Sustainable Capacity Market (SCM) Part 3

July 27, 2023   IMM

CIFP Stage 3

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SCM: Key Elements

1. **Capacity offered in the forward capacity market, ACAP (available capacity), is (ICAP * MEAF), where MEAF is the modified equivalent availability factor.**

2. **Capacity is paid in the delivery year only when available to produce energy, by hour. (Hourly price = annual capacity market clearing price/8,760)**

3. **Capacity market prices are single annual clearing prices by constrained LDAs determined per existing market rules defining LDA constraints.**

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SCM: Key Elements

4. **Must offer requirement in the capacity market applies to all existing capacity resources.**

5. **Must offer requirement in the energy market means that all committed capacity resources must offer all capacity at ICAP MW in a combination of the energy, ancillary services and reserve markets.**

6. **Capacity resources that require fuel must designate their status as: firm fuel in the form of dual fuel capability with a defined number of days of onsite stored fuel; firm transportation; or interruptible transportation.**

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SCM: Key Elements

7. **Capacity resources must be subject to biannual testing on a schedule determined by PJM that would include the results of economic operations.**

8. **Capacity resources that fail to start when called by PJM, or fail a PJM test, will not receive hourly capacity payments from the time of the last successful start to the next successful start.**

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SCM Basics

- **The SCM proposed changes to the capacity market design are simple.**

- **The capacity market clearing process accounts for the expected hourly, locational availability of individual resources.**

- **In the delivery year, capacity resources are paid only when they are available.**

- **If a unit fails to start when called by PJM for power or a test, the unit is not paid the hourly capacity price from the last successful start to the next successful start.**

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SCM Basics

- **In the forward looking capacity market clearing process that defines the resources needed to provide the target level of energy reliability, it is essential to have resource specific, locational hourly availability in order to match resource availability with the reliability objective.**

- **A simple assumption of average annual availability, or the assumption of an equivalent perfect resource at a derated MW value, will not accurately reflect actual expected availability.**

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SCM Basics

- **In the delivery year, it is essential to pay for capacity only when it is available to produce energy.**

- **The proposed design matches payment with availability to produce energy and ensures the opportunity for all resource types to cover their net avoidable costs if their actual availability matches their expected availability.**

- **The result is to provide a long term, stable incentive for investment in maintenance and investment in new, reliable resources.**

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Hourly Demand

- **PJM reliability analysis is the basis for hourly demand**
- **Hourly demand is a function of approved metric for reliability threshold (LOLE, EUE or LOLH)**

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Modified Availability Factor

- **Modified Equivalent Availability Factor (MEAF) for the delivery period (DP) is the ratio of the total capacity hours that are available to the total installed capacity hours of the resource during the delivery period.**

$$MEAF = \frac{\sum_{hour} Available\ MW_{hour}}{ICAP * (Number\ of\ hours\ in\ the\ DP)}$$

- **Offer per available MW**

$$Offer\ (\$/MW - Hour) = \frac{Offer\ (\$/DP)}{MEAF * ICAP * (Number\ of\ hours\ in\ the\ DP)}$$

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Availability

- **Average hourly available capacity (ACAP) equals MEAF*ICAP**

- **Analog of UCAP used in the current capacity market**

- **A competitive capacity offer price equals net ACR divided by ACAP**

- **The capacity revenue payment equals cleared ACAP MW multiplied by the clearing price ($/ACAP MW)**

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Hourly Availability

- **PJM calculates the expected hourly available capacity (HACAP) based on historical data**

- **PJM reliability study would be used to calculate expected availability**

- **HACAP of a thermal resource is a function of its planned, maintenance, forced outages, ambient derates, derates for any reason.**

- **HACAP of an intermittent resource is a function of the hourly distribution of the underlying energy potential (solar radiance, wind speed).**

- **HACAP of a demand resource is a function of its expected/offered load reduction.**

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Market Clearing: Objective

- **Objective is to minimize the total dead weight loss across all hours and all LDAs, similar to the current objective used for the Base Residual Auction.**
  - **Equivalent to minimizing the total cost if a vertical VRR curve is used.**
  - **Equivalent to maximizing the surplus (area between the VRR curve and the offer curve) for a single LDA capacity market.**

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Market Clearing: Constraints

- **Hourly capacity balance constraint**
  - **For every hour, the cleared hourly capacity should satisfy the reliability requirement as defined by the VRR curves.**

- **Hourly resource availability constraint**
  - **For every resource, the cleared hourly capacity for every hour should not exceed its available capacity for that hour.**

- **Annual capacity clearing constraint**
  - **For every resource, the cleared annual capacity is the maximum of all cleared hourly capacity values.**

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Key Features of the Clearing

- **Annual clearing.**

- **Annual clearing prices.**

- **Subset of resources needed to meet the reliability requirement of high demand hours are also available to meet the reliability requirement of all hours.**

- **The marginal cost of capacity cleared to meet the requirement of high demand hour is zero for all the other hours in which it is available.**

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Key Features of the Clearing

- **Resources may be offered in flexible or inflexible segments, including the entire resource.**

- **Resources offered in flexible segments can clear any number of MW between 0 and the maximum offered capacity of the segment.**

- **Resources offered in inflexible segments can clear at least a minimum offered capacity of the segment or not clear the segment at all.**

- **Inflexible resources would be made whole if they clear partially for the inflexible segment.**

Appendix

Formulation

$$Min \sum_r CAP_r * \frac{OFFER_r}{ICAP_r * MEAF_r * H}$$

Subject to:

$$\forall\, h, \sum_r HCAP_{h,r} = RR_h$$

$$\forall\, (r, h), HCAP_{h,r} = AVAIL_{h,r}$$

$$\forall\, (r, h), CAP_r \geq HCAP_{h,r}$$

Where:

r: capacity resource

h: hour

H: Number of hours in the delivery period

RR_h: Reliability Requirement (MW) for hour h (parameter)

$OFFER_r$: Offer in $/DY of capacity resource r (parameter)

CAP_r: Maximum cleared capacity (HACAP MW) of resource r for the entire delivery period (variable)

$HCAP_{h,r}$: Cleared capacity (MW) from resource r for hour h (variable)
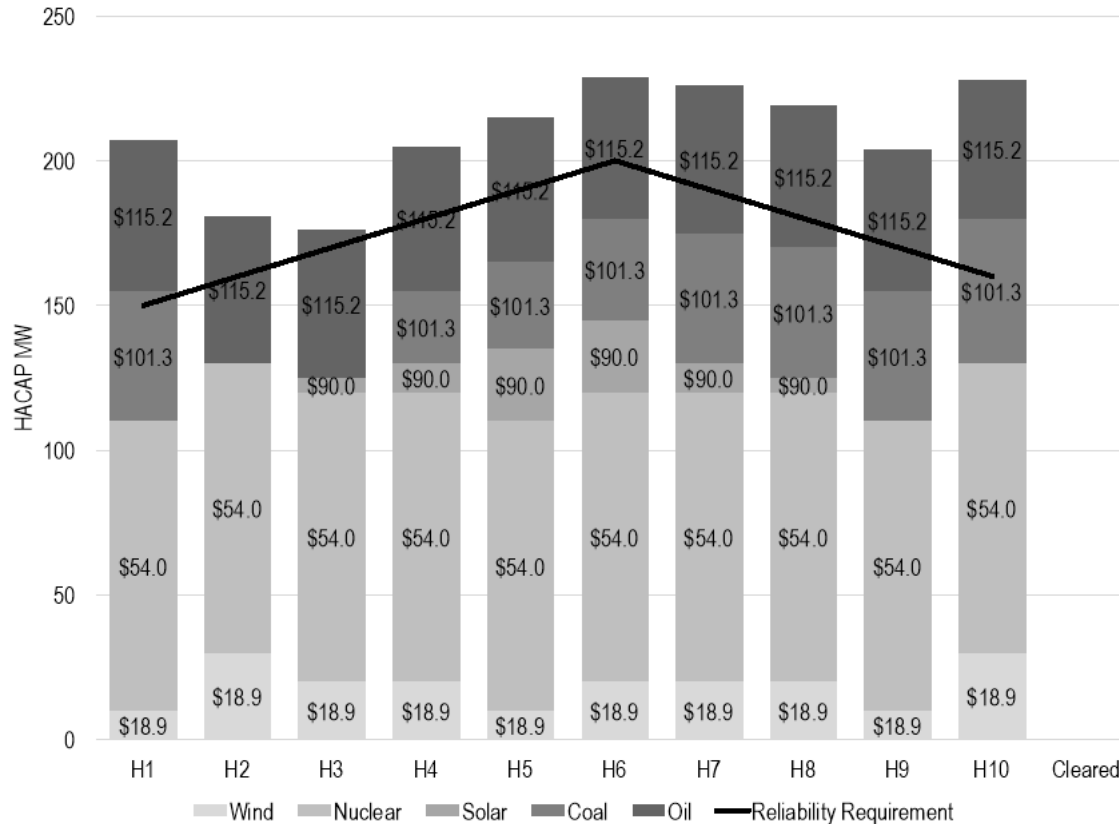
$AVAIL_{h,r}$: Expected available capacity (HACAP MW) from resource r for hour h (parameter)

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Appendix: Example

Capacity Revenue:

$$\begin{matrix}Capacity \\ Revenue \\ (\$/DP)\end{matrix} = \begin{pmatrix} Cleared \\ MW \\ (HACAP\ MW) \end{pmatrix} * \frac{ICAP * MEAF}{Max(Availability_h)} * \begin{pmatrix} Clearing \\ Price \\ (\$/MW - Hour) \end{pmatrix} * \begin{pmatrix} Number\ of \\ hours\ in\ DP \end{pmatrix}$$

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Example: Hourly Availability

- **Available Resources by Hour**
- **Objective is to find a least cost set of resources that satisfies the demand for every hour in the DP**

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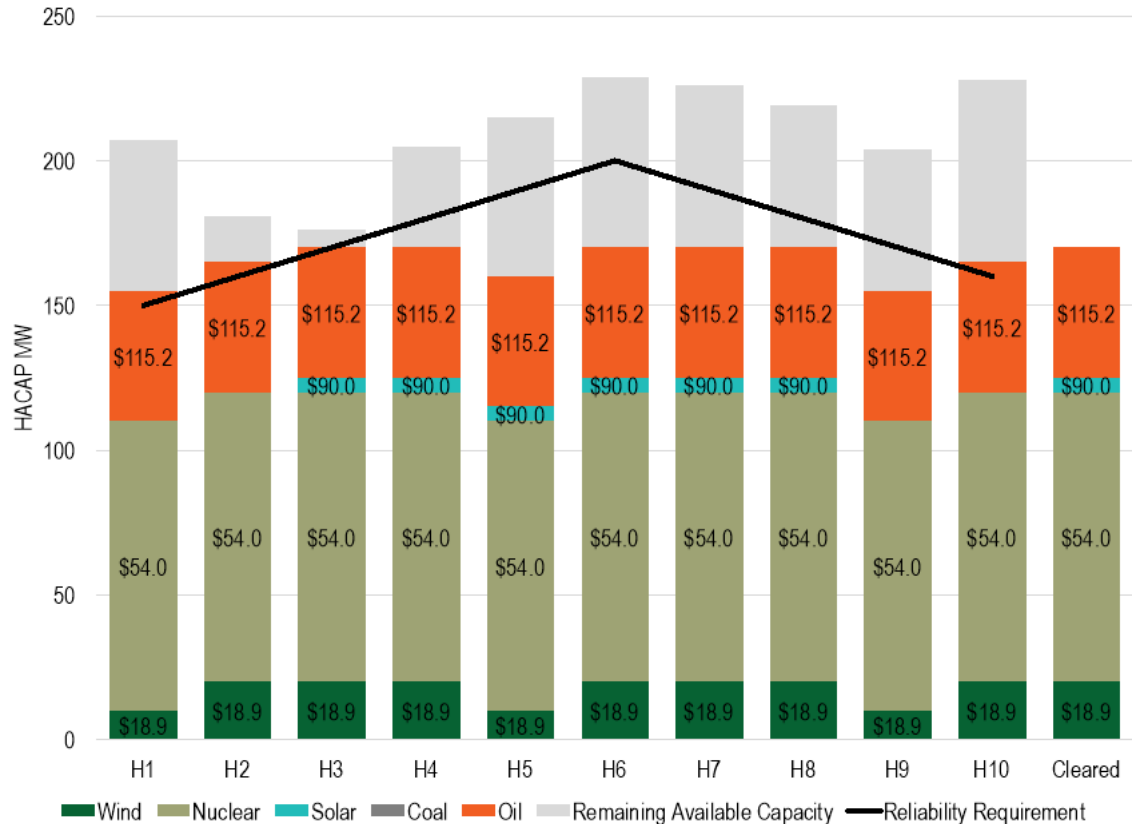
Example: Step 1

- **Coal resource is on outage in Hour 3**
- **45 HACAP MW of Oil, 100 HACAP MW of Nuclear, 5 HACAP MW of Solar and 20 HACAP MW of Wind satisfies the demand for Hour 3**
- **Demand for Hour 1 and Hour 10 are also satisfied**

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Example: Step 2
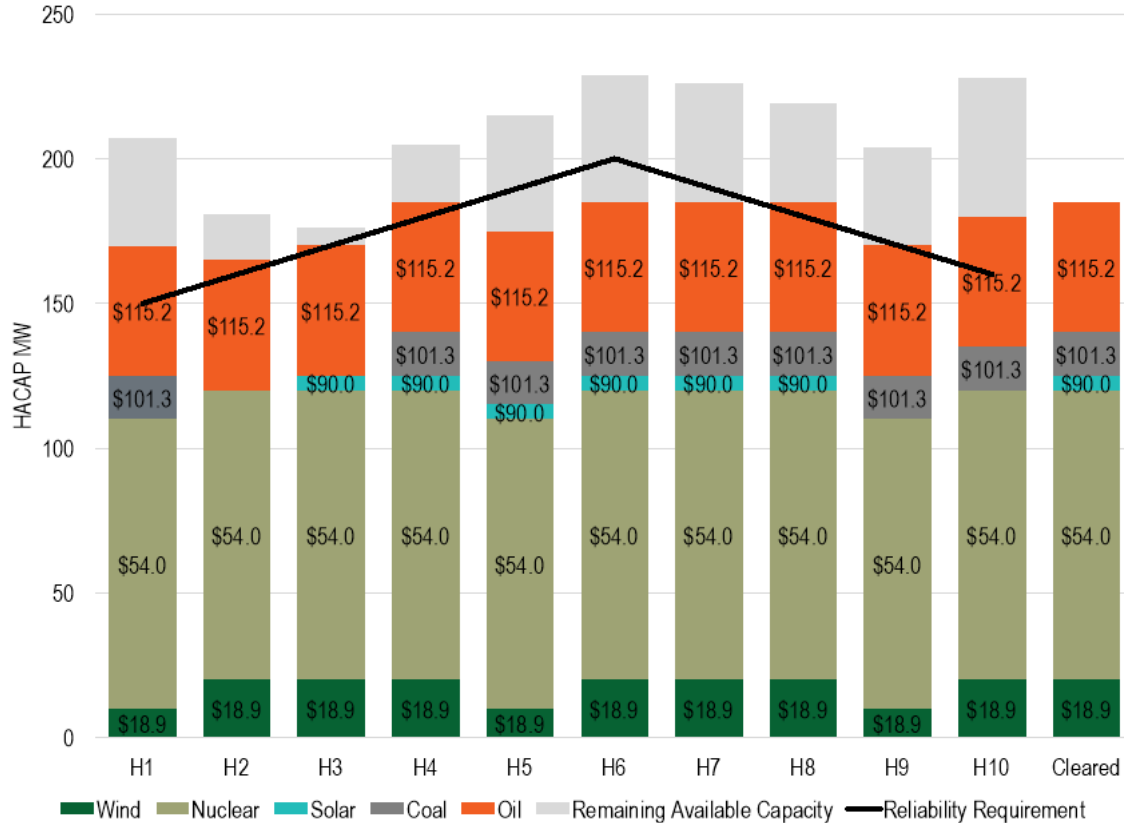
- **Clearing additional 15 HACAP MW of Coal satisfies all hours except Hour 5, Hour 6 and Hour 7**

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Example: Solution
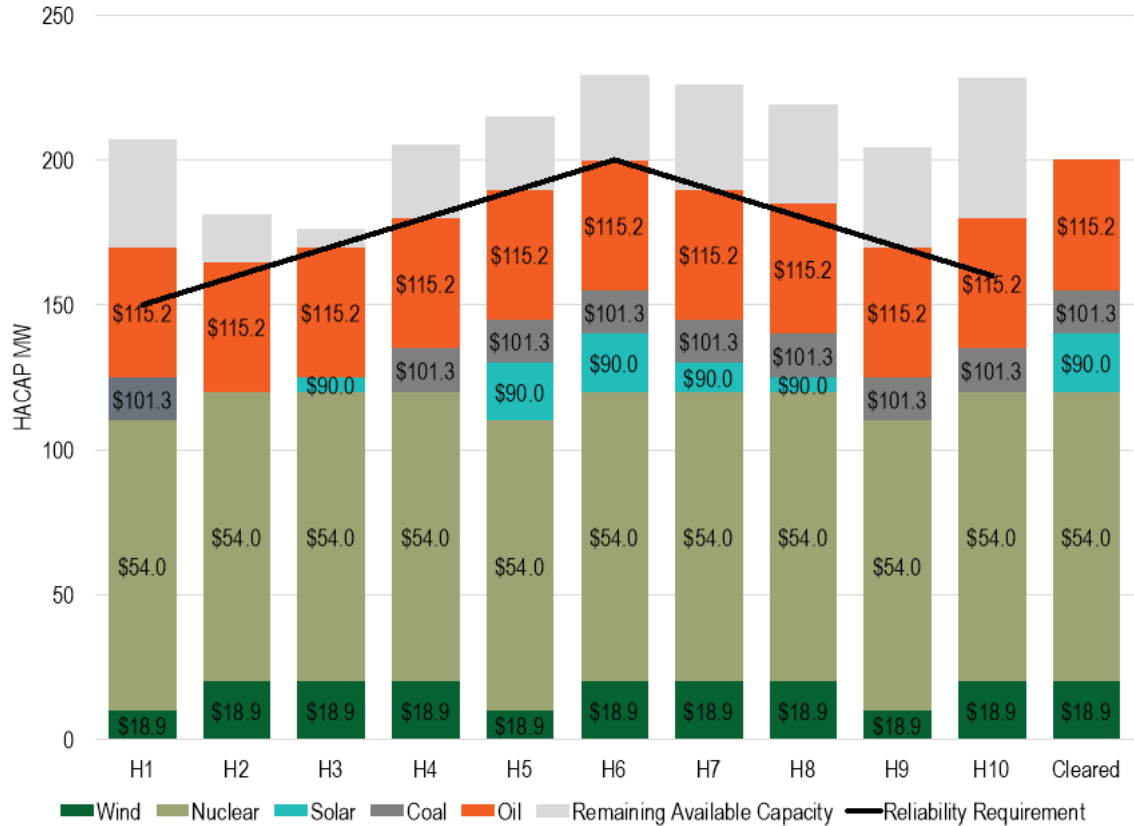
- **Increasing the clearing capacity of Solar to 20 HACAP MW satisfies the demand for all hours.**

- **Clearing additional resources does not reduce the overall cost.**

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Example: Auction Results

	ICAP MW	Minimum Hourly Availability (HACAP MW)	Maximum Hourly Availability (HACAP MW)	MEAF	Cleared (HACAP MW)	Cleared (ACAP MW)
Nuclear	100.0	100.0	100.0	1.000	100.0	100.0
Solar	40.0	0.0	25.0	0.200	20.0	6.4
Wind	40.0	10.0	30.0	0.475	20.0	12.7
Coal	50.0	0.0	50.0	0.640	15.0	9.6
Oil	70.0	48.0	52.0	0.714	45.0	43.3

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Capacity Revenue Payment

- **If the capacity resource's availability in the energy market matches its offered availability in the capacity market, the resource would recover at least its full offer.**

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Example: Capacity Revenue Payment

Expected Availability used in the Capacity Market Clearing (HACAP MW)											Expected Availability
	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	
Nuclear	100	100	100	100	100	100	100	100	100	100	1.000
Solar	0	0	5	10	25	25	10	5	0	0	0.200
Wind	10	30	20	20	10	20	20	20	10	30	0.475
Coal	45	0	0	25	30	35	45	45	45	50	0.640
Oil	52	51	51	50	50	49	51	49	49	48	0.714

Availability in the Energy Market (HACAP MW)											Actual Availability
	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	
Nuclear	100	100	100	100	100	100	100	100	100	100	1.000
Solar	0	0	0	5	35	35	5	0	0	0	0.200
Wind	10	30	20	20	10	20	20	20	10	30	0.475
Coal	30	0	20	20	40	50	40	30	50	40	0.640
Oil	70	70	0	70	50	50	50	50	50	40	0.714

Capacity Revenue ($/Hour)											Total ($/DP)	Factor for Partially Cleared Resources
	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10		
Nuclear	$11,520	$11,520	$11,520	$11,520	$11,520	$11,520	$11,520	$11,520	$11,520	$11,520	$115,200	1.00
Solar	$0	$0	$0	$461	$3,226	$3,226	$461	$0	$0	$0	$7,373	0.80
Wind	$768	$2,304	$1,536	$1,536	$768	$1,536	$1,536	$1,536	$768	$2,304	$14,592	0.67
Coal	$1,037	$0	$691	$691	$1,382	$1,728	$1,382	$1,037	$1,728	$1,382	$11,059	0.30
Oil	$6,978	$6,978	$0	$6,978	$4,985	$4,985	$4,985	$4,985	$4,985	$3,988	$49,846	0.87

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Clearing Price

- **The clearing price for the delivery year is set by the offer price of the marginal resource for the year.**

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