# **Flexibility Metrics and Standards Project**

- a California Energy Systems for the 21st Century (CES-21) Project

CPUC Workshop August 15, 2017

Project Team: Astrape Consulting, EPRI, LLNL, PG&E and SDG&E Advisory Group: CAISO, CEC, CPUC, ORA, SCE, and TURN

# Agenda

- 1. Project Objective
- 2. Framework and Study Cases
- 3. Results and Recommendations
- 4. Closing Thoughts

### **Project Objective – Key Questions**

- Did the range of projected CAISO system scenarios have sufficient capacity and operating flexibility to meet the 1 day in 10 years **reliability standard** in 2026?
- How did operating flexibility, or the lack of it, **impact costs and emissions** (i.e., system operations)? And what are the main drivers?
- Do we need to create new planning standards to maintain operational flexibility, if so, what would those standards be? (one example of planning metric/standard is Planning Reserve Margin as a % of peak load)

### In Scope

Examine whether planning standards need to be updated to explicitly include operating flexibility by studying the CAISO system under some pre-defined future scenarios

### Out of Scope

Develop optimal solution to meet reliability, operating flexibility (and cost) goals for a generic electric system

## Data: CAISO, WECC, and Uncertainties

- Updated **CAISO** modeling using 2016 LTPP assumptions
- Completed detailed modeling of **WECC** using TEPPC 2026 Common Case assumptions
- Modeled Uncertainties:
  - 33 weather years (correlated profiles for load / wind / solar)
  - 5 economic load growth uncertainty levels
  - 25 (or more) resource outage draws
  - Forecast errors for load / wind / solar (intra-day and intra-hour)

CES-21 project created a comprehensive, detailed representation of the projected 2026 planning year

### **Reliability Metrics: Existing and Additional**



CES-21 project created additional reliability metrics to explicitly detect a system's deficiencies in flexibility

### **CES-21 Scenarios: List of Study Cases**

Case #	Type of Case	RPS % by	Load Following	System Pmin	Interchange 3-	Net Exports
		2026			Hr Ramp	Limit
BC_01		33%	5% of Load			
BC_02	PRM Base Cases <sup>1</sup>	43%	7% of Load	Base Case	Unlimited	2,000 MW
BC_03		50%	9% of Load			
SC_01	CES-21 Reference Study Case <sup>2</sup>	50%	9% of Load	Base Case	Unlimited	2,000 MW
SC_02	Land Fallowing (0/		5%			
SC_03	Load Following (70		7%			
SC_04	or Load)		11%			
SC_05	Lord Following		95th Percentile			
SC_06	$(WSL Observed)^3$		99th Percentile			
SC_07	(WSL Observed)		100th Percentile			
SC_08				High Flex (-4,000)		
SC_09	System Pmin(+/-			(-2,000)		
SC_10	$MW)^4$			(+2,000)		
SC_11				Low Flex (+4,000)		
SC_12	Interchange 3-Hour				3,000 MW	
SC_13	Ramp Limit <sup>5</sup>				6,000 MW	
SC_14	Ramp Lanne				9,000 MW	
SC_15						3,500 MW
SC_16	Net Exports					5,000 MW
SC_17						8,000 MW

1. PRM Base Cases are designed at various RPS %, then adding or subtracting conventional resources to achieve LOLE of 1 event in 10 years

2. The CES-21 Study Case is designed to have 50% RPS and 1xAAEE, then adding 600 MW of AAEE to achieve LOLE of 1 event ini 10 years;

3. This load Following requirement is set based on observed net load - load minus wind & solar - volatility in the previous 60 days ("WSL Observed")

4. Maximum amount of interchange ramping (in either direction) within 3 hours

5. Adjust the aggregate Pmin level for conventional resources (e.g., ~16,000 MW of installed capacity and ~7,000 MW of aggregated Pmin for case SC\_01)

# Analytical Framework & Modeling Tool: Holistic Design

Inputs	Model	Results		
Load and Resource Assumptions	Strategic Energy Risk Valuation Model (SERVM)	System Performance		
(e.g., CAISO system with 50% RPS in 2026; TEPPC case for WECC)	(A hybrid resource adequacy and production cost model)	Reliability (capacity / flexibility) Cost Environmental Impact		
Uncertainties considered:	Modeling parameters:	Results included:		
<ul> <li>33 weather years (correlated profiles for load / wind / solar)</li> <li>5 economic load growth uncertainty levels</li> <li>25 (or more) resource outage draws</li> <li>Forecast errors for load / wind / solar (intra-day and intra-hour)</li> </ul>	<ul> <li># of simulations: 33 * 5 * 25 * 20 = 82,500 full years (8,760 hours each at 5 minute intervals) of system operation</li> <li>20 cases (operating policies/scenarios)</li> <li>Loss of Load (LOL) defined as operating reserves (including regulations) drop below 4.5% of load</li> <li>Load Following Reserves set to address intra-hour ramping needs</li> </ul>	<ul> <li>LOLE due to lack of capacity</li> <li>LOLE due to lack of flexibility Unserved Energy</li> <li>Production costs</li> <li>CO2 emissions</li> <li>RPS curtailment</li> <li>InFLEXion analysis (based on SERVM commitment/dispatch)</li> </ul>		

LLNL's High Performance Computing Platform



CES-21 project created a unique framework to assess holistic system impacts across a wide range of uncertainties & scenarios

### **PRM Cases – RPS Portfolios**

Resource Type (Name Plate MW)	33% RPS	43% RPS	50% RPS
Aggregated GHG Free Portfolio	38,888	50,000	54,289
Solar (IFM + BTMPV) <sup>1</sup>	13 <b>,</b> 075	23 <mark>,</mark> 897	27,495
Wind	6,027	<mark>6,31</mark> 7	7,008
Other Renewables	4,522	4,522	4,522
Energy Efficiency (EE) <sup>2</sup>	4,491	4,491	4,491
Energy Storage	1,350	1,350	1,350
Demand Response	1,559	1,559	1,559
Hydro and PSH <sup>3</sup>	7,863	7,863	7,863
Conventional			
Fossil Resources (CAISO)	26,740	26,740	26,740
Imports	11,665	11,665	11,665

1. In front of the meter and behind the meter PV;

2. EE values are based on IEPR Mid Base - Mid AAEE forecast (e.g., 1xAAEE)

3. Pumped Storage Hydro

M Cas

# PRM Cases – ELCC Captures Changes in Reliability Contribution

Average Effective Load Carrying Capability (ELCC) at Various RPS %

Levels



For certain resources, ELCC changed noticeably across different system portfolios

# PRM Cases – PRM metric still useful if resources are counted by their reliability contribution

Line	PRM Calculation	33% RPS	43.3% RPS	50% RPS
	Demand			
1	Peak Gross Consumption (MW)	54,727	54,727	54,727
	Supply			
2	Aggregated GHG Free Portfolio <sup>1</sup> (MW)	24,025	24,662	25,123
3	Fossil Resources (MW)	26,740	26,740	26,740
4	Imports (MW)	11,665	11,665	11,665
	Deficiency / (Surplus) to reach LOLE			
	standard			
5	Generic Resource Additions (MW)	1,348	730	393
6	Total Supply to reach LOLE standard	63,778	63,797	63,921
	PRM to satisfy LOLE standard (%)	116.5%	116.6%	116.8%

1. Measured in ELCC, including all supply and demand side (e.g., EE, BTMPV) resources

#### Notes and Caveats:

- The calculation of PRM is tied to a specific reliability standard, in this case LOLE = 1 in 10 years
- PRM values are derived based upon specific counting methods, in this case all resources (including demand side resources) are counted by their ELCC values
- One cannot use these PRM values and compare against PRMs derived using different counting methods (e.g., treating demand side resources as load modifiers may result in a higher PRM)

# <u>Recommendation</u>: Measure and count resources by their reliability contributions when using the PRM planning metric

### Load Following Cases





We tested a wide range of required load following reserves

# Direct relationship between the amount of LF reserved vs. LOLE Intra-Hour events

Case #	LF Method	Description	Annual LF	LOLEINTRA-
			Amount (TWh)	HOUR (Events /
				10 Years)
SC_05		95 Pct	6	99.5
SC_06	WSL Observed	99 Pct	8	25.3
SC_07		100 Pct	14	2.4
SC_02		5%	14	0.6
SC_03	% of Gross Load	7%	19	0.1
SC_01		9%	25	0.1
SC_04		11%	31	0.1

**Note:** The interpretation of LOLE<sub>INTRA-HOUR</sub> is an area of open discussion (e.g., should we treat a 5 minute event occurring in spring low load hours the same as loss of load when the system can readily lean on its neighbors for balancing?)

### <u>Recommendation</u>: Maintain sufficient load following capability to secure a desired level of reliability

### System Pmin Cases – Reliability Results



issues explicitly detected by flexibility metrics were small

### System Pmin – Curtailment as a flexibility solution



### System Pmin – Trade-off between flexibility solutions



As a flexibility solution, results show the <u>marginal</u> curtailment benefit of one MW of Pmin is greatest to a highly inflexible system

#### 4. Closing

#### Pmin Cases

### System Pmin – System Cost & Emissions

#### Impact of System Pmin on Costs and Emissions



### Net Export Cases



curtailment and (in this case) expanding the net export limit

### **Interchange 3-Hour Ramp Cases**



Interchange provides a valuable source of flexibility, especially as we add more renewables to our system

# Storage Sensitivities – Capacity Credit



The ELCC values of storage is reduced as more storage is added to the system (i.e., due to flattening of the peak net load)

### Storage Sensitivities – Economic and Curtailment Benefits

Economic Sensitivity Studies <sup>1</sup>	Marginal Economic Benefit (\$/kw-yr per incremental MWh of storage capacity) <sup>2,3</sup>	Marginal Curtailment Benefit (MWh curtailment reduction per incremental MWh storage capability)
0 <b>→</b> 2 HR Storage	24	133
2 <b>→</b> 4 HR Storage	16	103
4 <b>→</b> 6 HR Storage	8	58
6 <b>→</b> 8 HR Storage	2	6

1. Studies constructed by adding 1,000 MW of each duration type to the 50% RPS CES-21 Reference Case

2. Does not include any resource cost

3. Includes CAISO production cost benefits, net purchase cost benefits, and the economic scarcity rent.

For the projected 50% RPS system, the marginal economic and curtailment benefits of additional energy decline past a few hours of storage

### Finding the "right" flexibility solutions



**Resource Characteristics** (cost, capacity)

# <u>Recommendation</u>: Comprehensively evaluate and select the most efficient flexibility solutions

## **Open Questions / Future Work**

- Operational feasibility and costs of more frequent and larger magnitude in curtailment and import / export ramps?
- Assumptions regarding availability of capacity in neighboring systems need to be verified
- Economic parameters of energy limited resources such as DR need to be examined because they impact reliability contribution
- What can we assume for intra-hour diversity benefit amongst renewable resources at higher penetrations?

# <u>Recommendation</u>: Repeat this analysis as system conditions change sufficiently

### Next Steps – Project Close out

- Submit final report
- Allow parties to provide comments
- Offer training course to Commission staff
- Make input data available to parties

4. Closing

- 1. Project objectives and Requirements
- 2. Definitions by LOLE Type
- 3. Model Comparison (From the 2014 Collaborative Review of Planning Models)
- 4. 20 Sensitivity Cases Summary of Results
- 5. InFLEXion Results
- 6. PRM Calculation Treating EE as supply resource vs. load modifier
- 7. Additional results from study cases

# APPENDIX

## **Project Objective and Requirements**

### **PROJECT OBJECTIVE**

Study and recommend, if appropriate, planning metrics and standards that explicitly consider operational flexibility

### **RESOLUTION E-4677 REQUIREMENTS**

### Leverage results from collaborative review of planning model work

### Form a collaborative advisory group

- Meet every six months
- Connect project progress with LTPP/RA flexibility modeling efforts

### Produce results for use in the 2016 LTPP

- Present preliminary results / recommendations in a public workshop using 2014 LTPP assumptions
- Demonstrate recommended metrics / standards in the 2016 LTPP using updated assumptions

# Definitions by LOLE Type



# Model Comparison (From the 2014 Collaborative Review of Planning Models)

Models/Approaches

Scenario(s) Considered

### Simulating Operating Decisions

<b>Deterministic</b>	A single "base case" or "stress"	Assumes perfect foresight,	
(CAISO Deterministic)	scenario at a time	considers operating cost	
<b>Stochastic, statistical</b> (SCE)		Assumes perfect foresight, caps resource outage to 1,000 MW	
Stochastic + uncertainty +	Many scenarios, enables	Considers uncertainty, operating	
recourse	calculation of probability metrics	costs, and ability to adjust	
(REFLEX, SERVM)	(e.g. LOLE)	decisions (recourse)	
Physics-based weather uncertainty + stochastic unit commitment (LLNL)		Considers physics-based weather uncertainty, operating costs, stochastic unit commitment	

### Modeling approaches vary:

- One vs. multiple scenarios at a time
- A range vs. a cap of resource outages
- Various degrees of forecast error and variability
- Recourse

## Summary of Results

Case #	Type of Case	Description	LOLE	LOLE	LOLE	LOLE <sup>1</sup>	Curtailment		Emissions	Total Cost <sup>4</sup>
			CAPACITY	INTRA-HOUR	MULTI-HOUR	TOTAL	2	2		
				(Events /	10 Years)		(GWh) <sup>2</sup>	(%)	(MMT)	(\$ Billion)
BC_01		33%	1.0	0.1	0.0	1.0	242	0.2%	61	7.2
BC_02	PRM Base Cases	43%	1.0	0.1	0.0	1.0	2,652	2.1%	52	6.4
BC_03		50%	1.0	0.1	0.1	1.0	6,129	4.9%	49	6.5
SC_01	Study Case		1.0	0.1	0.1	1.0	6,466	5.2%	48	6.4
SC_02	Las I Dallassia	5%	0.8	0.6	0.0	1.4	5,503	4.4%	47	6.1
SC_03	Load Following	7%	0.9	0.1	0.0	0.9	5,961	4.8%	47	6.3
SC_04	(% of Load)	11%	1.1	0.1	0.0	1.1	7,045	5.6%	49	6.7
SC_05	Load Following	95 Pct	0.9	99.5	13.6	113.0	4,797	3.8%	46	5.9
SC_06	AVEL Observed	99 Pct	0.7	25.3	1.5	27.4	4,987	4.0%	46	6.0
SC_07	(WSL Observed)	100 Pct	0.7	2.4	0.0	3.1	5,624	4.5%	47	6.2
SC_08		(-4,000 MW)	1.0	0.2	0.1	1.2	3,751	3.0%	46	6.0
SC_09	$\mathbf{D}_{\mathrm{max}}(1,1,\mathbf{M}\mathbf{W})$	(-2,000 MW)	1.0	0.1	0.1	1.0	4,802	3.8%	47	6.2
SC_10	Pmin(+/-MW)	(+2,000 MW)	0.9	0.1	0.1	0.9	9,940	8.0%	49	6.7
SC_11		(+4,000 MW)	1.0	0.1	0.0	1.0	15,447	12.4%	51	7.3
SC_12	Interchange 3-	3,000 MW	1.7	0.2	0.1	1.7	8,548	6.8%	49	8.5
SC_13	Hour Ramp	6,000 MW	0.9	0.1	0.0	0.9	6,835	5.5%	48	7.1
SC_14	Limit	9,000 MW	0.9	0.1	0.0	0.9	6,572	5.3%	48	6.7
SC_15		3,500 MW	1.0	0.1	0.0	1.0	5,259	4.2%	48	6.3
SC_16	Net Exports	5,000 MW	1.0	0.1	0.0	1.0	4,553	3.6%	47	6.3
SC_17	*	8,000 MW	1.1	0.1	0.0	1.1	4,113	3.3%	47	6.3

1. Total LOLE represents the number of days with events of any LOLE type, and does not necessarily equal to the summation of LOLEs by type (e.g., two types of LOLE events can occur on a given day and only counted as 1 occurrence under LOLE total); 2. This study did not model additional resources to replace curtailed energy to meet RPS % 3. Percent of annual RPS output; 4. System production cost (includes cost of net imports) + cost of curtailment (assuming \$50 / MWh)

## InFLEXion analysis

- Further analysis of SERVM results using EPRI-developed flexibility tool and metrics
- Examines ramp available in each time period against requirements in different time horizons
- Provide additional insights for specific one-year runs of SERVM (not entire cases)

## Ramping Mileage: daily time series and accumulation

- Absolute ramping from 5-minute data daily (solid) and cumulative (dashed)
- Cumulative mileage percentage at last day (12/31): Net Load/Demand Ratio
  - 33% case: 172.2%; 43% case: 237.3%; 50% case: 259.8%
- Significant increase in ramping for 43% and 50% cases vs 33%



# Periods of Flexibility Deficit

- Frequency of available ramp less than observed ramp different percentiles and horizons
- Shows that <3 hour ramps do not have any ramping issues, but may have a few percent of hours where largest observed 8-hour ramp is greater than available
- Can be fixed with commitment or other operational issues
- Downwards ramping more significant, but main impact is curtailment



# **Expected Unserved Ramping**

- Average expected unserved ramp in the upward is relatively small
  - Recall that the maximum 3-hours upward ramping in the 50% case was  $\sim$ 26000MW



### Detailed PRM Calculation – EE as supply resource

PRM Calculation	33% RPS	43% RPS	50% RPS
Demand			
Gross Consumption (MW)	54,727	54,727	54,727
Supply			
RPS Resources <sup>1</sup>	8,297	8,419	9,158
Fossil Resources	26,740	26,740	26,740
Non Fossil, Non RPS <sup>2</sup>	8,494	8,564	8,696
Imports	11,665	11,665	11,665
Demand Side Resources Modeled as Supply			
BTMPV	1,723	2,295	2,151
Energy Efficiency <sup>3</sup>	4,053	3,844	3,631
Demand Response	1,457	1,539	1,485
Deficiency / (Surplus) to reach LOLE			
standard			
Generic Resource Additions	1,348	730	393
PRM to satisfy LOLE standard (%)	116.5%	116.6%	116.8%

1. Includes Utility solar, wind, geothermal, biomass; 2. Hydro and Others; 3. EE calculation is based on a single profile from the CEC; further study will be helpful as individual EE programs do not have the same load impacts; 4. PRM = Sum (Lines 2 through 9) / Line 1

### Detailed PRM Calculation – EE as load modifier

PRM Calculation	33% RPS	43% RPS	50% RPS
Demand			
Gross Consumption (MW)	54,727	54,727	54,727
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1. Includes Utility solar, wind, geothermal, biomass; 2. Hydro and Others; 3. EE calculation is based on a single profile from the CEC; further study will be helpful as individual EE programs do not have the same load impacts; 4. PRM = Sum (Lines 3 through 9) /(Line 1 - Line 2)

Using a different counting method that treats EE as load modifier, a higher PRM is required to achieve the same LOLE



Results showed larger amount of ramp at the interties under a highly inflexible system, operational feasibility and costs need to be studied

### System Pmin – Interchange as a solution



Average Hourly Net Import Mileage by Month – System Pmin + 4,000 MW (SC\_11)

Results showed larger amount of ramp at the interties – following a clear, consistent diurnal pattern – under a highly inflexible system

## Net Export Cases – Net Export Duration Curves



Results show expanded limit utilized to export excess CAISO supply in some hours, but not others (when neighbors also have over-supply)