Renewables Integration Study Update

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Executive Director, Market Analysis and Development

February 10, 2012

Agenda

1. Process Update: Summary of where we have been, where we are now, and where we are going
2. Detailed reports on work group activities
    1. Study Group 3 – PRM Analysis Deep Dive analysis of PRM
    2. Study Group 1 – Stochastic Simulation
    3. Study Group 2 – Step 1 Sensitivity
    4. Study Group 4 – 5 minute simulation
    5. Study Group 5 – Reserve and BAA Coordination
3. Next steps discussion

Note: Study work is in progress, results are not final and are subject to change

Process Update

Where We Have Been

- CAISO has been using PLEXOS to estimate need for new resources to integrate renewables
  - Develop detailed data inputs for hourly production simulation
    - Loads, renewable profiles, etc.
    - Regulation and Load Following Requirements (Step 1)
    - Import capabilities
  - Run PLEXOS to simulate hourly production
  - Log “violation” when resource stack is insufficient to meet load, reserve, regulation and LFU requirements
  - Add resources until no more violations

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What We Have Learned

- “Deep-dive” analysis showed us that PLEXOS results were being influenced by factors not strictly related to renewable integration needs:
  - Load levels
  - Import availability
  - Hydro production
  - Renewable production during critical hours
- These factors have traditionally been analyzed using techniques other than production simulation
  - Reliability analysis focused on loss of load

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“Deep-Dive” Analysis of All-Gas Case

- Previous analysis showed need in All-Gas Case, despite seemingly high reserve margins
- Deep-dive analysis revealed two key factors:
  1. Reserve margin was overstated -- effective PRM for the All-Gas Case is 21%, not 41%
     - Key differences are operating limits on imports, simulated hydro production vs. NQC values
  2. Need in All-Gas Case driven largely by Regulation Up and Load Following Up requirements
     - Accounts for remaining 4% increase above the 17% PRM

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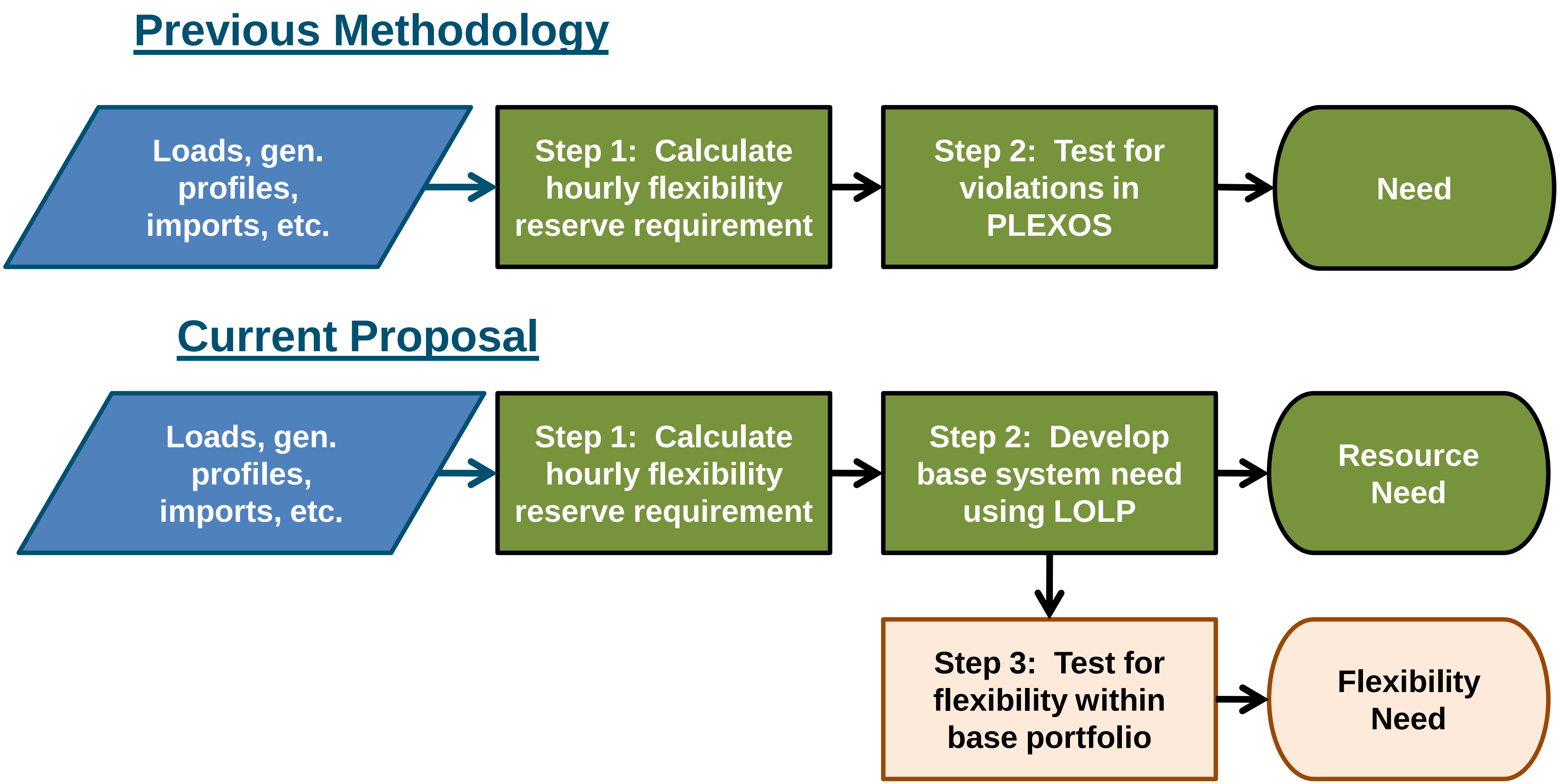
Where We Are Now

- CAISO is now proposing to supplement our modeling with a different type of analysis to address those factors unrelated to integration need, as a new step in the process
  - Reliability modeling that calculates Loss of Load Probability (LOLP) and Loss of Load Expectation (LOLE)
  - PG&E and E3 have been developing models to conduct this analysis
  - CAISO has also developed a stochastic analysis approach that to test simultaneous ramping capability
  - CAISO has not yet decided which model to use in this case

Note: Study work is in progress, results are not final and are subject to change

CAISO Proposed New Approach



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Potential Idea to Limit Scope of Current Analysis

- CAISO and some stakeholders continue to disagree about CAISO finding of need in All-Gas Case under 21% PRM
  - Some stakeholders believe Reg. and LFU requirements attributable to ***load*** are already accounted for in 17% PRM
  - CAISO continues to be concerned that the PRM does not account for these needs
- CAISO is considering whether to defer this question to a future PRM proceeding
  - This would limit the scope of our current analysis to incremental Reg. and LFU requirements associated with renewables

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Step 1 of Proposed New Approach

- Calculate Regulation and Load Following Requirements associated with variability and uncertainty of load, wind and solar for each resource portfolio
- Unchanged from previous approach

Note: Study work is in progress, results are not final and are subject to change

Step 2 of Proposed New Approach

- Conduct LOLP modeling to determine need for new capacity to meet a reliability standard of 1-day-in-10-years
  - Calibrate model to reflect 17% PRM under All-Gas Case
  - For each portfolio, calculate change to PRM needed to achieve same reliability as All-Gas Case
    - Expected renewable production will be different from NQC
    - Incremental increase in Reg. and LFU requirements due to renewable penetration
  - Add resources as needed to meet the updated PRM to reflect changes from All-Gas case

Note: Study work is in progress, results are not final and are subject to change

Step 3 of Proposed New Approach

- Test for flexibility within portfolio that comes from Step 2
  - Includes any resources added to meet reliability standard
- Need for ramping capability is not the same thing as need for new resources
  - Conversion of existing resources to something more flexible could solve a ramping problem without changing the PRM
- Stochastic component estimates the probability of having a ramping capacity shortage based on distribution of hourly ramps
  - Within-hour ramps also assessed through incorporation of Step 1 results
- PLEXOS runs to test operability of portfolio that comes from Step 3

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Study Group 3: 15-17% Planning Reserve Margin (PRM) Case Analysis

- Review of "All-Gas" indicates actual planning reserve margin is 21%
- Results are sensitive to load, imports, hydro and outages
- A portion of needs above traditional PRM attributable to load following requirements

Note: Study work is in progress, results are not final and are subject to change

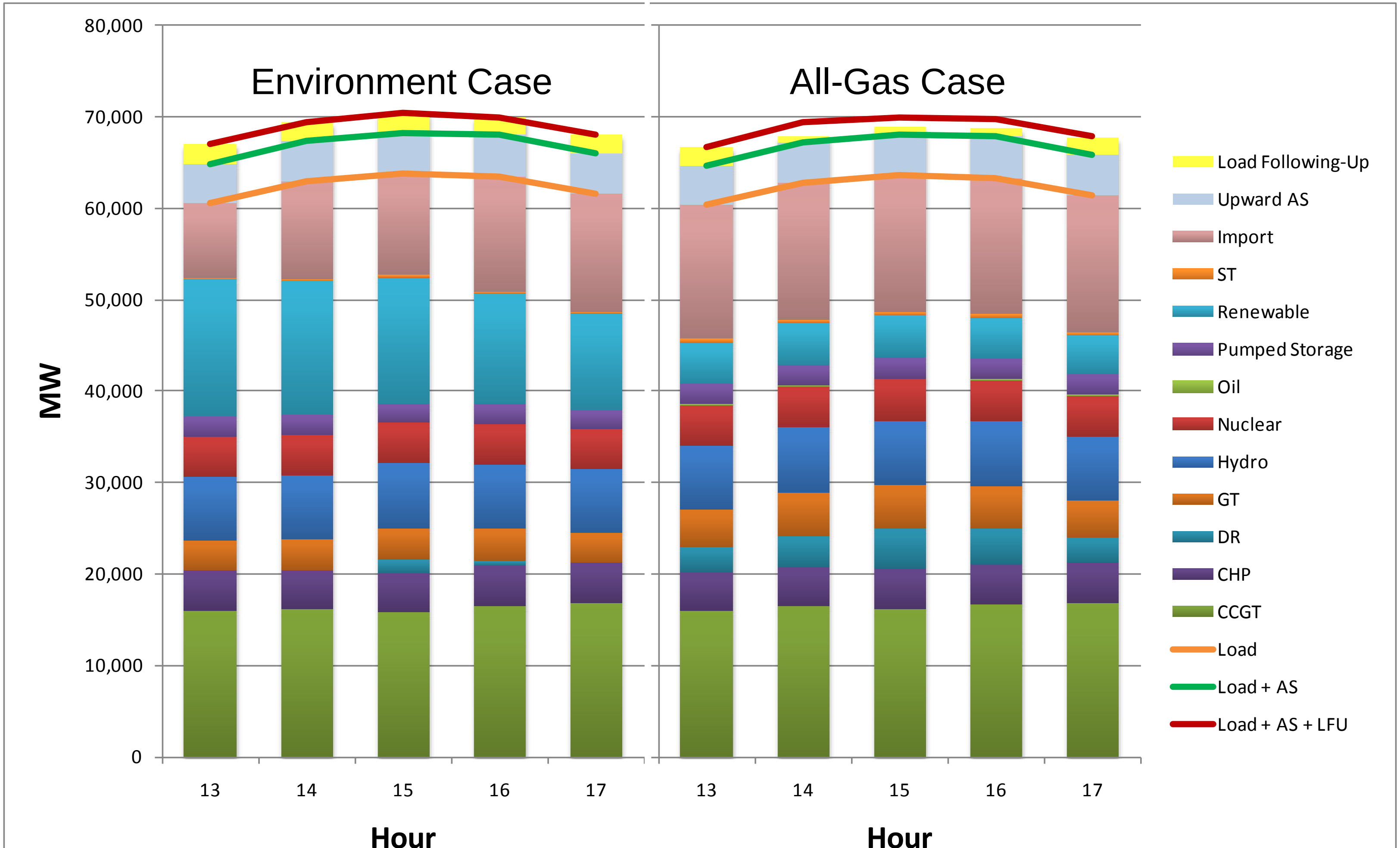
Update to the Deep-Dive Analysis – E3

Arne Olson, Partner
Nick Schlag, Consultant

CAISO Deep Dive Analysis

Shucheng Liu

Comparison of California Load and Resource Balance (July 22, 2020)



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Environment Constrained Case California Load and Resource Balance (July 22, 2020)

	H13	H14	H15	H16	H17
Demand (MW)					
Load	60,547	62,908	63,755	63,486	61,583
Upward AS	4,306	4,494	4,555	4,489	4,479
LFU	2,155	1,993	2,101	2,012	1,929
Total	67,008	69,396	70,412	69,987	67,991
Supply (MW)					
Import	8,143	10,614	11,085	12,560	12,921
Generation	52,404	52,294	52,670	50,926	48,622
Upward AS	4,306	4,494	4,555	4,489	4,479
LFU	2,155	1,993	2,101	2,012	1,929
Total	67,008	69,396	70,412	69,987	67,991
Shortage (MW)					
LFU	0	0	0	0	0
Outage (MW)	4,820	4,500	5,093	4,906	4,641

Note: Study work is in progress, results are not final and are subject to change

All-Gas Case California Load and Resource Balance (July 22, 2020)

	H13	H14	H15	H16	H17
Demand (MW)					
Load	60,389	62,744	63,589	63,321	61,422
Upward AS	4,313	4,463	4,442	4,562	4,414
LFU	1,934	2,134	1,880	1,798	2,100
Total	66,636	69,341	69,911	69,681	67,937
Supply (MW)					
Import	14,677	14,886	14,886	14,886	14,886
Generation	45,712	47,858	48,703	48,435	46,536
Upward AS	4,313	4,463	4,442	4,562	4,414
LFU	1,934	823	817	838	1,813
Total	66,636	68,031	68,848	68,721	67,650
Shortage (MW)					
LFU	0	1,311	1,063	961	287
Outage (MW)	4,820	4,500	5,093	4,906	4,641

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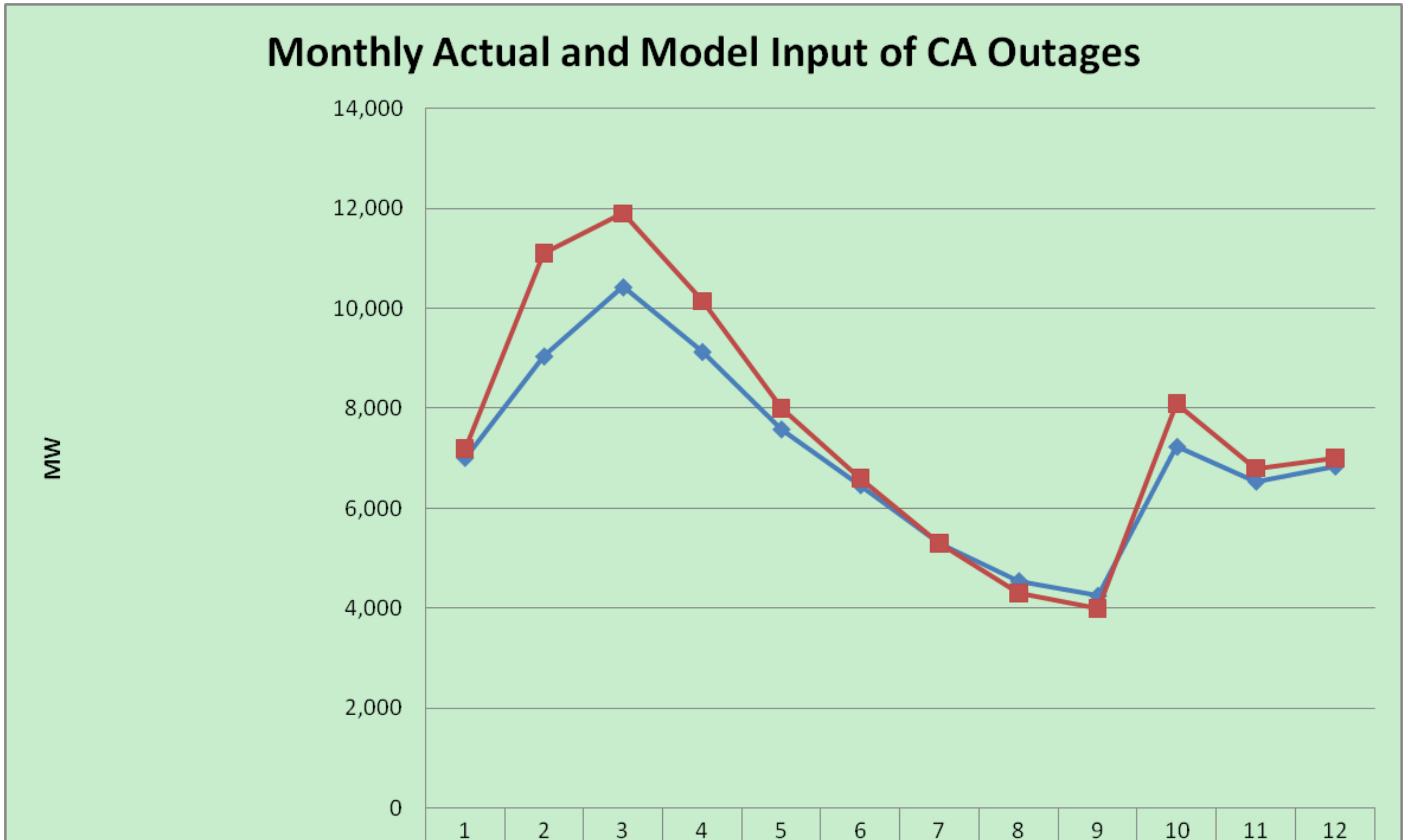
Plexos Model California Outage Assumption



	1	2	3	4	5	6	7	8	9	10	11	12
Model Input Assumption	7,014	9,045	10,428	9,133	7,584	6,467	5,309	4,547	4,256	7,236	6,540	6,843
2010 CAISO Monthly Minimum	7,200	11,100	11,900	10,146	8,000	6,600	5,300	4,300	4,000	8,100	6,800	7,000

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Study Group 1: Stochastic Simulation

- Purpose
  - To incorporate uncertainties in key input assumptions in determining need for capacity
- Scope
  - May apply to all cases
  - May be used together with Plexos simulation
- Study Approach
  - Probabilistic simulation
  - Loss of Load Probability (LOLP)

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E3- LOLP Analysis Work

California ISO Working Group

February 10, 2012

Arne Olson
Andrew DeBenedictis
Ryan Jones

PG&E Using GE-MARS to estimate resource need for 33% RPS scenarios

January 2012

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A Stochastic Model for Analyzing Ramping Capacity Sufficiency

Shucheng Liu, Ph.D.
Principal, Market Development

January 5, 2012

A stochastic model is needed to assess the probability of upward ramping capacity sufficiency.

- A deterministic production simulation case adopts only one of the many possible combinations of input assumptions
- A stochastic model can evaluate various input combinations based on probability distributions and correlations among the stochastic input variables
- Monte Carlo simulation determines the probability of having a ramping capacity shortage
- It complements the deterministic production simulation

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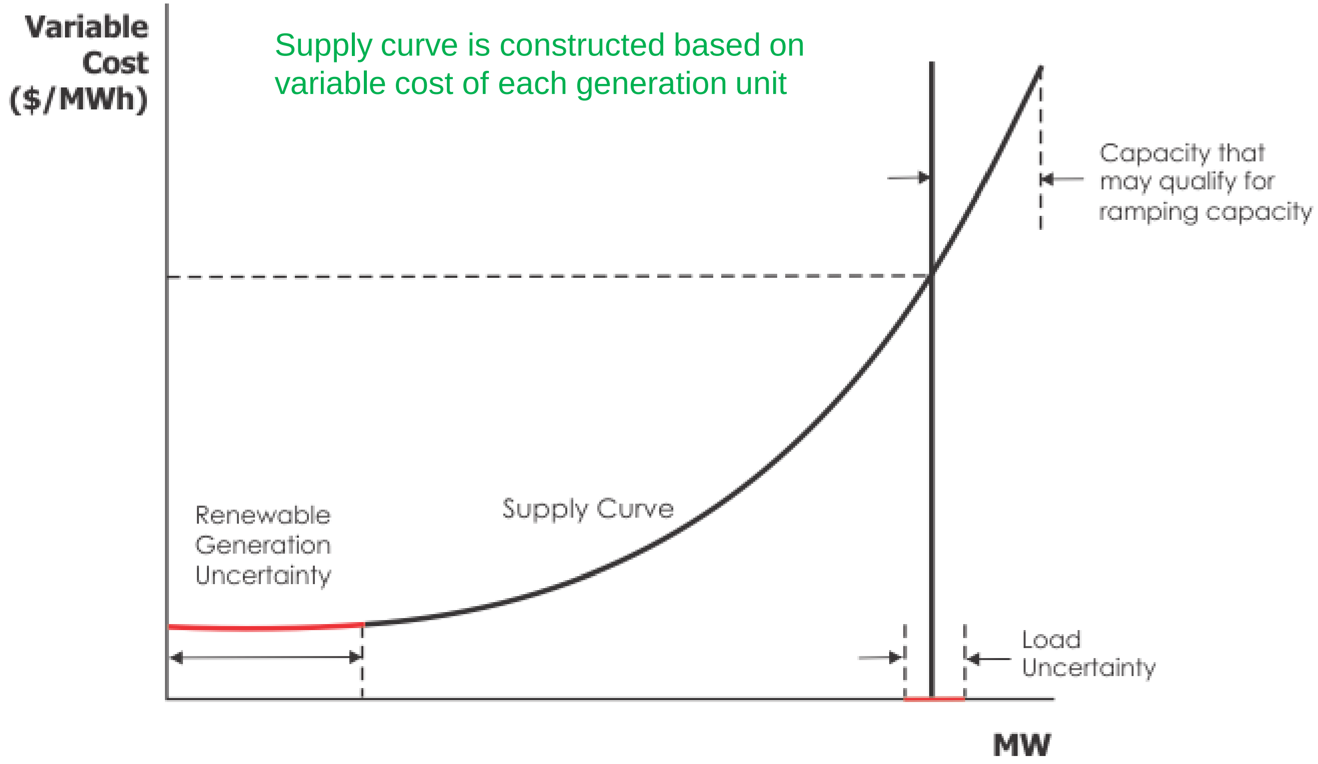
Available ramping capacity depends on the balance of supply and demand.



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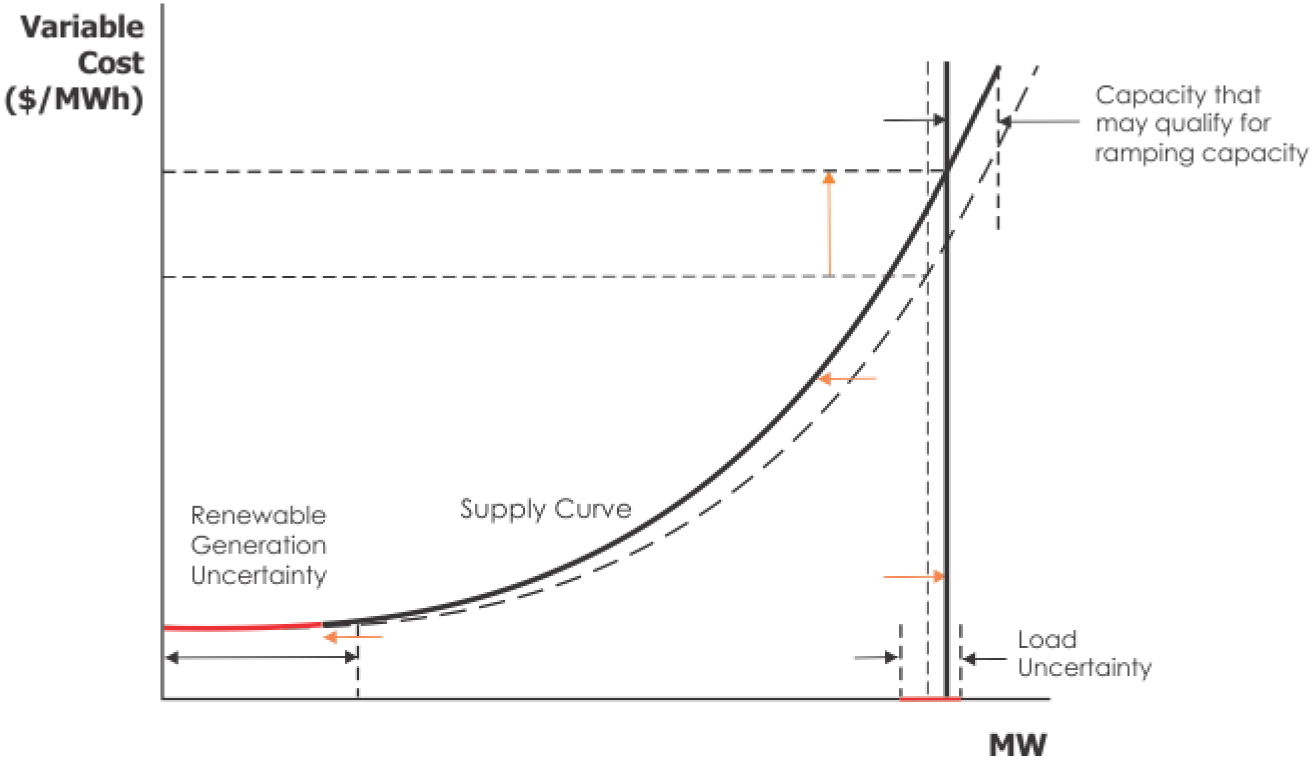
Uncertainties in supply and demand affect availability of ramping capacity.



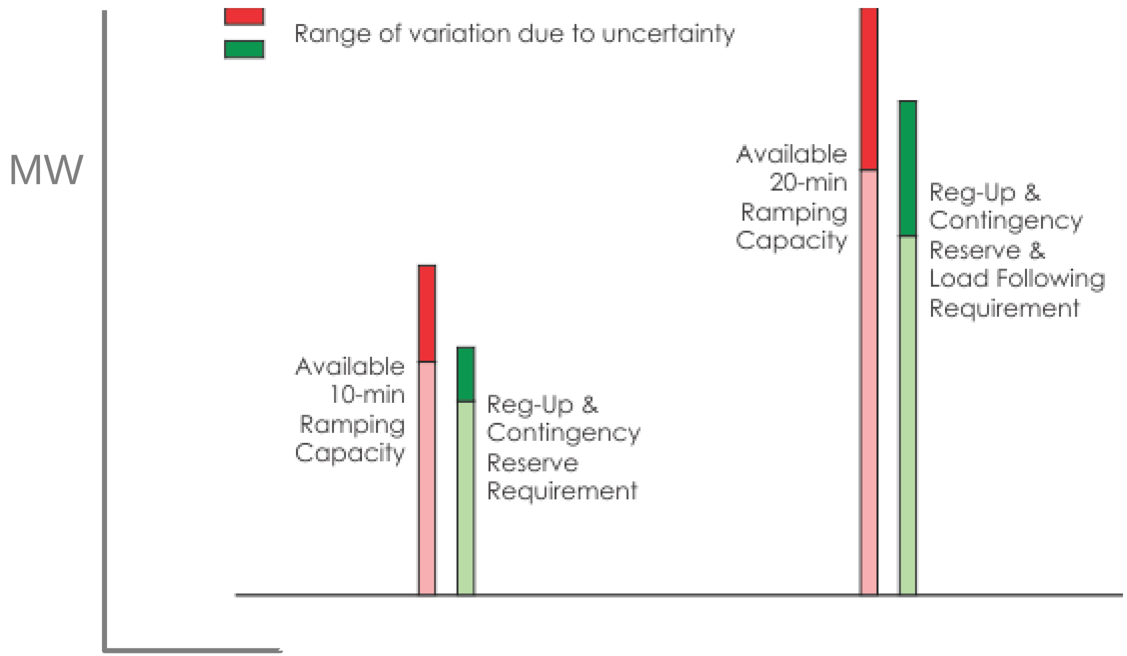
Note: Study work is in progress, results are not final and are subject to change

Available ramping capacity of each generation unit is determined based on the following factors:

- Maximum and minimum capacity
- Unit availability (due to forced and maintenance outages)
- Dispatch level
- Ramp rate
- Ramp time allowed (10 or 20 minutes)

Note: Study work is in progress, results are not final and are subject to change

Ramping capacity shortage may occur due to variations in both availability and requirement.



Note: Study work is in progress, results are not final and are subject to change

This CA-wide stochastic model considers uncertainties in some of the key inputs, including:

- California load forecast
- Requirements for regulation-up service and load following-up
- Generation by wind, solar, and hydro resources
- California total import capability
- Availability of generation units

Note: Study work is in progress, results are not final and are subject to change

The model is developed for a time period in which all hours have similar conditions.

- It is not a unit commitment model
- The model does not have chronologic constraint (such as min run time and min down time, etc.)
- All hours within the period are assumed to be independent from each other and have identical probability distribution functions
- Monte Carlo simulation determines the probability of having ramping capacity shortage for each hour
- Probability of ramping capacity shortage in the whole year is calculated using Binomial distribution

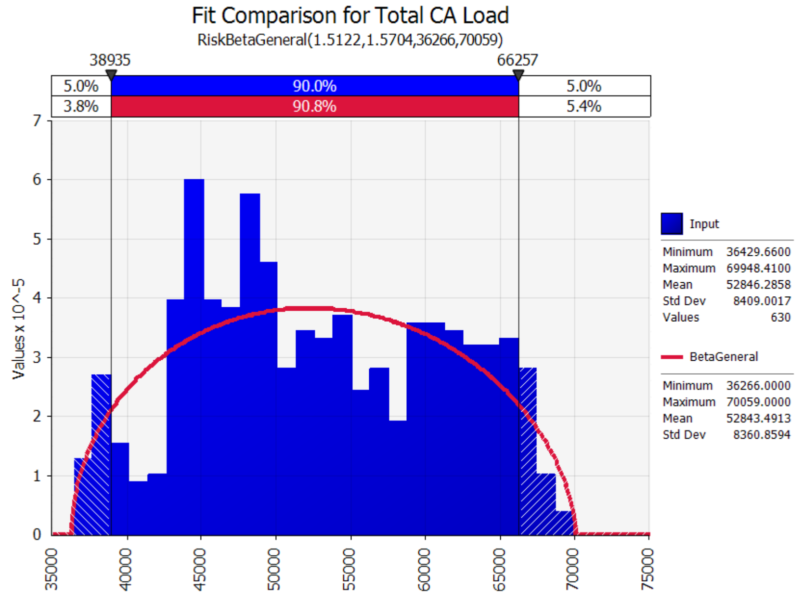
Note: Study work is in progress, results are not final and are subject to change

Probability distributions are fitted based on data from the Plexos production simulation model.

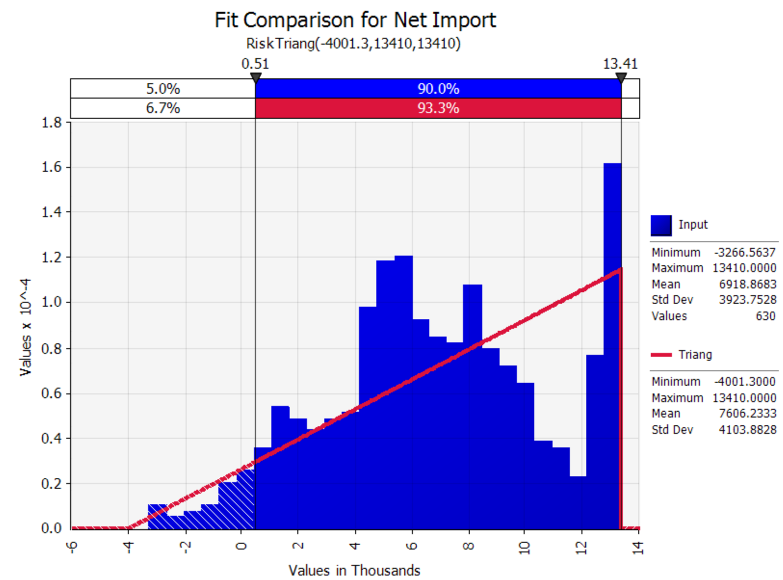
- Hourly California load forecast
- Hourly regulation and load following-up requirement
- Hourly wind, solar, and hydro generation
- California total import limit and hourly import and export results

Note: Study work is in progress, results are not final and are subject to change

The probability distribution functions for the High-Load case in "Super-Peak" period are as follows:



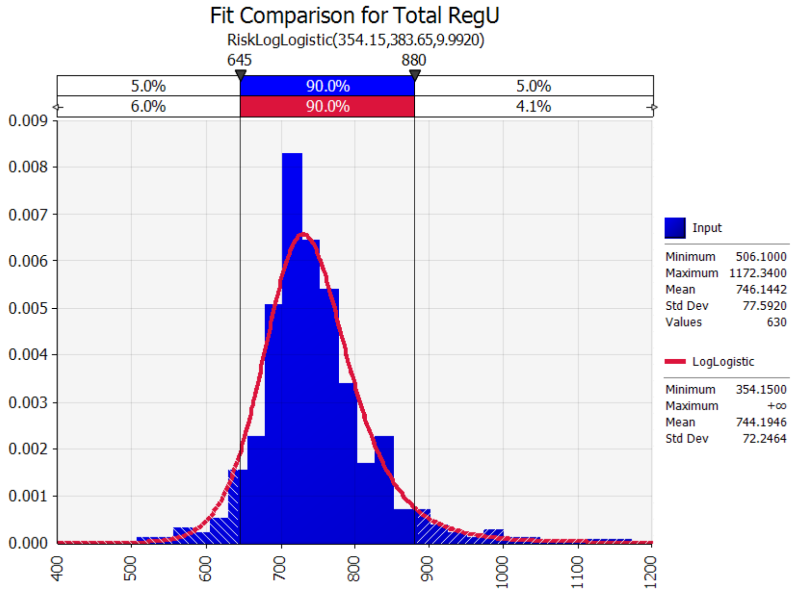
Super-Peak Period:
June-September
Monday-Saturday
H12-H17

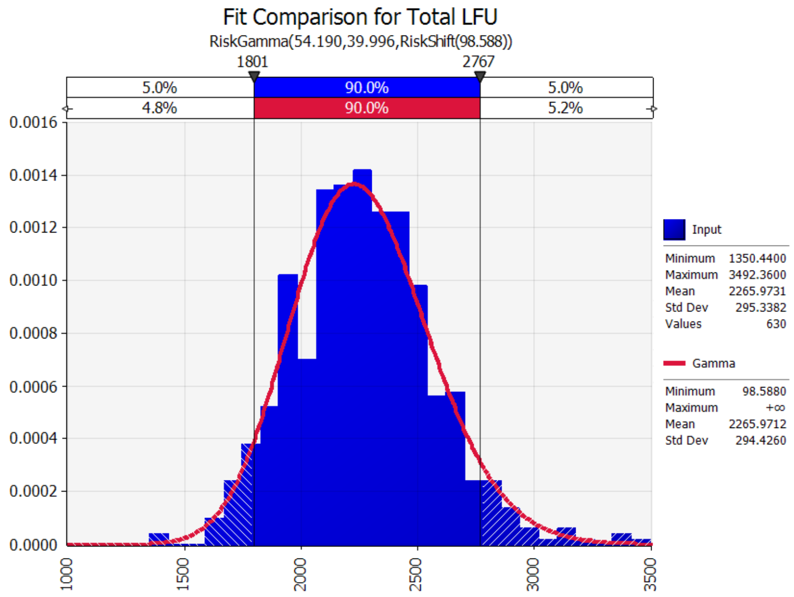


Net Import distribution function is not used in the cases presented in this document. The CA total import limit is used instead.

Note: Study work is in progress, results are not final and are subject to change

Probability distribution functions for the High-Load case in "Super-Peak" period.(cont.)





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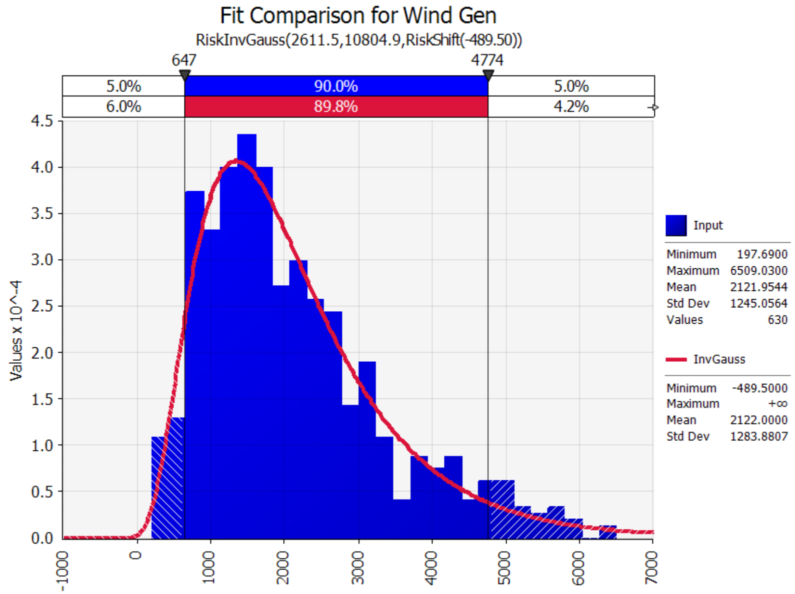
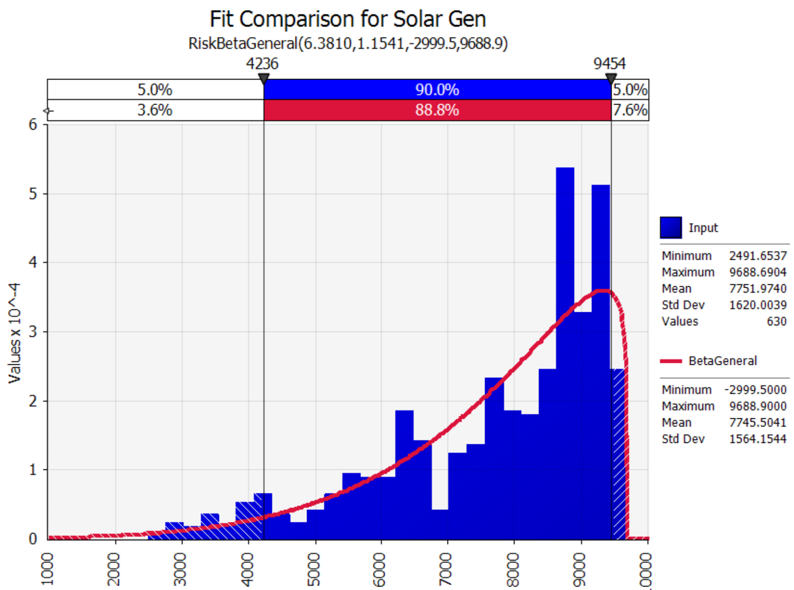
Probability distribution functions for the High-Load case in "Super-Peak" period.(cont.)





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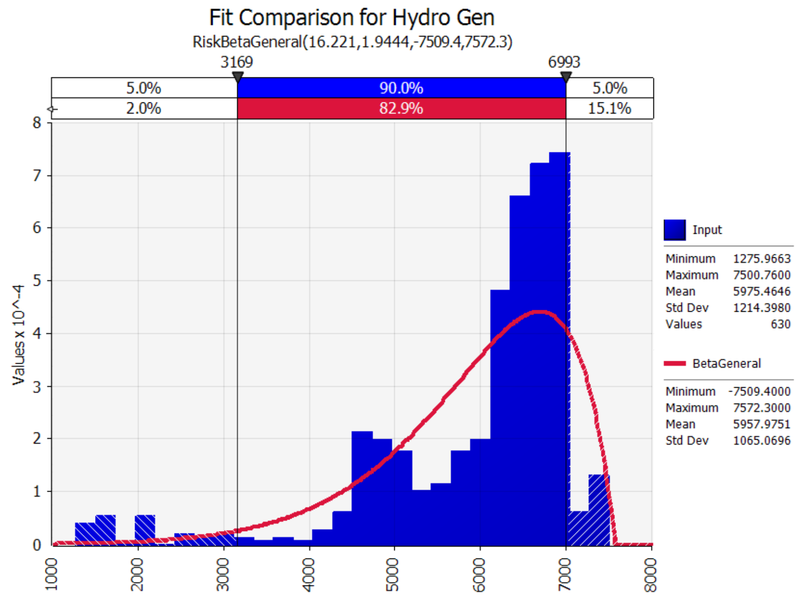
Probability distribution functions for the High-Load case in “Super-Peak” period.(cont.)



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Correlations among the stochastic variables are enforced.

	Load	Net Import	Wind	Solar	Hydro	RegU	LFU
Load	1	0.8092	-0.0947	-0.1997	0.4302	0.3801	0.0722
Net Import	0.8092	1	-0.2814	-0.3772	0.0040	0.2449	0.2203
Wind	-0.0947	-0.2814	1	-0.1618	0.2855	-0.0108	0.0609
Solar	-0.1997	-0.3772	-0.1618	1	0.0254	-0.1101	-0.5064
Hydro	0.4302	0.0040	0.2855	0.0254	1	0.3094	-0.1283
RegU	0.3801	0.2449	-0.0108	-0.1101	0.3094	1	0.1415
LFU	0.0722	0.2203	0.0609	-0.5064	-0.1283	0.1415	1

This is the correlation matrix of the High-Load case in “Super-Peak” period

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Generation units in the stochastic model have the following characteristics same as in the Plexos model.

- From input data
  - Maximum and minimum capacity
  - Ramp rate
  - Forced outage and maintenance outage rates
- From Plexos simulation results
  - Average generation cost

Note: Study work is in progress, results are not final and are subject to change

Generation unit availability is stochastically determined.

- Forced and maintenance outages are determined independently for each generation unit
- Each of the outages is determined based on the unit's outage rate and a draw using a uniform distribution function
- A maintenance outage allocation factor is applied to represent the seasonal pattern of maintenance
- The unit is unavailable when any one of the outages occurs

Note: Study work is in progress, results are not final and are subject to change

Contributions by each generation unit to meet energy, AS, and load following requirements are subject to:

- 10-min upward ramping capacity constraint

$$AS_i \le \min(10 \times RampRate_i, MaxCap_i - MinCap_i)$$

- 20-min upward ramping capacity constraint

$$AS_i + LFU_i \le \min(20 \times RampRate_i, MaxCap_i - MinCap_i)$$

- Maximum capacity constraint

$$E_i + AS_i + LFU_i \le MaxCap_i$$

E_i – energy dispatch AS_i – upward ancillary service contribution LFU_i – load following up contribution

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The model seeks a least-cost solution to meet energy, AS and load following requirements.

- Generation units are dispatched economically to meet load first
- Remaining qualified ramping capacity is used to meet upward ancillary service and load following requirements
- Dispatch and ramping capacity are co-optimized when there is a ramping capacity shortage initially

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Monte Carlo simulation produces probabilistic results.

- Monte Carlo simulation is conducted using this stochastic model
- The simulation results are presented in a probability distribution format
- The key results are the probability to have ramping capacity shortage each hour and the probabilistic distribution of the volume of the shortages

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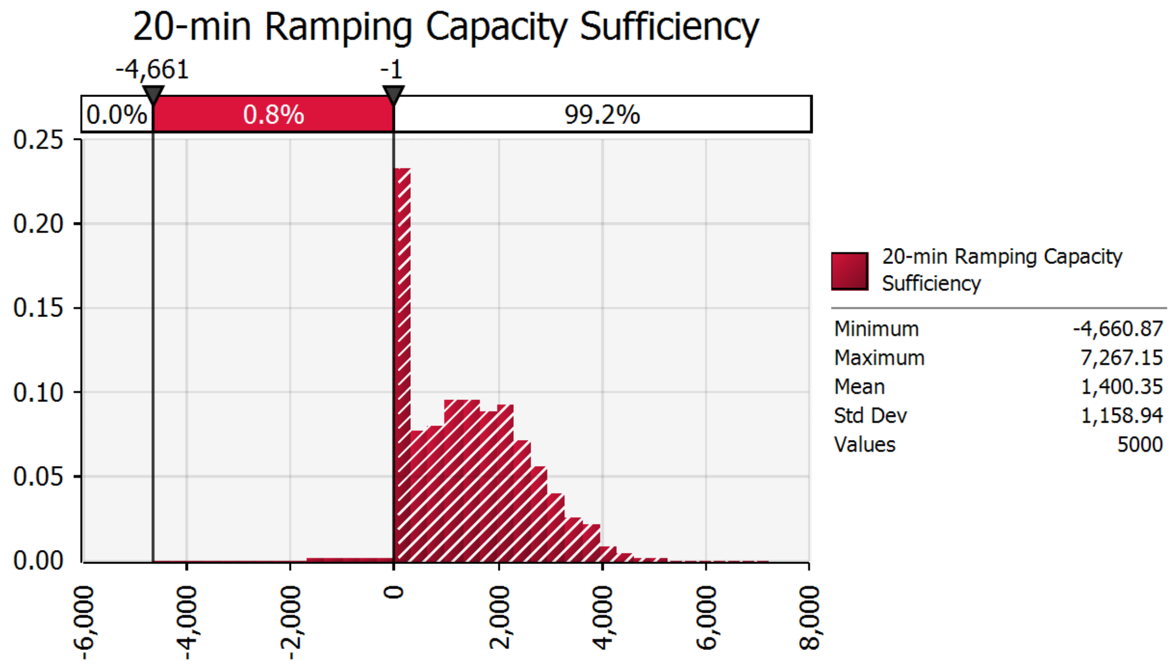
Three cases of the 33% renewable integration study were simulated using the stochastic model.

- The High-Load case for year 2020
- High-Load case with 4,600 MW additional generic resources (the capacity need identified in Need-Run of Plexos simulation)
- The Trajectory case for year 2020

Note: Study work is in progress, results are not final and are subject to change

The High-Load case has a 0.8% probability to have 20-min ramping capacity shortage each hour in the Super-Peak period.



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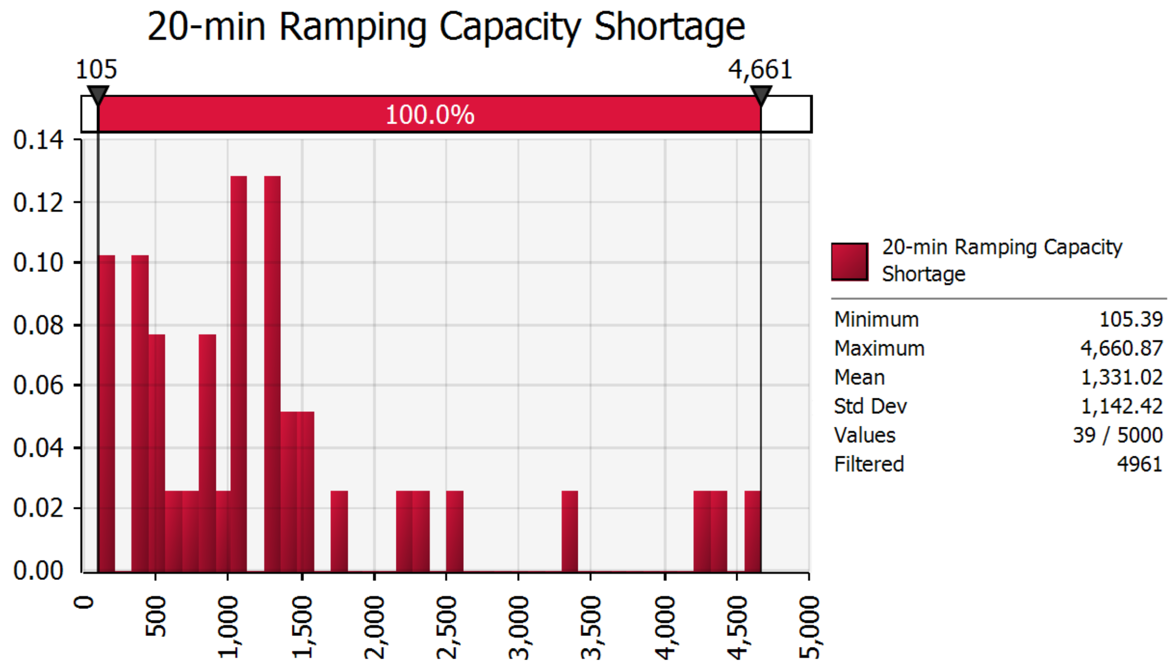
The highest 20-min ramping capacity shortage is 4,661 MW.



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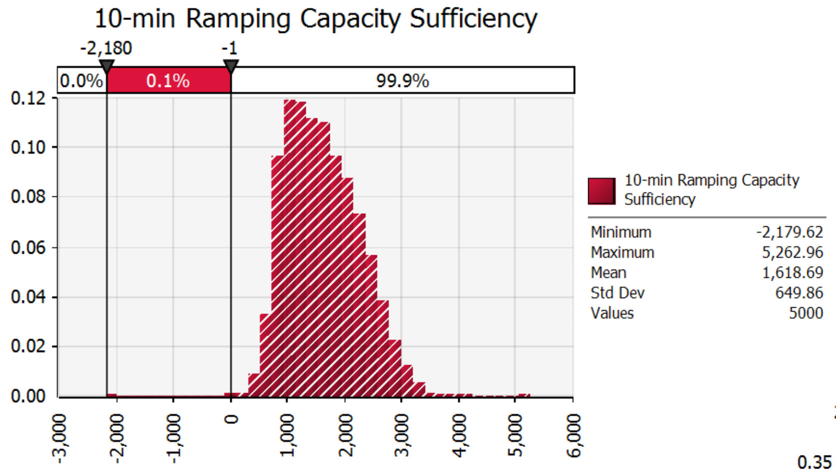
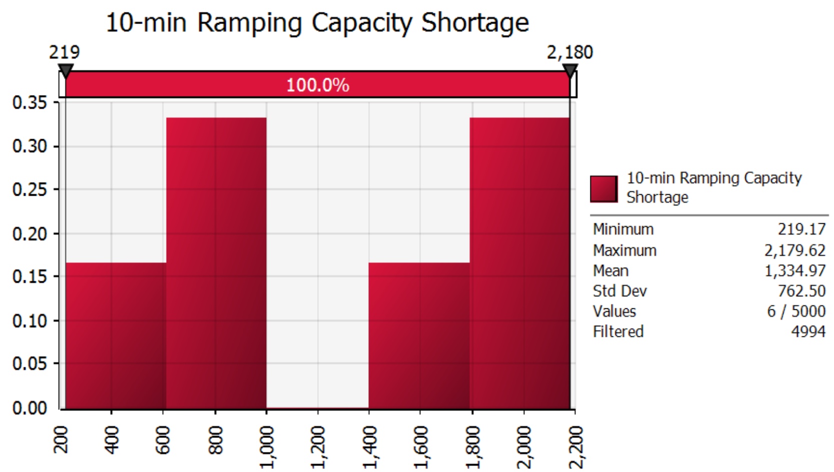
The probability to have 10-min ramping capacity shortage each hour is 0.1% in the Super-Peak period.





20-min ramping capacity shortage includes 10-min shortage based on the definition of 20-min ramping capacity constraint and additive requirement for AS and load following

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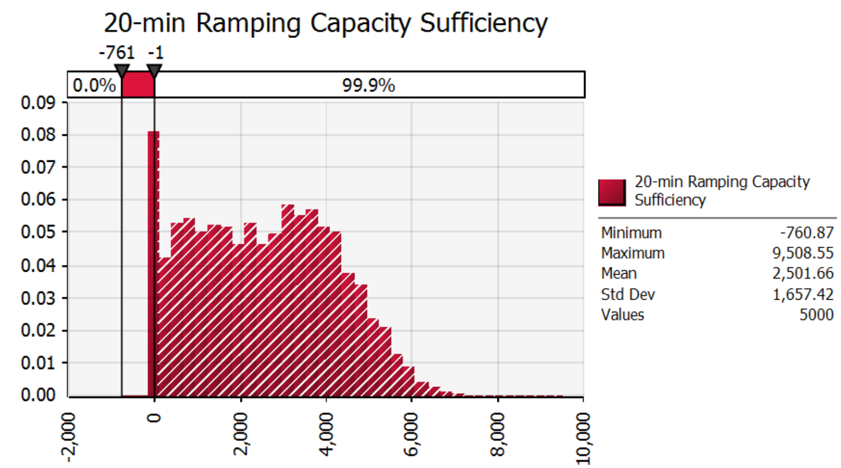
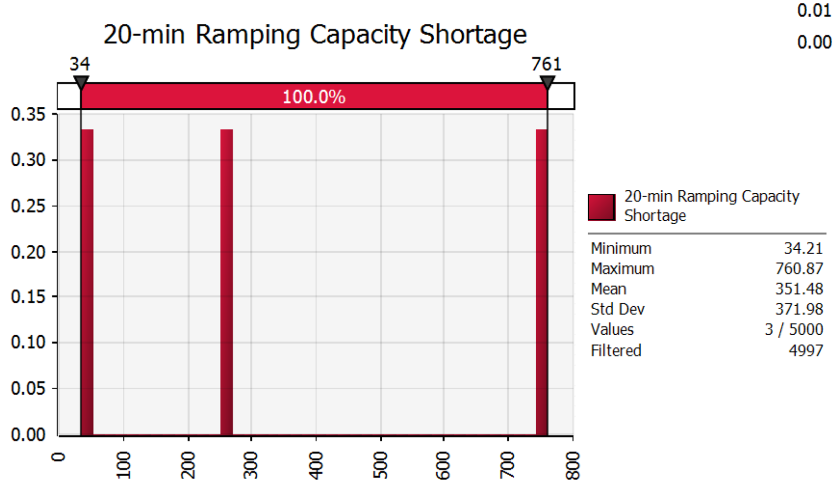
Probabilities of ramping capacity shortage decreased after 4,600 MW generic resources were added.

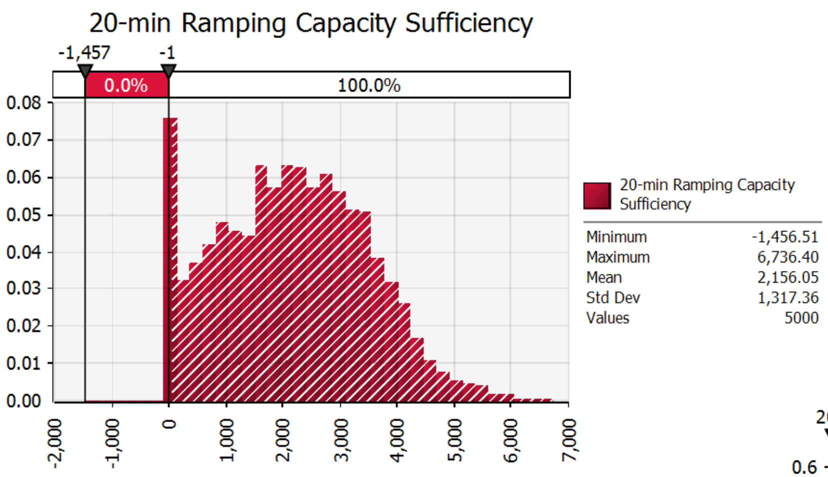


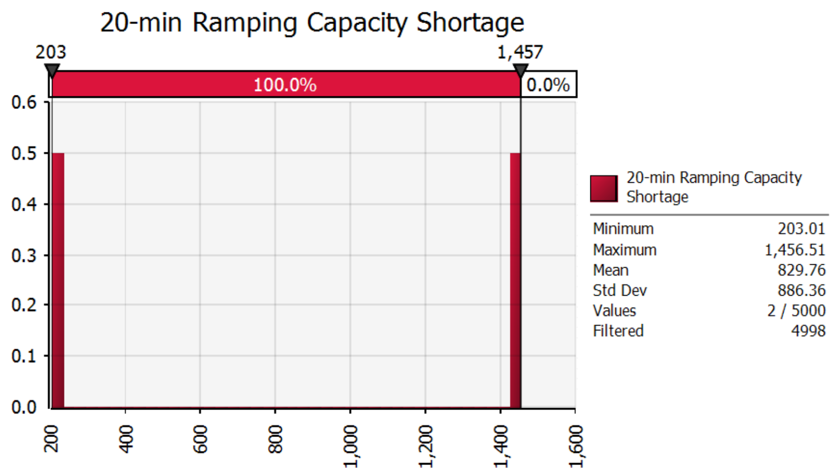


4,600 MW is the capacity need identified in Need-Run of Plexos simulation for the High-Load case

Note: Study work is in progress, results are not final and are subject to change

The Trajectory case also has a small probability of ramping capacity shortage in the Super-Peak period.





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The Monte Carlo simulation results are summarized as follows:

	High-Load Case				High-Load Case with 4,600 MW Generic Resources		Trajectory Case	
	Super-Peak		Summer Off-Peak		Super-Peak		Super-Peak	
	10-min	20-min	10-min	20-min	10-min	20-min	10-min	20-min
# of Hours in the Period	630	630	2298	2298	630	630	630	630
Probability of Shortage	0.12%	0.78%	0.04%	0.16%	0.00%	0.06%	0.04%	0.04%
Max Shortage (MW)	2,180	4,661	1,420	3,855	0	760	206	1,456

- Super-Peak: June-September, Monday-Saturday, H12-H17
- Summer Off-Peak: non-Super-Peak hours in June-September
- Periods not listed in the table do not have ramping capacity shortage

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The cumulative probabilities of ramping capacity shortage are calculated using Binomial distribution.

	High-Load Case		High-Load Case with 4,600 MW Generic Resources		Trajectory Case	
i	10-min	20-min	10-min	20-min	10-min	20-min
1	81.3%	100.0%	0.0%	31.5%	22.3%	22.3%
2	49.9%	99.8%	0.0%	5.6%	2.7%	2.7%
3	23.6%	99.1%	0.0%	0.7%	0.2%	0.2%
4	8.9%	97.2%	0.0%	0.1%	0.0%	0.0%
5	2.8%	93.0%	0.0%	0.0%	0.0%	0.0%
6	0.7%	85.8%	0.0%	0.0%	0.0%	0.0%
7	0.2%	75.4%	0.0%	0.0%	0.0%	0.0%
8	0.0%	62.7%	0.0%	0.0%	0.0%	0.0%
9	0.0%	49.0%	0.0%	0.0%	0.0%	0.0%
10	0.0%	35.9%	0.0%	0.0%	0.0%	0.0%
11	0.0%	24.6%	0.0%	0.0%	0.0%	0.0%
12	0.0%	15.9%	0.0%	0.0%	0.0%	0.0%
13	0.0%	9.6%	0.0%	0.0%	0.0%	0.0%
14	0.0%	5.5%	0.0%	0.0%	0.0%	0.0%
15	0.0%	2.9%	0.0%	0.0%	0.0%	0.0%
16	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%
17	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%
18	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%
19	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
20	0.0%	0.1%	0.0%	0.0%	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%

It is the probability to have at least i hours with ramping capacity shortage in year 2020.

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Expected number of hours with ramping capacity shortage in 2020 are calculated based on the probabilities.

High-Load Case		High-Load Case with 4,600 MW Generic Resources		Trajectory Case	
10-min	20-min	10-min	20-min	10-min	20-min
1.68	8.59	0.00	0.38	0.25	0.25

The expected hours with ramping capacity shortage can be compared with the "1-in-10" LOLP criteria (1 event in 10 years or 0.1 hours per year)

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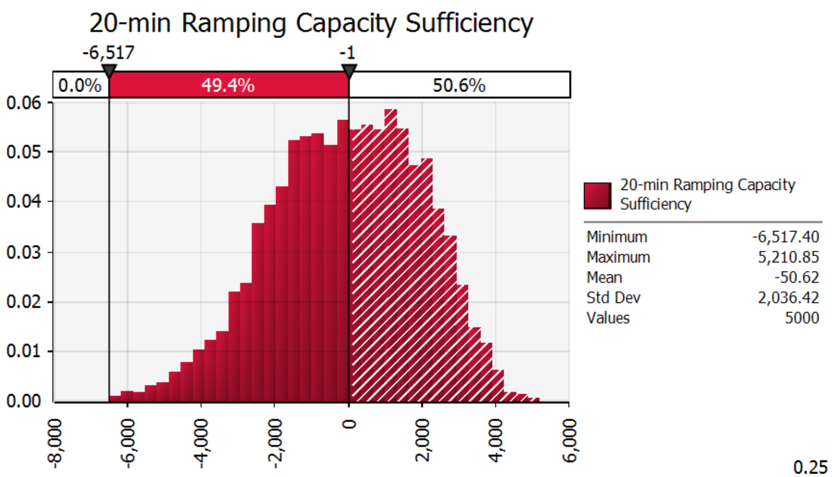
Co-optimization re-dispatches resources to free up more ramping capacity when needed.

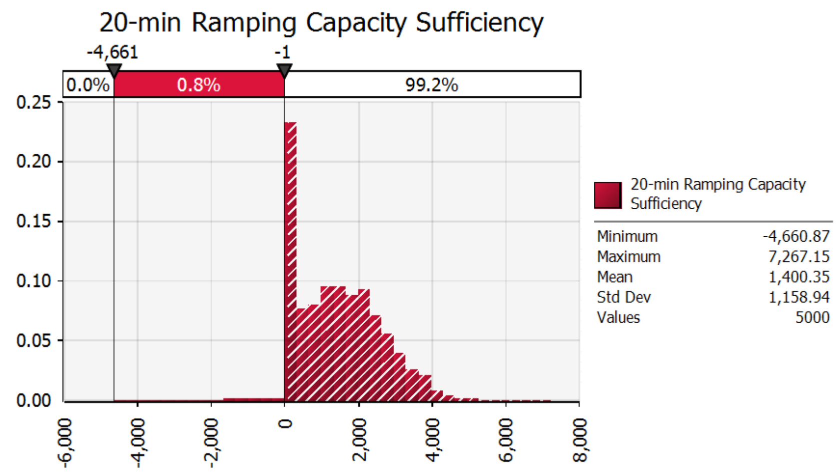
- In each iteration generation units are first dispatched based on capacity stacked up by cost
- Ramping capacity from remaining units is used to meet upward ancillary service and load following requirements
- Dispatch and ramping capacity are co-optimized when there is a ramping capacity shortage initially
- Co-optimization finds a least-cost solution to meet requirements for energy, ancillary service, and load following
- Shortage occurs in ramping capacity when supply is insufficient

Note: Study work is in progress, results are not final and are subject to change

Probability of ramping capacity shortage is much lower with co-optimization in the Monte Carlo simulation.



Left – High-Load case Super-Peak period without co-optimization



Right – with co-optimization in simulation

Note: Study work is in progress, results are not final and are subject to change

Commercial software is used to develop the model and conduct Monte Carlo simulations.

Palisade Decision Tools Suite

http://www.palisade.com/

Frontline Risk Solver Platform for Excel

http://solver.com/platform/risk-solver-platform.htm

Note: Study work is in progress, results are not final and are subject to change

Study Group 2: Step 1 Sensitivity

- Purpose:
  - Review and improve representation of variability and forecast error parameters for load/wind/solar being used in the study
- Scope:
  - To estimate Step 1 requirements for sue in Plexos simulations or stochastic simulations
- Study Approach:
  - Bracket range of forecast errors for wind and solar (PV and CST) based on past forecast experience and reasonable achievable forecast improvements
  - Where there is little or no forecast experience (PV and CST) use a range based on other studies or industry knowledge of forecast errors
  - Develop a range of forecast errors and corresponding Step 1 inputs to use in Plexos and in stochastic simulations
  - Refinement of forecast error for solar thermal should be incorporated

Note: Study work is in progress, results are not final and are subject to change

The Step 1 team is tasked with addressing concerns surrounding Step 1 results and conduct sensitivity analysis to better inform the larger workgroup

Proposed Agenda

- Task Force request that we calculate the following:
  - Calculate T-30 minutes for PIRP
  - Calculate T-30 minutes for Trajectory
- Wind Errors
  - Upper bound
  - Lower bound
- Solar Errors
  - Upper bound
  - Lower bound
- Load Forecast Errors (2010 or 2011)
- Monthly or hourly load-following values for needs run?

Note: Study work is in progress, results are not final and are subject to change

California ISO
Shaping a Renewed Future

What wind forecast errors should we use in our studies?

Wind	Persistent	Hours	Spring	Summer	Fall	Winter
Current Errors used in Studies	T-1	All	4.0%	3.8%	3.2%	3.1%
2010 PIRP HA Forecast Errors	PIRP	All	10.5%	8.9%	8.4%	6.7%
Future Studies						
Upper Limit Persistent (T-1)	PIRP	All	8.4%	7.1%	5.3%	3.9%
Lower Limit Persistent (T-30)	PIRP	All	2.9%	2.3%	1.8%	1.4%

- T-1 for the Trajectory case would be used for the Step 1 analysis
- PIRP T-1 and T-30 forecast errors would be used as the upper and lower bounds to bookend load-following and regulation requirements

Note: Study work is in progress, results are not final and are subject to change

Current solar HA forecast errors used in Step 1 studies

Technology	Persistent	Hours	0<=CL<0.2	.2<=CL<0.5	.5<=CL<0.8	.8<=CL<1.0
Large PV	T-1	Hours 12-16	3.5%	6.9%	5.6%	2.3%
Large solar Thermal	T-1	Hours 12-16	6.0%	10.9%	10.8%	3.0%
Distributed PV	T-1	Hours 12-16	2.2%	4.7%	3.9%	1.8%
Customer Side PV	T-1	Hours 12-16	1.6%	3.3%	3.1%	1.6%

Note: Study work is in progress, results are not final and are subject to change

Proposed solar HA forecast errors upper and lower bounds by technology for Step 1 studies

Technology	Persistent	Hours	0<=CI<0.2	0.2<=CI<0.5	0.5<=CI<0.8	0.8<=CI<=1
Large PV (PV) Upper Limit	(T-1) + 20%	12-16	4.20%	8.28%	6.72%	2.76%
Large PV (PV) Lower Limit	(T-1) - 20%	12-16	2.80%	5.52%	4.48%	1.84%
Large Solar Thermal (ST) Upper Limit	(T-1) + 20%	12-16	7.20%	13.08%	12.96%	3.60%
Large Solar Thermal (ST) Lower Limit	(T-1) - 20%	12-16	4.80%	8.72%	8.64%	2.40%
Distribute PV (DG) Upper Limit	(T-1) + 20%	12-16	2.64%	5.64%	4.68%	2.16%
Distribute PV (DG) Lower Limit	(T-1) - 20%	12-16	1.76%	3.76%	3.12%	1.44%
Customer Side PV (CPV) Upper Limit	(T-1) + 20%	12-16	1.92%	3.96%	3.72%	1.92%
Customer Side PV (CPV) Lower Limit	(T-1) - 20%	12-16	1.28%	2.64%	2.48%	1.28%

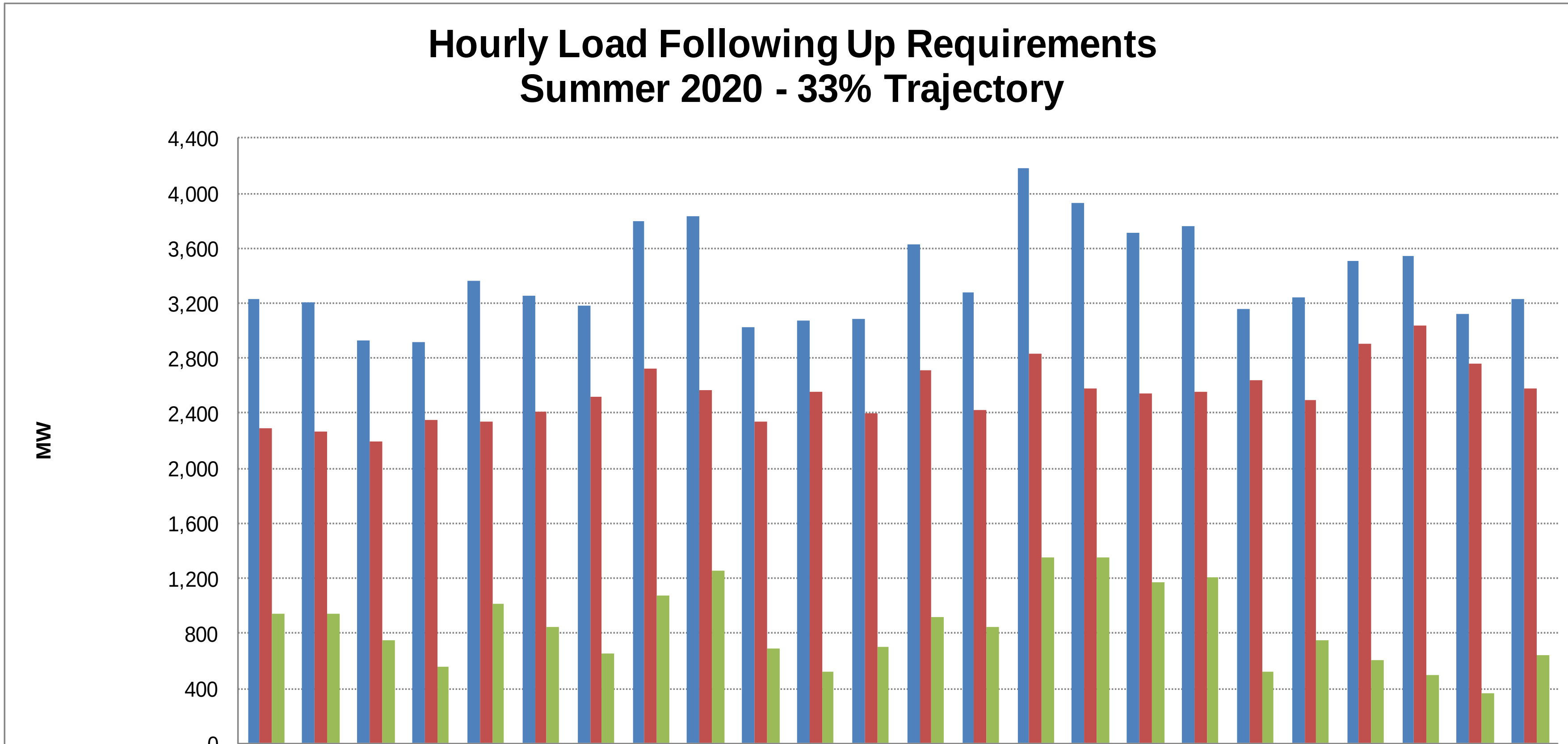
Current and proposed Load HA forecast errors for Step 1 studies

Load	Hours	Spring MW	Summer MW	Fall MW	Winter MW
Current HA Forecast Errors used in Studies (2010 Actual)	All	545	636	540	682
RT Forecast Errors (2010 Actual)	All	216	288	277	231
High Load Forecast Errors	All	611	700	602	764
Current HA Forecast Errors used in Studies (2011)	All	517	1002	662	622
RT Forecast Errors (2011)	All	243	264	290	255

- 2010 HA and RT forecast errors used for all scenarios
- High Load HA Forecast Errors used for the High Load Case

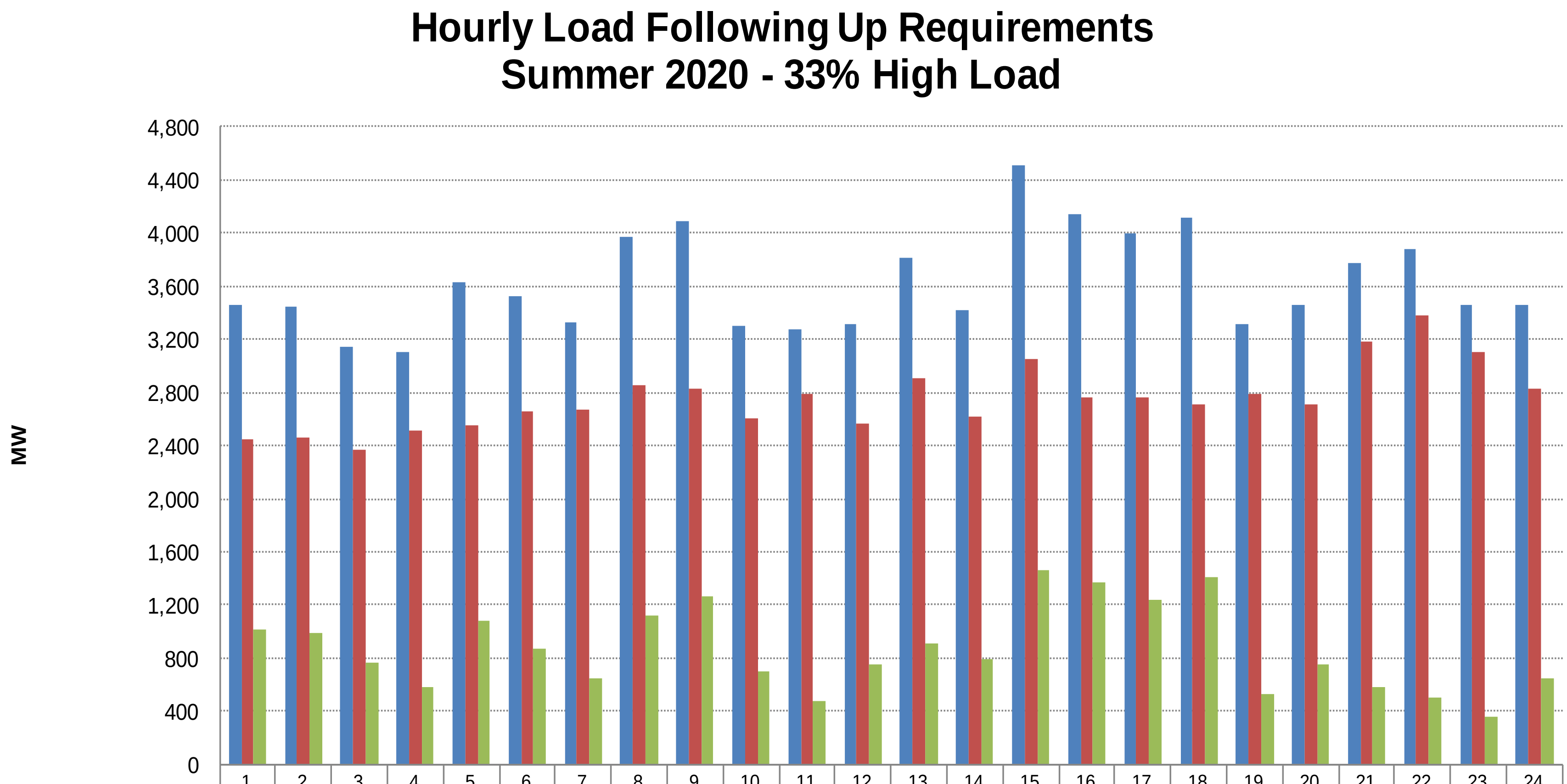
Note: Study work is in progress, results are not final and are subject to change

Hourly load following up requirement for the Trajectory scenario



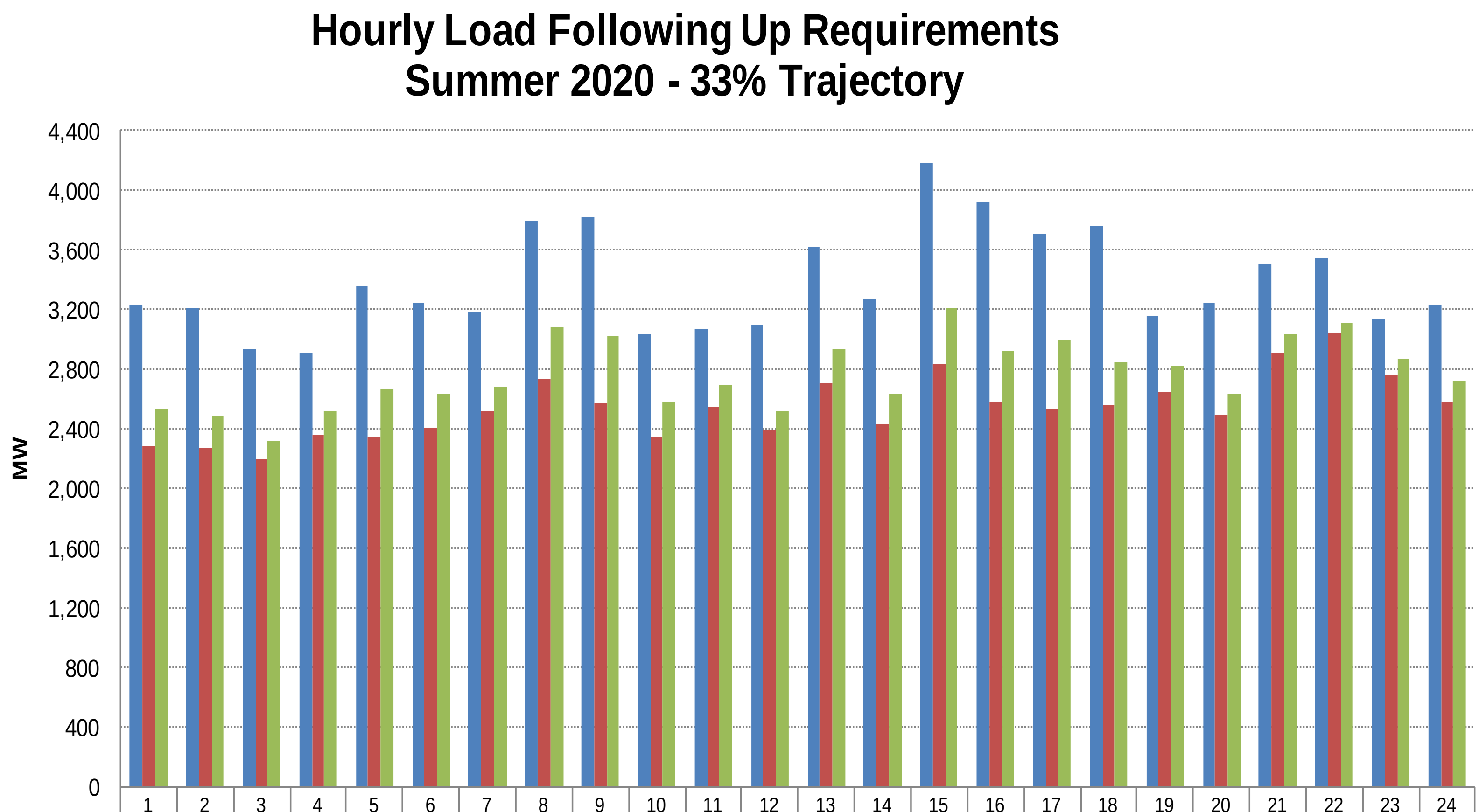
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Trajectory (High Errors)	3,229	3,209	2,934	2,913	3,363	3,252	3,180	3,798	3,827	3,029	3,072	3,091	3,627	3,275	4,183	3,927	3,707	3,761	3,163	3,243	3,509	3,546	3,128	3,229
Trajectory (Low Errors)	2,288	2,264	2,189	2,354	2,343	2,409	2,521	2,728	2,573	2,342	2,551	2,394	2,710	2,428	2,831	2,579	2,538	2,556	2,643	2,495	2,903	3,043	2,762	2,581
Difference	941	944	745	559	1,021	842	659	1,071	1,254	687	521	696	917	847	1,352	1,348	1,169	1,205	520	748	606	503	366	648

Hourly load following up requirement comparison for the High Load scenario



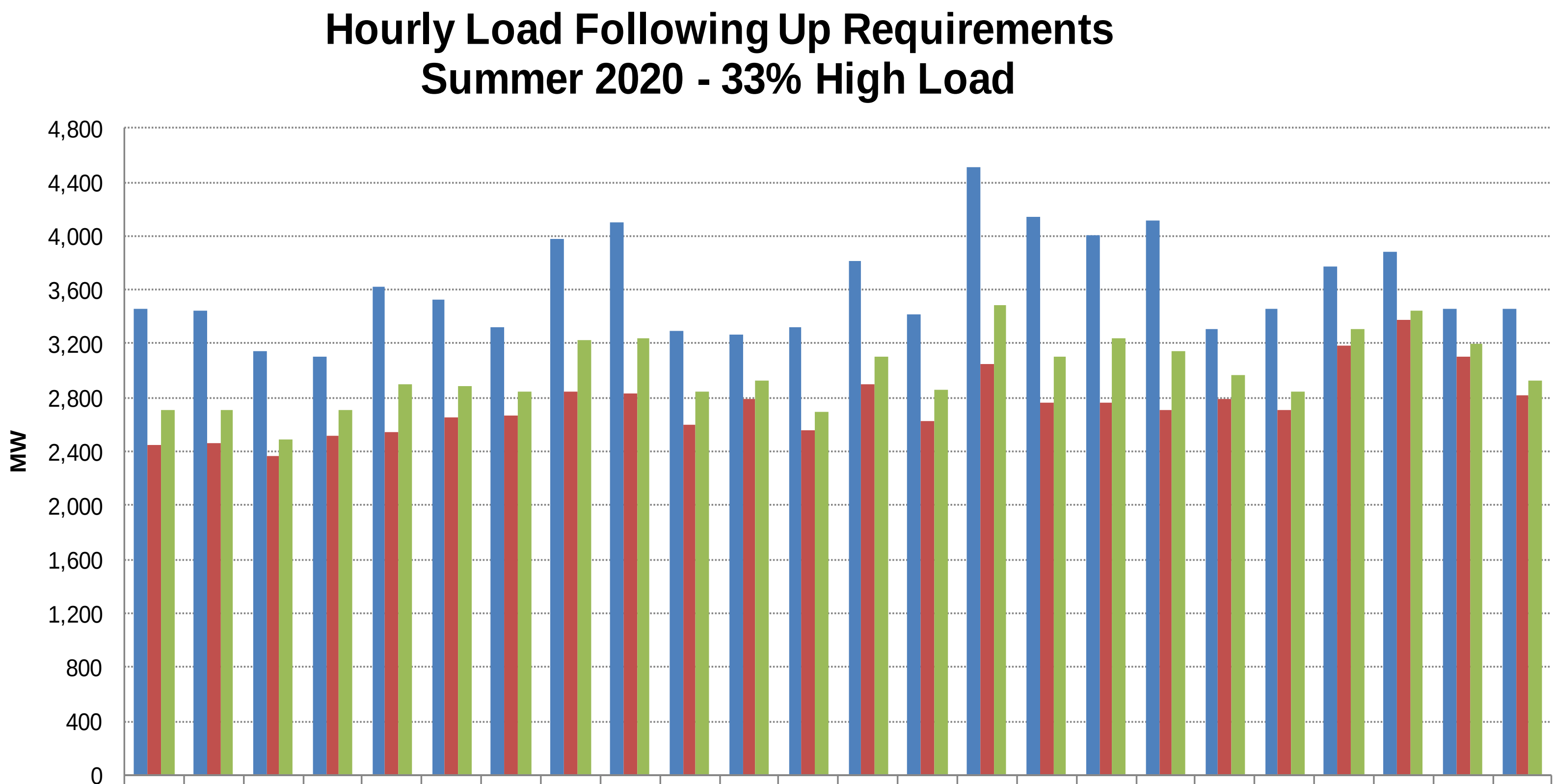
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
High Load (High Errors)	3,454	3,450	3,141	3,102	3,626	3,529	3,325	3,973	4,094	3,296	3,274	3,319	3,814	3,417	4,515	4,142	3,999	4,113	3,312	3,464	3,768	3,883	3,458	3,465
High Load (low Errors)	2,443	2,460	2,373	2,515	2,551	2,657	2,672	2,849	2,834	2,601	2,795	2,561	2,904	2,624	3,053	2,767	2,766	2,706	2,783	2,706	3,185	3,376	3,104	2,822
Difference	1,011	990	768	587	1,075	873	653	1,124	1,260	695	479	758	910	793	1,462	1,376	1,233	1,407	528	758	584	507	355	643

Hourly load following up requirement for the Trajectory scenario -- high and low forecast errors and T-1 errors



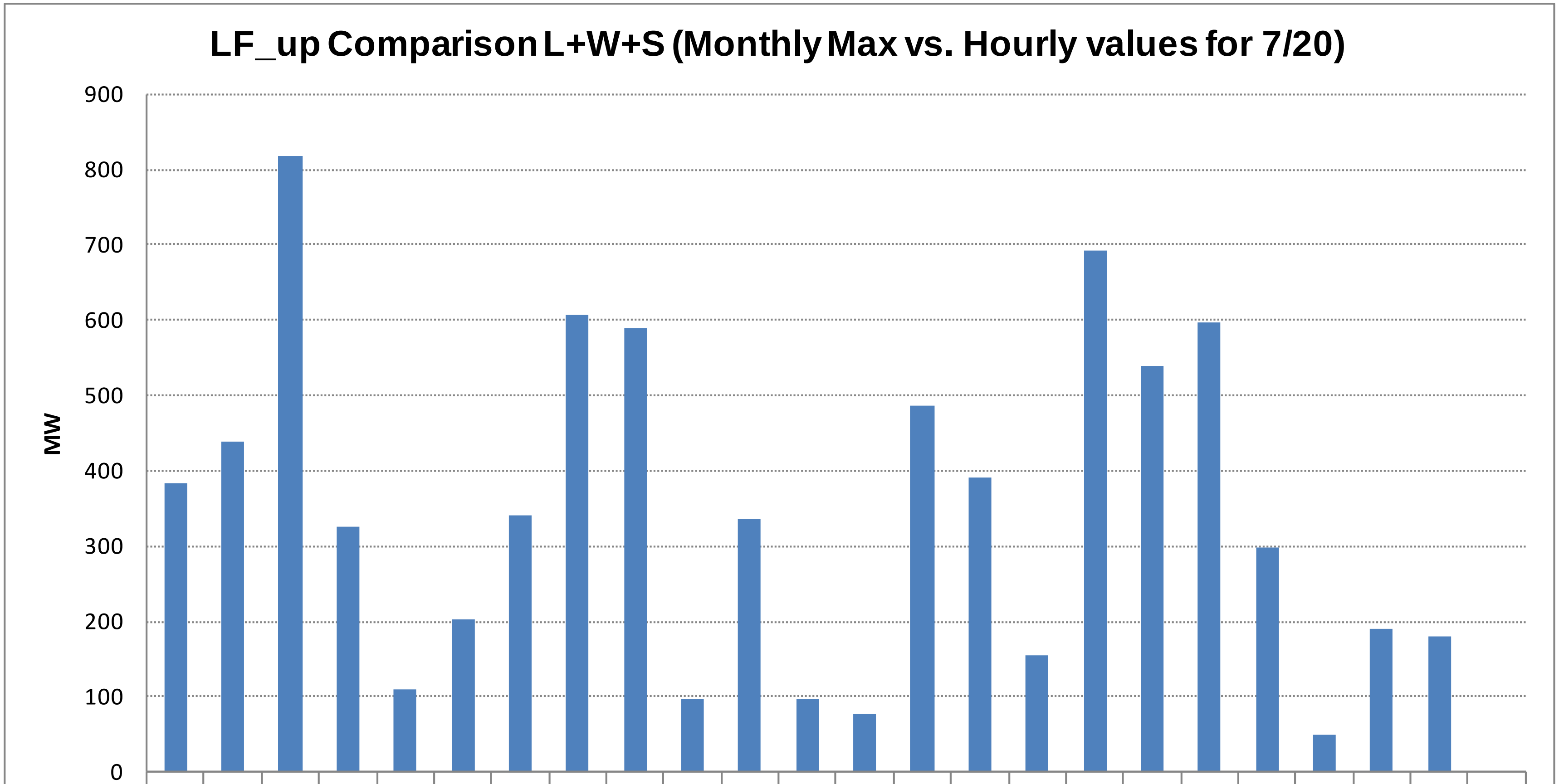
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Trajectory (High Errors)	3,229	3,209	2,934	2,913	3,363	3,252	3,180	3,798	3,827	3,029	3,072	3,091	3,627	3,275	4,183	3,927	3,707	3,761	3,163	3,243	3,509	3,546	3,128	3,229
Trajectory (Low Errors)	2,288	2,264	2,189	2,354	2,343	2,409	2,521	2,728	2,573	2,342	2,551	2,394	2,710	2,428	2,831	2,579	2,538	2,556	2,643	2,495	2,903	3,043	2,762	2,581
T-1 Forecast Errors	2,530	2,486	2,315	2,522	2,665	2,631	2,686	3,086	3,015	2,584	2,691	2,520	2,927	2,639	3,210	2,924	2,990	2,851	2,816	2,630	3,033	3,114	2,864	2,714

Hourly load following up requirement for the High Load scenario - high and low forecast errors and T-1 errors



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
High Load (High Errors)	3,454	3,450	3,141	3,102	3,626	3,529	3,325	3,973	4,094	3,296	3,274	3,319	3,814	3,417	4,515	4,142	3,999	4,113	3,312	3,464	3,768	3,883	3,458	3,465
High Load (low Errors)	2,443	2,460	2,373	2,515	2,551	2,657	2,672	2,849	2,834	2,601	2,795	2,561	2,904	2,624	3,053	2,767	2,766	2,706	2,783	2,706	3,185	3,376	3,104	2,822
T-1 Forecast Errors	2,715	2,702	2,487	2,703	2,902	2,892	2,839	3,230	3,240	2,848	2,921	2,701	3,111	2,864	3,492	3,105	3,242	3,151	2,972	2,847	3,309	3,446	3,204	2,921

Load-following difference between monthly maximum and hourly values for July 20



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
LF_up	382	438	818	325	109	202	342	607	588	97	336	97	77	487	390	155	693	538	596	298	50	191	180	0

Note: Study work is in progress, results are not final and are subject to change

What data should be passed from Step 1 to Step 2

Average hourly load values are used in production simulation for all 8760 hours including the peak hour (Preferred)

- **Regulation values passed to Step 2**
  - Pass on the maximum (95 percentile) hourly values as is currently done for all hours

- **Load Following values passed to Step 2**
  - **Needs Requirement**
    - Pass on hourly load-following values (95 percentile) from Step 1 for all hours
  - **Cost Requirements**
    - Pass on hourly load-following values (95 percentile) from Step 1 for all hours

The 95 percentile values are truncated from the seasonal values because of the larger sample size

Note: Study work is in progress, results are not final and are subject to change

Study Group 4: 5-minute Production Simulation

- Purpose
  - To validate findings from hourly production simulations
- Scope
  - Based on 2020 High-Load case
  - Selected days with upward ramping capacity shortage
- Schedule
  - Complete simulation in November, 2011

Note: Study work is in progress, results are not final and are subject to change

Study Group 4: 5-minute Production Simulation - Ramping Constraints

- 10-min upward AS constraint

$$AS_i \le 10 \times RampRate_i$$

- 20-min upward AS and LF constraint

$$AS_i + LFU_i \le 20 \times RampRate_i$$

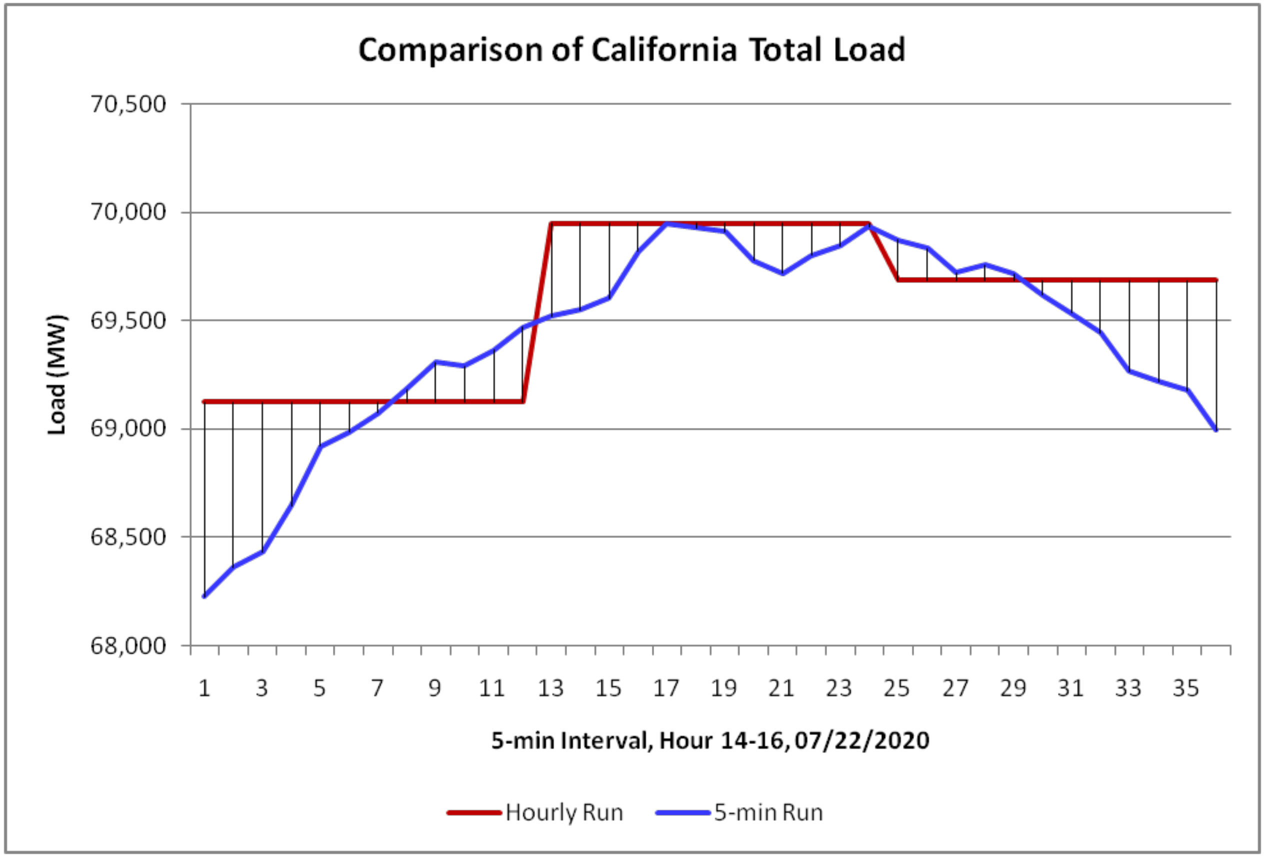
- Total ramping capacity constraint

$$12 \times E_i + AS_i + LFU_i \le 60 \times RampRate_i$$

E_i – 5 – min energy dispatch AS_i – upward ancillary service contribution LFU_i – load following up contribution

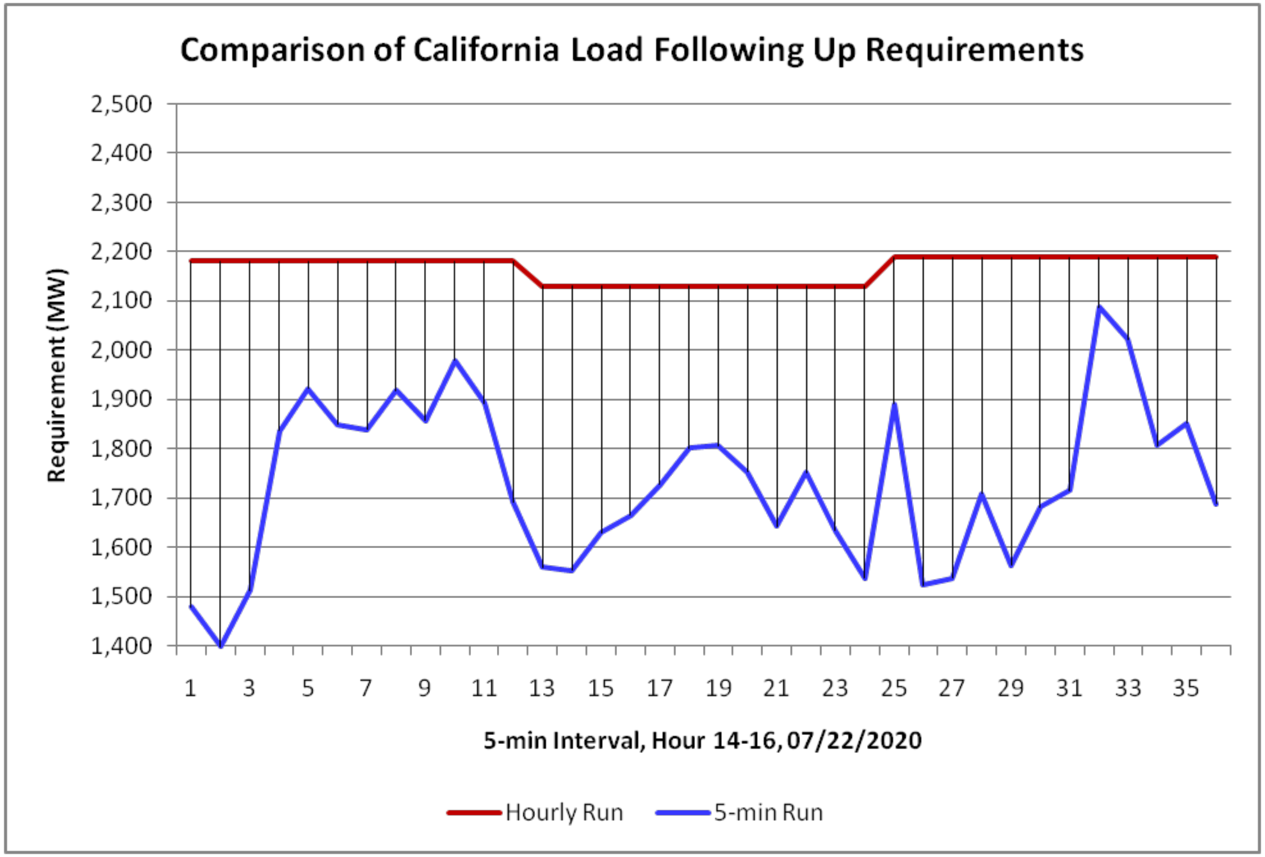
Note: Study work is in progress, results are not final and are subject to change

Study Group 4: 5-minute Production Simulation – Comparison of Load Profiles



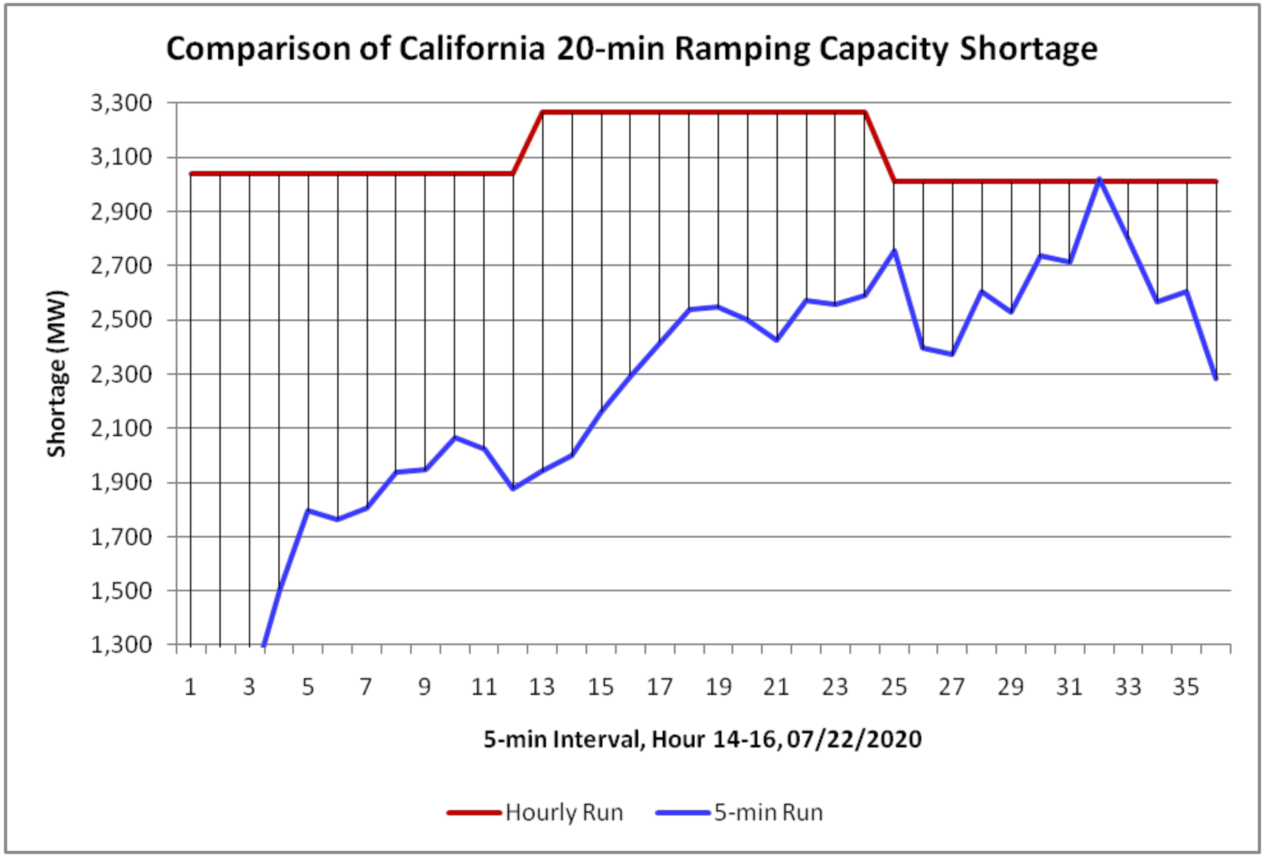
Note: Study work is in progress, results are not final and are subject to change

Study Group 4: 5-minute Production Simulation - Comparison of Load Following-Up Requirements



Note: Study work is in progress, results are not final and are subject to change

Study Group 4: 5-minute Production Simulation - Comparison of 20-min Ramping Capacity Shortages



Note: Study work is in progress, results are not final and are subject to change

Study Group 4: 5-minute Production Simulation – Summary of Results

- Load profiles
  - There is a small difference between the 5-min load profile and hourly load profile as the two came from different sources.
- Load following-up requirements
  - 5-min requirement is lower than hourly as it considers forecast errors only
- 20-min ramping capacity shortage
  - 20-min ramping capacity shortage exists in all 5-min intervals in the three hours simulated
  - Interval 8 of HE 16 has highest shortage in 5-min simulation due to large increase in load following-up requirement and ramping constraints

Note: Study work is in progress, results are not final and are subject to change

Study Group 5: Reserves with BAA Coordination

- Purpose

The renewable integrations studies to date have assumed existing inter balancing authority area operations:

- Intertie scheduling is predominantly hourly schedules
  - 40% of renewable imports
- Dynamic transfer will accommodate some transfers:
  - Existing dynamic scheduled resources
  - 15% of renewable imports
- Intra-hour schedule (15 minute scheduling)
  - 15% of renewable imports
- Ancillary services provided by existing resources specific system imports.

The renewable integrations studies to date have also assumed:

- Outside of CA, BAAs have no contingency, regulation, or load following requirements

Note: Study work is in progress, results are not final and are subject to change

Study Group 5: Reserves with BAA Coordination

- Proposed Sensitivities:
  - Part A: Suggestions to refine representation of neighboring BAs commitment/dispatch
  - Part B: Evaluate impact of increase in intra-hour scheduling and dynamic scheduling
  - Part C: Evaluate impact of CA's use of excess flexibility from neighboring BAs
- Status
  - Complete simulation in January, 2012

Note: Study work is in progress, results are not final and are subject to change

Study Group 5: WECC reserve requirements modeled

- Modeled reserve requirement in the WECC
  - spinning reserve requirement = 3% of regional load
  - non-spinning reserve requirements = 3% of regional load
  - regulation = 1% of regional load
  - Load following will be based on EIM study assumption
- Defined resources in WECC to provide reserves
  - CCs, CTs and dispatchable (above minimum) hydro; exclude baseload
  - Coal
- Represented Large Coal as more flexible
  - Jointly owned resources: Pmin = 70% of Pmax
  - Other large coal: Pmin=50% of Pmax

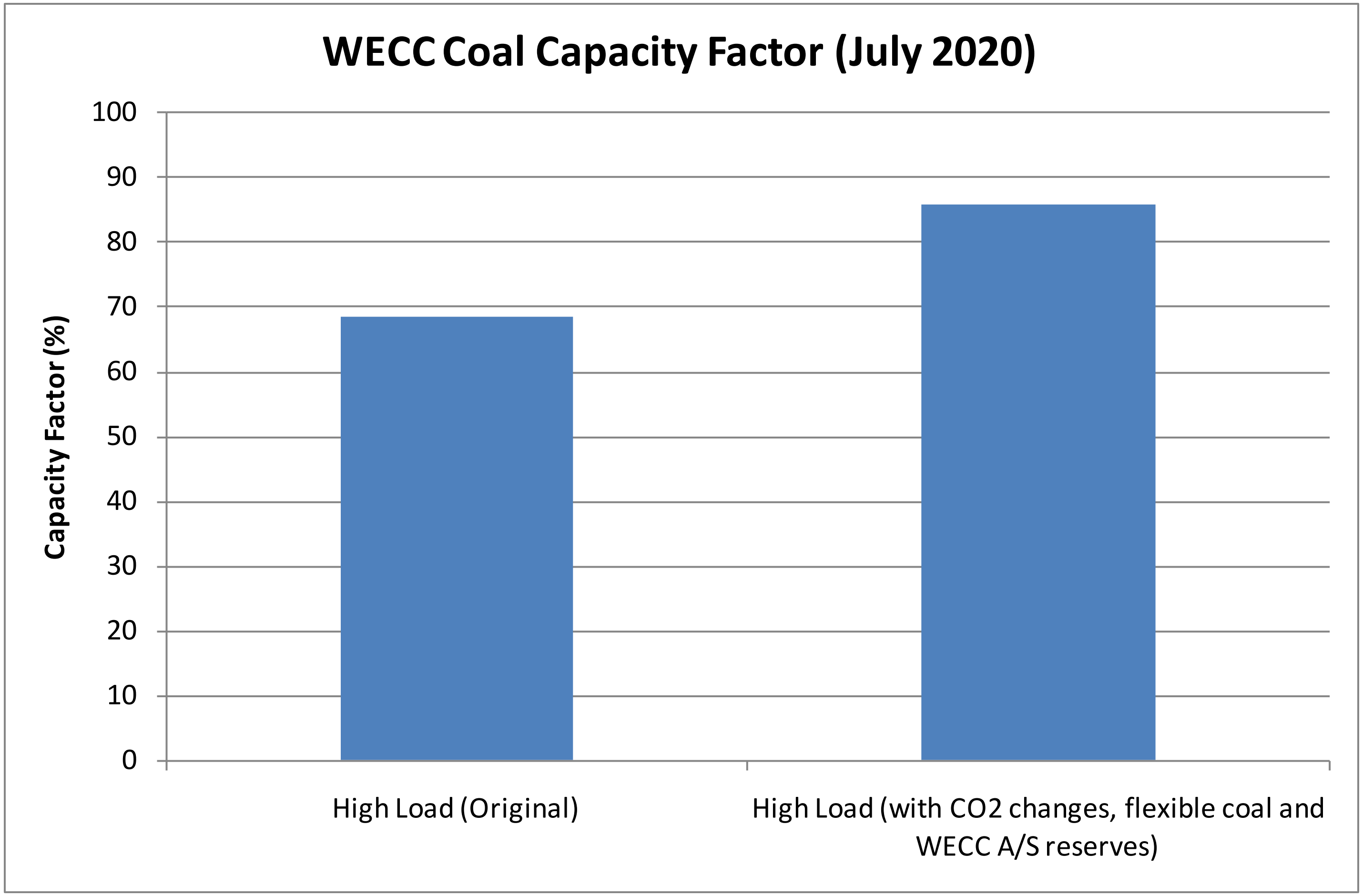
Note: Study work is in progress, results are not final and are subject to change

Study Group 5: CO_2 Adder representation

- CA
  - CO_2 adder in CA remained $36.60/Ston
- WECC (except CA and BPA)
  - Replace adder with hurdle rate
  - Hurdle rate = 0.435 MTons/Mwh * 36.3 $/STon * 1.102 (Ston/Mton) = $17.4 /Mwh
- BPA
  - 20% x $17.4/Mwh = $3.48/Mwh
  - Refer to ARB rules http://www.arb.ca.gov/regact/2010/ghg2010/ghgisoratta.pdf

Note: Study work is in progress, results are not final and are subject to change

Study Group 5: Changes to GHG and coal flexibility modeling observed increase capacity factor of external Coal resources.



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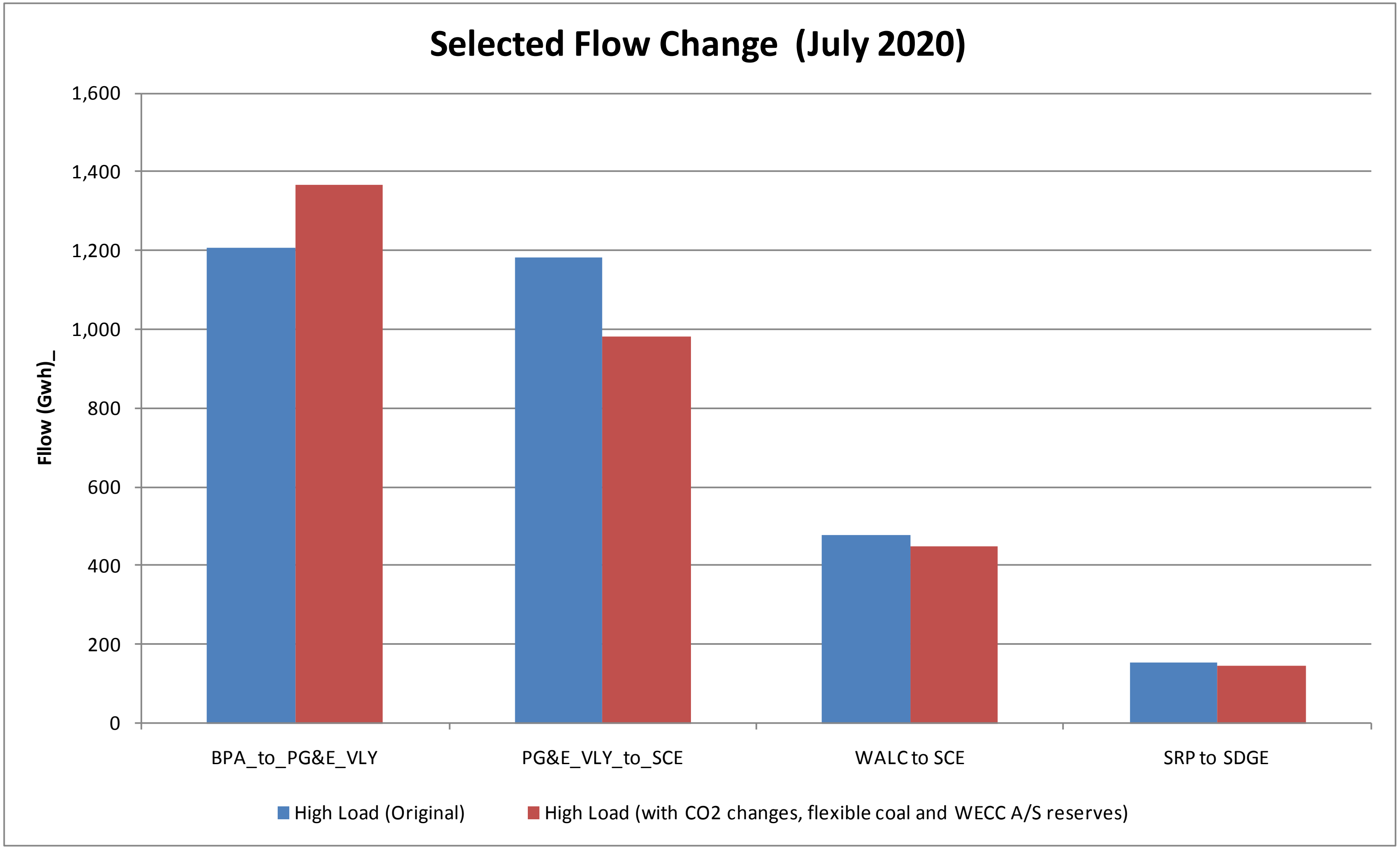
Study Group 5: Changes to GHG and coal flexibility modeling observed increase capacity factor of external Coal resources.



Note: Study work is in progress, results are not final and are subject to change

Next Steps:

- Incorporate local capacity resources
- Assess alternatives for meeting residual needs
- Test underlying assumptions regarding

Note: Study work is in progress, results are not final and are subject to change

Next Steps: Incorporate LCR Study results

- Purpose:
  - Consider resources capacity needed to meet local reliability needs as a result of retirement of OTC
  - Determine residual flexibility needs
- Scope
  - Big Creek/Ventura – 430 MW
  - LA Basin – 2,370 MW
  - San Diego – 531 MW
- Plan
  - Cases are prepared with LCR resource capacity
  - February apply study process with LCR resources

Note: Study work is in progress, results are not final and are subject to change

Next Steps: Test operational robustness of underlying assumptions

- Perform additional analysis testing robustness of assumptions
  - Demand Response
  - Energy Efficiency
  - Load forecast
  - Outage / Maintenance rates
  - Import / Export limitations
  - Renewable online schedule

Note: Study work is in progress, results are not final and are subject to change

Next Steps: Develop method for studying alternative to meeting needs

- Purpose:
  - After consideration of local resources, if residual shortage needs are identified test different solutions for meeting residual needs:
    - Storage
    - Curtailment / dispatchable renewable
    - Reserve sharing
    - Different combinations of conventional resources
    - Dynamic transfers
    - Additional demand response
  - Assess feasibility of alternative solutions
  - Leverage EPRI/NREL work to the extent possible

Note: Study work is in progress, results are not final and are subject to change