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# Calpine/E3 ELCC Proposal: Overview and Answers to Stakeholder Questions

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# Introduction/Overview

- **Calpine contracted with E3 to help investigate methods for calculating Net Qualifying Capacity (NQC) values for renewable projects in California using an Effective Load Carrying Capability (ELCC) approach**
  - As California moves toward a 50% RPS, it will be important to ensure that the RA program is accurately valuing the contribution of renewable resources to meeting system reliability needs
  - ELCC is emerging as the industry standard method for calculating the capacity contribution of renewable energy resources
  - E3's investigation has found that California's current exceedance methodology is increasingly inaccurate at high levels of renewable penetration
- **Calpine and E3 have developed a joint proposal for calculating project-specific NQC values using ELCC**

# Criteria for a Successful ELCC Calculation Method

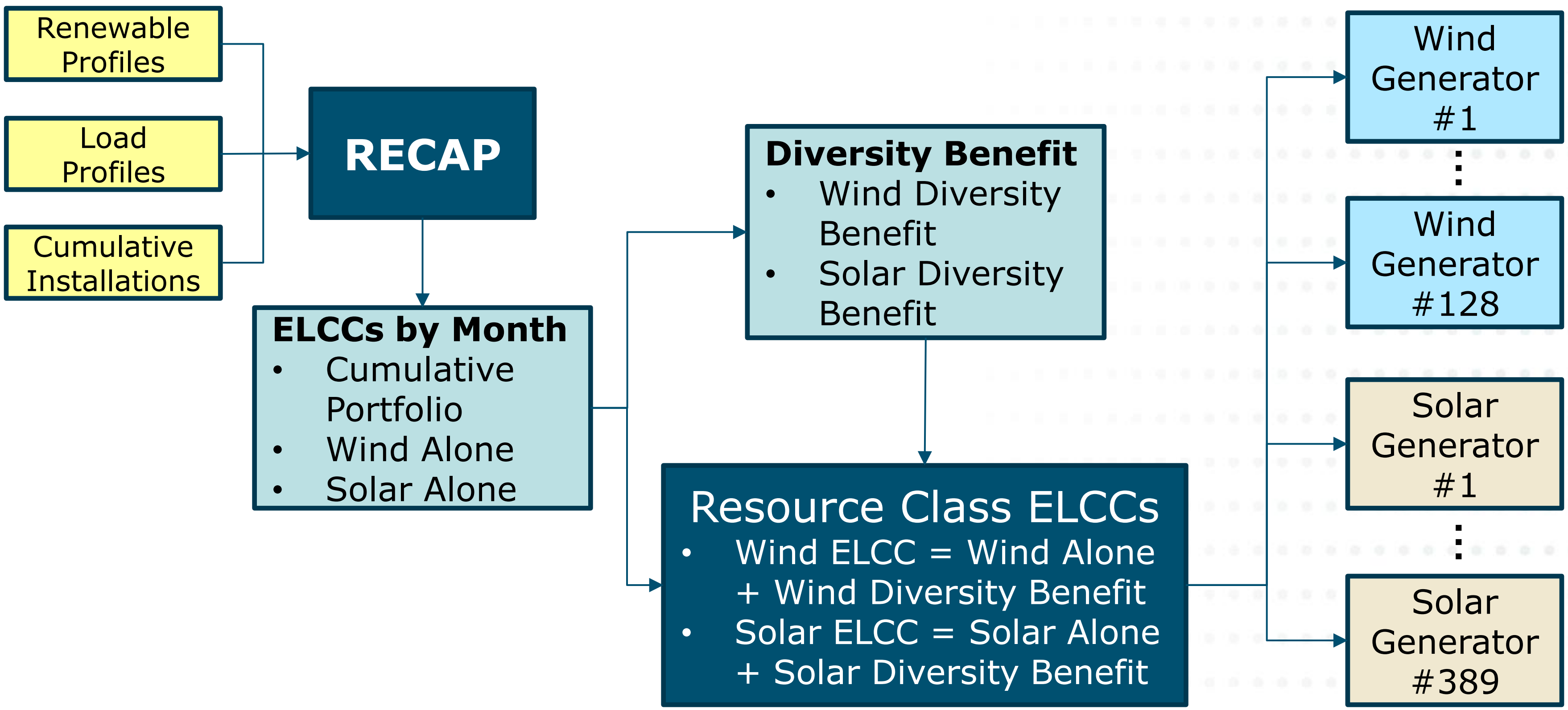
- **E3 and Calpine developed the following five criteria for a successful ELCC calculation method:**
  1. Ensure system reliability by accurately valuing the renewable portfolio
  2. Send appropriate signals to inform future procurement
  3. Send appropriate signals to reward project performance
  4. Allocate ELCC to specific resources in an equitable manner
  5. Process should be tractable and computationally manageable
- **We designed our proposal to strike an appropriate balance among these five goals**

# Process Flow Diagram for Calpine/E3 Proposal

**Step 1:** Portfolio ELCC

**Step 2:** Resource Class ELCC

**Step 3:** Project NQC




allocated based on time-window method

# Calpine/E3 ELCC Results

## 2018 RA Year

**2018 Vintage ELCC**

| | Wind ELCC (MW) | Solar ELCC (MW) | Wind ELCC (%) | Solar ELCC (%) |
|---|---|---|---|---|
| Jan | 853 | -2 | 15% | 0% |
| Feb | 1,023 | 167 | 18% | 1% |
| Mar | 585 | 998 | 10% | 6% |
| Apr | 934 | 5,303 | 17% | 34% |
| May | 1,271 | 5,808 | 23% | 38% |
| Jun | 1,393 | 6,933 | 25% | 45% |
| Jul | 1,218 | 7,201 | 22% | 47% |
| Aug | 805 | 6,562 | 14% | 43% |
| Sep | 519 | 5,631 | 9% | 37% |
| Oct | 542 | 4,221 | 10% | 27% |
| Nov | 492 | 481 | 9% | 3% |
| Dec | 784 | 2 | 14% | 0% |

# Target LOLE Does Not Substantially Affect ELCC

- Using RECAP results, monthly target LOLE does not substantially affect ELCC across a reasonable range of LOLE
- Calpine/E3 are open to alternative approaches to developing monthly LOLE targets

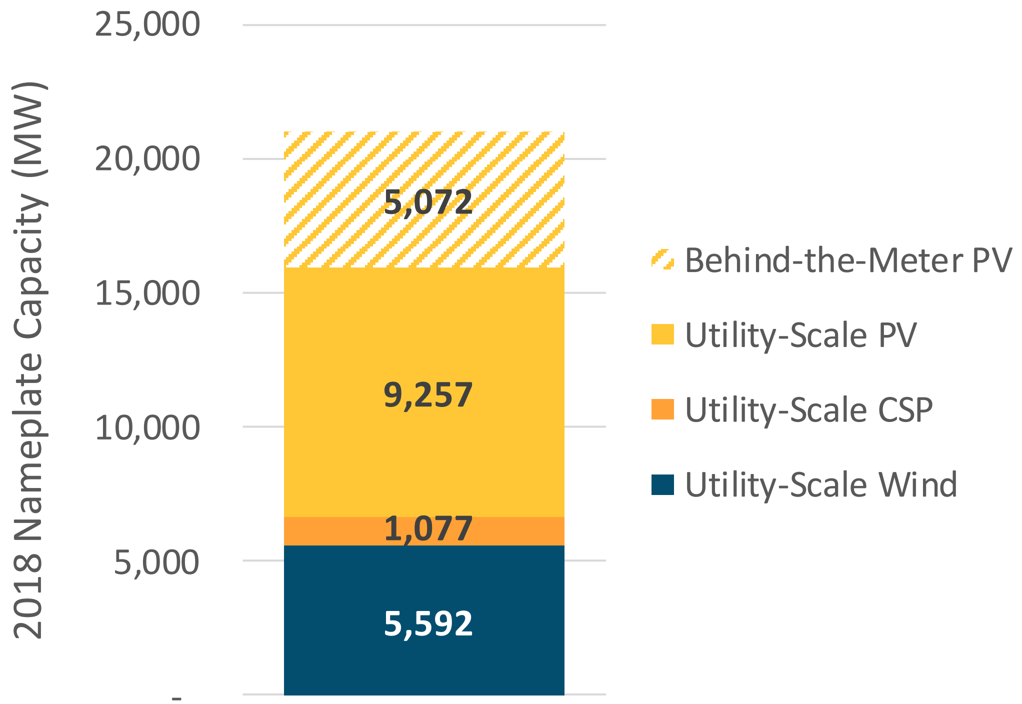
| Monthly ELCC (MW) by Annualized LOLE (hrs/yr) | | | | | |
|---|---|---|---|---|---|
| LOLE (hrs/yr) | 0.1 | 0.5 | 1 | 2.4 | 10 |
| All Months (MW) | 6,350 | 6,953 | 7,187 | 7,374 | 7,525 |
| Jan (MW) | 744 | 789 | 814 | 852 | 923 |
| Feb (MW) | 1,043 | 1,124 | 1,155 | 1,190 | 1,263 |
| Mar (MW) | 1,511 | 1,541 | 1,558 | 1,583 | 1,644 |
| Apr (MW) | 5,086 | 5,440 | 5,746 | 6,237 | 5,609 |
| May (MW) | 6,694 | 6,961 | 7,059 | 7,079 | 7,210 |
| Jun (MW) | 7,971 | 8,196 | 8,259 | 8,326 | 8,262 |
| Jul (MW) | 7,660 | 7,932 | 8,136 | 8,420 | 8,499 |
| Aug (MW) | 6,640 | 6,955 | 7,123 | 7,367 | 7,758 |
| Sep (MW) | 5,321 | 5,668 | 5,864 | 6,150 | 6,452 |
| Oct (MW) | 4,046 | 4,274 | 4,535 | 4,764 | 4,794 |
| Nov (MW) | 1,017 | 1,001 | 991 | 972 | 934 |
| Dec (MW) | 704 | 824 | 837 | 786 | 798 |

# Behind-the-Meter Solar

+ **BTM solar must be modeled as a resource to accurately determine its contribution to meeting RA needs**

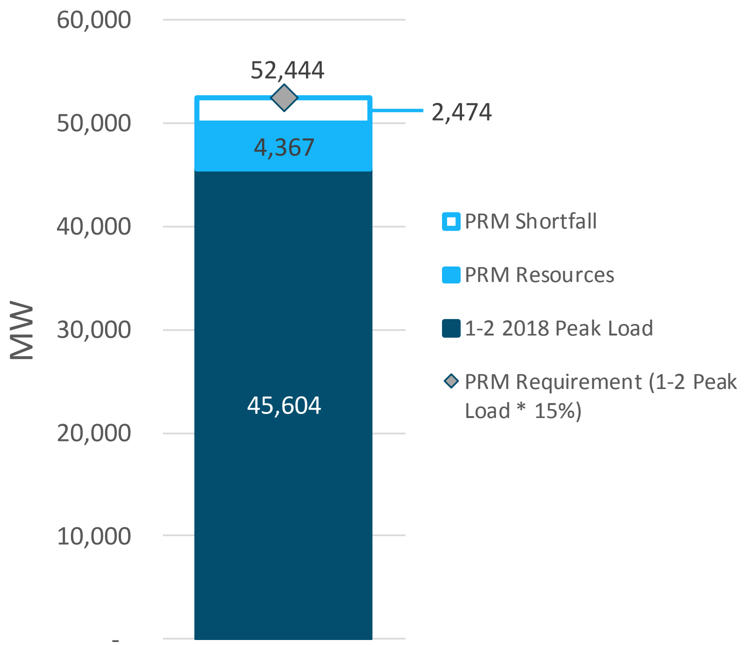
+ **Unless RA rules and load forecasting protocols are changed, BTM solar will continue to "count" toward RA requirements through its impact on load forecasts**

+ **Calpine/E3 proposal subtracts implicit impact of BTM solar on RA requirements from the Solar Resource Class ELCC between Steps 2 and 3**
  - Remaining Solar ELCC allocated to supply-side projects



# Transition Period to ELCC

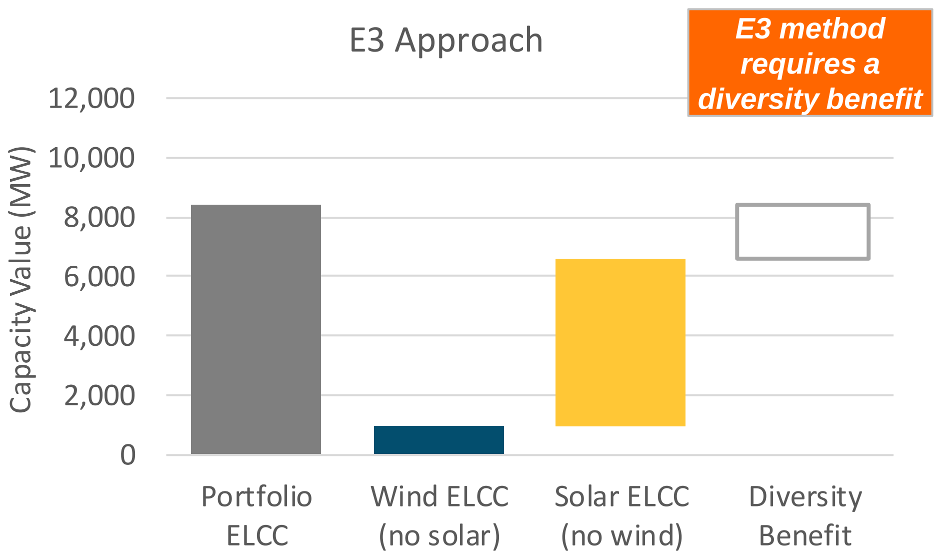
- **Calpine/E3 do not support a transition period to ELCC based NQC values**
- **Outputs from ED and Calpine/E3 suggest renewable resources are being overcounted toward RA by ~2,500 MW**
  - Implies a >5% reduction in PRM assuming an annual peak load of 45,000 MW in 2018
- **This overcounting implies a near-term reliability risk to California**
- **A transition may also impact future reliability by undermining the near-term economics of resources that will be needed once ELCC is fully implemented**

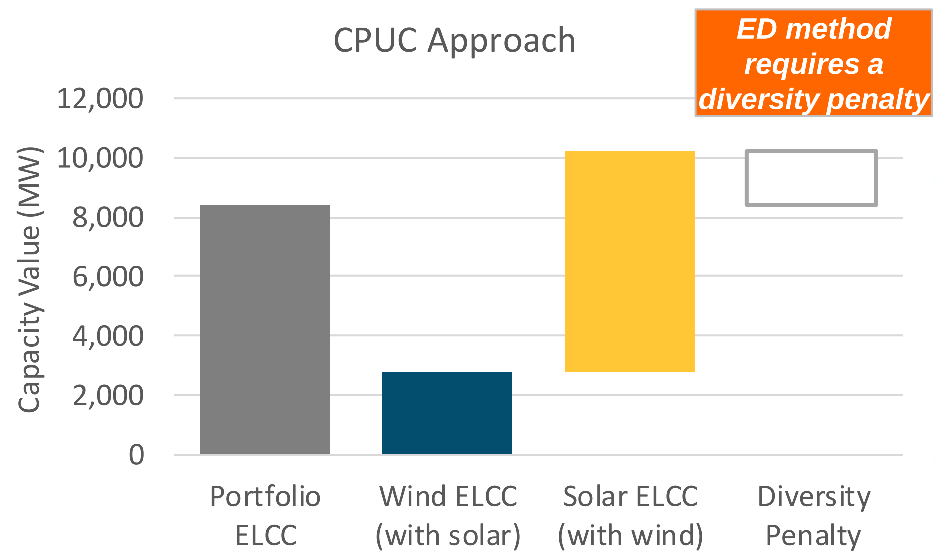


# Diversity Benefit

- **Calpine/E3 methodology calculates wind and solar ELCCs assuming no other renewables on the system**
  - This method requires the calculation of a diversity benefit, which is the Portfolio ELCC minus the sum of the independent wind and solar ELCCs

- **Current ED methodology calculates wind and solar ELCCs assuming the other renewables are on the system**
  - This method requires the calculation of a diversity penalty, which is the sum of the independent wind and solar ELCCs minus the Portfolio ELCC



# Vintaging

+ **Calpine/E3 proposal suggests calculating marginal ELCC values for new resources starting in 2019**
  - This important to accurately signal the incremental value of new wind and solar resources
  - Does NOT affect Portfolio ELCC or system reliability, only the allocation of ELCC to different vintages of resources
  - Not proposing to implement for the 2018 RA Year

| Month | Wind Alone (MW) [1] | Solar Alone (MW) [2] | Portfolio ELCC (MW) [3] | Diversity Benefit (MW) [4] = [3]–[2]-[1] |
|---|---|---|---|---|
| Jan | 50 | 0 | 51 | 1 |
| Feb | 47 | 15 | 62 | 1 |
| Mar | 38 | 3 | 40 | 0 |
| Apr | 133 | 101 | 237 | 3 |
| May | 159 | 97 | 258 | 2 |
| Jun | 193 | 200 | 400 | 7 |
| Jul | 223 | 209 | 436 | 4 |
| Aug | 167 | 157 | 328 | 4 |

$$\left(\frac{209}{209 + 223}\right) \times 4 + 209 = $$ **Solar ELCC 211 MW**

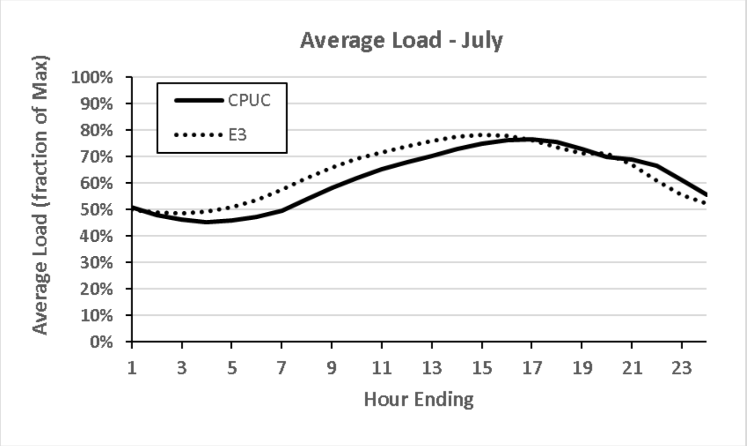
**11%** of incremental nameplate solar

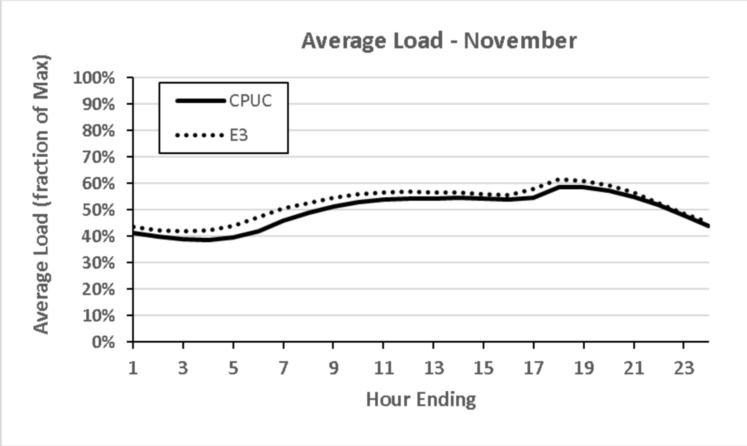
$$\left(\frac{223}{209 + 223}\right) \times 4 + 223 = $$ **Wind ELCC 225 MW**

**45%** of incremental nameplate wind

# Differences Between Calpine/E3 and ED ELCC Estimates

- **Calpine/E3 and ED renewable profiles are aligned (both are in standard time year round)**
- **Adjusting ED load profiles by an hour during DST (to put into standard time) partially closes the gap between Calpine/E3 and ED estimates**
- **Other unresolved load shape issues that we recommend investigating jointly with ED**
  - ED profiles appear to be slightly peakier than Calpine/E3 profiles



# Calpine/E3 used RECAP Model to perform ELCC calculations

- **RECAP has been used in a number of CPUC proceedings**
  - Formally adopted for calculating the capacity contribution of energy efficiency and demand response programs*
  - Also used in the RPS Calculator, LTPP, Net Energy Metering cost shift evaluation, CSI cost-effectiveness assessment
  - RECAP version used in this analysis available for download: https://ethree.sharefile.com/d-s379bf15c80e496f9
- **Current version uses load & resource profiles developed by E3, however ED's profiles could be substituted in RECAP**
  - Calculations could be performed by E3 or ED staff
- **Alternatively, the Calpine/E3 method could be implemented in SERVM**

# Scorecard for Calpine/E3 Proposal

| Criterion | Comments |
|---|---|
| Ensure system reliability by accurately valuing the renewable portfolio | ✓ Project ELCC values sum to the Portfolio ELCC for each month |
| Send appropriate signals to inform future procurement | ✓ Each new Vintage receives a Marginal ELCC<br>✓ E.g., ELCC for new solar is 11%, compared to 47% for existing solar |
| Send appropriate signals to reward project performance | ✓ Project ELCCs are calculated based on actual production data |
| Allocate ELCC to specific resources in an equitable manner | ✓ ELCC values for existing projects are protected from degradation due to vintaging of future projects<br>✓ Existing projects grouped with 2018 Vintage to reflect expectations at time of contracting |
| Process should be tractable and computationally manageable | ✓ ELCC calculations are needed only for the Portfolio and Resource Class (three values per Vintage per month)<br>✓ Could be calculated with RECAP or SERVM |

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# APPENDIX

# Definitions

- Portfolio ELCC is the true contribution to system reliability; Project ELCCs must sum to this value
- Since the RA program calculates capacity values by month, our ELCC calculations are also by month
- Using two resource classes strikes an appropriate balance between accuracy (capturing interactive effects) and simplicity (keeping the process computationally manageable)
- Individual Project ELCCs are also calculated

| Term | Explanation |
|---|---|
| Portfolio ELCC | The combined ELCC of the portfolio taking into account all renewables on the system. This is the true contribution to system reliability. |
| Resource Class ELCC | The ELCC that is attributed to a Resource Class. The Calpine/E3 proposal uses two Resource Classes: Wind and Solar. |
| Project ELCC | The ELCC value that is attributed to a specific renewable project. |
| Vintage | The set of projects that come online in a given calendar year. The 2018 Vintage includes all projects that came online in 2018 or before. |

# We propose a three-step ELCC allocation methodology

## Part I: Existing Resources

+ **Step 1: Calculate Portfolio ELCC by month**
    - Determine monthly Portfolio ELCC (accounts for all wind/solar online)
+ **Step 2: Calculate Resource Class ELCC**
    - Determine additional monthly ELCC added by each Resource Class (wind and solar), starting from no other resources online
    - Calculate the diversity benefit, which is the difference between the sum of individual Resource Classes (wind and solar) and Portfolio ELCCs
    - Allocate the diversity benefit based on the share of wind versus solar in each month
    - Add this proportional diversity benefit to the wind alone/solar alone ELCC to yield monthly Resource Class ELCC
+ **Step 3: Calculate Project ELCC**
    - Determine how much each individual resource contributes to overall generation for that Resource Class during peak load hours per month
    - Assign individual resource this proportion of Resource Class ELCC to obtain monthly ELCC value by individual resource (Project ELCC)

## Part II: New Resources

- Apply identical methodology, except base allocation off of marginal ELCC from new installations only

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# STEP 1: CALCULATE PORTFOLIO ELCC

# Step 1: Portfolio ELCC

## + Calculate monthly ELCCs for the whole portfolio

- The Portfolio ELCC is the value that maintains system reliability. In the next steps this Portfolio ELCC is allocated to Resource Classes first, and then to individual Projects.
- BTM is included in the total solar nameplate capacity, as there are interactive effects with other wind and solar resources. The treatment of BTM Solar will be addressed later in this presentation.

**Installations (MW)**

| | Wind | Solar |
|---|---|---|
| Nameplate Capacity (MW) | 5,592 | 15,406 |

| Month | Portfolio ELCC (MW) |
|---|---|
| Jan | 852 |
| Feb | 1,190 |
| Mar | 1,583 |
| Apr | 6,237 |
| May | 7,079 |
| Jun | 8,326 |
| Jul | 8,420 |
| Aug | 7,367 |
| Sep | 6,150 |
| Oct | 4,764 |
| Nov | 972 |
| Dec | 786 |

# Calculating Monthly ELCCs

- **The target LOLE of 2.4 is divided evenly among the 12 months of the year, so that each month's LOLE is 0.2 (or 2 hours in 10 years)**
  - Simple approach that yields reasonable ELCC values
- **Monthly load and generation resources are scaled until target reliability level is achieved**
- **This allows for determining Portfolio ELCC in that specific month**

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# STEP 2: CALCULATE RESOURCE CLASS ELCC

# Resource Class ELCC

## + Calculate ELCC for wind alone (zero solar), and solar alone (zero wind)

- Using two resource classes balances simplicity with accuracy:
  - Captures overall diversity and saturation effects
  - Solar/wind projects are similar enough that they can be grouped together
- Calculation is done using the same framework as portfolio ELCC
- Calculating resource alone will not capture diversity benefits. These will be added in the next step (next slide)

**Installations (MW)**

| Case | Total Wind | Total Solar |
|---|---|---|
| Portfolio ELCC | 5,592 | 15,406 |
| Wind Alone | 5,592 | 0 |
| Solar Alone | 0 | 15,406 |

| Month | ELCC, Wind Alone (MW) | ELCC, Solar Alone (MW) | Portfolio ELCC (MW) |
|---|---|---|---|
| | [1] | [2] | [3] |
| Jan | 853 | -2 | 852 |
| Feb | 975 | 159 | 1,190 |
| Mar | 438 | 747 | 1,583 |
| Apr | 781 | 4,436 | 6,237 |
| May | 1,026 | 4,690 | 7,079 |
| Jun | 1,160 | 5,773 | 8,326 |
| Jul | 960 | 5,677 | 8,420 |
| Aug | 632 | 5,153 | 7,367 |
| Sep | 438 | 4,758 | 6,150 |
| Oct | 476 | 3,706 | 4,764 |
| Nov | 446 | 436 | 972 |
| Dec | 781 | 2 | 786 |

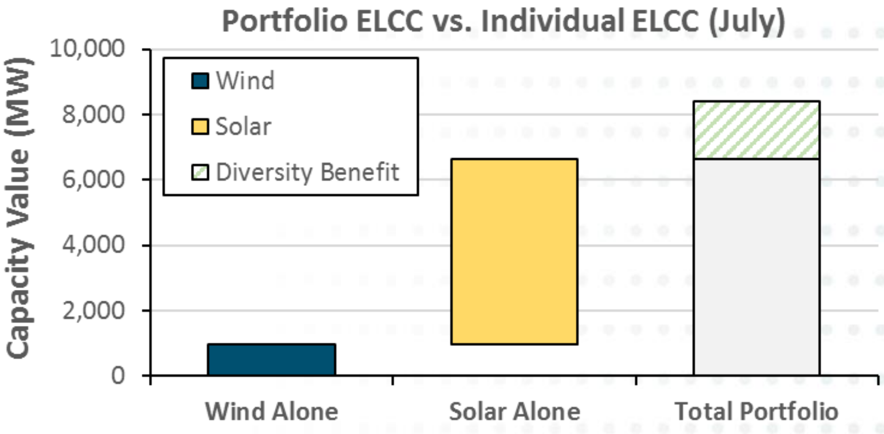
# Calculate Diversity Benefit

+ **Interactive effects are accounted for via the difference between wind alone plus solar alone and the combined portfolio ELCC**

+ **Diversity benefit is calculated on a monthly basis**

*Outputs from RECAP*

| Month | Wind Alone (MW) [1] | Solar Alone (MW) [2] | Portfolio ELCC (MW) [3] | Diversity Benefit (MW) [4] = [3]–[2]-[1] |
|---|---|---|---|---|
| Jan | 853 | -2 | 852 | 1 |
| Feb | 975 | 159 | 1,190 | 55 |
| Mar | 438 | 747 | 1,583 | 398 |
| Apr | 781 | 4,436 | 6,237 | 1,019 |
| May | 1,026 | 4,690 | 7,079 | 1,363 |
| Jun | 1,160 | 5,773 | 8,326 | 1,394 |
| Jul | 960 | 5,677 | 8,420 | 1,783 |
| Aug | 632 | 5,153 | 7,367 | 1,582 |
| Sep | 438 | 4,758 | 6,150 | 954 |
| Oct | 476 | 3,706 | 4,764 | 581 |
| Nov | 446 | 436 | 972 | 91 |
| Dec | 781 | 2 | 786 | 3 |




*For example, in July the diversity benefit is*
8,420 – 5,677 – 960 = **1,783 MW**

# Allocation to Resource Class

- The diversity benefit is split based on the relative capacity value (MW) of wind/solar alone
- This value is added to the ELCC for wind/solar alone to yield total Resource Class ELCC

*Outputs from RECAP*

| Month | Wind Alone (MW) [1] | Solar Alone (MW) [2] | Portfolio ELCC (MW) [3] | Diversity Benefit (MW) [4] = [3]–[2]-[1] |
|---|---|---|---|---|
| Jan | 853 | -2 | 852 | 1 |
| Feb | 975 | 159 | 1,190 | 55 |
| Mar | 438 | 747 | 1,583 | 398 |
| Apr | 781 | 4,436 | 6,237 | 1,019 |
| May | 1,026 | 4,690 | 7,079 | 1,363 |
| Jun | 1,160 | 5,773 | 8,326 | 1,394 |
| Jul | 960 | 5,677 | 8,420 | 1,783 |
| Aug | 632 | 5,153 | 7,367 | 1,582 |
| Sep | 438 | 4,758 | 6,150 | 954 |
| Oct | 476 | 3,706 | 4,764 | 581 |
| Nov | 446 | 436 | 972 | 91 |
| Dec | 781 | 2 | 786 | 3 |

$$\left(\frac{5{,}677}{5{,}677 + 960}\right) \times 1{,}783 + 5{,}677 = 7{,}201 \text{ MW}$$

**Solar ELCC**
**7,201 MW**
**47%** of nameplate solar capacity

$$\left(\frac{960}{5{,}677 + 960}\right) \times 1{,}783 + 960 = 1{,}218 \text{ MW}$$

**Wind ELCC**
**1,218 MW**
**22%** of nameplate wind capacity

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# STEP 3: CALCULATE PROJECT ELCC

# Project ELCC Allocation Methodology

- **We propose a heuristic approach for Project ELCCs**
  - Calculating monthly ELCCs for hundreds of individual projects would be overly time-consuming and complex
  - Heuristic approach is reasonable for allocating ELCC values among similar resources
- **Individual Project ELCC is assigned a fraction of total Resource Class ELCC based on a time-window approach**
  - We propose to use historic production data for calculating Project ELCCs
    - Summer: Average production during HE14-HE21
    - Winter: Average production during HE17-HE21
  - This maintains the incentive for performance during important hours

# Example Calculation

Illustrative example for the month of July:

Individual ELCCs sum up to equal the total July solar ELCC of 7,201 MW.

Individual ELCCs sum up to equal the total July wind ELCC of 1,218 MW.

**Solar ELCC**

| Project | Nameplate Capacity (MW) | Output during peak period (MWh) | % of total solar output in July | Project ELCC - July (MW) | Project ELCC - July (% of Nameplate) |
|---|---|---|---|---|---|
| 1 | 17 | 4,874 | 0.12% | 9 | 53% |
| 2 | 45 | 10,769 | 0.27% | 20 | 44% |
| 3 | 50 | 11,160 | 0.28% | 20 | 41% |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 389 | 4 | 911 | 0.02% | 2 | 42% |
| Totals | **15,406** | 3,921,739 | 100% | 7,201 | **47%** |

**Wind ELCC**

| Project | Nameplate Capacity (MW) | Output during peak period (MWh) | % of total wind output in July | Project ELCC - July (MW) | Project ELCC - July (% of Nameplate) |
|---|---|---|---|---|---|
| 1 | 24 | 1,684 | 0.54% | 7 | 28% |
| 2 | 13 | 671 | 0.22% | 3 | 21% |
| 3 | 59 | 3,339 | 1.07% | 13 | 22% |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 128 | 46 | 3,044 | 0.98% | 12 | 26% |
| Totals | **5,592** | 310,723 | 100% | 1,218 | 22% |

This is the total solar generation during all the peak hours in July

The % of total solar output is also the proportion of solar ELCC that gets allocated to this particular generator

# Behind-the-meter solar treated just like other solar resources

+ **Behind the meter solar is allocated a Project ELCC using the same methodology as any other solar resource**
  - This is important to capture interactive effects among BTM solar, utility-scale solar and wind
+ **Each LSE is allocated one aggregate BTM Project ELCC for BTM PV in its service area**

**Solar ELCC**

| Project | Type | Nameplate Capacity (MW) | Output during peak period (MWh) | % of total solar output in July | Project ELCC - July (MW) | Project ELCC - July (% of Nameplate) |
|---|---|---|---|---|---|---|
| 1 | Tracking | 17 | 4,874 | 0.12% | 9 | 53% |
| 2 | Fixed Tilt | 45 | 10,769 | 0.27% | 20 | 44% |
| 3 | Fixed Tilt | 50 | 11,160 | 0.28% | 20 | 41% |
| ⋮ | | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 51 | BTM, PG&E | 2,378 | 462,691 | 11.80% | 850 | 36% |
| 52 | BTM, SDG&E | 674 | 131,181 | 3.34% | 241 | 36% |
| 53 | BTM, SCE | 2,020 | 393,104 | 10.02% | 722 | 36% |
| ⋮ | | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| ⋮ | | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 389 | Fixed Tilt | 2 | 911 | 0.02% | 2 | 42% |
| Totals | | **15,406** | 3,921,739 | 100.00% | 7201 | **47%** |

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# PART II: NEW RESOURCES

# In future years, separate ELCCs are calculated for each Vintage

+ **All resources that come online in a given year are treated as part of the same Vintage**
+ **Each year the Portfolio ELCC for each Vintage is calculated as follows:**
  1. Calculate Portfolio ELCC for Initial 2018 Vintage (all resources online in 2018)
  2. Calculate Portfolio ELCC for 2019 Vintage as the 2019 Portfolio ELCC minus the 2018 Portfolio ELCC
  3. Calculate Portfolio ELCC for 2020 Vintage as the 2020 Portfolio ELCC minus the 2019 Portfolio ELCC
  4. Etc.
+ **This is important to send the correct economic signal for future procurement**
  - It also protects the ELCC values of existing projects from degrading due to new procurement

# 2019 New Resources

- ELCC allocation for 2019 resources looks at 2019 installations only, *starting from the 2018 portfolio (i.e. it looks at the marginal ELCC for 2019 resources)*. The methodology is otherwise the same.
- In this example, we assume 500 MW of new wind, 1000 MW of utility-solar, and 1000 MW of BTM Solar.

**2018 Existing Resources**

| | Wind (MW) | Solar (MW) | Combined (MW) |
|---|---|---|---|
| Cumulative Installations | 5,592 | 15,406 | 20,998 |

In the 2018 case, ELCC is calculated relative to these values

**2019 New Resources**

| | Wind (MW) | Solar (MW) | Combined (MW) |
|---|---|---|---|
| 2018 Cumulative Installations | 5,592 | 15,406 | 20,998 |
| 2019 Cumulative Installations | 6,092 | 17,406 | 23,498 |
| 2019 Incremental Installations | 500 | 2,000 | 2,500 |

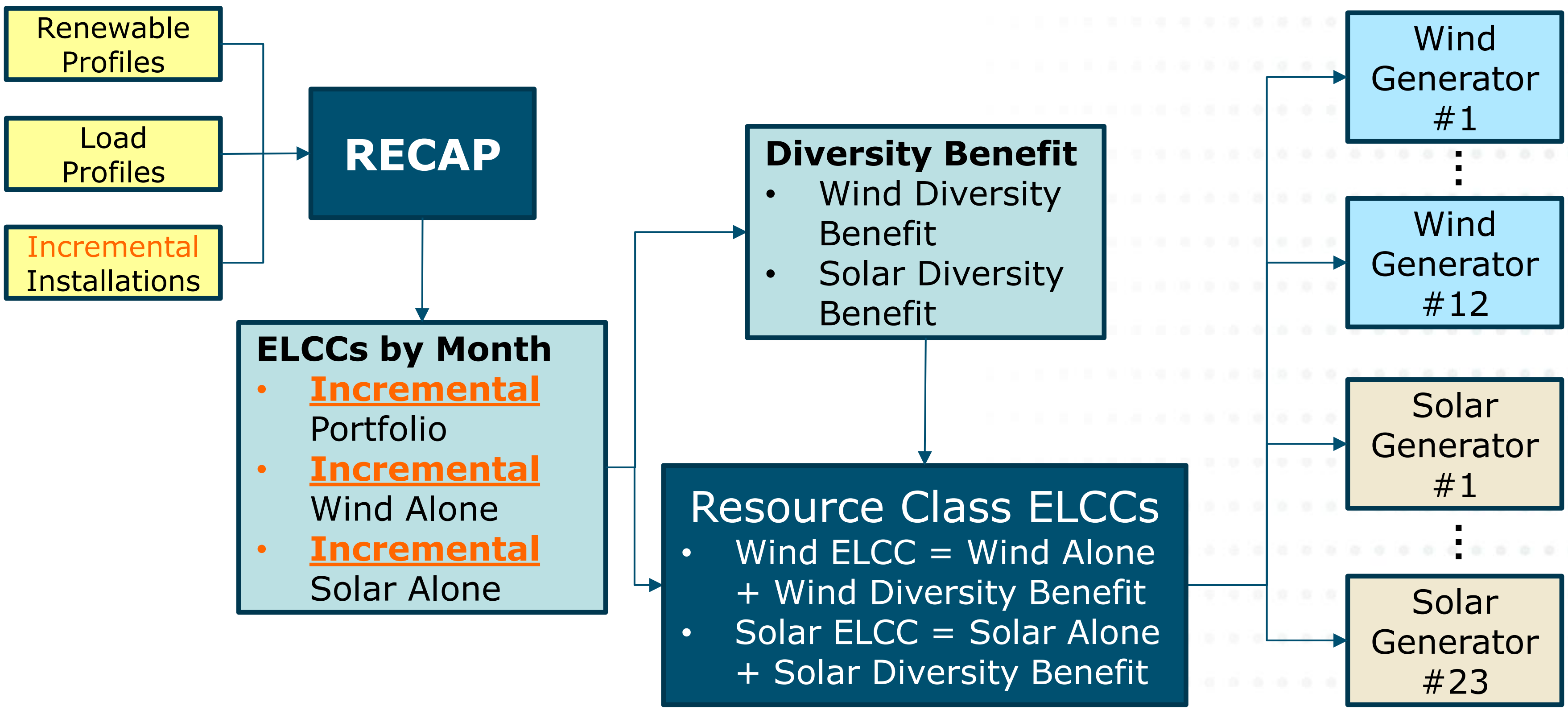
In the 2019 case, ELCC is calculated relative to these values (marginal to the existing 2018 portfolio)

# Methodology for New Resources

**Step 1:**
**Portfolio ELCC**

**Step 2:**
**Resource Class ELCC**

**Step 3:**
**Individual Allocation**



# Step 1: 2019 Portfolio ELCC

## + Calculate monthly ELCCs for the *marginal* portfolio

- Marginal portfolio includes all resources that come online in 2019
- The Portfolio ELCC is the value that maintains system reliability. In the next steps this Portfolio ELCC is allocated to Resource Classes first, and then to individual Projects.

**Installations (MW)**

| | Wind | Solar |
|---|---|---|
| Nameplate Capacity (MW) | 500 | 2,000 |

Marginal ELCC (as compared to 2018 portfolio)

| Month | Portfolio ELCC (MW) |
|---|---|
| Jan | 51 |
| Feb | 62 |
| Mar | 40 |
| Apr | 237 |
| May | 258 |
| Jun | 400 |
| Jul | 436 |
| Aug | 328 |
| Sep | 246 |
| Oct | 174 |
| Nov | 29 |
| Dec | 46 |

# Step 2: 2019 Resource Class ELCC

## + Calculate ELCC for incremental wind alone, and incremental solar alone

- Using two resource classes balances simplicity with accuracy:
  - Capture overall diversity and saturation effects
  - Solar/wind projects are similar enough that they can be grouped together
- Calculation is done using the same framework as portfolio ELCC
- Calculating resource alone will not capture diversity benefits. These will be added in the next step (next slide)

**Installations (MW)**

| Case | Total New Wind | Total New Solar |
|---|---|---|
| Portfolio ELCC | 500 | 2,000 |
| Incremental Wind Alone | 500 | 0 |
| Incremental Solar Alone | 0 | 2,000 |

| Month | ELCC, Wind Alone (MW) | ELCC, Solar Alone (MW) | Portfolio ELCC (MW) |
|---|---|---|---|
| | [1] | [2] | [3] |
| Jan | 50 | 0 | 51 |
| Feb | 47 | 15 | 62 |
| Mar | 38 | 3 | 40 |
| Apr | 133 | 101 | 237 |
| May | 159 | 97 | 258 |
| Jun | 193 | 200 | 400 |
| Jul | 223 | 209 | 436 |
| Aug | 167 | 157 | 328 |
| Sep | 104 | 138 | 246 |
| Oct | 83 | 91 | 174 |
| Nov | 29 | 0 | 29 |
| Dec | 45 | 0 | 46 |

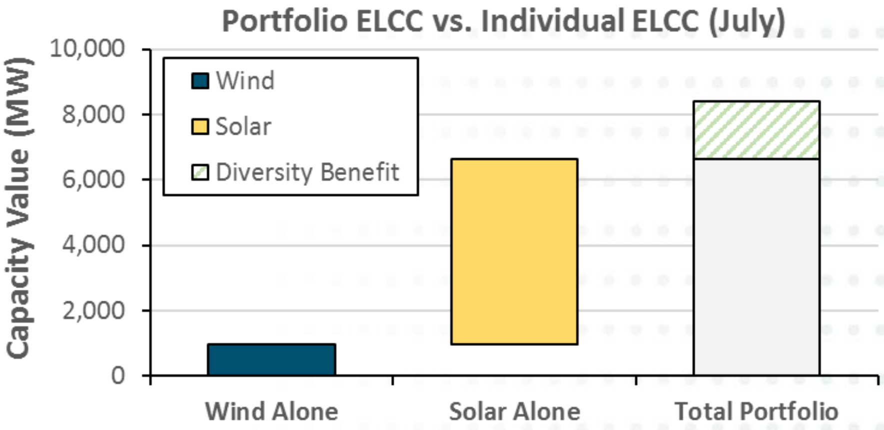
# Calculate 2019 Diversity Benefit

+ **Interactive effects are accounted for via the difference between wind alone plus solar alone and the combined portfolio ELCC**

+ **Diversity benefit is calculated on a monthly basis**

*Outputs from RECAP*

| Month | Wind Alone (MW) [1] | Solar Alone (MW) [2] | Portfolio ELCC (MW) [3] | Diversity Benefit (MW) [4] = [3]–[2]-[1] |
|---|---|---|---|---|
| Jan | 50 | 0 | 51 | 1 |
| Feb | 47 | 15 | 62 | 1 |
| Mar | 38 | 3 | 40 | 0 |
| Apr | 133 | 101 | 237 | 3 |
| May | 159 | 97 | 258 | 2 |
| Jun | 193 | 200 | 400 | 7 |
| Jul | 223 | 209 | 436 | 4 |
| Aug | 167 | 157 | 328 | 4 |
| Sep | 104 | 138 | 246 | 3 |
| Oct | 83 | 91 | 174 | 0 |
| Nov | 29 | 0 | 29 | 0 |
| Dec | 45 | 0 | 46 | 1 |




*For example, in July the diversity benefit is*
436 – 209 – 223 = **4 MW**

# 2019 Allocation to Resource Class

- **The diversity benefit is split based on the relative capacity value (MW) of wind/solar alone**
- **This value is added to the ELCC for wind/solar alone to yield total Resource Class ELCC**

*Outputs from RECAP*

| Month | Wind Alone (MW) [1] | Solar Alone (MW) [2] | Portfolio ELCC (MW) [3] | Diversity Benefit (MW) [4] = [3]–[2]-[1] |
|---|---|---|---|---|
| Jan | 50 | 0 | 51 | 1 |
| Feb | 47 | 15 | 62 | 1 |
| Mar | 38 | 3 | 40 | 0 |
| Apr | 133 | 101 | 237 | 3 |
| May | 159 | 97 | 258 | 2 |
| Jun | 193 | 200 | 400 | 7 |
| Jul | 223 | 209 | 436 | 4 |
| Aug | 167 | 157 | 328 | 4 |
| Sep | 104 | 138 | 246 | 3 |
| Oct | 83 | 91 | 174 | 0 |
| Nov | 29 | 0 | 29 | 0 |
| Dec | 45 | 0 | 46 | 1 |

$$\left(\frac{209}{209 + 223}\right) \times 4 + 209 =$$

**Solar ELCC**
**211 MW**

**11%** of incremental nameplate solar

$$\left(\frac{223}{209 + 223}\right) \times 4 + 223 =$$

**Wind ELCC**
**225 MW**

**45%** of incremental nameplate wind

# Step 3: 2019 Project ELCC

Illustrative example for the month of July:

Individual ELCCs sum up to equal the total July solar ELCC of 211 MW.

Individual ELCCs sum up to equal the total July wind ELCC of 225 MW.

## Solar ELCC

| Project | Nameplate Capacity (MW) | Output during peak period | % of total solar output in July | Project ELCC - July (MW) | Project ELCC - July (% of Nameplate) |
|---|---|---|---|---|---|
| 1 | 28 | 8,377 | 1.71% | 4 | 13% |
| 2 | 43 | 12,135 | 2.47% | 5 | 12% |
| 3 | 15 | 5,469 | 1.11% | 2 | 15% |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| Totals | **2,000** | **491,141** | **100%** | **211** | **11%** |

## Wind ELCC

| Project | Nameplate Capacity (MW) | Output during peak period | % of total wind output in July | Project ELCC - July (MW) | Project ELCC - July (% of Nameplate) |
|---|---|---|---|---|---|
| 1 | 39 | 3,882 | 5.88% | 13 | 34% |
| 2 | 46 | 6,859 | 10.38% | 23 | 50% |
| 3 | 42 | 5,778 | 8.74% | 20 | 47% |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| Totals | **500** | **66,078** | **100%** | **225** | **45%** |

This is the total solar generation during all the peak hours in July

The % of total solar output is also the proportion of solar ELCC that gets allocated to this particular generator

# 2019 BTM Solar Treatment

- **Behind the meter solar is allocated a Project ELCC using the same methodology as any other solar resource**
  - This is important to capture interactive effects among BTM solar, utility-scale solar and wind
- **Each LSE is allocated one aggregate BTM Project ELCC for BTM PV in its service area**

**Solar ELCC**

| Project | Type | Nameplate Capacity (MW) | Output during peak period (MWh) | % of total solar output in July | Project ELCC - July (MW) | Project ELCC - July (% of Nameplate) |
|---|---|---|---|---|---|---|
| 1 | Fixed Tilt | 28 | 8,377 | 1.71% | 4 | 13% |
| 2 | Fixed Tilt | 43 | 12,135 | 2.47% | 5 | 12% |
| 3 | Tracking | 15 | 5,469 | 1.11% | 2 | 15% |
| ⋮ | | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 51 | BTM, PG&E | 407 | 79,246 | 16.14% | 34 | 8% |
| 52 | BTM, SDG&E | 134 | 26,070 | 5.31% | 11 | 8% |
| 53 | BTM, SCE | 459 | 89,277 | 18.18% | 38 | 8% |
| ⋮ | | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| ⋮ | | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| Totals | | **2,000** | **491,141** | **100%** | **211** | 11% |

# E3 used its RECAP Model to perform ELCC calculations

+ **E3's Renewable Energy Capacity Planning (RECAP) Model is a publicly-available reliability planning model that calculates Loss-of-Load Probability (LOLP) and ELCC**
+ **RECAP has been used in a number of CPUC proceedings**
  - Formally adopted for calculating the capacity contribution of energy efficiency and demand response programs*
  - Also used in the RPS Calculator, LTPP, Net Energy Metering cost shift evaluation, CSI cost-effectiveness assessment
+ **RECAP used for demonstration purposes in this investigation; actual ELCC calculations could be performed using RECAP, SERVM or another model**

* http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M163/K338/163338441.docx

# Exceedance NQC methods are increasingly inaccurate

- Current exceedance approach did a relatively good job at capturing the most important hours when there was a low penetration of renewable energy
- At high penetrations of renewables, solar has shifted the peak to later in the day and later in the year, and current approach no longer does a good job at capturing the most important hours

## Gross Load LOLP

i.e. LOLP Pre-Renewables

NQC Hours

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 7.04E-13 | 0 | 3.74E-12 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | [illegible] | [illegible] | [illegible] | 4.75E-09 | 1.18E-08 | 2.64E-08 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | [illegible] | [illegible] | [illegible] | 1.31E-06 | 5.76E-06 | 7.77E-06 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 2.99E-09 | 8.01E-05 | 0.00014 | 7.25E-05 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 2.26E-08 | 0.0003 | 0.00052 | 0.00025 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 1.45E-07 | 0.00039 | 0.00092 | 0.00045 | 1.87E-10 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 | 0 | 1.05E-07 | 0.00017 | 0.00038 | 0.00021 | 7.61E-10 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 | 0 | 1.43E-09 | 1.00E-05 | 1.29E-05 | 1.19E-05 | 3.73E-12 | 0 | 0 |
| 18 | 0 | 0 | 0 | 0 | 0 | 3.53E-15 | 2.24E-07 | 2.67E-08 | 5.27E-08 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 5.99E-10 | 8.44E-09 | 8.17E-10 | 0 | 0 | 0 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 8.42E-10 | 1.31E-12 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## Net Load LOLP

i.e. LOLP With Renewables (2018)

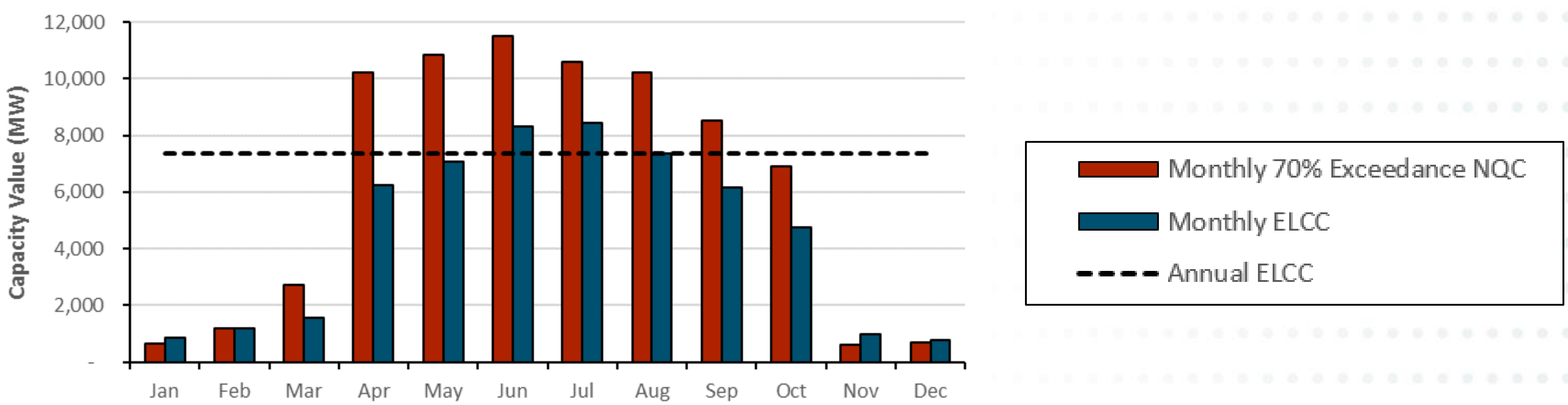
NQC Hours

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00E+00 | 0 | 2.51E-16 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | [illegible] | [illegible] | [illegible] | 0.00E+00 | 0.00E+00 | 6.88E-15 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | [illegible] | [illegible] | 0 | 5.35E-16 | 0.00E+00 | 3.05E-13 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 6.53E-17 | 2.36E-13 | 9.4E-13 | 1.42E-12 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 2.19E-13 | 7.1E-11 | 1E-10 | 2.5E-10 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 1.51E-11 | 1.3E-08 | 4.3E-08 | 8.7E-08 | 2.11E-12 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 | 0 | 2.16E-10 | 3.4E-07 | 2.8E-06 | 1.1E-05 | 3.75E-09 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 | 5.7E-17 | 6.12E-10 | 2.88E-06 | 2.56E-05 | 2.81E-04 | 9.04E-07 | 0 | 0 |
| 18 | 0 | 0 | 0 | 0 | 1.3E-15 | 2.94E-09 | 1.71E-05 | 1.35E-04 | 1.74E-03 | 3.8E-06 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 | 0 | 1.5E-09 | 1.38E-05 | 5.71E-04 | 5.96E-04 | 9.6E-07 | 0 | 0 |
| 20 | 0 | 0 | 0 | 0 | 0 | 1.5E-09 | 2.04E-05 | 2.53E-05 | 2.6E-05 | 3.8E-10 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 2.3E-09 | 3.4E-09 | 4.7E-09 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*All NQC hours shown in standard time (PST)*
*Tables show results for annual ELCC*

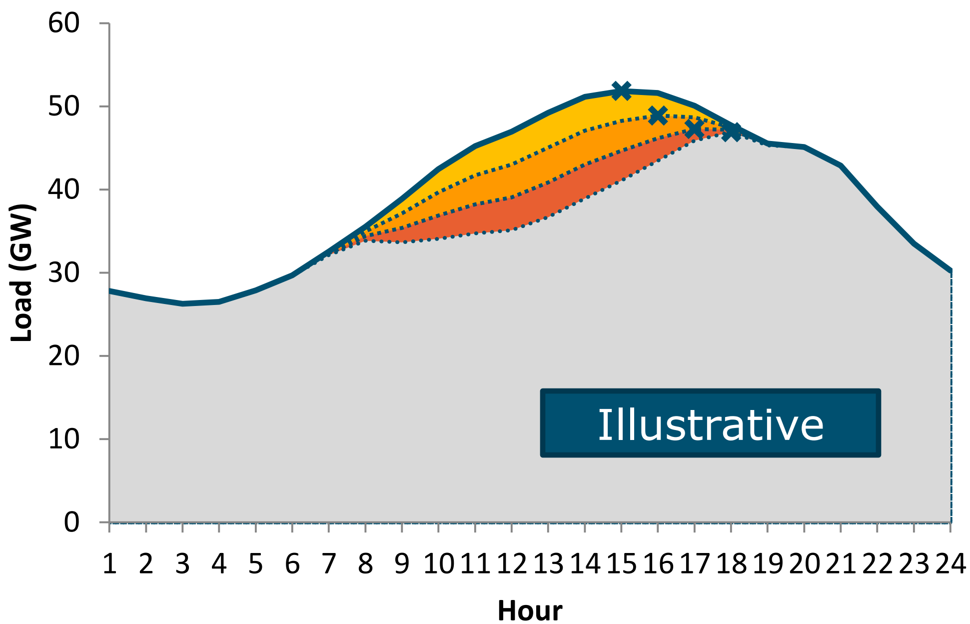
# Exceedance methodology overvalues the renewable portfolio

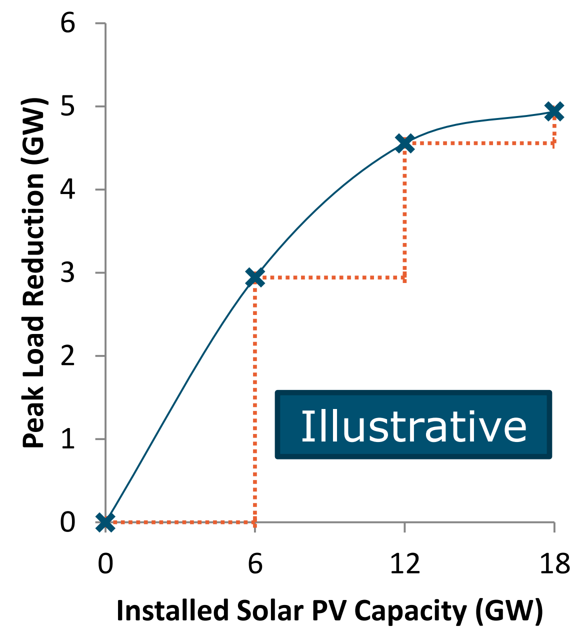
+ **Monthly ELCC values are low in winter and high in summer due to solar coincidence with highest load hours**
+ **Monthly 70% Exceedance NQC is significantly higher than monthly ELCC in the summer**
  - Average NQC based on exceedance in the peak summer months (Jul, Aug, Sep) is **9,786 MW**
  - Average monthly ELCC in the peak summer months (Jul, Aug, Sep) is **7,312 MW**
  - Both numbers include 5,072 MW of BTM PV
+ **Difference is due to diminishing returns as solar shifts the peak to night-time**



# ELCC captures interactive and saturation effects

+ **A resource's contribution towards reliability depends on the other resources on the system**
+ **The diminishing marginal peak load impact of solar PV is illustrative of this concept**
  - 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
  - This reduces the coincidence of the solar profile and the net peak such that **additional solar resources have a smaller impact on the net peak**

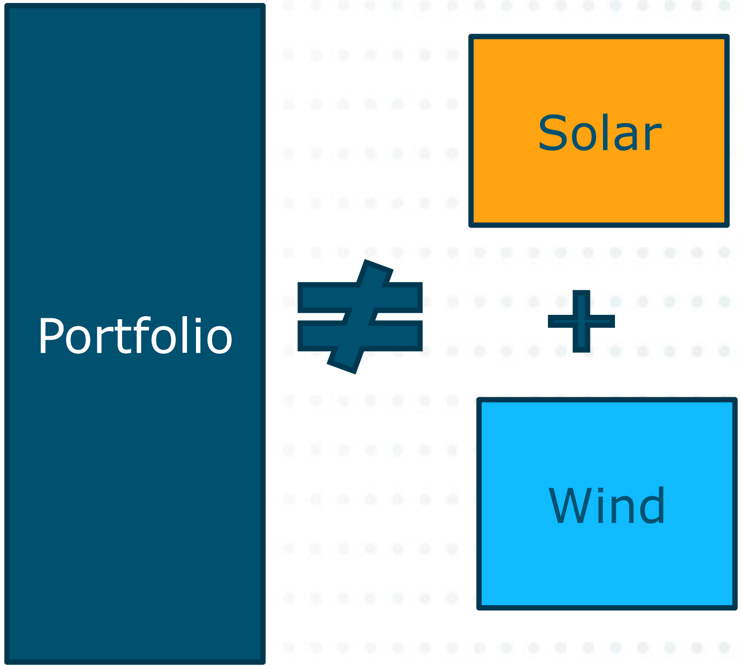


# Calculating ELCCs for specific projects requires both "art" and "science"

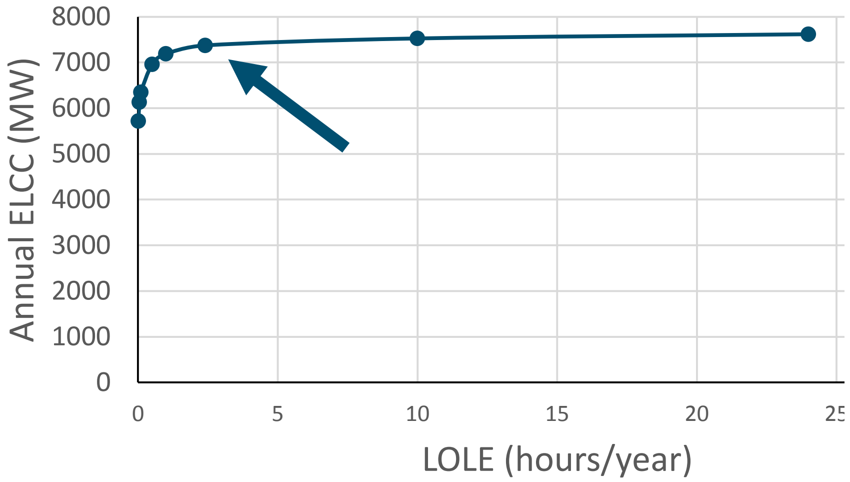
+ **Science:** LOLP modeling can accurately measure the capacity value contribution of the entire renewable portfolio

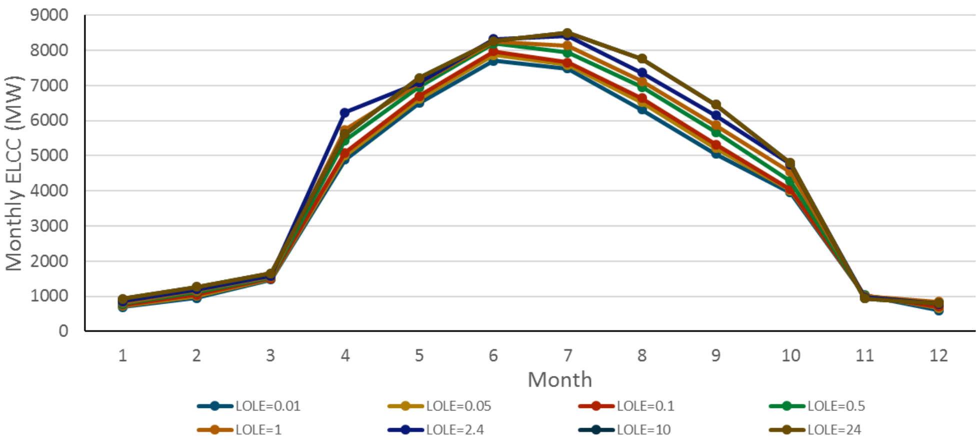
+ **Art:** There is no 'correct' method to allocate the portfolio capacity value to all of the individual resources
  - Summing the individual capacity contribution of resources will not equal the portfolio capacity value because it does not capture **interactive effects**
  - However, there are several reasonable methods to allocate portfolio capacity value



# Target or "baseline" LOLE has a small effect on ELCC values

- **As LOLE increases, relatively more daytime hours will matter for the determination of ELCC, slightly increasing the capacity value of solar**
  - Portfolio ELCC is sensitive to changes in LOLE at low values, but relatively inelastic at higher values.
- **We choose an LOLE of 2.4 hours per year (24 hours in 10 years) as our definition of 1 day per 10 years**
  - For simplicity, we propose a flat allocation to months (2.4 hrs./10 yrs.)



Energy+Environmental Economics

# Thank You!

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