PJM Initial Package for ELCC Solution

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Design Component 1: Classes
Solution Option A

Intermittent Resources	Onshore wind, offshore wind, fixed solar, tracking solar, landfill gas, intermittent hydro
Limited Duration Resources	6-hour energy storage resources, 10-hour ESR 6-hour generic limited duration resources, 10-hour generic limited duration resources. Linear derating allowed for ESR and limited duration resources.
Combination Resources (Intermittent + Limited Duration)	solar+6-hour ESR hybrids, solar+10-hour ESR, other gen+6-hour ESR, other gen+10-hour ESR, hydro with storage
Which classes is ELCC applied to	All intermittent, limited duration, and combination resources

PJM Initial Package: Design Component 2—Timing and Functional Application of ELCC, incl. ICAP and UCAP

$$\text{Unit ELCCMW}_{dy} = \text{Class ELCC\%}_{dy} \times \text{Unit performance adjustment}_{dy} \times \text{MFO or ICAP}$$

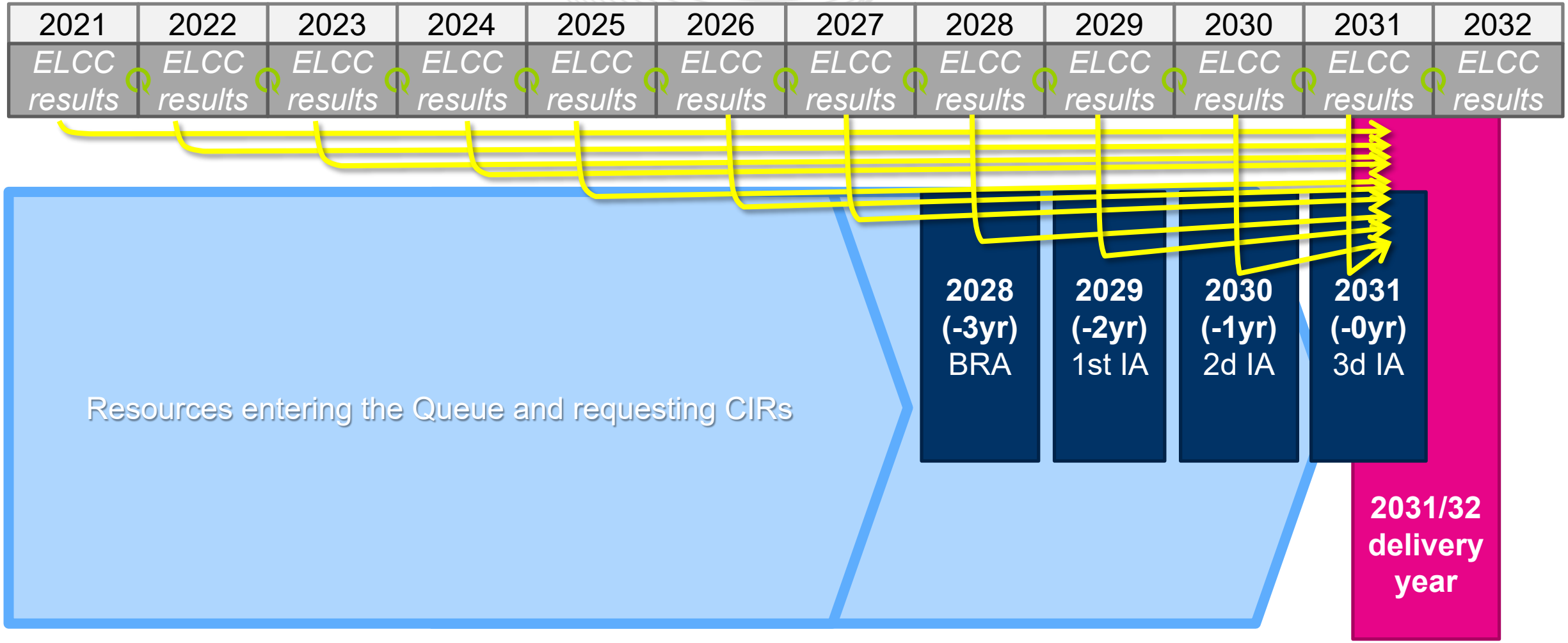
Unit ELCCMW$_{dy}$ = UCAP accreditation (i.e., capacity value) for that delivery year

Planned resources

Existing resources

Unit ELCCMW$_{dy}$ = Class ELCC%$_{dy}$ x Unit performance adjustment$_{dy}$

Proposed Timeline: **Class ELCC** for Planned Resources



Solution Option A

Unit ELCCMW$_{dy}$ = Class ELCC%$_{dy}$ x Unit performance adjustment$_{dy}$

Proposed Timeline: **Class ELCC** for Planned Resources

2021	202	…	2027	2028	2029	2030	2031	2032
ELCC results	*E*	…	*ELCC results*	*ELCC results*	*ELCC results*	*ELCC results*	*ELCC results*	*ELCC results*

Official Class ELCC% updated each year for the next 10 years using vendor forecast of resource mix. **Class ELCC% analysis results are rounded into bands (see next slide)→official accreditation may change less often than annually.**

Resources entering the Queue and requesting CIRs

CIR policy not to be changed: wind and solar CIRs based on 368-hour rule, all other limited resources (e.g., storage, hydro, etc.) CIRs are based on ICAP.

2028 (-3yr) BRA

2029 (-2yr) 1st IA

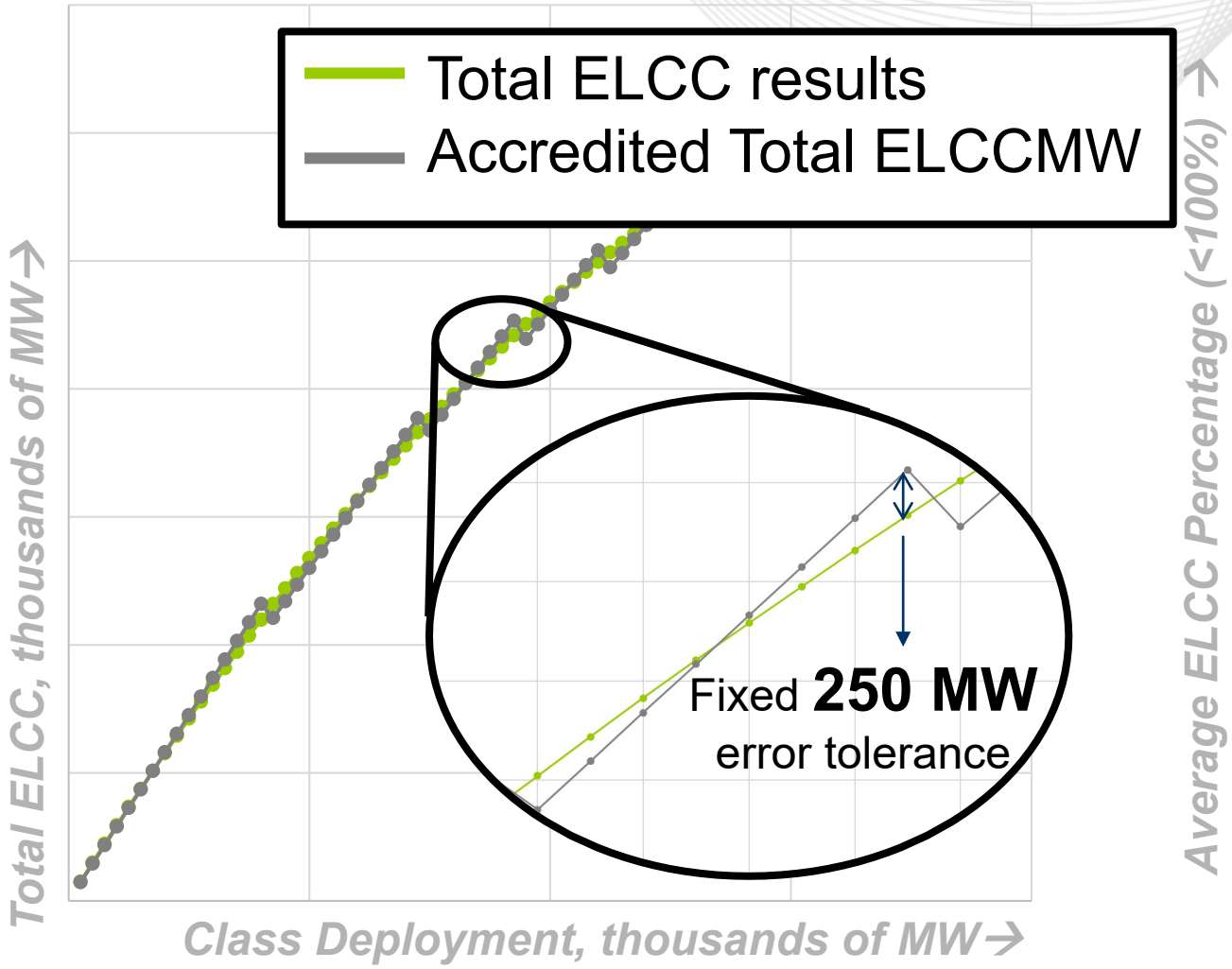
2030 (-1yr) 2d IA

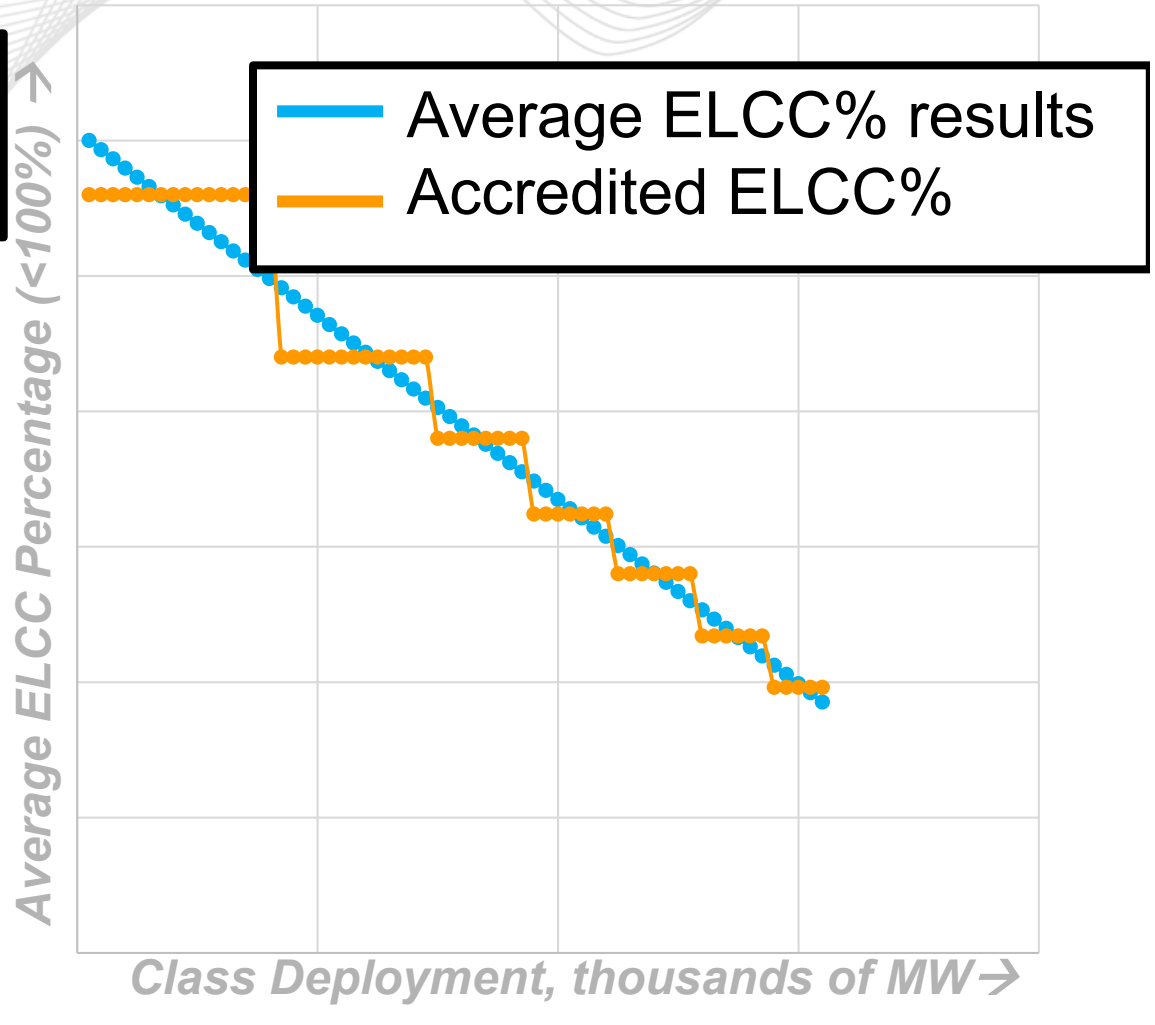
Sale in any auction is capped using most recent class ELCC%

Final class ELCC% released prior to 3d IA, used to calculate UCAP (i.e., capacity value) in actual delivery year

delivery year

Illustration of Banding Concept (NOT ACTUAL RESULTS)





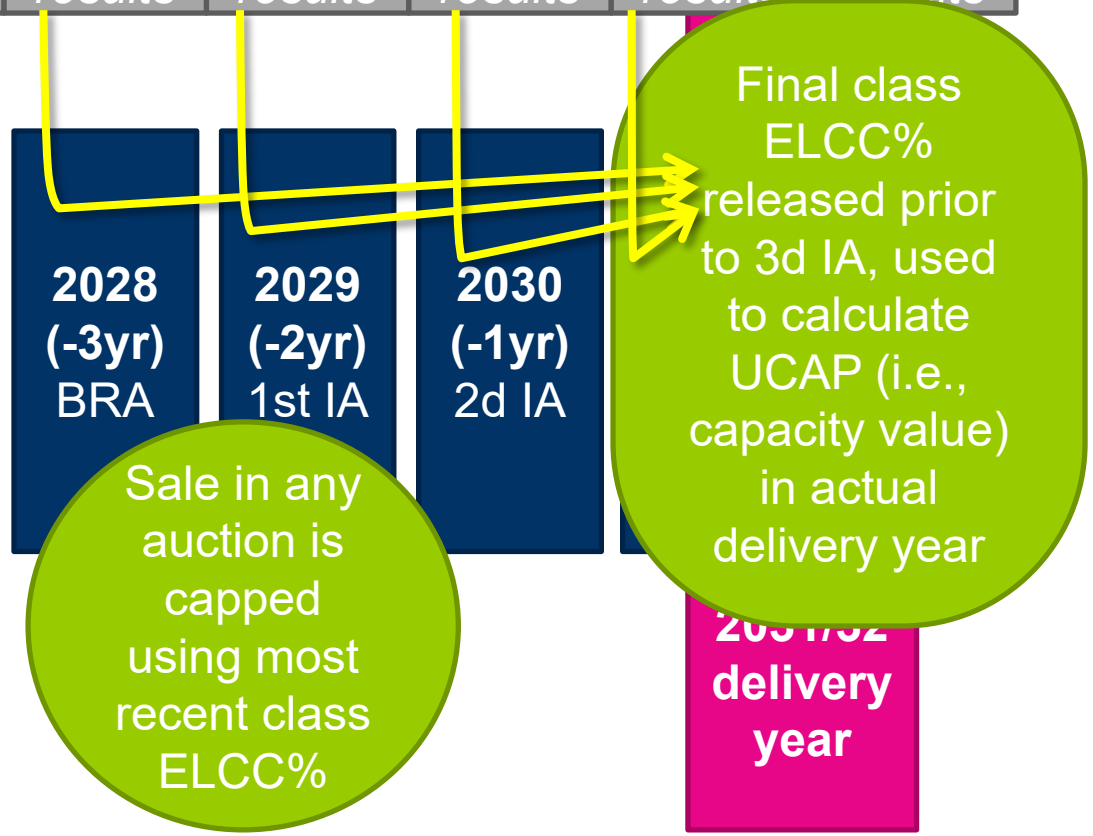
Solution Option A

Unit ELCCMW$_{dy}$ = Class ELCC%$_{dy}$ x Unit performance adjustment$_{dy}$

Proposed Timeline: **Class ELCC** for Existing Resources

2021	202	…	2027	2028	2029	2030	2031	2032
ELCC results	*E*	…	*ELCC results*	*ELCC results*	*ELCC results*	*ELCC results*	*ELCC results*	*ELCC results*

Official Class ELCC% updated each year for the next 10 years using vendor forecast of resource mix. **Class ELCC% analysis results are rounded into bands (see next slide)→official accreditation may change less often than annually.**



Final class ELCC% released prior to 3d IA, used to calculate UCAP (i.e., capacity value) in actual delivery year

Sale in any auction is capped using most recent class ELCC%

Solution Option A

Unit $ELCCMW_{dy}$ = Class $ELCC\%_{dy}$ x Unit performance adjustment$_{dy}$

Proposed Timeline: Performance Adjustment for Planned Resources

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Back-cast	Back-cast	Back-cast	Back-cast	Back-cast	Back-cast	Back-cast			Back-cast	Back-	Back-

In any year needed, a unit-specific hourly output backcast for last 10 years (not prior to 2012) is generated and used to calculate the unit's Performance Adjustment metric.

Update to backcast *not* required when selling into an auction

A new unit-specific Performance Adjustment is developed prior to 3d IA to calculate UCAP (i.e., capacity value) in actual delivery year

Resources entering the Queue and requesting CIRs

2028 (-3yr) BRA

2029 (-2yr) 1st IA

2030 (-1yr) 2d IA

2031/32 delivery year

For indicative purposes and for capping offers in auction, unit specific Performance Adjustment is developed upon entering the Queue

The most recent unit-specific Performance Adjustment is used to cap sale in any auction

Solution Option A

Unit ELCCMW$_{dy}$ = Class ELCC%$_{dy}$ x Unit performance adjustment$_{dy}$

Proposed Timeline: Performance Adjustment for Existing Resources

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Back-cast	*Back-cast*	*Back-cast*	*Back-cast*	*Back-cast*	*Back-cast*	*Back-cast*	*Actual data*	*Actual data*	*Actual data*	*Actual*	*Actual*

In each year, a unit's Performance Adjustment metric is calculated

2028 (-3yr) BRA

2029 (-2yr) 1st IA

2030 (-1yr) 2d IA

2031/32 delivery year

The final Performance Adjustment is developed prior to 3d IA, used to calculate UCAP (i.e., capacity value) in actual delivery year

The Performance Adjustment is based on both actual output and, for immature units, a unit-specific hourly output backcast for sufficient years to develop a total of 10 years of data (not prior to 2012).

The most recent unit-specific Performance Adjustment is used to cap sale in any auction

Note on Capacity Interconnection Rights

- Capacity Interconnection Rights (CIRs) are the firm deliverability rights for resources that PJM physically maintains on the transmission network.
- CIRs are not the same as UCAP (i.e., the capacity value) of a resource.
- The CCSTF is focused on capability→ICAP and UCAP.
- **No change to current CIR policy:**
  - Wind and solar CIRs related to the 368-hour rule.
  - All other limited resources (e.g., storage, hydro, etc.): CIRs are related to ICAP and summer tests.
  - Hybrid solar+storage and wind+storage:
    - If cannot charge from grid: CIRs of wind/solar component
    - If can charge from grid: sum of CIRs of wind/solar component and ESR component

Initial PJM Proposal for ICAP
Solution Option A

- ICAP of **Intermittent Resources** = status quo
- ICAP of **limited duration resources** = lesser of summer rating or new "X hour rule", where "X" is the duration of the class of the resource.
  - E.g., a 100 MW, 300 MWh battery (i.e., a 3-hour battery) in a 6 hour class would have an ICAP of 50 MW = 100MW*(3hr/6hr)
  - E.g., a 100 MW, 700 MWh battery (i.e., a 7-hour battery) in a 6 hour class would have an ICAP of 100 MW (its summer rating)
- ICAP of **combination resources (except hydro with storage)** = status quo (lesser of the sum of component ICAPs or MFO)
- ICAP of **hydro with storage** = status quo (summer rating)

Initial PJM Proposal for UCAP (i.e., Capacity Value)

Solution Option A

- *Note: Maximum Facility Output (MFO) is current term similar to "nameplate MW".*
- UCAP of **Intermittent Resources** = MFO*ClassELCC%*PerformanceAdjustment
- UCAP of **limited duration resources** = ICAP*ClassELCC%*(1-EFORd)

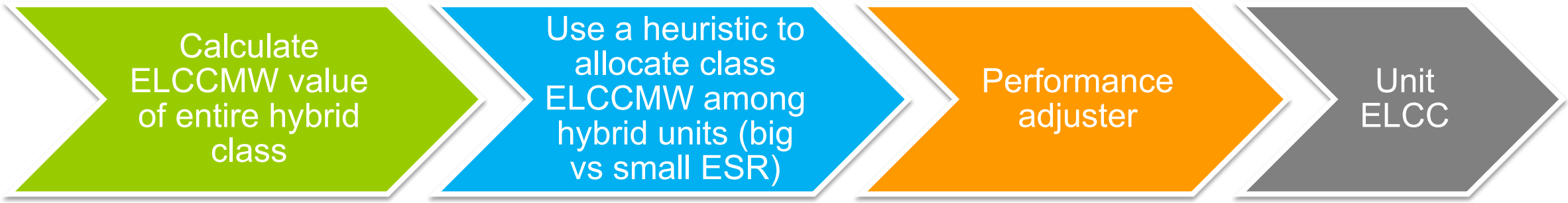
- UCAP of **combination resources (*following section explainins combo resources)*** = IntermittentNameplate*IntermittentClassELCC%*PerformanceAdjustment + ESRNameplate*HybridClassXESRResidualELCC%*(1-EFORd)

Where "*HybridClassXESRResidualELCC% =*

$$\frac{(\text{HybridClassXTotalELCC} - \text{SUM}(\text{HybridClassXIntermittentNameplate} * \text{IntermittentClassELCC\%}))}{\text{SUM}(\text{HybridClassXESRNameplate})}$$

Treatment of Combination Resources (excl. Hydro w/ Storage) → Hybrids

Potential Approach to Hybrids

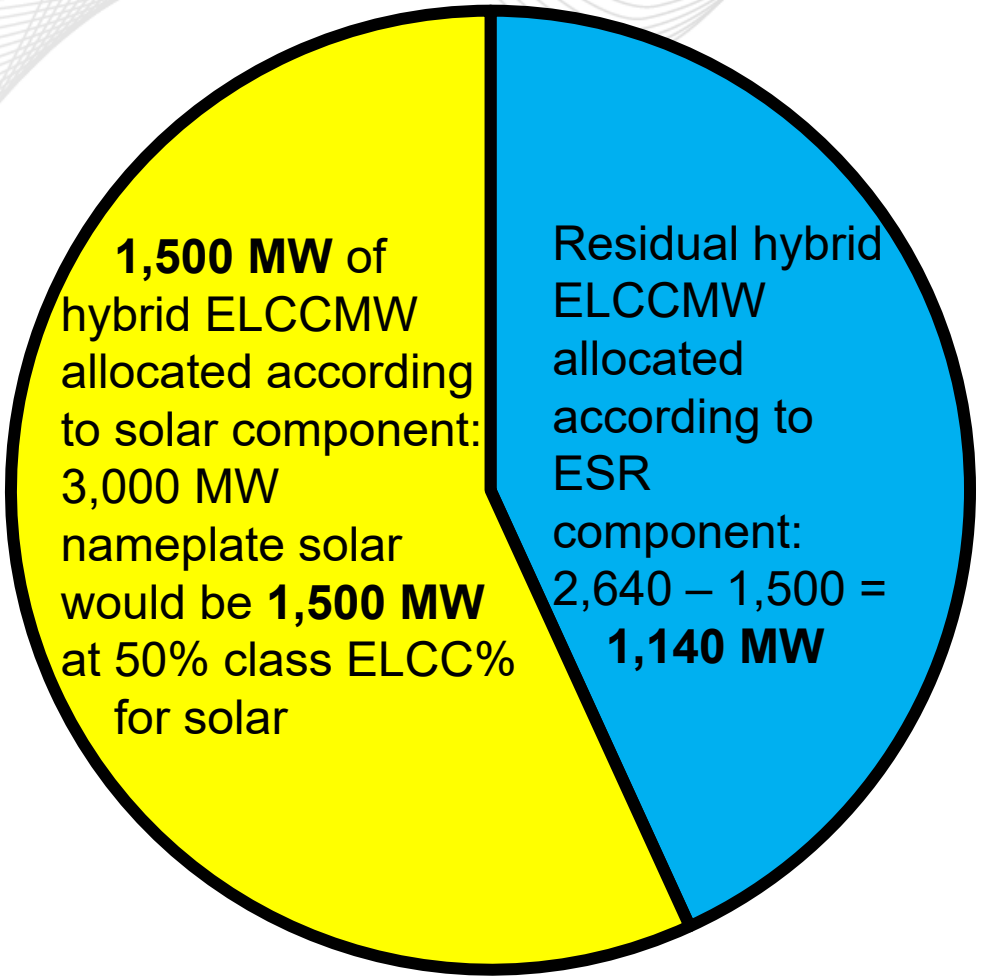


ELCC Model for Hybrids

- Each class of combination resources to be modeled separately. Each will have a separate hybrid class total ELCCMW calculated. There would be a total of 8 classes:
  - Open loop (i.e., capable of charging from grid)--Solar+6 hour ESR, solar+10 hour ESR, other Gen+6 hour ESR, other Gen+10 hour ESR
  - Closed loop (i.e., incapable of charging from grid)--Solar+6 hour ESR, solar+10 hour ESR, other Gen+6 hour ESR, other Gen+10 hour ESR
- Total ELCCMW per class would be allocated to each unit in the class via 2 metrics for each unit:
  1. [Solar/other gen nameplate MW]*PerformanceAdjuster
  2. [ESR nameplate]*(1-EFORd)
- The share of the hybrid class total ELCCMW that is allocated by each of the two above metrics is based on:
  A. Share of the hybrid class total ELCCMW corresponding to the solar/other gen ELCC. I.e.: [total nameplate solar/other gen]*[Class ELCC% of the solar/other gen class]
  B. Share of the hybrid class total ELCCMW corresponding to the ESR is the residual ELCCMW after subtracting the solar/other gen ELCC MW identified in step A above.

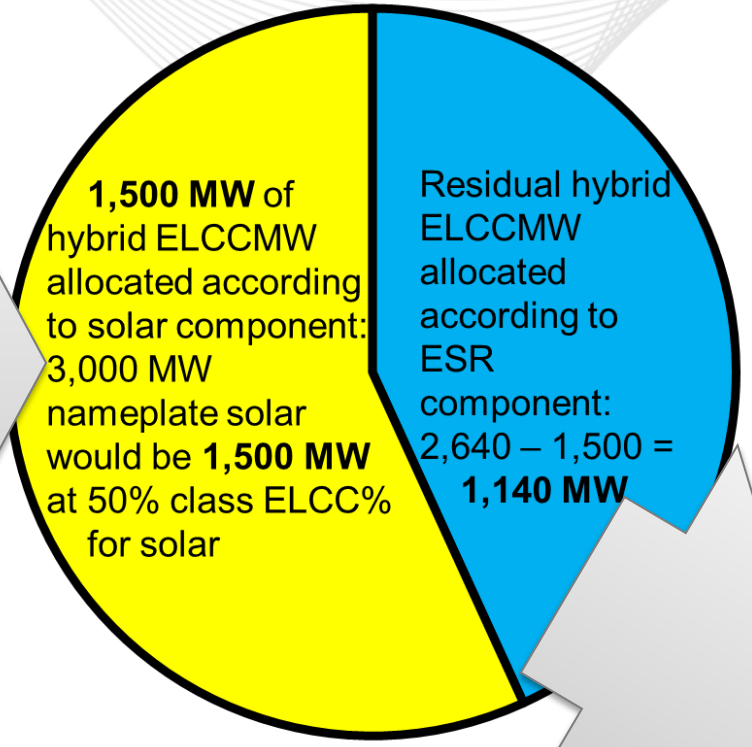
ELCC Model Example: Solar + 6hr ESR Open Loop

Solar+6 hour ESR total
ELCCMW = 2,640 MW
3,000 MW nameplate solar
1,600 MW nameplate ESR



ELCC Model Example: Solar + 6hr ESR Open Loop

Solar+6 hour battery total ELCCMW = 2,640 MW
3,000 MW nameplate solar
1,600 MW nameplate ESR

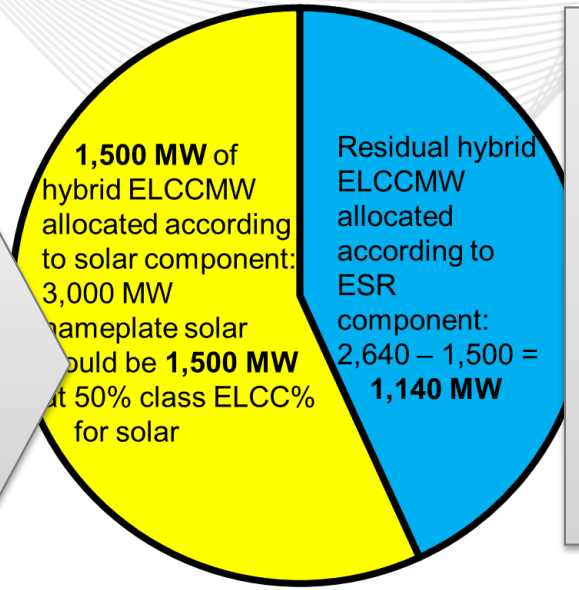


Unit ELCCMW of each solar+6 hour ESR hybrid unit is the sum of:

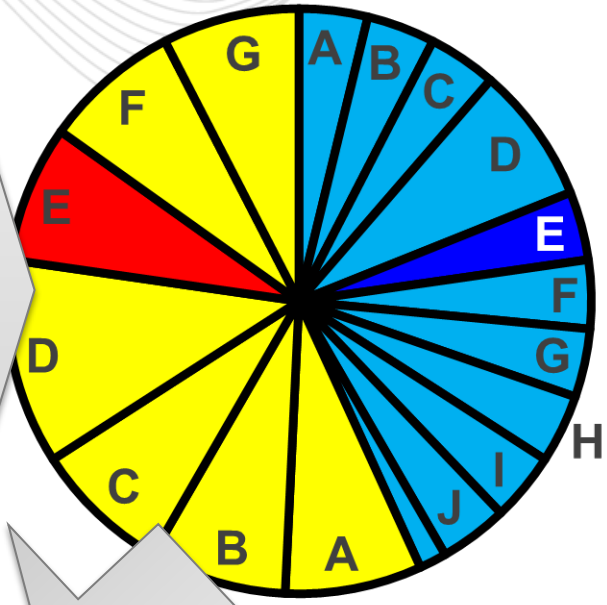
- Pro rata share of yellow portion based on UnitSolarMW*PerformanceAdjuster
- Pro rata share of blue portion based on UnitESRMW*(1-EFORd)

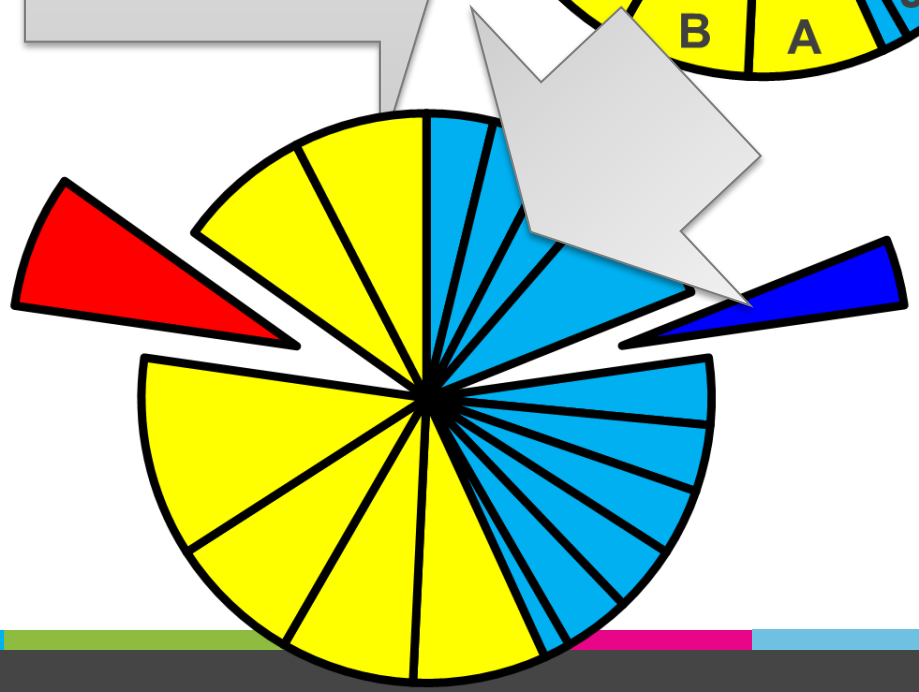
ELCC Model for Hybrids

Solar+6 hour battery total ELCCMW = 2,640 MW
3,000 MW nameplate solar
1,600 MW nameplate ESR

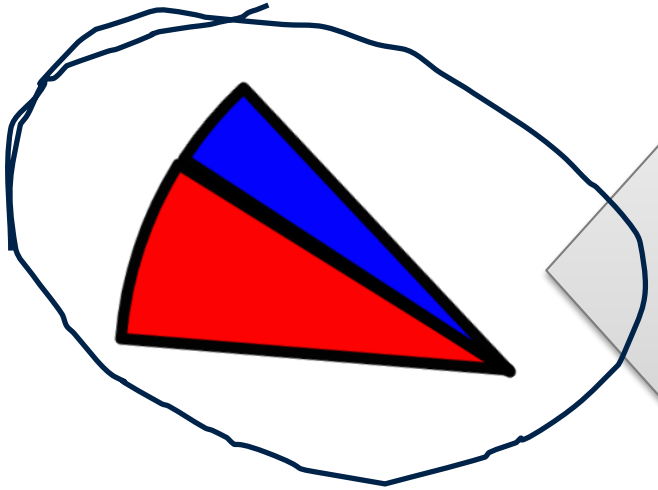


Allocate gen piece and ESR piece to each unit according to nameplate, performance



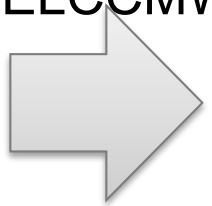


Sum the pieces for any given hybrid unit, not to exceed MFO



Hybrid Class and Unit Example

- ELCC model shows 2,640 MW total ELCCMW value for class of solar+6 hour storage.
- This class has 3,000 MW total nameplate of solar components and 1,600 MW total nameplate of ESR components.
- The ELCC% for the solar-alone class is 50%.
- The 2,640 MW hybrid class ELCCMW is divided into:
  - 3,000 MW * 50% = 1,500 MW related to the solar components
  - 2,640 MW – 1,500 MW = 1,140 MW related to the ESR components
- A given hybrid unit will have ELCC credit based on the sum of:
  - [1,500 MW/3,000 MW]*[Unit solar nameplate MW]*[PerformanceAdjuster] plus
  - [1,140 MW/1,600 MW]*[Unit ESR nameplate MW]*[1-EFORd]
- A hybrid with 100 MW solar and 25 MW storage, 110% solar Performance Adjuster, and 10% EFORd, would therefore have an ELCCMW of:
  - 0.5*100*110% = 55 MW, plus
  - 0.7*25*(100% - 10%) = 15.8 MW



70.8 MW

Hybrid Deployment Scenarios

- Developed from Queue numbers
- Subtracted from solar, storage, and other relevant deployment assumptions via vendor forecast

Overall Treatment of Hydro Resources with Storage = TBD

Treatment of Hydro Resources with Storage Reservoir = TBD

- Simulated dispatch in the ELCC model and relationship to historical data
- ELCCMW allocation to individual units
- Performance Adjustment metric

Design Component 3: Consideration of a Changing ELCC

Solution Option A

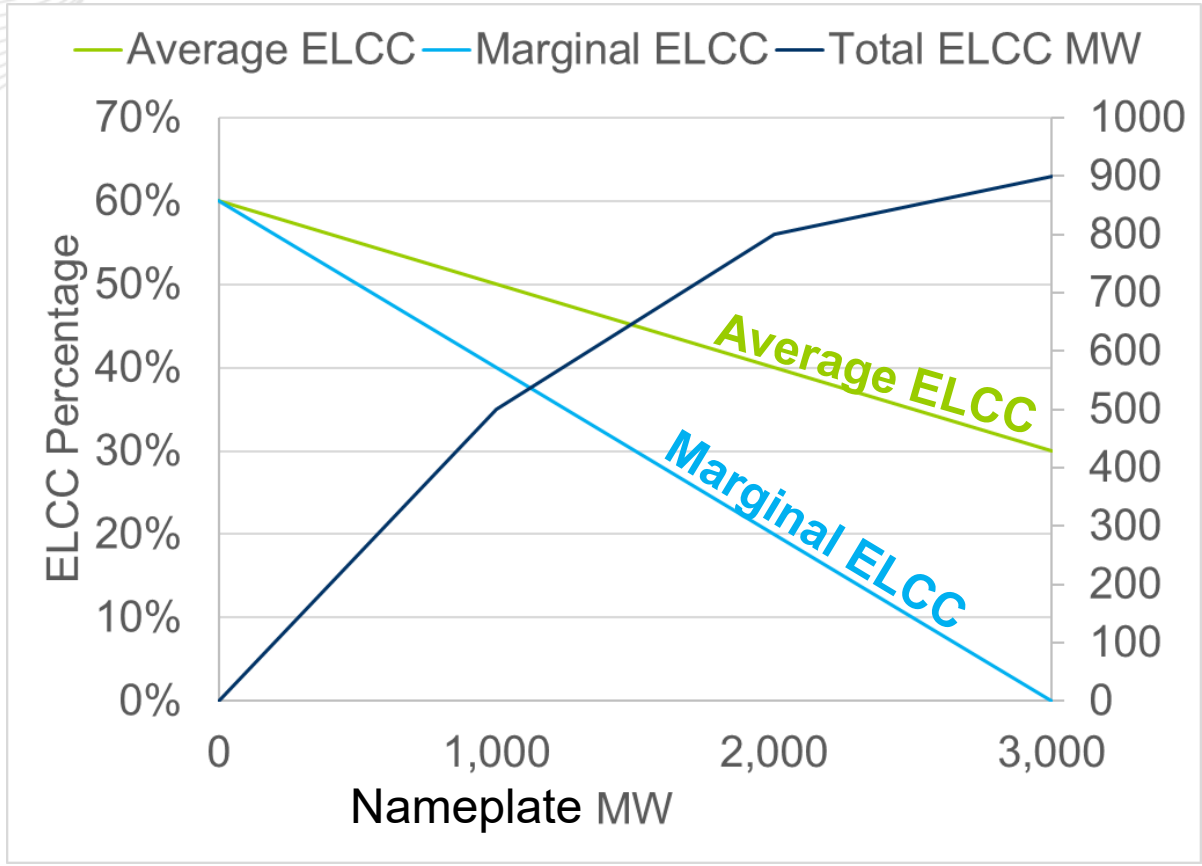
- In general, PJM proposes to calculate Class ELCC% using this quotient:

$$TotalClassELCCMW \Big/ TotalClassMW$$

- *(Note: TotalClassMW corresponds to MFO or ICAP, depending on resource category. Also combination resources are slightly more complex as described above.)*
- This can be referred to as the "average ELCC%" (as distinct from "marginal ELCC%").
- The Class ELCC% based on average ELCC% would be updated each year (subject to "rounding bands" discussed above), and can increase or decrease.
- The plan to transition from status quo rules to ELCC rules is TBD.

Marginal ELCC% vs. Average ELCC%

	Total ELCCMW of Fleet	Average ELCC%	Marginal ELCC%
1 MW	0.6 MW	60.00%	60%
1,000 MW	500.0 MW	50.00%	40%
1,001 MW	500.4 MW	49.99%	40%
2,000 MW	800.0 MW	40.00%	20%
2,001 MW	800.2 MW	39.99%	20%
3,000 MW	900.0 MW	30.00%	0%
3,001 MW	900.0 MW	29.99%	0%



Design Component 4: Technical considerations of ELCC

- The Class ELCCMW is determined by measuring the additional load that the Class resources can serve (while maintaining reliability) relative to the additional load that a perfect generating unit can serve (while maintaining reliability). This approach is described as the "Generation approach" in previous presentations.
- For resources expected to grow significantly: vendor forecast for resource mix going forward 10 years, including data that supports an assessment of the share per class that are likely to participate in the Capacity Market. **For combination resources: use Queue numbers.** For other resources: use current deployment levels.
- Scale up hourly profiles of existing and Planned intermittent class/units consistent with vendor resource mix forecast to develop forward ELCC cases.
- Energy Resources (i.e., those that do not participate in RPM) are *not* included in any classes, but do contribute towards the hourly net risk shape.
- The ELCC model will include all available years of data on the uncertainty of Intermittent Resource output relative to load, beginning with 2012.
- The ELCC model does not include forced outages of limited duration and combination type resources.

Design Component 5--Unit-specific Performance Adjustment for Intermittent Resources Used to Allocate Class ELCC to Specific Units

Principles of a Good Performance Adjustment for Intermittent Resources

- Commensurate with the ELCC metric
- Transparent and understandable
- Good signal-to-noise ratio

Marginal ELCC% vs. Average ELCC%

	Total ELCCMW of Fleet	Average ELCC%	Marginal ELCC%
1 MW	0.6 MW	60.00%	60%
1,000 MW	500.0 MW	50.00%	40%
1,001 MW	500.4 MW	49.99%	40%
2,000 MW	800.0 MW	40.00%	20%
2,001 MW	800.2 MW	39.99%	20%
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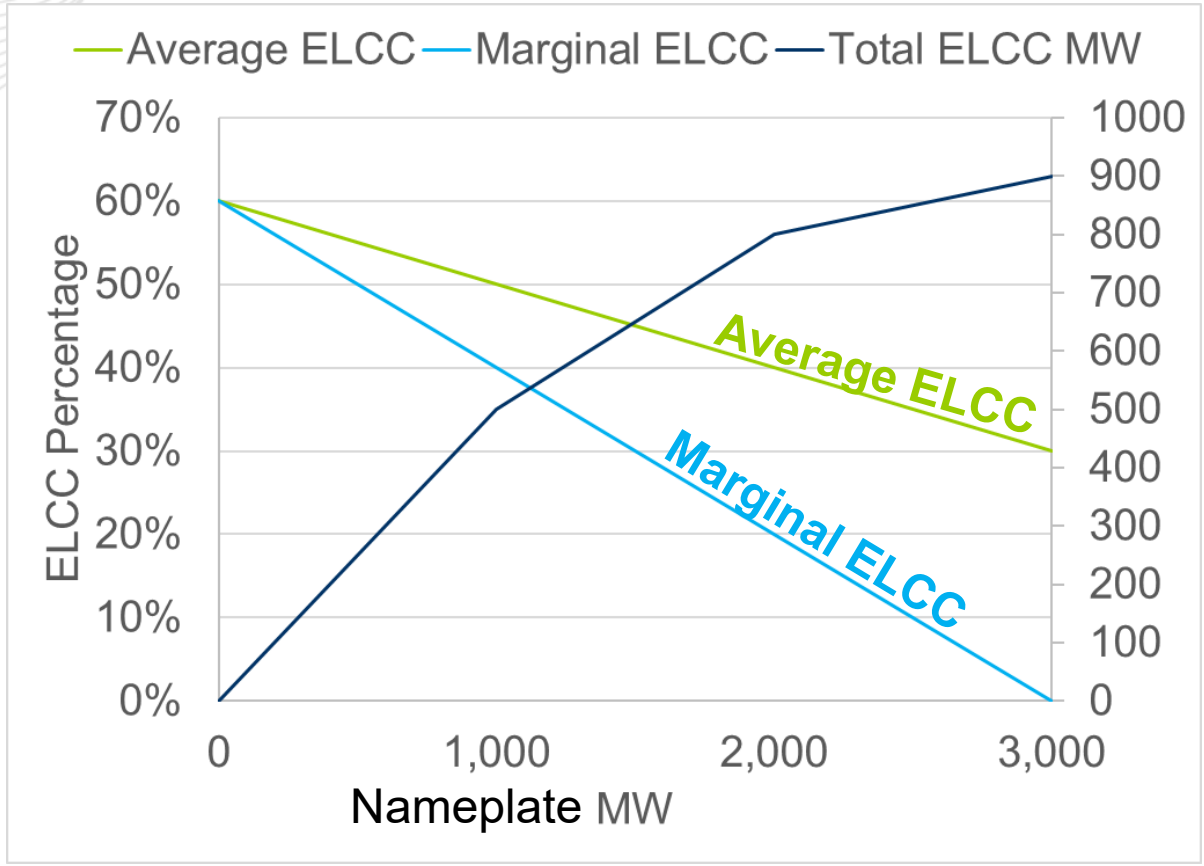
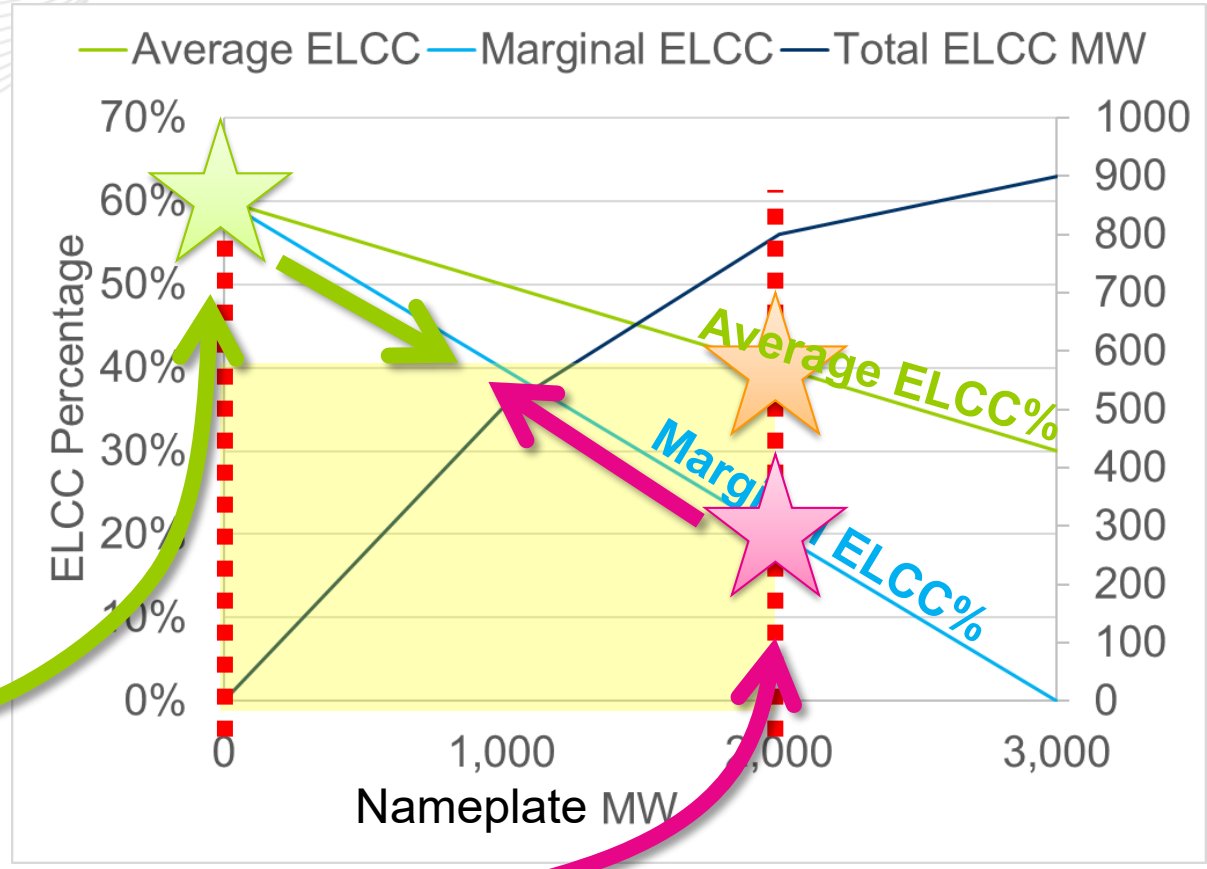


What is Average ELCC

- The metric “Average ELCC%” is the total ELCC value of a entire class fleet divided by the total nameplate of the fleet.
  - E.g., 2,000 MW nameplate of a class with a 800 MW ELCCMW yields an “average ELCC%” of 40%.
- If the marginal ELCC% is a ~linear function of deployment, then **average** ELCC is conceptually related to the average of:
  1. **The marginal ELCC% of adding a small unit to a resource mix with no other limited resources, and**
  2. **The marginal ELCC% of adding a small unit in the expected or actual resource mix, which includes many limited resources**



Example of identifying average ELCC at 2,000 MW

A = Marginal ELCC% at 1 MW = 60%
B = Marginal ELCC% at 2,000 MW = 20%
Average of A and B = 40%
Average ELCC% at 2,000 MW = 40%

	Total ELCC of Fleet	Average ELCC	Marginal ELCC
1 MW	0.6 MW	60.00%	60%
1,000 MW	500.0 MW	50.00%	40%
1,001 MW	500.4 MW	49.99%	40%
2,000 MW	800.0 MW	40.00%	20%
2,001 MW	800.2 MW	39.99%	20%
3,000 MW	900.0 MW	30.00%	0%
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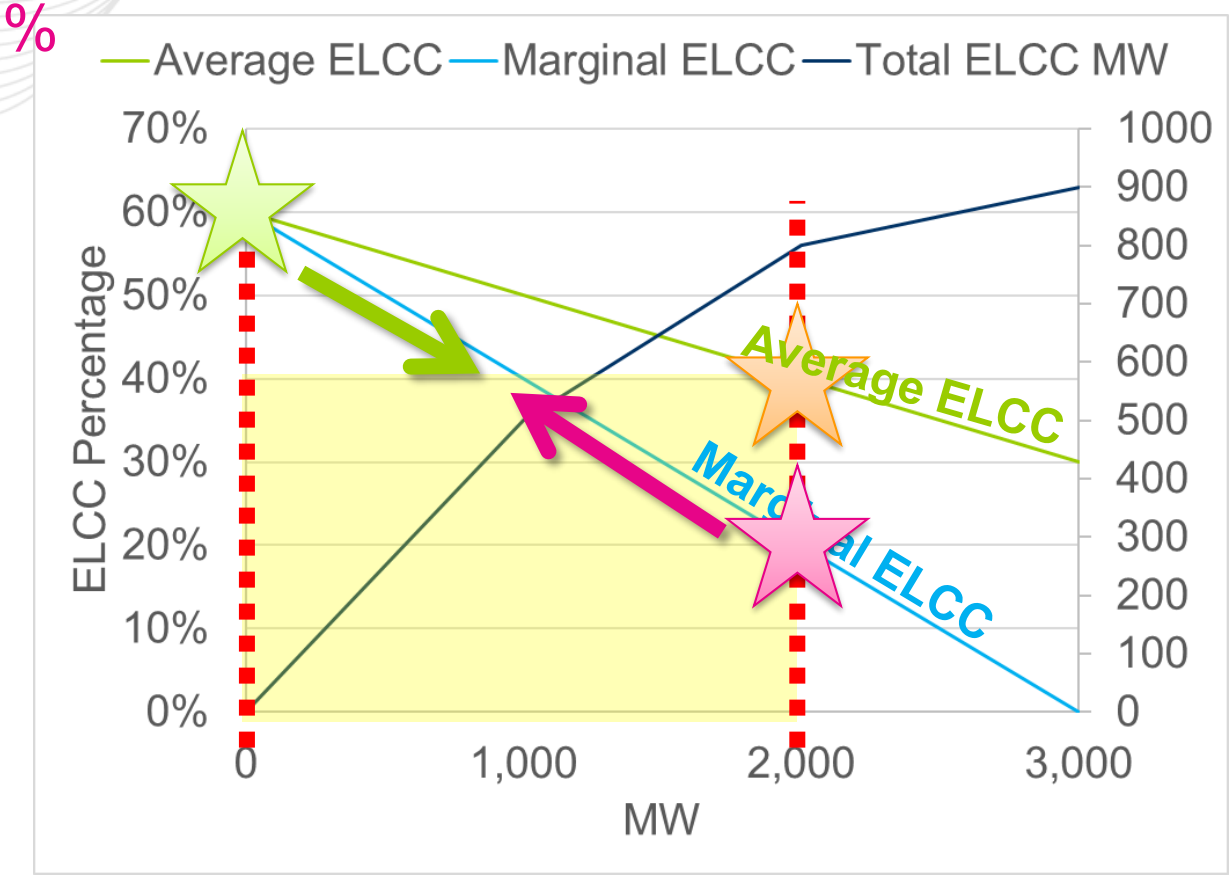


Performance Metrics and Marginal ELCC

- "Gross load" is actual PJM load.
- "Net load" is "Gross load" minus the output of Intermittent Resources.
- The output of a resource during the "gross load" peak hours is roughly commensurate with the marginal ELCC **of a small unit in a resource mix with no other limited resources.** That is because reliability risk in a world with no limited resources is completely dependent on load.
- The output of a resource during the "net load" peak hours is roughly commensurate with the marginal ELCC **of a small unit in the expected or actual resource mix, which includes many limited resources.**
- Given the foregoing slides, the average of the actual output of an intermittent resource during 1) the gross load peak hours and 2) the net load peak hours should be roughly commensurate with the average ELCC.

PJM Proposed Performance Metric for Intermittent Resources

1. Identify the 200 coincident peak “gross load” hours of the last 10 years, regardless of which year or which day they occurred.
   - Many years could have no hours in this set
   - Many days could have several hours in this set
2. Identify the 200 coincident peak “putative net load” hours of the last 10 years, regardless of which year or which day they occurred.
   - The “putative net load” is the gross load minus the putative output of the Intermittent Resources that are expected to be deployed in the year that the ELCC analysis is actually run.
3. For each unit: take the average of the actual or backcasted output of a resource during the above 200CP “gross load” hours and the 200CP “putative net load” hours. This is the “performance metric”, which forms the basis for the pro rata share of the class ELCCMW that is allocated to the unit.
4. The ratio of a unit’s “performance metric” to the entire class’s performance metric is that unit’s “unit specific performance adjustment” or simply “performance adjustment”.
5. The class ELCCMW is allocated to each unit on a pro rata share based on (Maximum Facility Output)*(Performance Adjustment).
6. Transition plan for Performance Adjustment for upcoming ELCC runs TBD. Might not use data prior to 2012.

Performance Metric Example

	Maximum Facility Output	ELCCMW	Performance metric	Performance adjustment	Pro rata share of total ELCC	Final Unit-Specific ELCCMW Accreditation = MFO* ClassELCC%* PerfAdj
Unit 1	1,600 MW	-	160MW/1600 MW = 10%	10%/12% = **83.33%**	1,600*83.33% = 1,333.33	133.33 MW = 1,600 MW * 10% * 83.33%
Unit 2	400 MW	-	80MW/400MW = 20%	20%/12% = **166.67%**	400*166.67% = 666.66	66.66 MW = 400 MW * 10% * 166.67%
Fleet total or average	2,000 MW	**200 MW**, average Class ELCC = 10%	240/2,000 MW = 12%	-	2,000	**200 MW**

Performance Adjustment for Limited Duration Resources

- The Performance Adjustment for Limited Duration Resources is (1-EFORd).
- Note that forced outages of limited duration resources would not be modeled in the ELCC model.

Design Component 6: Simulated Dispatch

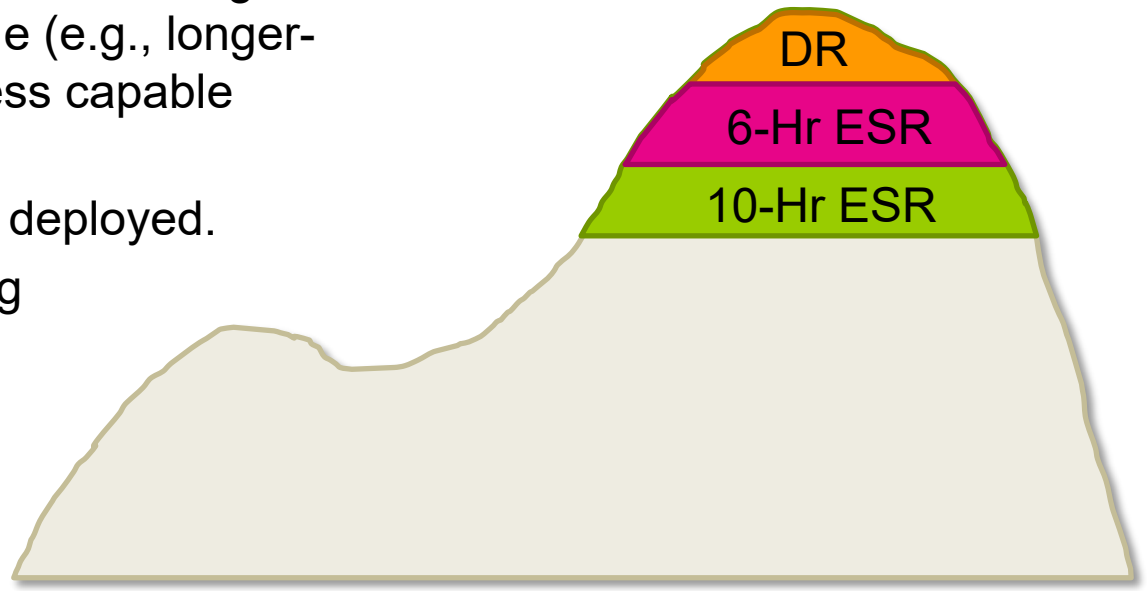
Simulated Dispatch of Intermittent Resources

- Intermittent Resources: unaltered backcast and unaltered actual historical output is considered in the hourly profiles used for ELCC accreditation.

Simulated Dispatch of Limited Duration Resources

Limited duration resources including Energy Storage Resources:

- Hour by hour dispatch such that the output of the resource is enough to prevent a loss of load before calling DR. More capable (e.g., longer-duration) generation resources are dispatched before less capable (e.g., shorter-duration) generation resources.
- Limited duration resources are dispatched before DR is deployed.
- Charging is during hours with sufficient margin, including between daily peaks in winter.
- Limited duration resource output not to exceed:
  - For Existing Resources: CIRs held in the year of the ELCC run, or
  - For Planned Resources offering into an auction: CIRs secured by a Facilities Study Agreement that will be executed by the February following the ELCC run, or
  - For other limited duration resources: CIRs set at ICAP



Simulated Dispatch of Combination Resources (excl. hydro with storage)

Combination resources including solar+battery hybrids:

- Modeled output from intermittent component is from submeter-based actual output or backcast
- Grid-charging is during the trough or other hours with sufficient margin. If no grid charging available, then on-site self-supply charging is during hours with sufficient margin.
- Hour by hour dispatch of ESR component such that:
  - The output of the resource is enough to prevent a loss of load before calling DR.
  - The combined output of the intermittent component and ESR component does not exceed the unit MFO.
- More capable (e.g., longer-duration) generation resources are dispatched before less capable (e.g., shorter-duration) generation resources.
- Limited duration generation resources are dispatched before DR is deployed (DR is deployed last).
- Combination resource output not to exceed:
  - For Existing Resources: CIRs held in the year of the ELCC run, or
  - For Planned Resources offering into an auction: CIRs requested in an active Queue position
  - For any combination resources in the model that are neither Existing nor Planned (as applicable): CIRs set at ICAP

Design Component 7: Reporting

- Annual report with details on results and methodology, broadly similar to MISO wind ELCC report: https://cdn.misoenergy.org/2020%20Wind%20&%20Solar%20Capacity%20Credit%20Report408144.pdf