

# Reliability and GHG Modeling Results

## Aggregated LSE Plans

### 38 MMT Core Portfolio

August 17, 2021  
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California Public  
Utilities Commission

# Outline of this Presentation

- Summary of Results
- Background/Definitions – Loss of Load and Production Cost Modeling
- Study Definitions - LOLE studies conducted on Aggregated System Plan
  - 46 MMT Aggregated LSE Plans
  - 38 MMT Aggregated LSE Plans
- Study Definitions - 38 MMT Core portfolio
  - 2026 38 MMT Core Results
  - 2030 38 MMT Core Results
- Study Definitions - sensitivities
  - 2026 38 MMT Sensitivity – Geothermal moved to 2026
  - 2026 38 MMT Sensitivity – PSH moved to 2026
  - 2026 38 MMT Sensitivity – 1000 MW batteries moved to 2026
- Conclusion and next steps

# Summary of results

## Aggregated LSE Plans

- LSE IRP plans - Aggregated 46 MMT and 38 MMT Portfolios are not reliable.
  - LOLE are greater than 0.1 in all studies and all years.
- GHG targets met in 46 MMT case, but not met in 38 MMT cases.
- More renewable and reliability capacity is needed in order to make the LSE plans meet state objectives.

## 38 MMT Core Portfolio and Sensitivities

- The 38 MMT Core portfolio is reliable – LOLE is below 0.1 - and modeling confirms GHG emissions are significantly lower than the Aggregated LSE Plans.
- The 2026 sensitivity, enforcing 2026 rather than 2028 delivery dates on a portion of the MTR resources, demonstrates significantly lower GHG emissions and reduced reliability risk.
  - LOLE of 0.065 is below 0.1 but there is some uncertainty as to operational constraints and resource viability.
- Additional operational and LOLE results data will be made available to stakeholders for their review.

# Background

- LSEs submitted IRP plans in September 2020
  - Reached Aggregated LSE Portfolios for both 46 MMT and 38 MMT GHG scenarios after several rounds of corrections and resubmittals.
- CPUC's IRP process:
  - Staff used aggregated LSE IRP portfolios to design portfolios of new resources expected to meet electric system planning goals at least cost.
  - Staff used the SERVVM probabilistic reliability and production cost model (PCM) to validate the reliability, operability, and emissions of resource portfolios generated by RESOLVE. Staff modeled 38 MMT and 46 MMT portfolios for both 2026 and 2030 study years.

# Overall PCM Framework

- Probabilistic reliability planning approach – primary goal: reduce risk of insufficient generation to an acceptable level.
- Uses the Strategic Energy Risk Valuation Model (SERVM), a probabilistic system-reliability planning and production cost model – Configured to assess a given portfolio in a target study year under a range of future weather (20 weather years), economic output (5 weighted levels), and unit performance (outages) assumptions
- Simulate hourly economic unit commitment and dispatch
- Multiple day look-ahead informs unit commitment
- Individual generating units and all 8,760 hours of year are simulated – hourly results
- 8 CA regions, 16 rest-of-WECC regions - pipe and bubble representation of regions

# Probabilistic Reliability Model Definitions

- **Expected Unserved Energy (EUE):** expected magnitude of unserved energy, expressed in total MWh of firm electric demand or reserves unserved per year
- **Loss of loss hours per loss of load event (LOLH/LOLE):** expected average duration of each LOLE event expressed as hours/event
- **Normalized EUE:** EUE normalized by the average annual load level for the target study year
- **0.1 loss of load expectation (LOLE) per year target:** value for LOLE that corresponds to the “1 day in 10 year” industry standard for probabilistic system reliability, where  $> 0.1$  LOLE indicates a less reliable system and  $< 0.1$  LOLE indicates a more reliable system. There are no commonly accepted standards for the other forms of reliability metrics.
- **EUE Intra-Hour:** Expected unserved energy due to ramping constraints not identified 1 hour prior to the hour being simulated.
- **EUE Multi-Hour:** Expected unserved energy due to ramping constraints identified  $> 1$  hour prior to the hour being simulated
- **EUE Capacity:** Expected unserved energy due to capacity shortage

# **PCM results – Aggregated LSE 38 MMT and 46 MMT Portfolios**

# Study Definitions

- **Aggregated LSE Plans 46 MMT for 2026 and 2030**

- Staff began with the PCM baseline and electric demand inputs used to produce the Transmission Planning Process (TPP) portfolios sent to the California Independent System Operator (CAISO) for their 2021-2022 TPP process. These portfolios are described in a CPUC ruling from October 2020. Staff updated the baseline resource fleet with new units online in CAISO information, then replaced RESOLVE planned capacity with capacity included in aggregated LSE 46 MMT portfolios to generate Aggregated 46 MMT LSE Plans.

- **Aggregated LSE Plans 38 MMT for 2026 and 2030**

- The Aggregated LSE Plans 38 MMT Portfolio is also based on the TPP portfolios sent to the CAISO, adjusted for new baseline units and RESOLVE planned capacity replaced by aggregated LSE 38 MMT portfolios. The resulting Aggregated 38 MMT LSE Plans were also tested in PCM model.

CPUC ruling issuing proposed 2021-2022 TPP portfolios linked here: <https://docs.cpuc.ca.gov/SearchRes.aspx?docformat=ALL&docid=348821790>



# Specific updates to SERVM PCM model since TPP studies

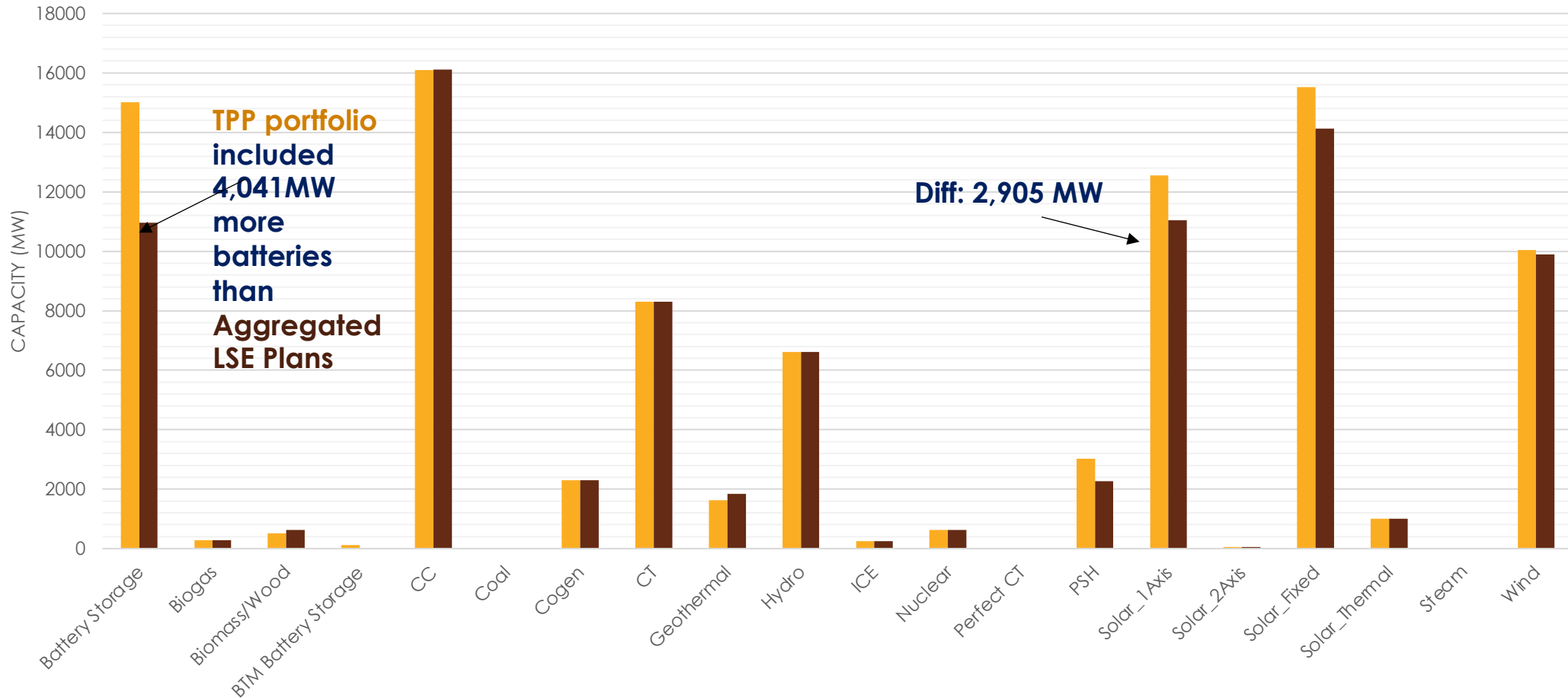
- The LSEs Portfolio represents a combination of the existing baseline resources with the new resource build-out proposed by LSEs in their IRP plans, adjusted for assumed physical limitations.
- Steps used to build the LSEs Portfolio:
  1. Began with the PCM inputs to SERVM for the TPP portfolios. The TPP portfolios are based on updated 2019 IEPR forecasts.
  2. Replaced the “Selected Resources” (new build) from RESOLVE to reflect the LSE new build portfolio preferences as submitted in their IRP plans
- Staff updated the resource baseline in SERVM in four steps - baseline reconciliation with updated CAISO generator lists, performed ground truth adjustments for data errors particularly in the WECC Anchor Data Set, added LSE IRP filings by adding Development resources firmly under contract, then finally added Review and Planned\_new resources that are not highly certain units or contracts yet

# SERVM Inputs – TPP versus PSP

- Staff studied years 2026 and 2030 of the 46 MMT and 38 MMT portfolios from LSE IRP filings. As a point of comparison to previous PCM results published for parties, staff compared the Aggregated LSE PSP to the TPP portfolio staff sent to the CAISO in January 2021 for the 2021-2022 TPP. The TPP portfolio showed greater capacity added, resulting in better LOLE and GHG results relative to the Aggregated PSP portfolio.
  - Large differences are seen in Solar and Battery additions, and by 2030 there is significantly less overall capacity in LSEs' plans
  - Other resource types are similar
  - Hybrid resources in LSE plans separated into battery and solar lines for comparison to TPP

# MW capacity – TPP portfolio vs. Aggregated LSE Plans

46MMT- capacity by category - 2030



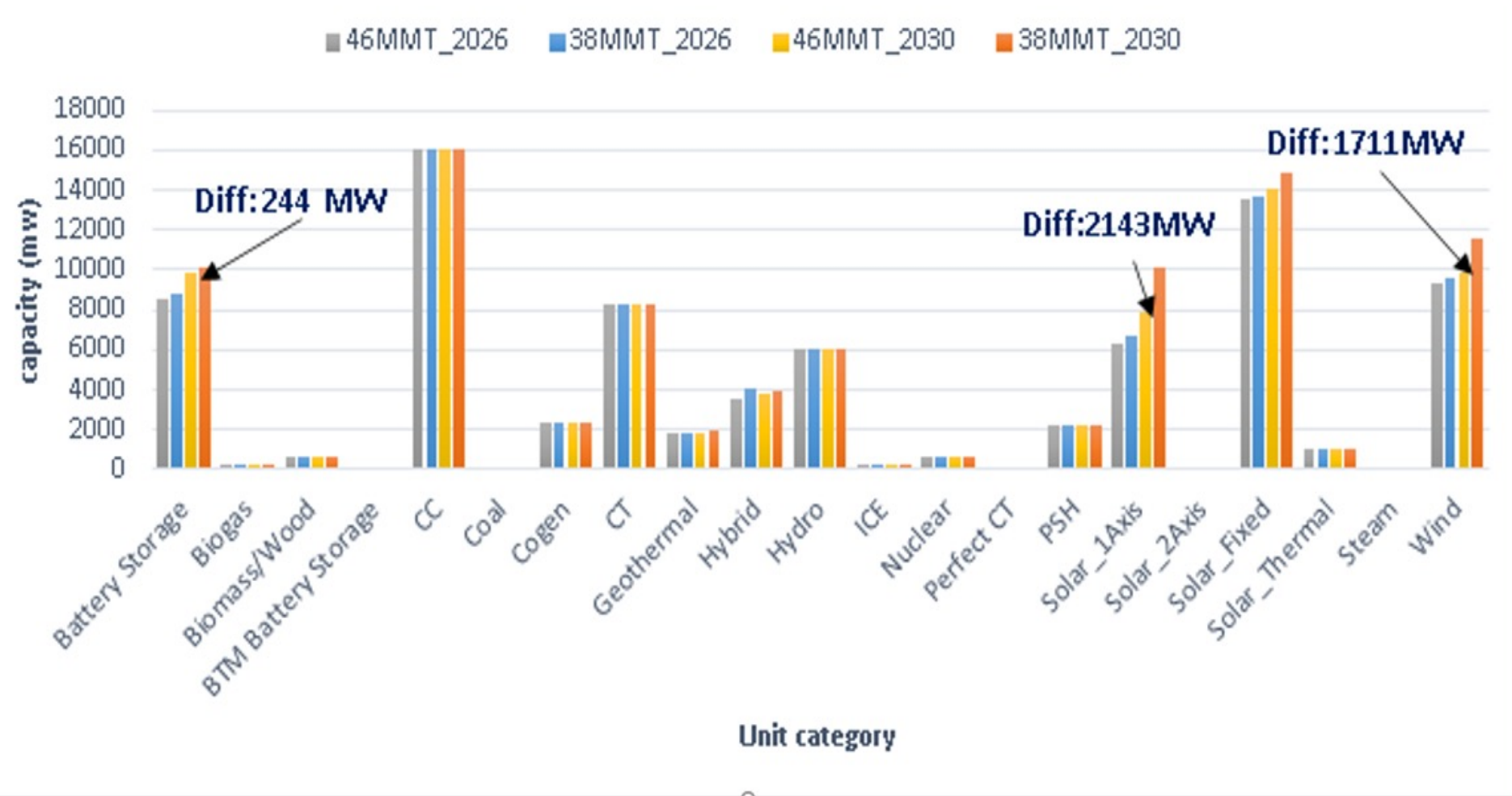
**Note – For purposes of comparison, hybrids were split into battery storage and solar categories. Also batteries were restricted to only charge from the solar, not the grid.**

# Capacity Comparison (MW) 46 and 38 MMT Aggregated LSE Plans

- Aggregated LSE Plans were similar between the 46 and 38 MMT portfolios, with the 38 MMT plans including slightly more solar and wind resources.

Unit Category	2026		2030	
	38MMT_PSP	46MMT_PSP	38MMT_PSP	46MMT_PSP
AAEE	2,121	2,121	3,279	3,279
Battery Storage	8,745	8,549	10,064	9,820
Biogas	290	290	290	290
Biomass/Wood	609	610	638	634
BTM Battery Storage	0	0	0	0
BTMPV	18,833	18,833	22,878	22,878
CC	16,116	16,116	16,116	16,116
Coal	0	0	0	0
Cogen	2,299	2,299	2,299	2,299
CT	8,307	8,307	8,307	8,307
DR	1,726	1,726	1,704	1,704
EV	-3,120	-3,120	-4,794	-4,794
Geothermal	1,803	1,768	1,910	1,840
Hybrid	4,051	3,503	3,954	3,829
Hydro	6,004	6,004	6,004	6,004
ICE	255	255	255	255
Nuclear	635	635	635	635
Perfect CT	0	0	0	0
PSH	2,273	2,273	2,273	2,273
Solar_1Axis	6,717	6,269	10,064	7,921
Solar_2Axis	47	47	47	47
Solar_Fixed	13,720	13,571	14,836	14,122
Solar_Thermal	997	997	997	997
Steam	0	0	0	0
TOU	-2,907	-2,907	-3,003	-3,003
Wind	9,658	9,393	11,602	9,891
Total	99,178	97,537	110,355	105,343

# Comparison of LSE 38MMT and 46MMT Portfolios

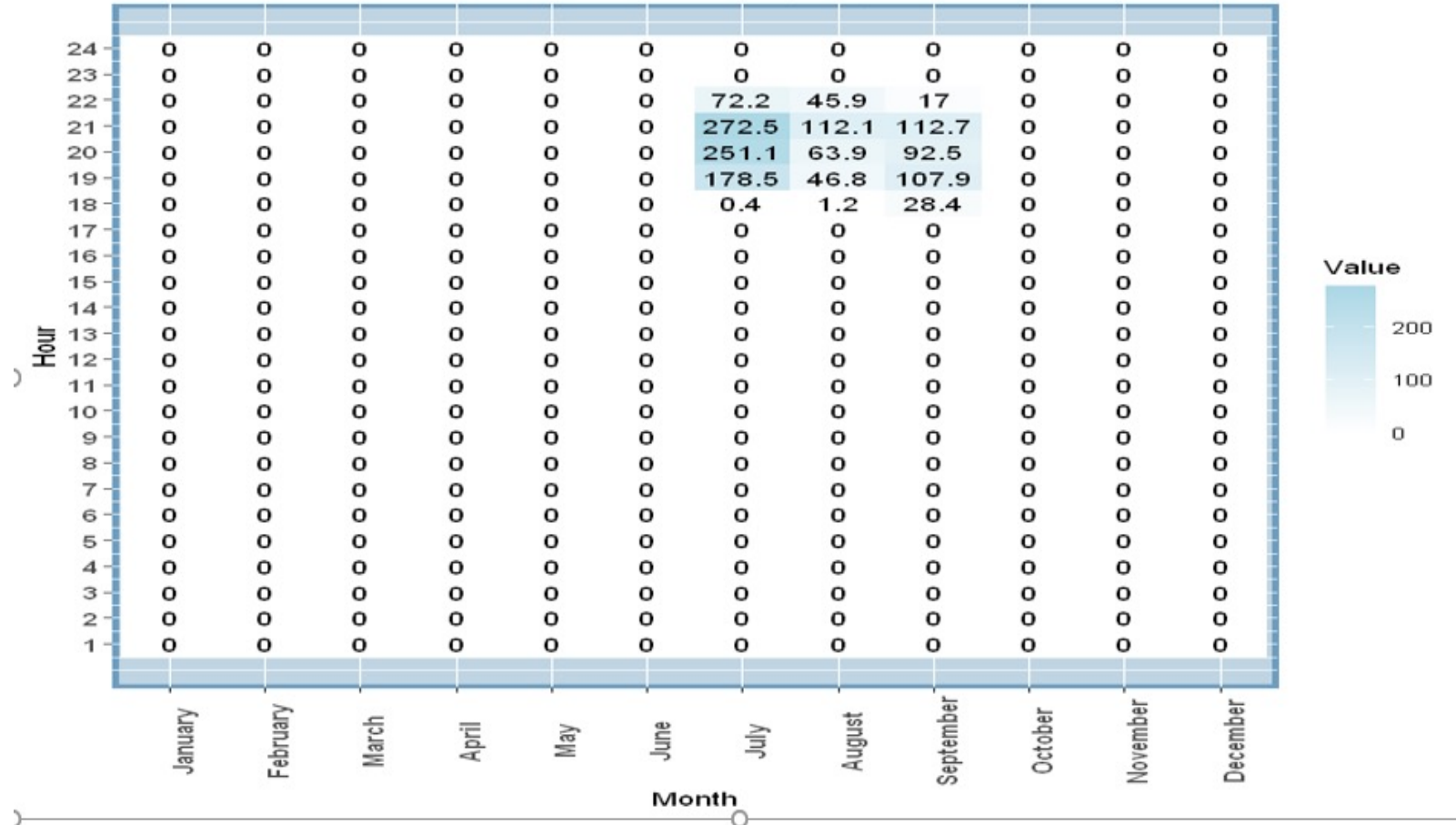


# Aggregated LSE Plans – CAISO LOLE Exceeds 0.1 target in all studies

Reliability Metrics	46MMT 2026	46MMT 2030	38MMT 2026	38MMT 2030
LOLE (expected outage events/year)	0.36	0.68	0.29	0.41
Loss of Load Hours (hours/year)	0.76	1.63	0.61	0.94
LOLH/LOLE (hours/event)	2.09	2.38	2.07	2.26
Expected Unserved Energy (MWh)	1,436.66	2,468.93	1,176.91	1,364.54
Annual load (MWh)	255,116,344	265,501,285	255,094,310	258,290,192
normalized EUE (%)	5.631E-06	9.299E-06	4.614E-06	5.283E-06

**Findings: LOLE is greater than 0.1 in all studies and all years, meaning the Aggregated LSE Plans portfolio is unreliable.**

# 38 MMT study for 2030 - EUE (MWh) by Hour and Month



- Bulk of EUE occurs in July evening hours.
- the EUE hours shift later, likely due to further peak shift from solar penetration.

NOTE: The chart only shows hours with nonzero EUE in at least one month. The graded color scale shows the magnitude of the EUE in a given month-hour. Dark blue indicates the largest EUE, followed by light blue, and white.

# SERVM Annual Energy Generation Results (GWh)

Resource type/Annual GWh	46MMT_2026	46MMT_2030	38MMT_2026	38MMT_2030
CAISO_CCGT1	44,715	46,109	43,721	41,023
CAISO_CCGT2	5,323	5,616	5,211	4,984
CAISO_Peaker1	2,795	3,138	2,852	3,002
CAISO_Peaker2	1,453	1,789	1,482	1,682
Perfect CT	0	0	0	0
Steam	0	0	0	0
Coal	0	0	0	0
Biomass	6,609	6,547	6,534	6,046
BTMPV	32,301	39,177	32,256	38,100
All Solar: fixed PV, tracking PV, solar thermal	51,436	57,487	53,075	63,541
Wind	23,534	24,730	24,570	28,056
Scheduled Hydro Plus ROR Hydro	25,122	25,394	25,392	24,735
Geothermal	14,486	14,951	14,714	14,760
Cogen	12,010	12,285	11,997	11,738
Nuclear	5,563	5,136	5,563	4,995
ICE	71	88	70	75
<b>Generation Subtotal Before Curtailment</b>	<b>225,418</b>	<b>242,446</b>	<b>227,437</b>	<b>242,736</b>
<b>Non-PV Load Modifiers (net effect of AAEE, EV load, TOU)</b>	<b>-858</b>	<b>-2,698</b>	<b>-858</b>	<b>-2,623</b>
<b>Curtailment not included inline above</b>	<b>-551</b>	<b>-1,370</b>	<b>-674</b>	<b>-3,107</b>
<b>TOTAL not including Non-PV load modifiers</b>	<b>224,867</b>	<b>241,076</b>	<b>226,763</b>	<b>239,628</b>

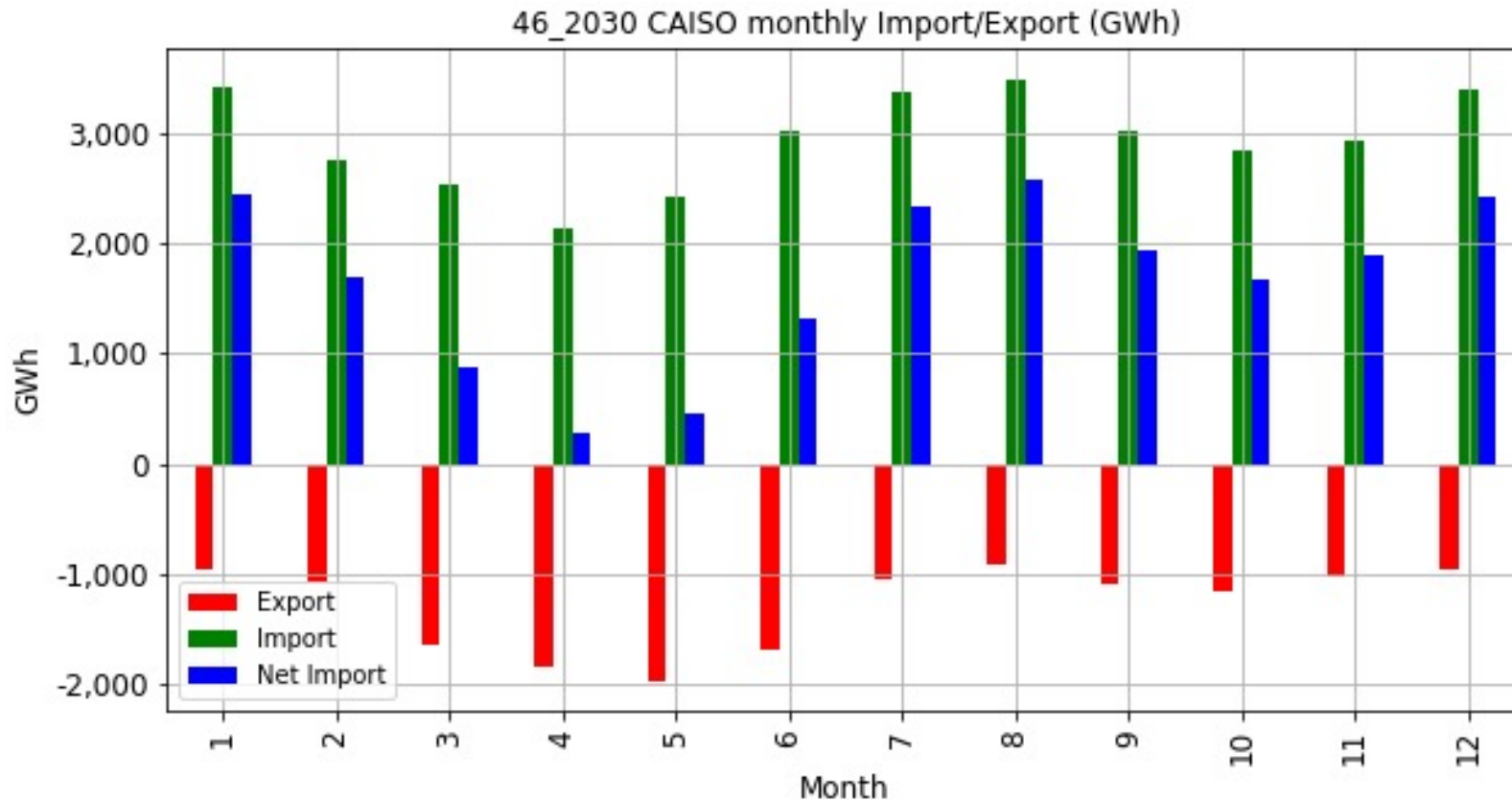


# SERV M Annual GHG Emissions Results

CAISO Emissions accounting	46MMT_2026	46MMT_2030	38MMT_2026	38MMT_2030
In-CAISO and gross direct imports thermal generation in GWh	66,367	69,024	65,332	62,504
In-CAISO and gross direct imports CO2 emissions in MMT	27.21	28.41	26.82	25.78
In-CAISO and gross direct imports average emissions factor in MT/MWh	0.41	0.412	0.411	0.412
Unspecified imports netted hourly (no NW Hydro) in GWh	20,109	17,134	19,239	13,922
NW Hydro imports in GWh	11,000	11,000	11,000	11,000
Carbon-free imports from RPS energy, RECs contracts	0	0	0	0
Unspecified imports netted hourly (no NW Hydro) CO2 emissions in MMT	8.61	7.33	8.23	5.96
Unspecified imports netted hourly (including NW Hydro) average emissions factor in MT/MWh	0.277	0.261	0.272	0.239
Total CAISO CO2 emissions in MMT	35.8	35.7	35.1	31.7
BTM CHP emissions in MMT	5	5	5	5
Total CAISO CO2 emissions in MMT, including BTM CHP	<b>40.8</b>	<b>40.7</b>	<b>40.1</b>	<b>36.7</b>

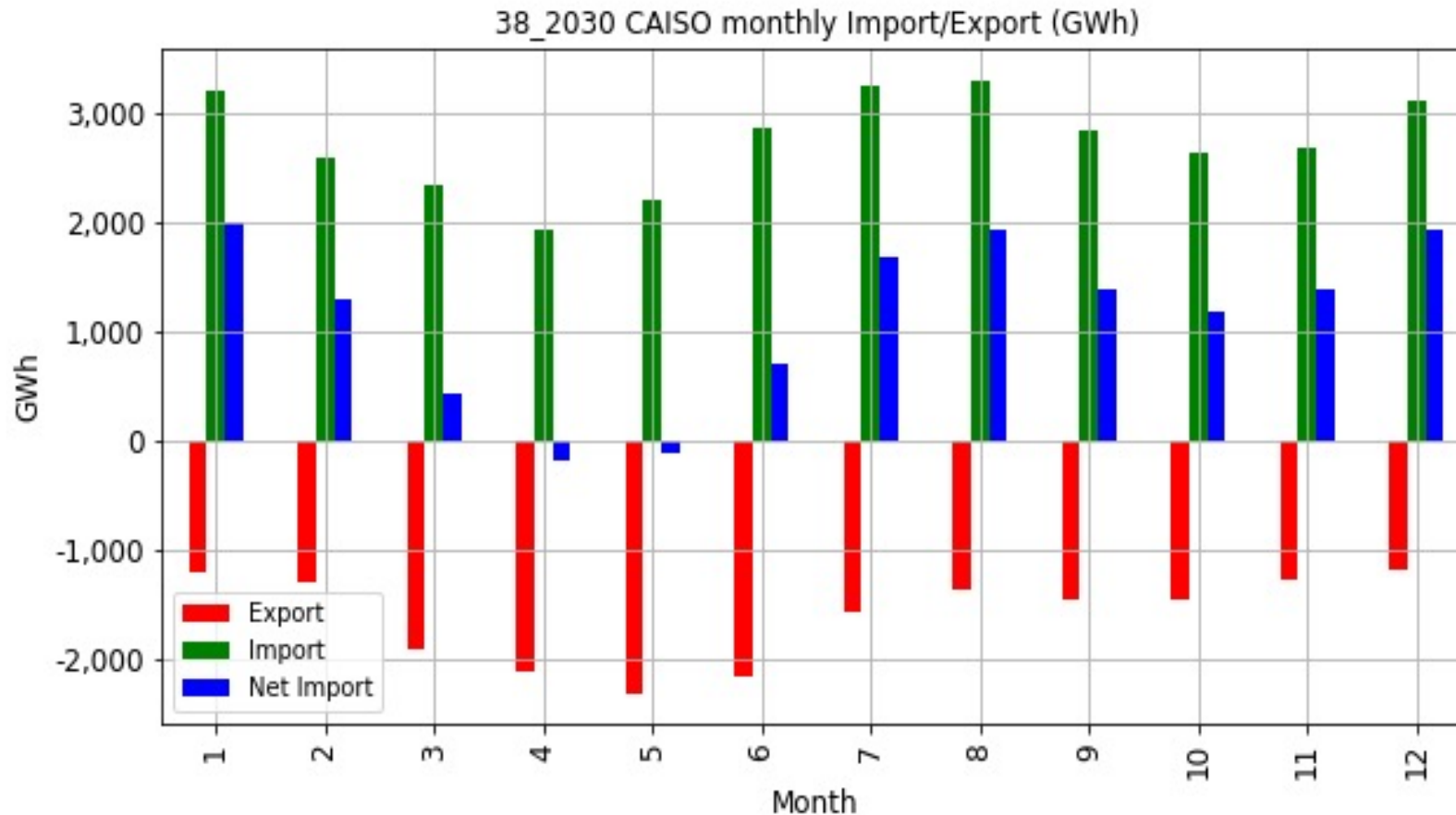
PSP portfolio GHG results close to RESOLVE in 46 MMT case **BUT about 5.5 MMT too high in the 38 MMT 2026 and 2030 cases.**

# 46 MMT 2030 CAISO average monthly Import/Export



With a 46 MMT buildout from LSE plans, CAISO is a net importer for all 12 months

# 38 MMT 2030 CAISO average monthly Import/Export



In the 38 MMT portfolio from LSE Plans, CAISO is a net importer in 10 out of 12 months and LSE plans lead to less imports in summer than 46 MMT portfolio

# Aggregated LSE Plans PCM Conclusions

- LSE IRP plans - 46 MMT and 38 MMT PSP Portfolios are not reliable.
  - LOLE are greater than 0.1 in all studies and all years.
- GHG targets met in 46 MMT case, but not met in 38 MMT cases.
- More renewable and reliability capacity is needed in order to augment the LSE plans to ensure meeting reliability and GHG targets.
- In developing the PSP, certain conventions were made even more conservative, meaning these results may understate LOLE resulting from the Aggregated LSE Plans would be even higher.
  - Reinforces that Aggregated LSE Plans portfolio is unreliable.

# **PSP 38 MMT Core Portfolio and Sensitivities**

# Study Definitions – 38 MMT Core Portfolio

38 MMT 2026 and 2030 Core Portfolio Definition:

Existing Baseline

- + Aggregated 38 MMT LSE plans
- + Mid Term Reliability procurement
- + RESOLVE resource additions

Definition of 38 MMT sensitivity cases:

2026 38 MMT Sensitivity – Geothermal moved to 2026

2026 38 MMT Sensitivity – Pumped Storage Hydro moved to 2026

2026 38 MMT Sensitivity – 1,000 MW Battery Storage moved to 2026

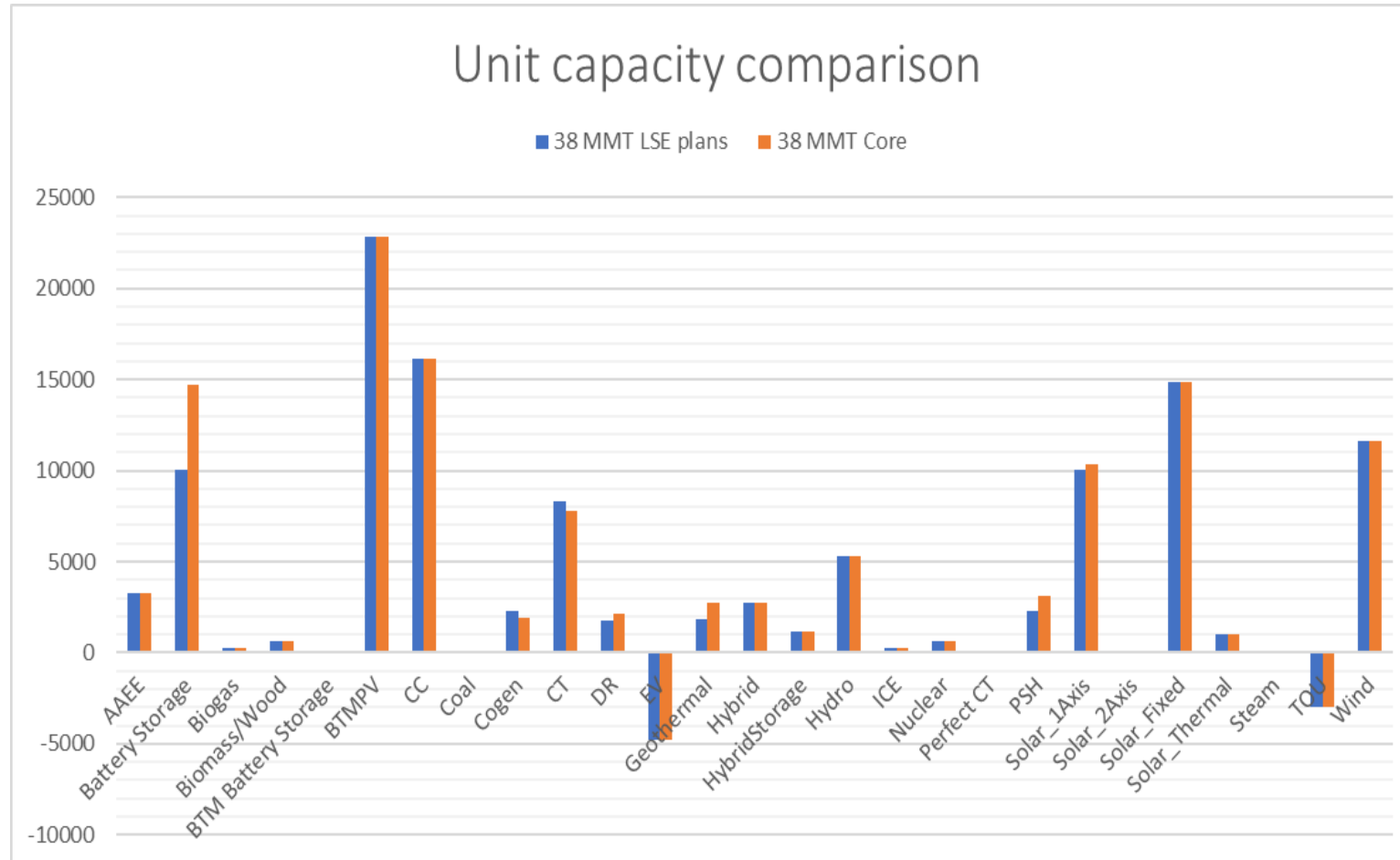
## 38 MMT Core - Modeling conventions

- 4,000 MW import restriction – imposed from HE17-HE22, Jun thru Sep (Jul thru Sep in previous studies)
- Fully implemented CAISO reserve requirements (including load following and regulation requirements) to create a LOLE event when 3% spinning reserves or 3% regulation up reserves are not met. In addition, other types of reserves (Quickstart reserves and load following reserves) were matched to CAISO requirements.
- Certain assumptions reflect historical data without projections of future climate change; for example hydro assumptions based on weather year 1998-2017, which means recent low hydro years since 2018 are not part of the analysis. Current low hydro conditions may recur in future years given climate change, particularly in California, which may exacerbate reliability conditions due to decreased overall hydro generation. Likewise, other planning assumptions may not fully represent a climate change future.

# Aggregated LSE Plans vs. 38 MMT Core (2030)

38 MMT Core case:

- +47% in battery storage
- +46% in geothermal
- +36% in PSH
- +21% in DR
- Slight increase in solar and wind
- ~950 MW thermal retirement (Cogen and CT)





# Generation in GWh RESOLVE vs. SERVM

Technology (GWh)	RESOLVE_2026	SERVM_2026	RESOLVE_2030	SERVM_2030
CAISO_CCGT1	46,106	47,036	32,273	41,118
CAISO_CCGT2	2	5,812	2	5,179
CAISO_Peaker1	1	4,341	1	4,431
CAISO_Peaker2	1	2,269	0	2,653
Battery Storage	-3,562	-3,555	-4,234	-3,838
PSH	-664	-1,772	-1,506	-2,274
Steam	0	0	0	0
Coal	0	0	0	0
Biomass	4,957	6,592	5,148	6,580
BTMPV	32,779	32,256	39,528	39,177
All Solar: fixed PV, tracking PV, solar thermal	70,302	68,749	78,547	74,688
Wind	27,334	25,066	32,980	28,849
Scheduled Hydro Plus	22,964	25,393	22,962	25,394
Geothermal	10,082	14,311	17,411	22,069
Cogen	8,967	10,156	8,967	9,961
Nuclear	5,108	5,563	5,108	5,136
ICE	7	75	6	62
Generation Subtotal	224,383	242,292	237,193	259,184
Imports (unspecified)	24,134	27,328	23,832	26,486
Exports	-3,877	-16,041	-7,030	-20,564
Net Import	20,257	11,287	16,803	5,923
Generation+NetImport	244,640	253,579	253,996	265,106

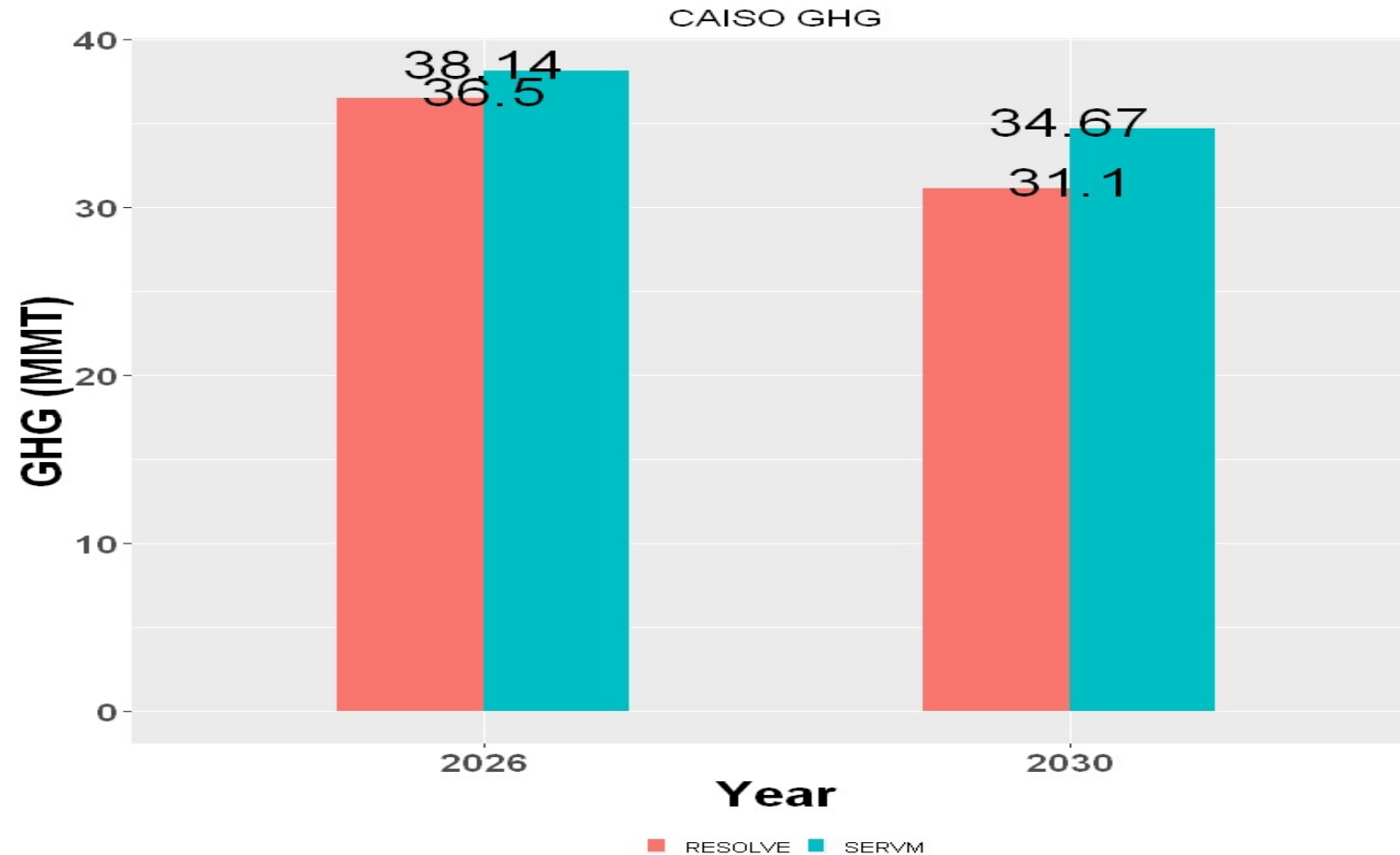
- SERVM produces similar amounts of GHG-free energy (about 201 TWh total in 2030) to RESOLVE, but more GHG emitting energy, and about 13 TWh more exports relative to RESOLVE
- SERVM produces 9% more in-CAISO generation than RESOLVE but lower net imports, totaling about 4% more total net energy for CAISO.

# 38 MMT Core LOLE Capacity results for the CAISO area

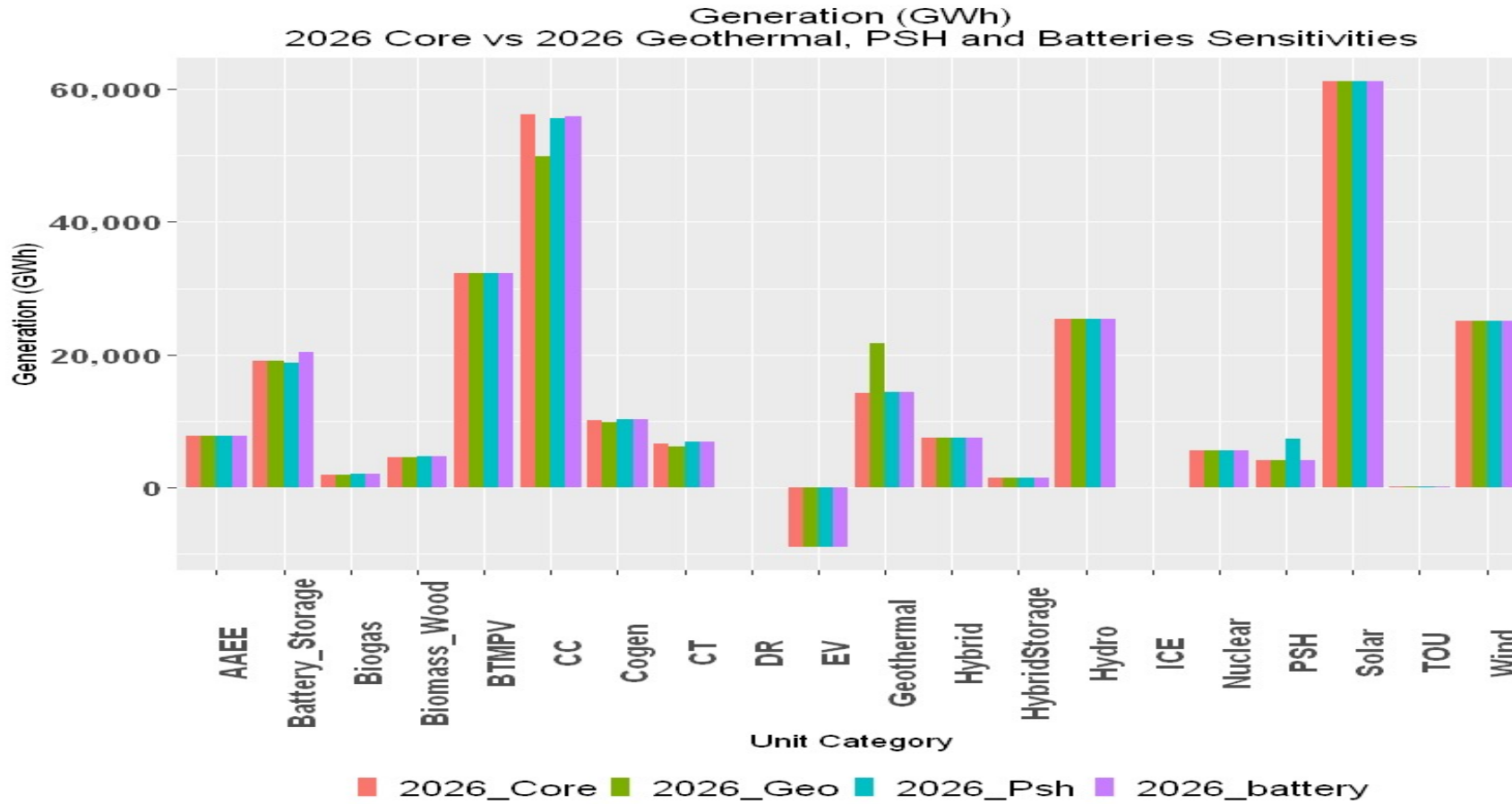
Reliability and GHG Metrics	38 MMT 2030	38MMT 2026
LOLE (expected outage events/year)	0.054	0.064
LOLH (hours/year)	0.15	0.21
LOLH/LOLE (hours/event)	1.72	1.76
EUE (MWh)	187.45	292.28
annual load (MWh)	265,753,062	255,345,985
normalized EUE (%)	7.054E-07	1.145E-06
GHG (MMT)	34.67	38.14

**Findings:** LOLE is less than 0.1 in both 2026 and 2030, meaning this portfolio is reliable. GHG emissions in 2026 are about 1 MMT higher than RESOLVE but GHG emissions in 2030 are about 3 MMT higher than RESOLVE.

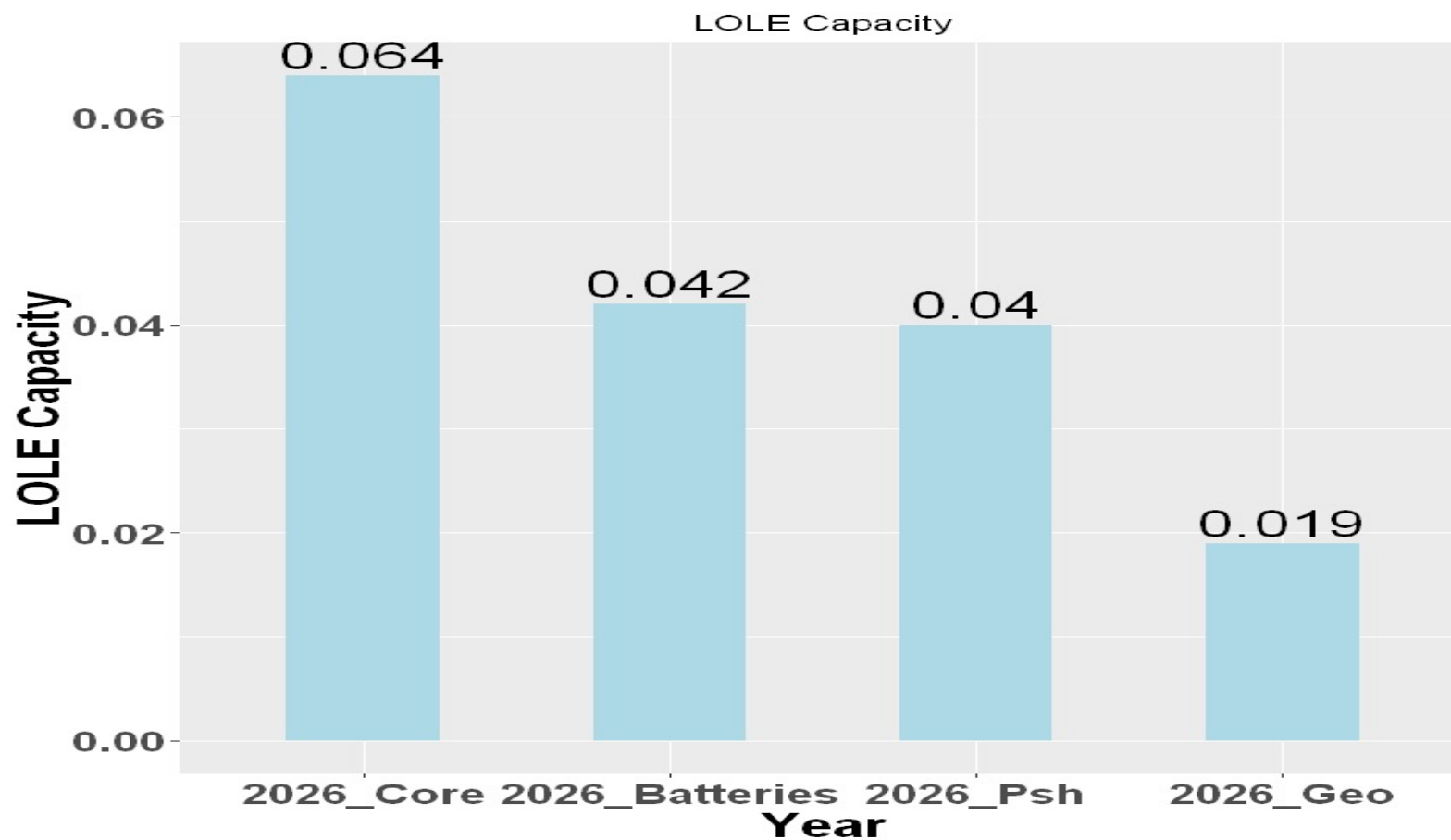
# 38 MMT Core Total CAISO CO2 emissions in MMT, including BTM CHP



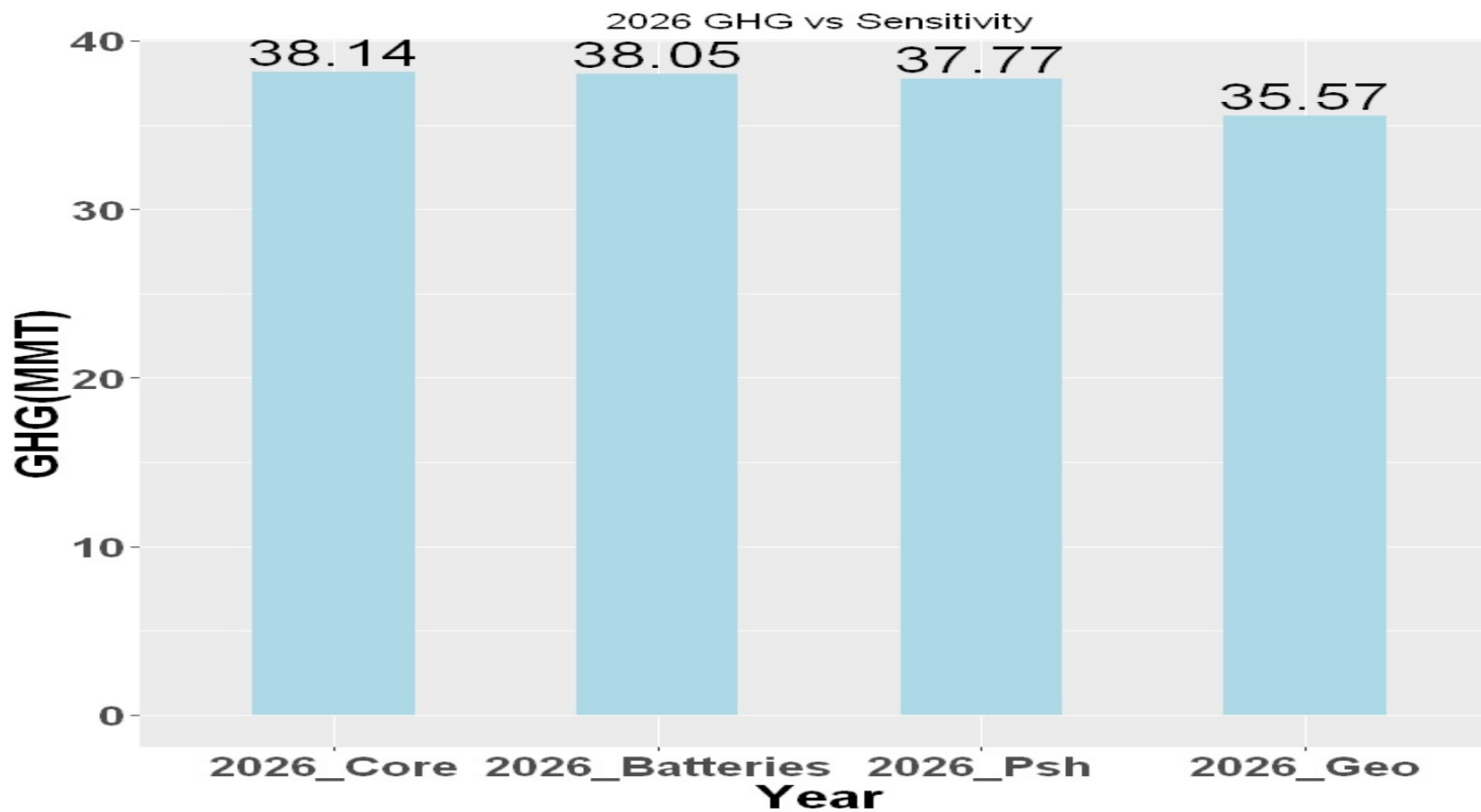
# Generation by unit category for 2026: Core vs. 3 Sensitivities



# LOLE for 2026: Core case vs. Sensitivities

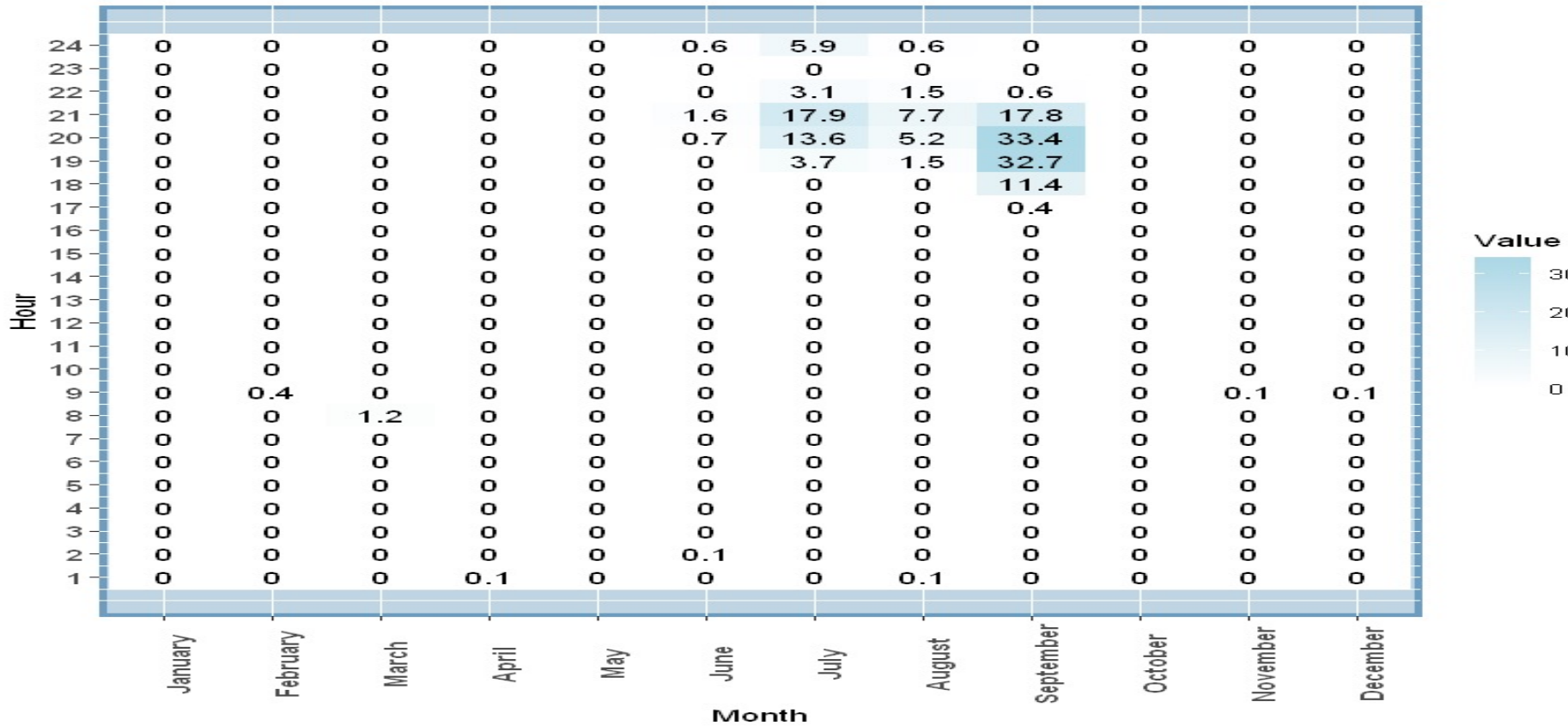


# GHG for 2026: Core case vs. Sensitivities

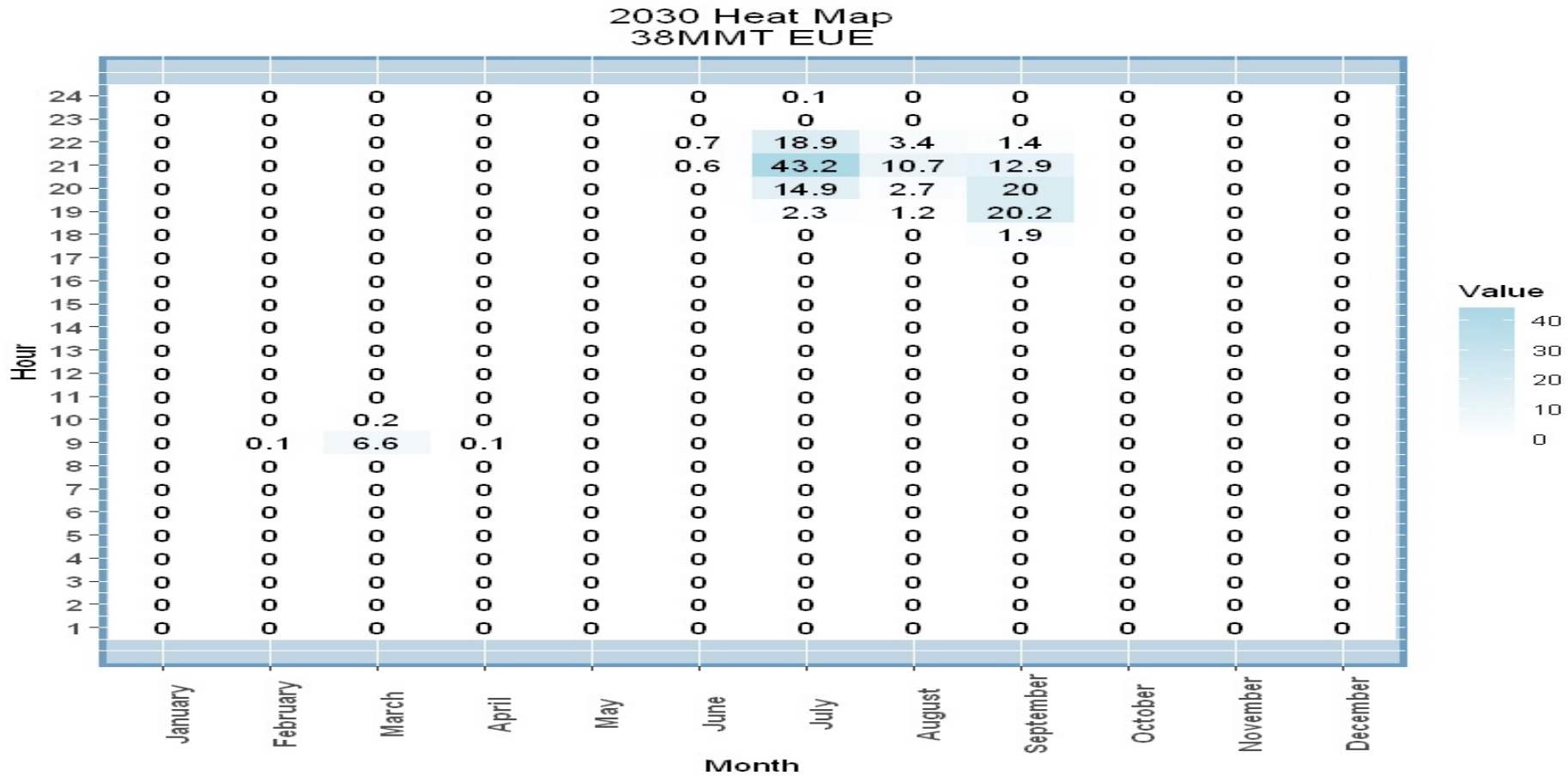


# 38 MMT Core (2026) – EUE (MWh) by Hour and Month

2026 Heat Map  
38MMT EUE

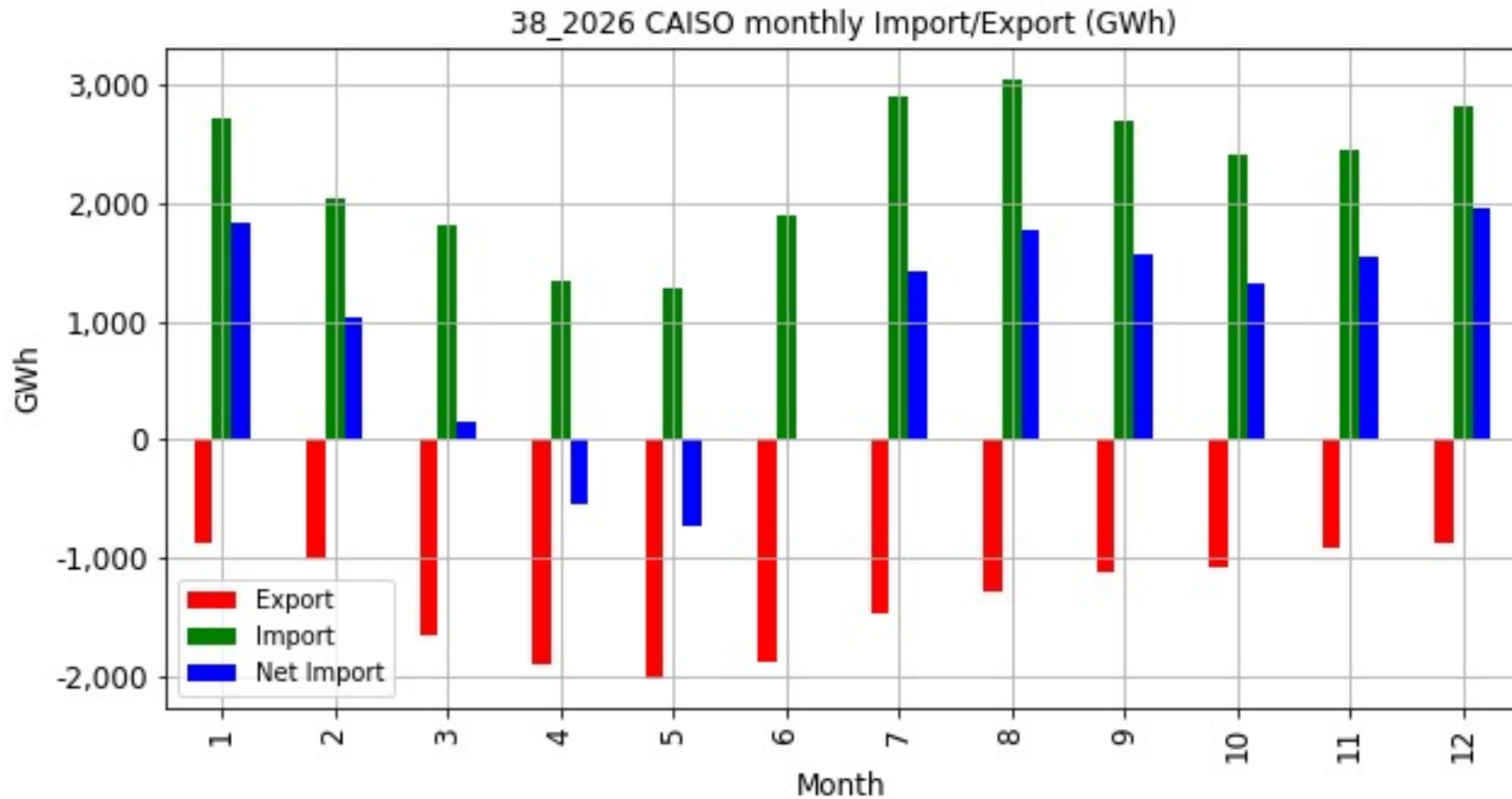


# 38 MMT Core (2030) – EUE (MWh) by Hour and Month



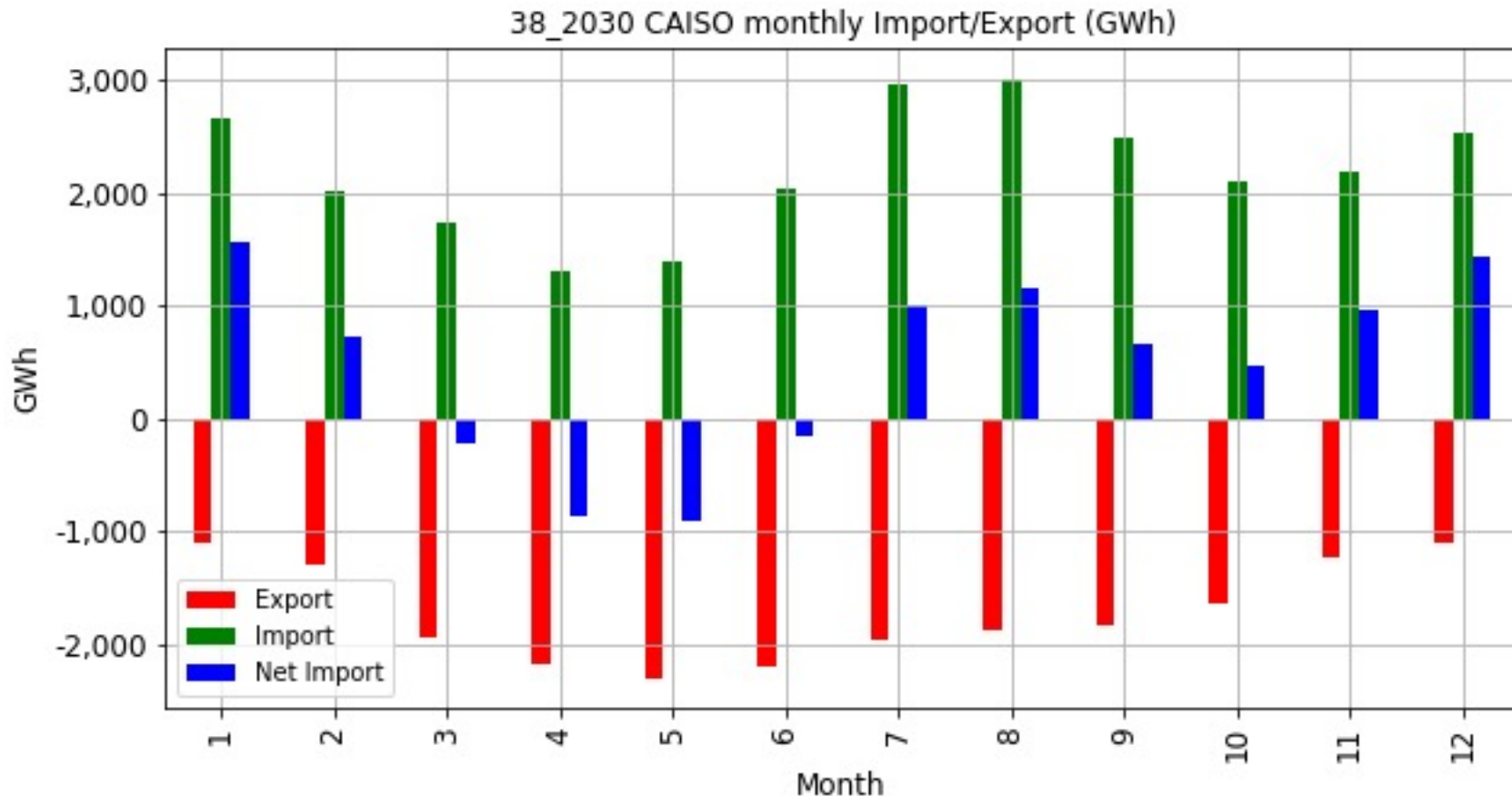


# 38 MMT Core -2026 CAISO monthly Import/Export



In 38 MMT Core case, CAISO is a net importer for 10 out of 12 months

# 38 MMT Core -2030 CAISO monthly Import/Export



In 38 MMT Core case, CAISO is a net importer for 8 out of 12 months

# 38MMT 2026 Core Criteria Pollutant metric tons

## CAISO total

	All_NOx_Emission	Cold_Emission	Hot_Emission	Warm_Emission	NOx_Steady_Emission	PM_Emission	SO2_Emission
<b>Unit_Category</b>							
<b>CC</b>	2281.2	23.3	186.7	35.3	2035.9	1248.9	132.5
<b>CT</b>	1666.8	972.5	56.8	230.3	407.2	234.1	24.8
<b>Cogen</b>	1152.2	44.5	0.5	0.0	1107.2	231.8	24.6
<b>ICE</b>	19.6	0.0	5.3	0.0	14.3	2.6	0.2
<b>Total</b>	5119.9	1040.3	249.3	265.6	3564.7	1717.4	182.1

These totals do not include biomass emissions due to incomplete data.

## CAISO DAC

	All_NOx_Emission	Cold_Emission	Hot_Emission	Warm_Emission	NOx_Steady_Emission	PM_Emission	SO2_Emission
<b>Unit_Category</b>							
<b>CC</b>	499.6	2.8	47.3	0.7	448.9	271.0	28.7
<b>CT</b>	494.3	283.9	17.2	66.2	127.1	74.1	7.9
<b>Cogen</b>	289.5	15.3	0.1	0.0	274.1	57.4	6.1
<b>Total</b>	1283.5	302.0	64.6	66.9	850.0	402.5	42.7
<b>Area_Category</b>							
<b>CA</b>	6038.2	1154.0	291.8	292.2	4300.1	2085.2	220.9
<b>OutOfCA</b>	47122.2	731.8	182.5	37.4	46170.4	14541.2	42955.4

# 38MMT 2030 Core criteria pollutant in metric tons

## CAISO total

	All_NOx_Emission	Cold_Emission	Hot_Emission	Warm_Emission	NOx_Steady_Emission	PM_Emission	SO2_Emission
<b>Unit_Category</b>							
<b>CC</b>	2042.4	17.3	206.9	37.4	1780.7	1095.3	116.2
<b>CT</b>	1735.5	1032.4	48.0	208.9	446.2	252.8	26.8
<b>Cogen</b>	1131.2	43.8	0.5	0.0	1086.9	227.6	24.1
<b>ICE</b>	16.3	0.0	4.5	0.0	11.8	2.2	0.2
<b>Total</b>	4925.4	1093.5	260.0	246.3	3325.5	1577.8	167.3

## CAISO DAC total

	All_NOx_Emission	Cold_Emission	Hot_Emission	Warm_Emission	NOx_Steady_Emission	PM_Emission	SO2_Emission
<b>Unit_Category</b>							
<b>CC</b>	444.2	1.9	50.4	0.6	391.3	236.0	25.0
<b>CT</b>	511.3	306.0	14.1	57.1	134.1	77.3	8.2
<b>Cogen</b>	286.7	14.6	0.1	0.0	272.0	57.0	6.0
<b>Total</b>	1242.2	322.5	64.6	57.7	797.4	370.3	39.3

## Area\_Category

<b>CA</b>	5891.6	1207.4	304.2	276.2	4103.8	1964.4	208.1
<b>OutOfCA</b>	47576.0	605.4	169.4	36.9	46764.3	15065.4	42852.9



# 38MMT Core CA criteria pollutants comparison in metric tons: SERVUM mix vs CARB projection

POLLUTANTS	2026 CARB	2030 CARB	2026 SERVUM	2030 SERVUM	2026 Difference	2030 Difference
NOX	7,341	7,567	6,038	5,891	-1303	-1675
SOX	1,356	1,409	221	208	-1135	-1201
PM	2,096	2,145	2,085	1,964	-11	-181

The SERVUM results reflect a cleaner resource mix than when CARB made their projections. Some of the cleaner resource mix may be driven by CPUC/LSE actions, and some may be driven by non-CAISO resource mix change.

Source for CARB projections here:  
<https://www.arb.ca.gov/app/emsinv/fce/mssumcat/fcemssumcat2016.php>



# Conclusions and Next Steps

- The 38 MMT Core portfolio is reliable – LOLE is below 0.1 – and modeling confirms GHG emissions are significantly lower than the Aggregated LSE Plans.
- The 2026 sensitivity, enforcing 2026 rather than 2028 delivery dates on a portion of the MTR resources, demonstrates significantly lower GHG emissions and reduced reliability risk.
  - LOLE of 0.065 in 2026 for the 38 MMT Core portfolio is below 0.1 but there is some uncertainty as to operational constraints and resource viability.
- Additional operational and LOLE results data will be made available after further internal and external review.

# Questions?

- Thank you for your comments and questions.
- For additional follow up, please email staff at [donald.brooks@cpuc.ca.gov](mailto:donald.brooks@cpuc.ca.gov)