Energy+Environmental Economics

Principles of Capacity Valuation

Overview and Recommendations

Oregon Public Utility Commission – UM 2011

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Outline

+ **Background and Work To Date (10 mins)**
  - July E3 Presentation
  - December E3 Report
  - December Staff Comments
+ **Capacity Valuation Framework – A Refresher (30 mins)**
  - 3 key questions
+ **Application of Capacity Valuation Framework (45 mins)**
  - General cross-cutting recommendations
  - Renewable generation
  - Storage
  - Hybrid resources (renewable + storage)
  - Demand response
  - Energy efficiency
+ **Conclusions (5 mins)**
+ **Q/A & Discussion (60 mins)**

Background

+ **E3 was engaged by the Oregon Public Utility Commission to advise on the topic of capacity valuation, as considered through UM 2011 *General Capacity Investigation***
+ **E3 presented a framework for capacity valuation in Oregon during a virtual Informational Workshop on July 9, 2020**
  - This workshop provided a background on capacity and addressed several “key questions” that are integral to the topic of capacity valuation
+ **E3 has since developed a written report on the principles of capacity valuation, including a section on the application of these principles to specific resources and programs in Oregon**
  - Released in December 2020
  - May provide basis for OPUC Staff to leverage in comments to Commission

Oregon Public Utility Commission

Timeline

Mar 2020
OPUC retains E3

Jul 2020
E3 presents at OPUC informational workshop

Dec 2020
E3 publishes final report summarizing principles and recommendations

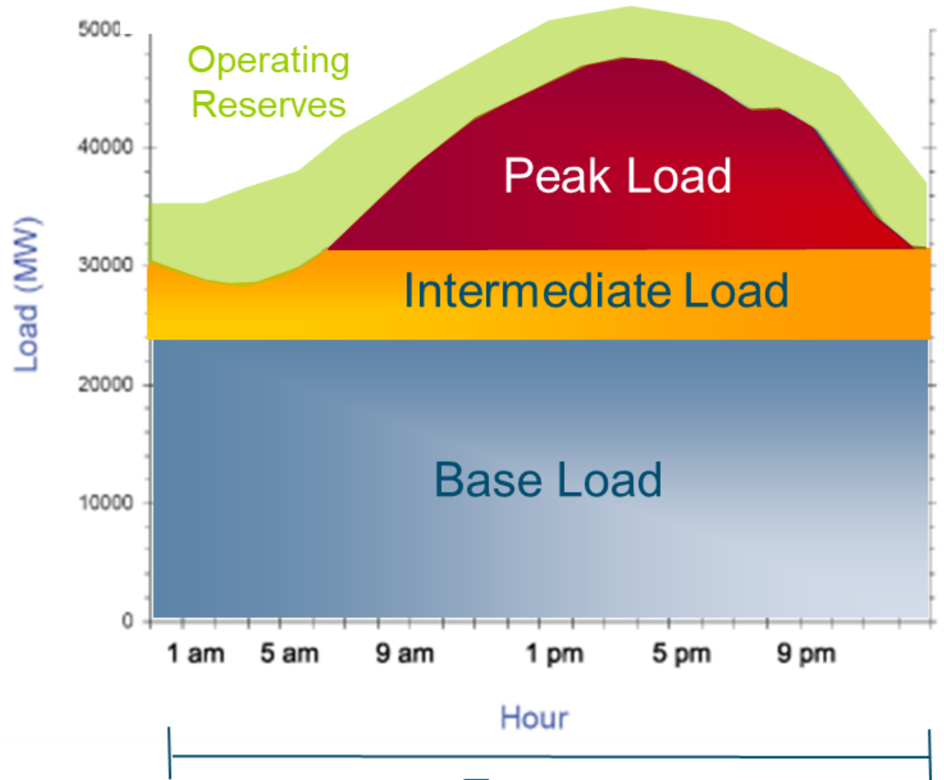
Dec 2020
E3 presents application of capacity principles

Today

Overview

+ **Today's presentation discusses**
  - Amount and value of capacity provided by different resources
  - Appropriate compensation mechanisms for 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



* "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 (MW)?

2) What is the value of capacity ($/MW)?

- A separate but related topic:

Compensation framework

  - 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?

+ **Primary basis to determine capacity contribution of a resource should be adherence to loss-of-load-probability principles that measure the reliability of the system**
  - If two resources yield equivalent system reliability, they provide equivalent capacity
+ **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**

ELCC Calculation Process

1. **Calculate System Reliability**
2. **Add desired resource to portfolio**
   Addition of new source of generation will improve reliability relative to measurement in Step 1
3. **Remove perfect capacity until system reliability is restored**
   Removal of perfect capacity results in reduces reliability until original level is met

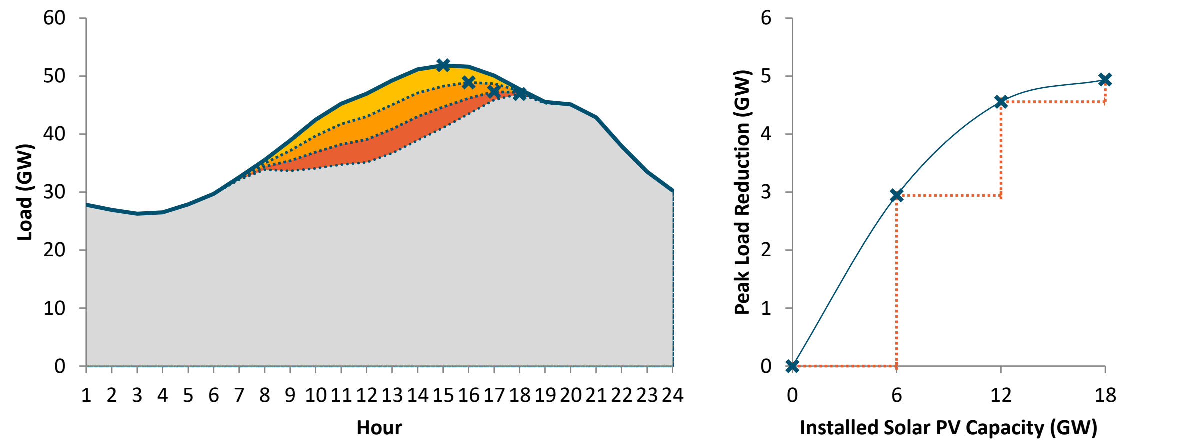
A resource's ELCC is equal to the amount of perfect capacity removed from the system in Step 3

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**

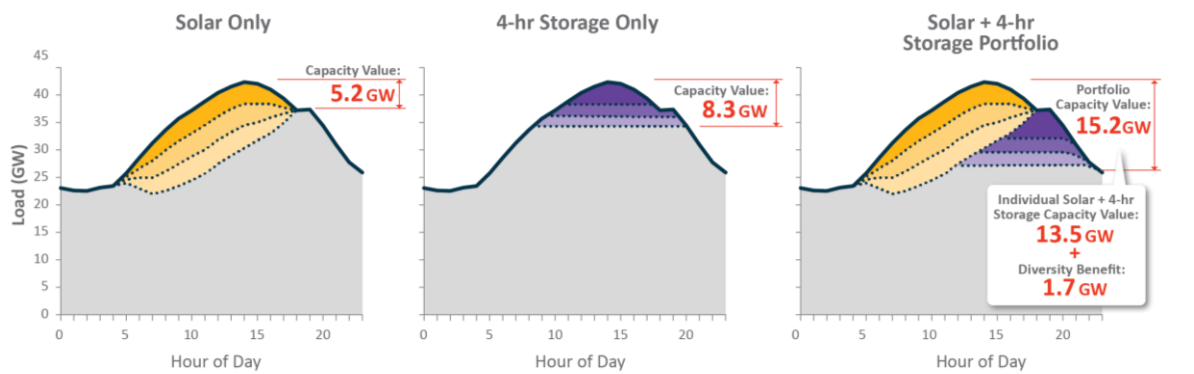
Antagonistic: *Diminishing Returns of Solar*

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



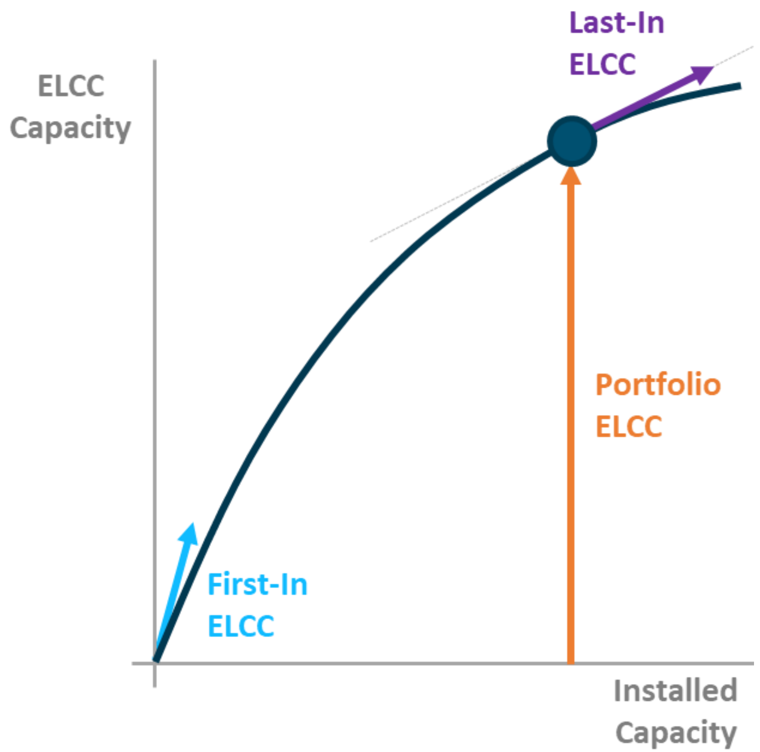
Synergistic: *Benefits of Solar + Storage*

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



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



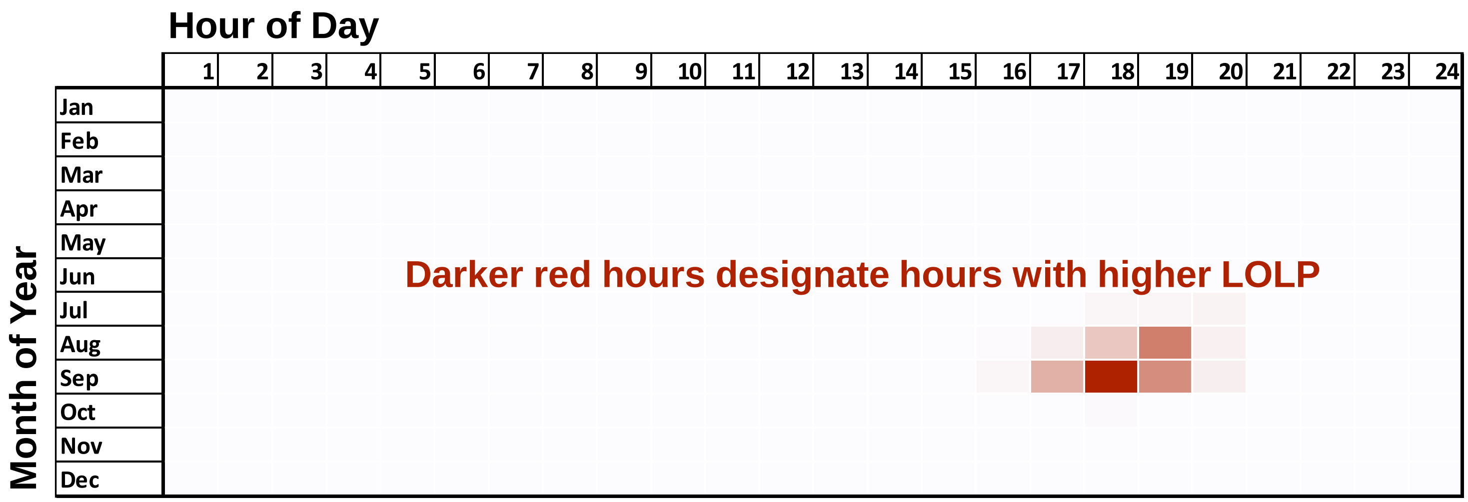
ELCC Computational Requirements

+ **Calculating ELCC in loss-of-load-probability models requires:**
  - Significant data
  - Significant computational horsepower
+ **Many industry models can calculate this metric, but should be able to capture load and resource performance over a wide array of system conditions**
  - Hundreds or thousands of simulated years given infrequency of loss-of-load events in a reliable system

Heuristics to Approximate ELCC

- **Computational and data requirements of ELCC may not be practical and lead to simplified alternatives or "heuristics" to approximate ELCC**
- **Use of hourly loss of load probability (LOLP) value is basis of the most common ELCC heuristic**
  - 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

Illustrative LOLP Table



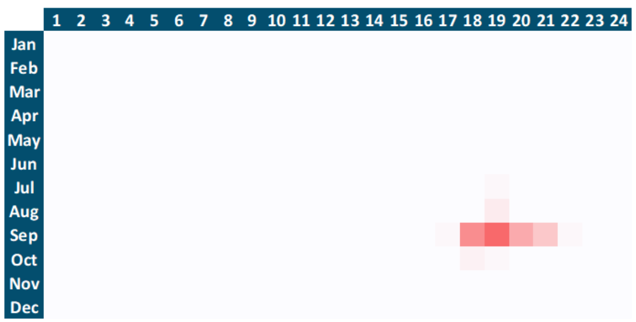
**Most electricity systems use a reliability standard of days/year instead of hours/year – the most common standard is 1-day-in-10 years which corresponds to a 0.1 days/year reliability standard*

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



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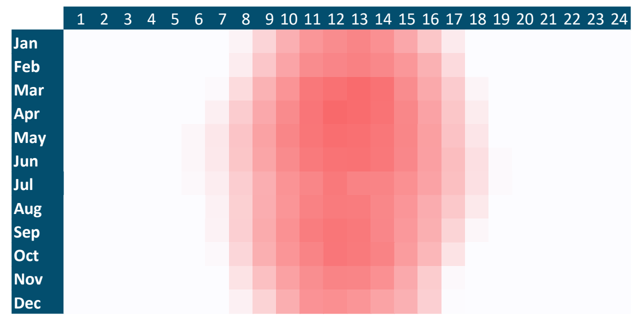
Solar Production (MW)



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Approximate ELCC Value (MW or %)

Normalize hourly 12x24 LOLP values for the year such that they sum to 1.0

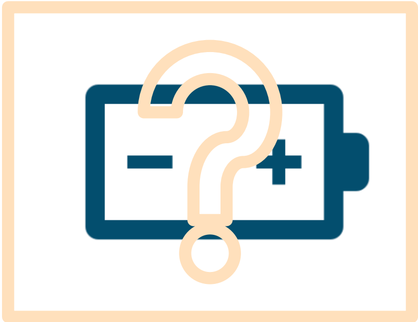
Gather average 12x24 generation of a specified resource over the year

Calculate weighted average resource generation over LOLP hours by calculating sumproduct of normalized LOLP and generation

+ This LOLP heuristic approximates Last-In ELCC because the LOLP values are measured on a system after all resources have contributed to minimizing LOLP

What the Hourly LOLP Heuristic Misses

- **Using hourly LOLPs is 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
- **E3’s resource-specific applications address these shortcomings**



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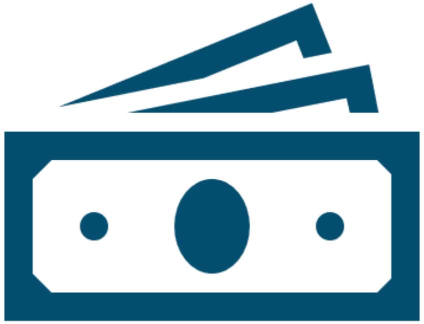
Key Question 2) What is the Value of Capacity?

Monetary Value of Capacity

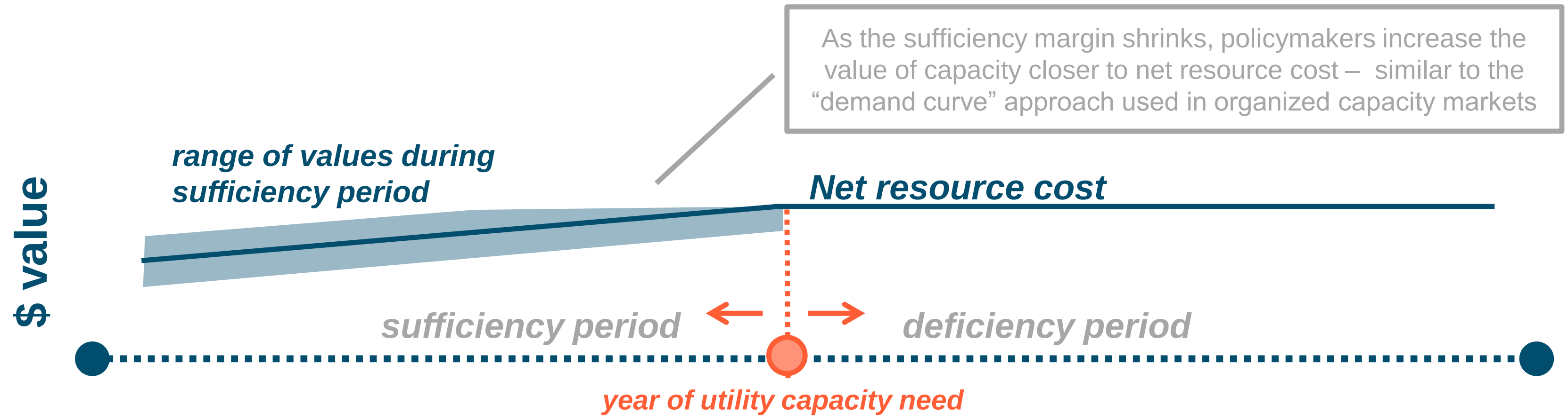
+ **Monetary value of capacity ($/MW) is a distinct and separable question from the quantity of capacity a resource is able to provide**
  - Any combination of resources can provide 1 MW of ELCC capacity and should be compensated equivalently
+ **Primary basis to determine monetary value of capacity should be adherence to avoided cost principles**
  - A resource should be provided no more compensation than the least cost resource that can be procured by the utility that provides equivalent reliability



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 resource cost, with the fixed O&M of the resource cost 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 resource cost**

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**

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Capacity Compensation Frameworks

Goals of a Compensation Framework

+ **Compensation framework should:**

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

+ **If price signals impact how a resource is dispatched, framework should seek to dispatch resources in a manner that maximizes the capacity contribution to the utility system, without creating unnecessary requirements**

+ **It is difficult to construct a single compensation framework that is appropriate for all use cases and all technologies, tradeoffs include:**
  - **Efficiency:** encourage economically efficient new resource development, procurement, and operation
  - **Acceptability:** transparent, tractable, understandable, and implementable for stakeholders and policymakers

Approaches to Compensating Capacity

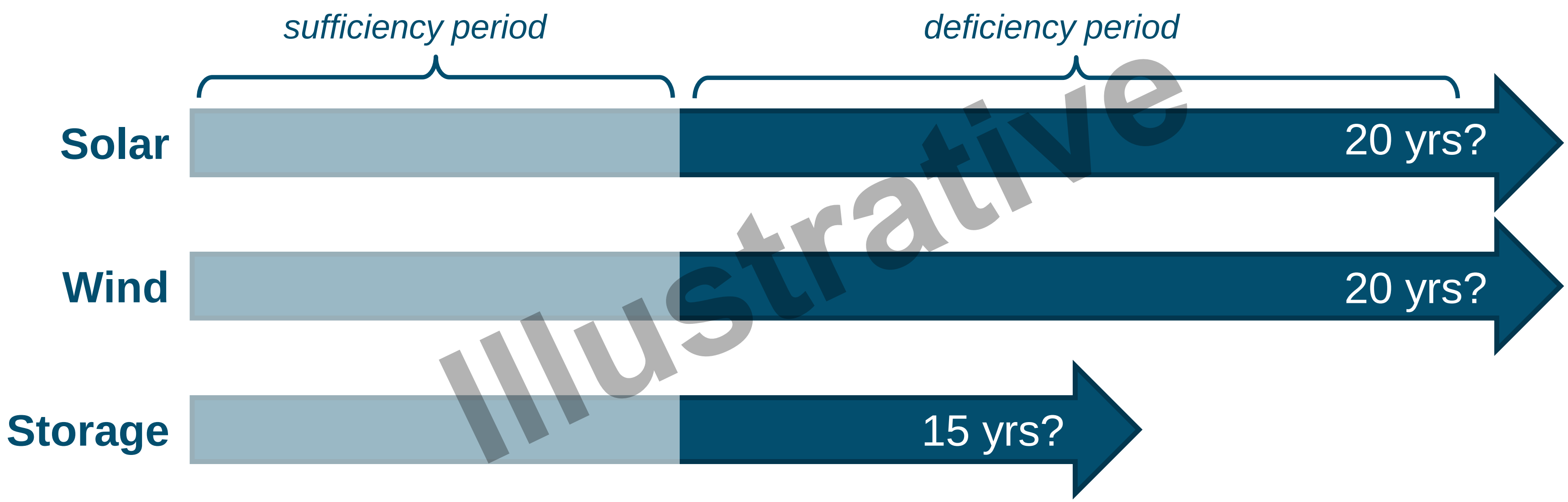
- There are two general approaches to compensating capacity

	Fixed Payment	Pay-as-You-Go
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)
Performance Evaluation	Evaluated though "performance penalties"	Based on production during capacity compensation hours

- **Pay-as-you-go compensation structure can either compensate resources on a dynamic basis only during times of system stress or send a consistent pre-determined price signal for all hours that have a higher probability of loss of load**

Contract Length

- Capacity resources are often capital intensive and require a degree of certainty from third-party developers to procure financing
- Longer contract lengths are often advantageous to developers since the early years of a contract have lower-priced “sufficiency” capacity payments
- Equity between utility-owned and third-party resources is an important consideration and utilities generally are eligible to recover the full costs of a resource over its economic life



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Application of Capacity Value in Oregon

General Principles and Cross-Cutting Considerations

+ Capacity Contribution

- Marginal or “Last-In” ELCC is consistent with avoided cost principles
- Multi-year contracts that lock-in capacity contributions (MW) for each future year can provide certainty and equity
- For dispatchable resources, fixed-payment accreditation with performance requirements can provide certainty to both third-party resources and the utility
- For non-dispatchable resources, pay-as-you-go compensation can appropriately compensate resources without undue performance requirements

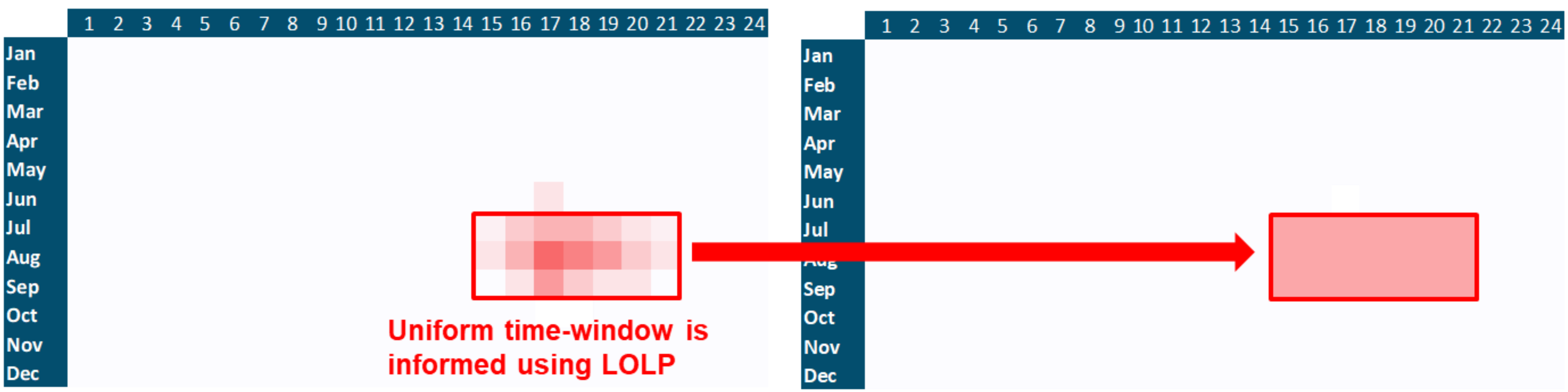
+ Capacity Value

- Capacity value based on net cost of capacity during periods of deficiency and operations and maintenance cost during periods of sufficiency is consistent with avoided cost principles

Determining Peak Periods for Pay-as-You-Go

- **Pay-as-you-go compensation structures can compensate resources during pre-defined time periods of high-LOLP**
- **Because these values change on a month-to-month and hour-by-hour basis, it can be simpler to condense into a single or a few uniform peak periods**
  - Multiple approaches to this, but k-means is a common and reasonable approach
- **A peak period that contains twice as many hours as an alternative will have half the price, assuming the same annual fixed cost is being allocated over those hours**
- **While condensing into a single time period is simpler, it is also less accurate – if and how to do this is a policy decision**

Raw LOLPs | **LOLP-Informed Uniform Time-Windows**



Renewable Generation

- Non-dispatchable renewable generation can be compensated via a pay-as-you-go structure to balance accuracy and simplicity
- Fixed payment compensation with performance requirements is difficult for renewables since it is unclear if a lack of performance is due to weather factors that are already captured in ELCC or another factor
- $/MWh values set equal to hourly LOLP values multiplied by monetary value of capacity and adjusted by ratio of Last-In ELCC to hourly LOLP-generation coincidence

Renewable Generation

Capacity contribution	Last-In ELCC, attributed via a pay-as-you-go compensation structure
Compensation framework	Pay-as-you-go compensation structure with hourly compensation values set proportionally to normalized hourly LOLP values, adjusted by the ratio of Last-In ELCC to hourly LOLP-generation coincidence

- **Benefits**
  - Captures production during high-LOLP hours and compensates equivalently to Last-In ELCC
  - Provides resource owners with incentive to ensure resources are productive and well-maintained without imposing difficulty to measure performance requirements

Hourly LOLP Adjustment Process for Pay-As-You-Go Compensation Structure

Step 1

Normalized hourly LOLP values sum to 100%

	Hour 1	Hour 2	Hour 3	Hour 4
Hourly LOLP, Yr 1	0%	0%	50%	50%
Hourly LOLP, Yr 2	0%	20%	60%	20%

Step 2

Calculate Last-In ELCC using model

	Year 1	Year 2
Last-In ELCC	25 MW	40 MW

Step 3

Calculate LOLP-generation coincidence

	Hour 1	Hour 2	Hour 3	Hour 4
Energy Generation	10 MW	50 MW	40 MW	10 MW

Assuming Energy Generation is the same for Year 1 and 2

	Year 1	Year 2
LOLP Coincidence	25 MW	36 MW

Example Calculation for Year 2

0% * 10 MW
+ 20% * 50 MW
+ 60% * 40 MW
+ 20% * 10 MW
= 36 MW

Step 4

Calculate ratio of ELCC to LOLP-generation coincidence

	Year 1	Year 2
Adjustment Factor	100%	111%

Example Calculation for Year 2

$$\frac{\text{40 MW Last-In ELCC}}{\text{36 MW LOLP-generation coincidence}} = 111\%$$

Hourly LOLP Adjustment Process for Pay-As-You-Go Compensation Structure

Step 5

Calculate adjusted hourly LOLP values for capacity compensation

	Hour 1	Hour 2	Hour 3	Hour 4
Adj. LOLP, Yr 1	0%	0%	50%	50%
Adj. LOLP, Yr 2	0%	22%	67%	22%
Example Calculation for Year 2	0% * 111%	20% * 111%	60% * 111%	20% * 111%

Step 6

Allocate annual capacity value to each hour by multiplying adjusted hourly LOLP values with annual generation capacity value

	Year 1	Year 2
Capacity ($/kW-yr)	30	100

Hourly Gen Capacity Avoided Costs ($/kWh)

	Hour 1	Hour 2	Hour 3	Hour 4
Year 1	0	0	15	15
Year 2	0	22	67	22
Example Calculation for Year 2	$/kW-yr * 0%	$/kW-yr * 22%	$/kW-yr * 67%	$/kW-yr * 22%

Step 7

Get hourly capacity payment by multiplying hourly avoided costs with hourly generation

Hourly Capacity Payment ($)

	Hour 1	Hour 2	Hour 3	Hour 4
	10 MW * $/MWh	50MW * $/MWh	40MW * $/MWh	10MW * $/MWh
Year 1	$0	$0	$600,000	$150,000
Year 2	$0	$1,100,000	$2,680,000	$220,000

Sum of Hourly Capacity Payment = Last-in ELCC * Annual Capacity Value

Storage

- Compensation through fixed annual payment with performance requirement can provide appropriate compensation while balancing accuracy and fairness
- Fixed payment based on product of Last-In ELCC and monetary value of capacity

Storage	
Capacity contribution	Last-In ELCC, attributed via a fixed payment compensation structure
Compensation framework	Annual fixed payment ($/MW) with performance requirements

- Performance is easier to measure for storage since it can be directly compared to operator instructions which factor in the limitations of storage
- Benefits
  - Doesn’t require storage to cycle every day since it is not necessary for capacity
  - Doesn’t compensate storage for production on days without a capacity need
- Performance penalties based on performance relative to a day-ahead signal from utility that is based on the storage resource’s capabilities

Demand Response

- **Compensation for demand response based on fixed annual payment with performance requirements can provide appropriate signals that balance accuracy and fairness**
  - Similar to storage
- **Fixed payment equal to Last-In ELCC times monetary value of capacity**

Demand Response	
Capacity contribution	Last-In ELCC, attributed via a fixed payment compensation structure
Compensation framework	Annual fixed payment ($/MW) with performance requirements

- **Performance requirements would be based on inherent capabilities of the demand response resource, identical to what is used in its ELCC calculation**

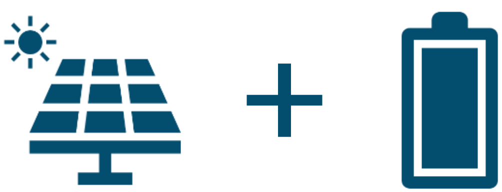
Hybrid Resources

- Hybrid resources share characteristics of renewables and storage
- Could be compensated either through:
  - Pay-as-you-go for all generation (similar to renewable only)
  - Pay-as-you-go structure for renewable + fixed payment structure for storage

Hybrid Resources

Capacity contribution	Last-In ELCC, attributed solely via a pay-as-you-go compensation structure or in conjunction with a fixed payment compensation structure
Compensation framework	Two options: 1. Pay-as-you-go compensation structure for combined system 2. Pay-as-you-go structure for the renewable portion of the system and a fixed payment structure for the storage portion of the system

- Fixed payment only would require complex performance evaluation that is likely impractical (similar to renewable only)



Energy Efficiency

- **Energy efficiency is a unique resource as it is generally not directly meterable**
  - Capacity contribution (MW) is likely best calculated through models and assumptions about performance
  - Capacity contribution can be based on Last-In ELCC
- **Value of capacity can be based on monetary value of capacity in each year, similar to other resources**

Energy Efficiency

Capacity contribution	Last-In ELCC
Compensation framework	Value of energy efficiency for cost-benefit analysis purposes could be based on the net present value of the product of a) the forecasted Last-In ELCC by year over the life of the measure and b) the monetary value of capacity for each year of the resource's life

- **This exercise would likely not be used directly in "compensation" of energy efficiency but rather in the cost-benefit analysis evaluation of efficiency programs**

Conclusions

- **Proper evaluation of capacity contribution requires consideration of**
  - Capacity contribution (MW)
  - Value of capacity ($/MW)
- **Compensation structure should strive to properly reflect both of these factors**
- **No single compensation structure is appropriate for all resources and use cases and tradeoffs between competing factors is required**
  - Economic efficiency – equity – transparency – tractability
- **Marginal or "Last-In" ELCC sends efficient signal for procurement and is consistent with avoided cost principles**
- **Locking-in values (MW and $/MW) over length of contract provides certainty**
- **Monetary value based on net resource cost or operations and maintenance cost is consistent with avoided cost principles**

Questions and Discussion

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Appendix

LOLP Heuristic Calculation Example

Step 1

Hourly LOLP values sum to 100%

	Hour 1	Hour 2	Hour 3	Hour 4
Hourly LOLP	0%	20%	60%	20%
Energy Generation	10 MW	50 MW	40 MW	10 MW

Step 2

Calculate weighted average generation of energy resource

0% * 10 MW
+ 20% * 50 MW
+ 60% * 40 MW
+ 20% * 10 MW
= 36 MW

Step 3

Divide weighted average production of resource by nameplate capacity

$$\frac{\text{36 MW weighted average}}{\text{50 MW nameplate}} = \text{72\% Capacity Credit}$$

Net Resource Cost Calculation

Gross cost of capacity	*$/kW-yr*
– System benefits	*$/kW-yr*
energy	
ancillary services	
etc.	
= Net cost of capacity	*$/kW-yr*