



Western US RA Study

ESIG Spring Technical Workshop

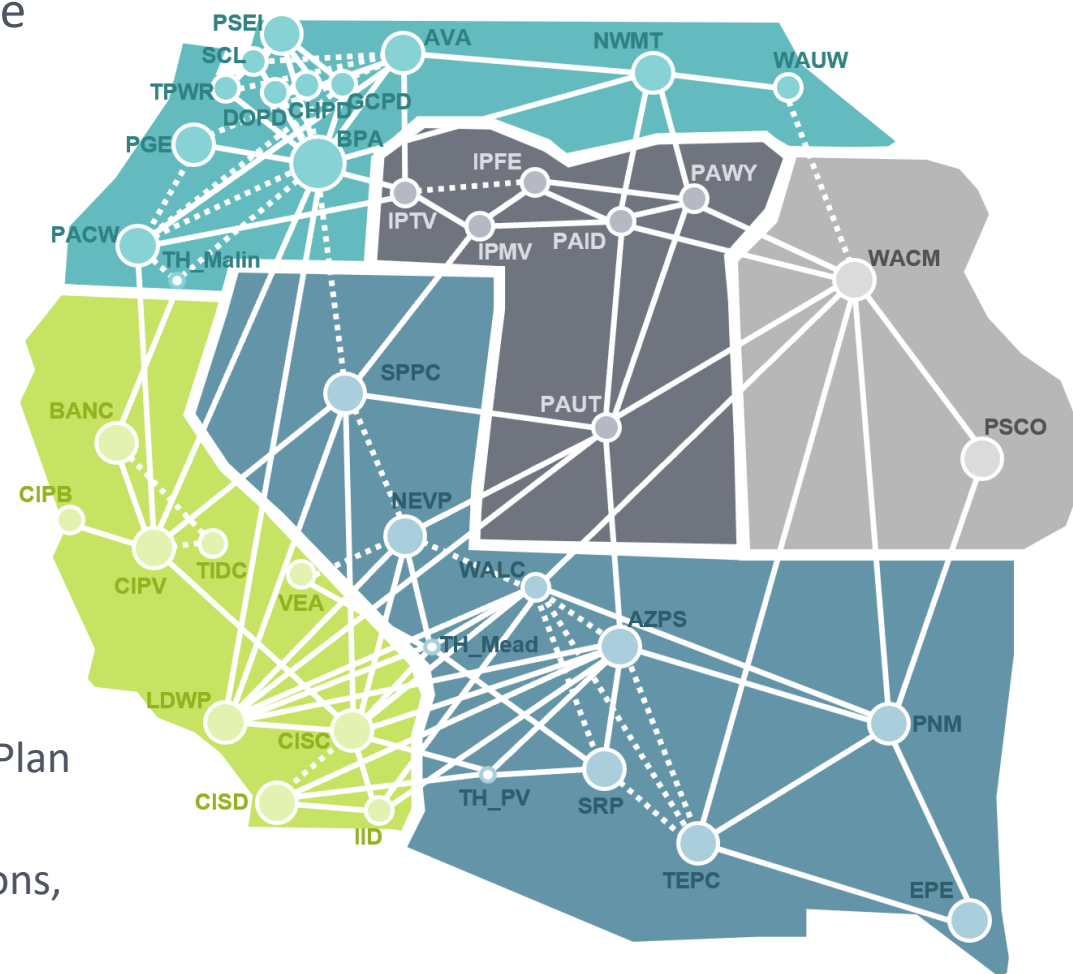
Elaine Hart, Moment Energy Insights

Ana Mileva, Blue Marble Analytics

March 22nd, 2022

A modern approach to RA in the West

- Open-source model (GridPath) with publicly available datasets
- Study sponsored by **GridLAB**
- Phase 1 areas of focus and innovation:
 - Transmission flows and regional coordination
 - Weather correlations across the West
 - Dynamic dispatch of energy-limited resources
 - Weather-dependent thermal derates
- Three scenarios for 2026:
 - **Base Scenario** – no planned additions
 - **California Additions Scenario** – CPUC Preferred System Plan additions
 - **Less Coal Scenario** – CPUC Preferred System Plan additions, ~11 GW of additional coal retirements
- Subregional perspectives



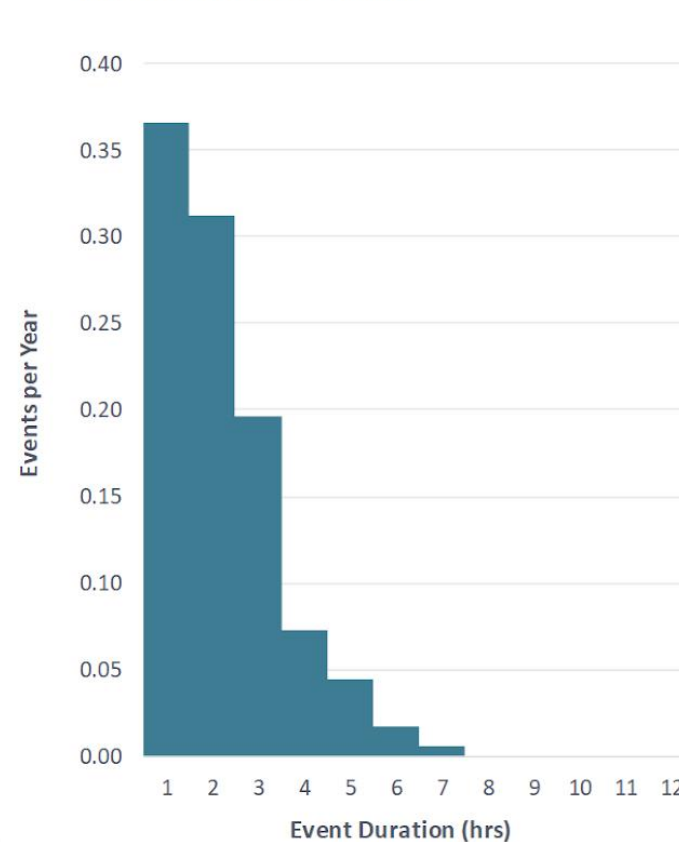
Base Scenario

No planned additions

(a) Loss of Load Hours per Year

	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Hour Ending (PST)												
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.13	0.01	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.31	0.05	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.70	0.13	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.49	0.01	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

(b) Event Duration Distribution



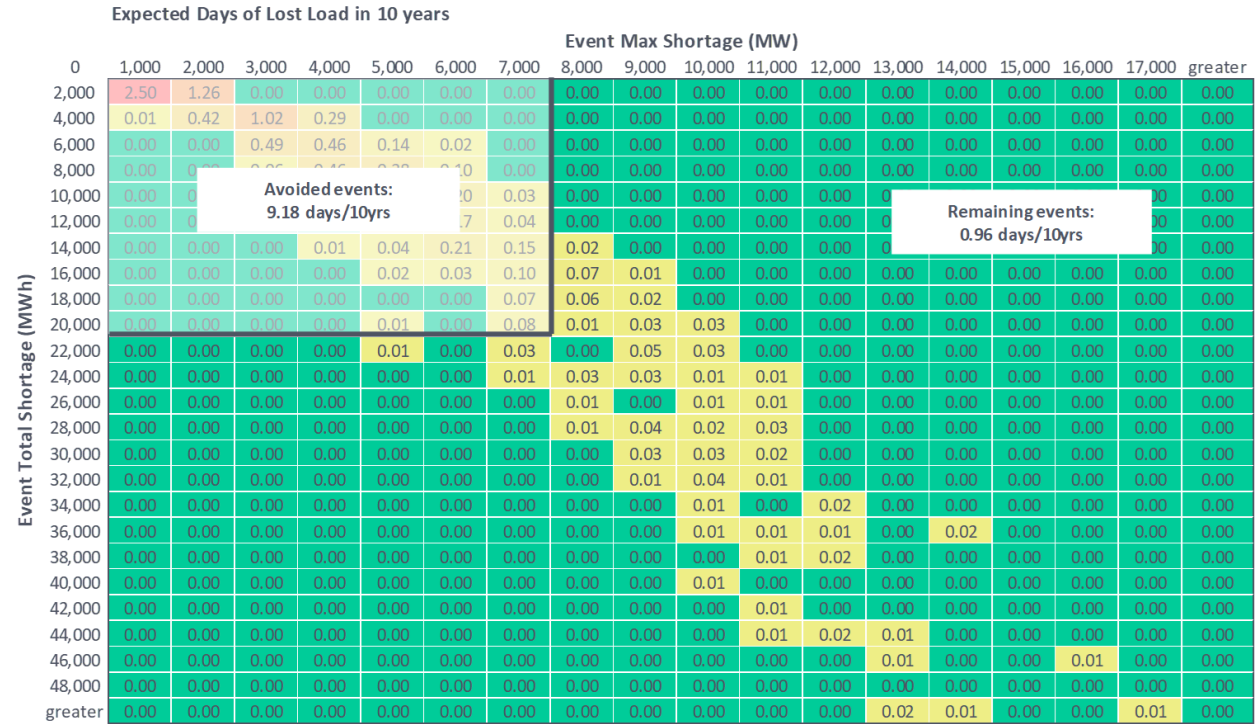
Metric	Value
LOLP _{year}	52%
LOLE (days/10yrs)	10.1
LOLH (hrs/yr)	2.23
EUE (MWh/yr)	6,546
Average Event Duration (hrs)	2.20

West-wide loss of load events/risk:

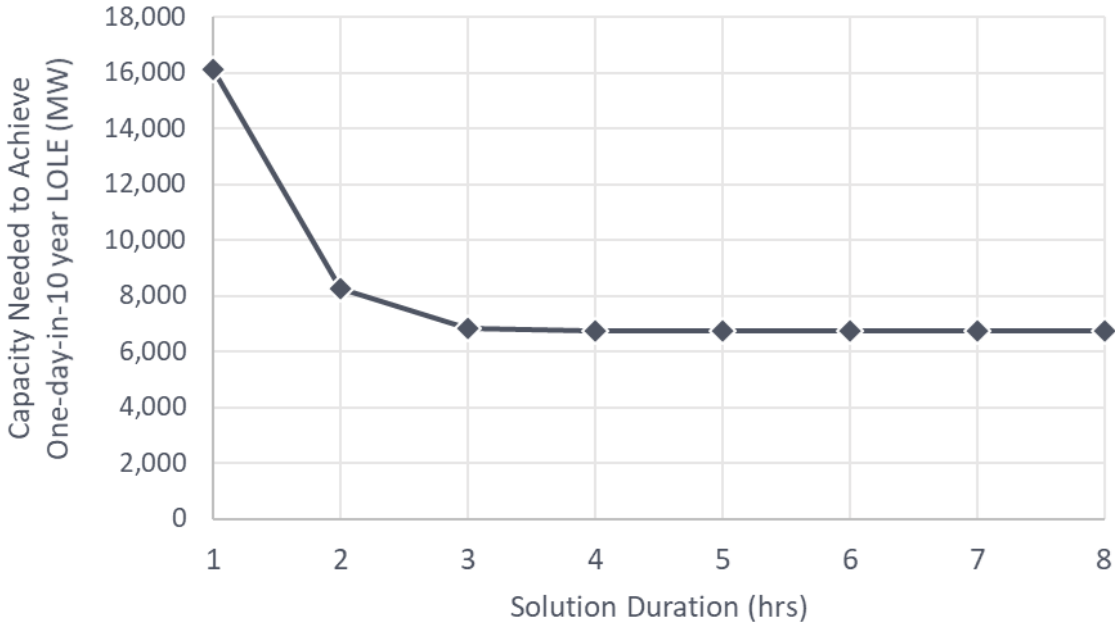
- Are concentrated in the evening on hot summer days
- Peaks at HE 18 (7pm PDT) in August
- Are limited to <8 hours in duration

Base Scenario

No planned additions



RA Standard	Perfect Capacity Need
LOLE = One-day-in-10-years	6,758 MW
LOLH = 2.4 hrs per year	0 MW



Base Scenario

CAISO subregional analysis

CAISO - Islanded

(a) Loss of Load Hours per Year

Hour Ending (PST)	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.25	0.12	0.01	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.01	0.15	0.71	0.33	0.07	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.04	0.58	1.96	1.44	0.77	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.35	2.06	6.73	5.48	1.45	0.00	0.00
19	0.00	0.00	0.00	0.00	0.08	1.47	6.07	11.86	4.11	0.68	0.00	0.00
20	0.00	0.00	0.00	0.00	0.01	1.01	3.52	6.19	1.62	0.26	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.31	0.95	2.11	0.55	0.04	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.01	0.14	0.40	0.14	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

CAISO – With Imports

(a) Loss of Load Hours per Year

Hour Ending (PST)	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.11	0.01	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.30	0.05	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.70	0.13	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.49	0.01	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Metric	CAISO as an Island	CAISO w/ imports
LOLP _{year}	100%	52%
LOLE (days/10yrs)	265	10.1
LOLH (hrs/yr)	64.2	2.19
EUE (MWh/yr)	155,021	5,800
Average Event Duration (hrs)	2.42	2.16
Perfect Capacity Need (MW) One-day-in-10-year std.	10,356 MW	6,495 MW

Accounting for imports:

- Significantly reduces the LOLE & LOLH
- Reduces perfect capacity need by ~4 GW
- Concentrates identified loss of load risk into fewer months and hours of the day
- Reduces event durations

Note: This study uses a physical representation of CAISO and does not account for resources outside of CAISO that are contractually obligated to serve LSEs within CAISO

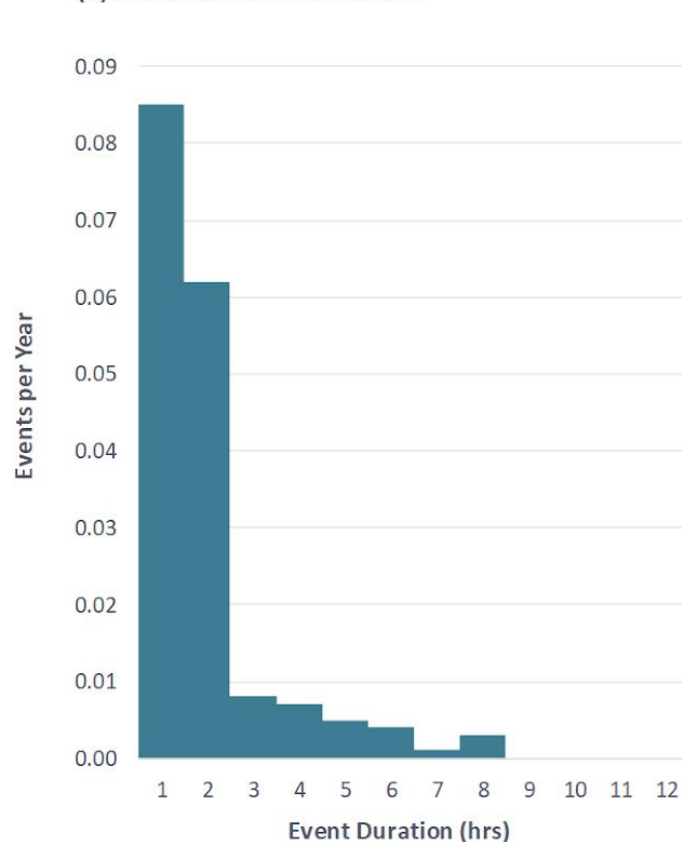
Less Coal Scenario

Swaps clean in CA for coal in WRAP

(a) Loss of Load Hours per Year

	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.01	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

(b) Event Duration Distribution



Metric	Less Coal Scenario	Base Scenario
LOLP _{year}	14%	52%
LOLE (days/10yrs)	1.75	10.1
LOLH (hrs/yr)	0.34	2.23
EUE (MWh/yr)	749	6,546
Average Event Duration (hrs)	1.95	2.20
Perfect Capacity Need (MW) One-day-in-10-year standard	1,259	6,758

Adding the CPUC Preferred System Portfolio resources and retiring ~11,000 GW of additional coal (beyond current plans):

- Reduces LOLE, LOLH, and capacity need
- Further concentrates loss of load risk into August HE 18-19
- Limits most events to 2 hours

Less Coal Scenario

WRAP subregional analysis

WRAP - Islanded

(a) Loss of Load Hours per Year

Hour Ending (PST)	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
2	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
3	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
4	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
5	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
6	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
7	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32
8	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
9	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
10	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.20
11	0.02	0.00	0.00	0.00	0.00	0.01	0.05	0.00	0.00	0.00	0.00	0.16
12	0.02	0.00	0.00	0.00	0.00	0.06	0.43	0.10	0.00	0.00	0.00	0.13
13	0.01	0.00	0.00	0.00	0.00	0.18	1.64	0.93	0.01	0.00	0.00	0.13
14	0.02	0.00	0.00	0.00	0.00	0.35	3.98	3.33	0.08	0.00	0.00	0.11
15	0.02	0.00	0.00	0.00	0.00	0.64	6.42	6.22	0.29	0.00	0.00	0.12
16	0.02	0.00	0.00	0.00	0.00	1.06	9.03	9.06	0.51	0.00	0.00	0.14
17	0.02	0.00	0.00	0.00	0.00	1.55	10.67	11.81	0.84	0.00	0.00	0.29
18	0.05	0.00	0.00	0.00	0.00	2.37	13.99	15.78	1.10	0.00	0.00	0.44
19	0.04	0.00	0.00	0.00	0.00	2.96	15.17	13.62	0.45	0.00	0.00	0.41
20	0.03	0.00	0.00	0.00	0.00	1.62	8.42	4.74	0.06	0.00	0.00	0.32
21	0.02	0.00	0.00	0.00	0.00	0.29	1.62	0.87	0.00	0.00	0.00	0.24
22	0.02	0.00	0.00	0.00	0.00	0.04	0.05	0.01	0.00	0.00	0.00	0.13
23	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
24	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09

WRAP – With Imports

(a) Loss of Load Hours per Year

Hour Ending (PST)	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.01	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Metric	WRAP as an Island	WRAP w/ imports
LOLP _{year}	100%	14%
LOLE (days/10yrs)	389	1.75
LOLH (hrs/yr)	158	0.34
EUE (MWh/yr)	186,509	748
Average Event Duration (hrs)	4.05	1.95
Perfect Capacity Need (MW)	9,111 MW	1,259 MW
One-day-in-10-year std		

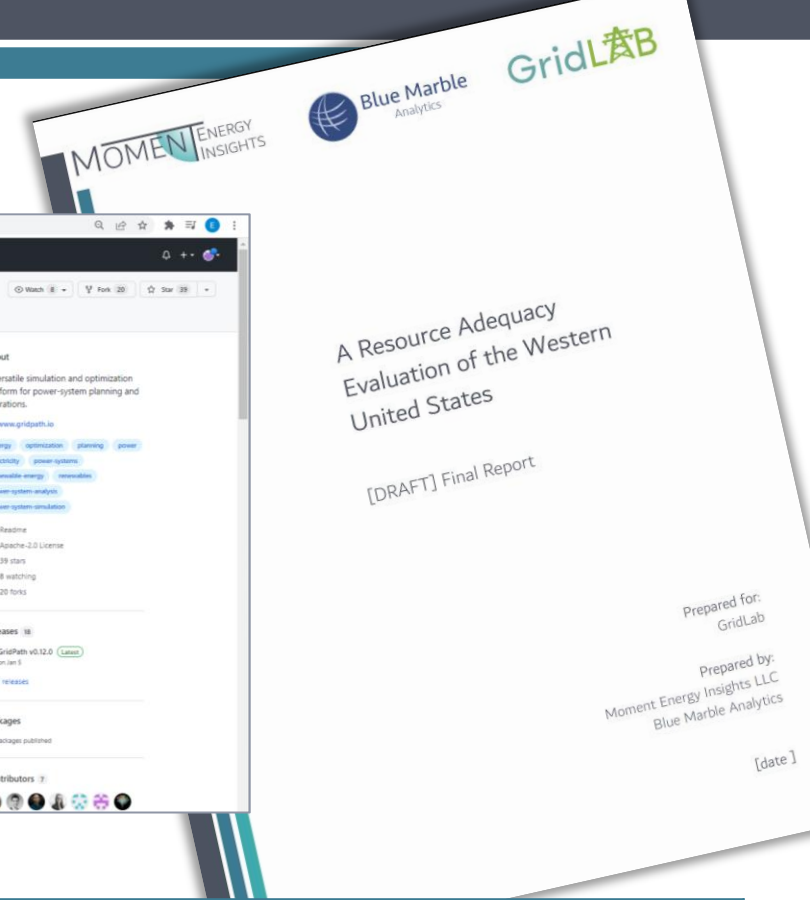
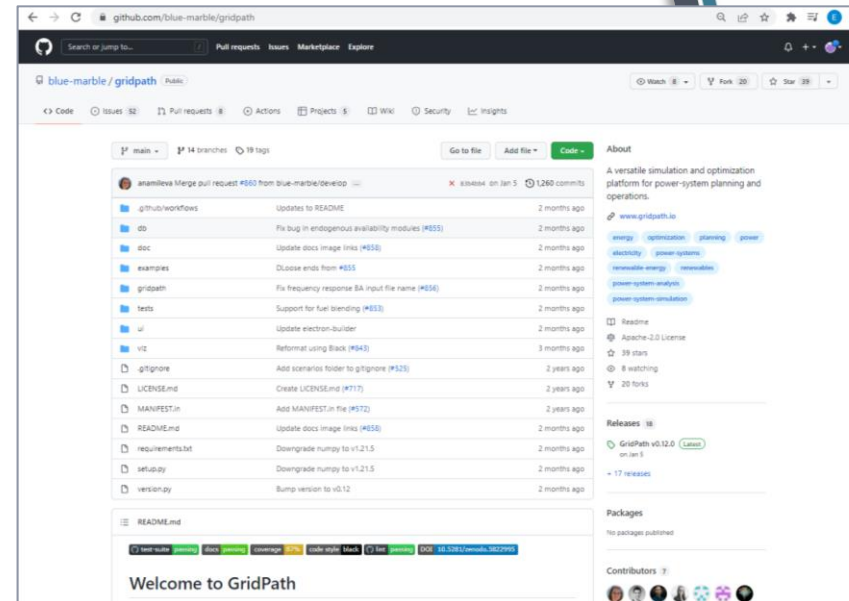
Accounting for imports:

- Significantly reduces LOLE & LOLH
- Reduces perfect capacity need by ~8 GW
- Eliminates identified winter risk and concentrates summer risk into fewer months and hours of the day
- Significantly reduces event durations

Note: This study uses a physical approximation of the WRAP footprint, which includes loads and resources in the following WECC BAs: AVA, AZPS, BANC, BPAT, CHPD, DOPD, GCPD, IPFE, IPMV, IPTV, NEVP, NWM, PACW, PAID, PAUT, PAWY, PGE, PSEI, SCL, SPPC, SRP, TIDC, TPWR

Final report coming soon!

- GridPath code base available on GitHub (<https://github.com/blue-marble/gridpath>)
- Supporting code and input data to run cases will also be posted on GitHub
- Additional intermediate data will be available upon request



Shapes	Years	Geographical Resolution
Hourly Load	2006-2020 (transformed to study year)	WECC BA
Hourly Wind	2007-2014	EIA Plant
Hourly Solar	1998-2019	EIA Plant
Hourly Thermal Derates	1998-2019	EIA Generator
Monthly Hydro Energy, Pmin, and Pmax	2001-2020	WECC BA



Questions?

For more information about GridPath or this project, please reach out to us:

Ana Mileva

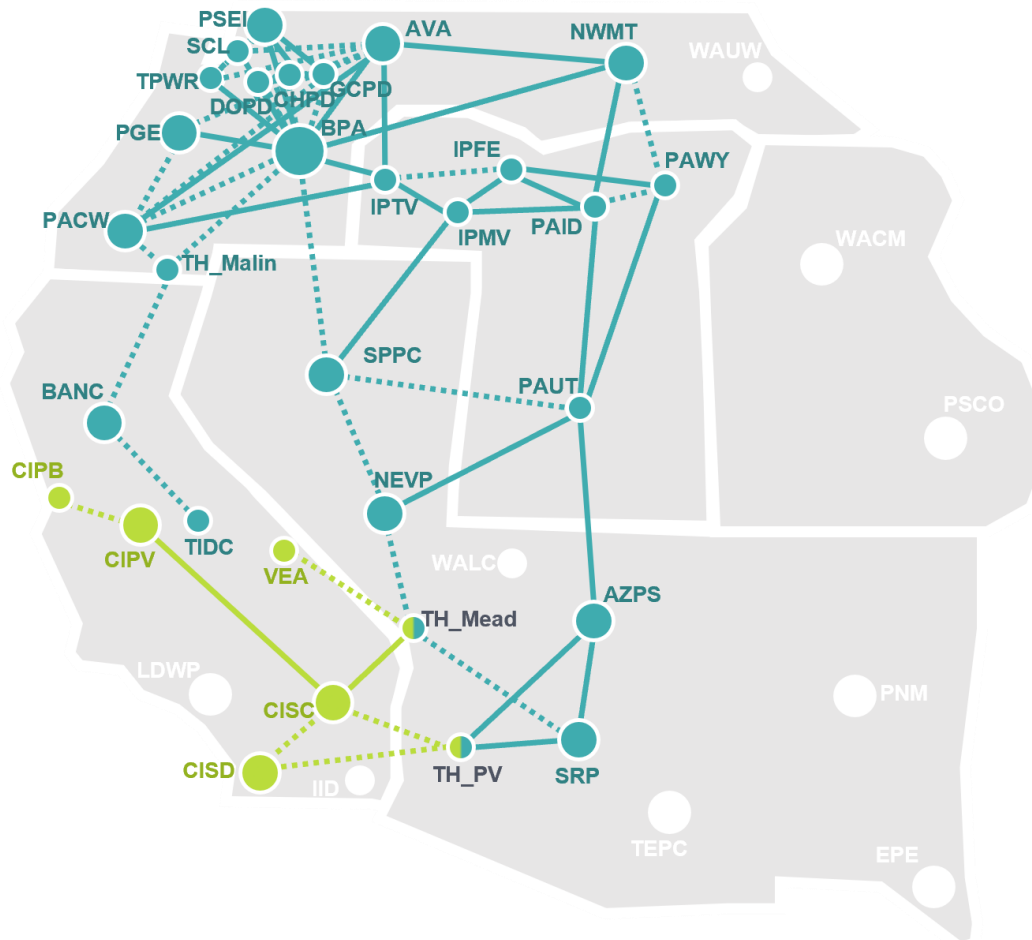
ana@bluemarble.run

Elaine Hart

elaine@momentenergyinsights.com

Additional information

Subregional analysis



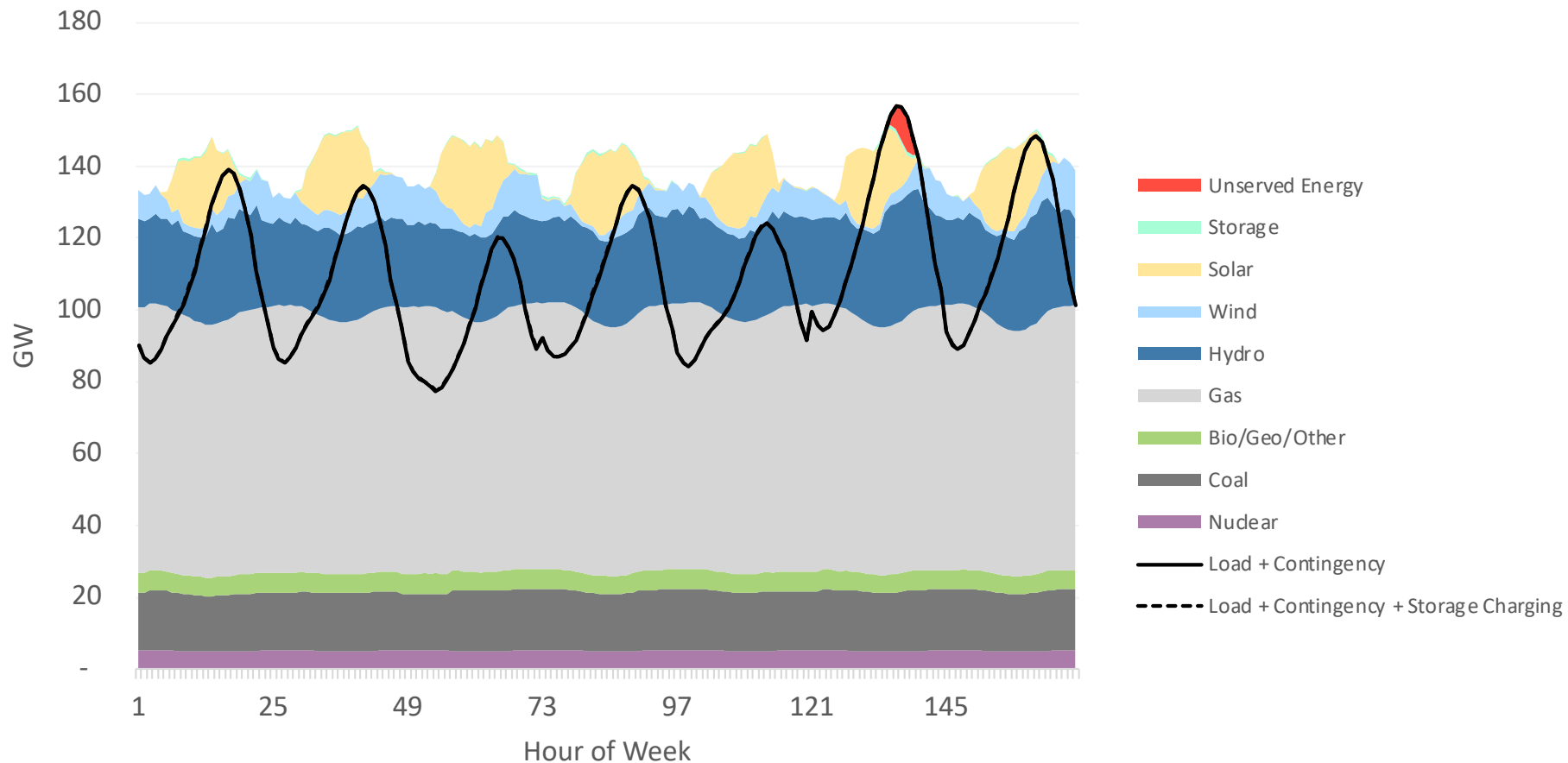
Subarea	WECC BAs/Zones
CAISO	CIPB, CIPV, CISC, CISD, VEA, TH_Mead (partial), TH_PV (partial)
WRAP	AVA, AZPS, BANC, BPAT, CHPD, DOPD, GCPD, IPFE, IPMV, IPTV, NEVP, NWMT, PACW, PAID, PAUT, PAWY, PGE, PSEI, SCL, SPPC, SRP, TIDC, TPWR, TH_Malin, TH_Mead (partial), TH_PV (partial)
Excluded	EPE, IID, LDWP, PNM, PSCO, TEPC, WACM, WALC, WAUW

Accounting for imports

- In the “Imports” cases, unserved energy for a given subregion (CAISO or WRAP) is only recorded to the extent that it is observed in the islanded simulation AND in the West-wide simulation. In each hour:
 - Unserved energy w/ Imports = $\min(\text{Islanded unserved energy}, \text{West-wide unserved energy})$
 - If every decision-maker takes this approach, the system will still tend to be somewhat overbuilt because multiple entities could be taking full responsibility for the same West-wide problem in some hours

Additional information

Example resource availability and dispatch

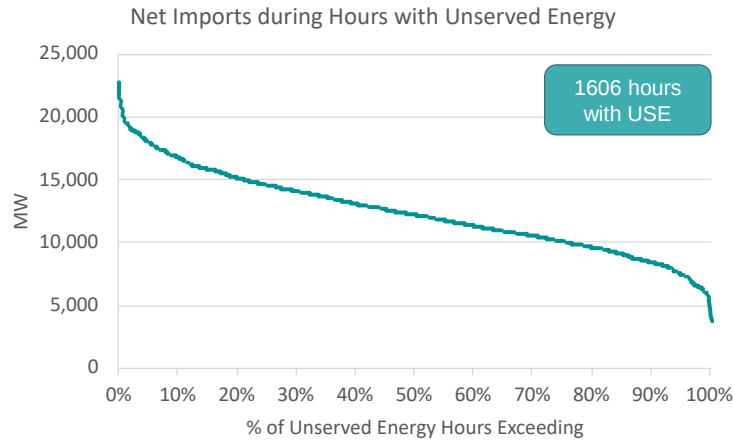


DRAFT OR ILLUSTRATIVE – DO NOT CIRCULATE

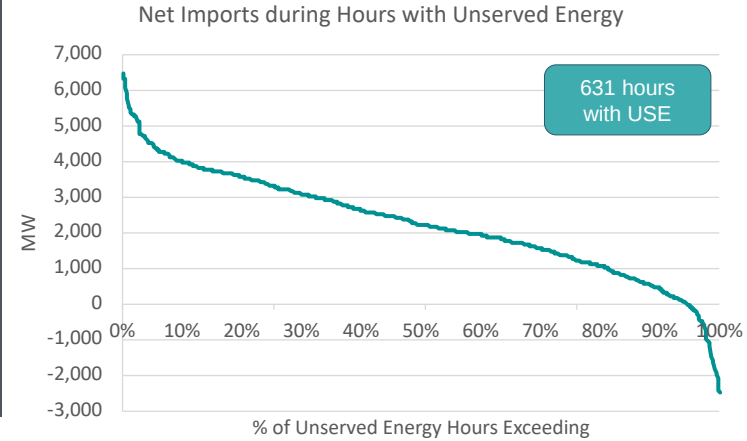
Additional information

Example regional flow information

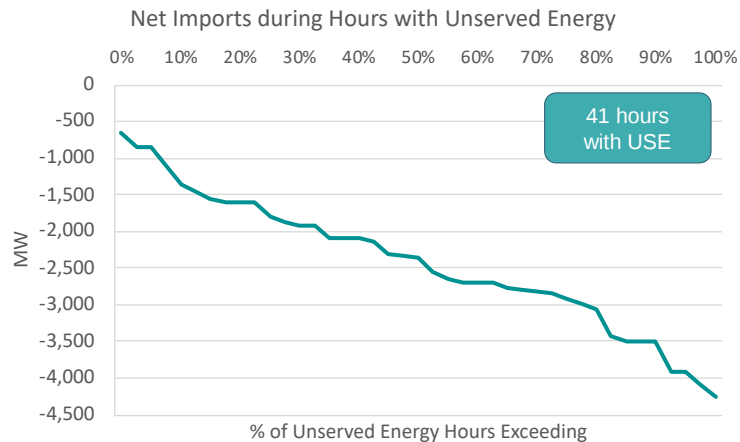
California



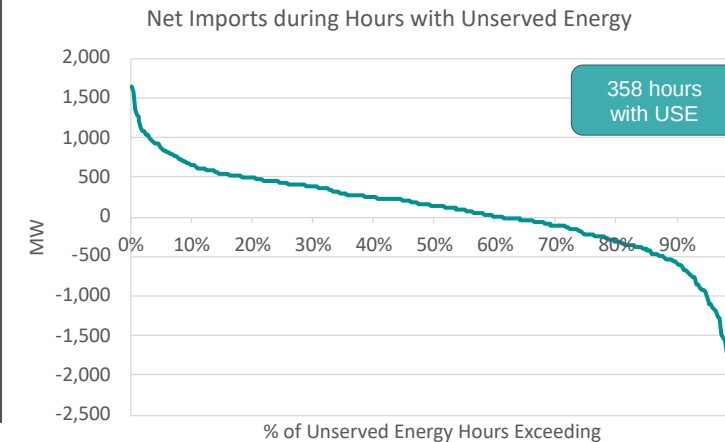
Southwest



Northwest



Rocky Mountain - Basin



DRAFT OR ILLUSTRATIVE – DO NOT CIRCULATE