



Energy+Environmental Economics

Capacity Value Framework & Allocation Options

Oregon PUC, Informational Workshop

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- + Introduction to the *General Capacity Investigation* proceeding (UM 2011)
- + Background on Capacity
- + *Key Question 1*: How much capacity can a resource provide?
- + *Key Question 2*: What is the value of capacity?
- + *Key Question 3*: What compensation framework should be used?
- + Use Cases and Examples
- + Wrap Up and Conclusions
- + *Appendix*

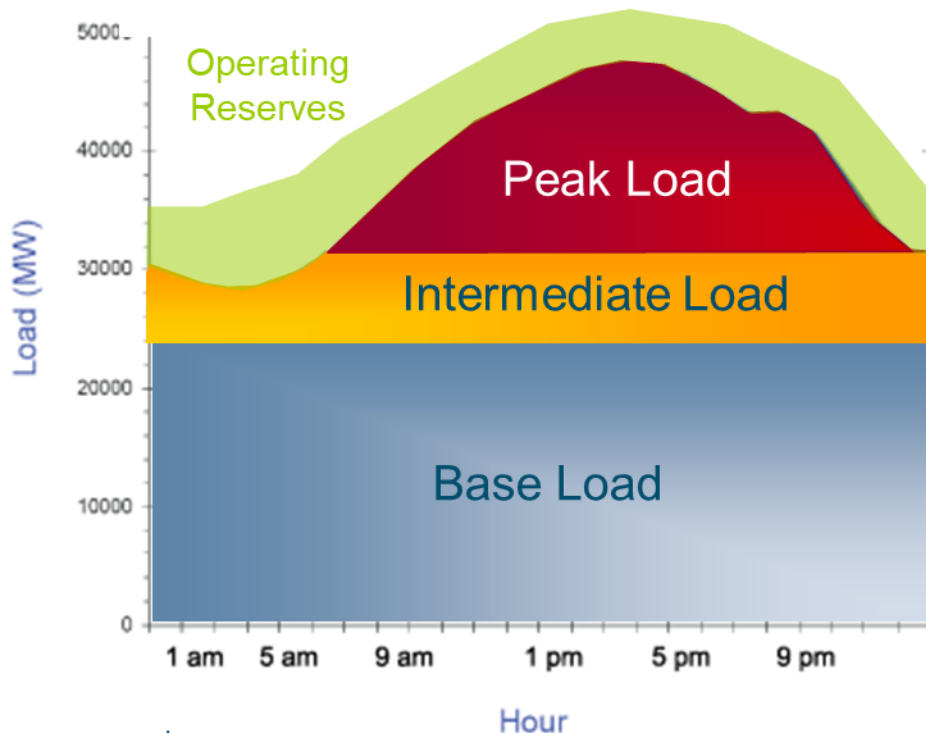


What is Capacity?

- + **Capacity is one critical element of a resource portfolio for reliability**
- + **Reflects portfolio's ability to:**
 - **Meet demand in all hours** (incl. peak), across a wide range of load / resource availability conditions
 - **Provide reliability on an equivalent basis to a “perfect” resource** (one that is always available without any outages)*

Capacity:

Instantaneous measure of electricity when needed to ensure load is met



Energy:
Electricity Produced over Time

* “Perfect” capacity is a theoretical concept, as in reality all resources have some probability of a forced outage



Key Questions

+ Against the backdrop of the OPUC *General Capacity Investigation* proceeding (UM 2011), there are two key questions:



1) How much capacity can a resource provide?



2) What is the value of capacity?

+ A separate but related question:



3) What compensation framework should be used?

- Ideally, the compensation framework should appropriately measure the capacity contribution (#1) and reflect the value of capacity (#2)

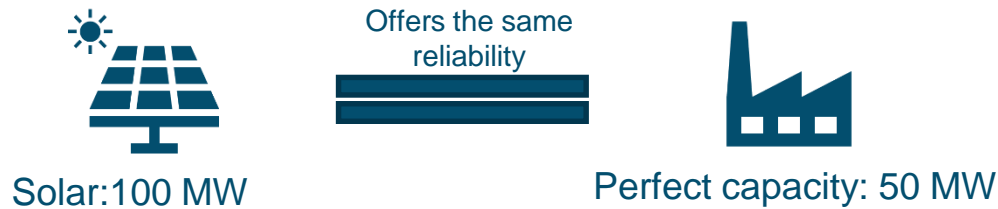


Key Question 1) How Much Capacity Can a Resource Provide?



How Much Capacity Can a Resource Provide?

- + The “gold standard” for measuring the capacity contribution of a resource is *effective load carrying capability (ELCC)*
- + ELCC measures the quantity of perfect capacity that would yield equivalent system reliability
- + For example, 50% ELCC of a solar generator



ELCC Calculation Process



A resource’s ELCC is equal to the amount of perfect capacity removed from the system in Step 3

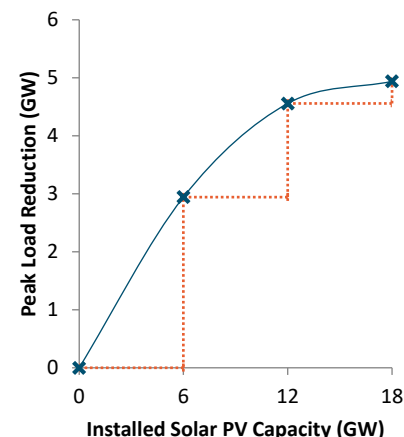
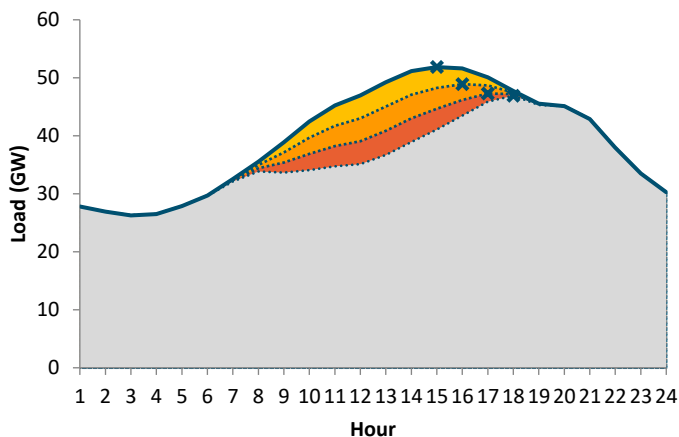


ELCC Dynamics

+ Because of complex interactions between resources such as wind, solar, storage, and demand response, it is difficult to measure the ELCC of an individual resource

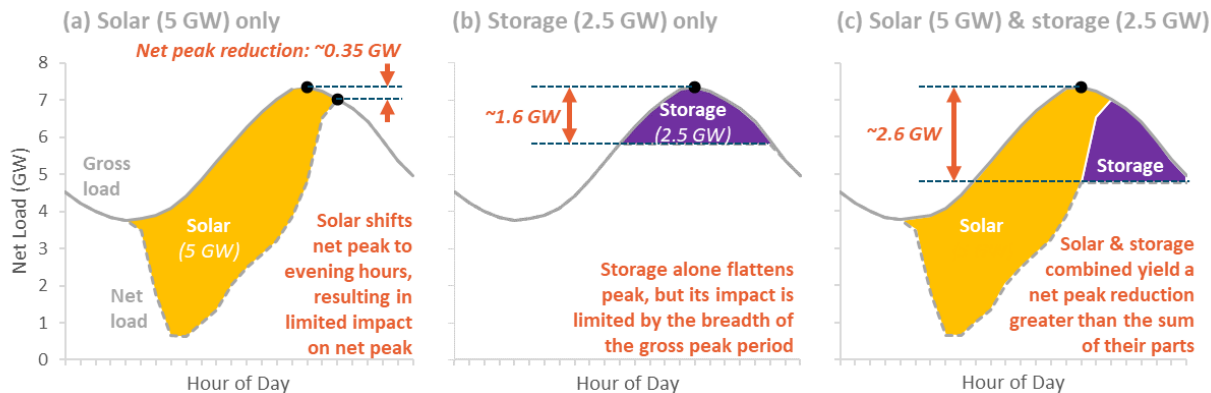
- **Antagonistic pairings:** resources with similar limitations **diminish** each other's ability to provide capacity

Antagonistic: Diminishing Returns of Solar



Synergistic: Benefits of Solar + Storage

- **Synergistic pairings:** resources with different characteristics **enhance** each other's ability to provide capacity

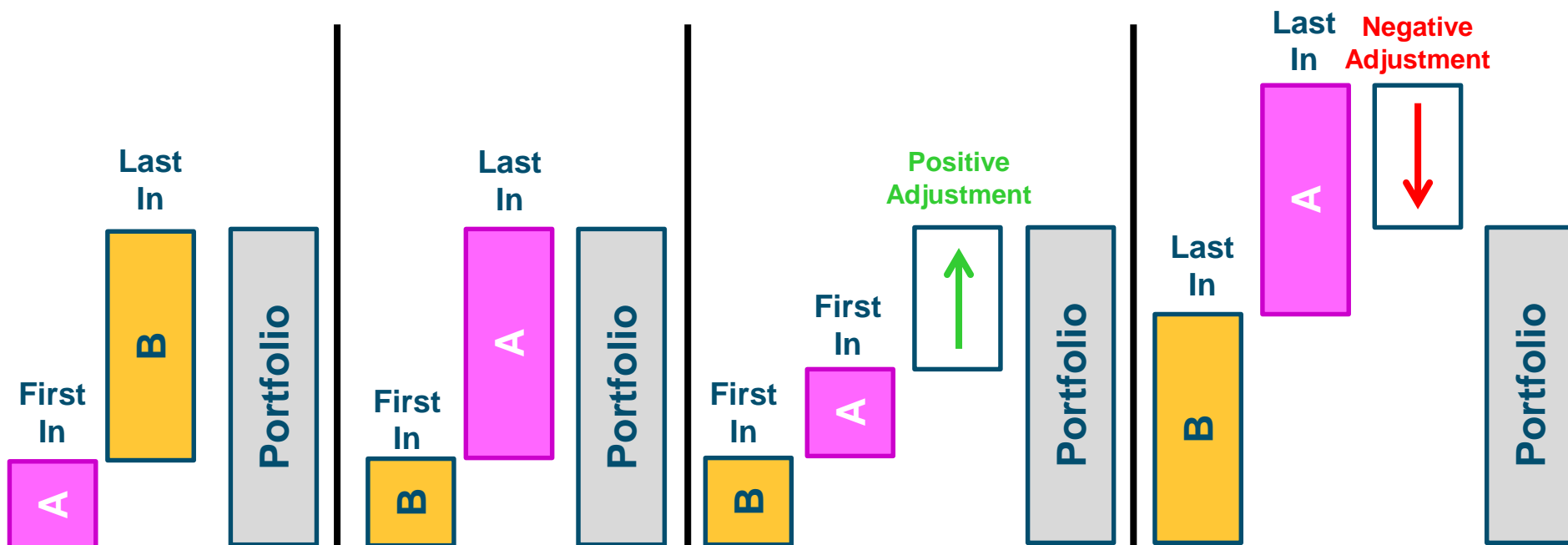




How to Measure ELCC?

+ There are multiple approaches to measuring the ELCC of a resource(s)

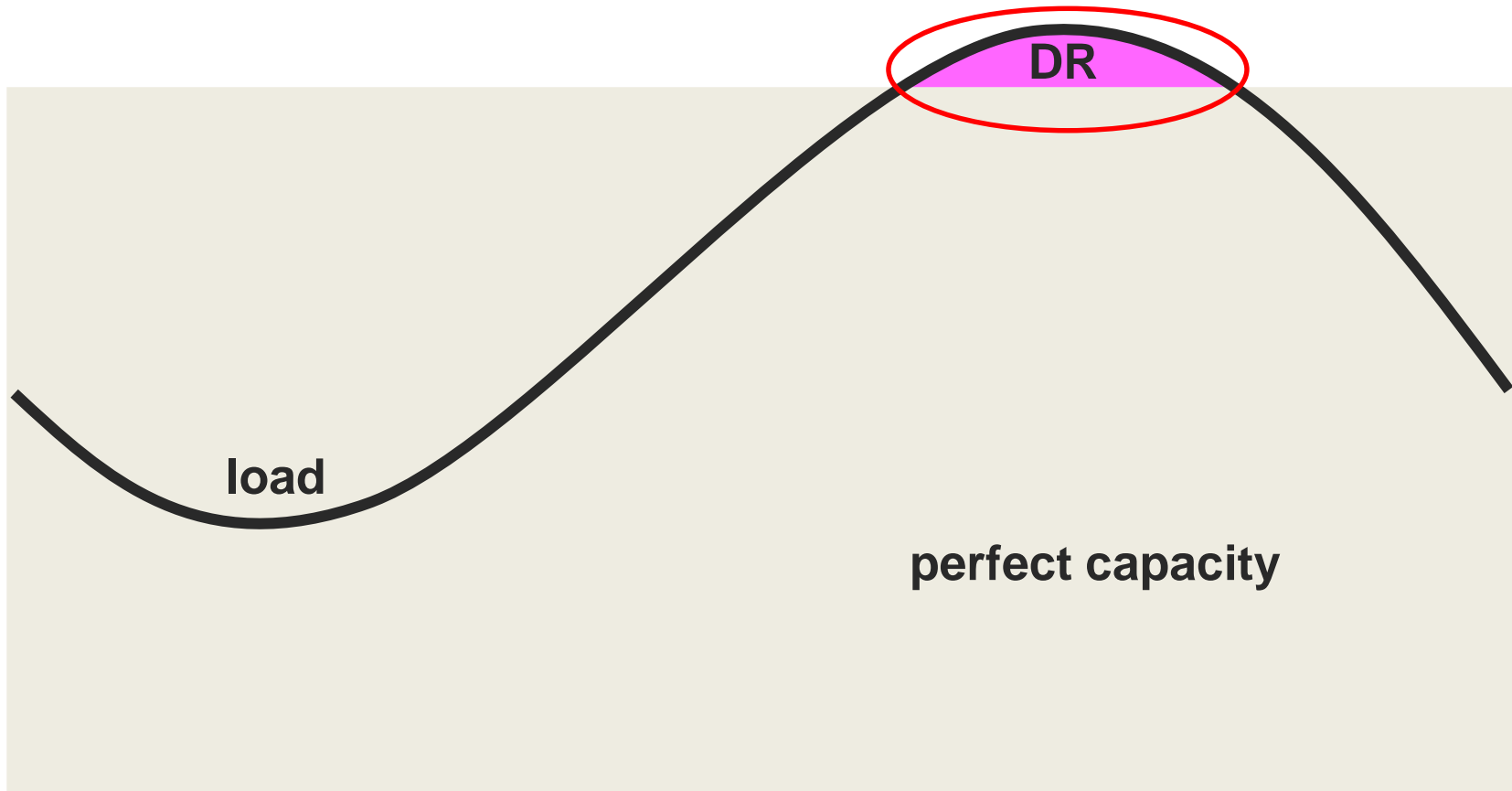
- **Portfolio ELCC:** measures the combined ELCC of all intermittent and energy-limited resources on the system
- **First-In ELCC:** measures the marginal ELCC of a resource as if it were the only intermittent or energy-limited resource on the system, thus ignoring interactive effects
- **Last-In ELCC:** measures the marginal ELCC of a resource after all other intermittent or energy-limited resources have been added to the system, capturing all interactive effects with other resources





“First-In” ELCC

- + **First-in ELCC measures the ability of a resource to provide capacity, absent any other resource on the system**
 - Measures the ability of a resource to “clip the peak,” and is often analogous to how many industry participants imagine capacity resources being utilized



DR = Demand Response

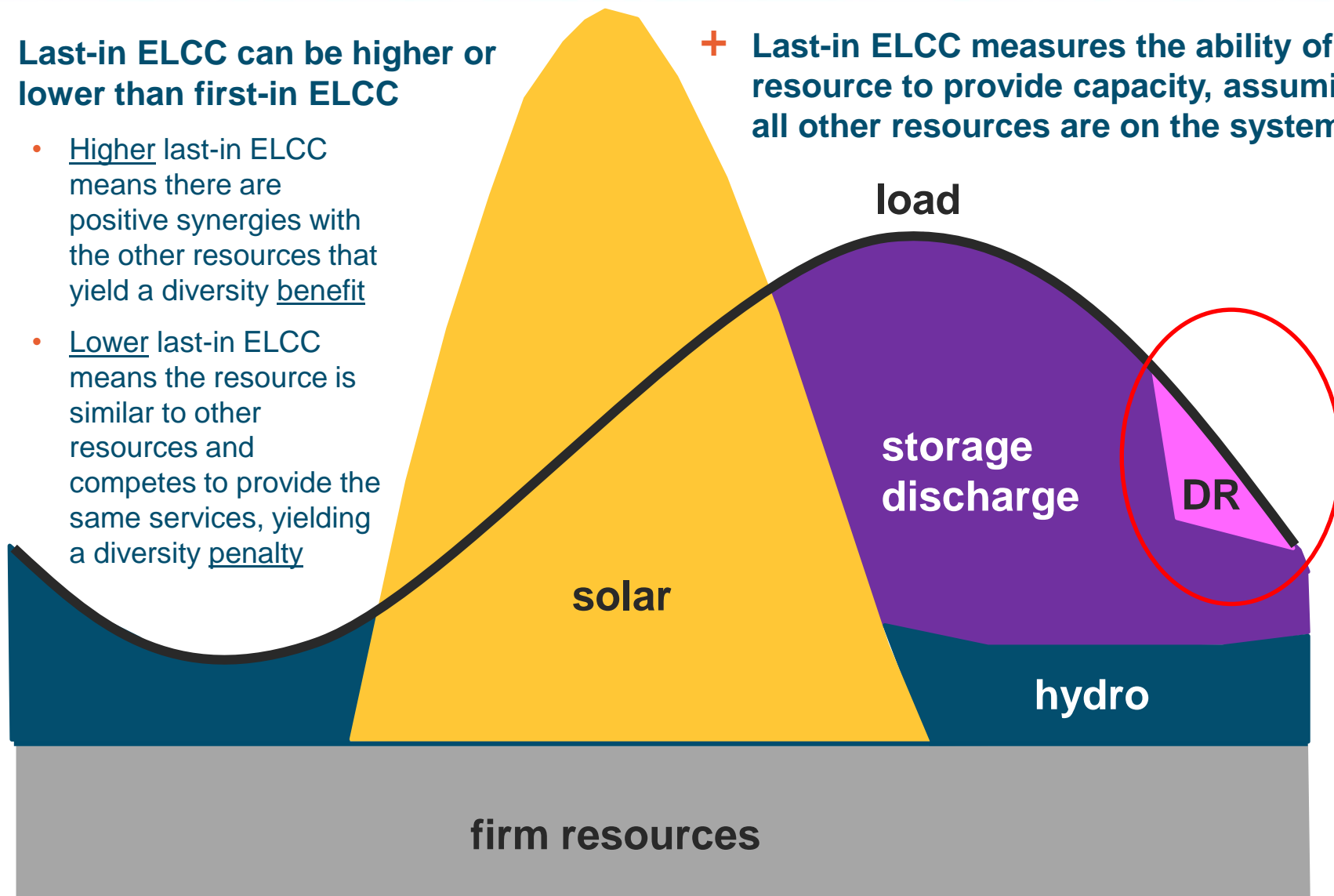


“Last-In” ELCC

+ Last-in ELCC can be higher or lower than first-in ELCC

- Higher last-in ELCC means there are positive synergies with the other resources that yield a diversity benefit
- Lower last-in ELCC means the resource is similar to other resources and competes to provide the same services, yielding a diversity penalty

+ Last-in ELCC measures the ability of a resource to provide capacity, assuming all other resources are on the system





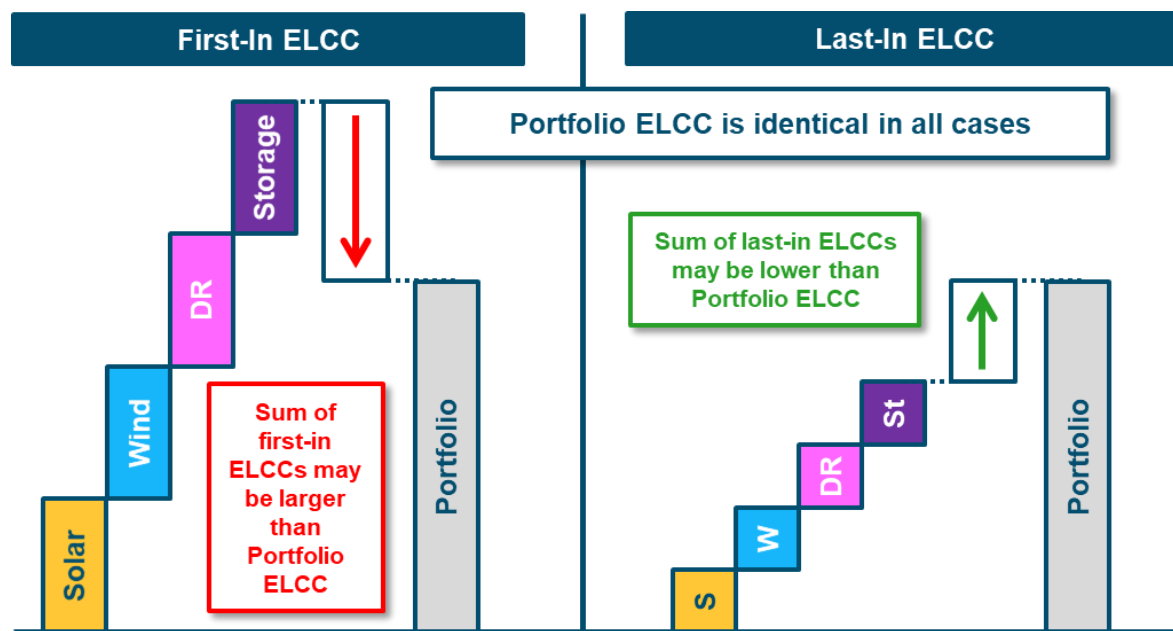
How to Use ELCC?

+ There are different reasons for using ELCC for different applications

- **Portfolio ELCC:** appropriately characterizes the capacity contribution of intermittent and energy-limited resources – this is *important for assessing system reliability*
- **Last-In ELCC:** appropriately characterizes the marginal ELCC of the next unit of an intermittent or energy-limited resource – this is *important for procurement* to understand how new resources will contribute to system capacity needs

+ To assign a capacity credit to individual resources, one must allocate the Portfolio ELCC using a subjective method such as:

- First-in proportional
- Last-in proportional
- A combination of the two



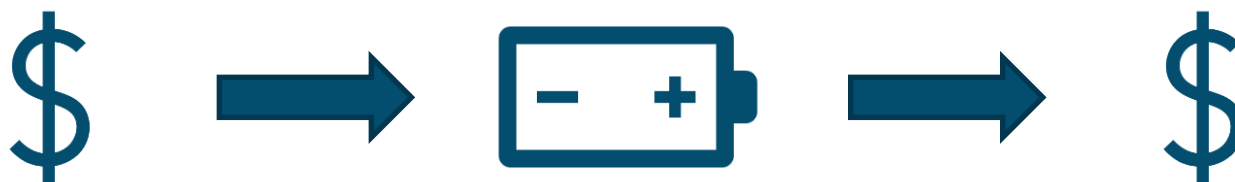


Factors that Affect ELCC

+ *How a resource is used can impact its ELCC*

- Storage is a great example of this with multiple value streams
 - Energy arbitrage
 - Ancillary services
 - Etc.
- Operating storage to maximize total value may limit its ability to provide capacity value in order to provide other services

+ **The compensation framework can also impact how a resource is dispatched, which makes the linkage between these two key questions critical**





Issues with ELCC

- + **Calculating ELCC can be time-intensive and difficult** due to:
 - Significant data requirements
 - Computational horsepower requirements

- + **“Heuristics” or simplified calculations are often used to approximate ELCC**

- + **Example heuristic approaches include:**
 - **Time-window methods**
 - Calculates the average production of a resource during pre-defined time periods
 - **Exceedance method**
 - Calculates the production of a resource that exceeds a specified percentile

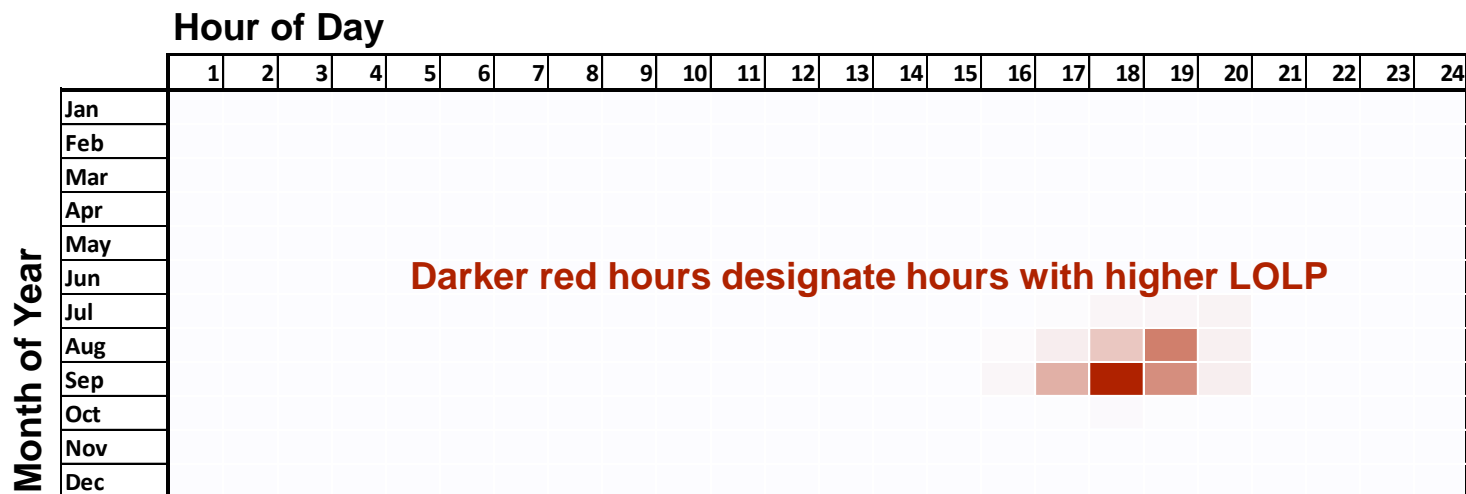




Loss of Load Probability

- + **Loss of load probability (LOLP):** the most common heuristic tools for approximating a resource's ELCC
 - **LOLPs represent the probability that there will be loss of load in a given time period**, based on many simulations of the electricity system under different load and resource conditions
 - LOLPs are **represented as percentage values (%)** for each hour of the year
 - Summing hourly LOLPs across the entire year yields the expected number of hours with lost load per year

Illustrative LOLP Table



**Most electricity systems use a reliability standard of days/year instead of hours/year – the most common standard is 1-day-in-10 years which corresponds to a 0.1 days/year reliability standard*

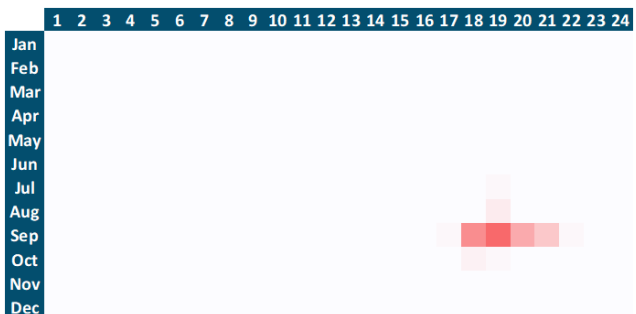


Using LOLP to Approximate ELCC

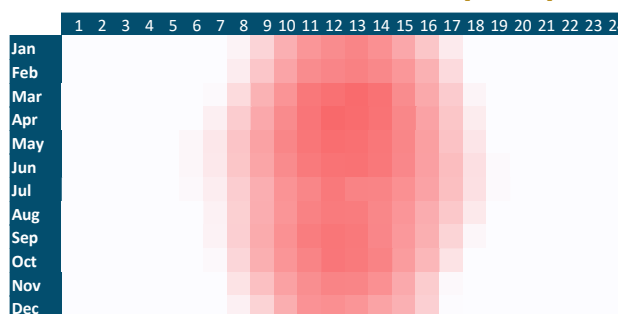
+ Because LOLPs represent the hours when the system is most likely to need capacity, calculating a resource's production during these hours is a reasonable approximation of ELCC

+ Calculation steps:

Normalized LOLP % Values



Solar Production (MW)



Approximate
ELCC
Value
(MW or %)

Normalize hourly 8760 LOLP values for the year such that they sum to 1.0

Calculate the weighted average production (MW) of a specified resource over the year

Dividing weighted average production (MW) by the nameplate capacity (MW)

+ LOLPs approximate last-in ELCC because they are measured on a system *after* all resources have contributed to minimizing LOLP



What LOLP Misses

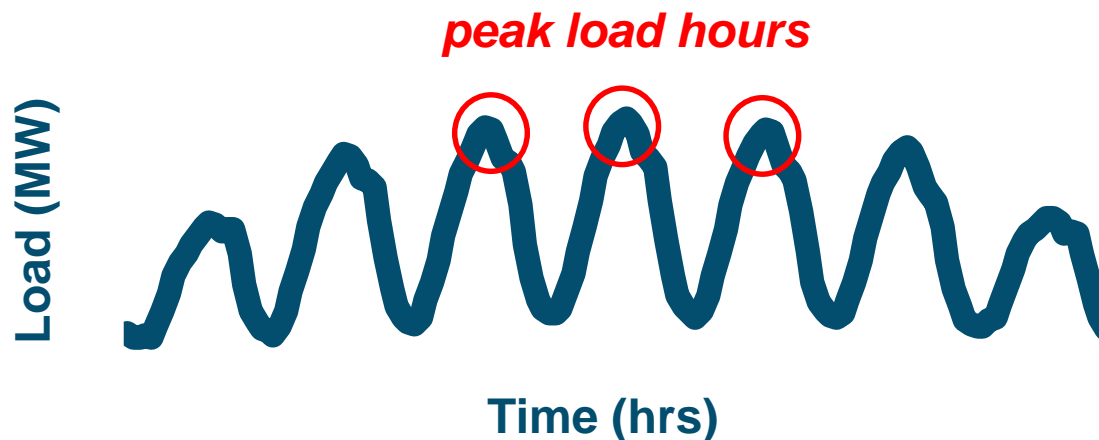
- + LOLPs are a decent approximation of ELCC for non-dispatchable intermittent resources, BUT this approach
 - **Misses key correlations between resource output during *actual* loss of load hours**, while capturing it for hours with *probability* of loss of load
 - The LOLP calculation approach essentially calculates the average production (e.g., solar output) during all days within a month instead of only the days that *actually result* in loss of load
 - Hours with loss of load tend to happen on peak days >> which tend to be hot >> which tend to be sunny >> which have high solar output
 - **Does not work as well for energy storage or other energy-limited resources since it does not capture the length of loss of load events**
 - For example, LOLP during the 4pm – 10pm period does not necessarily mean that a 6-hr resource is needed
 - If this LOLP represents loss of load events that occur independently from 4pm – 8pm on one day and 6pm – 10pm on another day, then a 4-hr resource may be sufficient to provide 100% ELCC





Using Peak Loads to Approximate ELCC

- + Another relatively accurate approximation of Last-in ELCC is to calculate average production of a resource during the top X “net load” hours/year
 - Net load = [load] – [production from all intermittent and energy-limited resources]
- + Calculating average production of a resource during the top X “gross load” hours/year is a reasonable approximation for First-In ELCC
 - Gross load does not include the impact of intermittent or energy-limited resources which makes it appropriate for approximating the First-In ELCC calculation



*Reasonable values for “X”: 50, 100, or 200 hours per year



Key Question 2) What is the Value of Capacity?



What is the Value of Capacity?

- + The monetary value (\$) of capacity is a separable question from quantifying the capacity (MW) that a resource can provide
- + To answer the monetary (\$) question, two key pieces of information are necessary:

1) Does the utility need new capacity?

2) How much does new capacity cost?



How Much Capacity Does a Utility Need?

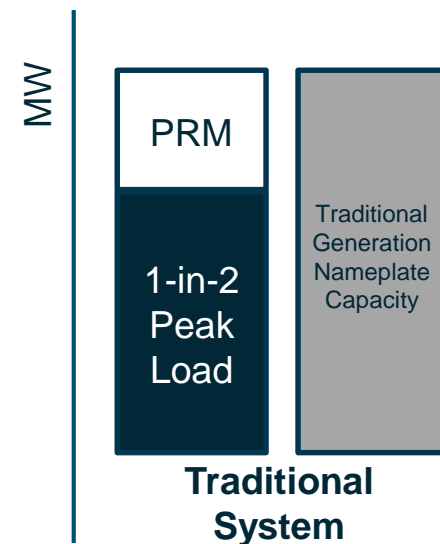
+ Utilities plan to a specified reliability target

- Most commonly a 1-day-in-10-year standard, or 0.1 days/year loss of load expectation (LOLE)

+ Planners ensure this reliability standard is met through adherence to a planning reserve margin (PRM) that provides excess capacity above typical peak loads to maintain reliability in the event of:

- Unplanned forced generator outages
- Higher than normal peak loads (very cold or very hot weather)
- Operating reserve requirements

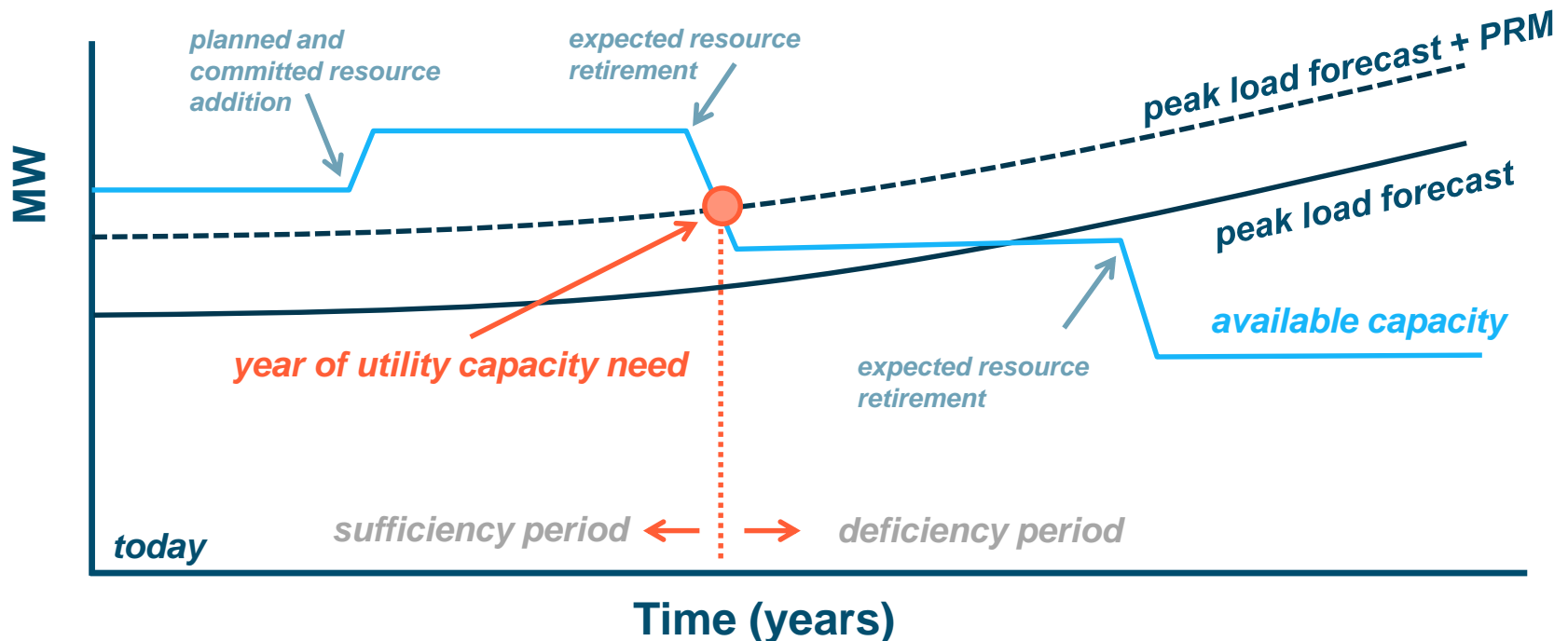
+ Typical PRMs range from 12% to 20% depending on a range of system characteristics





Does the Utility Need New Capacity?

- + It is common for utilities to hold reserves in excess of the minimum PRM to maintain reliability
 - Peak demand is difficult to predict exactly and investments in capacity are both “lumpy” and require significant lead-time
 - If reserves > PRM, additional capacity is not needed
- + Looking forward, utilities generally forecast load growth and generator retirements, resulting in a future year in which they are expected to need new capacity

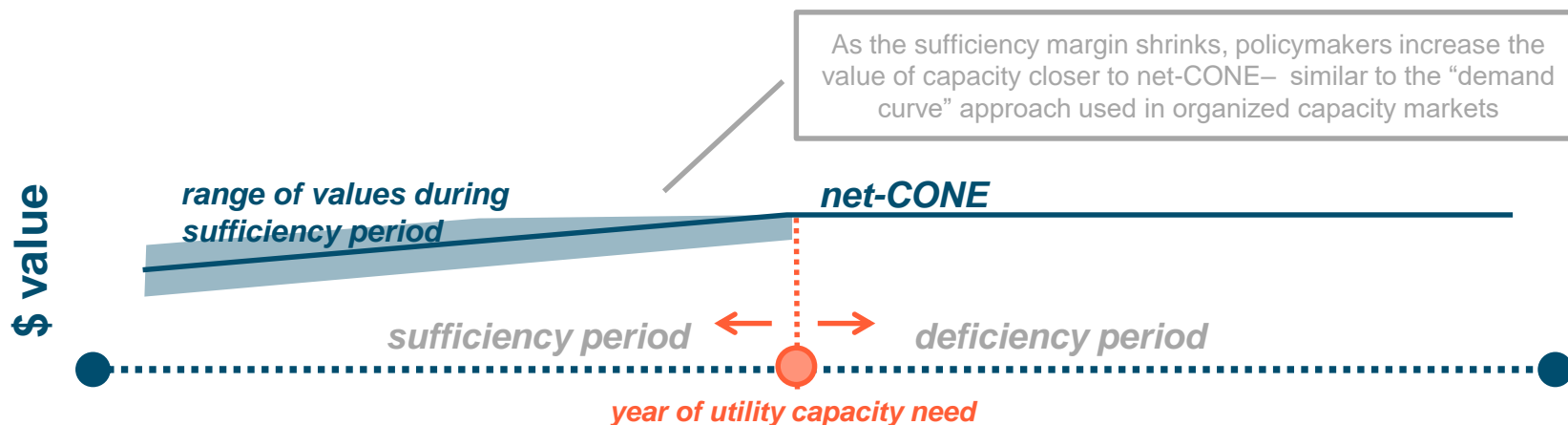




What is Capacity Worth?

- + **Sufficiency period in Oregon:** times when the utility holds capacity in excess of the PRM → capacity is not needed by the utility and is less valued
 - Multiple approaches value capacity from \$0 up to net-CONE, with the fixed O&M of the net-CONE resource as a widely used value
- + **Deficiency period in Oregon:** times when the utility is forecasted to need additional capacity → capacity is valued at what it would otherwise cost the utility to procure new capacity
 - Approach to value capacity: **net-CONE**

Illustrative Timeline



- + Other competitive electricity markets (PJM, NYISO, ISONE, etc.) use a demand curve construct to adjust the clearing price of capacity based on how short or long the system is relative to the reliability standard

*See following slides for more info on net-CONE



Equity Issues Between Utility and DERs/Third Parties

- + Important to ensure *equity* between utilities and DERs/third-parties in the respective contributions that they make toward resource adequacy
- + Potentially inequitable for a utility to be able to earn full cost recovery for capacity procured in excess of the PRM and not provide the same opportunities to DERs/third-parties
 - Policymakers and stakeholders should consider the equity impacts associated with this treatment in conjunction with the potential economic inefficiency associated with the cost of paying for capacity that is not needed
- + In assessing whether the utility is sufficient or deficient in future years, **analysis should only consider projects that are fully committed and have no opportunity for deferral or modification**
 - Avoids reliance on projects that may not materialize





Net Cost of New Entry (Net-CONE)

+ Net cost of new entry is the industry benchmark for the value of capacity in periods of deficiency

- Net-CONE identifies the resource with the *lowest* net cost of capacity where net cost is defined as:

Gross cost of capacity	\$/kW-yr
– System benefits	\$/kW-yr
<i>energy</i>	
<i>ancillary services</i>	
<i>etc.</i>	
<hr/>	
= Net cost of capacity	\$/kW-yr



Traditionally, combustion turbines (CTs) have been the lowest net cost of capacity resource in the electricity system

VS.



To the extent that a different resource is **lower cost or there are policy limitations**, lowest net cost developable resource (e.g., energy storage) should be used



Key Question 3) What Compensation Framework Should Be Used?

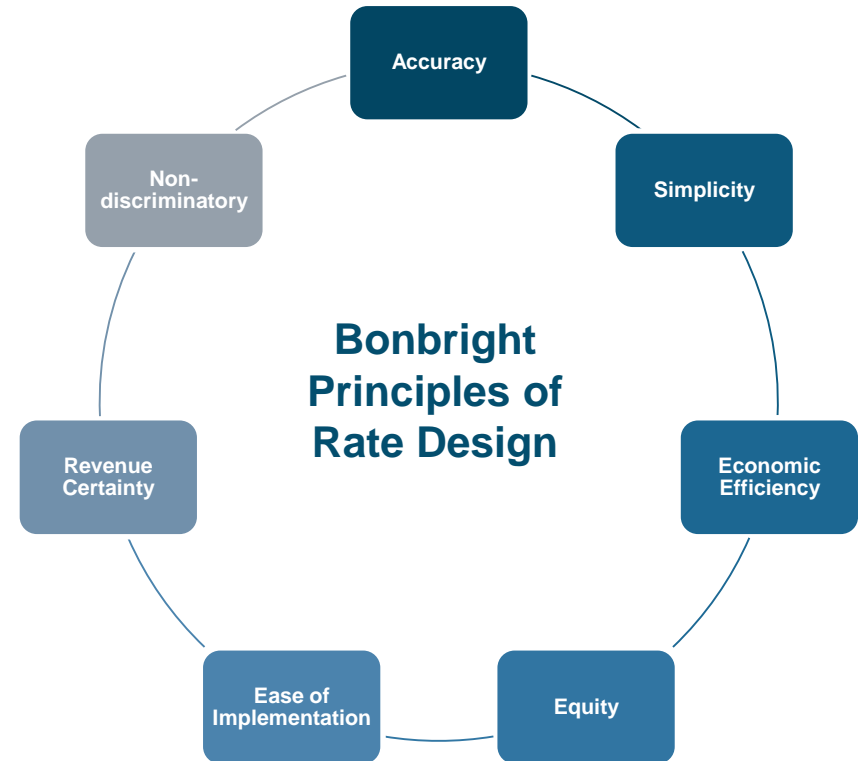


Goals of a Compensation Framework

- + No single compensation framework is appropriate for all use cases and all technologies
- + Requires some balancing of tradeoffs
 - Bonbright rate design principles
- + A compensation framework should seek to achieve:

Capacity (MW) (Question 1)	Properly credit resources for the capacity they provide to the system
Value (\$) (Question 2)	Properly compensate for the value of the capacity resources provide

- + In addition to these objectives, a **compensation framework must also balance** the following objectives
 - **Efficiency:** encourage economically efficient new resource development and procurement
 - **Acceptability:** transparent, tractable, understandable, and implementable for stakeholders and policymakers





Approaches to Compensating Capacity

+ There are two general approaches to compensating capacity

	Fixed Payment	Pay for Performance
Method	A resource is compensated based on a fixed annual value (\$/yr) that aligns with its capacity credit (MW) and the value of capacity (\$/MW-yr)	A resource is compensated based on production during capacity scarcity hours (e.g., peak hours or high LOLP hours)
Application	Organized capacity markets in deregulated electricity markets (PJM, NYISO, etc.)	PURPA and other DER contracts where resources are compensated based on production
Performance	Evaluated though “performance penalties”	Based on production during capacity scarcity hours





Fixed Payments

+ Fixed payments can either be determined using

- ELCC calculations, or
- Heuristic methods (e.g., LOLP-based approximations of ELCC)

+ Performance can be ensured via performance penalty periods where the utility evaluates a resource's performance during peak periods and penalizes it if it does not perform according to its capabilities

+ Works best for storage

- Performance discharge requirements that are sent to storage dynamically when the system needs storage for capacity.
 - Could be sent on a day-ahead time frame to storage with instructions to discharge for as long as the duration of the storage
- Primary limitation: implementation feasibility



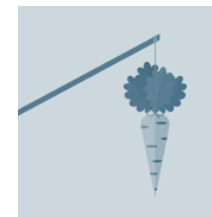


Pay for Performance

+ Pay for performance can either be implemented via:

	Real-time dynamic payments	Pre-determined time periods
Method	Compensates resources on a dynamic basis during times of system stress	Compensates resources for performing during pre-determined time periods (e.g. high LOLP hours)
Time Period Frequency	Relatively rare	Relatively common
Pros	Properly rewards resources for generating when they are needed	Easy to plan for; predictable outcomes
Cons	Difficult to plan for as capacity periods are inherently uncertain	Rewards resources for performing when capacity is not needed Does not capture the correlation in output of resources on actual peak days*

*One solution to this issue is to implement a “scalar” that grosses up capacity values to account for this factor – E3 accounted for this in the RVOS methodology through an ELCC to Solar-LOLP-coincidence ratio

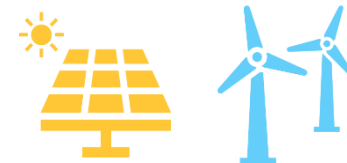




Pre-Determined Time Periods

+ Pre-determined time period compensation is a **reasonable** framework to **compensate intermittent resources**

- Analysis shows that production during high LOLP hours is a reasonable proxy for the ELCC



+ Yet it has **potential limitations for energy storage resources**

- Pre-determined time periods are generally longer than individual loss of load event windows, creating a burden of higher performance for energy storage resources than is necessary for system reliability



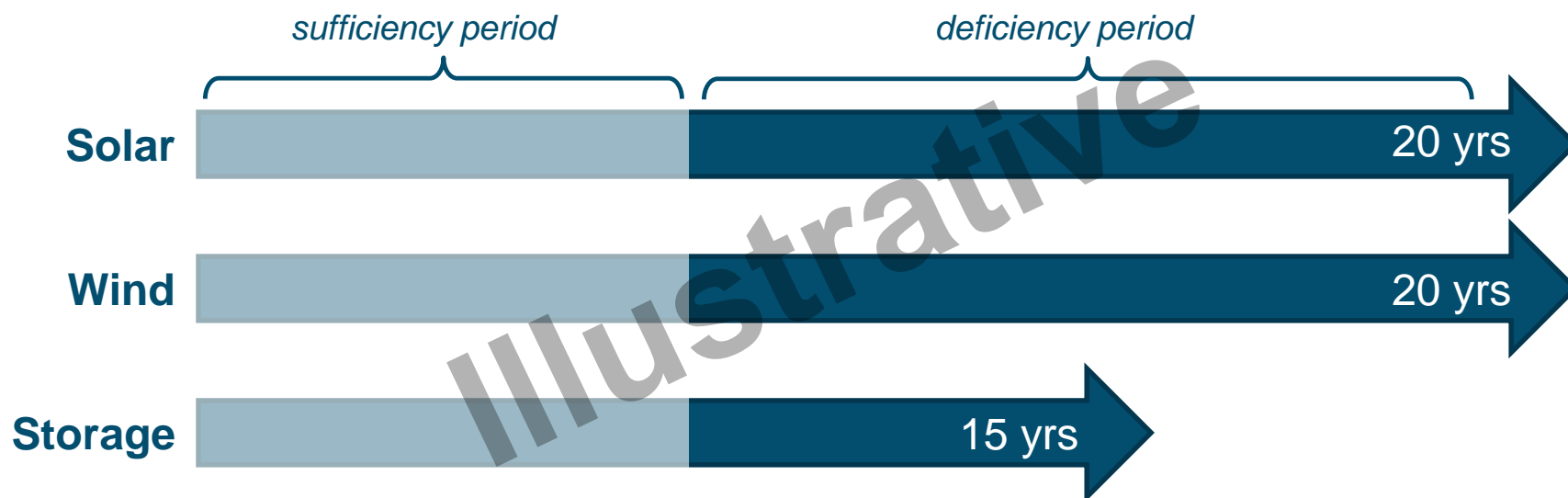
+ Pre-determined time period compensation must necessarily be associated with either

- First-In ELCC (gross load peak time periods)
- Last-In ELCC (net load peak time periods)



Contract Length

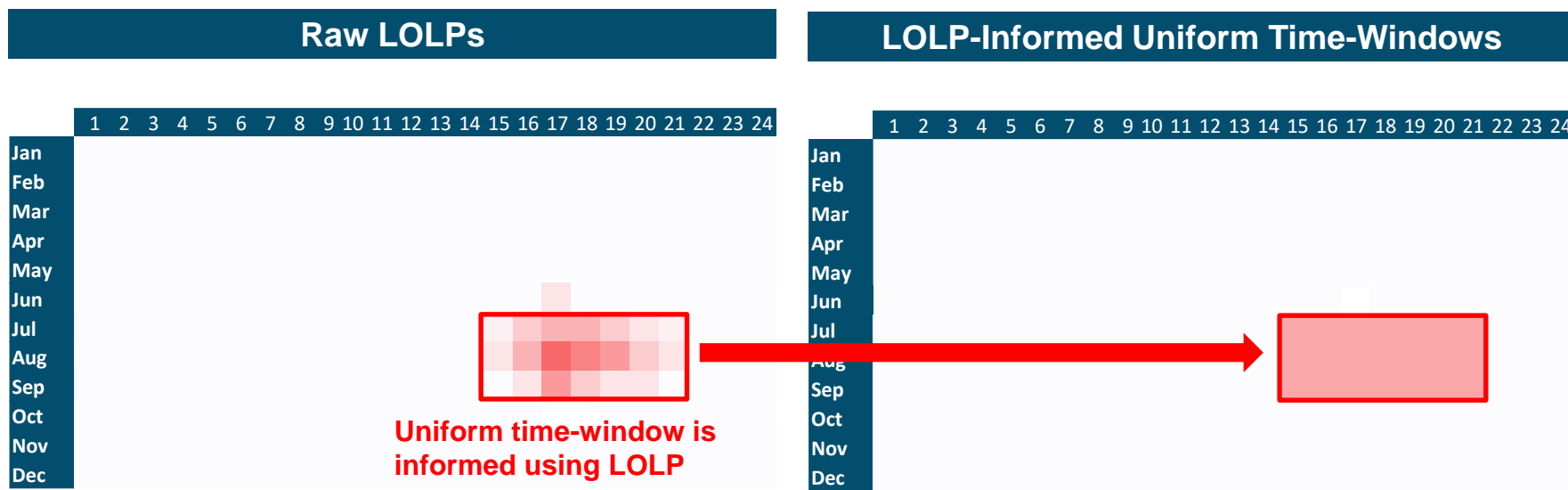
- + Within the context of PURPA, **contract length is an important topic**
 - Equity with utilities as well as the consistent year-to-year “excess” capacity that is maintained on the system, despite ongoing investments, lends credence to the notion that longer contract lengths should be used
- + In this context, **contract lengths would approximate the economic life of each particular resource**
- + **Contract value should reflect the net present value of capacity for all sufficiency and deficiency periods over the life of the contract**





Practically Implementing LOLPs

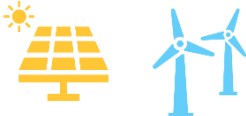

- + Using LOLPs as a basis for Last-In ELCC is a reasonable heuristic (subject to the previously mentioned constraints)
 - However, even pre-determined time periods that are proportional to LOLP weights are a complex signal to respond to
- + Consolidating actual LOLP values uniformly across “peak periods” can help to simplify the implementation of PURPA contracts





Compensation Framework Application

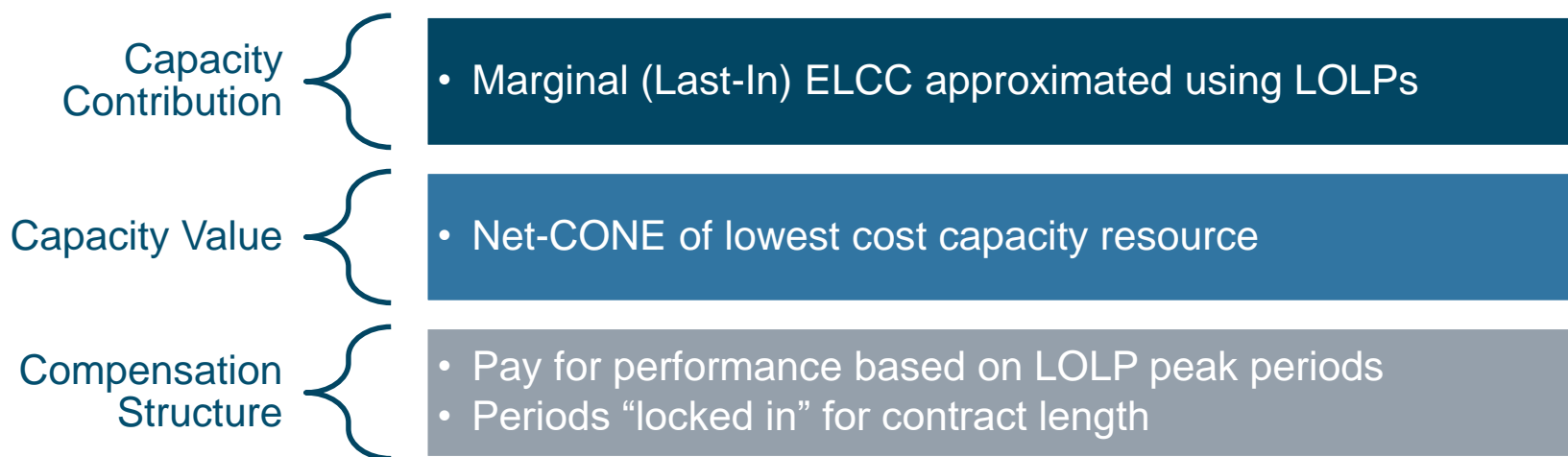
- + Different compensation frameworks are more or less appropriate for different use cases
- + For new QF contracts being executed, Last-In ELCC (i.e. marginal) is appropriate to value their incremental contribution to system capacity

Resource	Appropriate ELCC Heuristic Methodology
Intermittent resources 	Uniform time-window periods that overlap with highest LOLP hours
Energy Storage/ Dispatchable Resources 	ELCC analysis to determine ELCC contribution of various durations (hrs) for energy storage resources QF contracts would update annually with new pre-determined peak time periods to incentivize dispatch of storage resources during highest value hours



Features and limitations of one potential QF capacity compensation structure

Key Components of QF Capacity Compensation



Important Limitations

- + **LOLP heuristic misses key correlations** between resource output during actual loss of load hours
- + **Last-In ELCCs** for each resource may under or overcount the capacity contribution of the portfolio
- + Resources are **compensated for hours of potential, rather than *actual*, capacity need**
- + **Length of loss of load events is not captured**, limiting the flexibility of storage assets to respond to actual capacity needs



Additional Considerations

+ Hybrid Resources

- Contain attributes and characteristics of multiple generation capacity resources
- Different compensation structures are more / less appropriate for different generation technologies
- Would need to be compensated under one of the aforementioned compensation frameworks based on stakeholder feedback



+ Transmission & Distribution

- Transmission and distribution capacity value is a separate and distinct value stream (although with many similar issues and concepts) that is not addressed in this presentation
- Should be considered and included as a utility value stream in an additive manner to the generation capacity values discussed in this presentation





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Use Cases and Examples



Applying the compensation framework to capacity from new QF resources in Oregon

- + As described throughout this presentation, **there is no single “correct” approach for capacity valuation and compensation applicable to all scenarios**
 - E3 understands the primary use case of interest for this group to be evaluating capacity contributions and associated payments for new qualifying facilities under PURPA

- + Given the balance of accuracy, data requirements, and implementation feasibility, **using LOLP values to establish pre-determined time windows or “peak periods” may be the best method for allocating capacity value**
 - However, the limitations of this approach must be understood and acknowledged



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PGE Allocation Using LOLP



“Raw” LOLP values serve as the starting point for developing allocation factors

- + PGE LOLP hours are concentrated in Jul/Aug afternoons, and Nov-Jan evenings
- + Using the unadjusted LOLP values has the advantage of directly mapping capacity payments to highest-probability loss of load hours
 - However, this may be more temporally granular than would be desired (more difficult to implement)

PGE LOLP (2019)*

Month	Hour																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000

*Source: UM 1912 July 18, 2019 compliance filing



Pre-defined time windows offer an alternative allocation approach

- + The current PGE on-peak periods are defined as
 - 6am – 10pm, Mon – Sat, year round
 - 5,008 hours included in window (57% of *all* hours)
- + This clearly results in unnecessary capacity payment in many non-peak hours, when compared to PGE’s LOLP

PGE Time Window

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000



A somewhat more realistic time window for PGE? (Alternative 1)

+ Alternative time window 1:

- 12pm – 8pm, Mon – Sat, Jun – Sep
- 832 hours included in window (9% of all hours), 31% of unadjusted LOLPs captured*

+ Each hour is allocated a uniform .10% of capacity value.

- Hourly capacity payment (\$) = Price of capacity (\$/MW-yr) * 0.001 * MW produced in that hour
- Pay the full prorated share of capacity to each hour and all generators that generate during that hour get paid

+ Constrained window narrows capacity payment hours but misses the winter evening peaks

PGE Time Window (alternative 1)

Month	Hour																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

* Percentage of unadjusted LOLP values captured by the time window is not a metric that can be used in isolation



A somewhat more realistic time window for PGE? (Alternative 2)

+ Alternative Time Window 2:

- July- August: 2pm – 7pm; Nov – Jan: 5pm – 8pm
- 586 hours included in window (7% of all hours), 39% of unadjusted LOLPs captured*

+ Each hour is allocated a uniform .20% of capacity value

- Hourly capacity payment (\$) = Price of capacity (\$/MW-yr) * 0.002 * MW produced in that hour

+ Constrained window narrows capacity payment hours and captures winter evening peaks

+ Many other peak window definitions are possible

PGE Time Window (Alternative 2)

Month	Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.002	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.002	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.000	0.000	0.000	0.000

* Percentage of unadjusted LOLP values captured by the time window is not a metric that can be used in isolation



Energy+Environmental Economics

PacifiCorp Allocation



PacifiCorp's LOLP distribution looks fairly different from that of PGE

- + **PacifiCorp's LOLP heavily concentrated in July and August**
 - Much more concentrated than PGE LOLP
- + **Summer evenings contain almost all LOLP hours**
 - Small amount of winter evening hours with non-zero LOLP
- + **The current PacifiCorp on-peak periods are defined as:**
 - 6am – 10pm, Mon – Sat, year round

PacifiCorp LOLP*

Month	Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003	0.004	0.004	0.001	0.000	0.000	
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.001	0.000	0.000	0.000	
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	

*Source: UM 1910 March 18, 2019 compliance filing



Potential time window for concentrating PacifiCorp LOLP hours (Alternative 1)

+ Alternative Time Window 1:

- 4pm – 9pm, Mon – Sat, July – Aug
- 270 hours included in window (3% of all hours), 52% of unadjusted LOLPs captured*

+ Each hour receives .37% of capacity value

- Hourly capacity payment (\$) = Price of capacity (\$/MW-yr) * 0.0037 * MW produced in that hour

+ Constrained window narrows capacity payment hours

- Notably this window misses the winter evening peaks, given the selected months

PacifiCorp Time Window (Alternative 1)

Month	Hour																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.003	0.003	0.003	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.003	0.003	0.003	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

* Percentage of unadjusted LOLP values captured by the time window is not a metric that can be used in isolation



Potential time window for concentrating PacifiCorp LOLP hours (Alternative 2)

+ Alternative Time Window 2:

- July- August: 4pm – 9pm; Dec – Jan: 6pm – 8pm
- 434 hours included in window (5% of all hours), 68% of unadjusted LOLPs captured*

+ Each hour receives 0.23% of capacity value

- Hourly capacity payment (\$) = Price of capacity (\$/MW-yr) * 0.0023 * MW produced in that hour

+ Constrained window narrows capacity payment hours

- Again, many other possible window definitions

PacifiCorp Time Window (Alternative 2)

Month	Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.002	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.002	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000	0.000	0.000

* Percentage of unadjusted LOLP values captured by the time window is not a metric that can be used in isolation



Energy+Environmental Economics

Wrap Up and Conclusions



Takeaways

- 1. Several key questions frame capacity considerations:**
 1. How much capacity can a resource provide?
 2. What is the value of capacity?
 3. What compensation framework should be used?
- 2. No single “correct” approach to evaluating and compensating resources’ capacity contributions; inherently use case-specific**
- 3. For establishing new QF contracts in Oregon, using pre-determined time windows based on LOLP values is a reasonable approach**
- 4. Limitations to this approach exist and must be understood**
 - Provides payment for many hours of potential (but not *actual*) capacity need
 - Ignores interactive effects of resources
 - Can be problematic / limit value for dispatchable resources such as energy storage



Thank You

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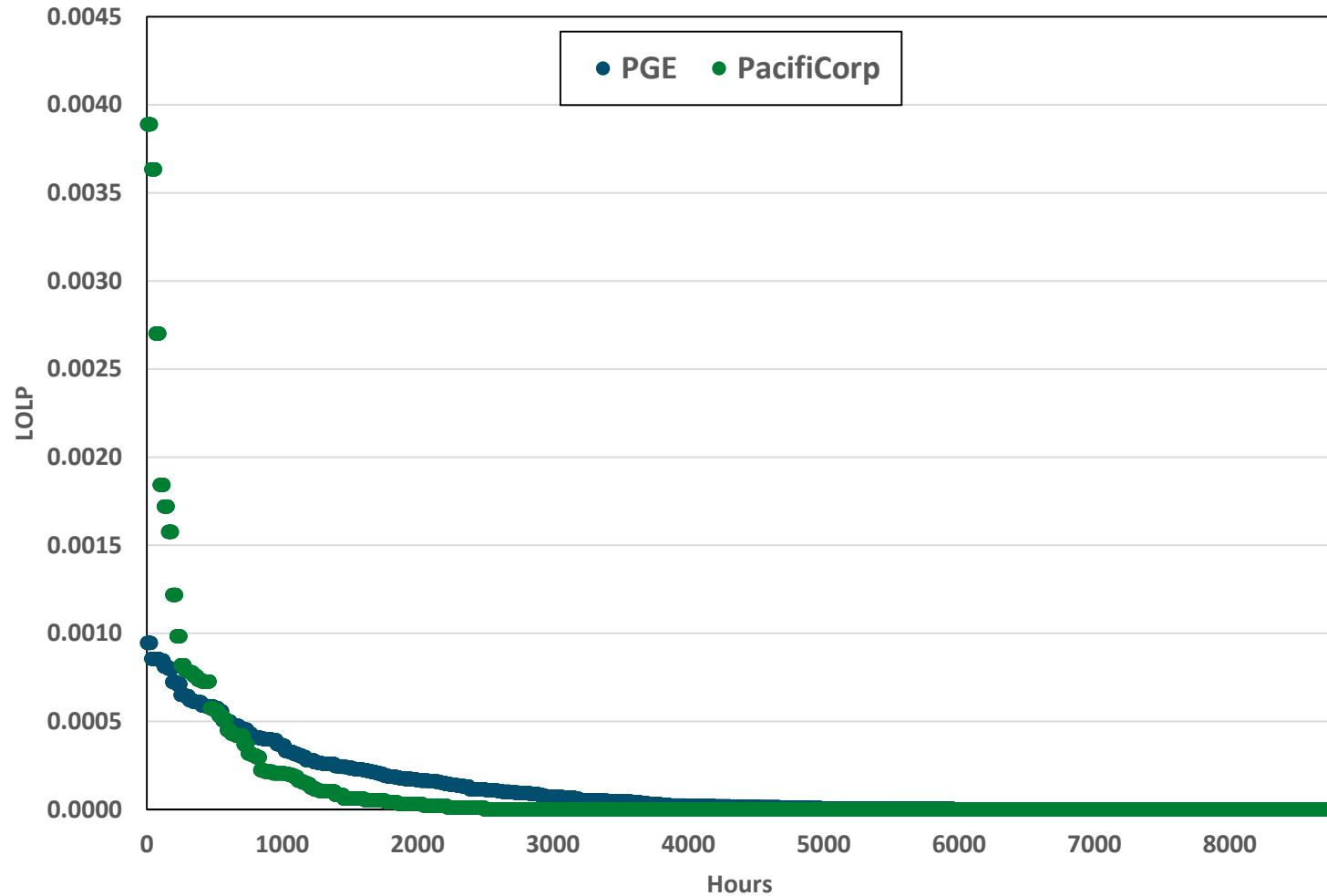


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Appendix



Direct Comparison of LOLP Values

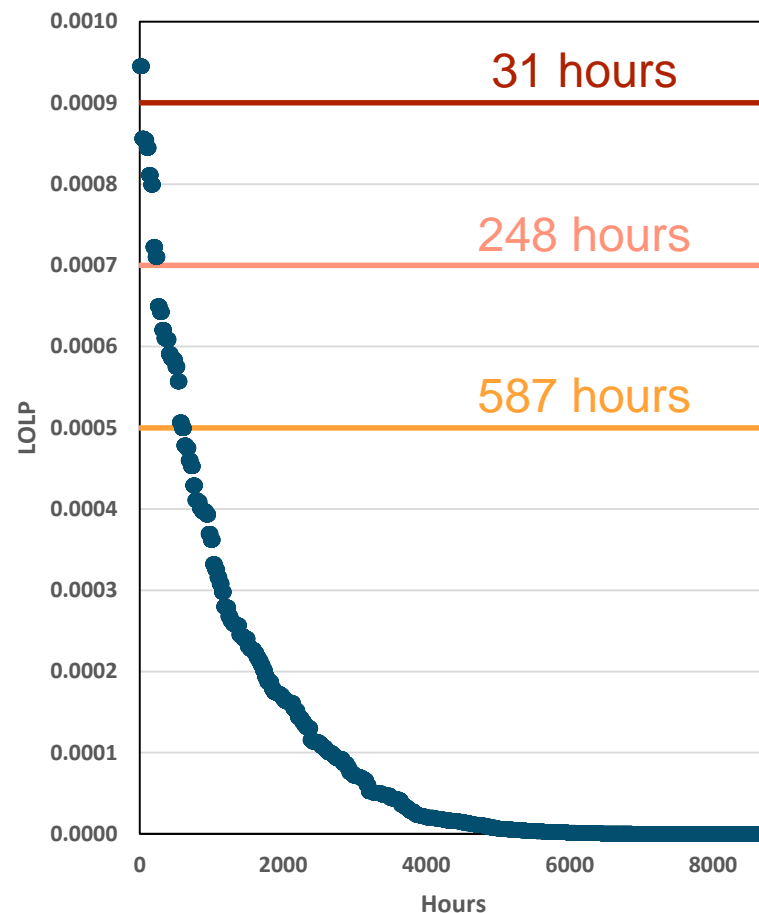




Setting a threshold is one way to narrow in on hours with relatively high LOLP

- + Hours with LOLP above the threshold are allocated their share of the remaining LOLP
- + Three illustrative threshold levels highlight the number of hours which might be counted for capacity value
 - .09%
 - .07%
 - .05%

PGE LOLP Hours





Use of a threshold approach concentrates LOLP hours into peak periods

- + At a .05% threshold, 587 hours remain as potential capacity value allocation hours
- + These hours maintain a similar shape or pattern as the “raw” LOLP values
 - Outer “tails” are eliminated or reduced (e.g., January hour beginning 17 or 20, July hour beginning 11-14 and 18-20)

PGE Threshold (.05%)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.001	0.000	0.000	0.000



More restrictive threshold values further concentrate hours, eventually “too much”

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004	0.004	0.004	0.004	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.005	0.004	0.000	0.000	0.000	0.000	0.000

PGE Threshold (.07% above, .09% below)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.032	0.000	0.000	0.000	0.000	0.000

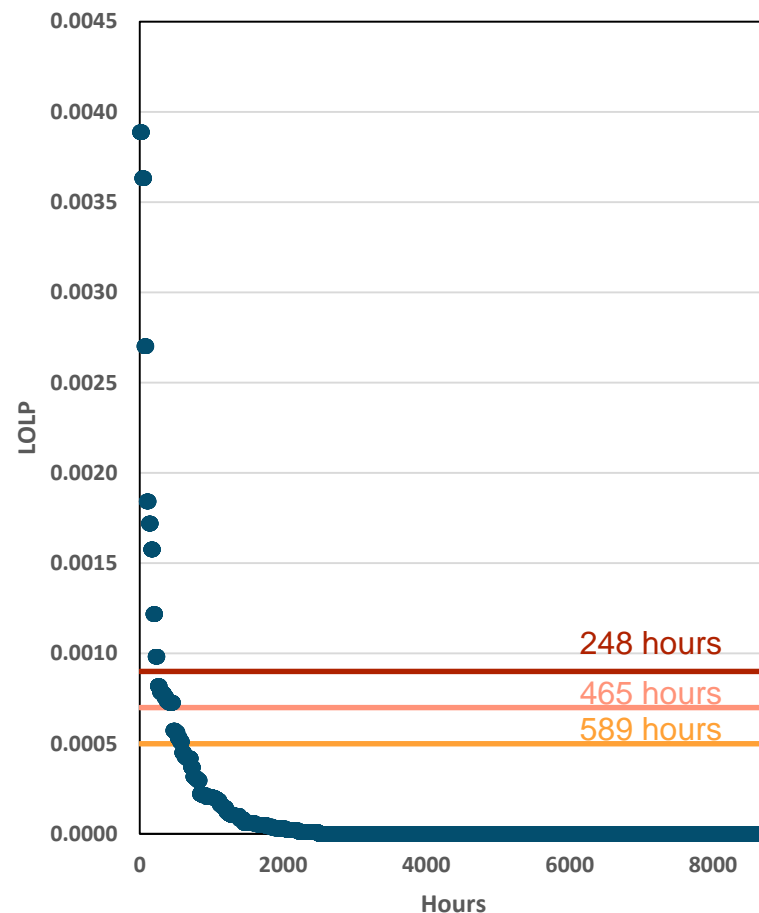
+ .09% threshold is an extreme example, clearly a poor choice for PGE (31 hours remain, all in Dec. hour beginning 18)



PacifiCorp LOLP relative to threshold levels discussed previously

- + The same threshold levels explored for PGE above result in more remaining LOLP hours for PacifiCorp
- + This is driven by the higher concentration of LOLP values among specific hours
 - Presumably due to differences in LOLP modeling
- + Over 6,000 “zero” hours
 - Again, distinct approach from PGE

PacifiCorp LOLP Hours





The initial threshold has a relatively small impact

- + At a .05% threshold, 589 hours remain as potential capacity value allocation hours
- + This results in hours with a very similar shape as the “raw” LOLP values, esp. given the concentration of PacifiCorp LOLPs in relatively few hours

PacifiCorp Threshold (.05%)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003	0.005	0.005	0.001	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.002	0.001	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000



More restrictive threshold values further concentrate LOLP hours

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.004	0.005	0.005	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.003	0.001	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000

PacifiCorp Threshold (.07% above, .09% below)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.005	0.007	0.007	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.003	0.002	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

+ Jump from .07% to .09% has no effect on PAC allocation (no hours w/ LOLP values between .07% and .09%)



Different ELCC calculations are appropriate for different situations

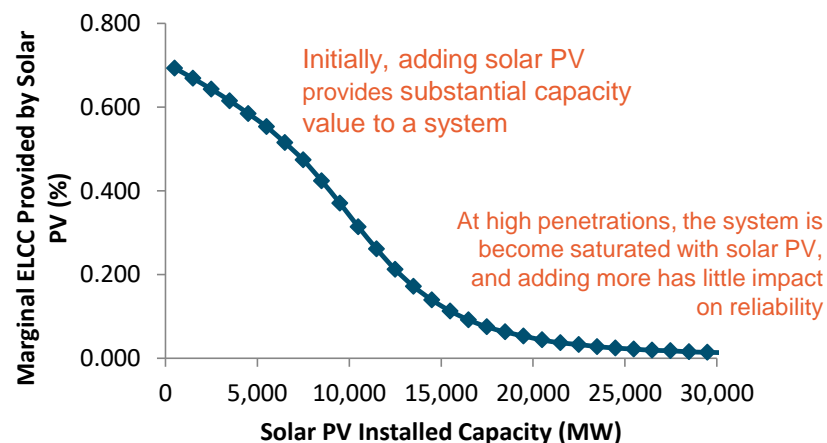
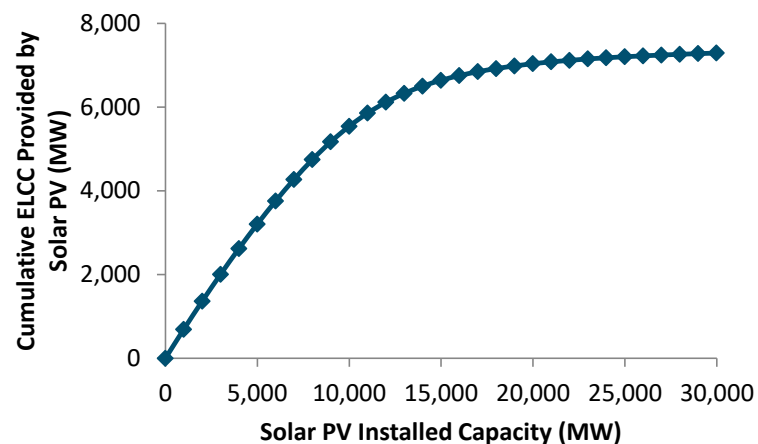
ELCC Calculation	Description	Relevant for
Portfolio ELCC	Combined ELCC of all intermittent / energy-limited resources in the electricity system Includes interactive effects	Allocation of capacity value to individual resources (e.g., in capacity markets of RA programs)
First-in ELCC	ELCC of a resource measured as if it were the first and only intermittent / energy-limited resource Ignores interactive effects	Assessing the capacity contribution of a resource in the absence of interactive effects with other resources
Last-in (Marginal) ELCC	ELCC of a resource measured after all other intermittent / energy-limited resources have been added to the system Includes interactive effects	Planning decisions, where ensuring incremental resource capacity contributions merit the incremental cost



PV ELCC example

- + While the first increment of solar PV has a relatively large impact on peak, it also shifts the “net peak” to a later hour in the in day
- + Stochastic modeling reveals that the effective load carrying capability of solar PV *declines* as penetration *increases*
- + At high penetration, the conventional paradigm that additional solar PV contributes value towards meeting peak loads no longer applies

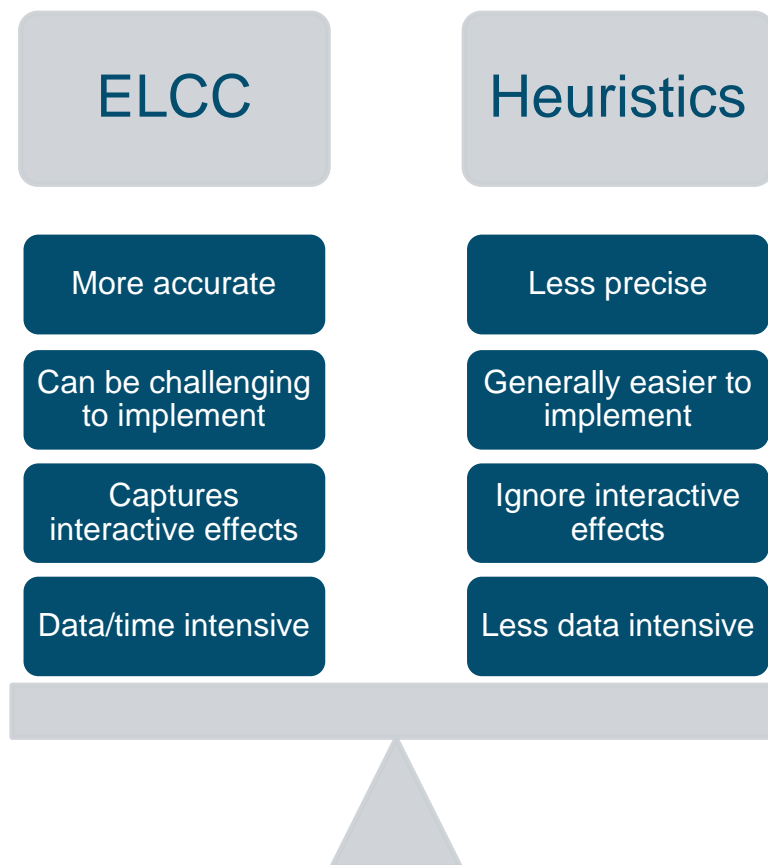
Cumulative vs. Marginal PV ELCC





Where calculating ELCC is unrealistic, heuristics can be used as a proxy

+ Heuristics are methods that approximate more precise approaches





ELCC vs. Heuristics

ELCC

Time-sequential LOLP modeling to calculate the ELCC of a resource correctly captures the capabilities of the resource and interactions with other resources

Each resource must be run individually in order to capture these effects

There is a difference between the initial ELCC and marginal ELCC of a resource – there is also a difference between both of these and the portfolio ELCC which captures all resources and their interactions

It is necessary to allocate a final ELCC to each resource using the various ELCCs that can be calculated

Running individual ELCCs is data and time intensive

Heuristics

Heuristic methods include:

- Average or certain percentile production during certain pre-defined time periods meant to approximate highest LOLP hours
- Assigning an LOLP weight to each hour of the year and determining the ability of a resource to generate during that hour

Does not capture interactive effects or diminishing returns

Does not accurately capture ability of energy-limited resources such as storage, demand response, or hydro to provide capacity

Data requirements are workable. This method can be applied to individual resources at scale

Key Questions

How should the value of transparency and simplicity be traded off against the value of accuracy?

How extensive should the data requirements be for new/existing resources?



Combustion Turbine

Simple to value

Historical precedent

Unclear on future appetite for new fossil generation in the NW, despite this resource's role in a least-cost deeply decarbonized portfolio

Storage

Simple(ish) to value

- Easy to calculate costs
- Difficult to calculate required duration

Growing discussion across industry about whether Li-ion battery is the new CT proxy resource

Portfolio

Captures the true 'shadow price' of capacity through a portfolio approach by identifying which resources are needed

Data-intensive and computationally complex

Lack of transparency for stakeholders

Key Questions

How should accuracy vs. simplicity play a role here?



Sufficiency / Deficiency Framework

Maintain Demarcation

Appropriately reduces the value of capacity in the near-term when the system may already have sufficient excess capacity

Reduces ratepayer costs by avoiding unnecessarily paying for capacity that is not needed

Modify / Eliminate Demarcation

Utility planning and foresight can keep the system in a perpetual state of sufficiency

Utility investments that are made to keep the system sufficient are eligible for full cost recovery beginning in the year they are commissioned

Utilities still make short-term capacity purchases, even during periods of sufficiency, begging the question of the appropriateness of the framework

Key Questions

To what extent should utility and non-utility assets be treated differently?

What are the equity considerations with respect to utility and non-utility capacity options?

How far into the future should the capacity need be evaluated? How should this interact with contract term?

What should happen if there is a future capacity need when a resource is built, but then that need disappears?



Compensation Structure Considerations

Fixed Annual Payment	Pre-Defined Time Period Compensation	Real-Time Pricing
Requires predicting the output/performance of generators in advance	Relevant time period is predictable and simple	Most accurate signal to send to generators
Simple to administer once the value is determined	Rewards generators for producing during high value hours	Difficult to allocate annual fixed cost of capacity to 'reliability hours'
Does not compensate generators for continued availability and performance (e.g., good maintenance)	Pre-defined time periods are inherently much broader than the actual limited reliability hours. Generators earn a lot of money when system is constrained and could theoretically not produce during actual peak hours and still make a lot of money in the other hours	Increased complexity and metering required
Does not compensate dispatchable generators for generating when the system needs them		

Key Questions

Should capacity be compensated like the fixed annual cost that it is, or should it be based on production during key hours?

Should there be concern about compensating generators during peak hours when the system has no issues?



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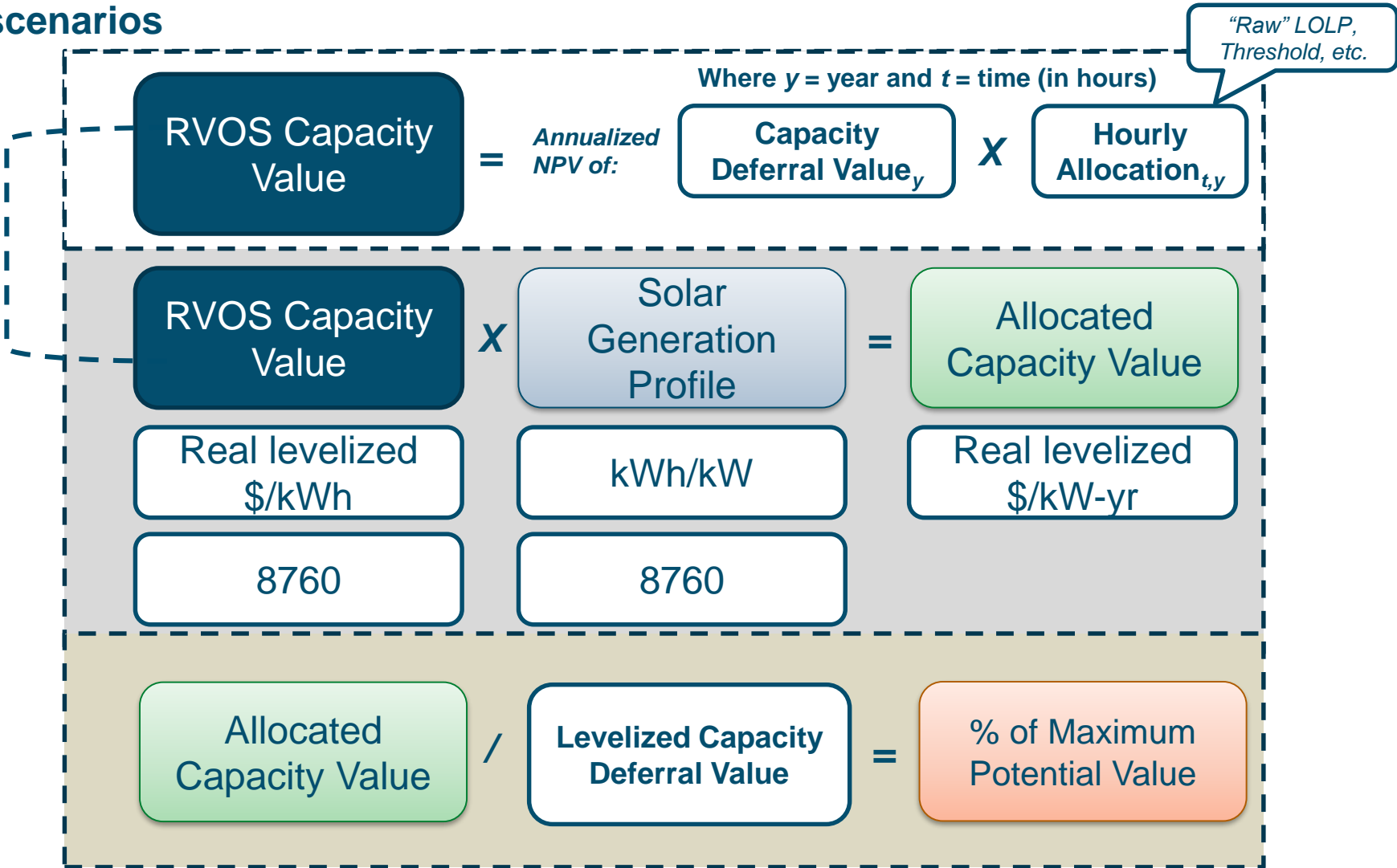
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Example RVOS calculations highlight differences between allocation methods

- + RVOS model used to calculate capacity value under several different scenarios





PGE (draft updated windows)

+ Time window (TW) 1 over-values solar relative to raw LOLP due to coincidence with PV generation

Annual Generation Capacity Value relative to Maximum Capacity Value (%)

	PGE						
	Raw	0.05% Threshold	0.07% Threshold	TW 1, Summer Peak Only	TW 2, Summer+Winter Peak	TW 3, Incl Winter Morning Peak	TW 4, Oregon General
West, Single Axis, ILR 1.1	23.8%	25.8%	29.3%	43.8%	25.9%	22.2%	22.9%
West, Fixed Tilt, ILR 1.1	19.0%	18.6%	20.7%	35.9%	18.5%	16.7%	14.2%
West, Double Axis, ILR 1.1	26.6%	29.1%	33.8%	50.0%	30.6%	25.6%	28.5%
West, Rooftop Solar, ILR 1.1	18.7%	18.3%	20.4%	35.3%	18.2%	16.4%	14.0%
West, Single Axis, ILR 1.4	30.3%	32.8%	37.3%	55.6%	32.9%	28.3%	29.1%
East, Single Axis, ILR 1.1	25.1%	21.7%	24.2%	43.0%	21.1%	21.8%	17.3%



PacifiCorp (draft updated windows)

Annual Generation Capacity Value relative to Maximum Capacity Value (%)

	PacifiCorp						
	Raw	0.05% Threshold	0.07% Threshold	TW 1, Summer Peak Only	TW 2, Summer+W inter Peak	TW 3, Incl Winter Morning Peak	TW 4, Oregon General
West, Single Axis, ILR 1.1	15.0%	14.0%	13.9%	23.9%	17.0%	15.1%	22.9%
West, Fixed Tilt, ILR 1.1	8.7%	6.7%	6.2%	12.3%	8.8%	7.8%	14.2%
West, Double Axis, ILR 1.1	21.1%	21.1%	21.6%	32.5%	23.0%	20.0%	28.5%
West, Rooftop Solar, ILR 1.1	8.6%	6.7%	6.2%	12.2%	8.7%	7.7%	14.0%
West, Single Axis, ILR 1.4	19.2%	17.8%	17.7%	30.5%	21.7%	19.3%	29.1%
East, Single Axis, ILR 1.1	12.1%	9.2%	8.8%	17.0%	11.7%	11.6%	17.3%



Factors affecting the capacity value of variable generation

+ Coincidence with load

- Locations with better solar resources and more production later in the day will have higher ELCC values

+ Production variability

- Statistically, the possibility of low production reduces the value of a resource

+ Location

- Distributed resources avoid transmission and distribution losses

+ Existing quantity of variable generation

- Common resource types exhibit diminishing marginal returns, each additional unit of variable generation has less capacity credit than the previous unit



Jurisdictional Review of Wind Capacity Value Methodology

Jurisdiction	Method	Notes
SPP	<u>Heuristic¹</u> <ul style="list-style-type: none"> 60th percentile value of wind production during top 3% of peak load hours, calculated separately for winter and summer 	SPP has initiated an investigation to explore switching to an ELCC methodology. They have conducted ELCC analysis and are comparing to their existing heuristic method
MISO	<u>ELCC²</u>	MISO calculates ELCC for the entire portfolio of wind across the system and then allocates this value to each node within the system. All wind within each node receives the same value.
NYISO	<u>Heuristic³</u> <ul style="list-style-type: none"> Winter: average wind production from December to February during hours ending 16-19 Summer: average wind production from June to August during hours ending 14-17 	NYISO is currently investigating more sophisticated methods, including ELCC, using loss-of-load-probability modeling to capture the diversity effects of the portfolio of non-firm resources ⁴
ISONE	<u>Heuristic⁵</u> <ul style="list-style-type: none"> Winter: median wind production from October to May during hours ending 18-19 plus all hours with capacity scarcity Summer: median wind production from June to September during hours ending 14-18 plus all hours with capacity scarcity 	
PJM	<u>Heuristic⁶</u> Average wind production from June to August during hours ending 14-17	PJM is evaluating adopting the ELCC method which is currently open to stakeholder comment ⁷
CAISO	<u>ELCC⁸</u>	

^[1] <https://www.spp.org/documents/60434/2019%20elcc%20wind%20study%20report.pdf>

^[2] <https://cdn.misoenergy.org/2019%20Wind%20and%20Solar%20Capacity%20Credit%20Report303063.pdf>

^[3] https://www.nyiso.com/documents/20142/2923635/app_a_attach_icapmnl.pdf/503354b6-0607-9a12-f2d4-f866c25eac65

^[4] <https://www.nyiso.com/documents/20142/6785167/Grid+in+Transition+DRAFT+FOR+POSTING.pdf/74eb0b20-6f4c-bdb2-1a23-7d939789ed8c?version=1.1&t=1558703451381&download=true>

^[5] pg 24, https://www.iso-ne.com/static-assets/documents/regulatory/tariff/sect_3/mr1_sec_13_14.pdf

^[6] <https://www.pjm.com/~media/documents/manuals/m21.ashx>

^[7] <https://www.pjm.com/~media/committees-groups/committees/pc/20190207/20190207-item-08-elcc-update.ashx>

^[8] https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/UtilitiesIndustries/Energy/EnergyPrograms/ElectPowerProcurementGeneration/DemandModeling/ELCC_2_13_19.PDF



Reliability Metric Definitions

+ Loss of load expectation (“LOLE”, unit of days/yr)

- Average number of days per year with loss of load (at least once during the day) due to system load exceeding available generating capacity

+ Loss of load events (“LOLEV”, units of events/yr)

- Average number of loss of load events per year, of any duration or magnitude, due to system load exceeding available generating capacity

+ Loss of load probability (“LOLP”, units of %)

- Probability of system load exceeding the available generating capacity during a given time period

+ Loss of load hours (“LOLH”, units of hours/yr)

- Average number of hours per year with loss of load due to system load exceeding available generating capacity

+ Expected unserved energy (“EUE”, units of MWh/yr)

- Average total quantity of unserved energy over a year due to system load exceeding available generating capacity

NWPP 2019, <https://www.nwpp.org/resources/exploring-a-resource-adequacy-program-for-the-paci>