Seasonal Auction Clearing: Detailed Walkthrough

RASTF – CIFP

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Overview

Seasonal Auction Clearing – Detailed Walkthrough

1. Seasonal Demand Curves
2. Seasonal Supply Offer Curves and Seasonal Clearing
3. Adjustments to fit to an Annual VRR curve ("Seasonal Demand + Annual VRR Approach")

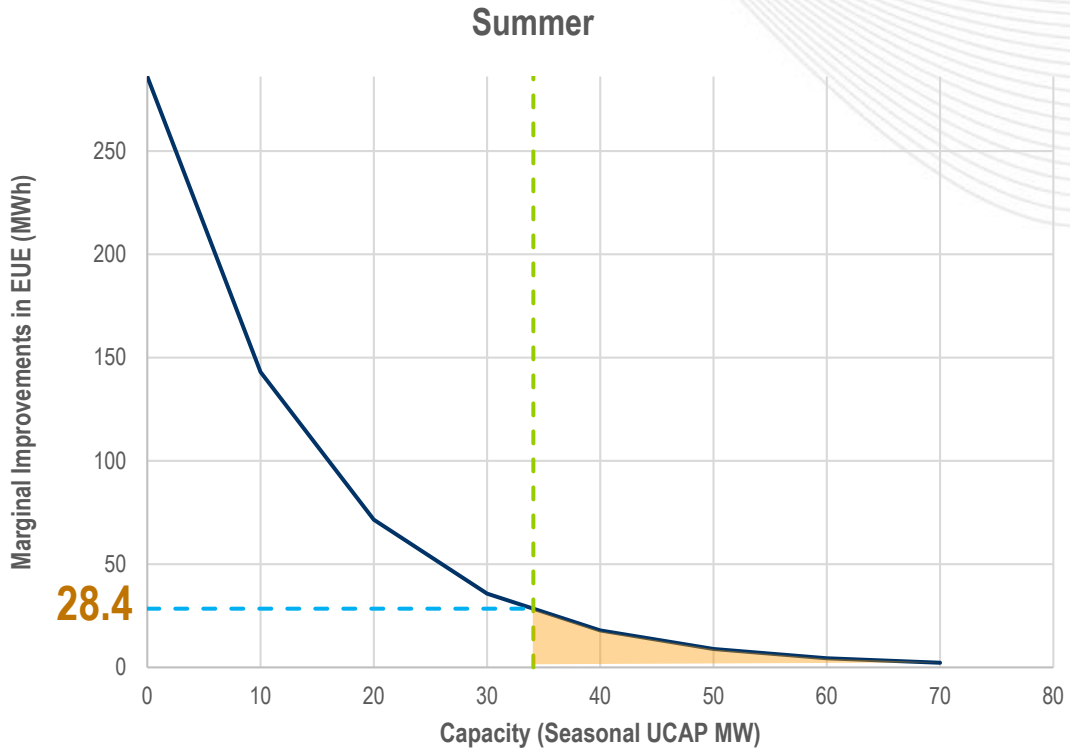
Objective: Review PJM proposed approach to determining supply and demand inputs in the proposed seasonal capacity market framework, and to clearing the auction to select lowest-cost seasonal and annual resources to maximize efficiency of the market clearing outcomes.

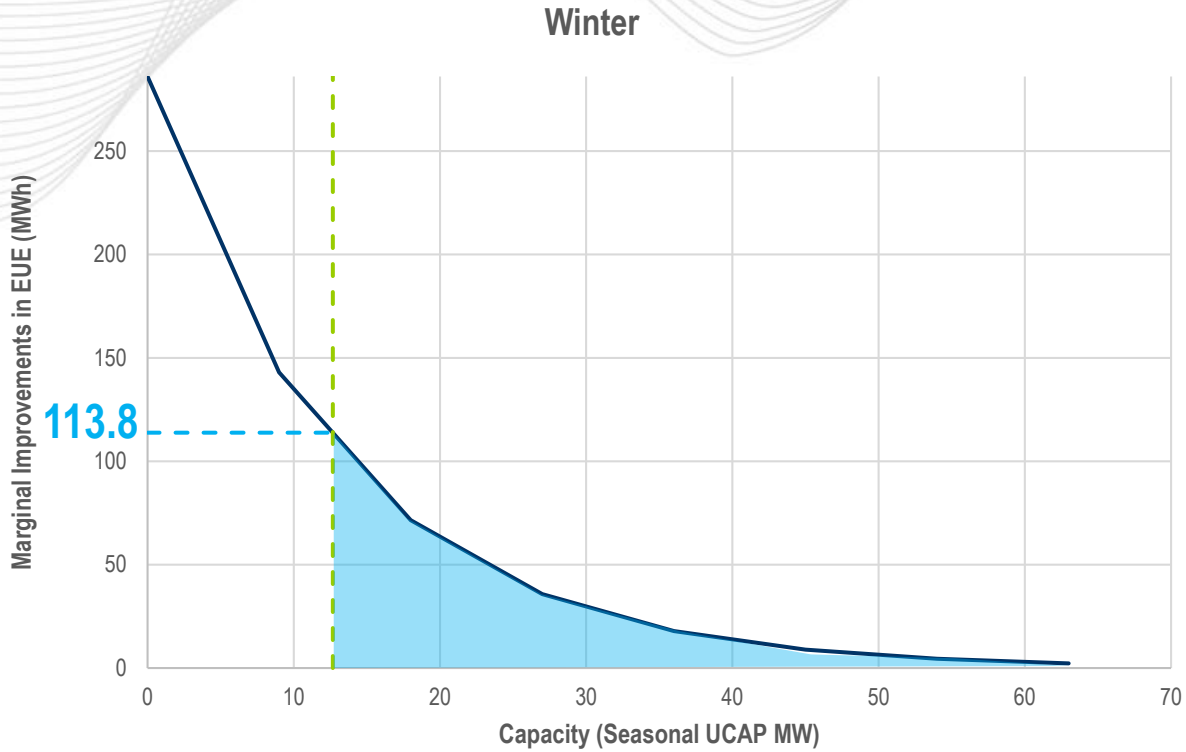
Seasonal Demand Curves

Seasonal Demand Curves: Overview

- **Seasonal Demand Curves** reflect willingness to pay for seasonal capacity
  - Reliability target based on modeled assumptions (resource mix, unit performance, weather patterns, etc.).
  - Each seasonal curve is calculated as the derivative of EUE with respect to seasonal capacity (dEUE/dQ).
  - The marginal reliability impact of an increment of capacity in each season is equal to the expected number of MWh of unserved energy that such capacity can serve (i.e., 1 MW x LOLH hours).
- At the expected reliability requirement there are a certain number of EUE MWh expected in each season. The sum of the expected EUE MWh, at the reliability requirement, equals the 1-in-10 equivalent standard.

Seasonal Demand Curves: Expected Modeled EUE Allocation





$mEUE_{Summer} = 28.4\ MWh$

$mEUE_{Summer}\ Risk = 20\%$

$\sum EUE_{Summer} = 372\ MWh$

$mEUE_{Winter} = 113.8\ MWh$

$mEUE_{Winter}\ Risk = 80\%$

$\sum EUE_{Winter} = 1{,}428\ MWh$

$$\boldsymbol{EUE_{Annual} = 372\ MWh + 1{,}428\ MWh = 1{,}800\ MWh}$$

Seasonal Demand Curves: Adjust for the Reference Resource

- **Reference Resource Net CONE** is used to convert the marginal EUE curves from MWh/MW UCAP to $/MW UCAP
  - **Objective**: Determine the willingness to pay for incremental capacity for each season such that (1) the Reference Resource covers annual Net CONE at the seasonal targets, while (2) appropriately reflecting relative reliability value of capacity in each season.
  - **Approach:** Convert the annual Reference Resource's Net CONE from $/MW-Day ICAP to a Seasonal $/MW-Day UCAP based on relative seasonal mEUE at the Reliability Requirement.
- **Factors needed for conversion:**
  - **Net CONE** – Tariff approved value
  - **Seasonal ELCC accreditation** – Output from probabilistic model
  - **Expected Seasonal mEUE risk weight** – Calculated on the previous slide

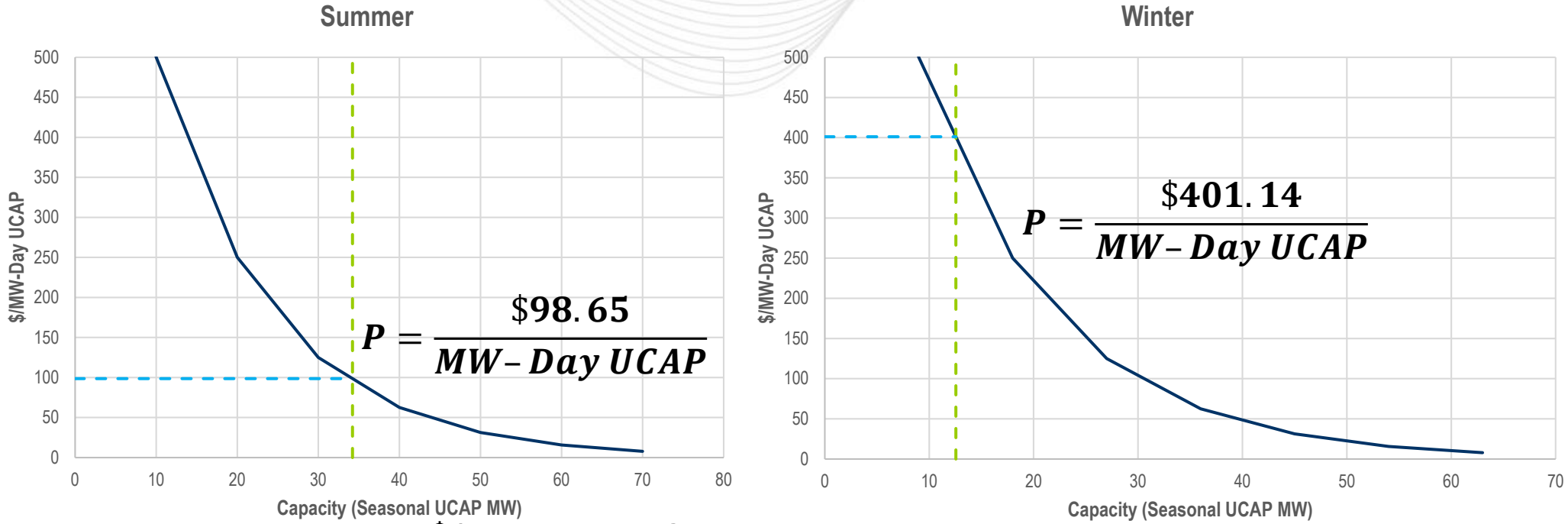
Seasonal Demand Curves: Reference Resource Conversion

	Summer	Winter	Annual
ICAP	1,000 MW	1,000 MW	1,000 MW
Net CONE ICAP			$184/MW-Day ICAP
Seasonal ELCC Accreditation	90%	70%	
Seasonal UCAP $ICAP \times ELCC_{Season}$	900 MW	700 MW	
Expected Seasonal mEUE Risk Weight	20%	80%	
Annual UCAP Contribution $UCAP_{Season} \times mEUE_{Seasonal\ Share}$	180 MW	560 MW	740 MW
Net CONE UCAP	$98.65/MW-Day Summer UCAP $Annual\ Net\ CONE_{UCAP} \times mEUE_{Seasonal\ Share} \times \frac{365}{184}$	$401.14/MW-Day Winter UCAP $Annual\ Net\ CONE_{UCAP} \times mEUE_{Seasonal\ Share} \times \frac{365}{181}$	$248.65/MW-Day UCAP $\frac{Annual_{ICAP}}{Annual_{UCAP}} \times \frac{Net\ CONE\ \$}{MW-Day\ ICAP}$

The Seasonal Net CONE prices are set to the reliability requirement for each Seasonal Demand Curve.

The "$\frac{365}{X}$" factor reflects numbers of days in the year over number of days in the season.

Seasonal Demand Curves: Seasonal Demand Curves Adjustment



- Convert the vertical axis to $/MW-Day UCAP by setting the reliability requirement intersection for each curve to the calculated Seasonal Net CONE of the Reference Resource.
- **Seasonal Demand Curves are set!**

Seasonal Supply Offer Curves and Seasonal Demand Curves Clearing

Seasonal Offer Structure

- Each resource is enabled to offer in a way that best reflects its economic going-forward avoidable costs of selling capacity and taking on a capacity obligation:
  - **Summer offer component:** reflects costs avoidable only if not committed for summer commitment period.
  - **Winter offer component:** parallel with summer.
  - **Annual offer component:** reflects costs avoidable only if not committed in either season. *May be zero if resource plans continued operation and relevant costs (CPQR, etc.) of a capacity commitment are seasonal and included in seasonal offer components.*

(Simplified) Illustrative Examples

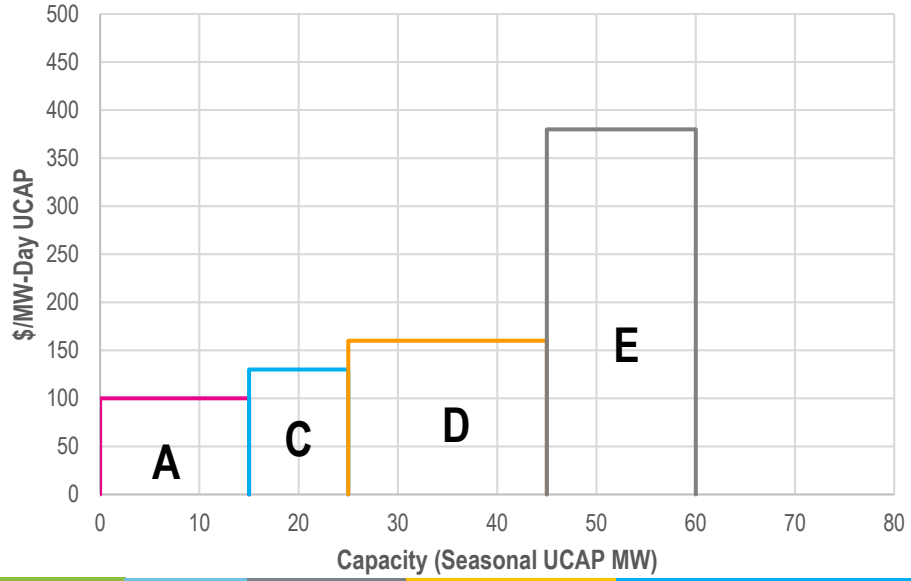
Example Resource	Offer Structure
Resource with qualified & accredited capacity in summer only ("summer only resource")	Includes all costs in summer offer component
Resource with qualified & accredited capacity in both seasons ("annual resource") whose avoidable costs are incurred for continued operation, but is indifferent to receiving revenues in one or both seasons, AND is indifferent to receiving commitment in one or both seasons	Includes all costs in annual offer component; seasonal offer components equal zero
Annual resource who plans to continue operation whose avoidable costs are entirely attributable to one season or the other	Separate all costs into summer and winter costs; annual offer component equals zero
Annual resource who incurs some costs it could avoid if uncommitted in both seasons, and other costs it could avoid if uncommitted in one season or the other	Provide non-zero offer summer, winter, and annual offer components reflecting costs

Example 1: Only Seasonal Offers

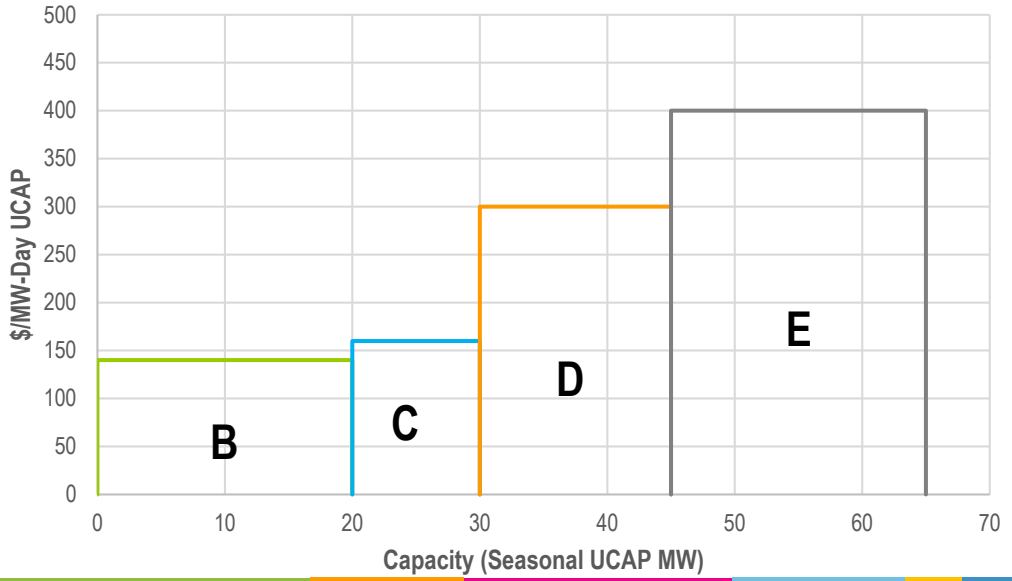
- Each resource only offers as a seasonal resource based on accredited UCAP MW and costs avoidable if not committed for that season.
- Resources can have different accredited UCAP MW depending on the season.

	Accredited UCAP MW		Offer $/MW-Day UCAP	
Resource	Summer	Winter	Summer	Winter
A	15		$100	
B		20		$140
C	10	10	$130	$160
D	20	15	$180	$300
E	15	20	$380	$400

Summer



Winter

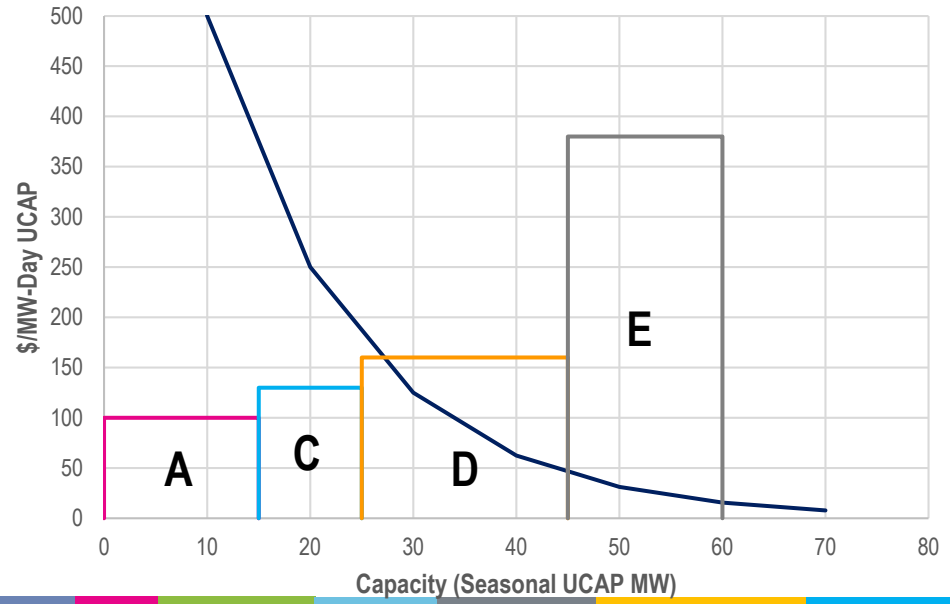


Example 1: Only Seasonal Offers + Demand

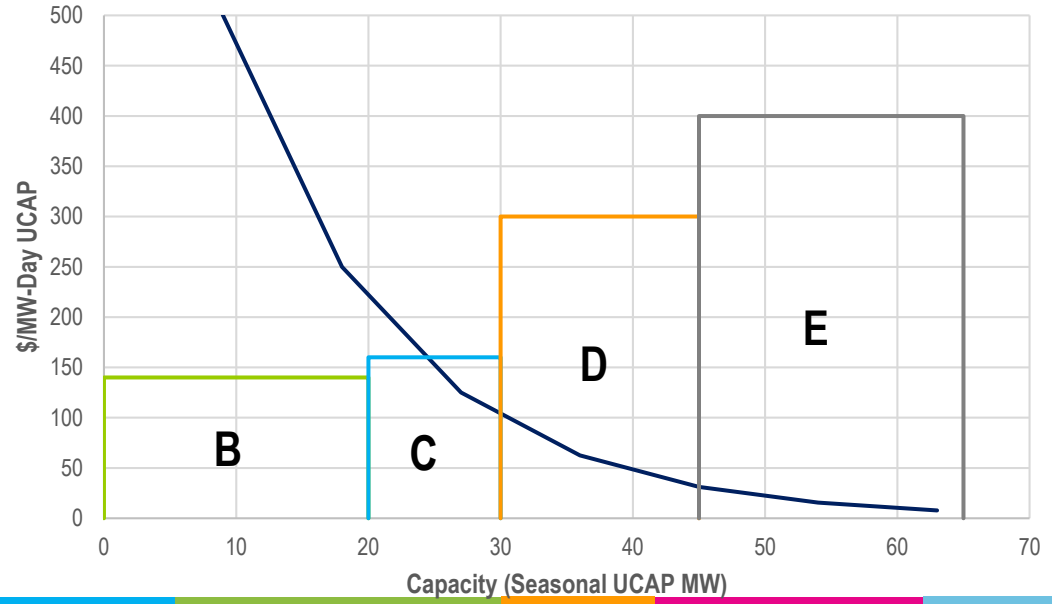
- All offers are flexible, meaning any amount of MW can clear.
- Example with only Seasonal offers is intuitive to understand.
- Resource D is marginal in Summer, and Resource C is marginal in Winter

	Accredited UCAP MW		Offer $/MW-Day UCAP	
Resource	Summer	Winter	Summer	Winter
A	15	0	$100	
B	0	20		$140
C	10	10	$130	$160
D	20	15	$180	$300
E	15	20	$380	$400

Summer



Winter



Example 1: Clearing Results

	Summer Auction Results		Winter Auction Results	
Clearing Price ($/MW-Day UCAP)	**$180**		**$160**	
	Cleared Summer MW (UCAP)	Summer Daily Revenue	Cleared Winter MW (UCAP)	Winter Daily Revenue
A	15 MW	$2,700 per day		
B			20 MW	$3,200 per day
C	10 MW	$1,800 per day	5 MW	$800 per day
D	3 MW	$540 per day		
E				
Total	**28 MW**	**$5,040 per day**	**25 MW**	**$4,000 per day**

Example 2: Seasonal and Annual Offers

	ICAP	Accredited UCAP		Offer $/MW-Day ICAP (Season)		Offer $/MW-day ICAP (Annual)	Offer $/MW-Day UCAP (Season)	
Resource		Summer	Winter	Summer	Winter		Summer +maximum annual	Winter +maximum annual
	[1]	[2]	[3]	[4]	[5]	[6]	$\frac{[4]\times[1]}{[2]}+\left(\frac{[6]\times[1]}{[2]}\times 2\right)$	$\frac{[5]\times[1]}{[3]}+\left(\frac{[6]\times[1]}{[3]}\times 2\right)$
A	16	13	0	$65.00			$80	
B	5	0	4		$80.00			$100
C	6	5	5			$50.00	$120	$120
D	12	5	10	$66.67	$108.33	$25.00	$160+$120	$130+$60
E	25	15	20	$120.00	$176.00		$200	$220

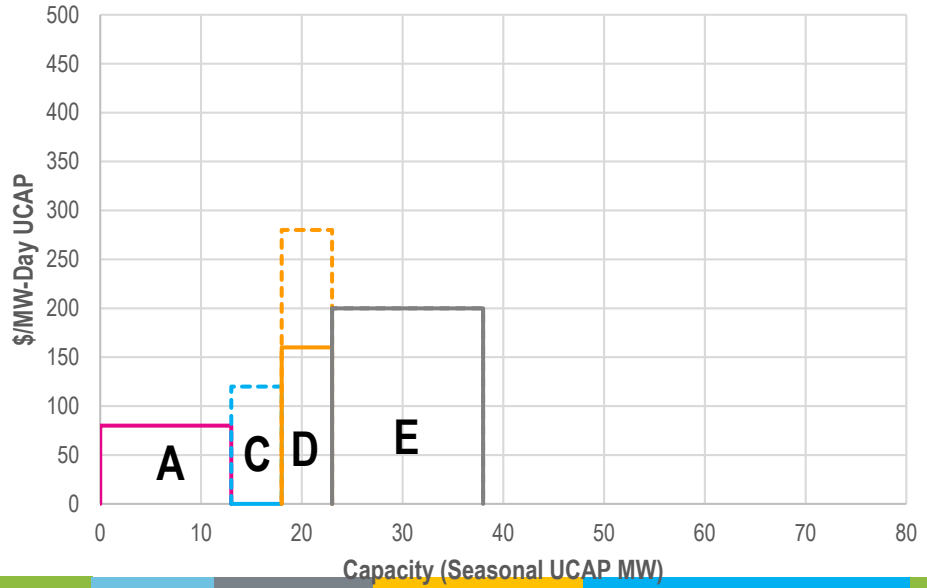
- Resources would input offers based on ICAP and $/MW-Day ICAP per season and annually.
- Maximum annual offer component reflects costs that would need to be recovered in a single season if the other season did not contribute to recovery of annual costs.
- Simplified $\frac{365}{X}$ to $\frac{365}{182.5}$ when calculating the maximum annual offer component (just for example).

Example 2: Seasonal and Annual Offers, *Continued*

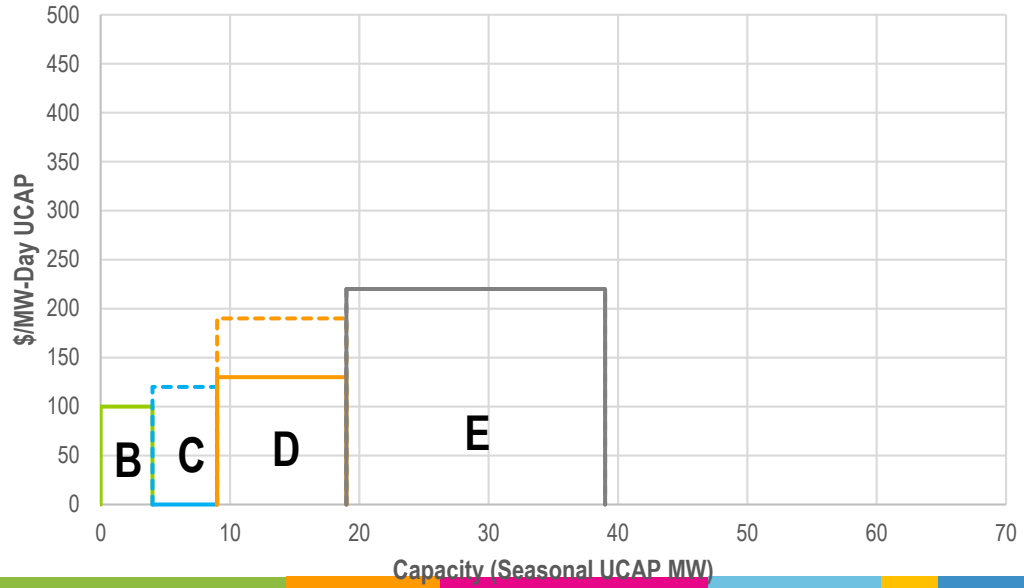
- Each resource offers as a seasonal, annual, or combination of seasonal and annual resource for costs avoidable if not committed for that season or annually.
- Annual offers represent the total cost required to operate for the entire Delivery Year. Dollars earned in one season reduce the dollars needed in the other season to meet the Annual offer.

	Accredited UCAP		Offer $/MW-Day UCAP	
Resource	Summer	Winter	Summer +maximum annual	Winter +maximum annual
A	13	0	$80 (S)	
B	0	4		$100 (W)
C	5	5	$120 (A)	$120 (A)
D	5	10	$160 (S) +$120 (A)	$130 (W) +$60 (A)
E	15	20	$200 (S)	$220 (W)

Summer



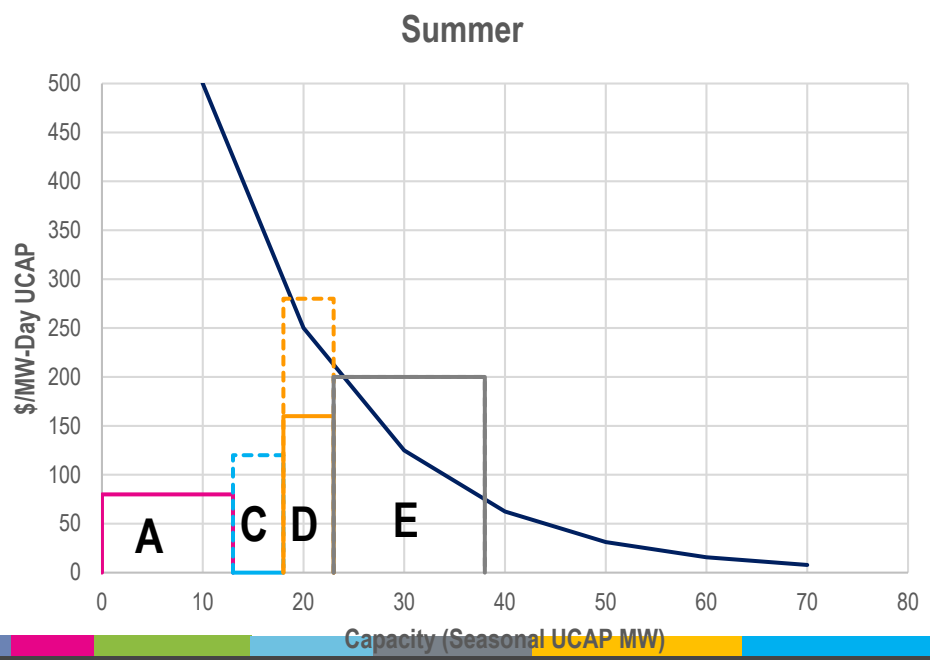
Winter

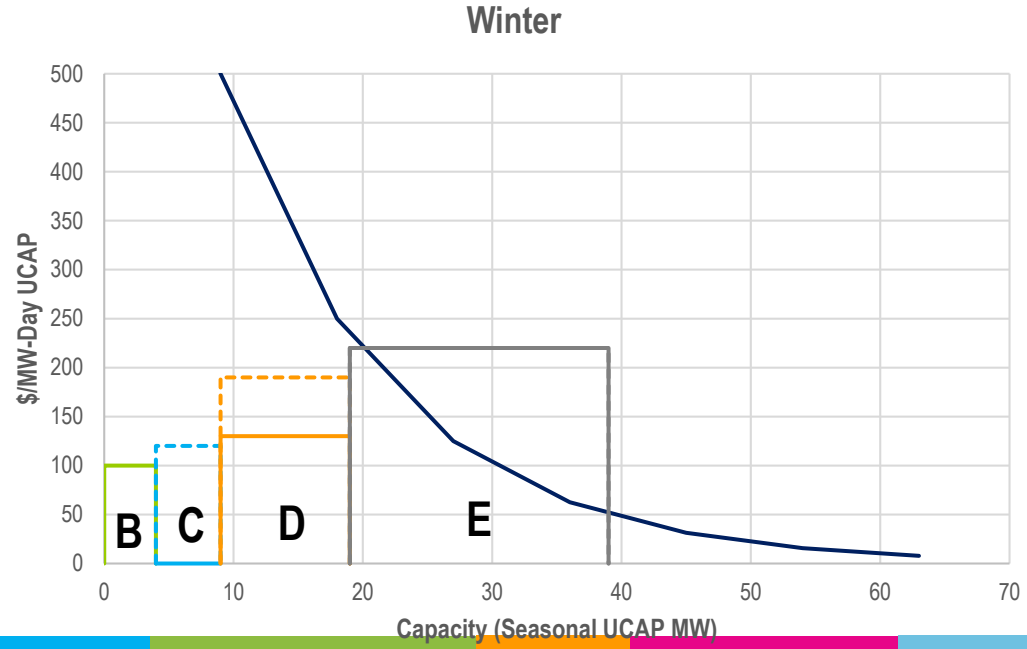


Example 2: Seasonal and Annual Offers + Demand

- All offers are flexible, meaning any amount of MW can clear.
- Resource D fully clears in Winter, allowing Resource D to also fully clear in Summer.
- Resource E is marginal in Summer and Winter

	Accredited UCAP		Offer $/MW-Day UCAP	
Resource	Summer	Winter	Summer +maximum annual	Winter +maximum annual
A	13	0	$80 (S)	
B	0	4		$100 (W)
C	5	5	$120 (A)	$120 (A)
D	5	10	$160 (S) +$120 (A)	$130 (W) +$60 (A)
E	15	20	$200 (S)	$220 (W)





Example 2: Clearing Results

	Summer Auction Results		Winter Auction Results	
Clearing Price ($/MW-Day UCAP)	**$200**		**$220**	
	Cleared Summer MW (UCAP)	Summer Daily Revenue	Cleared Winter MW (UCAP)	Winter Daily Revenue
A	13 MW	$2,600 per day		
B			4 MW	$880 per day
C	5 MW	$1,000 per day	5 MW	$1,100 per day
D	5 MW	$1,000 per day	10 MW	$2,200 per day
E	1 MW	$200 per day	1 MW	$220 per day
Total	**24 MW**	**$4,800 per day**	**20 MW**	**$4,400 per day**

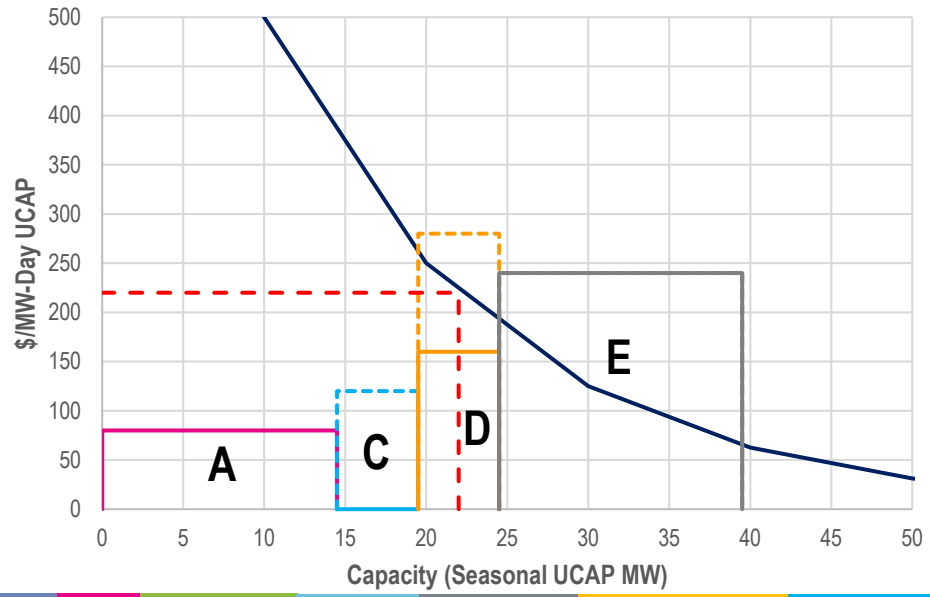
- Resource D's marginal value exceeded both its seasonal and annual costs.
- Resource D's annual costs are fully covered in winter, therefore it only required the summer offer component in order to clear.

Example 3: Seasonal and Annual Offers + Demand

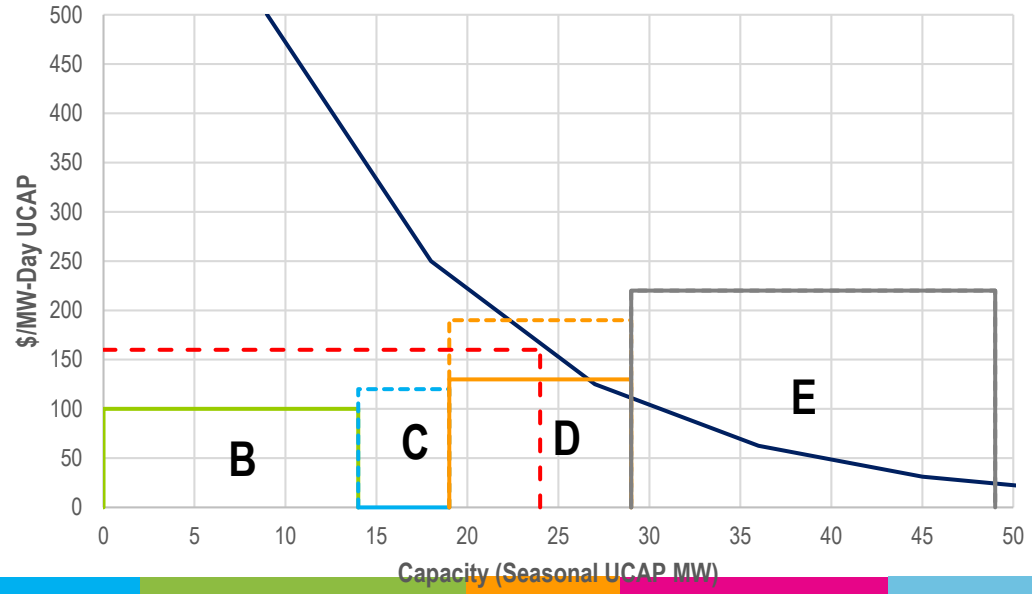
- All offers are flexible, meaning any amount of MW can clear.
- In both seasons, seasonal revenue exceeds seasonal offer component for all cleared resources. Both seasons contribute to recovery of annual costs sufficiently so Resource D partially clears.
- Resource D is the marginal resource in both seasons.

	Accredited UCAP		Offer $/MW-Day UCAP	
Resource	Summer	Winter	Summer (+maximum annual)	Winter (+maximum annual)
A	14.5	0	$80 (S)	
B	0	14		$100 (W)
C	5	5	$120 (A)	$120 (A)
D	5	10	$160 (S) +$120 (A)	$135 (W) +$60 (A)
E	15	20	$240 (S)	$220 (W)

Summer



Winter



Example 3: Clearing Results

	Summer Auction Results		Winter Auction Results	
Clearing Price ($/MW-Day UCAP)	**$220**		**$160**	
	Cleared Summer MW (UCAP)	Summer Daily Revenue	Cleared Winter MW (UCAP)	Winter Daily Revenue
A	14.5 MW	$3,190 per day		
B			14 MW	$2,240 per day
C	5 MW	$1,100 per day	5 MW	$800 per day
D	2.5 MW	$550 per day	5 MW	$800 per day
E				
Total	**22 MW**	**$4,840 per day**	**24 MW**	**$3,840 per day**

- Resource D is partially clearing and recovering it's total costs required for the cleared amount.
- Total seasonal revenue is equal to the total cleared costs of Resource D.

Example 3: Resource D's Costs and Revenues, *Detail*

	ICAP	Summer UCAP	Winter UCAP
Total	12 MW	5 MW	10 MW
Cleared	6 MW	2.5 MW	5 MW

	Costs				Revenue			
	Cleared MW ICAP [1]	$/MW-Day ICAP [2]	Days [3]	$/Year [1] × [2] × [3] = [4]	Cleared MW UCAP [5]	$/MW-Day UCAP [6]	Days [7]	$/Year [5] × [6] × [7] = [8]
Summer	6 MW	$66.67	182.5	$73,000	2.5 MW	$220.00	182.5	$100,375
Winter	6 MW	$108.33	182.5	$118,625	5 MW	$160.00	182.5	$146,000
Annual	6 MW	$25.00	365	$54,750				
Total				**$246,375**				**$246,375**

- Total costs for 6 MW ICAP cleared of **$246,375** per year [4] is equal to the total revenue for 2.5 MW summer UCAP cleared and 5 MW Winter UCAP cleared of **$246,375** per year [8].

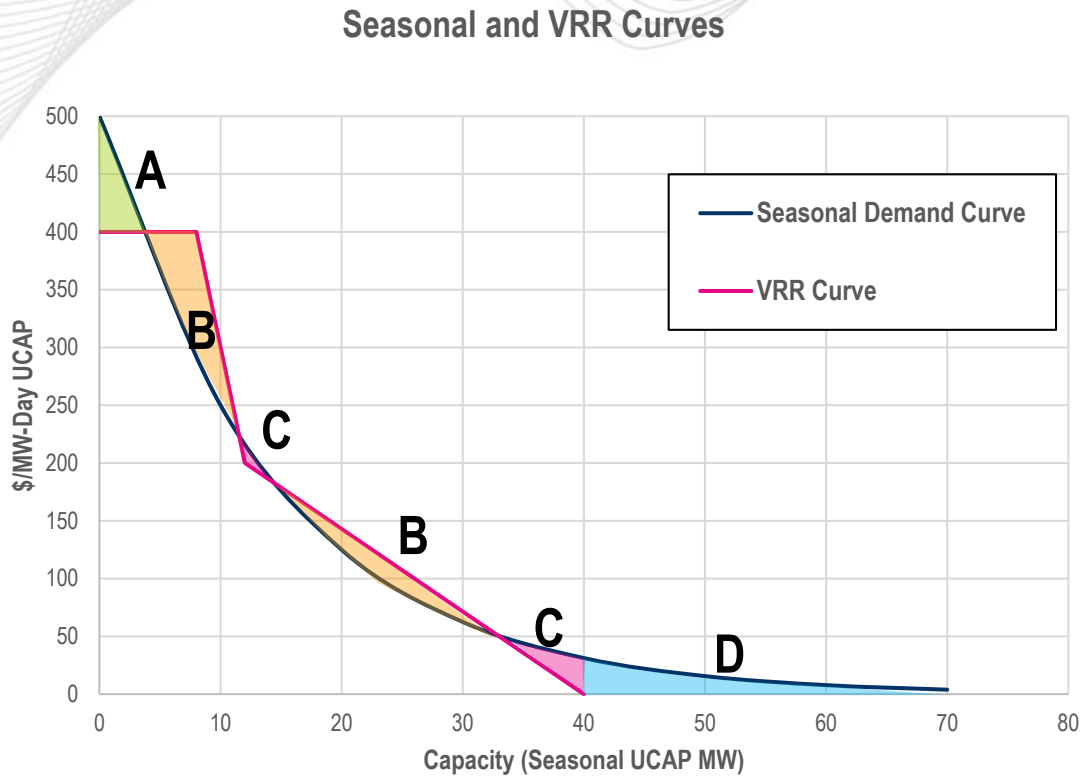
Adjustments to fit the Annual VRR Curve

Seasonal Demand Curves and Annual VRR Curves Interactions

- **Seasonal Demand Curves** are an output from the probabilistic modeling and are scaled based Net CONE of the Reference Resource, the Seasonal Reliability Requirements, and the relative mEUE expected across seasons.
- **Annual VRR Curves** are set based on Net CONE of the Reference Resource, and the Annual Reliability Requirements (as today).
- Both curve designs are downward sloping, but there are a few key differences.
  - **Seasonal Demand Curves** are naturally non-linear and convex that extend to positive infinity along the y-axis and positive infinity along the x-axis.
  - **The VRR curves** are based on three points (A, B, C) which cannot exceed the price of Point A and cannot exceed the quantity of Point C.

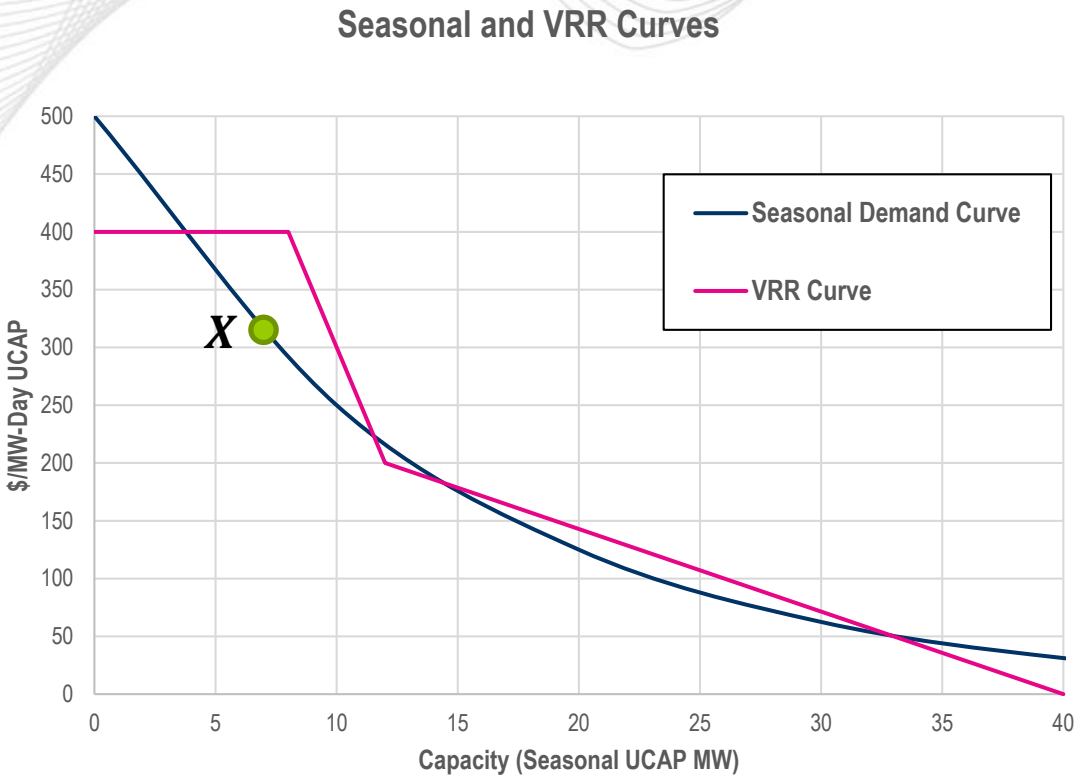
Annual VRR curve and Seasonal Demand Curves

- **A:** there is no prescribed maximum price on the Seasonal Demand Curves
- **B:** Seasonal Demand Curve is under valuing Capacity relative to the VRR curve
- **C:** Seasonal Demand Curve is over valuing capacity relative to the VRR curve
- **D:** there is no maximum quantity on the Seasonal Demand Curves



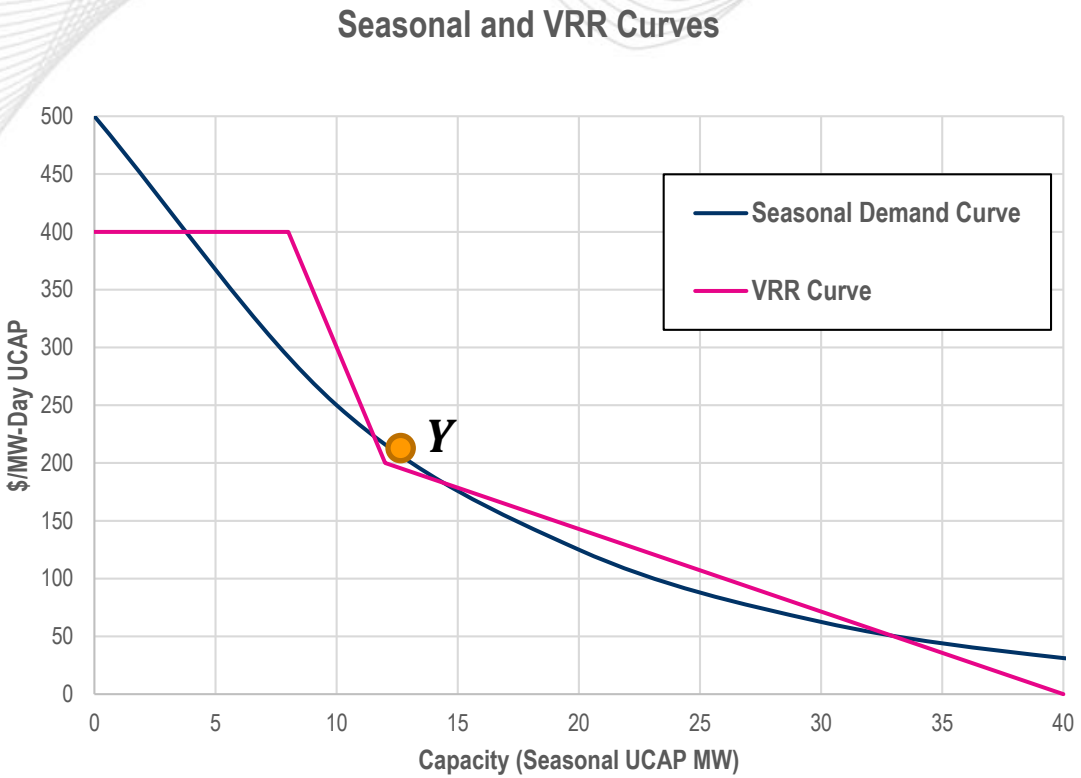
Seasonal-VRR Adjustment Factor Up

- Clearing at point ***X*** on the Seasonal Demand Curve values capacity less than the Annual VRR Curves.
- The Seasonal Demand Curves must be adjusted to align the auction clearing amount with the Annual VRR Curves.
- A **Seasonal-VRR Adjustment Factor** will be proportional scaling of both seasonal demand curves to align with the Annual VRR curve.
- The **Seasonal-VRR Adjustment Factor** when clearing at point ***X***, will be above 100% to re-align the Seasonal Demand Curves with the Annual VRR Curves.



Seasonal-VRR Adjustment Factor Down

- Clearing at point ***Y*** on the Seasonal Demand Curve values capacity more than the Annual VRR Curves.
- The Seasonal Demand Curves must be adjusted to align the auction clearing amount with the Annual VRR Curves.
- A **Seasonal-VRR Adjustment Factor** will be proportional scaling of both seasonal demand curves to align with the Annual VRR curve.
- The **Seasonal-VRR Adjustment Factor** when clearing at point ***Y***, will be below 100% re-align the Seasonal Demand Curves with the Annual VRR Curves.



Clearing Approaches: Review and Conclusions

- **Seasonal Demand Curves:**
  - **Seasonal Demand Curves:** Once created from the modeling, are easily scalable to the appropriate pricing scale, similar to the VRR curve.
  - **Seasonal Supply Offers:** Allow flexibility for allocating costs, or allow resources to offer like today with a single annual offer.
  - **Seasonal Clearing:** Clears on the least cost solution based on the combination of seasonal offers, allowing for greater flexibility within the optimization.
- **Including the Annual VRR Curves:**
  - **Seasonal Demand Curves:** No longer anchored, and will require a **Seasonal-VRR adjustment factor**, calculated as part of the auction clearing, to ensure the calculated annual MW and annual clearing price clear along the annual VRR curve. This **Seasonal-VRR adjustment factor** will be the same for both seasons (e.g. 101%, 102%, 99%, etc.)
  - Adds complexity behind the scenes, but preserves clearing along the approved Annual VRR Curves.
  - Under this approach, PJM will not be able to post seasonal demand curves before the auction as they will shift depending on the submitted sell offers, and the seasonal intersection points.

Comparison of two clearing approaches

Component	Seasonal Demand Curves	Annual VRR + Seasonal Design
Complexity	Simpler approach to a multi period market	More complicated, but technically feasible
Optimization	Less computationally intensive to clear	More computationally intensive, and requires adjustable Seasonal Demand Curves
Representation of Capacity Value	Maintains consistent willingness to pay to avoid EUE MWh	VRR Curve does not value capacity beyond Point C Fluctuating value for willingness to pay per avoided EUE
Just and Reasonable	FERC-approved marginal reliability impact (“MRI”) curves for ISO-NE	FERC-approved approach for PJM
Changes from Status Quo	Ignore the Annual VRR curve; preserve Reference Resource & Net CONE	Most direct translation to what we do today

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Auction Clearing Examples

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