



Energy+Environmental Economics

2020 ACC Workshop

Energy, Ancillary Services and Capacity Avoided Costs

5/7/2020

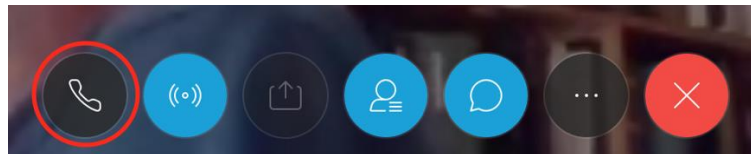
Eric Cutter
Michael Sontag
Sumin Wang



- + Please use the Q&A feature to ask questions.
- + Questions will be answered during the allotted discussion periods after each section.
- + If you have a longer question you would prefer to use your microphone for, you can request to be unmuted by clicking on the button with the phone icon:



- Once you are given speaking permissions, you will need to connect your audio by clicking on the phone icon on the main screen:





+ Introduction

- Comparing 2019 and 2020 Vintage ACC
- Reference System Plan (RSP) and No New DER Case

+ Energy Avoided Cost Results

- Comparing 2019 and 2020 Vintage Energy Prices and Curtailment
- Comparing No New DER and RSP SERVM Results

+ Post-processing SERVM Results

- Post-processing steps for SERVM Prices
- Avoided Energy Prices
- Ancillary Service Prices

+ Battery Storage Resource

- Battery Storage System Costs
- Storage Net-CONE Calculation



2020 ACC Updates for Today's Webinar

Avoided Cost	2019 ACC	2020 ACC	Data Source
Generation Capacity	Combustion Turbine Cost of New Entry	Battery Storage Cost of New Entry	RESOLVE input assumptions
Energy	Energy futures and gas turbine modeling	RESOLVE and SERVM modeling	SERVM outputs
Ancillary Services	percentage of energy	RESOLVE and SERVM modeling	SERVM outputs

Revenue	2019 ACC	2020 ACC	Data Source
Energy and AS Prices for Dispatchable DER	n/a	RESOLVE and SERVM modeling	SERVM outputs

- + Providing Day-Ahead and Real-Time Energy Prices and Ancillary Service Prices to calculate value for dispatchable DER (e.g. SGIP energy storage)
- + Not included in Avoided Costs



Changing Avoided Cost Paradigm

+ 2019 ACC: CCGT/CT is marginal resource

- ~ 60% Variable
- Planning grid for peak capacity
- Focus on efficient fossil generation and dispatch



+ 2020 ACC: Solar and Storage are marginal resources for energy and capacity:

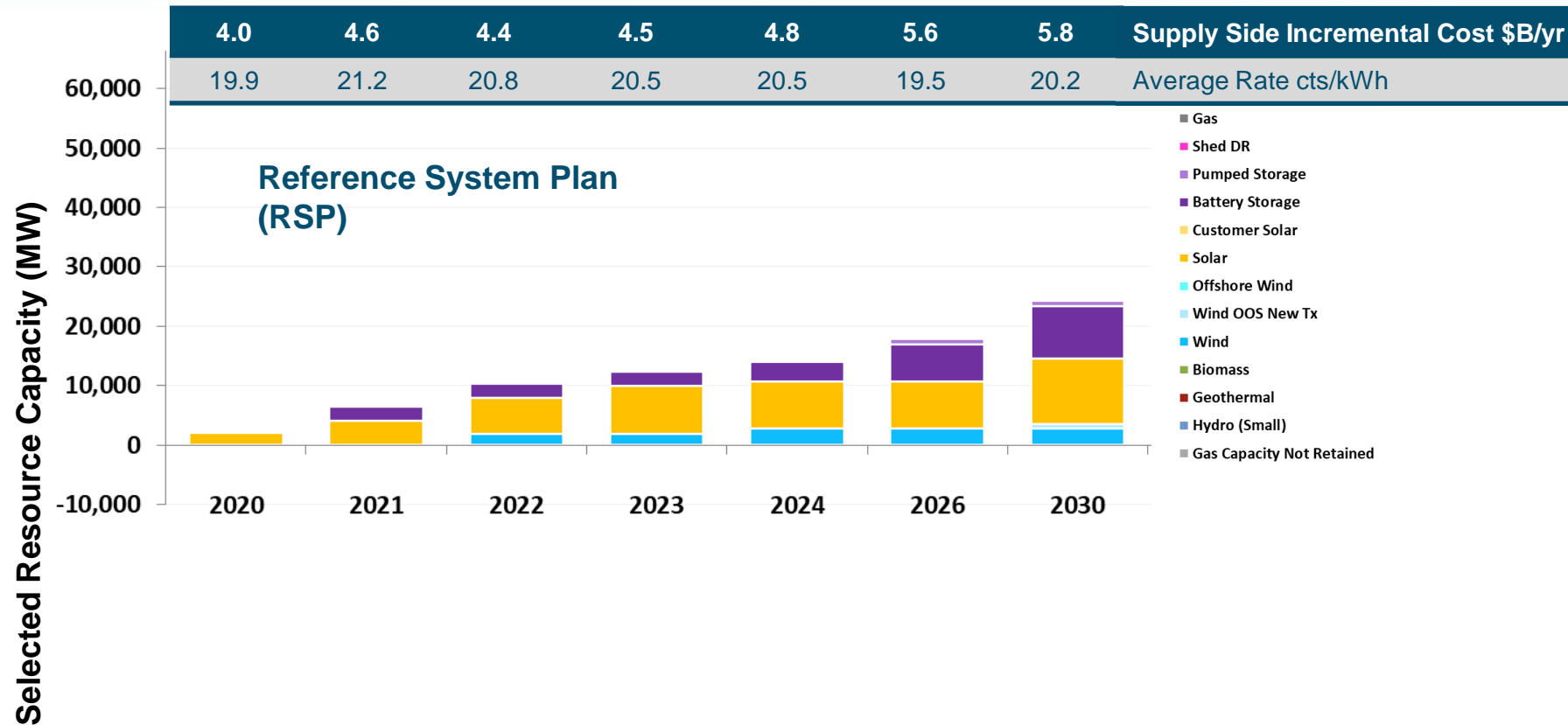
- ~ 90% fixed cost
- Planning grid for delivered renewable energy
- Focus on efficient capital investment



Based on Integrated Resource Planning Proceeding



IRP RESOLVE Modeling of Reference System Portfolio



2030 CAISO Emissions Target of 37.9 MtCO2/year

+ To meet emissions target by 2030, the RSP builds

- **2.8 GW** of in state wind and **0.6 GW** of out of state wind
- **11 GW** of utility scale solar
- **8.8 GW** of battery storage
- **1 GW** of pumped storage
- **0.2 GW** of added Shed DR

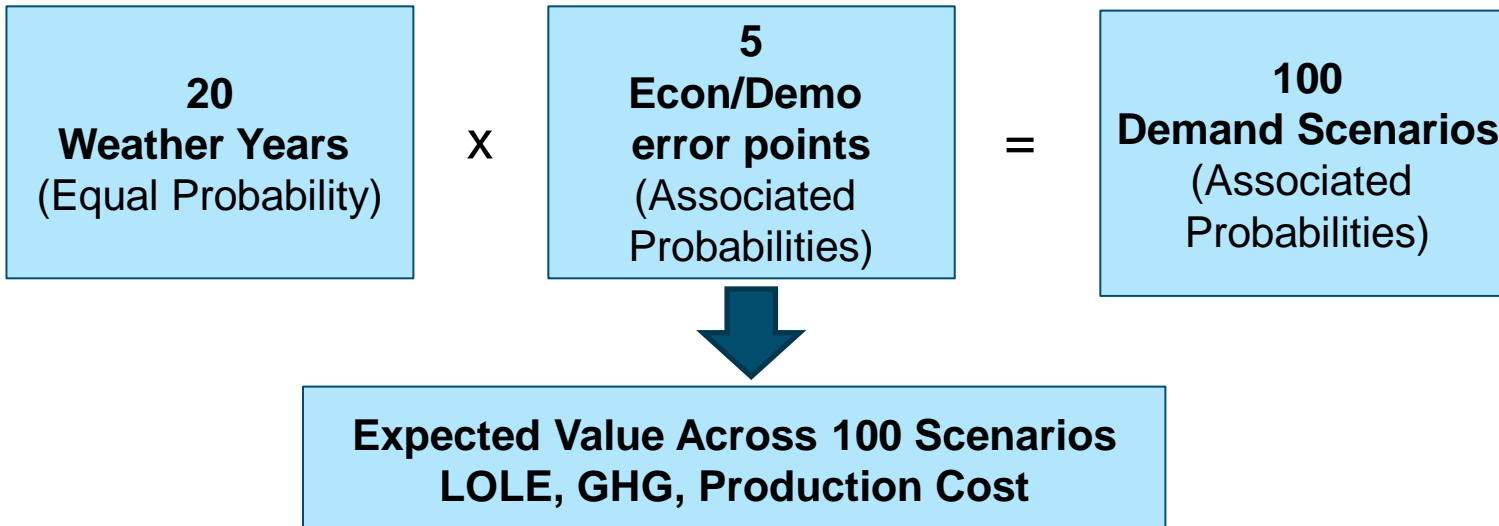


SERVM Production Simulation from IRP

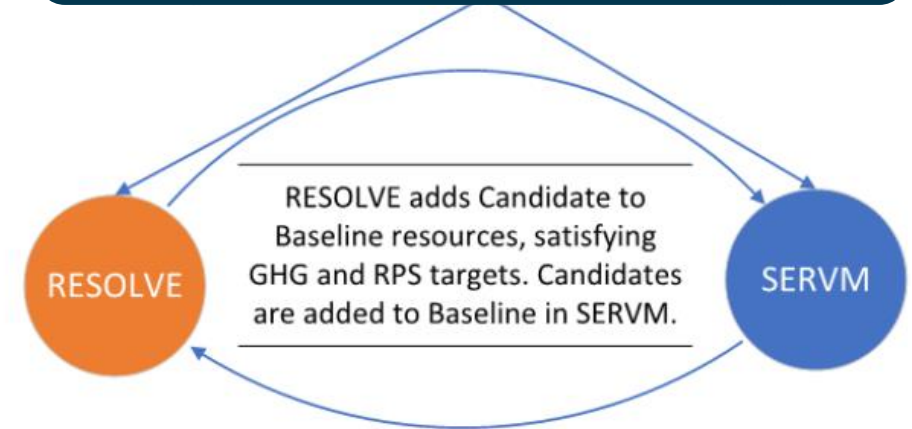
SERVM Framework



- + 20+ weather years of 8760 hourly electric consumption demand data for each forecast area in California (currently 8 areas in California, 4 in CAISO and 4 outside CAISO)
- + Corresponding 8760 hourly shapes for the same weather years and the same forecast zones for weather dependent load modifiers (BTMPV, EV, TOU, AAE)E)



RESOLVE – SERVM Calibration for IRP



SERVM validates that Baseline plus Candidates is reliable (Annual LOLE under 0.1) and consistent with key operational results from RESOLVE (GHG emissions, production costs, curtailment, dispatch patterns etc.)

2019 Reference System Portfolio

When results demonstrate a reliable and operable system and consistency between model outputs, CPUC issues Reference System Portfolio for party comment.



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Comparing 2019 and 2020 ACC Results



2020 ACC Update Process

Gather
Ingredients



Test Recipes



Plan Meal



Cook



Plan Meal



Gather
Ingredients

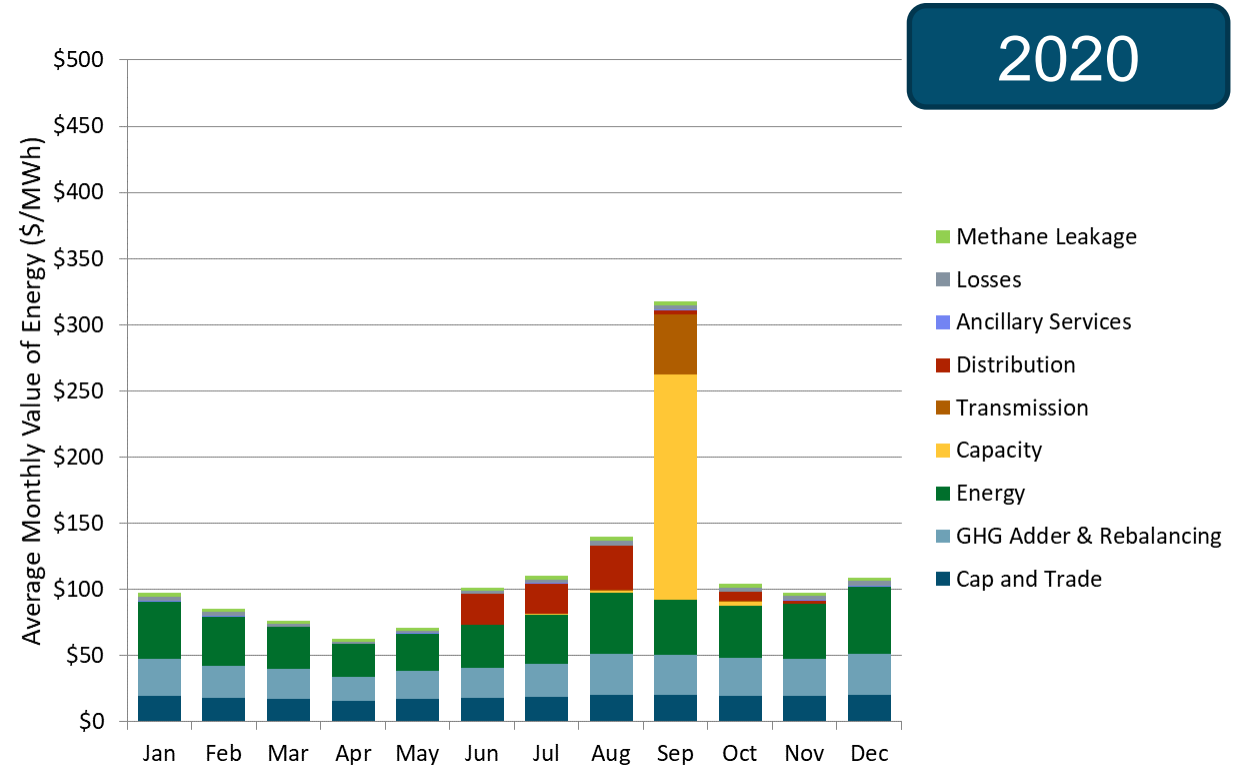
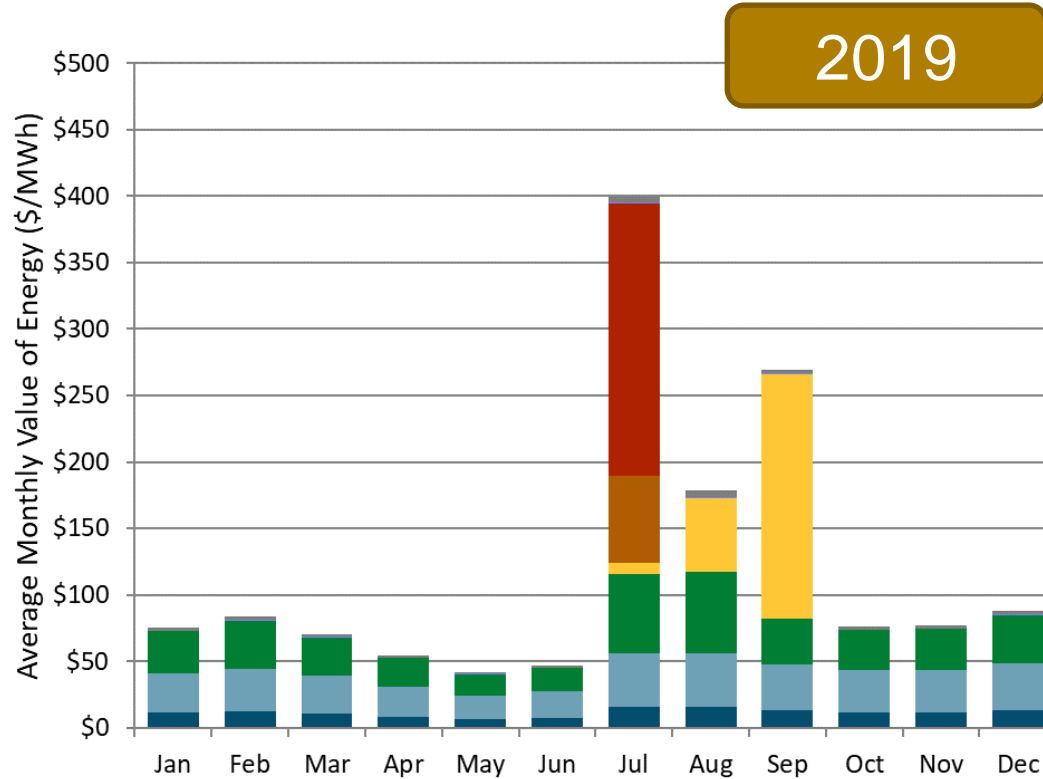


Cook





Monthly Average Avoided Costs



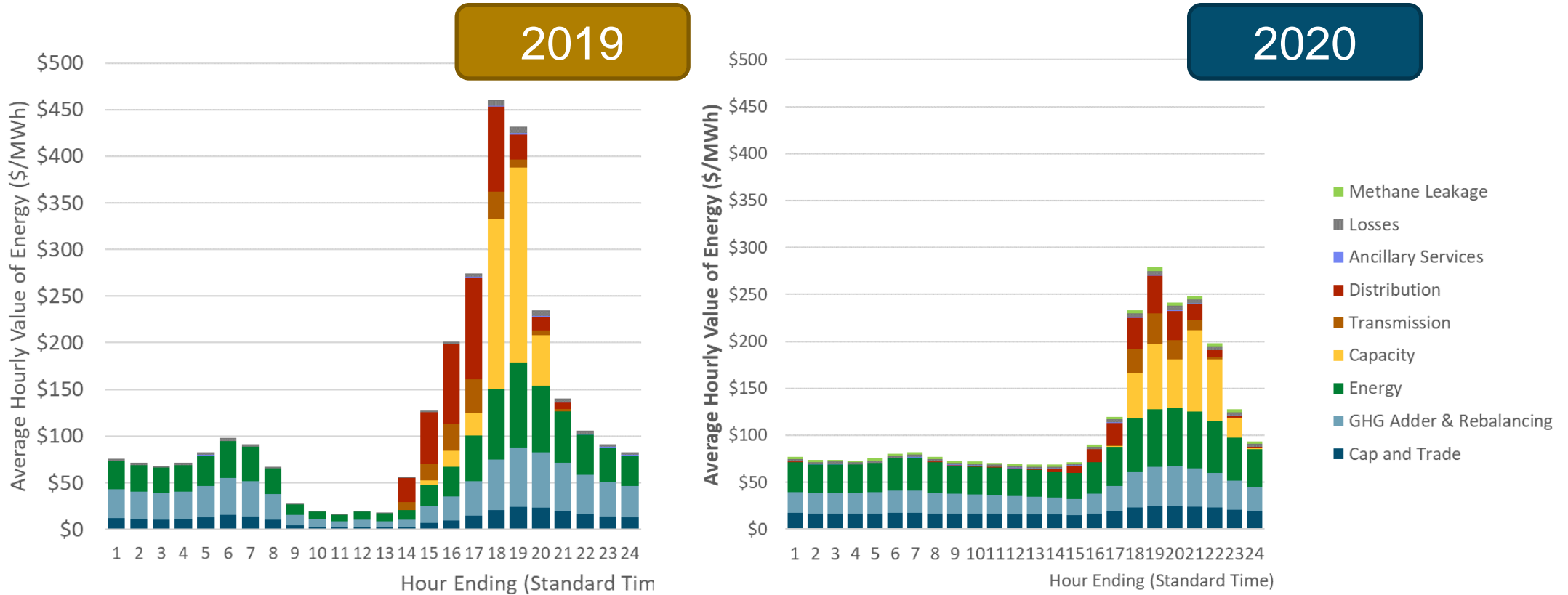
Hold your questions...

- Higher energy and GHG avoided costs in 2020 ACC except during July and August

SCE Climate Zone 9 (Los Angeles) in 2025



Hourly Average Avoided Costs



- Higher mid-day and lower evening avoided costs in 2020 ACC

SCE Climate Zone 9 (Los Angeles) in 2025



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No New DER Case



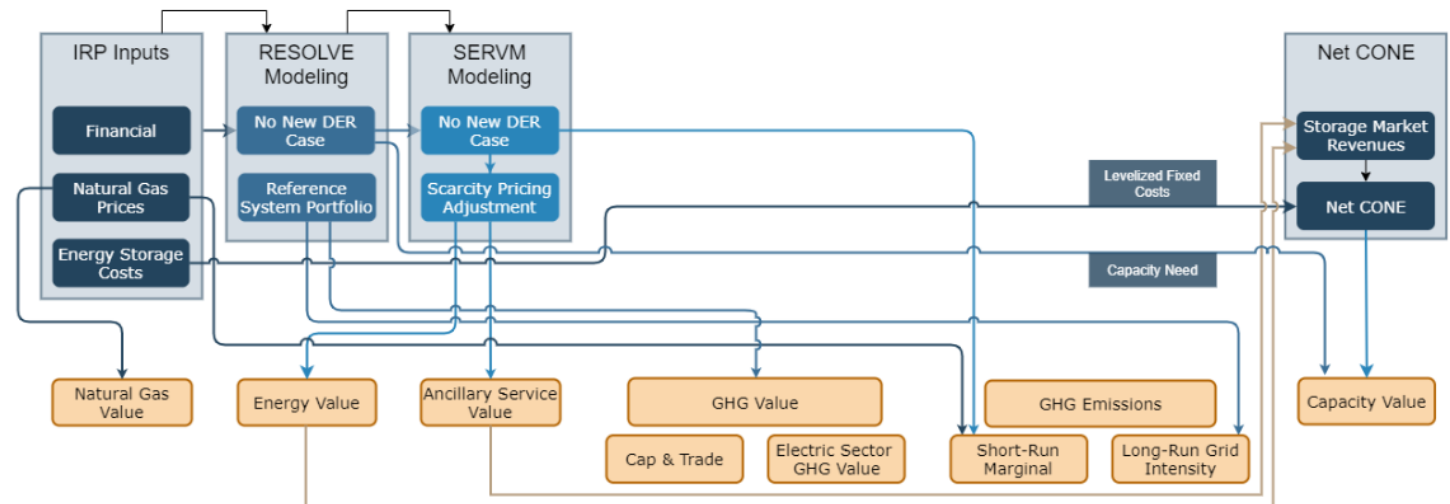
No New DER Case

+ Reference System Plan

- IRP Least-cost portfolio to achieve GHG emissions targets
- Included CEC Integrated Energy Policy Report (IEPR) forecast of DER
- ACC uses RSP for:
 - GHG value
 - planned grid emissions intensity

+ No New DER Case

- Removes DER associated with utility programs
- Counterfactual, what would system costs be without DER
- ACC uses No New DER case for:
 - Energy and ancillary service values
 - Marginal GHG emissions



+ Battery storage resource costs from IRP

- Independent of supply portfolio



No New DER Resources Removed Assumptions

+ CEC IEPR DER Adoption in RSP

+ Existing DER included in No New DER Case

No New DER Energy Resources Removed

CAISO Sales Forecast Buildup	2018	2020	2025	2030
Energy Efficiency (GWh)				
CEC 2018 IEPR - Mid Mid AAEE	1,906	5,930	17,322	27,940
No New DER Case	1,906	1,906	1,906	1,906
Committed BTM PV				
CEC 2018 IEPR - Mid PV + Mid-Mid AAPV	12,439	16,797	25,446	32,466
No New DER Case	12,439	12,439	12,439	12,439
Additional Achievable BTM PV				
CEC 2018 IEPR - Mid PV + Mid-Mid AAPV	-	134	1,441	2,657
No New DER Case	-	-	-	-
Behind-the-Meter CHP (GWh)				
CEC 2018 IEPR - Mid Demand	13,594	13,637	13,648	13,595
No New DER Case	13,594	13,594	13,594	13,594
Non-PV Non-CHP Self Generation (includes storage losses) (GWh)				
CEC 2018 IEPR - Mid Demand	764	751	716	681
No New DER Case	764	751	716	681

No New DER Capacity Resources Removed

BTM PV and BTM Storage Capacity from CEC 2018 IEPR	2018	2020	2025	2030
Committed BTM PV				
CEC 2018 IEPR - Mid PV + Mid-Mid AAPV	7,269	9,694	14,387	18,555
No New DER Case	7,269	7,269	7,269	7,269
AAPV (Additional Achievable BTM PV)				
CEC 2018 IEPR - Mid PV + Mid-Mid AAPV	-	134	843	1,511
No New DER Case	-	-	-	-
BTM Storage (MW)				
CEC 2018 IEPR - BTM Storage installed capacity	92	722	1,239	1,647
CEC 2018 IEPR - BTM Storage peak impact	(81)	(641)	(1,072)	(1,390)
No New DER Case	(81)	(81)	(81)	(81)
Load Modifying Demand Response				
Load-Modifying Demand Response: Mid Mid AAEE	(137)	(162)	(186)	(200)
No New DER Case	-	-	-	-
Capacity Contribution of BTM Resources Modeled as Supply-Side in RESOLVE				
BTM PV (MW peak reduction)				
CEC 2018 IEPR - Mid PV + Mid-Mid AAPV	3,532	4,408	5,859	5,641
No New DER Case	3,532	3,532	3,532	3,532
Baseline DR 1-in-2 Peak Load Impact (MW)				
DR 1-in-2 Load Impact (MW)				
Mid Case	1,617	1,617	1,617	1,617
No New DER Case	-	-	-	-



Added Supply Side and Removed Demand Side Resources

		Added Supply Side Resources						
		2020	2021	2022	2023	2024	2026	2030
MW	Wind	-	-	472	659	659	759	1,838
	Solar	1,994	1,994	1,994	1,994	4,677	11,060	15,337
	Storage	2,030	2,236	2,236	1,759	3,068	4,790	3,838
	DR	-	(222)	(222)	(222)	(222)	(222)	(222)
	Gas	-	-	-	-	-	-	2,810
		Removed Demand Side						
		2020	2021	2022	2023	2024	2026	2030
MW	BTM PV	9,827	11,137	12,284	13,303	14,288	16,156	20,066
	BTM Storage	722	839	942	1,054	1,157	1,320	1,647
	DR 1-2 Load Impact	1,617	1,617	1,617	1,617	1,617	1,617	1,617
	DR Load Modifying	(162)	(158)	(166)	(172)	(181)	(192)	(200)
GWH	EE	5,930	8,069	10,186	12,701	15,029	19,550	27,940
	BTM PV	16,931	19,342	21,537	23,451	25,209	28,503	35,123
	CHP	13,637	13,648	13,655	13,657	13,655	13,638	13,595
	Other Self Gen	751	745	737	730	723	708	681

+ Added Supply Side

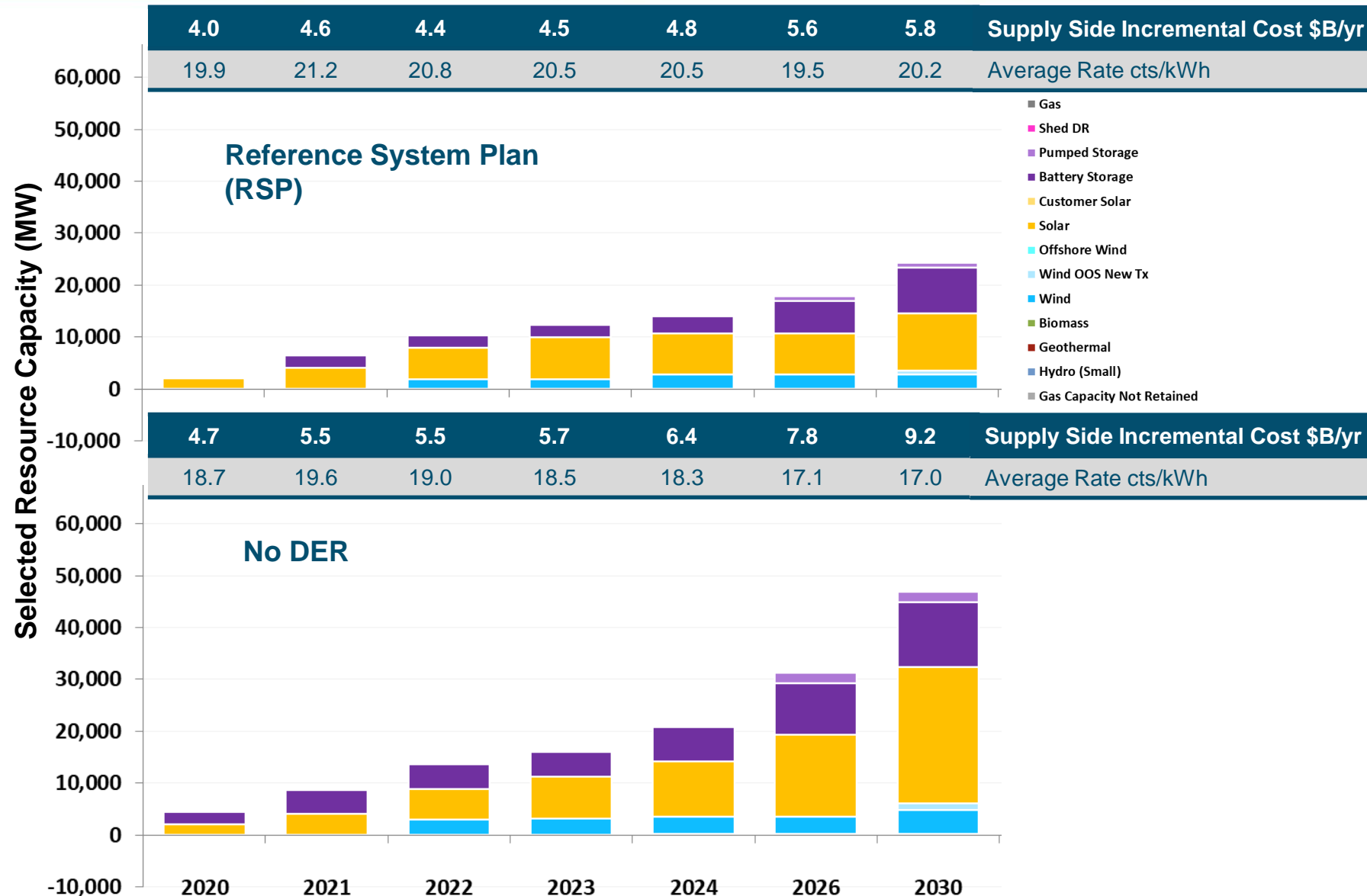
- **1.8 GW** of in state wind
- **~15 GW** of utility scale solar
- **~3.8 GW** utility scale storage

+ Removed DER

- **~20 GW** of BTM solar
- **~1.6 GW** BTM Storage
- **1.6 GW** DR



No New DER Case Change in Supply Side Portfolio



+ To meet emissions target by 2030, the RSP builds

- **2.8 GW** of in state wind and **0.6 GW** of out of state wind
- **11 GW** of utility scale solar
- **8.8 GW** of battery storage
- **1 GW** of pumped storage

+ By 2030 the “No DER” scenario results in:

- Additional **15 GW** utility scale solar
- Building **1.8 GW** more in-state wind and **0.7GW** of out-of-state wind
- Increasing the amount of **battery storage by 3.6 GW** and additional **1 GW** of pumped storage
- Adding **300 MW** of Geothermal



Comparison of 2019 and 2020 ACC Curtailment and Energy Prices



Looking Back 2019 ACC Underestimated Curtailment

+ 2019 ACC understated the number of curtailment hours compared to actual curtailments in CAISO

Total Curtailment Hours	
2019 ACC NP15 & SP15 (all-year)	1111
2019 CAISO (Jan – Aug)	1379

ACC NP15 and SP15 Curtailment 2019
NP 15 & SP 15

	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	3	5	5	5	4	1	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	1	29	29	30	30	30	30	29	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	1	30	30	30	30	30	30	30	30	30	27	-	-	-	-	-	-	-	-
5	-	-	-	-	-	3	31	31	31	31	31	31	31	31	31	31	-	-	-	-	-	-	-	-
6	-	-	-	-	-	2	30	30	30	30	30	30	30	30	27	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

2019 ACC

CAISO System Curtailment 2019 (note that data from Sep - Dec was not available at the time of data collection)
CAISO System Curtailment (2019 Jan - August)

	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	-	-	-	-	-	-	-	7	4	2	2	4	4	4	8	1	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	4	6	9	2	8	5	8	11	9	4	-	-	-	-	-	-	-	-
3	1	-	-	-	-	2	16	18	14	16	16	16	17	20	19	11	-	-	-	-	-	-	-	-
4	-	-	-	-	1	9	12	15	18	18	17	16	13	13	18	17	5	-	-	-	-	-	-	-
5	-	1	1	-	1	6	18	13	19	22	22	19	17	20	18	19	17	9	4	2	1	1	-	-
6	-	-	-	-	11	19	19	18	16	16	12	16	12	16	20	14	19	16	1	-	-	-	-	-
7	-	-	-	-	7	14	22	19	19	18	26	19	18	19	19	21	24	12	2	-	-	-	-	-
8	-	-	-	-	19	18	20	17	22	21	20	15	18	18	11	17	7	-	2	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Curtailment data from Sep to Dec was not available at the time of data collection

Actual Curtailment Reported by CAISO



Curtailment Hours Currently in 2020 ACC

+ Curtailment hours derived from SERVM prices are significantly lower in 2020 ACC, using implied heat rate methodology

Total Curtailment Hours	
2020 ACC NP15 & SP15	82
2030 ACC NP15 & SP15	233

ACC Curtailment Hours, SEVRM Implied Marginal Heat Rate
NP15 & SP15

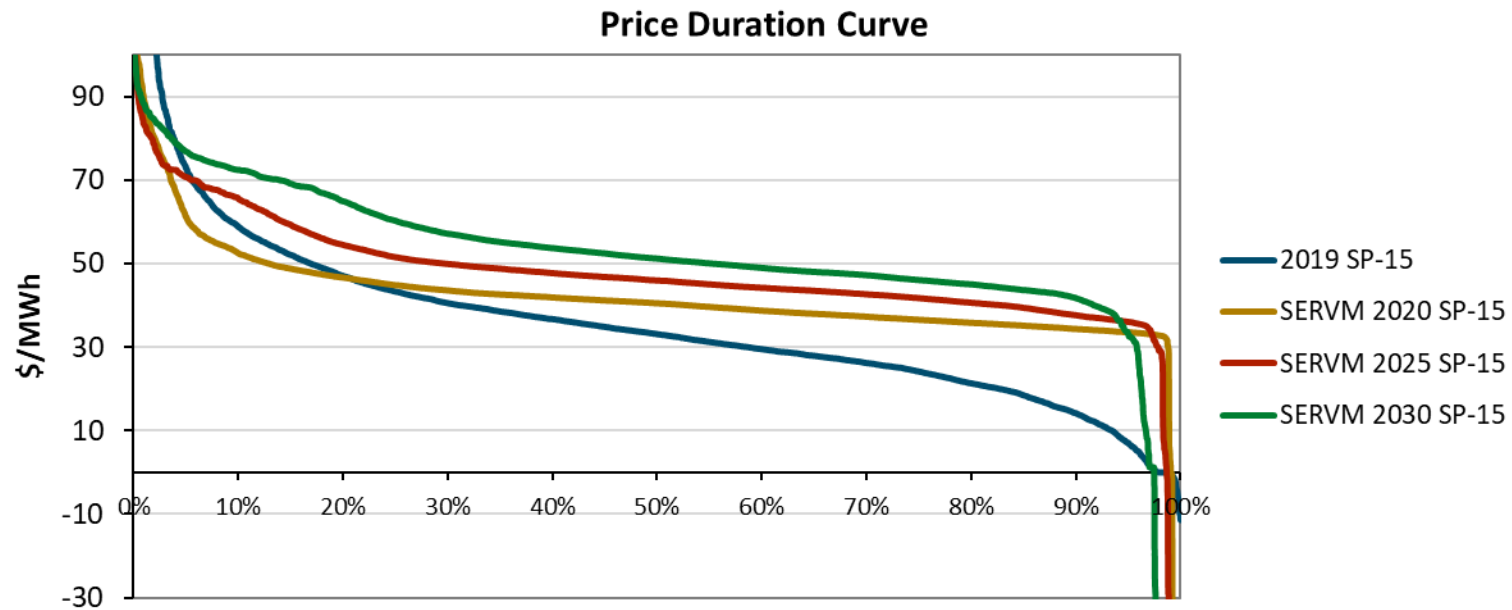
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
2020	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	5	3	4	2	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	2	1	1	1	1	1	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	1	4	6	5	7	7	3	-	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-	3	3	4	5	6	1	-	-	-	-	-	-	-	-	-
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	7	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2030	1	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-
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	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Keep holding your questions...



Price Duration Curve Comparison

- + SERVM raw results for 2020 show similar amount of negatively priced hours compared to 2019 historical prices
- + Small increase in negatively priced hours by 2030





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No New DER and RSP SERVM Price Comparison



2030 No DER vs RSP SERVM Energy Prices

- + Month-hour average of SERVM energy price outputs show more negatively priced hours in RSP case
- + No DER case has negative priced hours largely in spring
- + RSP case has some negative priced hours in summer, fall

No DER Case – 2030 SP-15

M/H	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan	49	49	49	49	49	51	55	58	50	46	45	44	44	43	43	47	60	69	70	70	68	65	61	52
Feb	49	50	49	48	49	50	57	62	54	51	49	46	46	45	41	39	55	66	69	68	66	61	54	53
Mar	44	42	45	45	46	48	49	43	37	36	36	36	35	34	-19	-80	35	52	57	55	54	51	48	48
Apr	44	43	44	43	45	51	45	39	36	34	36	33	32	11	-66	-85	27	48	51	51	50	47	46	45
May	43	44	44	44	44	45	41	28	29	31	31	32	8	-60	-151	-154	-82	54	56	57	53	49	47	46
Jun	43	43	43	43	45	44	41	39	40	41	42	42	42	42	31	30	44	54	63	65	61	53	49	47
Jul	46	45	45	45	45	45	42	41	42	42	43	43	44	46	43	54	61	72	74	72	68	62	55	52
Aug	48	48	48	48	49	50	46	42	42	43	43	44	45	47	50	58	65	78	76	77	71	68	61	56
Sep	47	47	47	47	48	52	48	42	41	41	42	42	43	44	36	51	57	71	74	69	66	64	60	52
Oct	46	46	46	46	46	49	51	44	42	41	41	41	41	41	43	48	55	66	65	64	62	58	52	48
Nov	48	49	48	49	48	49	52	52	49	46	46	45	44	44	45	47	67	69	68	66	64	63	60	54
Dec	51	52	49	49	49	51	56	62	56	56	53	50	50	49	47	50	63	74	74	72	70	67	64	55

RSP Case – 2030 SP-15

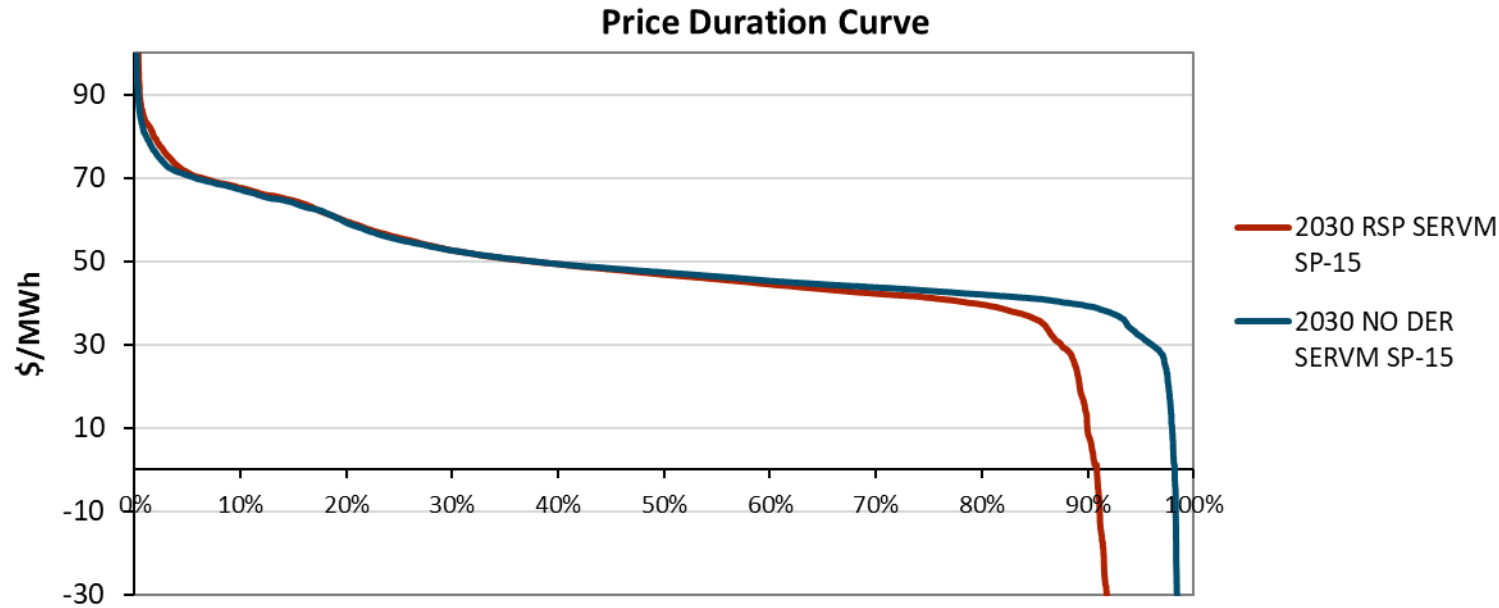
M/H	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan	50	49	49	48	48	51	58	58	49	43	42	16	7	-81	-73	28	65	65	70	69	68	65	61	54
Feb	49	50	49	48	48	50	56	59	51	47	39	3	-81	-155	-158	-97	36	61	69	68	66	59	53	53
Mar	45	42	45	45	46	48	49	44	38	31	29	-42	-122	-214	-248	-177	32	50	55	57	56	52	49	48
Apr	46	44	44	44	47	56	48	41	33	27	-13	-56	-106	-210	-227	-162	21	48	51	53	53	49	50	51
May	43	44	43	44	44	44	42	38	28	25	5	-58	-181	-275	-278	-246	-49	53	53	58	55	52	49	46
Jun	43	43	42	43	45	45	42	40	37	37	35	27	-87	-214	-172	-95	37	54	61	67	64	59	55	48
Jul	45	44	44	44	45	46	42	41	41	42	37	40	22	-65	-33	34	60	72	77	73	69	67	61	52
Aug	48	47	47	47	49	50	46	42	41	42	42	43	41	-6	-2	54	61	112	89	84	80	77	66	54
Sep	48	47	46	46	48	54	48	42	39	38	29	11	-21	-15	3	38	57	87	77	74	70	70	63	54
Oct	47	46	46	46	47	51	51	44	39	38	31	6	-68	-44	-2	23	57	65	66	65	63	59	55	52
Nov	49	49	49	49	48	50	54	52	46	43	42	20	-9	-46	-15	41	63	70	70	68	65	64	61	55
Dec	51	53	49	49	49	52	59	59	54	49	47	42	20	-37	-14	45	66	76	76	75	71	68	65	55

Note: SERVM raw outputs assume -\$300/MWh for curtailment



2030 No DER vs RSP SERVM Energy Prices

- + Price duration curve shows approximately 2% of hours have negative prices in No DER case
- + Approximately 10% of hours have negative prices in RSP case
- + Difference due to difference in resource build, as both cases meet binding RPS, emissions targets

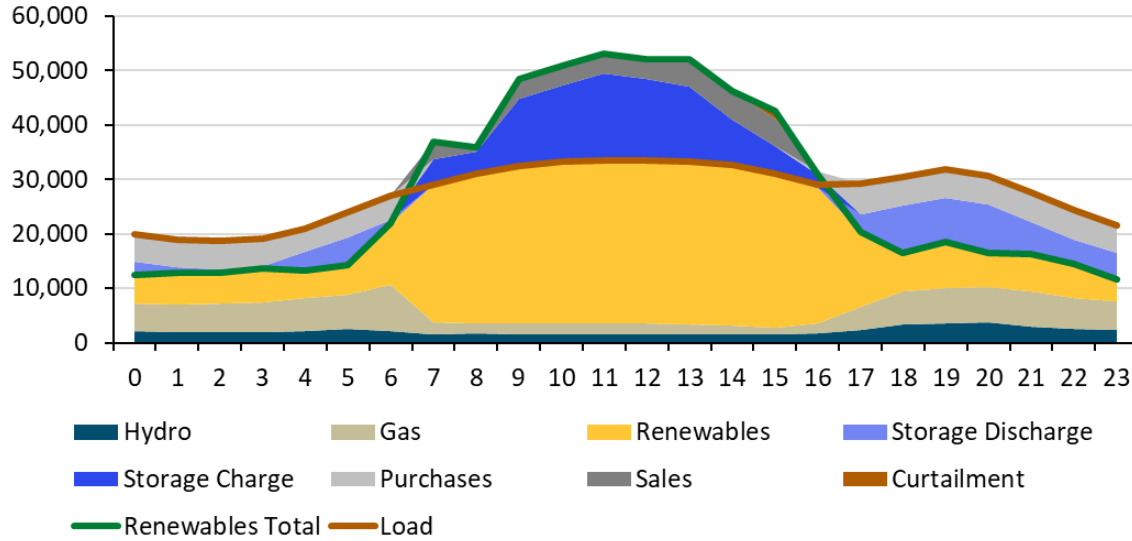


No New DER Case has less curtailment than RSP

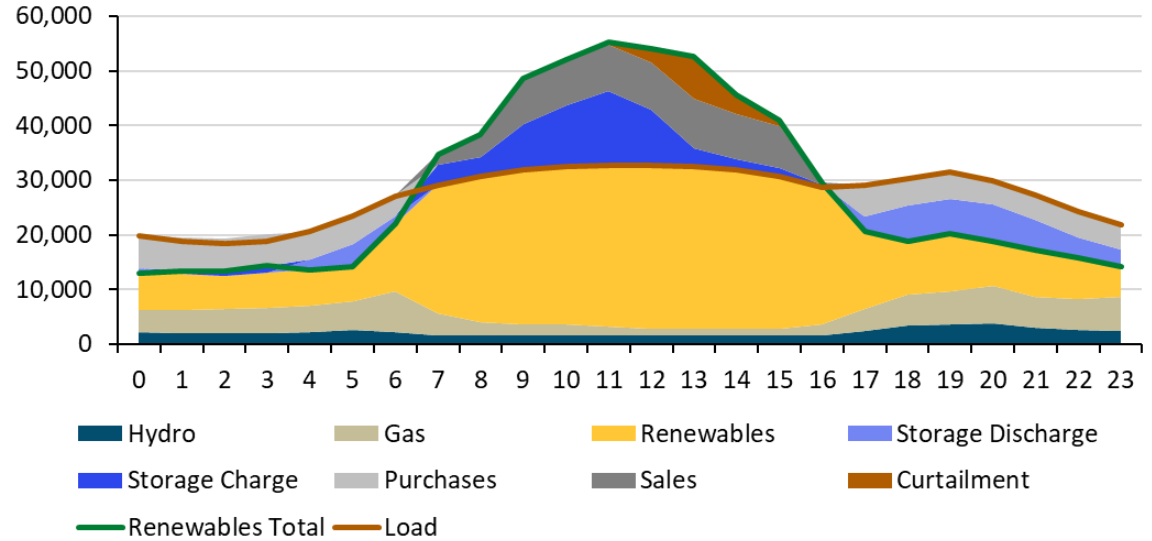


2030 No DER vs RSP Spring Day SERVM Dispatch

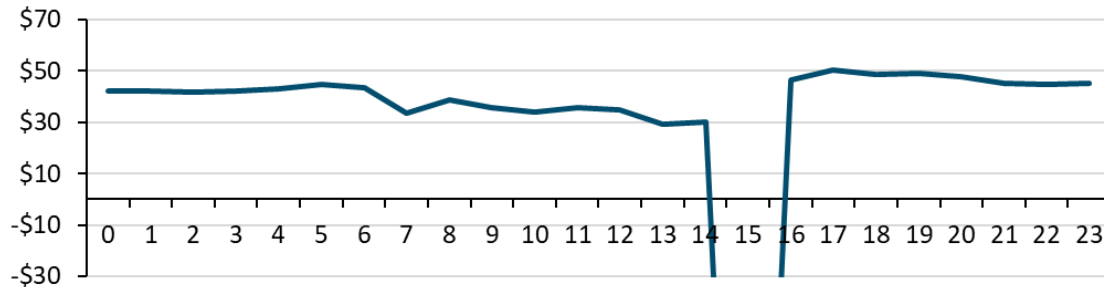
April 12, 2030 No DER SERVM Dispatch



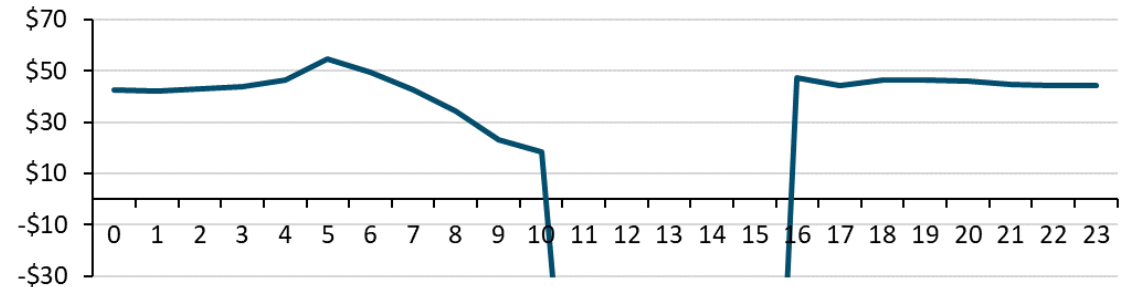
April 12, 2030 RSP SERVM Dispatch



April 12, 2030 No DER CAISO-avg Market Price



April 12, 2030 RSP CAISO-avg Market Price



Increased storage, decreased solar in No DER case limit curtailment hours in SERVM



Energy+Environmental Economics

SERVM Prices Post-Processing



SERVM Post-Processing Steps

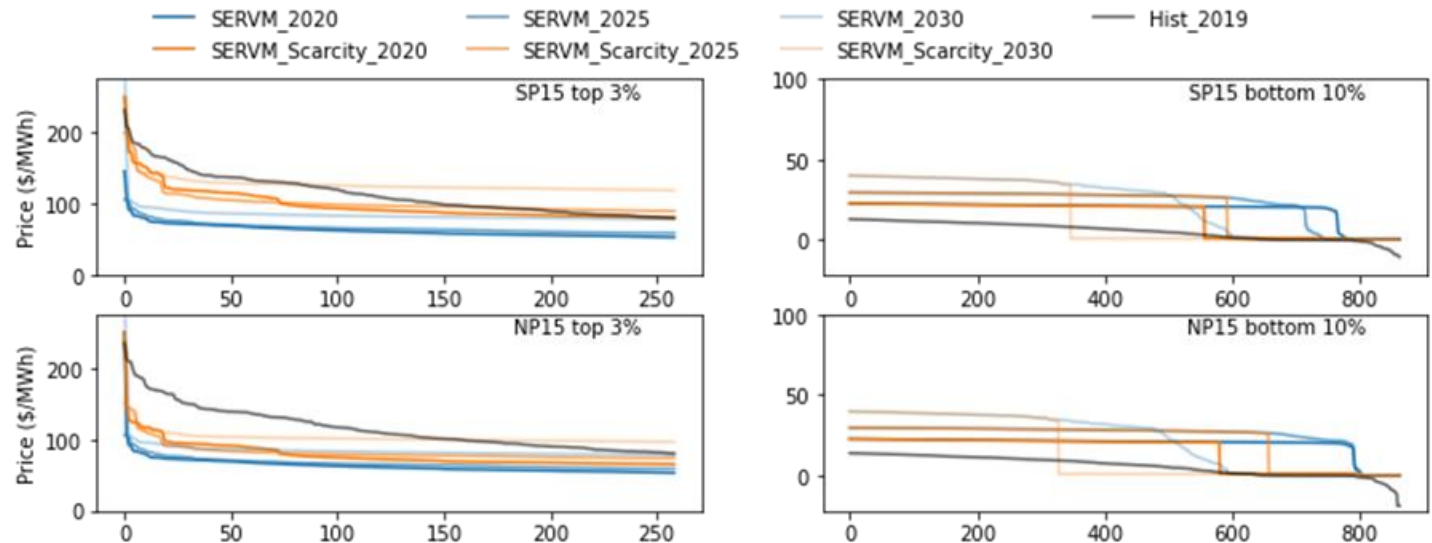
- + **Scarcity scaling function**
- + **Price ceiling and price floor set**
 - Price floor at \$0/MWh – negative price signal in ACC come through GHG fields
- + **Consistent gas price forecast with Gas Avoided Costs**
- + **2030 prices projected forward based on implied marginal heat rate**
- + **Calendar matching**



Scarcity Price Scaling Overview

- + Additional step applied to SERVM outputs to more accurately reflect historical prices spikes
- + Implied marginal heat rate compared to create scaling factors, based on 2020 reference year
- + Scaling factors applied to subsequent years

IMHR Tranches, Lower Bound (MMBtu/MWh)	SP15	NP15
-9999.0	1	1
0.0	0	0
5.5	1	1
7.5	1.45	1.22
9.0	1.53	1.25
13.0	1.5	1.19
16.0	1.67	1.32
18.0	1.93	1.57
20.0	1.89	1.35





Avoided Energy Cost Results

- + Near-term years show low energy prices in spring months
- + 2030 and beyond shows further effects of increased solar penetration
- + Peak energy prices remain largely in summer evenings

2020 Prices

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Avg.
Jan	26	25	25	25	26	26	28	30	29	27	26	26	25	26	26	26	29	36	40	38	35	36	30	27	29
Feb	23	23	23	23	23	24	27	28	24	22	21	20	20	19	21	22	24	32	36	34	31	29	27	26	25
Mar	20	20	21	21	21	23	24	22	20	19	19	19	19	19	21	23	30	34	34	33	27	26	24	23	
Apr	16	15	15	18	17	20	20	18	15	17	17	16	17	15	15	18	24	25	30	33	30	24	21	20	20
May	14	15	14	13	15	16	14	9	13	15	18	18	17	15	16	20	24	27	31	33	32	25	22	18	19
Jun	21	19	20	18	18	21	19	19	20	21	21	22	22	23	24	27	30	36	39	41	39	29	24	23	25
Jul	22	22	22	22	22	22	21	21	22	23	23	24	24	26	33	38	69	62	61	58	53	26	23	32	
Aug	26	25	25	25	26	26	26	26	26	26	27	28	30	31	36	42	48	62	72	71	64	52	35	28	37
Sep	26	26	25	25	26	27	27	25	25	25	25	26	26	28	32	37	41	55	66	63	52	50	33	29	34
Oct	25	25	25	25	26	28	26	25	25	25	26	26	27	28	33	39	42	43	40	36	33	28	26	30	
Nov	29	29	29	28	29	29	30	30	29	29	28	28	28	28	29	32	40	46	46	42	38	38	33	32	32
Dec	32	31	31	31	31	32	34	36	34	33	32	32	32	31	32	33	40	45	45	44	44	43	35	32	35
Avg.	23	23	23	23	23	24	25	24	23	23	24	24	24	24	25	29	33	42	46	45	41	37	28	26	28

2030 Prices

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Avg.
Jan	66	68	63	63	65	68	78	93	89	87	82	77	74	68	64	66	83	102	105	103	100	92	87	73	80
Feb	66	68	67	65	66	70	79	84	64	57	55	54	53	53	52	56	67	89	95	93	88	82	74	72	69
Mar	59	52	60	60	63	66	67	51	40	39	37	38	36	37	31	35	61	70	82	83	83	75	67	67	57
Apr	44	45	46	46	47	56	51	20	10	10	12	13	10	6	3	5	26	67	71	70	66	61	54	52	37
May	50	50	50	51	56	55	41	20	23	24	26	27	26	21	14	20	47	70	76	82	75	68	61	58	45
Jun	53	50	51	51	56	51	41	39	41	44	45	46	48	45	43	51	71	75	85	88	81	72	63	60	56
Jul	48	49	48	48	49	48	41	40	42	46	46	43	40	35	35	52	62	98	96	93	89	87	63	58	56
Aug	64	61	62	63	65	67	57	49	51	51	52	53	57	58	65	79	88	108	104	103	98	96	86	81	72
Sep	65	65	65	65	66	74	63	46	46	46	46	47	48	51	55	66	74	94	93	92	90	87	81	76	67
Oct	62	63	62	62	63	69	68	53	51	49	49	51	51	52	56	67	86	91	91	90	87	81	73	67	66
Nov	61	62	61	60	60	62	65	61	52	51	51	50	50	51	51	58	72	88	88	87	87	83	76	68	65
Dec	68	66	65	64	65	66	70	74	75	73	69	66	65	64	63	68	76	96	97	96	94	92	88	74	75
Avg.	59	58	58	58	60	63	60	52	49	48	47	47	47	45	44	52	68	88	90	90	87	81	73	67	62



Energy+Environmental Economics

Ancillary Services



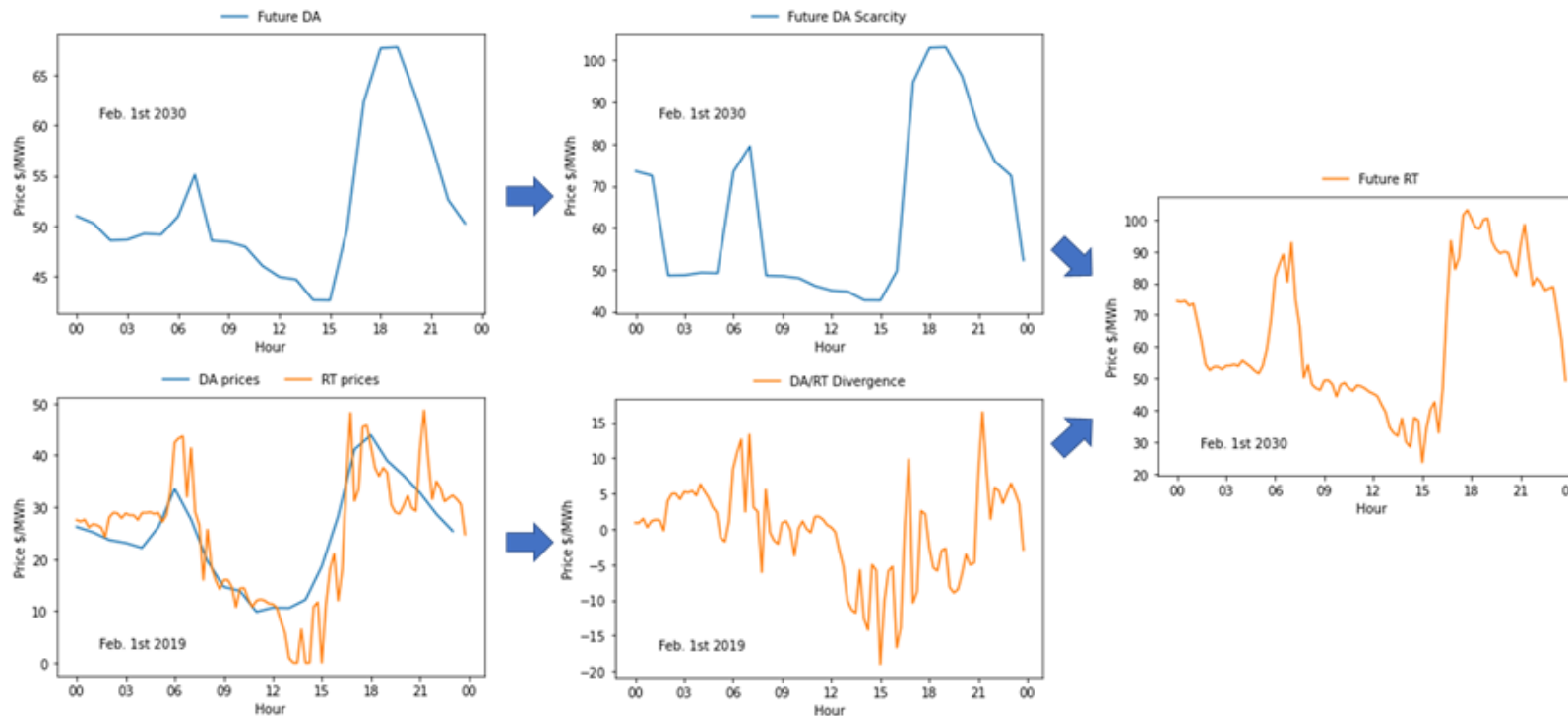
Ancillary Services

- + **Avoided Ancillary Services Procurement**
- + **Real-time Energy Market Prices**
- + **Ancillary Service Market Prices Forecasts**
 - Regulation market prices
 - Spinning reserve prices



Real-time Pricing Overview

- + 2019 historical hourly price divergence between real-time (15-minute) and day-ahead market prices is applied to forecasted energy prices
- + Real-time pricing is not included in avoided energy costs, but available as an additional data stream to evaluate potential wholesale market revenue for dispatchable DERs





Regulation Market Prices

- + SERVM Model outputs regulation prices as unitary regulation market (no disaggregation between regulation up and regulation down)
 - SERVM Regulation market prices divided by half to split between Regulation Up and Regulation Down
- + Regulation market price stream can be used to evaluate wholesale market revenue from dispatchable DERs

2020 Prices

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Avg.
Jan	0.5	0.4	0.4	0.4	0.4	0.6	0.9	1.1	1.1	0.9	0.8	0.7	0.6	0.6	0.6	0.7	1.2	1.3	1.6	1.5	1.2	1.9	1.2	0.8	0.9
Feb	0.5	0.5	0.4	0.4	0.4	0.7	1.2	1.3	0.9	0.6	0.5	0.4	0.4	0.4	0.4	0.5	0.9	1.3	1.5	1.3	1.2	1.2	0.9	0.6	0.8
Mar	0.4	0.2	0.3	0.3	0.5	0.8	1.1	0.8	0.6	0.5	0.4	0.4	0.5	0.5	0.4	0.6	1.0	1.2	1.3	1.5	1.3	1.1	1.0	0.7	0.7
Apr	0.4	0.4	0.4	0.4	0.4	0.8	1.3	2.2	2.3	2.5	2.4	2.1	2.6	2.8	1.4	0.8	0.7	0.4	0.3	0.4	0.4	0.3	0.3	1.1	1.1
May	0.3	0.3	0.3	0.3	0.3	0.4	0.8	1.2	1.6	1.9	2.1	2.2	2.3	2.2	2.1	0.9	0.8	0.7	0.4	0.5	0.4	0.4	0.4	0.3	1.0
Jun	0.2	0.1	0.1	0.1	0.1	0.2	0.4	0.4	0.6	0.6	0.6	0.6	0.8	0.7	1.0	1.4	1.6	1.2	1.1	1.4	1.1	0.8	0.6	0.3	0.7
Jul	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.3	0.5	0.5	0.6	0.6	1.0	1.6	1.4	9.0	5.0	4.3	3.7	3.0	0.6	0.2	1.4
Aug	0.6	0.4	0.4	0.6	0.6	0.7	0.6	0.6	0.7	0.8	0.8	0.9	1.2	1.2	1.5	2.0	2.5	5.1	7.0	7.1	5.8	2.5	1.4	0.8	1.9
Sep	0.5	0.4	0.4	0.4	0.5	0.7	0.7	0.6	0.6	0.6	0.6	0.7	0.9	1.0	1.3	1.5	1.4	3.6	6.1	5.6	3.4	3.4	1.1	0.8	1.5
Oct	0.4	0.3	0.3	0.3	0.4	0.7	0.9	0.7	0.6	0.6	0.6	0.5	0.7	0.7	0.9	1.2	1.2	1.4	1.4	1.3	1.1	0.9	0.8	0.6	0.8
Nov	0.4	0.3	0.3	0.3	0.3	0.4	0.7	0.7	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.9	1.1	1.2	1.3	1.1	1.0	1.4	0.9	0.7	0.6
Dec	0.5	0.5	0.4	0.4	0.4	0.5	0.6	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.6	0.7	0.9	1.1	1.2	0.9	0.7	1.1	0.6	0.6	0.7
Avg.	0.4	0.3	0.3	0.3	0.4	0.5	0.7	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.1	1.1	1.2	2.3	2.4	2.2	1.8	1.5	0.8	0.5	1.0

2030 Prices

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Avg.
Jan	1.0	1.0	1.0	1.0	1.1	1.4	2.3	6.3	6.8	7.3	6.0	5.1	4.3	3.2	2.4	2.5	4.3	5.7	6.3	5.9	5.5	6.7	7.8	2.1	4.0
Feb	1.1	1.0	1.0	1.1	1.2	2.0	3.5	5.6	4.0	3.7	3.7	3.7	3.3	2.9	3.2	2.1	1.8	6.4	8.1	8.4	7.2	5.5	2.7	1.6	3.5
Mar	1.5	1.1	1.4	1.4	1.4	1.9	2.2	2.7	7.9	9.1	9.3	9.6	9.6	9.5	9.0	5.9	2.4	4.3	8.4	8.7	8.5	5.7	3.4	2.5	5.3
Apr	0.5	0.3	0.3	0.3	0.4	1.3	5.5	13.1	12.0	12.1	11.5	11.2	9.6	8.4	5.9	6.1	7.3	2.7	3.9	4.5	3.3	2.1	1.2	0.5	5.2
May	0.9	1.0	0.8	1.1	2.7	3.3	8.5	12.7	15.2	15.2	17.1	16.8	15.0	12.8	13.0	14.2	5.9	3.0	4.2	4.0	3.6	2.3	1.0	0.9	7.3
Jun	1.6	0.5	0.6	0.7	1.6	0.9	4.2	8.7	9.3	9.5	9.8	10.4	10.8	10.3	10.6	7.0	2.2	3.6	7.0	7.1	5.5	3.9	2.0	2.2	5.4
Jul	1.0	0.6	0.6	0.6	0.6	0.7	2.8	4.4	5.5	5.8	6.1	7.0	7.7	7.8	7.7	5.0	2.5	6.4	6.9	6.9	6.4	5.7	2.2	1.7	4.3
Aug	2.6	1.7	1.7	1.7	1.9	2.4	1.6	2.8	3.0	3.4	3.7	4.3	4.8	5.2	5.4	3.5	3.3	7.4	5.7	5.7	7.0	7.2	7.1	5.5	4.1
Sep	2.8	2.3	2.2	2.2	2.2	5.1	2.3	2.4	3.0	3.2	3.7	4.0	4.4	4.7	4.7	3.4	3.1	6.2	7.3	7.6	8.4	7.3	7.0	5.5	4.4
Oct	1.9	1.7	1.4	1.4	1.5	3.2	2.7	2.0	2.4	2.4	2.7	3.1	3.1	3.2	3.0	2.7	2.5	9.0	9.0	9.4	9.2	7.2	5.0	2.7	3.8
Nov	1.2	1.3	1.5	1.2	1.3	1.7	2.3	2.4	2.1	2.2	2.1	2.0	1.9	2.0	2.3	2.8	3.4	9.0	9.2	10.3	10.7	9.5	6.2	2.2	3.8
Dec	1.1	1.1	0.8	0.8	0.8	1.3	1.9	3.1	4.2	4.1	3.7	3.4	3.2	2.8	2.4	3.0	2.4	5.5	5.9	6.9	9.7	9.9	8.7	2.6	3.7
Avg.	1.4	1.1	1.1	1.1	1.4	2.1	3.3	5.5	6.3	6.5	6.6	6.7	6.5	6.1	5.8	4.9	3.4	5.8	6.8	7.1	7.1	6.1	4.6	2.5	4.6



Spinning Reserve Market Prices

- + SERVM outputs Spinning Reserve Market Prices
- + Also included to evaluate wholesale market revenue potential of dispatchable DERs

2020 Prices

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Avg.
Jan	0.5	0.4	0.4	0.4	0.4	0.6	0.9	1.1	1.1	0.9	0.8	0.7	0.6	0.6	0.6	0.7	1.2	1.3	1.6	1.5	1.2	1.9	1.2	0.8	0.9
Feb	0.5	0.5	0.4	0.4	0.4	0.7	1.2	1.3	0.9	0.6	0.5	0.4	0.4	0.4	0.4	0.5	0.9	1.3	1.5	1.3	1.2	1.2	0.9	0.6	0.8
Mar	0.4	0.2	0.3	0.3	0.5	0.8	1.1	0.8	0.6	0.5	0.4	0.4	0.5	0.5	0.4	0.6	1.0	1.2	1.3	1.5	1.3	1.1	1.0	0.7	0.7
Apr	0.4	0.4	0.4	0.4	0.4	0.4	0.8	1.3	2.2	2.3	2.5	2.4	2.1	2.6	2.8	1.4	0.8	0.7	0.4	0.3	0.4	0.4	0.3	0.3	1.1
May	0.3	0.3	0.3	0.3	0.3	0.4	0.8	1.2	1.6	1.9	2.1	2.2	2.3	2.2	2.1	0.9	0.8	0.7	0.4	0.5	0.4	0.4	0.4	0.3	1.0
Jun	0.2	0.1	0.1	0.1	0.1	0.2	0.4	0.4	0.6	0.6	0.6	0.6	0.8	0.7	1.0	1.4	1.6	1.2	1.1	1.4	1.1	0.8	0.6	0.3	0.7
Jul	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.3	0.5	0.5	0.6	0.6	1.0	1.6	1.4	9.0	5.0	4.3	3.7	3.0	0.6	0.2	1.4
Aug	0.6	0.4	0.4	0.6	0.6	0.7	0.6	0.6	0.7	0.8	0.8	0.9	1.2	1.2	1.5	2.0	2.5	5.1	7.0	7.1	5.8	2.5	1.4	0.8	1.9
Sep	0.5	0.4	0.4	0.4	0.5	0.7	0.7	0.6	0.6	0.6	0.6	0.7	0.9	1.0	1.3	1.5	1.4	3.6	6.1	5.6	3.4	3.4	1.1	0.8	1.5
Oct	0.4	0.3	0.3	0.3	0.4	0.7	0.9	0.7	0.6	0.6	0.6	0.5	0.7	0.7	0.9	1.2	1.2	1.4	1.4	1.3	1.1	0.9	0.8	0.6	0.8
Nov	0.4	0.3	0.3	0.3	0.3	0.4	0.7	0.7	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.9	1.1	1.2	1.3	1.1	1.0	1.4	0.9	0.7	0.6
Dec	0.5	0.5	0.4	0.4	0.4	0.5	0.6	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.6	0.7	0.9	1.1	1.2	0.9	0.7	1.1	0.6	0.6	0.7
Avg.	0.4	0.3	0.3	0.3	0.4	0.5	0.7	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.1	1.1	1.2	2.3	2.4	2.2	1.8	1.5	0.8	0.5	1.0

2030 Prices

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Avg.
Jan	0.7	0.6	0.7	0.6	0.6	0.8	1.3	3.4	3.9	4.2	3.2	2.7	2.6	1.8	1.4	1.5	2.6	3.5	3.9	3.7	3.4	4.0	4.4	1.3	2.4
Feb	0.6	0.6	0.6	0.6	0.7	1.1	2.0	3.1	2.2	2.1	2.2	2.2	2.0	1.6	1.9	1.2	1.0	3.8	4.6	5.0	4.2	3.3	1.7	1.0	2.1
Mar	0.9	0.6	0.8	0.8	0.8	1.2	1.3	1.6	4.6	5.3	5.4	5.5	5.6	5.5	5.1	3.3	1.3	2.5	4.9	5.0	4.9	3.1	2.0	1.5	3.1
Apr	0.2	0.2	0.2	0.2	0.2	0.8	3.2	7.6	7.0	7.2	6.7	6.6	5.8	5.0	3.5	3.5	4.2	1.6	2.3	2.7	1.8	1.1	0.5	0.2	3.0
May	0.5	0.6	0.4	0.7	1.6	2.0	4.8	7.3	8.8	8.9	9.8	9.7	8.8	7.6	7.3	8.2	3.6	1.7	2.3	2.2	2.0	1.4	0.5	0.5	4.2
Jun	0.9	0.2	0.4	0.4	0.9	0.5	2.5	5.1	5.6	5.4	5.8	6.2	6.4	6.1	6.2	4.1	1.3	2.0	4.0	4.1	3.1	2.3	1.1	1.2	3.2
Jul	0.5	0.3	0.3	0.3	0.3	0.4	1.6	2.6	3.2	3.4	3.5	4.2	4.4	4.5	4.4	2.9	1.4	3.5	3.9	3.8	3.5	2.9	1.1	0.8	2.4
Aug	1.5	1.0	0.9	1.0	1.2	1.4	0.9	1.6	1.7	2.0	2.1	2.4	2.7	3.1	3.1	1.9	2.1	4.3	3.3	3.4	4.2	4.1	4.1	3.1	2.4
Sep	1.6	1.3	1.2	1.3	1.3	2.9	1.3	1.4	1.6	1.8	2.2	2.2	2.5	2.8	2.7	1.9	1.8	3.6	4.2	4.5	5.0	4.2	4.0	3.1	2.5
Oct	1.1	0.9	0.7	0.8	0.8	1.9	1.7	1.2	1.4	1.4	1.5	1.8	1.9	1.9	1.8	1.6	1.6	5.2	5.3	5.6	5.6	4.3	2.9	1.4	2.3
Nov	0.7	0.8	0.9	0.8	0.8	1.1	1.4	1.5	1.3	1.4	1.3	1.2	1.1	1.2	1.4	1.8	2.0	5.0	5.1	5.8	6.2	5.7	3.7	1.5	2.2
Dec	0.5	0.7	0.5	0.5	0.5	0.8	1.1	1.7	2.3	2.3	2.0	1.8	1.8	1.5	1.3	1.7	1.4	3.2	3.3	4.2	5.6	5.6	5.1	1.3	2.1
Avg.	0.8	0.6	0.6	0.7	0.8	1.2	1.9	3.2	3.6	3.8	3.8	3.9	3.8	3.6	3.3	2.8	2.0	3.3	3.9	4.2	4.1	3.5	2.6	1.4	2.7



Energy+Environmental Economics

Avoided Capacity Costs



Energy Storage ELCC

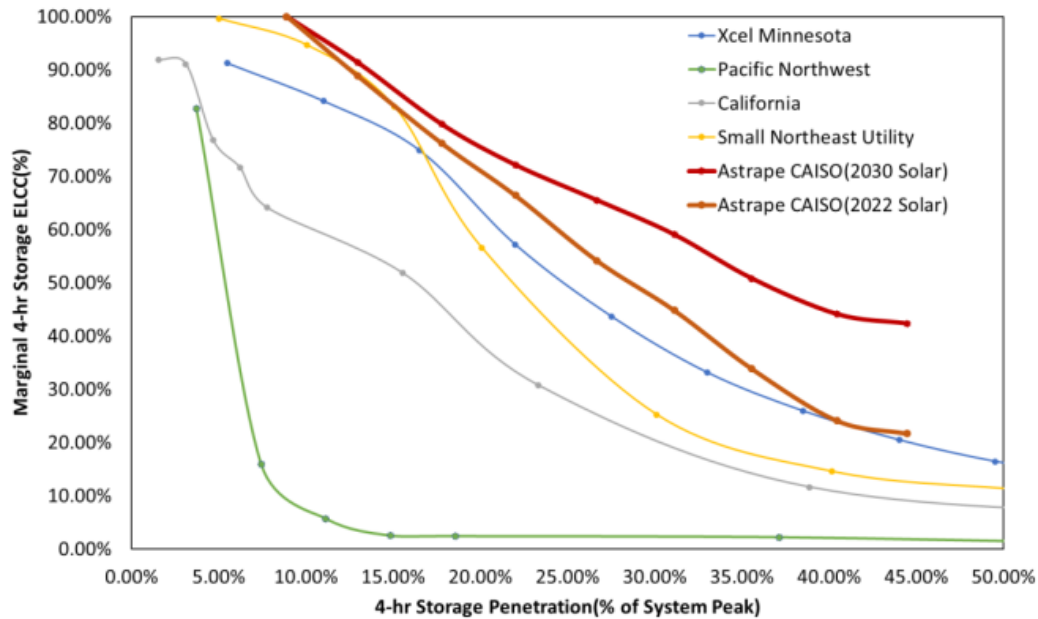


Figure 8: Energy Storage Capacity Value Results, Including Previous E3 studies⁵

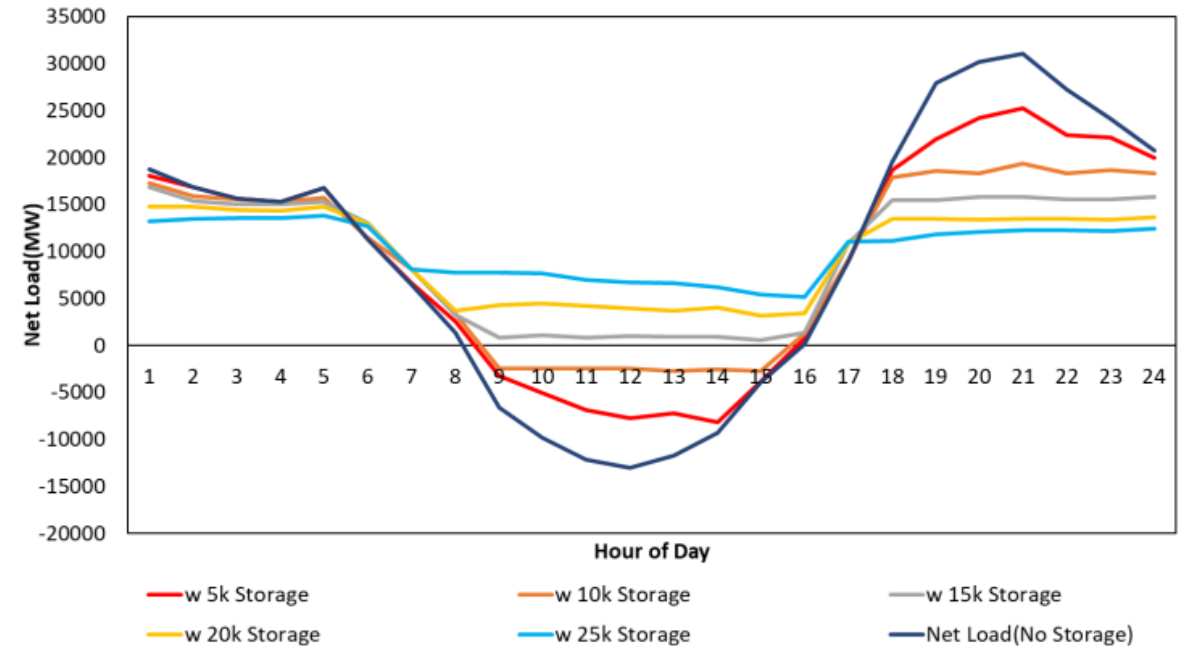


Figure 5: July Net Load Shapes with Various Storage Portfolios



IRP Inputs

Tax Rate		Cell Color Coding							
Federal Tax Rate	21.00%	Input							
State Tax Rate	8.84%	Calculated Input							
Effective Tax Rate	28%	Dropdown Menu Input							
Utility-scale Li-ion Battery Cost (Standalone, No ITC)		Lookup Formula							
Battery duration (hours)	4	Yearly Lookup Value							
Escalation rate	2.00%	Final Outputs							
IRP Pro Forma Dollar Year	2016	Values Pasted from Calculation/Macros							
<i>RESOLVE Years Only --></i>									
RESOLVE Outputs: Storage Build	Capacity Contribution	2020	2021	2022	2023	2024	2026	2030	2045
CAISO_New_Li_Battery	100%	3,418	6,048	6,048	6,436	7,312	7,485	7,786	9,022
CAISO_New_Li_Battery_2	76%	-	-	-	-	916	3,968	5,470	6,334
CAISO_New_Li_Battery_3	50%	-	-	-	-	-	-	790	9,484
CAISO_New_Li_Battery_4	25%	-	-	-	-	-	-	-	6,221
CAISO_New_Li_Battery_5	6%	-	-	-	-	-	-	-	29,773
CAISO_New_Li_Battery_6	0%	-	-	-	-	-	-	-	-
Cumulative Battery Storage Additions (MW)		3,418	6,048	6,048	6,436	8,228	11,453	14,046	60,834
Incremental Additions (compared to prior RESOLVE year)		3,418	2,630	-	388	1,792	3,225	2,593	46,788
Effective Capacity (MW)		3,418	6,048	6,048	6,436	8,007	10,497	12,332	22,017
ELCC		100%	100%	100%	100%	97%	92%	88%	36%



IRP Battery Storage Resource Costs

	Energy Storage Fixed Costs (\$2016)	2020	2024	2027	2030	2045	2050
Capital	Capacity (\$/kW)	\$ 20	\$ 12	\$ 10	\$ 9	\$ 8	\$ 7
	Energy (\$/kWh Installed)	\$ 28	\$ 17	\$ 14	\$ 12	\$ 10	\$ 10
Fixed O&M	Capacity (\$/kW)	\$ 3	\$ 2	\$ 2	\$ 2	\$ 1	\$ 1
	Energy (\$/kWh Installed)	\$ 4	\$ 3	\$ 2	\$ 2	\$ 2	\$ 2
Periodic Replacement and Augmentation	Capacity (\$/kW)	\$ 2	\$ 2	\$ 1	\$ 1	\$ 1	\$ 1
	Energy (\$/kWh Installed)	\$ 14	\$ 10	\$ 9	\$ 8	\$ 7	\$ 6
Total Fixed Cost	Capacity (\$/kW)	\$ 25	\$ 16	\$ 13	\$ 12	\$ 10	\$ 9
	Energy (\$/kWh Installed)	\$ 46	\$ 30	\$ 25	\$ 22	\$ 19	\$ 18
	Capacity	\$25	\$16	\$13	\$12	\$10	\$9
	Energy x 4	\$184	\$120	\$99	\$89	\$76	\$72
	Total Levelized Fixed Costs (\$2016)	\$209	\$135	\$113	\$101	\$86	\$82
	Total Levelized Fixed Costs Nominal	\$227	\$159	\$140	\$133	\$153	\$160
	ELCC Adjustment	100%	97%	91%	88%	36%	19%
	ELCC Adjusted Nominal Fixed Costs	\$227	\$163	\$154	\$151	\$422	\$844



Financial Pro-Forma for IRP Resource Costs

Pro_Forma tab from RESOLVE Resource Costs and Build

Resource Cost, Performance, & Financing			
System Cost		Income Tax Assumptions	
System Size (MW)	1	Income Tax - Federal	21.0%
Duration (hours)	4	Income Tax - State	8.8%
Capacity Costs (\$/kW)	\$191	Income Tax - Effective Tax Rate	27.98%
Energy Costs (\$/kWh Installed)	\$265	Tax Credit - Federal PTC (\$/MWh)	50.00
System Cost (\$/kW)	\$1,250	Tax Credit - Federal PTC (Years)	0
Capacity Costs (\$)	\$190,956	Tax Credit - Federal PTC Escalator	2.00%
Energy Costs (\$)	\$1,059,409	Tax Credit - Federal ITC (%)	0%
System Cost (\$)	\$1,250,365	Tax Credit - Federal ITC - % of Capital Cost Eligible	95%
Initial debt service reserve funding (\$)	0	Tax Depreciation Basis Reduction - % of ITC	50.00%
Total System Cost (\$)	\$1,250,365	MACRS Term	7
Interconnection Cost (\$/kW)	\$0	Bonus Depreciation	FALSE
Interconnection Cost (\$)	\$0	Bonus Depreciation Amount	100.00%
Performance Inputs		Financing	
Capacity Factor (AC)	15.0%	Optimize Leverage for IPP Return?	FALSE
Annual Output for Year 1 (kWh)	1,314	Equity Share	80.00%
Degradation Factor	0.00%	% Financed w/ debt	20.0%
System Economic Life (=PPA Term)	20	Cost of Debt	4.7%
Ongoing Costs		Cost of Equity	10.6%
Fixed O&M Costs Capacity (\$/kW-yr)	\$2.86	Debt period in years	18
Fixed O&M Costs Energy (\$/kWh Installed-yr)	\$3.97	WACC	9.13%
Fixed O&M Costs (\$/kW-yr)	\$18.76	Interest Rate on DSRF	2.36%
Fixed O&M Costs Escalator (%/yr)	2.00%	PPA Escalation Rate	2.00%
Variable O&M Costs (\$/MWh)	\$0.00	Variable Cost Pass Through	TRUE
Variable O&M Costs Escalator (%/yr)	2.00%	Equity Amount	\$1,000,292
Fuel Costs (\$/MMBtu)	\$0.00	Debt Amount	\$250,073
Fuel Escalator (%/yr)	0.00%	NPV Equity Return Check	\$0
Heat Rate (Btu/kWh)	0	Target DSCR	1.40
CO2 Allowance Price (\$/ton)	\$0.00	Active DSCR	7.48
CO2 Allowance Price Escalation (%/yr)	0.00%	Cell Color Coding	
CO2 Emission Rate by Fuel (lb/MMBtu)	-	Input	
Property Tax (%)	0.0%	Calculated Input	
Insurance (%)	0.00%	Lookup Formula	
Warranty (%)	1.5%	Final Outputs	
Warranty Start Year	2.000	Not used	
Augmentation (%) (per kWh installed)	4.2%		

Outputs	\$/MWh	\$/kW-yr
Capital	\$99.56	\$130.82
Interconnection Cost	\$0.00	\$0.00
Property Tax & Insurance	\$0.00	\$0.00
ITC	\$0.00	\$0.00
Fixed O&M	\$14.27	\$18.76
Warranty	\$11.62	\$15.27
Augmentation	\$33.86	\$44.50
Periodic Replacement	\$0.00	\$0.00
Variable O&M	\$0.00	\$0.00
Fuel	\$0.00	\$0.00
Carbon	\$0.00	\$0.00
PTC	\$0.00	\$0.00
Total	\$159.31	\$209.34



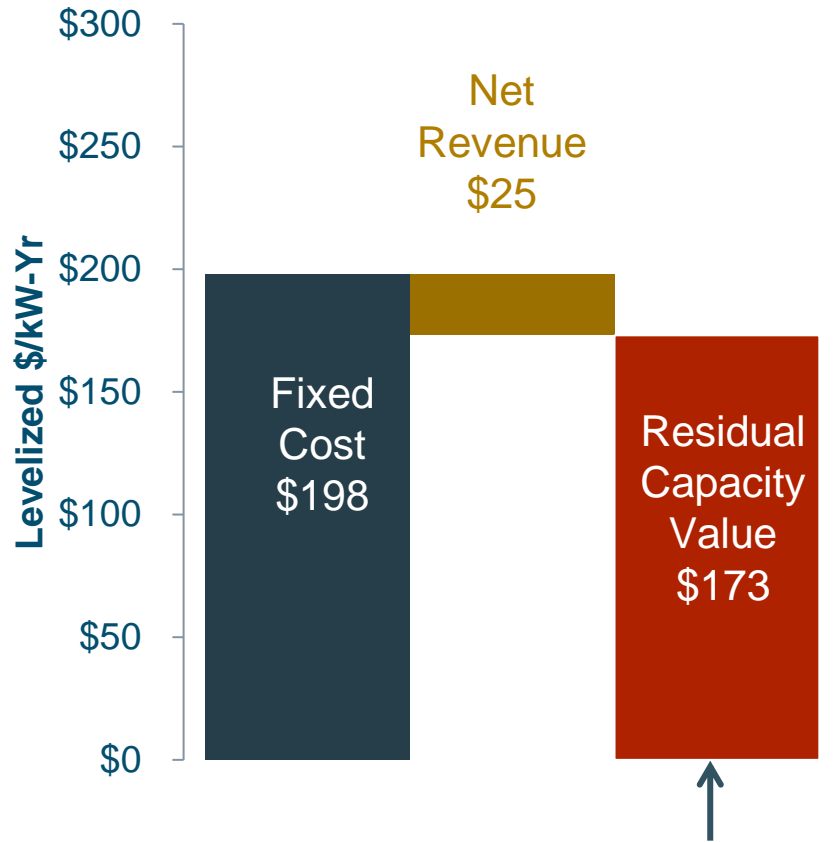
Energy+Environmental Economics

Net CONE Results

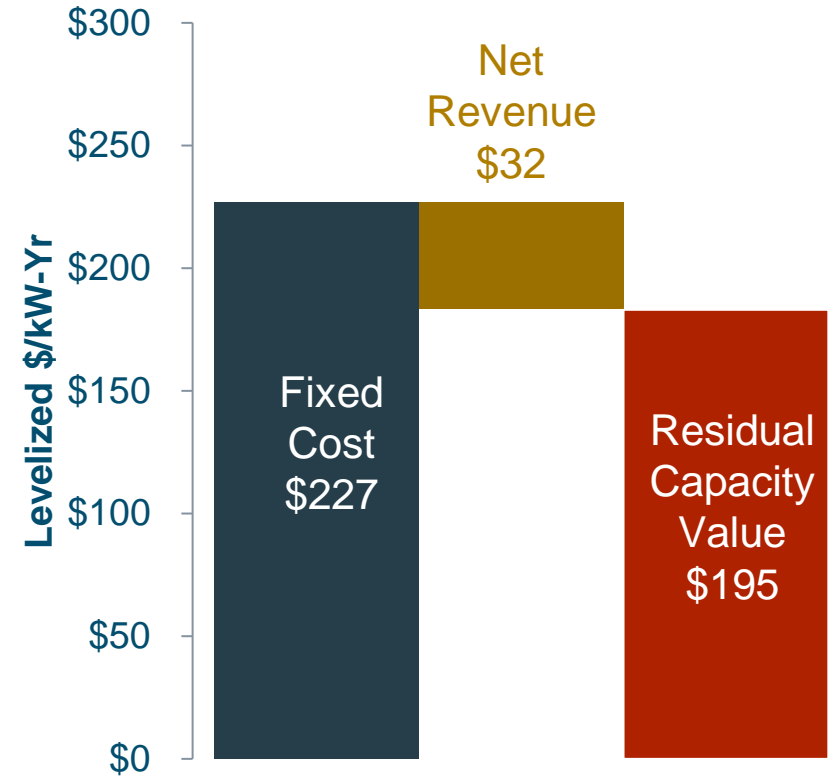


Comparing Capacity Value

Combustion Turbine



Energy Storage



aka "CONE": Cost of New Entry



E3 Energy Storage Modeling

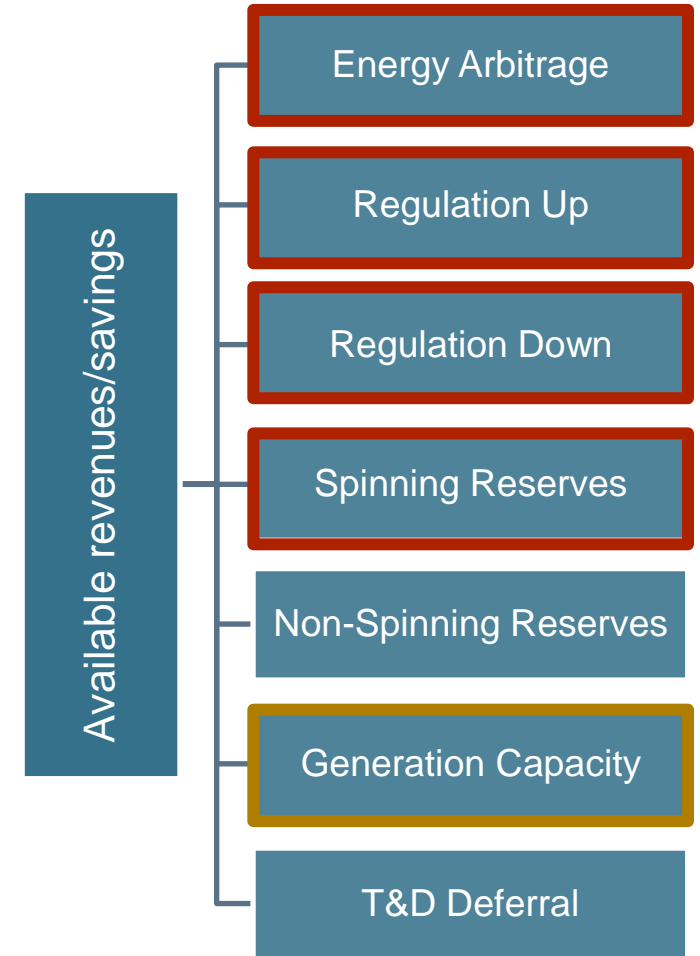
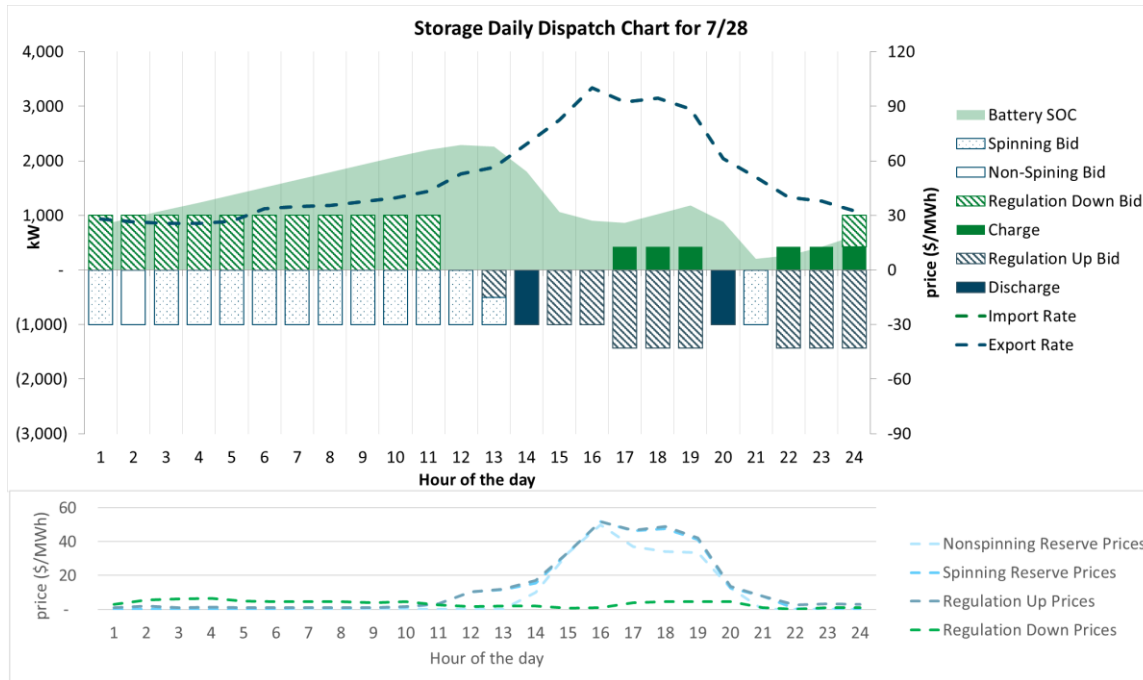
- Benefit-cost analysis
- Asset valuation
- Simulation of market operations
- Market revenue potential
- Utility retail rate design
- Adoption modeling
- Batteries
- Pumped Hydro
- CAES
- Flow batteries
- Ice storage





Overview of Storage Dispatch Modeling

- + CEC Solar + Storage tool developed by E3 and used for SGIP Storage Evaluation
- + A price-taker optimization model with perfect foresight to maximize value across multiple revenue streams
 - Maximize net revenues
 - Value stacking to achieve maximum potential value





Net CONE Results

+ Files and storage dispatch results available here:

<https://www.ethree.com/cpuc-acc-downloads-page/>

	A	I	J	K	L	T	U	Z	AA
	weather year	regulation_down_prices	regulation_up_prices	spinning_reserve_prices	Charge	Mileage	Net_Load	Reg_Down	Reg_Down_Revenues
1	1/1/2016 0:00	0.0016	0.0016	0.001	150	0	150	1000	1.5849
2	1/1/2016 1:00	0.0008	0.0008	0.0004	150	0	150	1000	0.7722
3	1/1/2016 2:00	0.0008	0.0008	0.0004	243.5991	0	243.5991	889.8835	0.6743
4	1/1/2016 3:00	0.0008	0.0008	0.0005	150	0	150	1000	0.823
5	1/1/2016 4:00	0.0007	0.0007	0.0004	150	0	150	1000	0.6993
6	1/1/2016 5:00	0.0009	0.0009	0.0005	150	0	150	1000	0.9386
7	1/1/2016 6:00	0.0013	0.0013	0.001	150	0	150	1000	1.3352

Fixed Costs (\$2016)	2020	2024	2027	2030	2045	2050
Capacity	\$25	\$16	\$13	\$12	\$10	\$9
Energy x 4	\$184	\$120	\$99	\$89	\$76	\$72
Total Levelized Fixed Costs (\$2016)	\$209	\$135	\$113	\$101	\$86	\$82
Total Levelized Fixed Costs Nominal	\$227	\$159	\$140	\$133	\$153	\$160
ELCC Adjustment	100%	97%	91%	88%	36%	19%
ELCC Adjusted Nominal Fixed Costs	\$227	\$163	\$154	\$151	\$422	\$844
Revenues						
Net Energy Revenue (\$)	24,203	25,647	33,437	51,622	61,887	66,717
Regulation Down Revenues (\$)	13,281	20,901	27,369	28,917	175,048	266,710
Regulation Up Revenues (\$)	5,029	11,718	13,387	20,627	135,583	215,491
Spin Revenues (\$)	3,828	5,882	7,241	10,040	26,484	33,786
Total Revenues (\$)	44,141	61,484	77,835	107,110	399,002	582,705
Net Revenue (\$/kW-Yr)						
Net Revenue	\$44	\$61	\$78	\$107	\$399	\$583
After Tax Net Revenue	\$32	\$44	\$56	\$77	\$287	\$420
Net CONE	\$195	\$119	\$98	\$74	\$135	\$424
Annual Charge (kWh)	1,432,257	1,431,217	1,430,423	1,429,563	1,429,253	1,429,197
Parasitic Losses (kWh)	67,743	68,783	69,577	70,437	70,747	70,803
Annual Discharge (kWh)	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000
Round Trip Efficiency	84%	84%	84%	84%	84%	84%
Energy Revenue/Annual Discharge (\$/MWh)	\$20	\$21	\$28	\$43	\$52	\$56



Energy+Environmental Economics

Appendix



SERVM Energy Balance

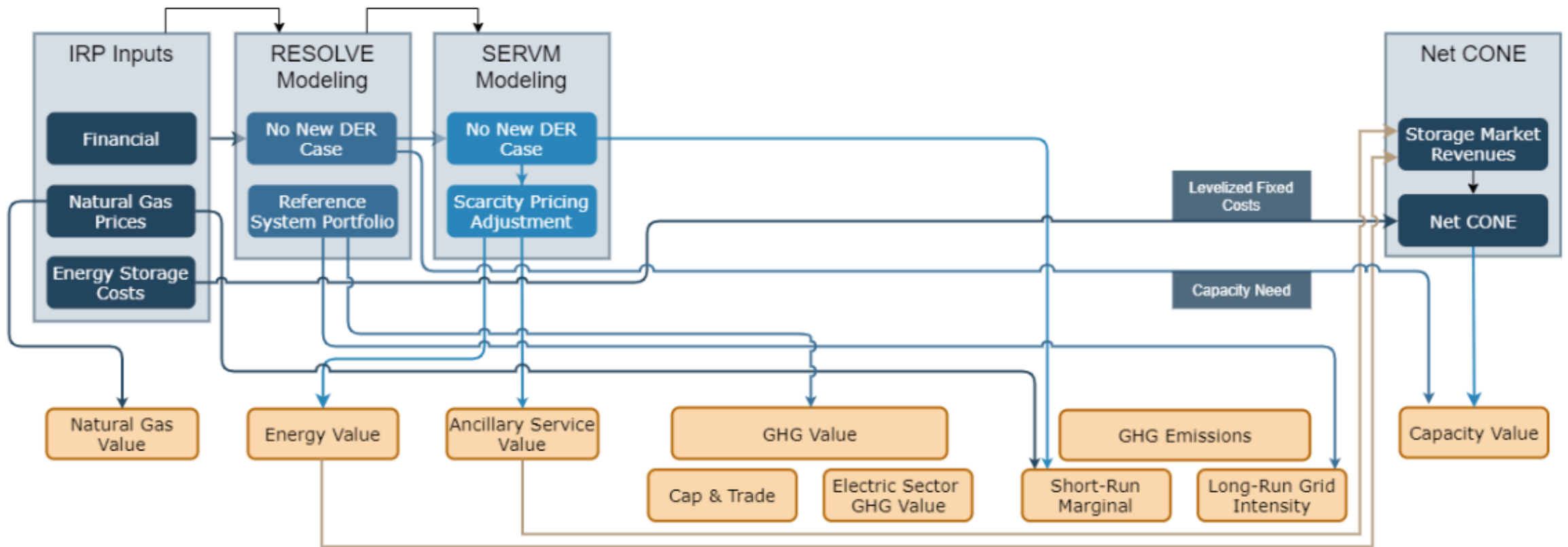
Case				
Year	2020	2022	2026	2030
Model	SERVM	SERVM	SERVM	SERVM
RA Import Limit *	5.0 GW	5.0 GW	5.0 GW	5.0 GW
Category				
CHP	10,145	9,812	10,196	10,574
Nuclear	25,711	25,711	5,563	5,136
Hydro In-state	25,392	25,391	25,392	25,391
Hydro From NW	11,000	11,000	11,000	11,000
CCGT	45,267	42,113	47,168	48,420
Peaker	1,892	2,689	6,676	8,107
BTM PV	18,579	23,225	30,556	37,949
Solar	39,697	52,455	56,892	65,177
Wind	13,810	18,830	19,631	20,508
Geothermal	13,588	13,391	13,779	13,598
Biomass	6,206	5,740	5,935	5,339
Curtailment	(119)	(411)	(260)	(1,057)
Imports (unspecified)	29,974	21,407	26,247	17,031
Exports	(743)	(3,520)	(2,402)	(7,563)
Load	241,974	246,957	252,862	255,838



Weather Year Assumption in SERVM

- + **SERVM run assumes a CTZ 22 Weather Year**
 - CTZ 22 Weather Year reflects recent climatic trends
 - Renewable generation profiles, system load profile tuned to this weather year
- + **Consistent with 2022 TDV Code Cycle**

CTZ22 Weather Year	
Month	Year
1	2004
2	2008
3	2014
4	2011
5	2017
6	2013
7	2011
8	2008
9	2006
10	2012
11	2005
12	2004





SCE CZ 9 (Los Angeles) 2025 Avoided Costs

