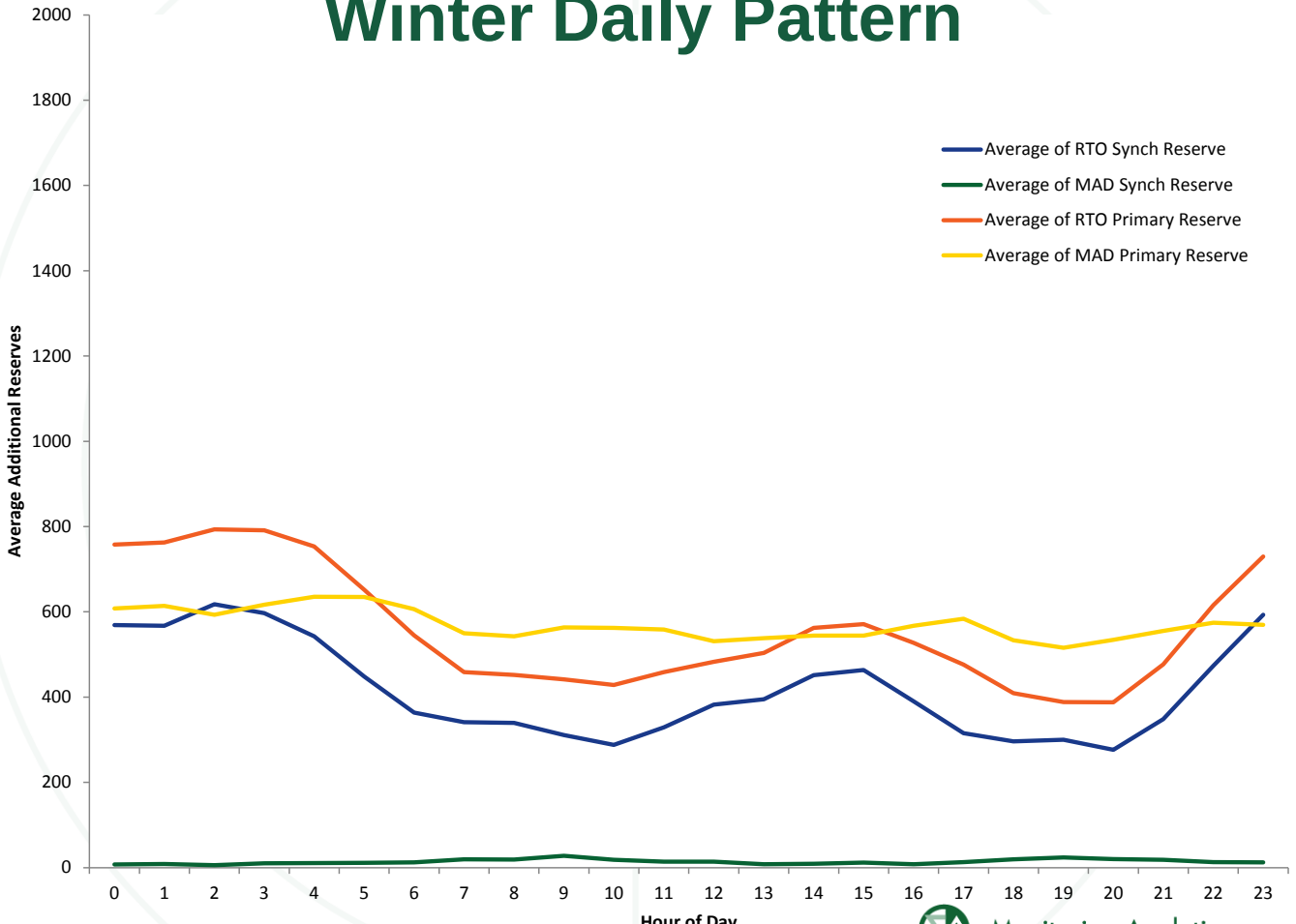
Winter Daily Pattern



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Tight Days

- **Tight days are days when reserves fall close to the reserve requirement during peak load periods.**
- **Tight day definition: primary reserves within 150 MW of the reserve requirement for 36 five minute intervals during the peak hours of the day**
- **Tight days include:**
  - **Annual peak load days in 2015, 2016, and 2017**
  - **Winter peak load days in 2015 and 2017**
  - **Highest balancing uplift days 2016 and 2017**

Days with Tight Peak Periods by Season and Load Level 2015, 2016, and 2017

Season	Load Level	Tight Days	Percent of Days
Fall	Over 125 GW	11	68.8%
Summer	Over 125 GW	56	50.9%
Summer	100 to 125 GW	64	45.7%
Winter	100 to 125 GW	78	45.3%
Winter	85 to 100 GW	33	43.4%
Fall	0 to 85 GW	15	38.5%
Fall	100 to 125 GW	22	37.3%
Fall	85 to 100 GW	57	35.8%
Spring	0 to 85 GW	19	32.8%
Spring	100 to 125 GW	17	30.9%
Winter	Over 125 GW	6	30.0%
Summer	85 to 100 GW	6	23.1%
Spring	85 to 100 GW	35	21.6%
Spring	Over 125 GW	-	0.0%
Winter	0 to 85 GW	-	0.0%

Calculating the Benefit of Additional Reserves

- **Some probability of a tight day regardless of the level of reserves.**
- **As reserves shrink, the probability of a tight day should increase.**
- **The purchase of more reserves can decrease the probability of a tight day.**
- **Relative effectiveness of a reserve purchase now instead of later is**
  - **Probability of a tight day given the reserve level now**
  - **Minus the overall probability of a tight day**

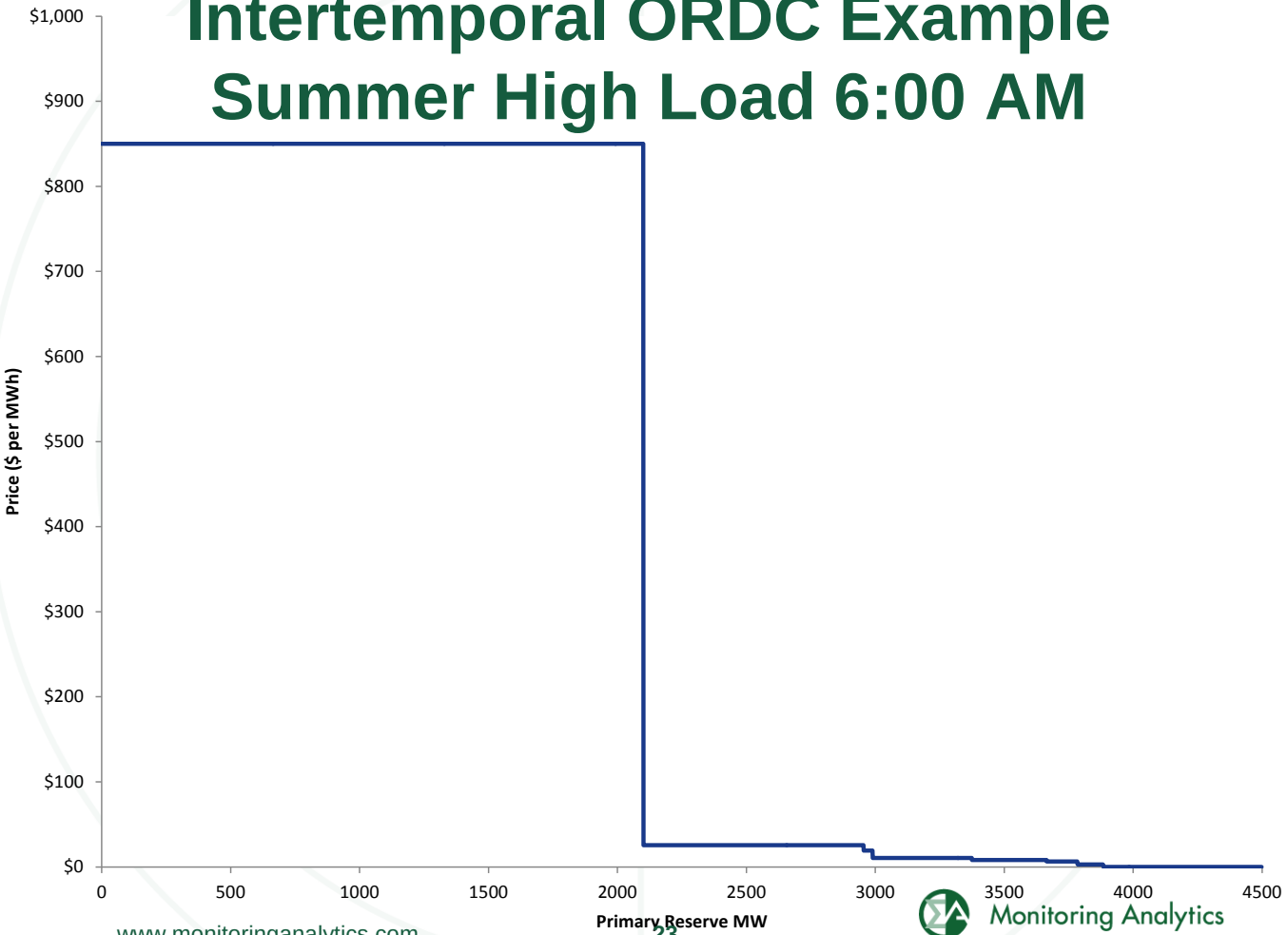
The Cost of Additional Reserves

- **The cost of additional reserves during the peak period is no greater than the peak period LMP, which is the next best option for available capacity.**
- **Multiplying the cost by the relative effectiveness of reserves now vs. later provides the willingness to pay for more reserves now.**

Deriving the Cost of Reserves at Peak from the Percent of Tight Days Given the Reserve Level at 6:00 AM for Summer High Load Days

Additional Reserve MW	Percent of Tight Days Given Reserve Level at 6:00 AM	Difference in Percent Tight Days Given Reserve Level and Overall	Peak Hour Average LMP	Willingness to Pay for Additional Reserves
840	71.4%	36.0%	$71.00	$25.57
855	62.5%	27.1%	$71.00	$19.23
890	50.0%	14.6%	$71.00	$10.35
1,275	46.9%	11.5%	$71.00	$8.14
1,565	44.4%	9.0%	$71.00	$6.41
1,685	39.5%	4.1%	$71.00	$2.92
1,785	37.8%	2.4%	$71.00	$1.68
1,890	37.0%	1.5%	$71.00	$1.09
2,052	36.2%	0.8%	$71.00	$0.54
2,238	35.4%	0.0%	$71.00	$0.00

Intertemporal ORDC Example Summer High Load 6:00 AM



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