ELCC Allocation Methodologies

Marginal, Average, and the Delta Method

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Energy+Environmental Economics

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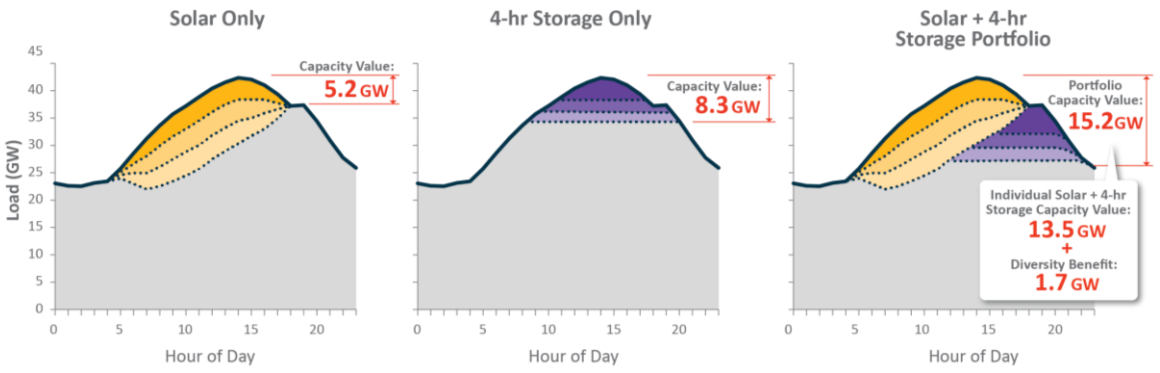
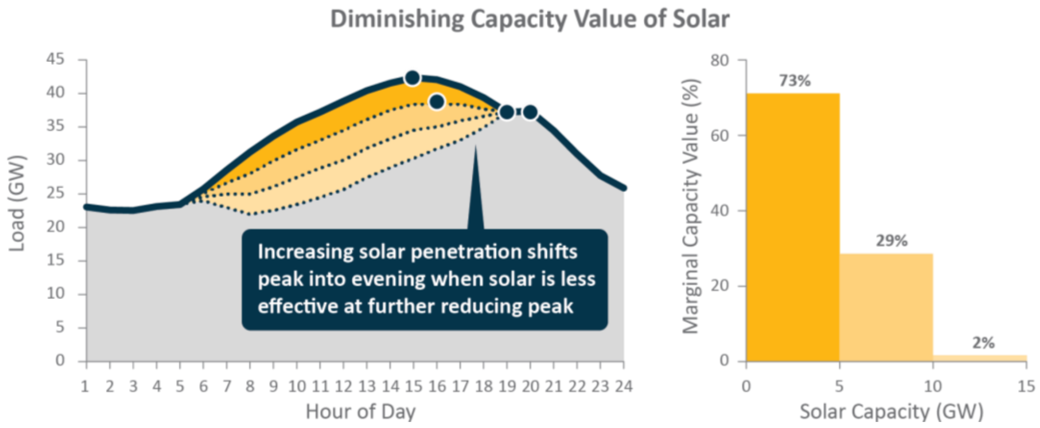
Outline

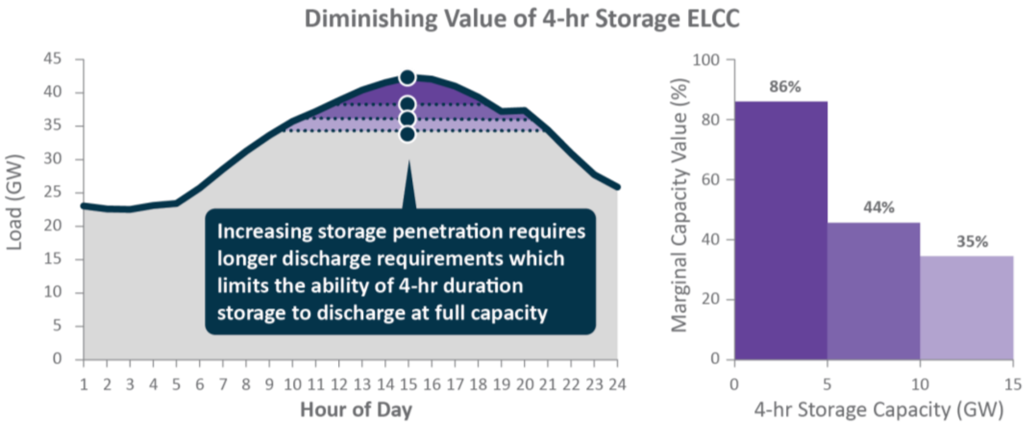
- Brief refresh on ELCC dynamics
- Methodological challenges with an “average” ELCC framework
- Delta method details

Refresh on ELCC Dynamics

- E3 presented on ELCC concepts and considerations at NYISO stakeholder meeting on August 30, 2021
- Effective Load Carrying Capability (ELCC) represents the equivalent "perfect" capacity that a resource provides
- ELCC is a function of a portfolio of resources and captures both 1) diminishing returns and 2) diversity benefits among resources







Measuring ELCC of a Portfolio and Individual Resources

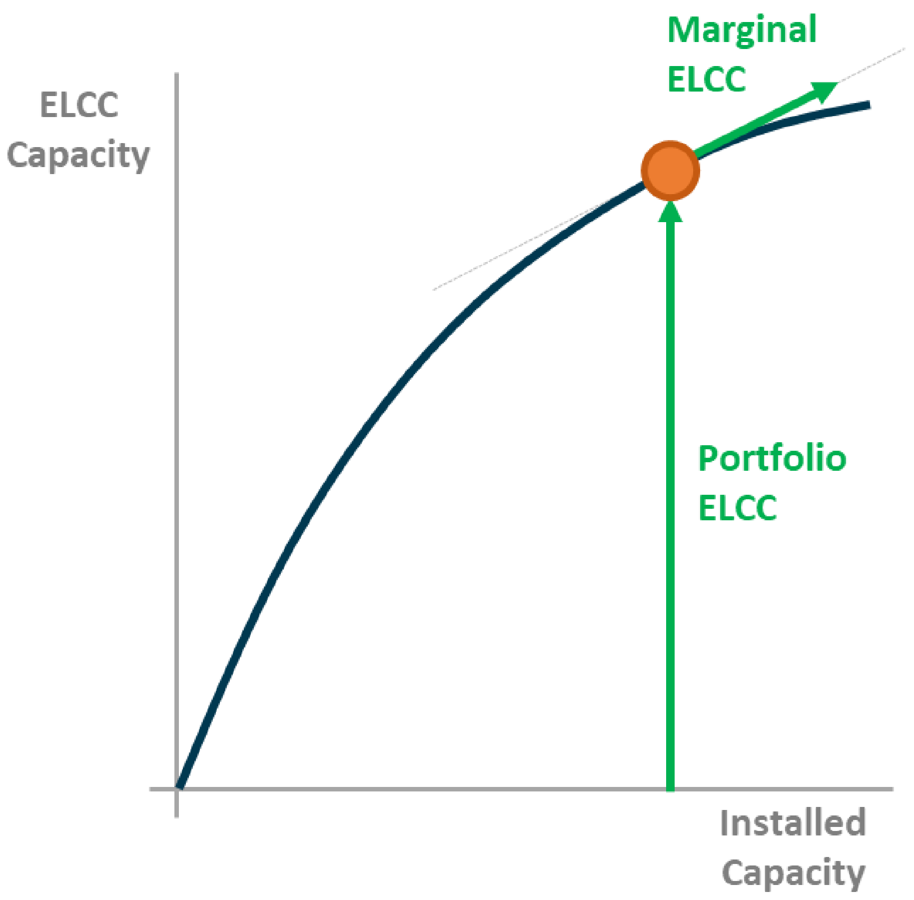
+ **ELCC of is a function of the portfolio of resources**
  - The function is a surface in multiple dimensions
  - The Portfolio ELCC is the height of the surface at any given point on the surface

$$Portfolio\ ELCC = f(G_1, G_2, \ldots, \ G_n)\ (MW)$$

  - The Marginal ELCC of any individual resource is the gradient (or slope) of the surface along a single dimension – mathematically, the partial derivative of the surface with respect to that resource

$$Marginal\ ELCC_{G_1} = \frac{\partial f}{\partial G_1}(G_1, , G_2, \ \ldots\ G_n)\ (\%)$$

+ **The functional form of the surface is unknowable**
  - Marginal ELCC calculations give us measurements of the contours of the surface at specific points
  - It is impractical to map out the entire surface

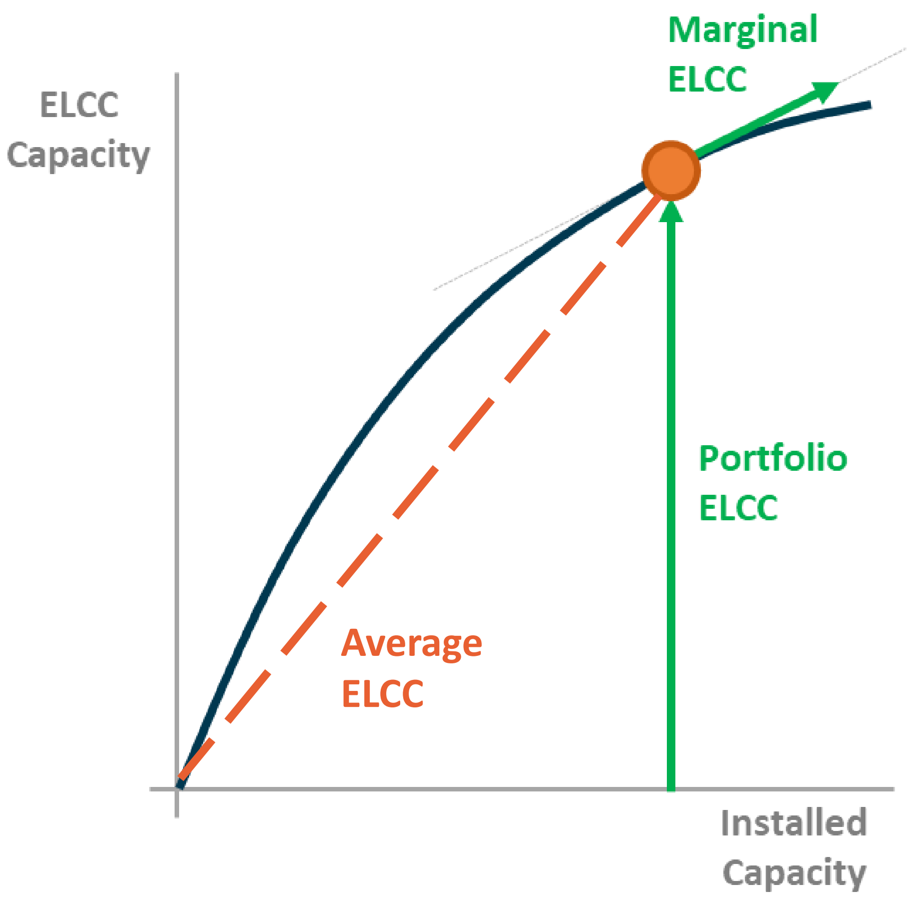


What is an "Average ELCC"?

- With only one resource, an Average ELCC can be defined as the Portfolio ELCC divided by the total installed MW

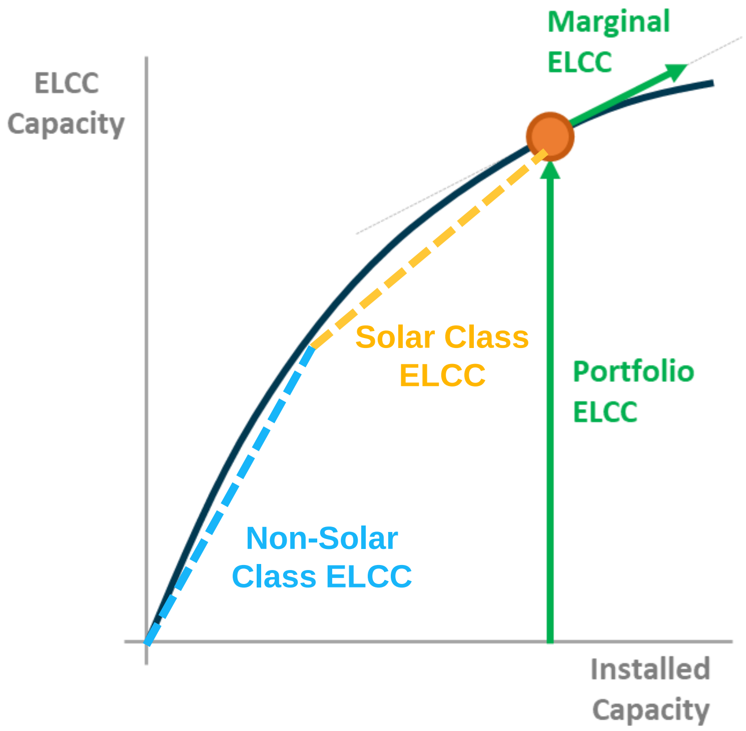
$$Average\ ELCC_{G_1} = \frac{f(G_1)}{G_1}\ (\%)$$

- Average ELCCs are perceived as useful because the sum of individual ELCCs can be made to be equal to the total Portfolio ELCC
  - This is done by starting with the Portfolio ELCC and allocating it among individual resources
  - Useful for display in a load-resource table
- Any averaging method requires an allocation of the interactive effects among the various resource types

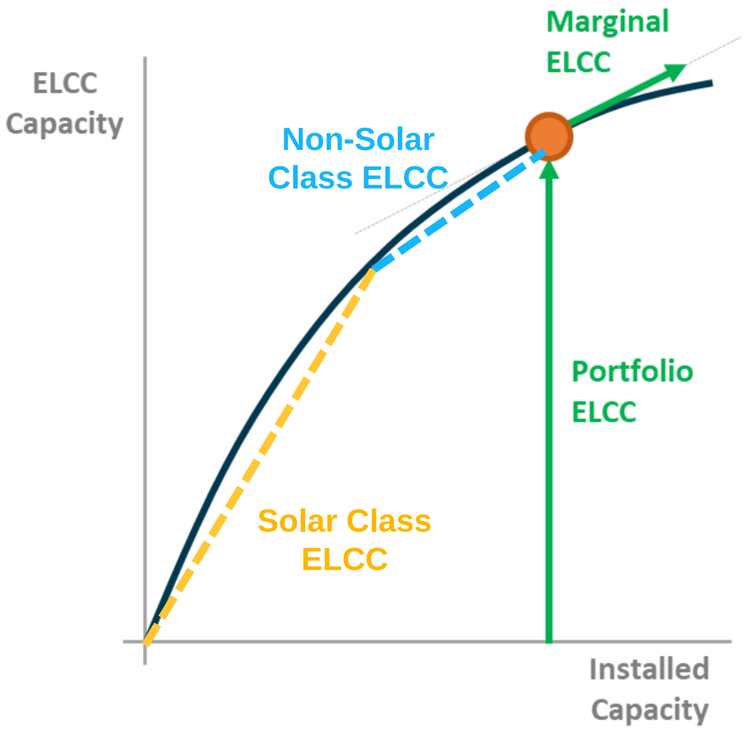


Issue 1: The Starting Portfolio

- **With multiple resource classes on the system, measuring the ELCC of each class requires the decision of whether to include or exclude all other classes**
  - Excluding other classes will ignore interactive effects
  - Including other classes will double count interactive effects
- **If the ELCC of each class is measured consistently (meaning other classes are always included or always excluded), the sum of resource class ELCCs will not equal portfolio ELCC due to the exclusion or double counting of interactive effects**
- **In either case, resource class ELCCs must be adjusted or scaled such that they sum to Portfolio ELCC**
- **Note, this issue can be eliminated by deciding an "ordering" to measuring resource class ELCCs, but this introduces inequity in determining the arbitrary order**



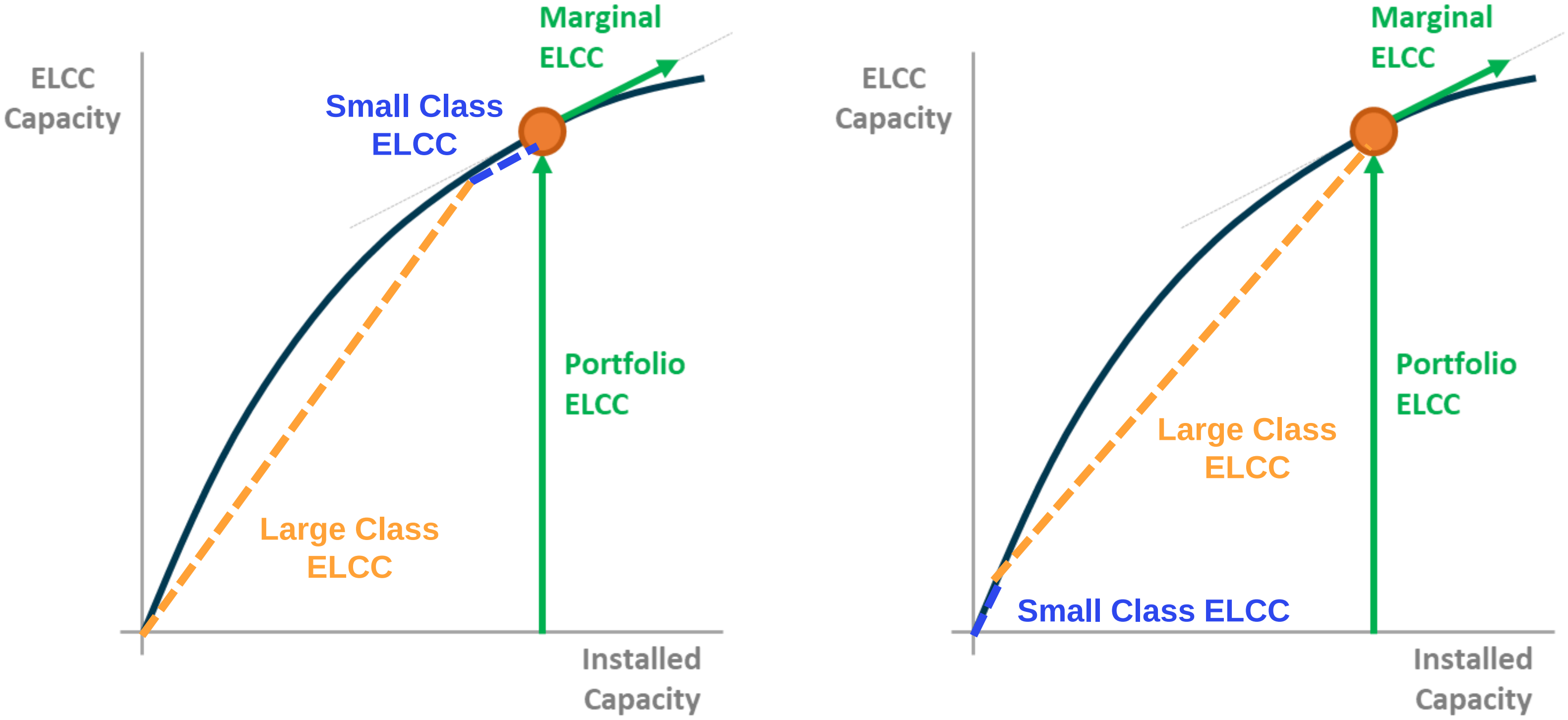
Solar class ELCC is measured from a starting portfolio *with* all non-solar resources



Solar class ELCC is measured from a starting portfolio *without* all non-solar resources

Issue 2: Differences in Resource Class Sizes

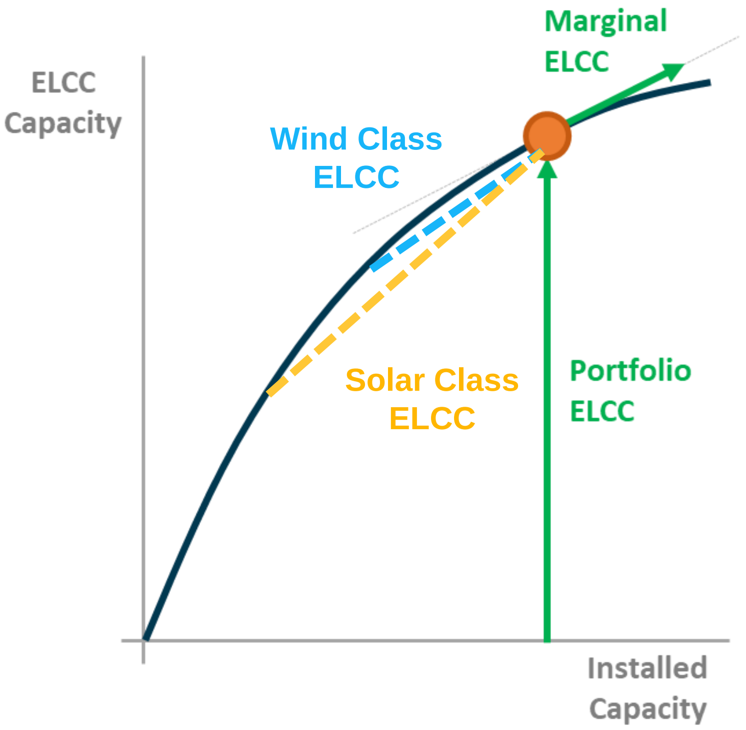
- An important and related topic to issue #1 (starting portfolio) is inequities that can result from resource classes of different sizes
- For large resource classes that dominate the portfolio, there may not be a large difference in resource class ELCC if the other smaller classes are included or excluded
- For small resource classes, there may be a large difference in resource class ELCC if the large class is included or excluded
- The ELCC of these resources should be differentiated by their underlying generation characteristics alone, not the difference in size of their potentially arbitrary resource class assignments
- In either case, resource class ELCCs must be adjusted or scaled such that they sum to Portfolio ELCC



Large Class ELCC is largely the same in both figures while Small Class ELCC differs significantly depending on whether it is measured with or without the Large Class

California Approach

- The California Public Utilities Commission (CPUC) administers the state's resource adequacy program, including using ELCC for the accreditation of wind and solar resources
- The CPUC calculates the ELCC of solar and wind using the following process
  - Calculate portfolio ELCC for solar and wind
  - Calculate ELCC for entire solar class (with wind included in starting portfolio) and entire wind class (with solar included in starting portfolio)
  - Scale wind and solar ELCC classes proportionally such that they sum to portfolio ELCC
- This approach can inadvertently scale resources that should not be scaled
  - For a resource like solar with diminishing returns, its low marginal ELCC should be scaled upward to account for the fact that early additions of solar had a much higher ELCC
  - For a non-interactive baseload resource like geothermal with constant high ELCC, its high marginal ELCC should not be scaled upward since early additions of geothermal had the same ELCC as marginal additions
    - California has experienced this phenomenon in the early investigation of storage ELCC – storage had a marginal ELCC of 100% since not enough had been installed to experience diminishing returns. Scaling storage ELCC proportionally to wind and solar ELCC resulted in >100% ELCC

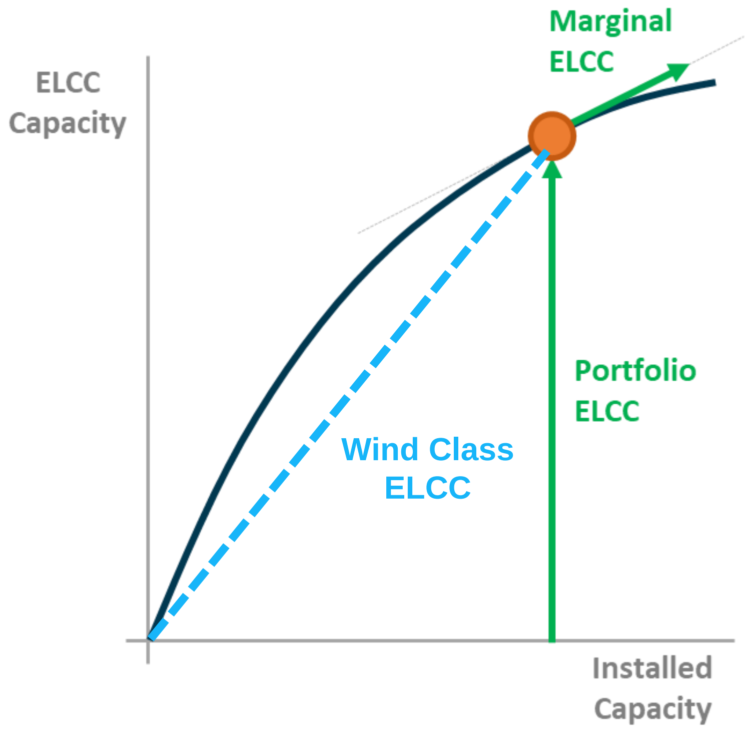


Solar class ELCC and Wind class ELCC are scaled such that they sum to Portfolio ELCC

https://www.cpuc.ca.gov/-/media/cpuc-website/files/legacyfiles/r/6442452545-revised-elcc-propsal-2-14.pdf

MISO Approach

- **The Midcontinent Independent System Operator (MISO) employs an ELCC approach for wind only**
- **MISO uses the following calculation process**
  - Calculate wind portfolio ELCC
    - Only wind is included in the portfolio
    - Solar and other resources are included in the background system but have historically been small
  - Proportion out wind portfolio ELCC to wind generators in different geographic locations using historical capacity factor during peak load hours
    - i.e. a wind location with twice as much generation during peak load hours would receive twice the allocation of the wind portfolio ELCC
- **While this approach is reasonable for wind, it is not scalable to incorporate different resource classes such as solar or storage**



https://cdn.misoenergy.org/2019%20Wind%20and%20Solar%20Capacity%20Credit%20Report303063.pdf

The Delta Method

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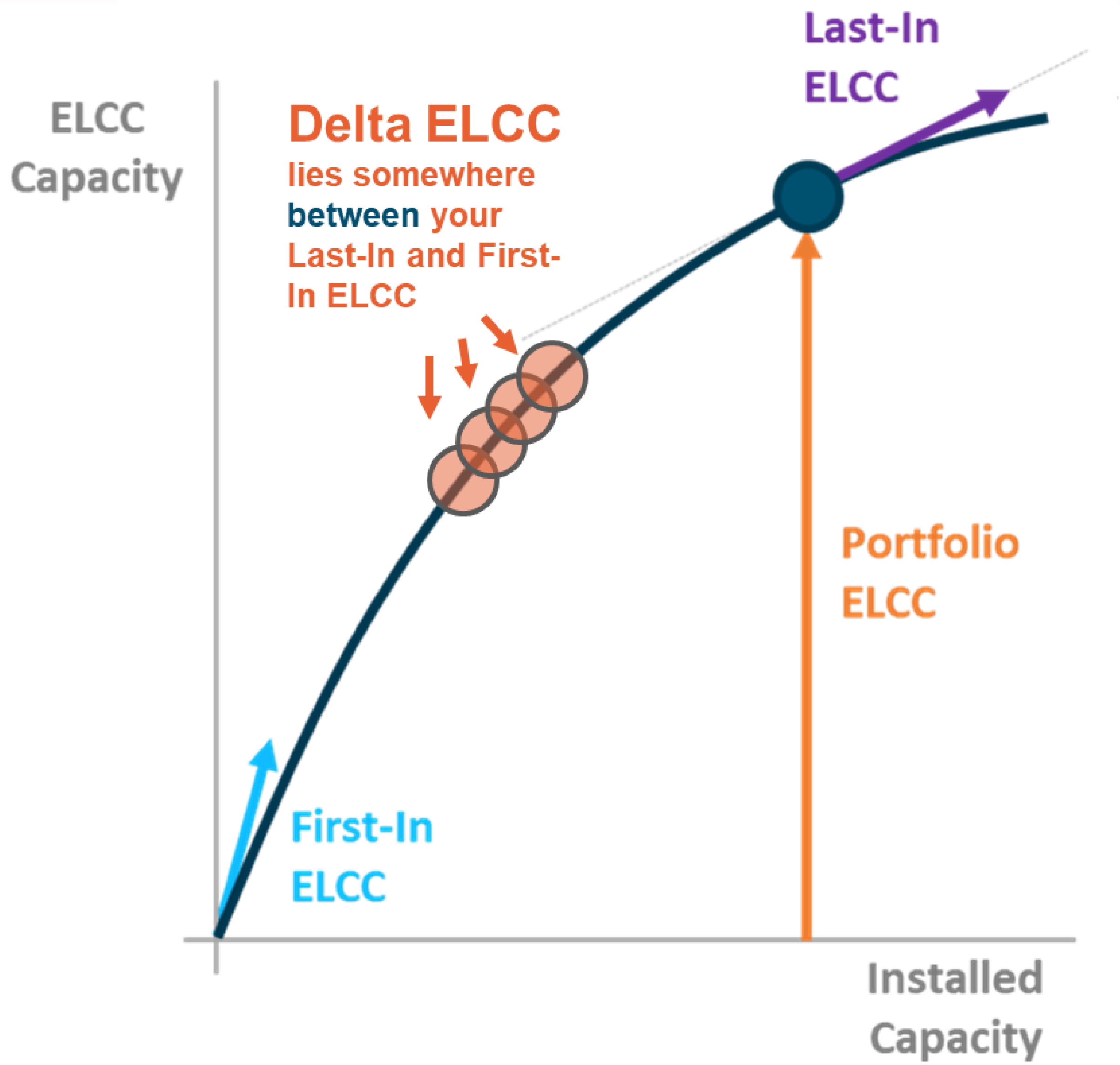
Delta Method captures resource's capacity value and their interactions with the rest of the portfolio

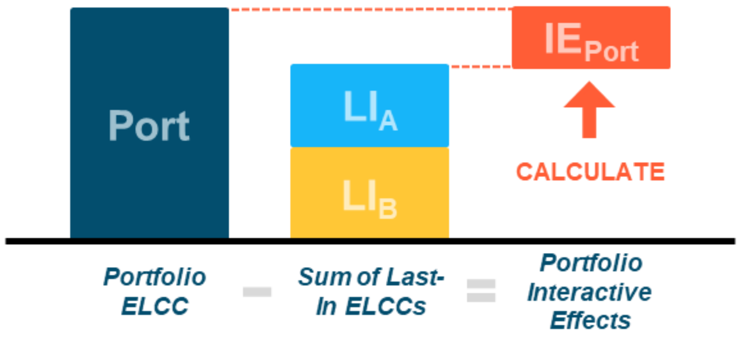
+ **The Delta Method was developed to ensure an "average" ELCC accreditation framework that is fair, robust, and scalable to any portfolio of intermittent and energy-limited resources**
+ **The Delta Method relies on are 3 measurable metrics:**
  - **Portfolio ELCC:** total ELCC provided by a combination of variable and use-limited resources
  - **"First-In" ELCC:** the marginal ELCC of each individual resource in a portfolio with no other variable or use-limited resources
  - **"Last-In" ELCC:** the marginal ELCC of each individual resource when taken in the context of the full portfolio
+ **The Delta Method ensures that each resource receives an ELCC value that is in-between its First-In and Last-In values**
  - Resources that exhibit diminishing returns (e.g. chart to right) receive an upward adjustment to Last-In (or equivalently a downward adjustment to First-In)
  - Resources that exhibit constant ELCC (i.e. First-In = Last-In) receive no adjustment
+ **This approach can simultaneously account for synergistic, antagonistic, and neutral reactions within a single portfolio**
  - Different resources can receive positive, negative, or no adjustments



Delta Method:
Calculation Approach

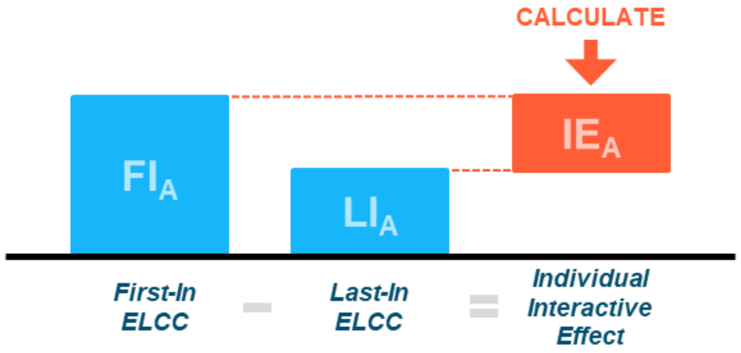
STEP 1 Calculate Portfolio Interactive Effects

Calculated as the difference between the **Portfolio ELCC** and the sum of the **Last-In ELCCs** for all individual resources



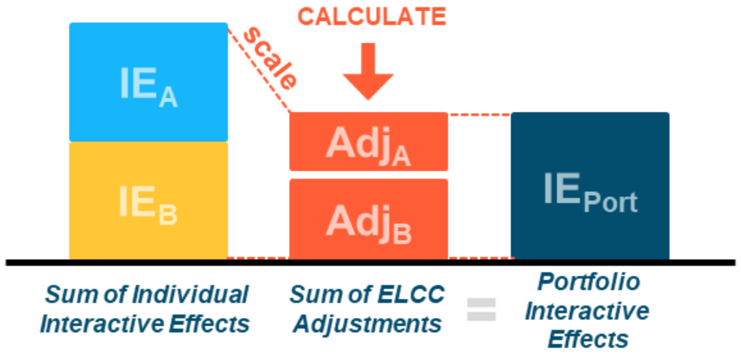
STEP 2 Calculate Individual Interactive Effects (for each resource)

Calculated as the difference between the **First-in ELCC** and **Last-In ELCC** for each individual resource



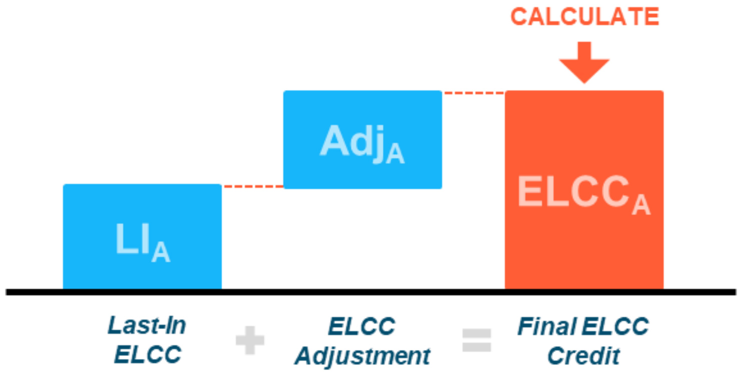
STEP 3 Calculate Individual ELCC Adjustments

Calculated by scaling all *Individual Resource Diversity Impacts* to match the *Portfolio Diversity Impact*



STEP 4 Calculate ELCC Accreditation (for each resource)

Add *Individual Resource ELCC Adjustment* to **Last-In ELCC** for each individual resource



Delta Method: Numerical Example

- The following represents a simple and illustrative numeric example demonstrating how ELCC credits would be calculated using the Delta methodology on a system with solar, wind, and storage resources
- This example illustrates how ELCCs would be calculated for technology classes, but a similar approach could be utilized for individual resources

			Solar	Wind	Storage	
Step 1	A	Total Capacity (MW)	20,000	5,000	1,000	Nameplate Capacity of each technology
	B	Portfolio ELCC (MW)	8,000			Produced by reliability model
	C	First-in ELCC (%)	50%	40%	80%	
	D	Last-in ELCC (%)	10%	20%	90%	
	E	Sum of Last-in ELCCs (MW)	3,900			SUMPRODUCT(D, A)
	F	Portfolio Interactive Effects (MW)	4,100			B – E
Step 2	G	Individual Interactive Effects (MW)	8,000	1,000	-100	(C – D) * A
Step 3	H	Sum of Individual Interactive Effects (MW)	8,900			SUM(G)
	I	Scaling Ratios (%)	89.9%	11.2%	-1.1%	G / H
	J	Allocated Interactive Effects (MW)	3,685	461	-46	I * F
Step 4	K	Delta Method ELCC (MW)	5,685	1,461	854	(A * D) + J

Sum of class ELCCs equals Portfolio ELCC

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Delta Method: Mathematical Representation

The Delta Method: Doing the Math

Consider a system with resources $r_1, r_2 \ldots r_n$ with installed capacities of $C_1, C_2 \ldots C_n$, respectively. The ELCC function for this system is given by $f(r_1, r_2 \ldots r_n)$. Then:

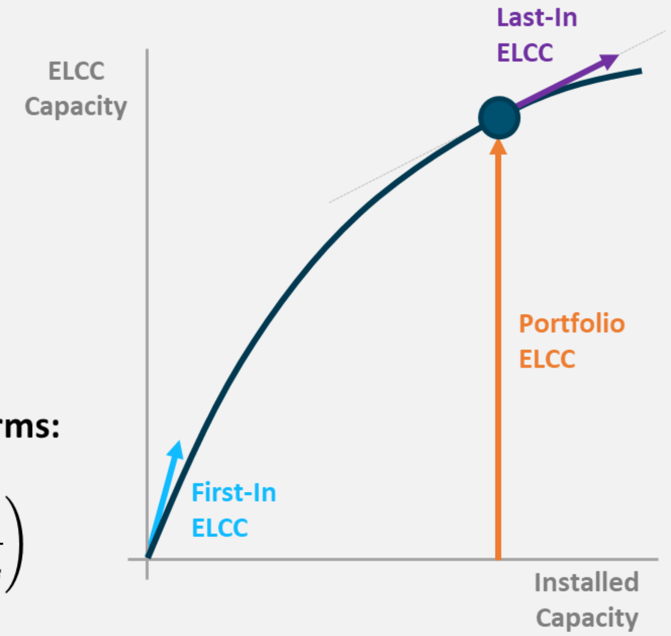
Portfolio ELCC: $P = f(C_1, C_2 \ldots C_n)$

First-In ELCC: $FI_i = C_i \cdot \frac{\partial f}{\partial r_i}(0, 0 \ldots 0)$

Last-In ELCC: $LI_i = C_i \cdot \frac{\partial f}{\partial r_i}(C_1, C_2 \ldots C_n)$

The ELCC attributed to each resource is calculated from these terms:

Resource ELCC: $ELCC_i = LI_i + \left(P - \sum_{j=1}^{n} LI_j\right)\left(\frac{LI_i - FI_i}{\sum_{j=1}^{n} LI_j - FI_j}\right)$



Market Considerations

+ **While the Delta Method presents a theoretical framework for resource-specific ELCCs, there are practical issues associated with implementing this method**
  - **Computational Burden and Simplicity**
    - **Problem:** Running ELCC calculations for thousands of individual resources will likely be too computationally intensive given existing modeling techniques
    - **Consideration:** A pre-defined library of ELCC values could be used to assign an ELCC to a resource with similar characteristics. This application to individual resources should not be confused with class-based approach which calculates the ELCC of an entire class instead of individual resources
  - **Certainty and Risk Mitigation**
    - **Problem:** ELCC accreditation may reduce transparency and predictability of capacity value
    - **Consideration:** Some entities have considered conducting forward-looking studies under a variety of resource portfolios, provide indications of future ELCCs or proposed guarantees to provide more certainty around ELCC for a period of time

Current ELCC Accreditation Methodologies

ISO	Status	Resources	Description	Takeaway	Source
CAISO	Implemented	Solar, Wind, Storage	Diversity benefit is allocated to resource classes based on their share of total Last-In ELCC	Can result in ELCCs outside the bounds of first-in/last-in, requiring manual reallocation of ELCC across resource classes.	2020 Qualifying Capacity Methodology Manual
MISO	Implemented	Wind	Wind portfolio ELCC is calculated using the past 15 weather-years. ELCC is redistributed geographically based on capacity factor.	Does not scale to new resource classes	PY 2021-22 Wind & Solar Capacity Credit Report
PJM	Approved	Solar, Wind, Storage, Hydro, Biogas	Delta method is used to allocate the diversity benefit. Vintaged floor was rejected at FERC.	More intuitive allocation of diversity benefit across resource classes.	PJM Manual 20
NWPP	Proposed	Solar, Wind, ROR Hydro	Last-in ELCC determined by class. Storage capacity value is determined via capability test.	Ignores interactive effects when setting procurement targets	NWPP Resource Adequacy Program – Detailed Design
SPP	Initial studies	Solar, Wind, Storage	Solar and wind: First-in ELCC is split into three tiers, first-in ELCC for each tier is calculated, and a weighted average is taken across the tiers	Ignores interactive effects when setting procurement targets	SPP 2020 ELCC Wind and Solar Study Report SPP Energy Storage Study

Challenges with Average ELCC approaches

+ **There are a variety of challenges with the way Average ELCC values have been calculated to date**
  - Any averaging method requires an allocation of the interactive effects among the various resource types
+ **These allocations are, by definition, arbitrary and can lead to counter-intuitive results**
  - If different resource classes are dramatically different in size (e.g., 10,000 MW of solar, 200 MW of storage)
  - CA: average ELCC for solar and wind with marginal diversity benefit allocation calculated on a monthly basis
+ **E3 developed the Delta Method to ensure intuitive allocation of interactive effects**
  - PJM's application of the Delta Method was recently approved by FERC
  - Average ELCC of a given resources is its Marginal ELCC plus an allocation of the Diversity Benefit based on its contribution to it

Thank You

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