California ISO

Flexible Ramping Product Refinements discussion

Kun Zhao, Ph.D.

Market Engineering Specialist Lead

Guillermo Bautista Alderete, Ph. D.

Director, Market Performance and Advanced Analytic

Market Surveillance Committee Meeting

General Session

September 25, 2023

FRP Enhancements implemented on February 2023

- Enhanced methodology to calculate FRP requirement as a function of demand, solar, and wind forecast
  - Change from histogram calculation to quantile regression
  - Recognize the current operating condition by using forecasts as inputs
- Remove features of NIC/NEC, FRU/FRD credit from uncertainty requirement in market optimization
- Enforce transmission constraints and EIM transfer constraints
  - Assume full uncertainty realization -> FRP deployment scenario
  - FRP nodal pricing

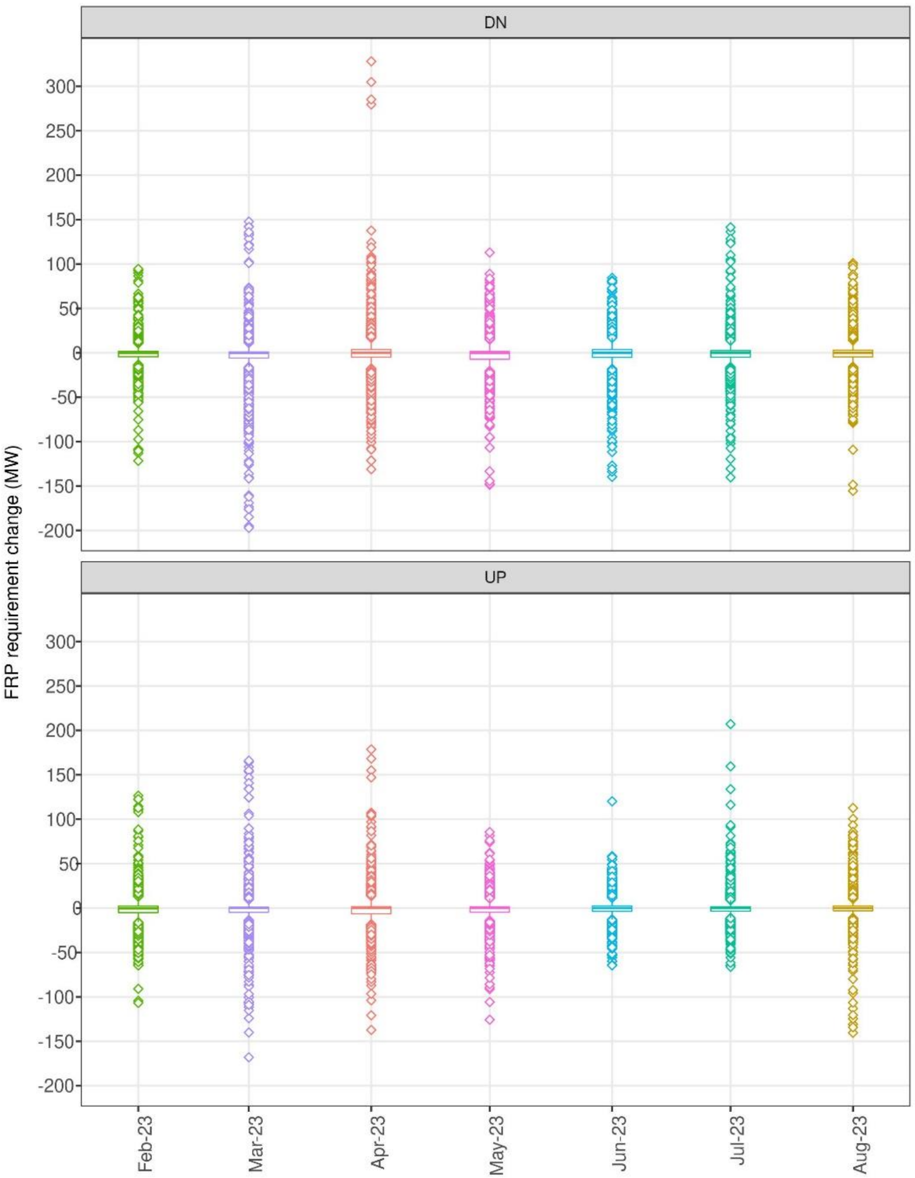
FRP requirements may change across the three test passes

For the flex test, there are three passes at T-75, T-55 and T-40

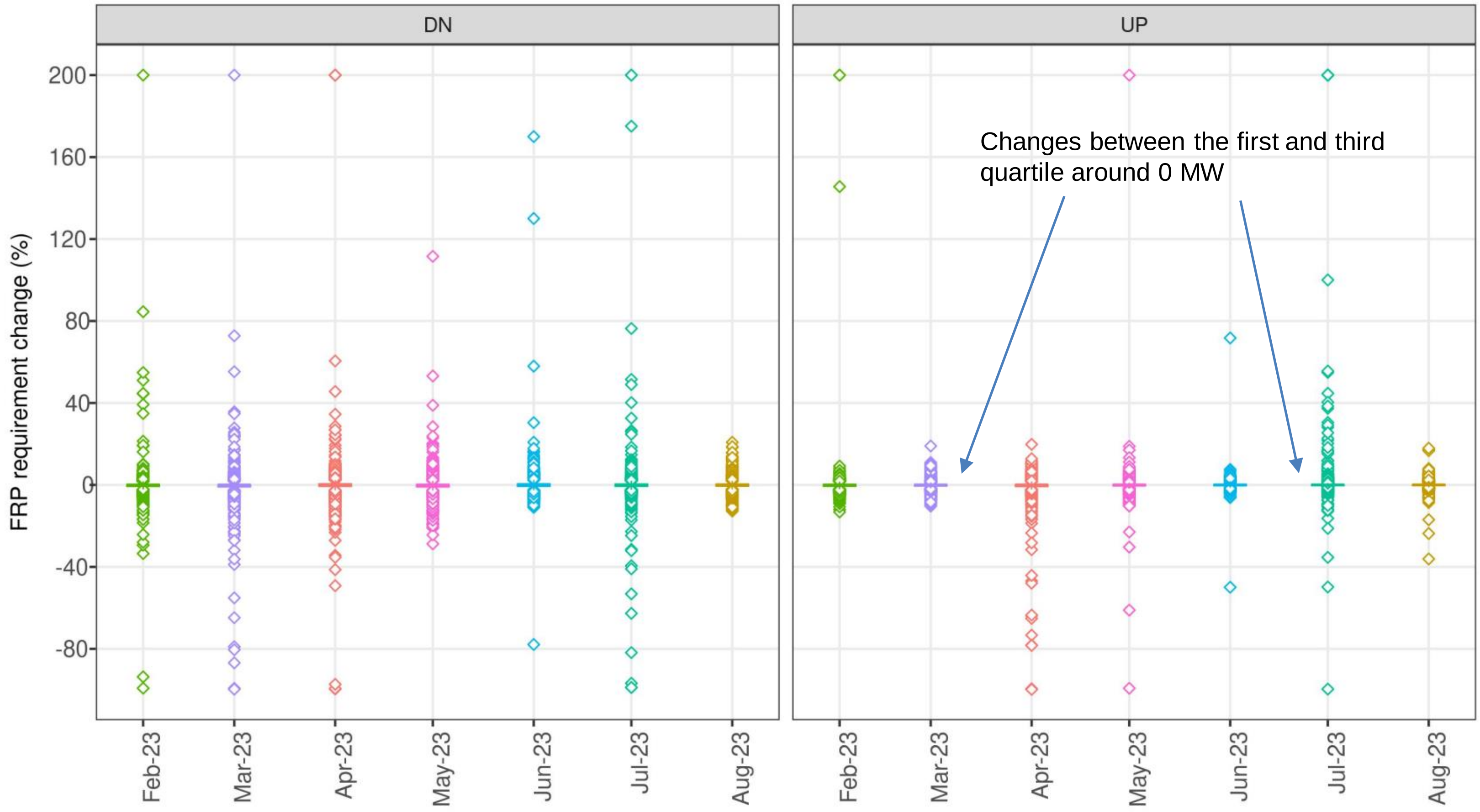
Changes happens only from T-75 to T-55

With inputs fixed for the last pass,
there are no changes from T-55 to T-40

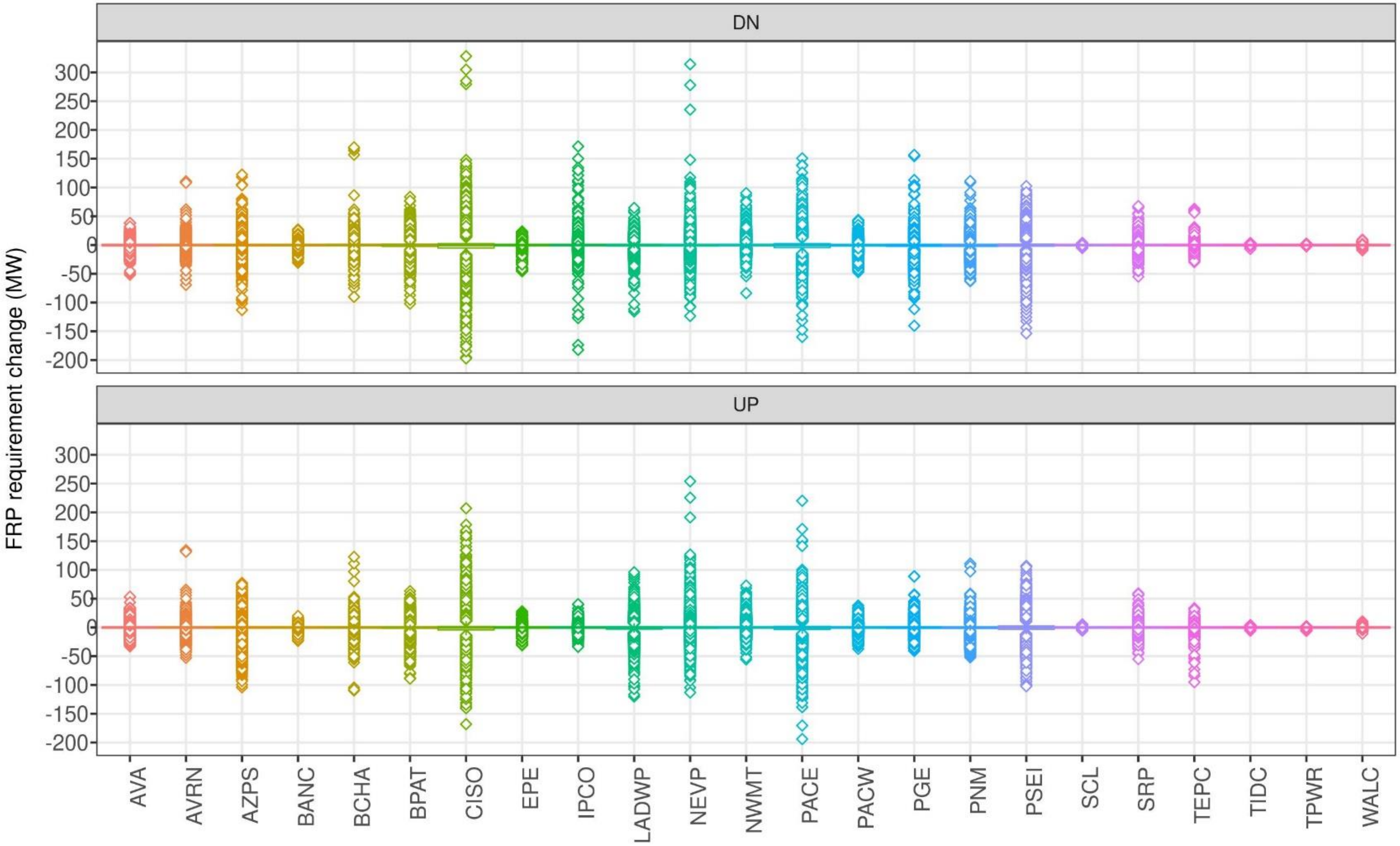
If T-55 > T-75 then requirements increased and the value of change is positive



The majority the FRP requirement changes (in percent) between the test passes are relatively small for CISO area



The changes from the first to the second test is generally small across all WEIM areas for both directions of requirements



The frequency of flexible ramping test failures may appear to increase during the months of transitioning seasons

	Dec-2022	Jan-2023	Feb-2023	Mar-2023	Apr-2023	May-2023	Jun-2023	Jul-2023	Aug-2023
AVA	0.1	0	0	0	0.2	0.2	0	0	0
AVRN					1	0.7	0.1	0.2	0
AZPS	0.4	0.9	1.8	2.5	1.1	0.2	0.1	0	0
BANC	0	0	0	0	0	0.1	0	0	0
BCHA	0	0	0.2	0	0	0	0	0	0.1
BPAT	0.4	0	0.1	0.6	0.2	1.2	0.3	1.8	0.3
CISO	0	0	0	0	0	0	0	0	0
EPE					0.8	0.6	0.3	2.1	0.5
IPCO	0	0	0.1	0.3	0.3	0.5	0.1	0	0
LADWP	0	0	0.3	0	0.1	0	0.1	0	0.1
NEVP	0	0.1	0.3	0	0.1	0.1	0	0.1	0.2
NWMT	0.8	0.3	0.1	0.2	0.8	0.3	0.2	1	0.4
PACE	0	0.1	0	0	0.1	0	0	0.2	0
PACW	0	0.1	0.1	0	0.1	0.6	0	0.2	0
PGE	0.1	0	0.1	0	0.1	1.5	0.7	0.1	0
PNM	0.8	0.2	0	1.2	5.1	0.9	0.6	0.5	0.4
PSEI	0	0	0.1	0.8	0.2	1	0.6	2.6	1.3
SCL	0	0	0.1	0	0	0	0	0	0.5
SRP	0.8	3.5	1.2	1.8	2	0.6	0.2	3.5	1.1
TEPC	0.2	0.3	0.3	0.3	0.1	0.1	0	0.2	0.3
TIDC	1.2	0	0	0	0	0	0	0.1	0
TPWR	0	0.2	0.1	0.2	0	0.1	0	0	0
WALC					2	0.7	0.8	0.3	0.8

Percentage of up failures (%) 0 1 2 3 4 5

Percentage of failures remain relatively low

The frequency of flexible ramping test failures may appear to increase during the months of transitioning seasons

	Dec-2022	Jan-2023	Feb-2023	Mar-2023	Apr-2023	May-2023	Jun-2023	Jul-2023	Aug-2023
AVA	0	0	0	0.1	0.1	0.1	0	0	0
AVRN					0.1	0	0	0	0
AZPS	0.1	0.9	0.5	2.1	0.7	1.2	0.1	0	0
BANC	0	0	0	0	0	0	0	0	0
BCHA	0	0.1	0.1	0	0.2	0	0	0	0
BPAT	0.2	0	0	0.1	0.6	5.5	0.3	0.5	0
CISO	0	0	0	0	0	0	0	0	0
EPE					0.2	0.9	1.9	0.5	0
IPCO	0	0	0	0.9	0.2	0	0	0	0
LADWP	0	0.1	0	0	0	0	0	0	0
NEVP	0.1	0.1	0.1	0.1	0	0.1	0.4	0.1	0.1
NWMT	0.1	0	0	0	0	0.2	0.2	0	0.1
PACE	0	0	0	0	0	0	0	0	0
PACW	0	0	0	0	0	0.2	0	0	0
PGE	0	0	0	0	0	0	0	0	0
PNM	0	0	0	0.4	1.6	2.1	0	0.1	0.4
PSEI	0	0	0	0	0	0.8	0	0	0
SCL	0.6	0.1	0.2	0	0.3	0	0.3	0.4	1.1
SRP	0.3	1.4	3.2	1	0.3	0.1	0.1	0.1	0
TEPC	0	0	0	0	0	0	0	0	0
TIDC	0	0.1	0.1	0.1	0.1	0.4	0	0	0
TPWR	0.1	0	0.2	0.1	0	0	0	0	0
WALC					2.3	0.3	0.7	0.1	0.2

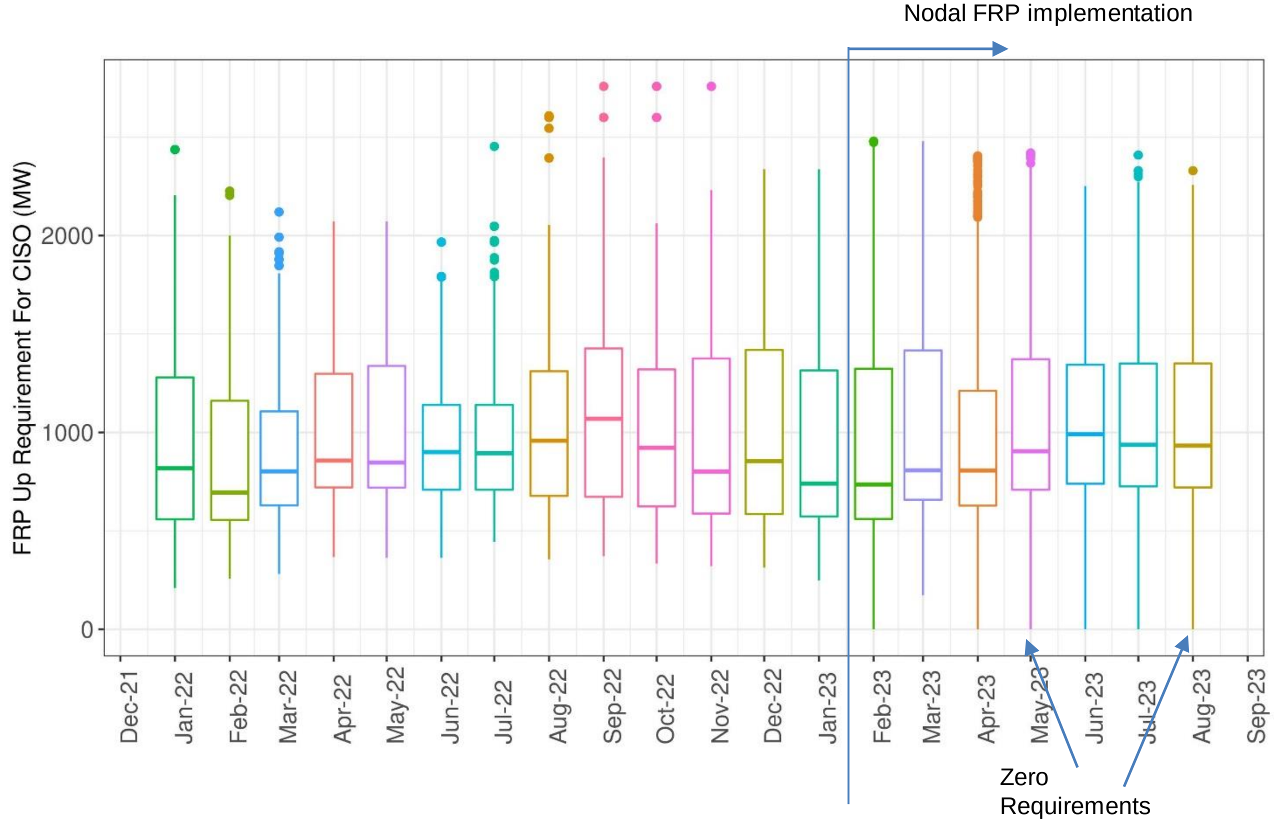
Percentage of down failures (%) 0 1 2 3 4 5

Percentage of failures remain relatively low

FRP Up Requirement for CAISO area remain within typical ranges

This is in part because of caps imposed on the naturally-produced requirements

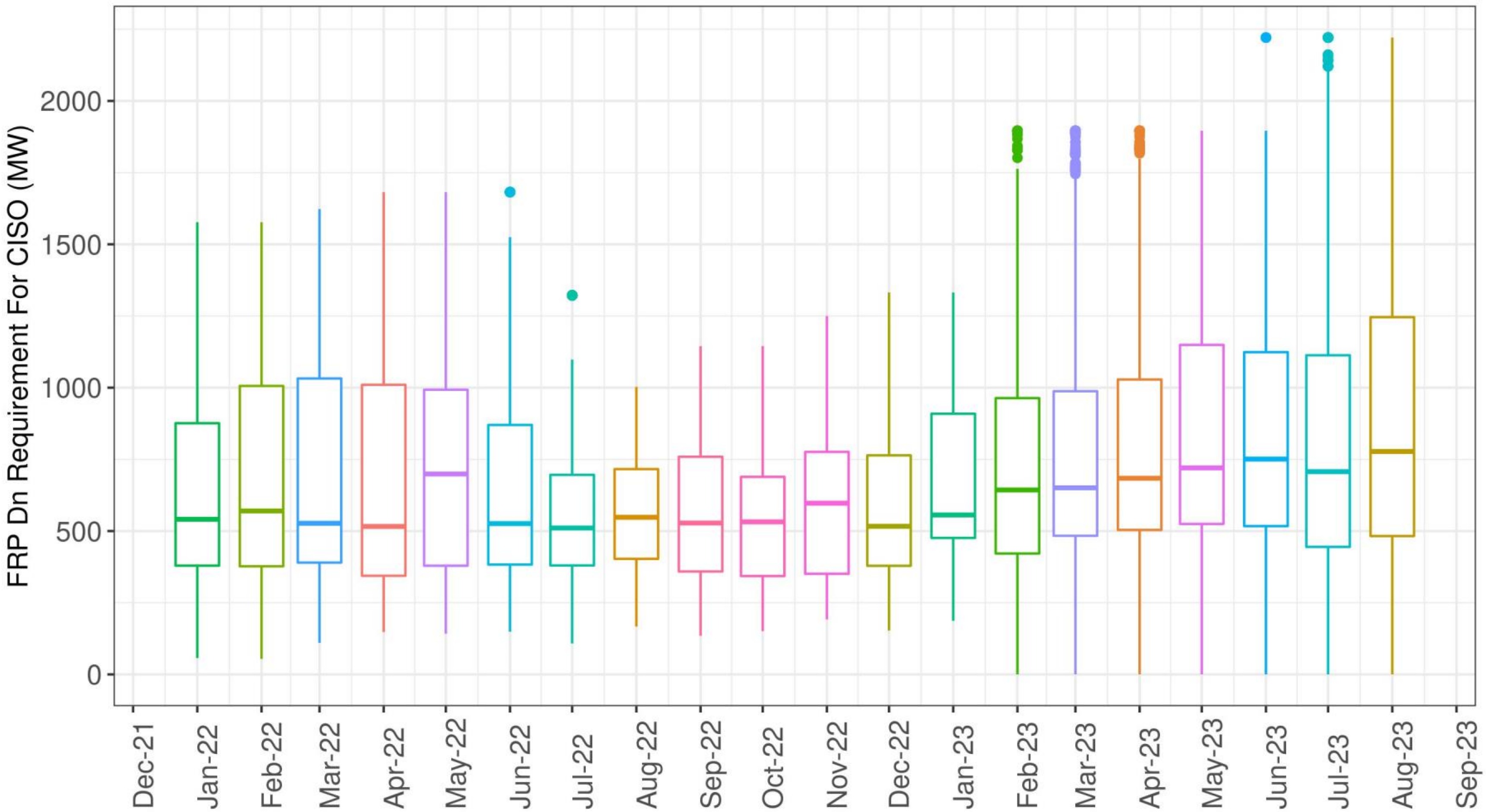
Zero requirements are being now observed.



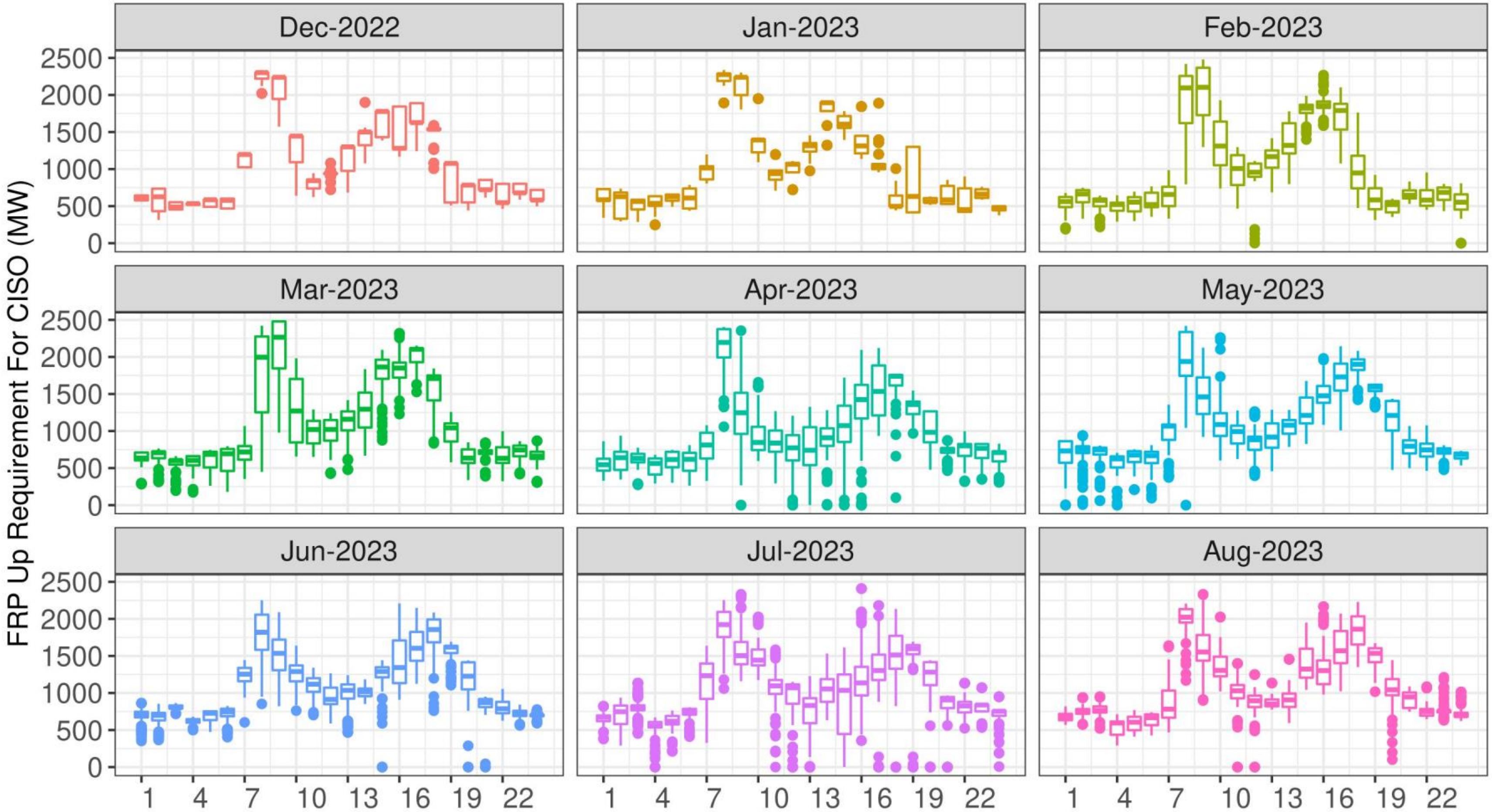
The final requirements produced by the Mosaic approach are bounded by

- a histogram-based cap
- a higher-percentile mosaic cap
- a 0.1MW lower bound to disregard negative requirements

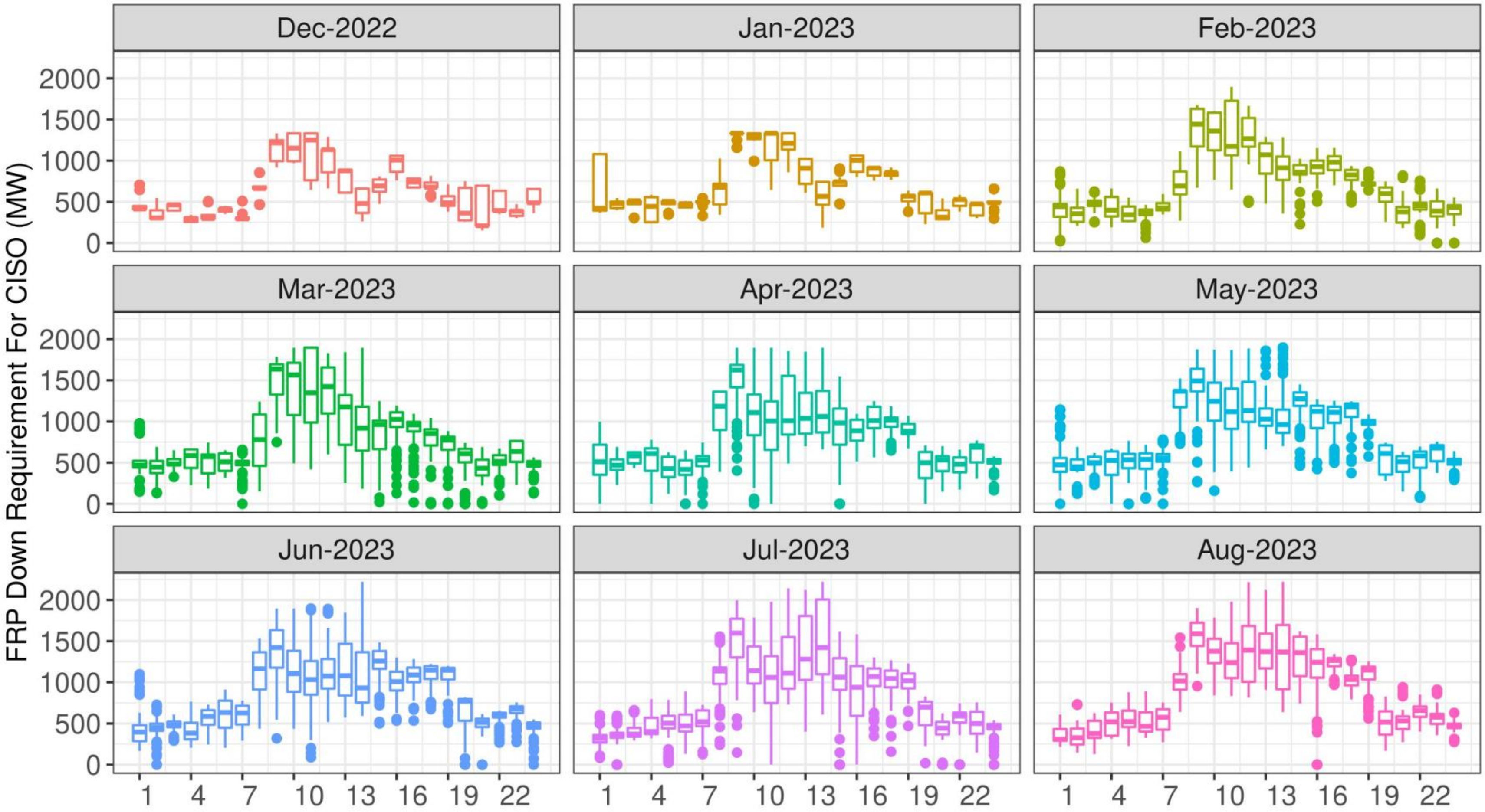
FRP Down Requirement for CAISO area remain within typical ranges



The hourly profile of upward FRP tends to follow a pattern of morning and evening peaks



The hourly profile of downward FRP tends to follow a complementary pattern to the upward FRP, with higher values in midday hours

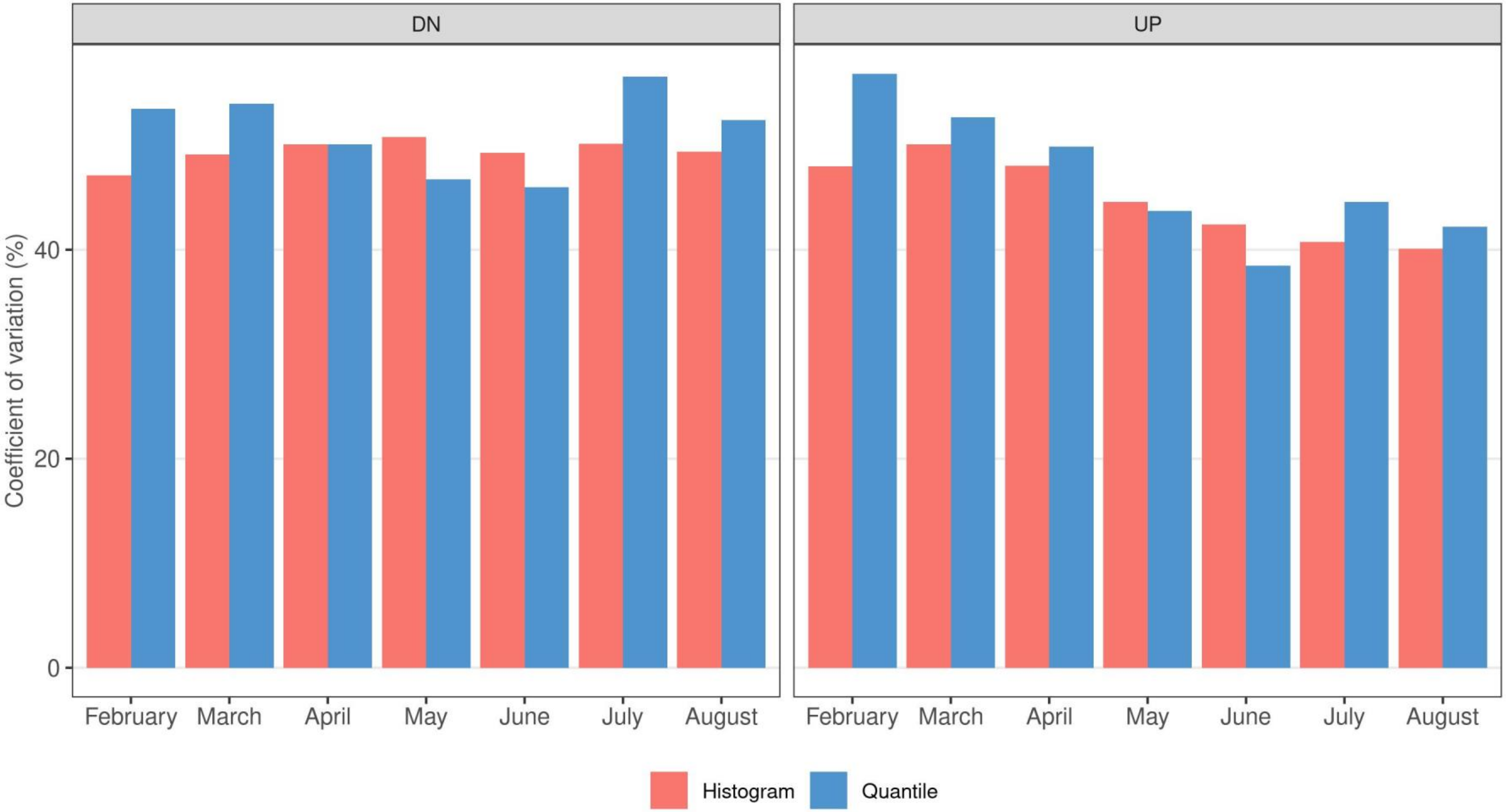


ISO PUBLIC

Methodology to calculate FRP requirements

- Previous methodology relied only on historical data of net load errors
  - a histogram calculation with the use of 97.5th and 2.5th percentiles to define the upward and downward requirement
  - Requirement were hourly
- New quantile calculation is used mainly to account also for current system conditions
  - Based on historical data
  - Based also on prevailing load, wind and solar forecasts
  - Use a type of quadratic regression methodology, with forecasts being the regressors
  - Because forecasts are on 15-minute basis, FRP requirements are now on 15 minute basis
  - Therefore, it is expected and by design that new methodology will produce more variability in the requirements

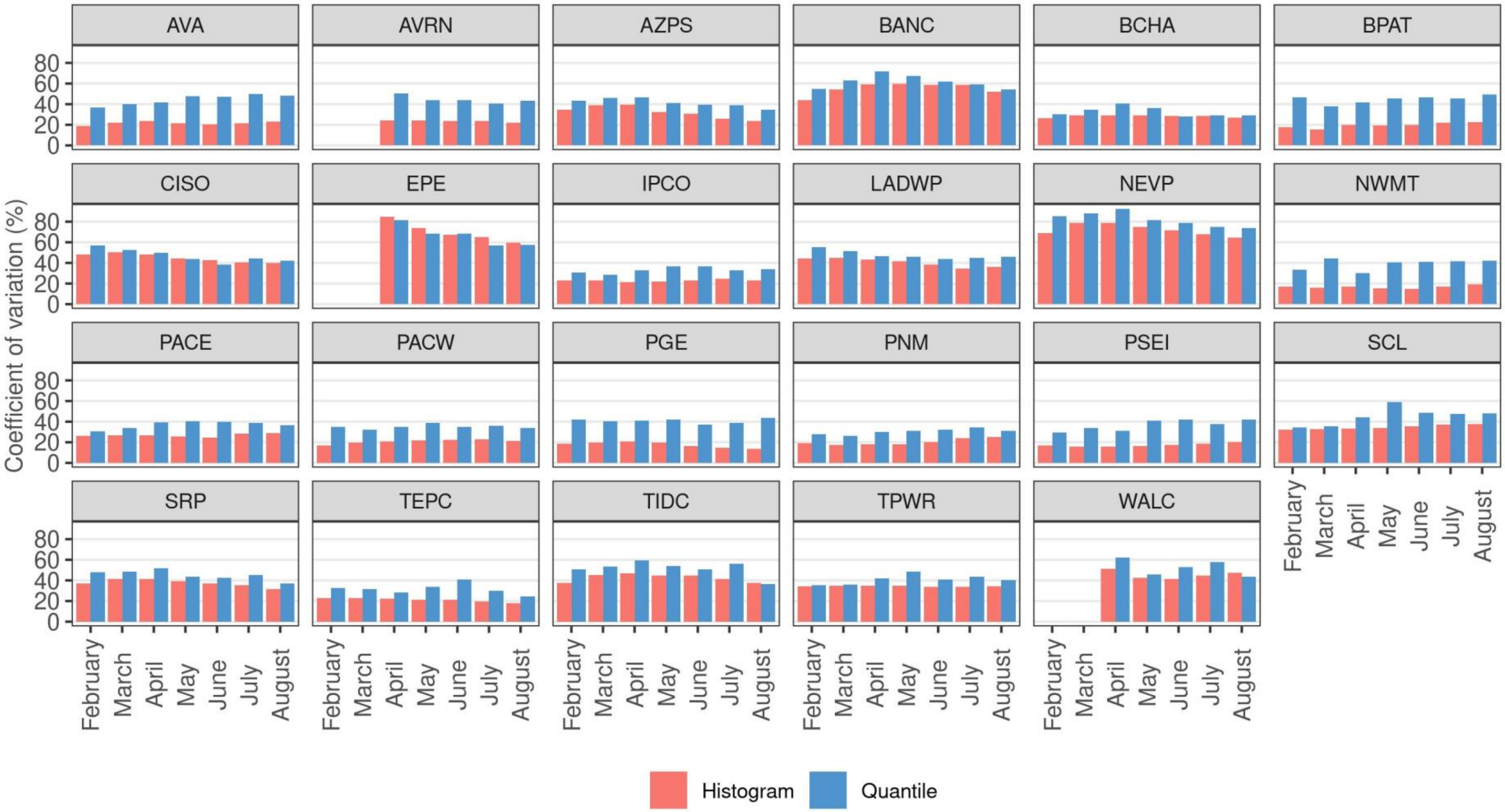
As expected, the variability of requirements is higher with new methodology. CISO area



$$Coefficient\ of\ variation = 100\frac{Standard\ deviation}{mean}$$

This coefficient is useful to compare degree of dispersion of different data sets.
The higher the index the more variability in the data set

The level of variability among areas is more spread in the WEIM market areas, with some areas exhibiting larger variations with the new methodology



California ISO

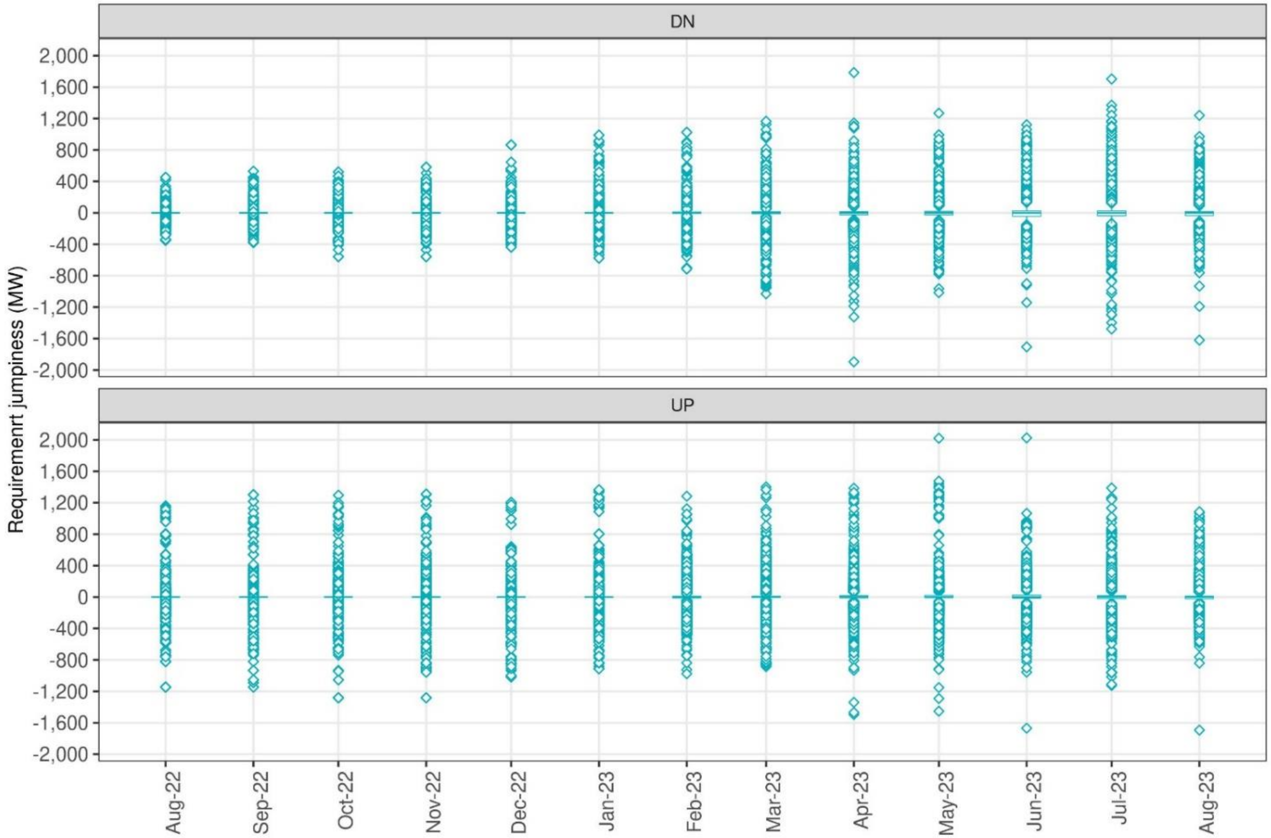
With the new methodology, FRP requirements are expected to exhibit more variability. CISO area only.

Inter-hourly variability:

- Use of different regression model among hours
- Use 15-minute forecasts

Intra-hour variability

- Use 15-minute forecasts



Variation = current interval req – previous interval req
A positive value means the requirement increase relative to previous interval

FRP requirement between adjacent intervals exhibits larger variability since February. CISO area only.

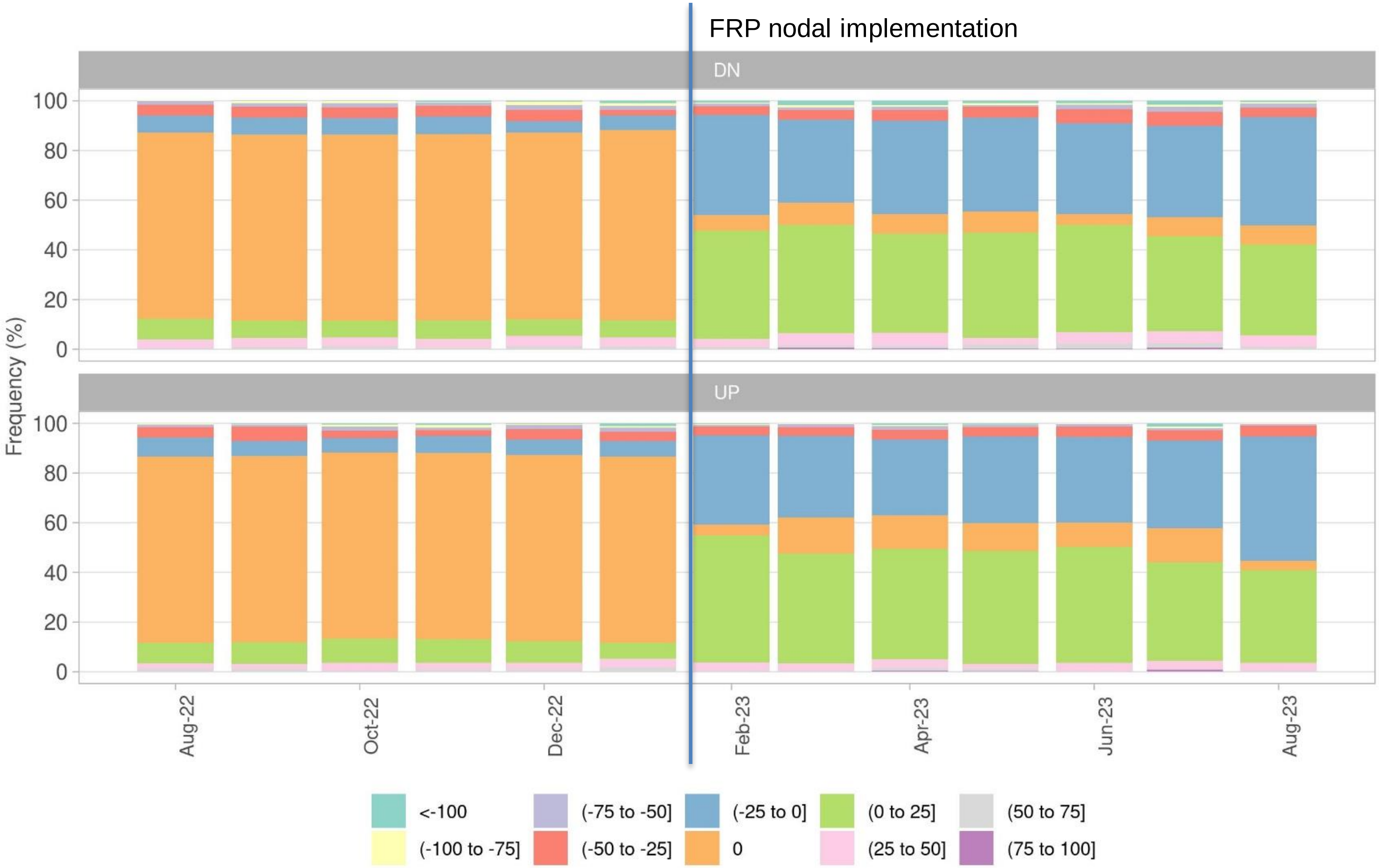
Inter-hourly variability:
- Use of different regression model among hours
- Use 15-minute forecasts

Intra-hour variability
- Use 15-minute forecasts

The most significant volume of variability is contained within a tight range between -50 MW to +50 MW

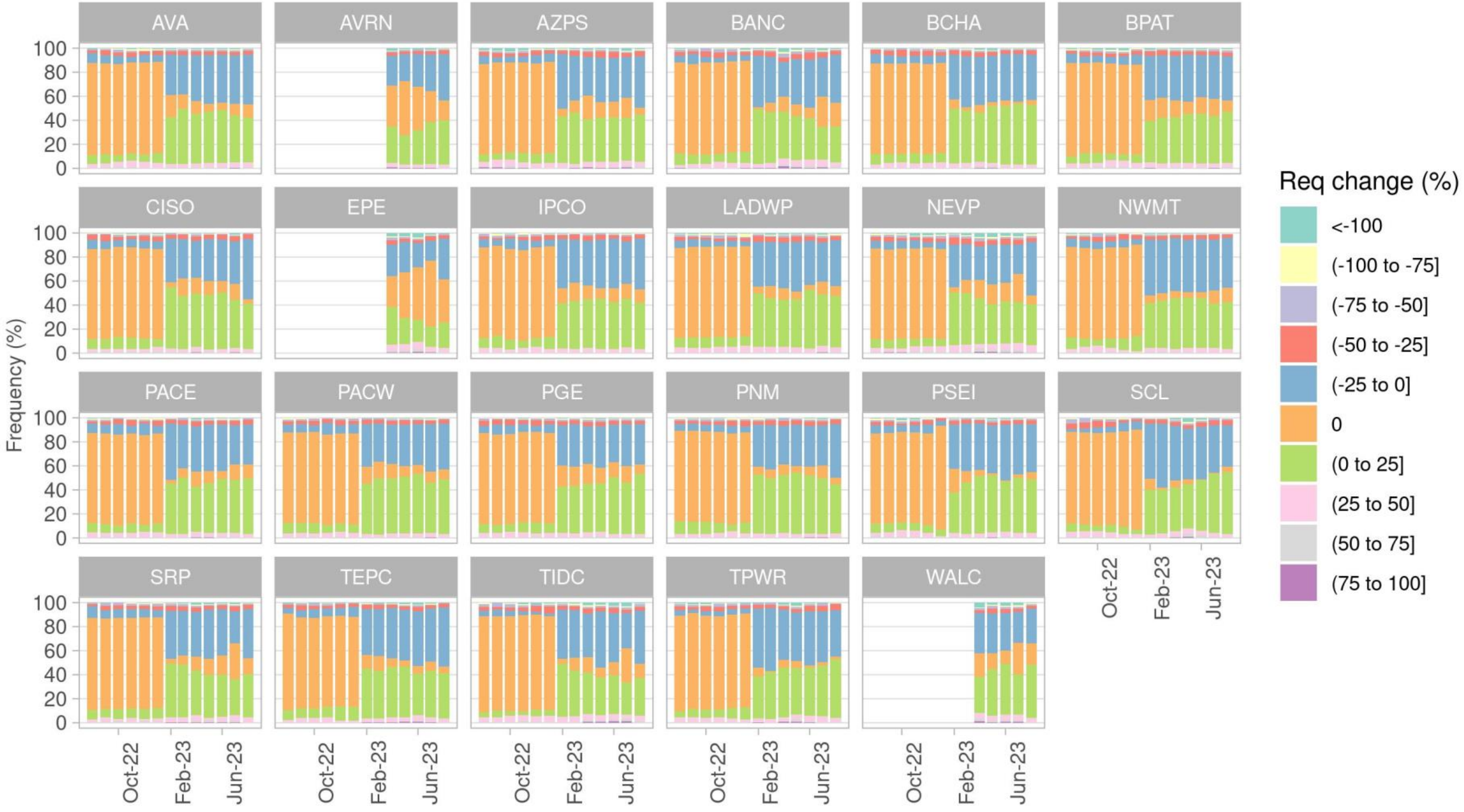
Variation = current interval req – previous interval req
A positive value means the requirement increase relative to previous interval

The requirement changes within ±25 percent of the value from previous interval account for over 80%. CISO area

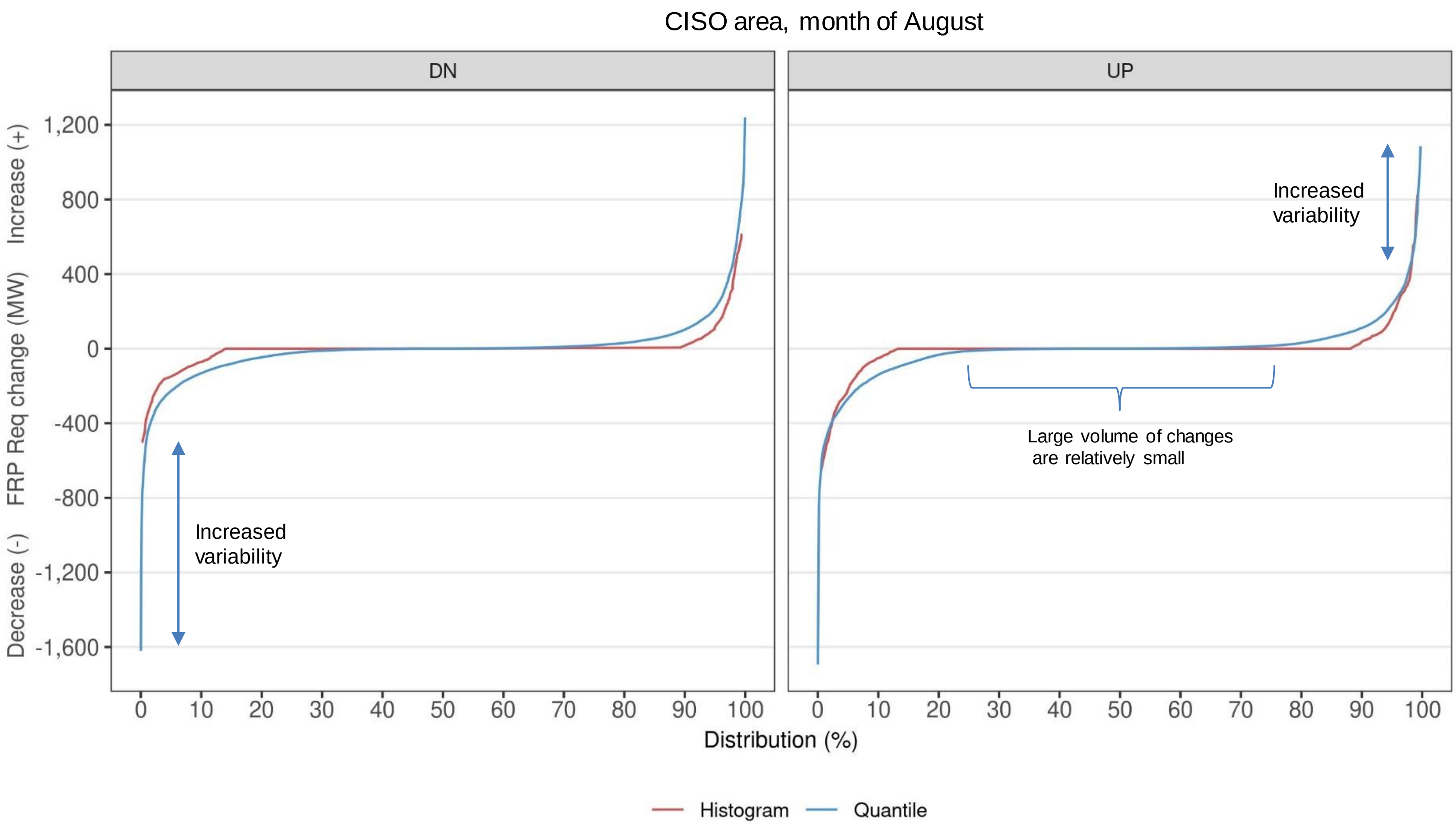


The percentage of each group is estimated $= \frac{current\ interval - previous\ interval}{previous\ interval}$

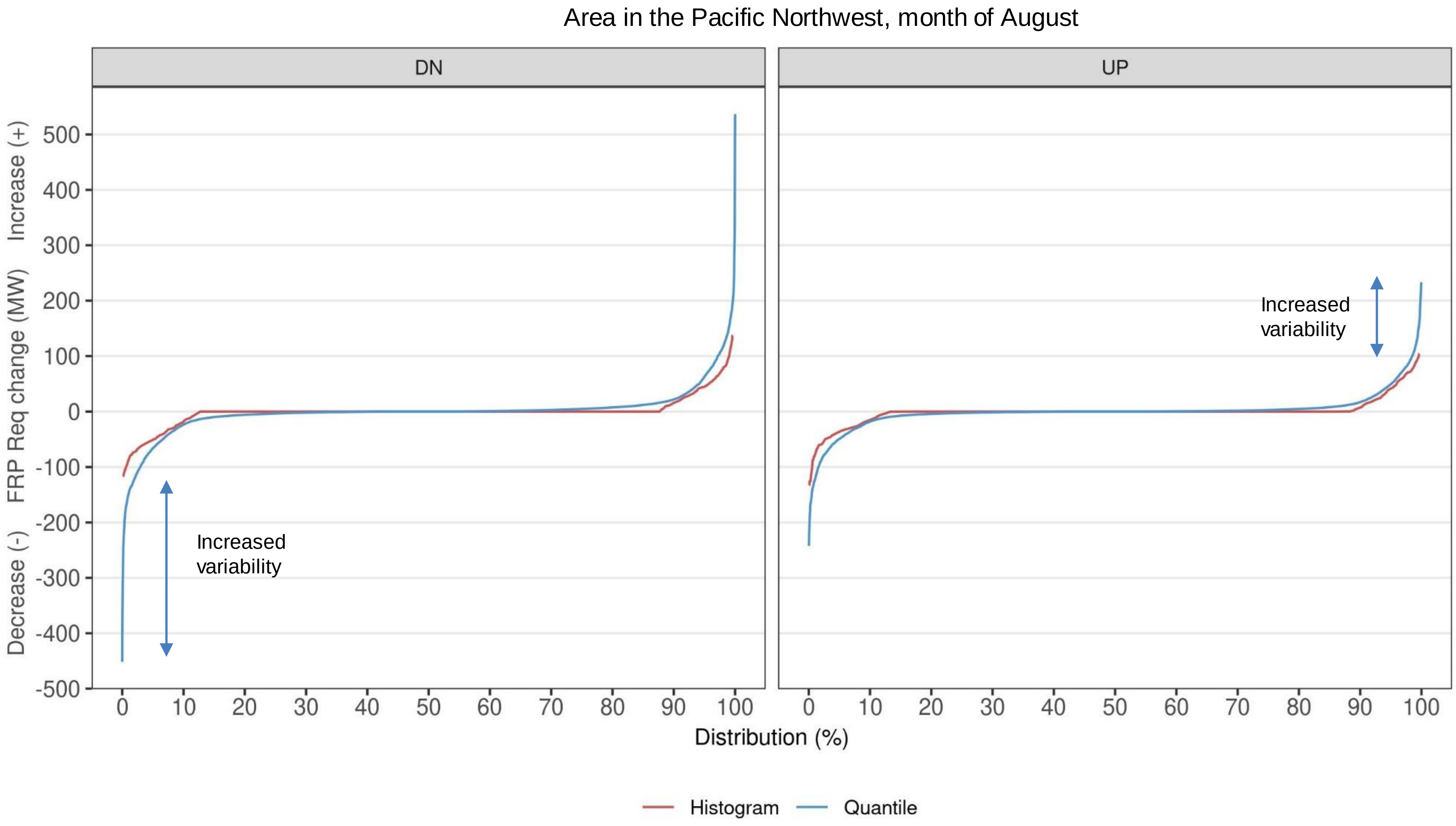
Across all WEIM areas, over 90 percent of the requirement changes are within 25 percent of the previous requirement



Although the majority of the variability is in a tight range, there are more extreme changes as reflected at the tails of the distributions



Although the majority of the variability is in a tight range, there are more extreme changes as reflected at the tails of the distributions

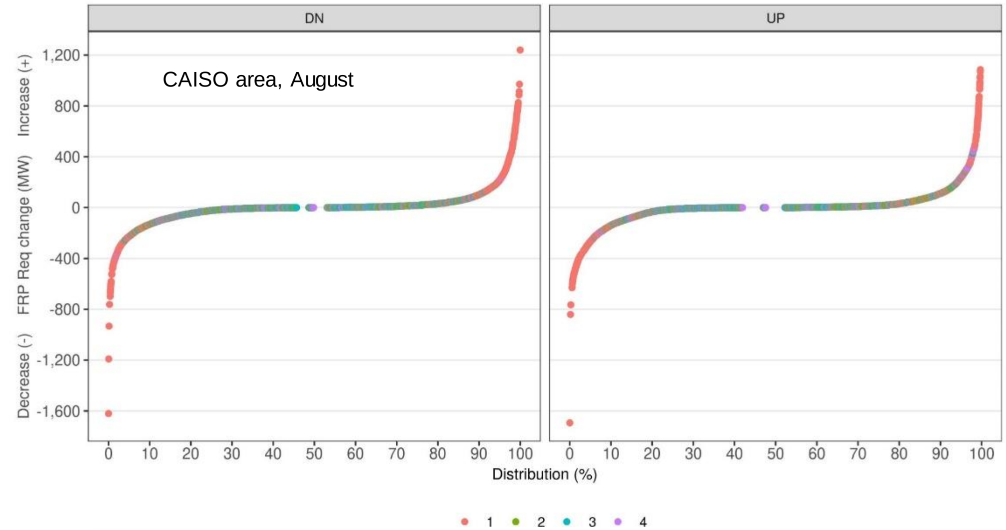


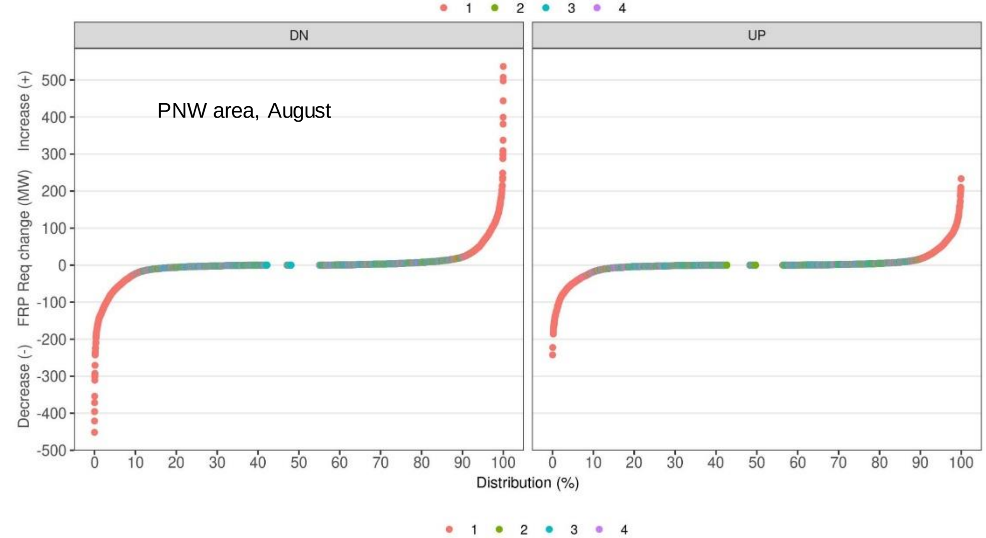
The largest changes of FRP requirements with the new methodology happen between hours

Changes from interval 4 to interval 1 means a change between hours

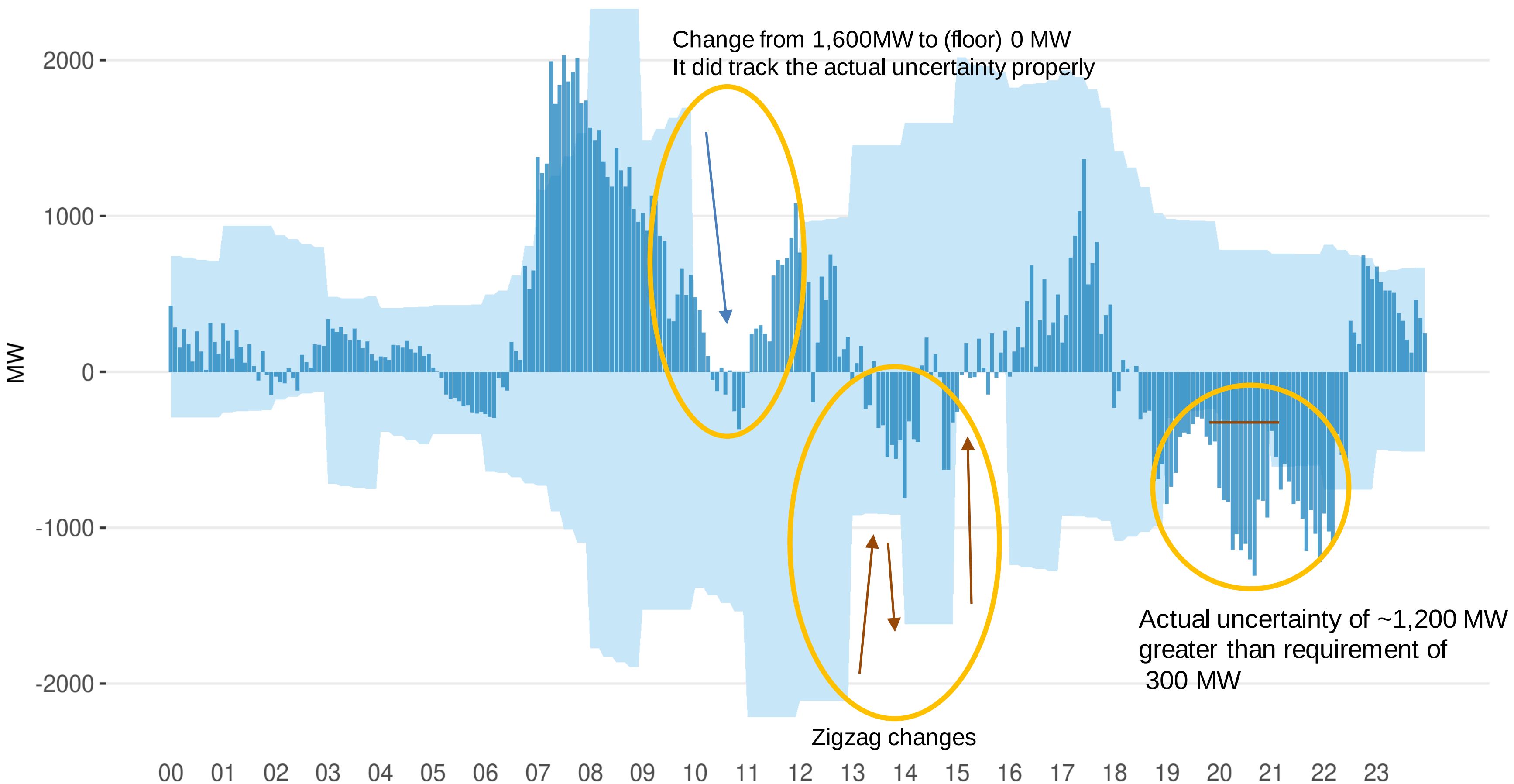
In addition to 15-minute changes of forecasts, the regression model changes between hours

Hypothesis: Since intra-hour changes show to be smaller for other intervals, the extreme changes of requirements (red dots) clustered at intervals 1 seem to be driven by the regression coefficient changes

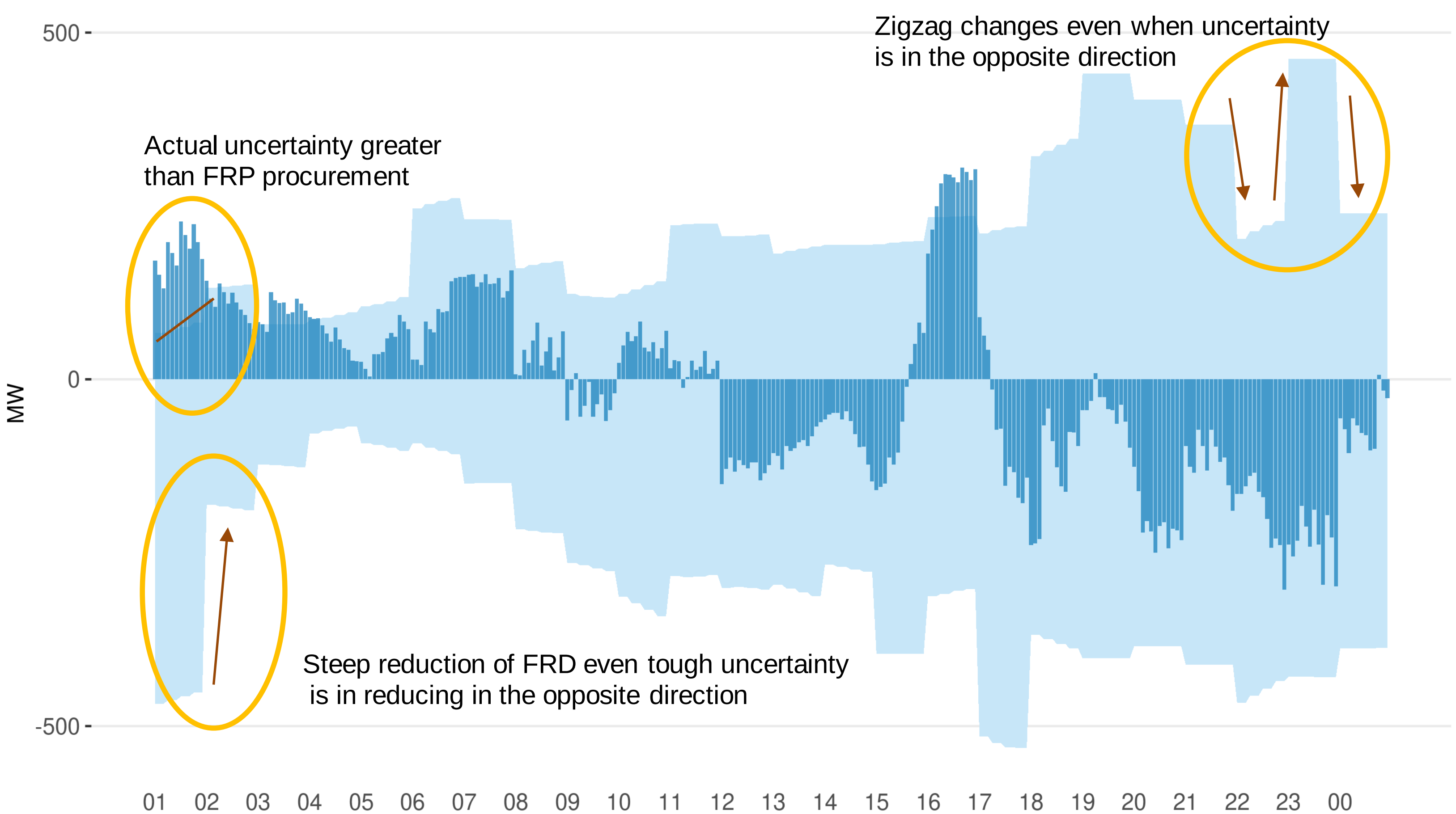




Visualization of one of the outlier of FRP changes for CISO area



Visualization of one of the outlier of FRP changes for an area in the Pacific Northwest



Steep changes in the requirements pose a challenge for entities to assess conditions to pass the test

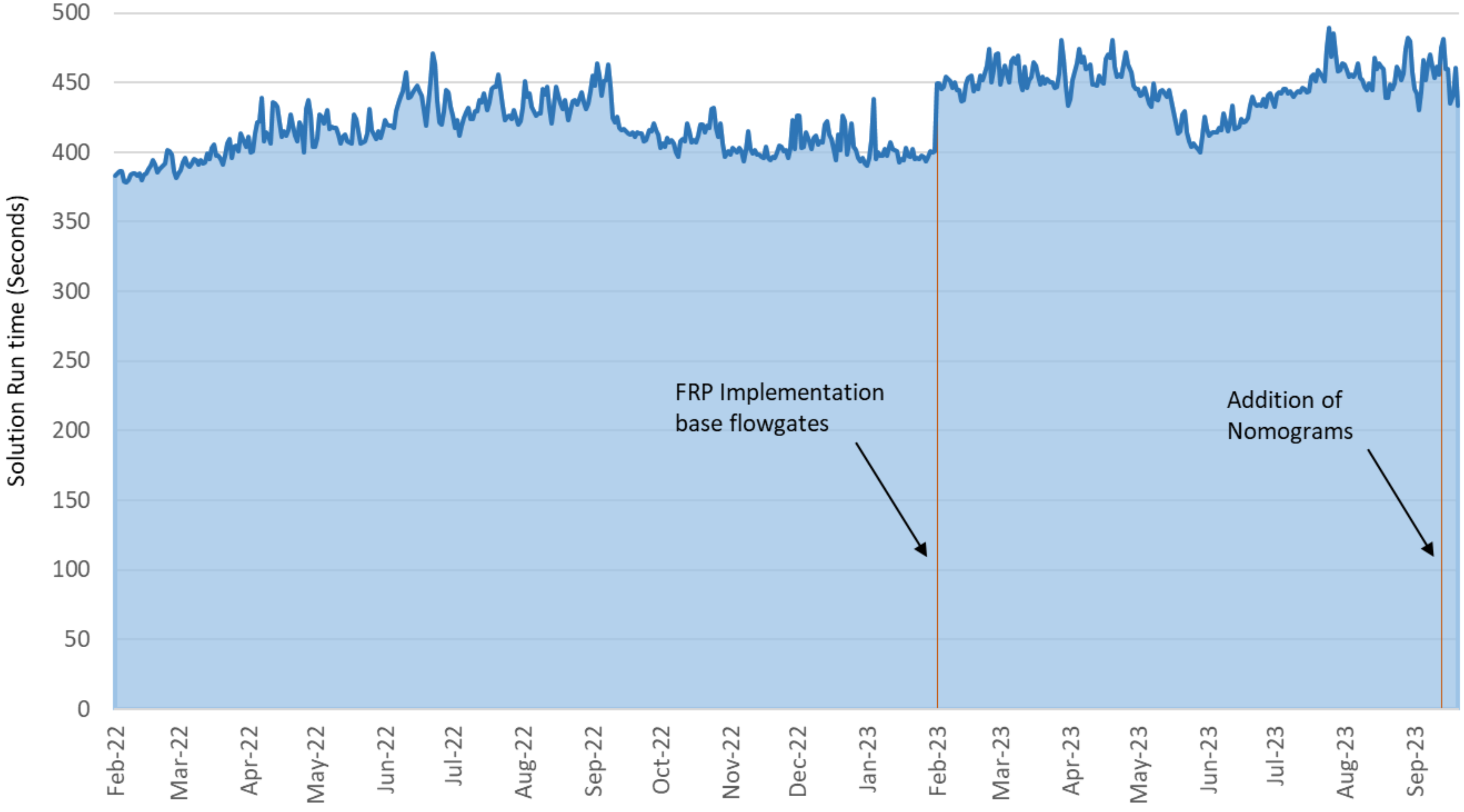
Nodal procurement of FRP

- Previous market formulation did not consider transmission feasibility when awarding FRP
- Previous CAISO analysis showed deliverability to be one of the main issues impacting FRP efficacy
- FRP enhanced formulation relies on nodal procurement to tackle FRP deliverability
- New formulation enforce transmission constraints and EIM transfer constraints in FRP deployment scenarios

Considerations for enforcement of transmission constraints

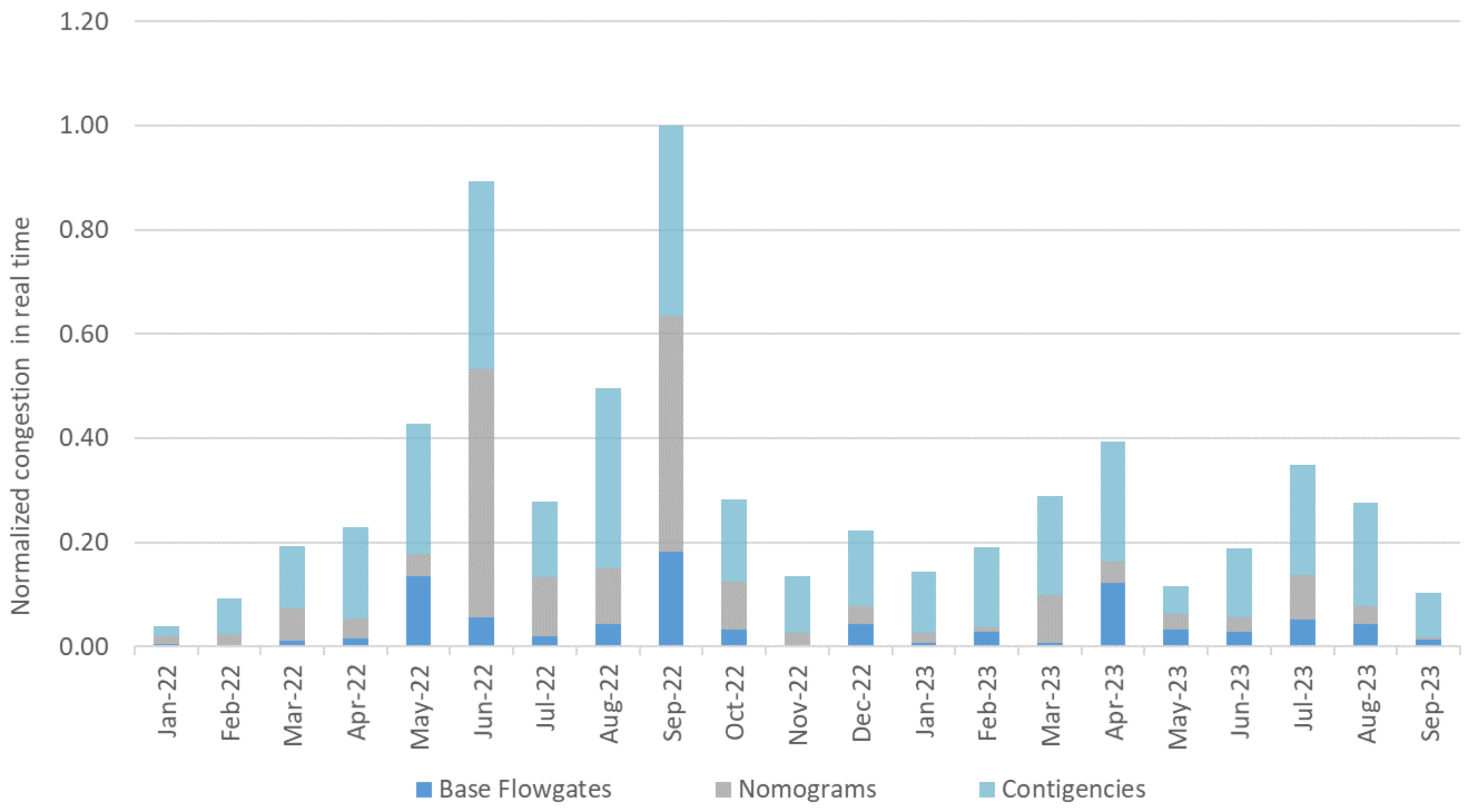
- Flow-based transmission constraints in CAISO's markets can be
  - Base flowgates
  - Contingency flowgates
  - Nomograms
- There are also scheduling and transfer limits
- FRP nodal model introduced with a limited set of constraints while gaining operational experience and settling systems
- With the go-live on Feb 2023, only base flowgates constraints were enforced for FRP nodal procurement
- On September 13, nomograms started to be enforced for FRP

Nodal FRP has direct computational implications for the real-time market due to needing to solve for additional constraints



The inclusion of flowgate constraints for FRP increase run time by about 100 seconds
The real-time market runs need to be completed within specific pre-determined timelines

Nomograms started to be enforced for FRP on September 13; this added to the existing enforcement of base flowgates



The level of congestion observed in real-time for energy has been relatively modest for the base flowgates, which is the type of constraints enforced for FRP for the first six months of nodal FRP

Base Flowgate constraints have been binding at relatively low frequency for FRU in CAISO area

CONSTRAINT	Mar	Apr	May	Jun	Jul	Aug	Sep
22208_EL CAJON_69.0_22408_LOSCOCHS_69.0_BR_1_1					0.13		0.05
22444_MESA RIM_69.0_22480_MIRAMAR _69.0_BR_1_1						0.20	
22476_MIGUELTP_69.0_22456_MIGUEL _69.0_BR_1_1							0.44
22480_MIRAMAR _69.0_22756_SCRIPPS _69.0_BR_1_1						0.91	
22740_SANYSDRO_69.0_22616_OTAYLKTP_69.0_BR_1_1						0.37	
22884_WARNERS _69.0_22688_RINCON _69.0_BR_1_1			0.20			0.17	0.05
24155_VINCENT _230_24128_S.CLARA _230_BR_1_1		0.03					
24303_BIG CRK3_230_24235_RECTOR _230_BR_1_1							0.66
24420_NEENACH _66.0_24452_TAP 85 _66.0_BR_1_1		5.14	4.67	0.45	1.21	0.27	
24957_COLRIVER_230_24900_COLRIVER_500_XF_2_P		0.17					
25406_J.HINDS _230_99254_J.HINDS2_230_BR_1_1		0.03					
30005_ROUND MT_500_30015_TABLE MT_500_BR_1_2				0.07			
30015_TABLE MT_500_30068_TB MT 5M_ 1.0_XF_5		0.14					
30040_TESLA _500_30050_LOSBANOS_500_BR_1_1		0.66					
30055_GATES1 _500_30060_MIDWAY _500_BR_1_1					0.20	0.27	0.60
30060_MIDWAY _500_24156_VINCENT _500_BR_1_3					0.03		
30060_MIDWAY _500_29402_WIRLWIND_500_BR_1_1					0.07		
30060_MIDWAY _500_29402_WIRLWIND_500_BR_1_2				0.03			
30114_DELEVAN _230_30450_CORTINA _230_BR_1_1					0.03		
30209_PIT5 JT2_230_30225_PIT4 JT _230_BR_2_1			0.57				
30225_PIT4 JT _230_30245_ROUND MT_230_BR_2_1			0.64				
30275_CRESTA _230_30330_RIO OSO _230_BR_1_1		0.17					
30500_BELLOTA _230_38206_COTTLE A_230_BR_1_1		0.28					
30515_WARNERVL_230_30800_WILSON _230_BR_1_1		1.04	1.08		0.44		0.22
30622_EIGHT MI_230_30495_STAGG _230_BR_1_1			0.44				
30765_LOSBANOS_230_30766_PADR FLT_230_BR_1A_1						0.03	
30797_LASAGUIL_230_30790_PANOCHE _230_BR_1_1			0.03				
30805_BORDEN _230_30810_GREGG _230_BR_2_1				0.03			
30870_PINE FLT_230_30875_MC CALL _230_BR_1_1			0.27			0.57	
30900_GATES _230_30905_TEMPLETN_230_BR_1_1			0.03				
31334_CLER LKE_60.0_31338_KONOCTI6_60.0_BR_1_1		0.07					
31336_HPLND JT_60.0_31206_HPLND JT_115_XF_2			1.08				
31486_CARIBOU _115_30255_CARBOU M_ 1.0_XF_11		6.15	3.06	6.08	45.73	39.58	36.35
31501_CHICOTP1_115_31502_CHICO B _115_BR_1_1						0.07	
31574_ANDERSON_60.0_31604_COTTONWD_60.0_BR_1_1					0.03		
32214_RIO OSO _115_30330_RIO OSO _230_XF_1						0.20	
32214_RIO OSO _115_32225_BRNSWKT1_115_BR_1_1				0.03			
32214_RIO OSO _115_32244_BRNSWKT2_115_BR_2_1		0.35					
32218_DRUM _115_32244_BRNSWKT2_115_BR_2_1		0.24	0.60	0.17			
32225_BRNSWKT1_115_32222_DTCH2TAP_115_BR_1_1				0.21			
32314_SMRTSVLE_60.0_32316_YUBAGOLD_60.0_BR_1_1	0.20	0.07	0.17				
32756_CHRISTIE_115_33010_SOBRANTE_115_BR_1_1						0.03	

CONSTRAINT	Mar	Apr	May	Jun	Jul	Aug	Sep
32769_ELCTOTP1_115_33010_SOBRANTE_115_BR_1_1						0.03	
32990_MARTINEZ_115_33014_ALHAMTP1_115_BR_1_1		0.35					
33010_SOBRANTE_115_30540_SOBRANTE_230_XF_1	0.07						
33014_ALHAMTP1_115_33010_SOBRANTE_115_BR_1_1		0.07					
33016_ALHAMTP2_115_32754_OLEUM _115_BR_1_1		0.31					
33500_MELNS JA_115_33509_AVENATP1_115_BR_1_1		0.14		10.21	14.78	3.86	2.30
33509_AVENATP1_115_33514_MANTECA _115_BR_1_1		0.21					
33516_RIPON J _115_33514_MANTECA _115_BR_1_1			0.10				
33541_AEC_TP1 _115_33540_TESLA _115_BR_1_1		9.24	0.10	0.52			0.16
33914_MI-WUK _115_33917_FBERBORD_115_BR_1_1		0.49	0.77	6.32	27.65	12.23	10.91
33916_CURTISS _115_33917_FBERBORD_115_BR_1_1		2.15	1.88			2.05	
33932_MELONES _115_33500_MELNS JA_115_BR_1_1		0.03		3.06	2.92	1.31	0.22
33932_MELONES _115_33936_MELNS JB_115_BR_1_1		0.42	0.97				
33936_MELNS JB_115_33951_VLYHMTP1_115_BR_1_1	0.03	3.51	0.87				
34101_CERTANJ2_115_34116_LE GRAND_115_BR_1_1						0.03	
34112_EXCHEQUR_115_34116_LE GRAND_115_BR_1_1		17.67		0.69	5.44	30.58	5.48
34366_SANGER _115_34370_MC CALL _115_BR_3_1						0.03	
34396_PIEDRA 2_115_34397_KNGSRVR _115_BR_1_1			0.37				
34454_RIVERROC_70.0_34464_COPPRMNE_70.0_BR_1_1				0.83	0.20		
34471_SNJQJCT _70.0_34469_GFFNJCT _70.0_BR_1_1			0.13				
34774_MIDWAY _115_34225_BELRDG J_115_BR_1_1			0.03	0.07			
34930_MC FRLND_70.0_34932_WASCO _70.0_BR_1_1					0.17		
35061_PSEMCKIT_115_34225_BELRDG J_115_BR_1_1			0.17				
35201_VASCO _60.0_35202_USWP-WKR_60.0_BR_1_1		0.28	0.50	0.03	0.20		
35602_ZNKER J2_115_36850_KIFER _115_BR_1_1	0.03						
35618_SN JSE A_115_35616_SNJOSEB _115_BR_1_1		0.03					
35621_IBM-HR J_115_35642_METCALF _115_BR_1_1					0.54	0.64	0.11
35642_METCALF _115_35651_BAILY J3_115_BR_2_1					0.17		
35646_MRGN HIL_115_35648_LLAGAS _115_BR_1_1		0.28					
35648_LLAGAS _115_35650_GILROY F_115_BR_1_1		0.07					
35656_PIERCY _115_35642_METCALF _115_BR_1_1		0.03					
36075_COBURN _60.0_30760_COBURN _230_XF_1		0.14			0.84	0.54	
37563_MELONES _230_30800_WILSON _230_BR_1_1		0.10	0.67		0.81		
38136_MARBLE _69.0_64281_MARBLSPP_60.0_XF_1		0.03	0.44				
38206_COTTLE A_230_37563_MELONES _230_BR_1_1		2.15					
64228_SUMMIT 1_115_32218_DRUM _115_BR_1_1					1.14	0.60	
64229_SUMMIT 2_115_32218_DRUM _115_BR_1_1				1.35	0.34	0.57	0.05
99254_J.HINDS2_230_24806_MIRAGE _230_BR_1_1						1.65	0.05
CONTRL-INYOTP_115_BR_1_1				3.44	2.49	0.47	
CONTRL-INYOTP_115_BR_2_1		0.03		0.38		0.03	
SILVERPK_BG				0.17			

Values are shown in percent of intervals binding for FRU per constraint.
Majority of constraints binding are lower voltage and more local in nature.

Base Flowgate constraints have been binding at relatively low frequency for FRD in CAISO area

CONSTRAINT	Mar	Apr	May	Jun	Jul	Aug	Sep
22208_EL CAJON_69.0_22408_LOSCOCHS_69.0_BR_1_1					0.37	0.03	
22444_MESA RIM_69.0_22480_MIRAMAR _69.0_BR_1_1						0.07	
22476_MIGUELTP_69.0_22456_MIGUEL _69.0_BR_1_1							0.05
22480_MIRAMAR _69.0_22756_SCRIPPS _69.0_BR_1_1					0.03	0.77	
22604_OTAY _69.0_22616_OTAYLKTP_69.0_BR_1_1		0.21			0.03		
22644_PENSQTOS_69.0_22444_MESA RIM_69.0_BR_2_1		0.10					
24155_VINCENT _230_24128_S.CLARA _230_BR_1_1		0.14					
24420_NEENACH _66.0_24452_TAP 85 _66.0_BR_1_1		1.46	0.87	0.49	1.14	0.03	
25406_J.HINDS _230_99254_J.HINDS2_230_BR_1_1		0.03					
30055_GATES1 _500_30060_MIDWAY _500_BR_1_1							0.05
30114_DELEVAN _230_30450_CORTINA _230_BR_1_1					0.03		
30515_WARNERVL_230_30800_WILSON _230_BR_1_1		0.24	0.67		0.17		
30900_GATES _230_30905_TEMPLETN_230_BR_1_1			0.03				
31574_ANDERSON_60.0_31604_COTTONWD_60.0_BR_1					0.10		
32214_RIO OSO _115_30330_RIO OSO _230_XF_1					0.64	0.20	
32214_RIO OSO _115_30330_RIO OSO _230_XF_2				0.28			
32218_DRUM _115_32244_BRNSWKT2_115_BR_2_1		0.56	0.03				
32225_BRNSWKT1_115_32222_DTCH2TAP_115_BR_1_1				0.28			
32314_SMRTSVLE_60.0_32316_YUBAGOLD_60.0_BR_1_1		0.10	0.10				
32332_PEASE _60.0_32333_PEASETP _60.0_BR_1_1					0.07	0.17	
32756_CHRISTIE_115_33010_SOBRANTE_115_BR_1_1						0.17	
32769_ELCTOTP1_115_33010_SOBRANTE_115_BR_1_1						0.07	
32990_MARTINEZ_115_33014_ALHAMTP1_115_BR_1_1		0.24					
33016_ALHAMTP2_115_32754_OLEUM _115_BR_1_1		0.35					
33500_MELNS JA_115_33509_AVENATP1_115_BR_1_1		0.14		0.10	0.40	0.37	0.16
33541_AEC_TP1 _115_33540_TESLA _115_BR_1_1		0.17					

CONSTRAINT	Mar	Apr	May	Jun	Jul	Aug	Sep
32769_ELCTOTP1_115_33010_SOBRANTE_115_BR_1_1				0.17		0.10	
32990_MARTINEZ_115_33014_ALHAMTP1_115_BR_1_1		0.45	0.13				
33010_SOBRANTE_115_30540_SOBRANTE_230_XF_1		0.83	0.37				
33014_ALHAMTP1_115_33010_SOBRANTE_115_BR_1_1						0.03	
33016_ALHAMTP2_115_32754_OLEUM _115_BR_1_1					1.48	0.07	
33500_MELNS JA_115_33509_AVENATP1_115_BR_1_1					0.07		
33509_AVENATP1_115_33514_MANTECA _115_BR_1_1				0.14			
33516_RIPON J _115_33514_MANTECA _115_BR_1_1		0.03					
33541_AEC_TP1 _115_33540_TESLA _115_BR_1_1					0.07		
33914_MI-WUK _115_33917_FBERBORD_115_BR_1_1			0.07	0.10	0.07	0.07	
33916_CURTISS _115_33917_FBERBORD_115_BR_1_1					0.10		
33932_MELONES _115_33500_MELNS JA_115_BR_1_1			0.07				
33932_MELONES _115_33936_MELNS JB_115_BR_1_1		0.07					
33936_MELNS JB_115_33951_VLYHMTP1_115_BR_1_1		0.03					
34101_CERTANJ2_115_34116_LE GRAND_115_BR_1_1					0.94	1.08	
34112_EXCHEQUR_115_34116_LE GRAND_115_BR_1_1					0.10		
34366_SANGER _115_34370_MC CALL _115_BR_3_1					0.13		
34396_PIEDRA 2_115_34397_KNGSRVR _115_BR_1_1			0.03		0.17		
34454_RIVERROC_70.0_34464_COPPRMNE_70.0_BR_1_1				0.07			
34471_SNJQJCT _70.0_34469_GFFNJCT _70.0_BR_1_1					0.50	0.30	
34774_MIDWAY _115_34225_BELRDG J_115_BR_1_1				0.59	0.50	0.30	
34930_MC FRLND_70.0_34932_WASCO _70.0_BR_1_1						1.21	
35061_PSEMCKIT_115_34225_BELRDG J_115_BR_1_1				10.76	2.49	2.42	
35201_VASCO _60.0_35202_USWP-WKR_60.0_BR_1_1				0.35		0.03	
35602_ZNKER J2_115_36850_KIFER _115_BR_1_1			0.13				
35618_SN JSE A_115_35616_SNJOSEB _115_BR_1_1							

Values are shown in percent of intervals binding for FRU per constraint.
Majority of constraints binding are lower voltage and more local in nature.

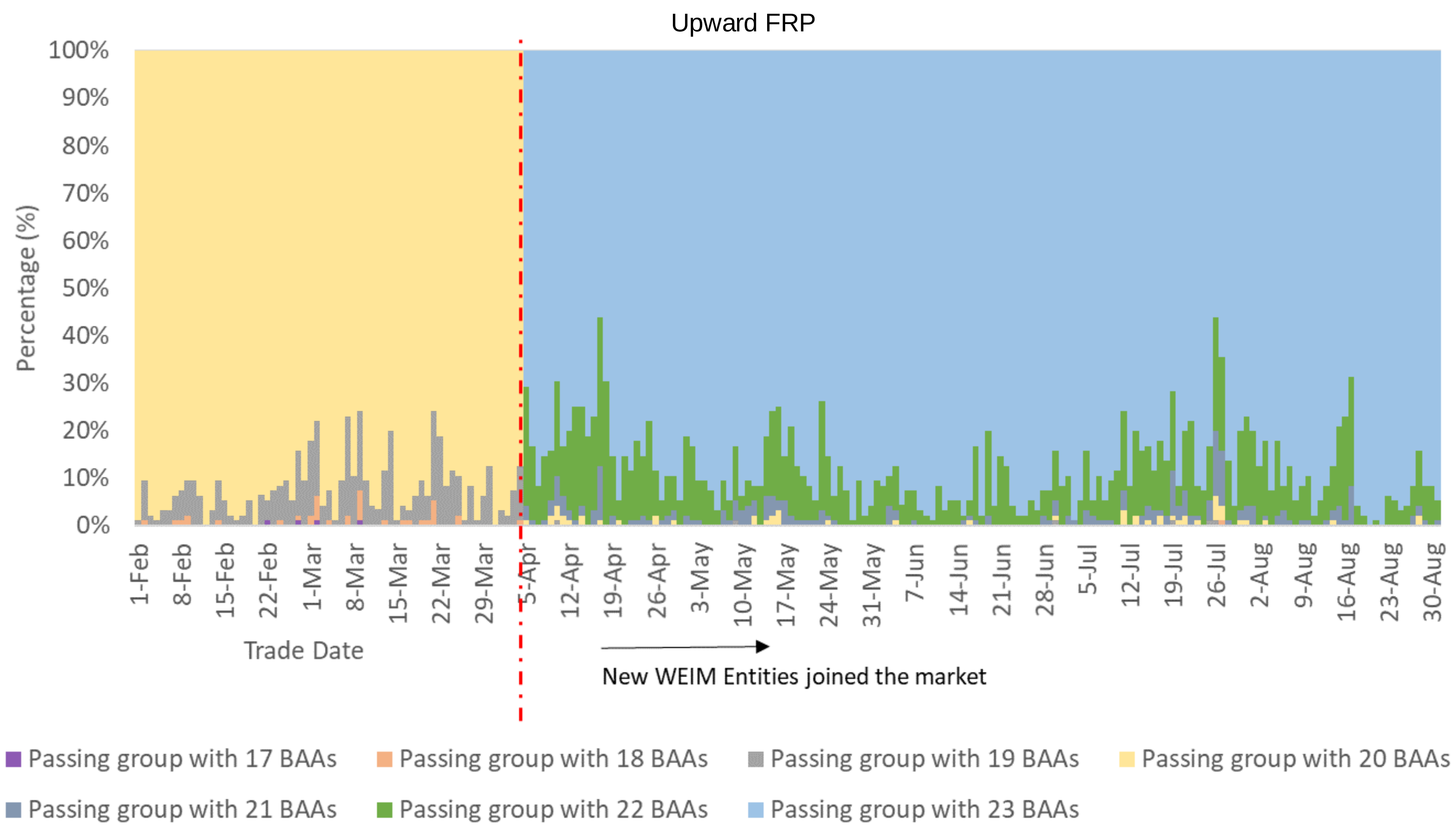
Congestion on flowgate constraints in other WEIM areas has been sporadic and *de minimis*

BAA	CONSTRAINT	Mar	Apr	May	Jun	Jul	Aug	Sep
AZPS	Line_CC-ME_230KV					1.48		
AZPS	Line_DV-WW_230KV					0.13		
AZPS	Line_PP-CX_230KV					0.13		
AZPS	Line_SG-OJX_115KV					0.03		
BANC	ORG_WLD			0.03				
BANC	Txfmrh1 230.KES		0.03		0.07			
BANC	Txfmrh2 230.KES	0.03						
EPE	12800_NWM_CHA			0.24				
EPE	15100_NWM_SHT			0.10				
IPCO	BLPR-HCPR1_A			0.27				
IPCO	PATH_14			0.13				
IPCO	PATH_55		0.14		0.07	0.13	0.07	
LADWP	SYL_SS BK G			0.20				
LADWP	TAR BK E				0.03			
NEVP	BOR PS#1					0.17		
NEVP	HACC GSU_XF5				0.10			
NEVP	HACC GSU_XF6				0.17		0.17	
NEVP	NTR-DRM_1 120						0.34	
PACE	AMASA_DIFFICUL_230			0.03				
PACE	BONANZA$_MONA_345					0.17		
PACE	EAST_WYO_EXP		0.10					
PACE	TOTAL_WYOMING_EXPORT					0.37	0.03	0.22
PACE	WINDSTAR EXPORT TCOR	0.60	1.25	0.03		0.07	0.20	
PGE	MCL_PE_SHW_V682					0.03	0.37	
PNM	115kv DL_Mi_Wm						0.24	
PNM	115kv EB Fron				0.45		0.13	
PNM	115kv LK		0.07		0.24			
PNM	115kv ML					0.10	0.27	0.66
PNM	345kV CLCR-DMND1					0.07		
PNM	ABO S_COMP_WESP1					0.60		
PNM	LunaPNM345_115X					0.17		
PNM	PAJA_ABO S_COMP					0.20		
WALC	Line_SG-OJX_115KV					0.03		

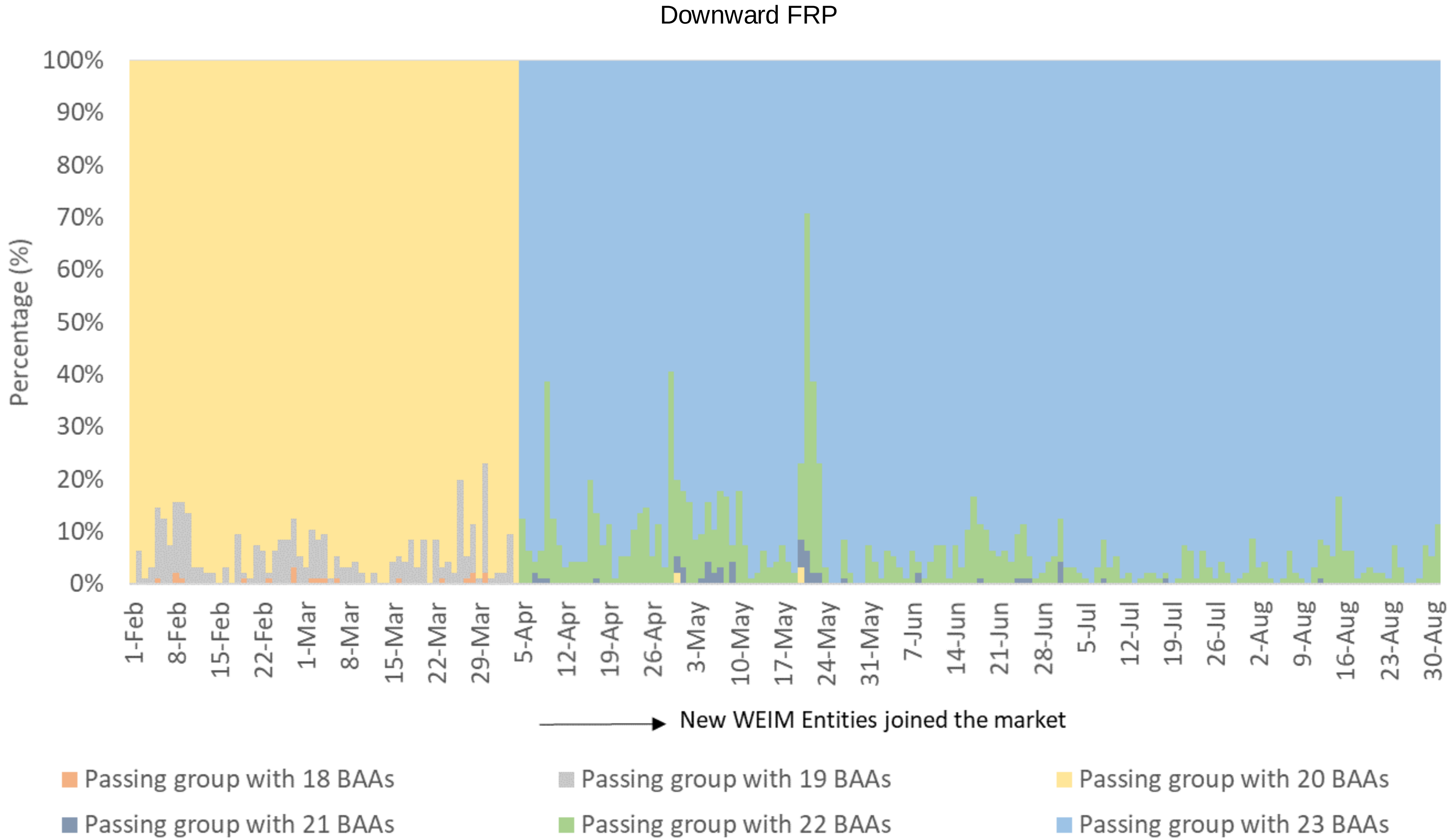
BAA	CONSTRAINT	Mar	Apr	May	Jun	Jul	Aug	Sep
AZPS	LSS XFMR10 A 230KV					0.03		
AZPS	Line_CC-ME_230KV					0.74		
AZPS	Line_DV-WW_230KV					0.17		
AZPS	Line_PP-CX_230KV					1.04		
IPCO	BLPR-HCPR1_A			0.03				
IPCO	PATH_14					0.03		
IPCO	PATH_55		0.14		0.07	0.13	0.07	
LADWP	SYL_SS BK G			0.10				
NEVP	BOR PS#1					0.03		
PACE	BONANZA$_MONA_345					0.17		
PACE	WINDSTAR EXPORT TCOR	1.01	0.73			0.10		0.2[illegible]
PGE	MCL_PE_SHW_V682					0.03	0.81	
PNM	115kv DL_Mi_Wm						0.30	
PNM	115kv EB Fron				1.84		0.37	
PNM	115kv LK				0.14			
PNM	115kv ML					0.13	0.37	0.5[illegible]
PNM	ABO S_COMP_WESP1					0.64		
PNM	LunaPNM345_115X					0.10		

Values are shown in percent of intervals binding for FRU per constraint

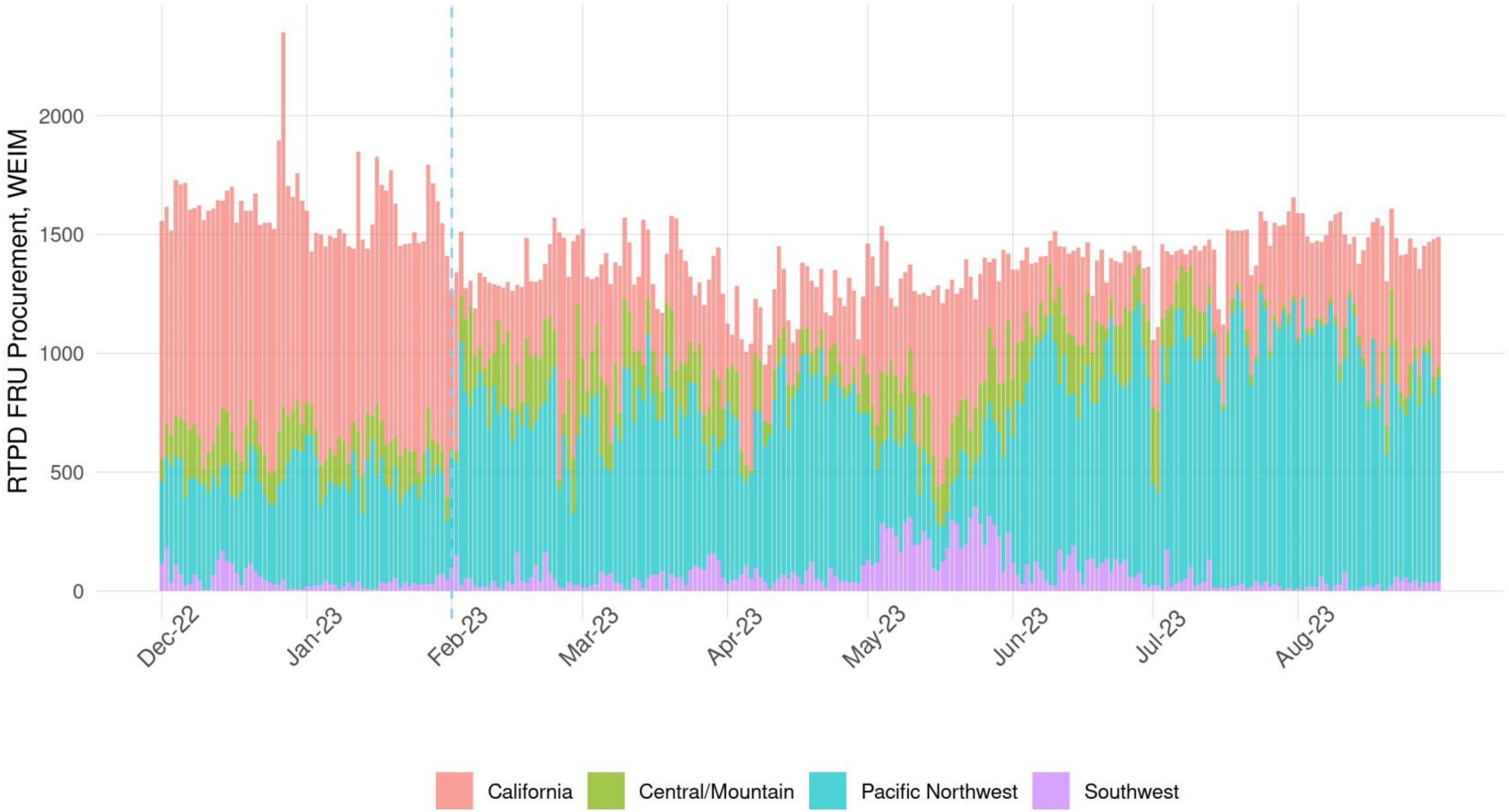
Most of the time the majority of areas pass the test and are part of the passing group, which is the only requirement enforced in the real-time market



Most of the time the majority of areas pass the test and are part of the passing group, which is the only requirement enforced in the real-time market

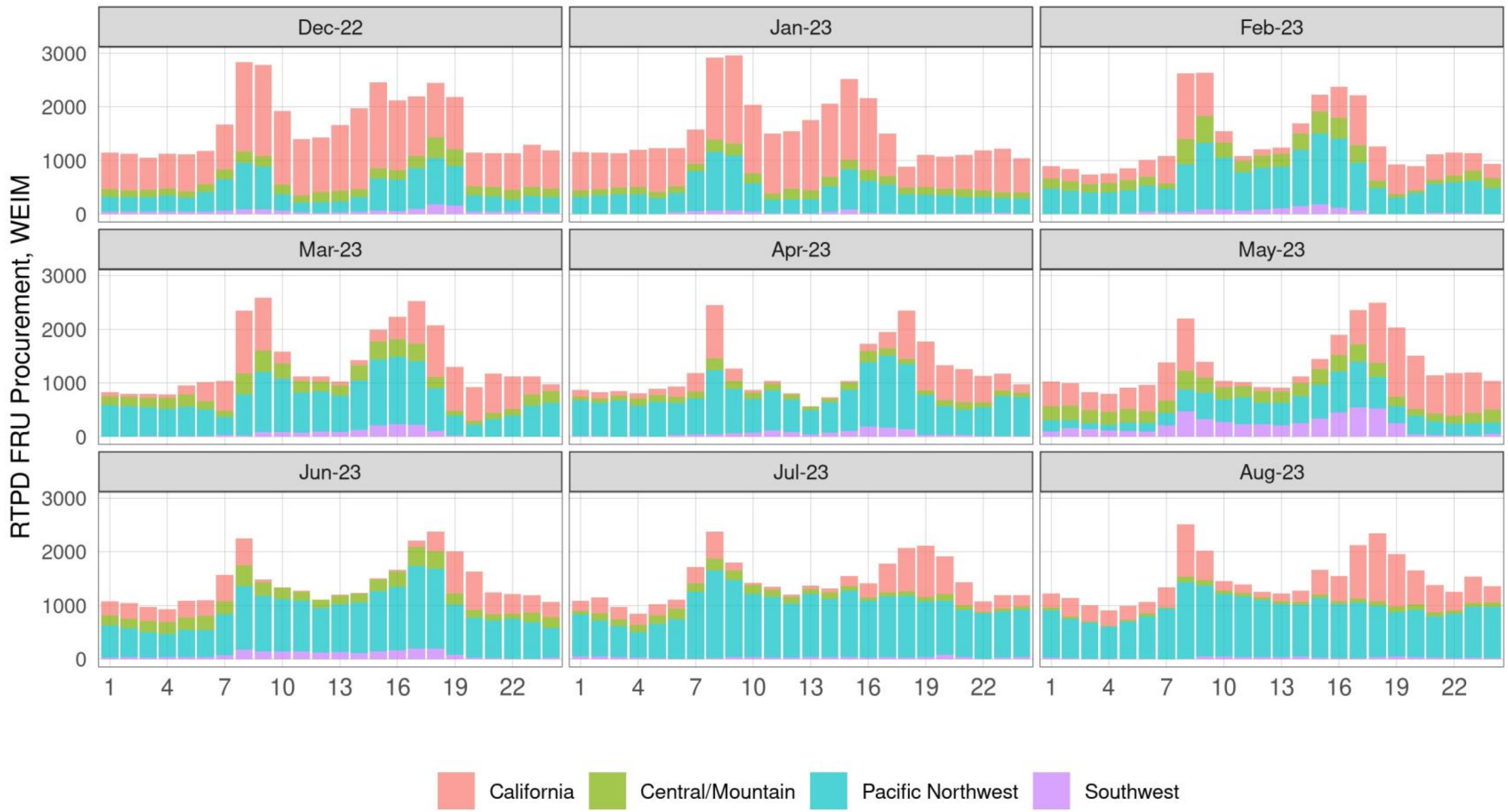


With the introduction of nodal formulation, upward FRP procurement from CAISO area reduced significantly

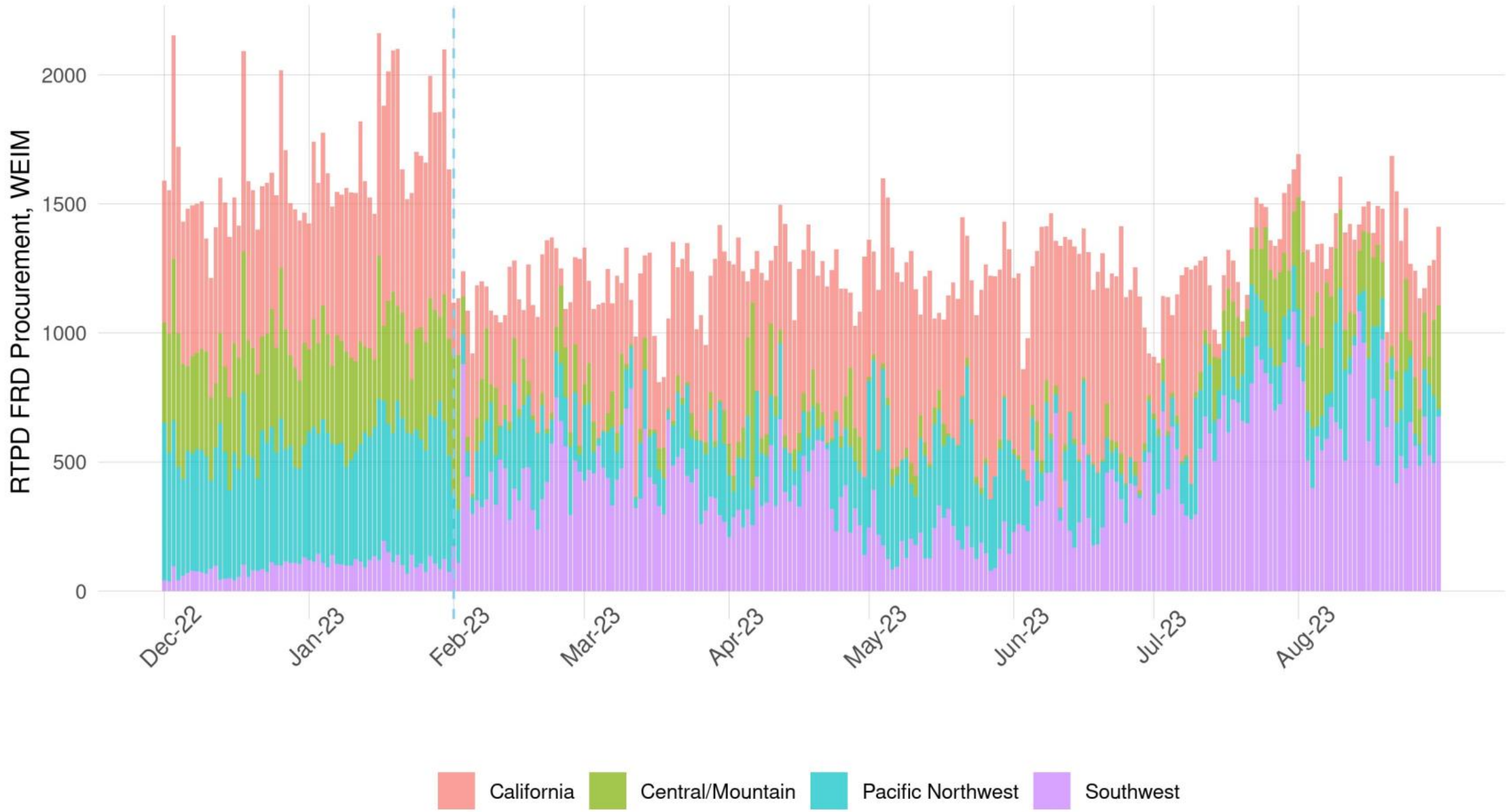


Prior to February 2023, CAISO area had a minimum FRP requirement, which forced FRP procurement from internal resources. With the nodal implementation, this minimum requirement is no longer in place. Procurement from CAISO area is driven by overall economics

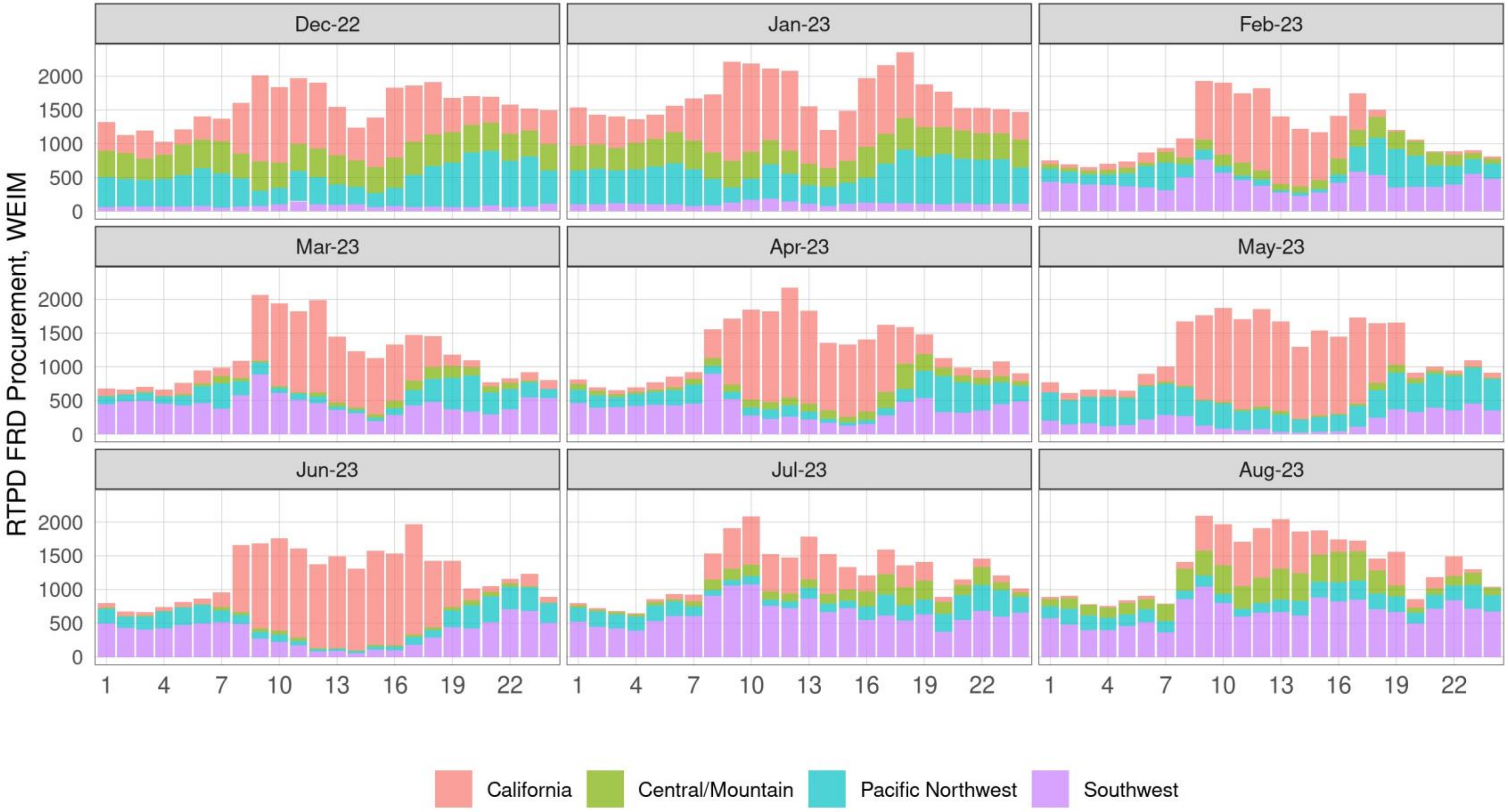
Upward FRP procurement is largely supported by areas from the Pacific Northwest



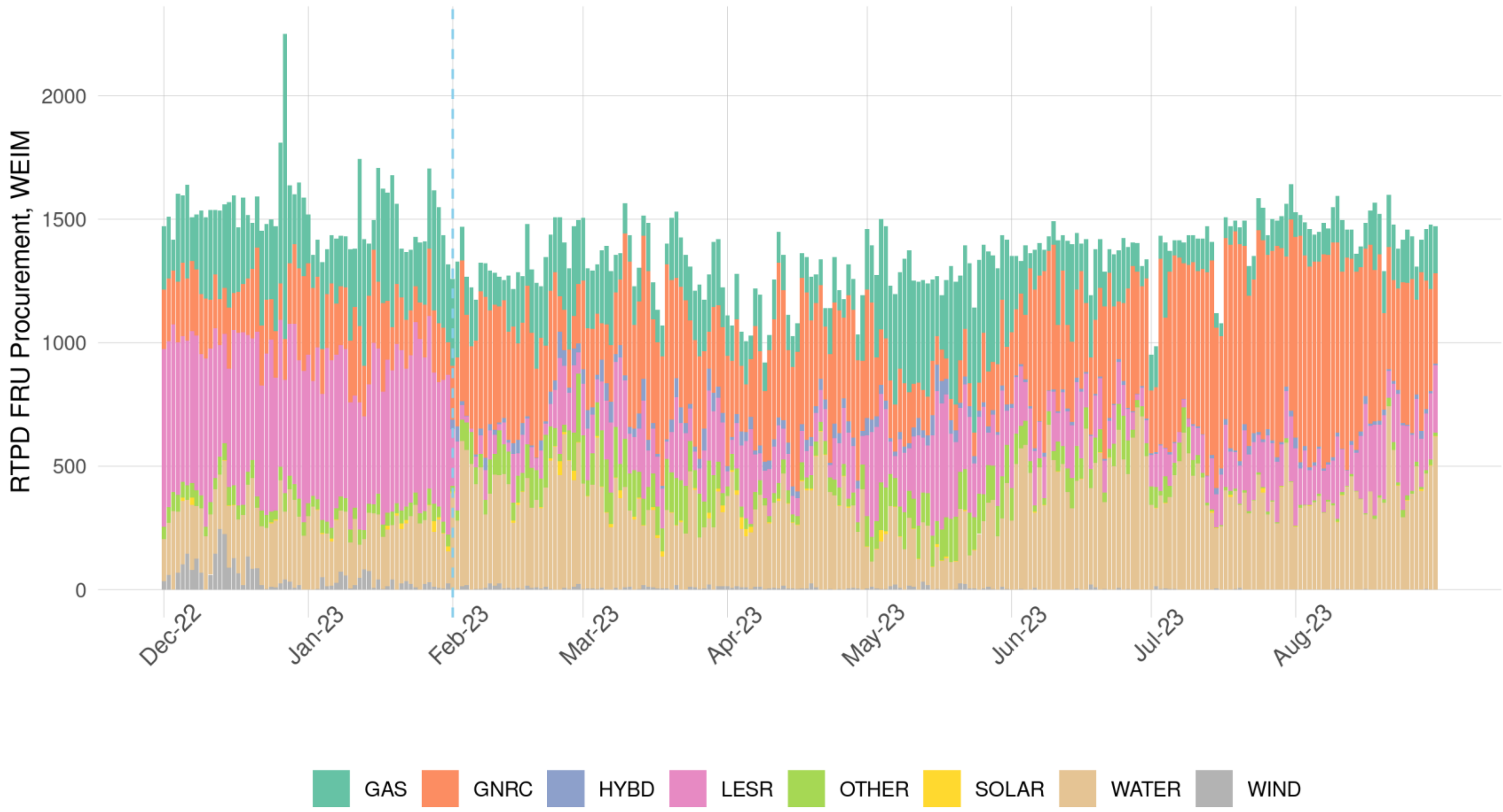
With the introduction of nodal procurement, downward FRP is largely procured from areas in the southwest and California



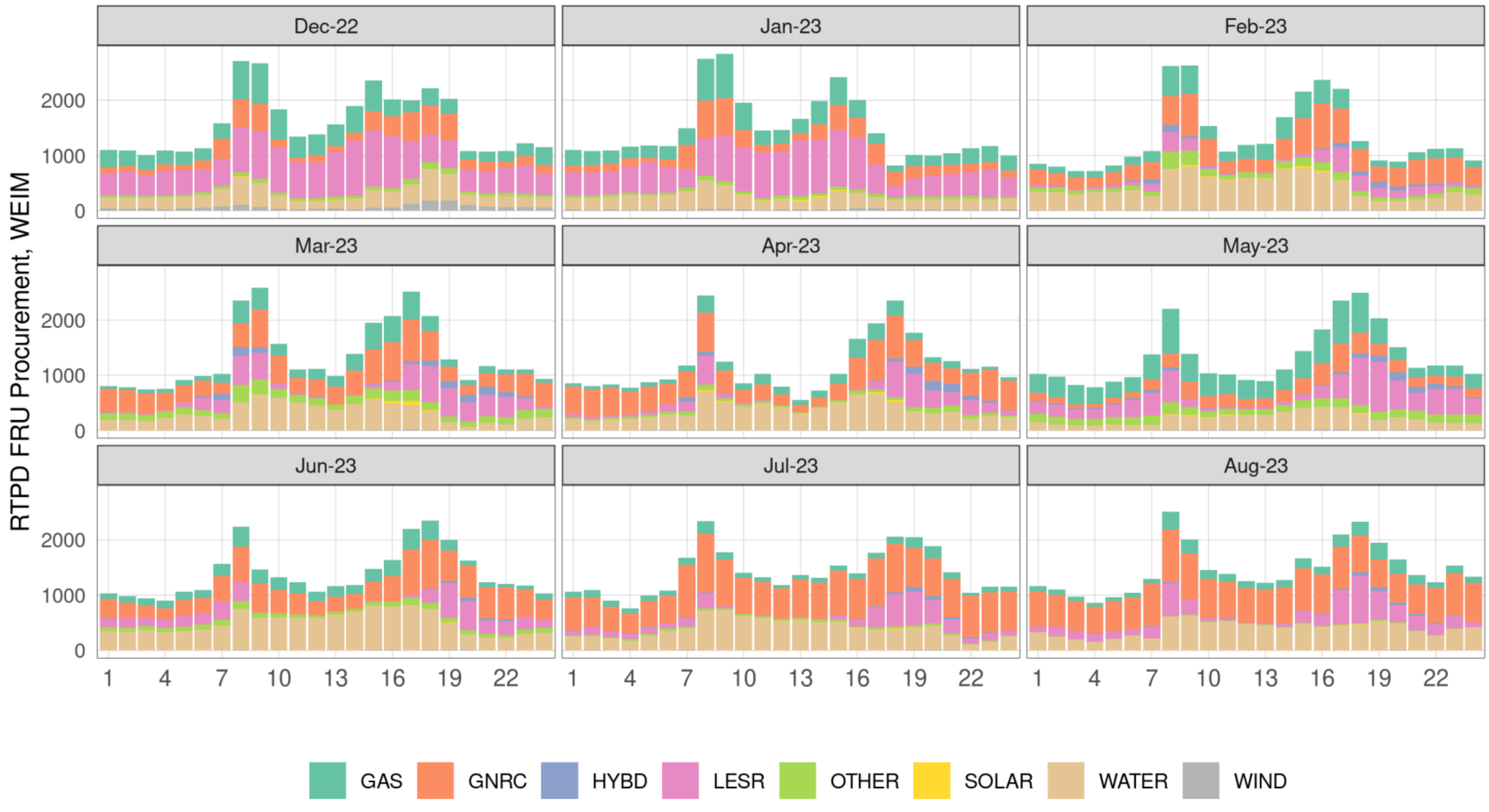
Downward FRP procurement from CAISO area is largely occurring in midday hours when solar production is plentiful and months with modest demand level



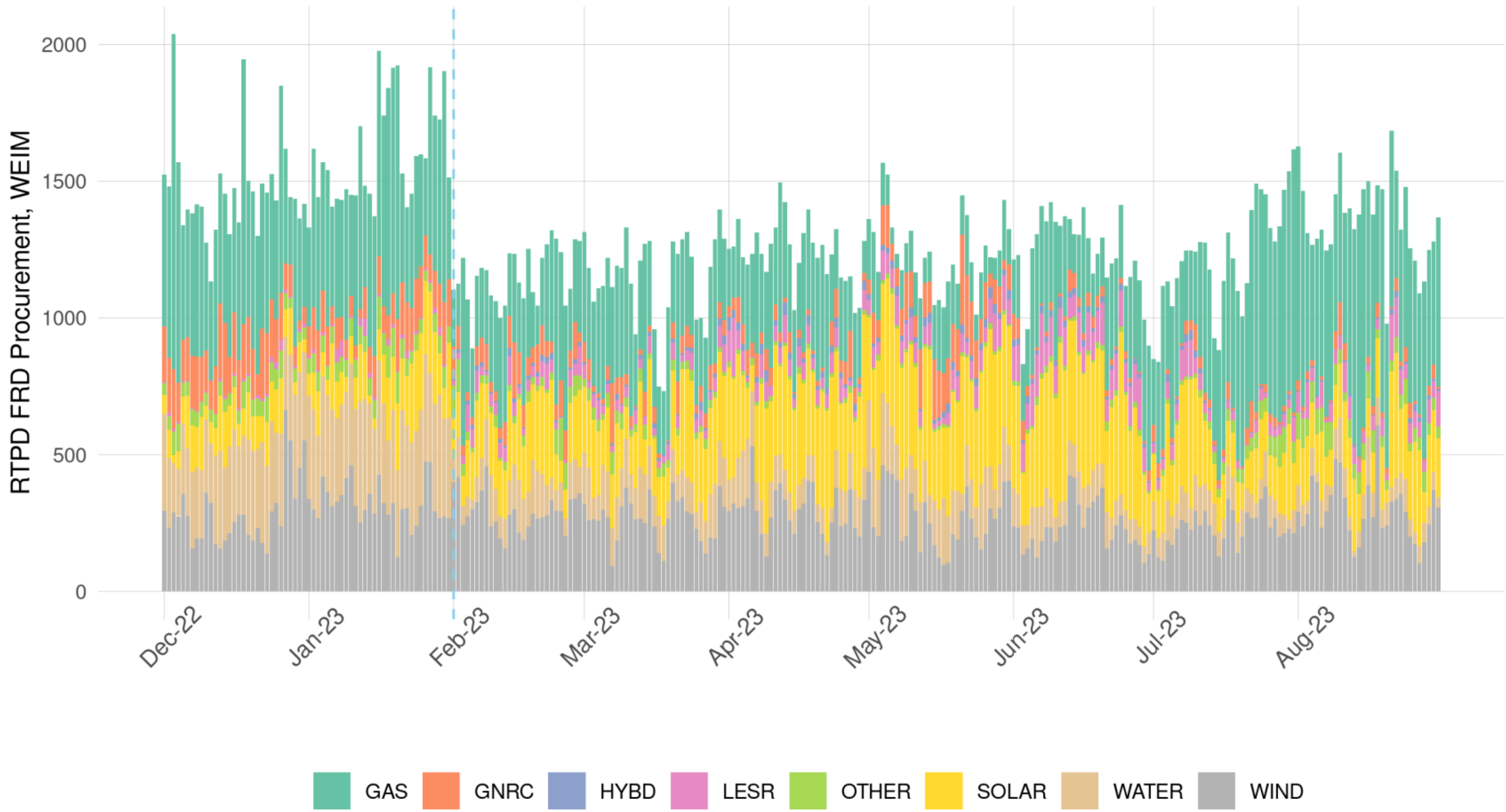
Upward FRP procurement is supported by various types of technologies



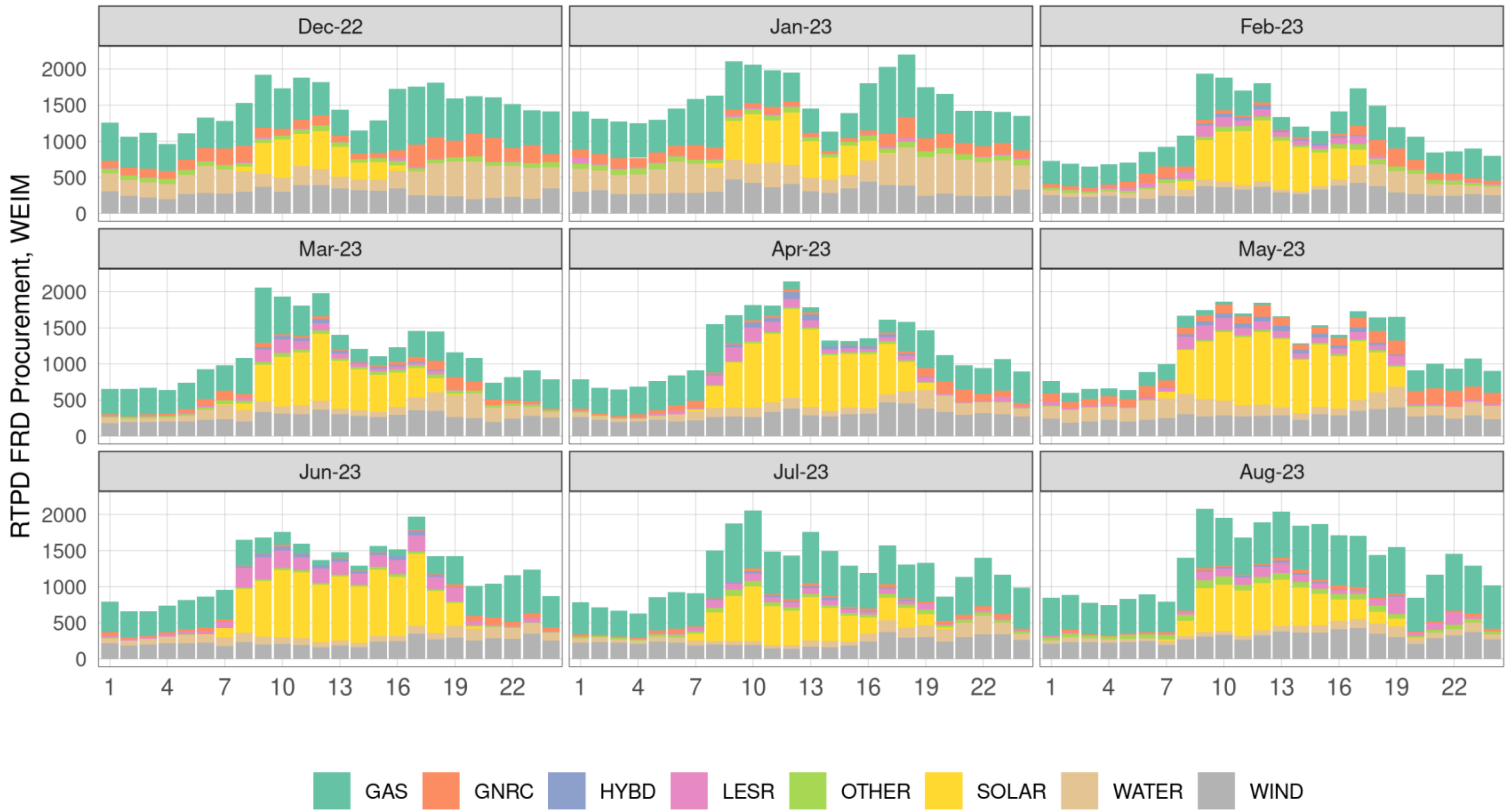
With nodal formulation, storage resources tend to support upward FRP procurement for evening ramping hours



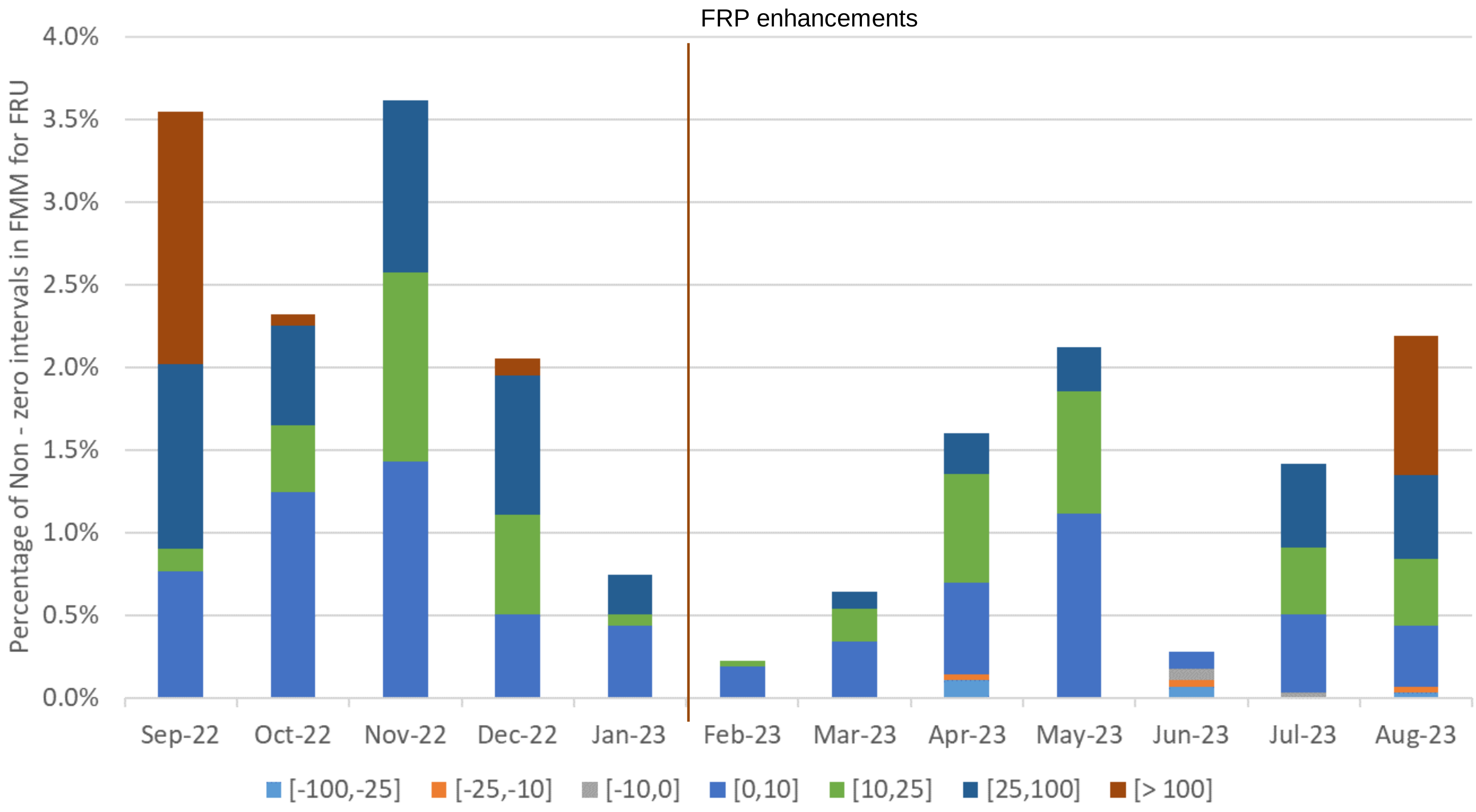
Downward FRP procurement is supported by various types of technologies



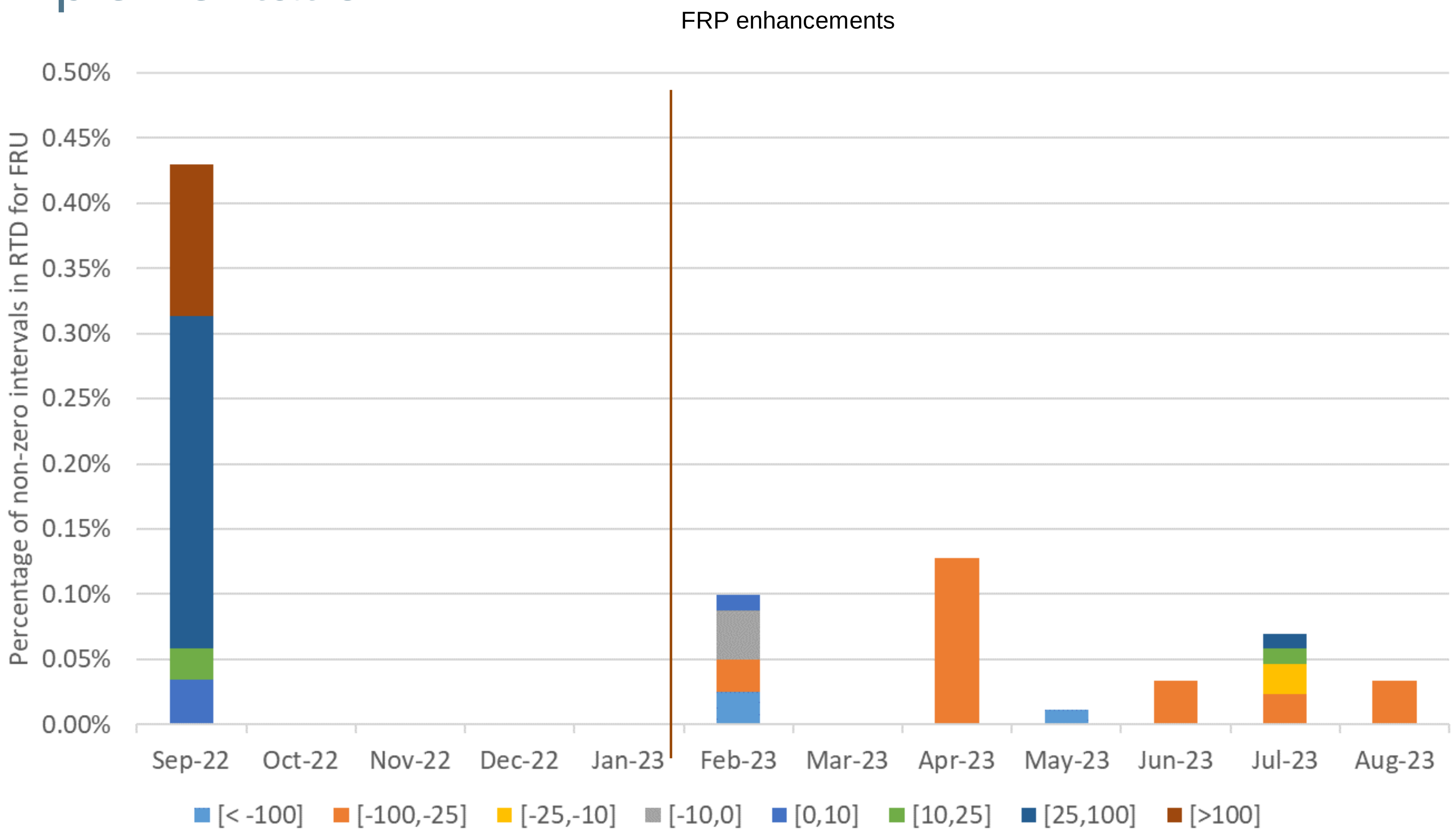
With nodal formulation, storage resources tend to support downward FRP procurement for evening ramping hours



Frequency of intervals with non-zero FMM prices for upward FMM continues to be low after nodal implementation



Frequency of intervals with non-zero RTD prices for upward FRP continues to be low after nodal implementation



Why FRP clears at $0?

- FRP procurement is from a larger area (passing area), in which there is plenty of capacity available from a diverse generation mix

- A small subset of transmission constraints have been enforced so far for deployment scenarios as the ISO gains experience with the new model

- FRP (nodal, zonal or system wide) is based on opportunity costs instead of bids.

Example of $0 FRP prices

- February 24, HE18. FMM market
- Passing group: all WEIM areas except BPA
- Uncertainty requirement: 1019.8 MW
- Total resource awards matches the requirement. Procurement was met from 18 units from 5 out of the 19 balancing areas in the group
- Therefore, there is no relaxation (surplus variable) to trigger the demand curve.
- No resource experienced an opportunity cost to procure FRP

BAA	CC	CT	GNG	Hy	HYB	LES	ST	Total
BANC				121.0				121.0
BCHA			50.2					50.2
CISO	30.0	23.4			86.0	142.7	20.1	302.2
PGE				308.3				308.3
PSEI				238.1				238.1
								1019.8

With nodal approach, the nodal FRP prices have more than the FRP procurement shadow prices defining the price

02/24/2023 18:35 hrs, FRP RTD binding

Passing group FRP req shadow price: -$100.4

Passing group total FRU award: 305.5 MW

All FRP requirement is met with 7 resources

There are nodal prices!

Resource	Fuel Type	FRU MW	FRU Nodal $
1	WATER	3.3	7.7
2	GAS	26	3.8
3	LESR	26.8	19.3
4	LESR	0.08	0
5	LESR	32.3	19.3
6	LESR	178.3	19.3
7	LESR	38.6	0

FRP nodal price is composed of both FRP req shadow price and congestion component

Resource 5 FRU award: 32.3MW

FRU nodal price: $\$19.3$

Nodal pricing components:

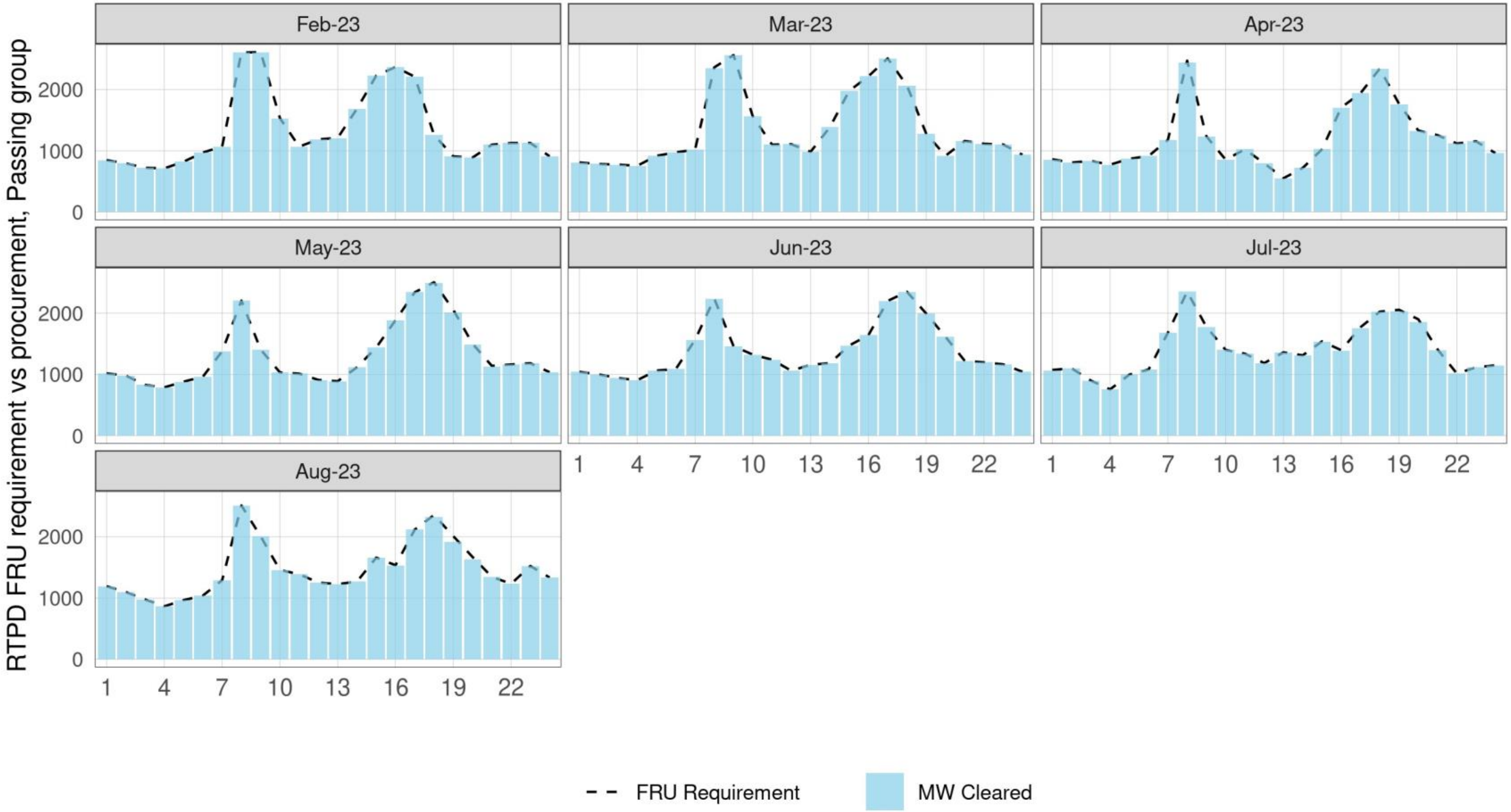
- Shadow price for Passing group FRU: $-\$100.4$
- Binding constraint $\$3861.6$

  99254_J.HINDS2_230_24806_MIRAGE _230_BR_1 _1
- Shift factor: -0.031
- Congestion component FRU deployment:

$$-\$119.7 = \$3861.6 * (-0.031)$$

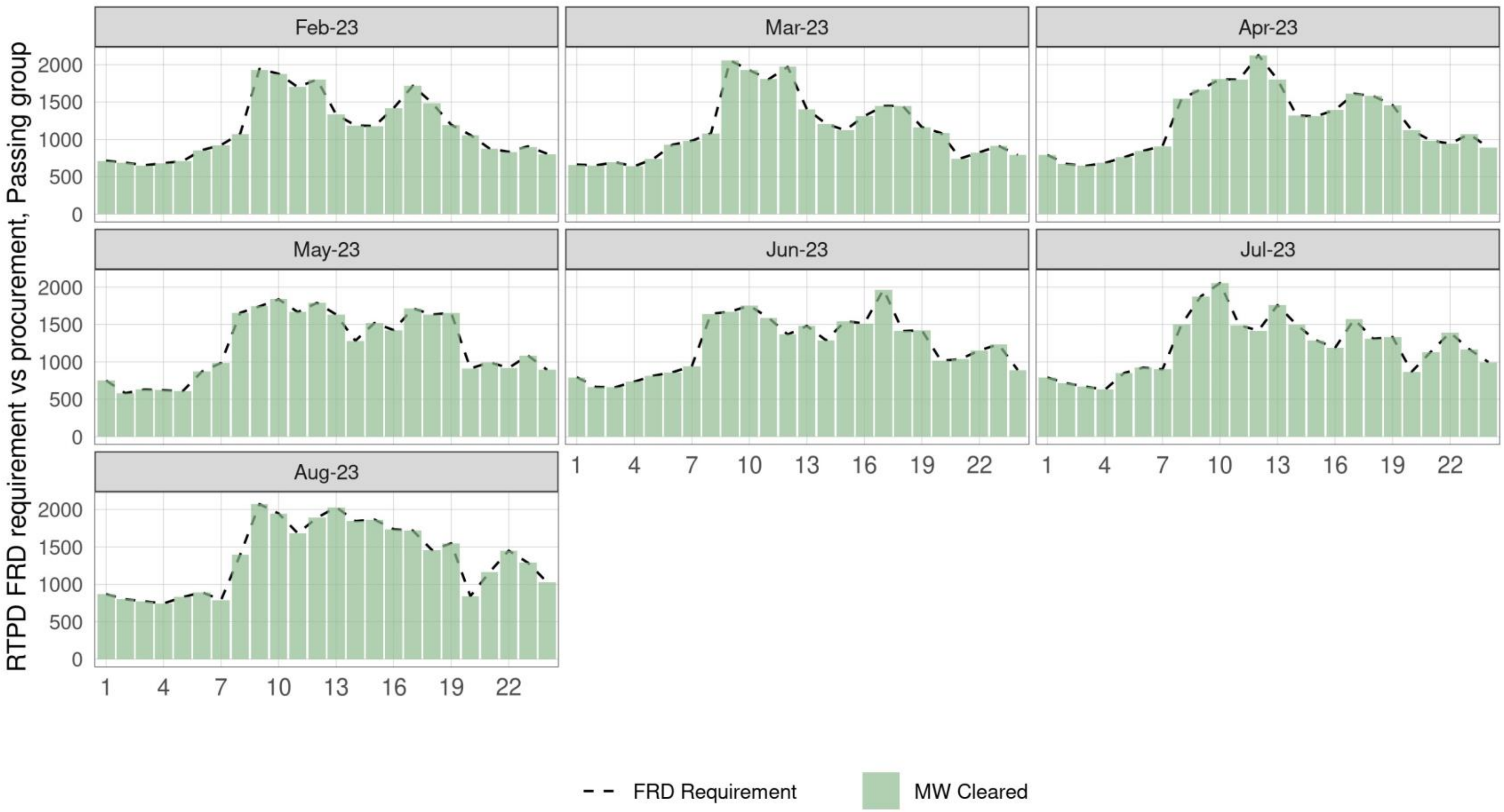
- FRU LMP= -$100.4+$119.7=$19.3

On average, the upward FRP requirements tend to be fully procured, which in turns may result in a zero price

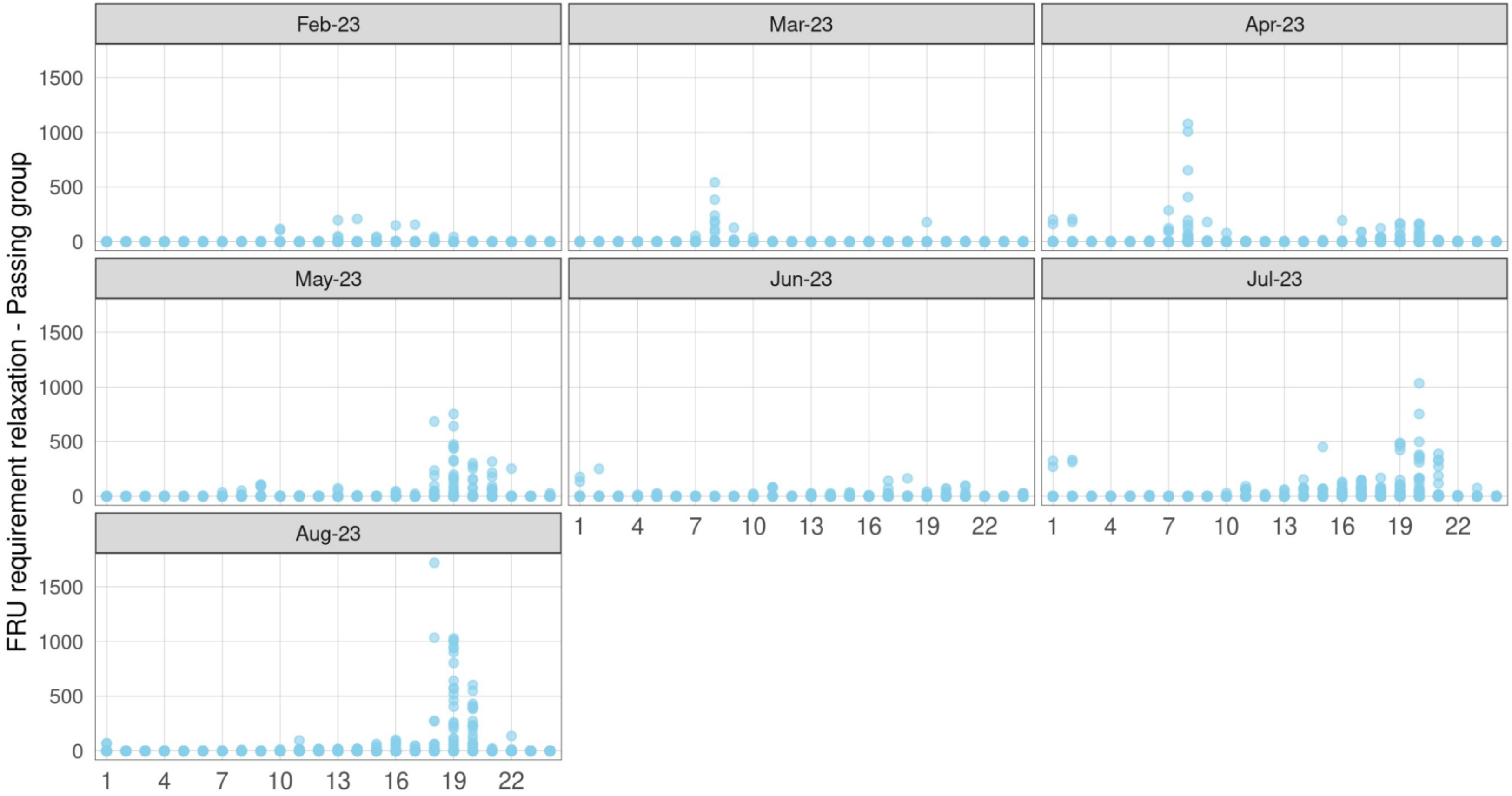


ISO PUBLIC

On average, the upward FRP requirements tend to be fully procured, which in turns may result in a zero price



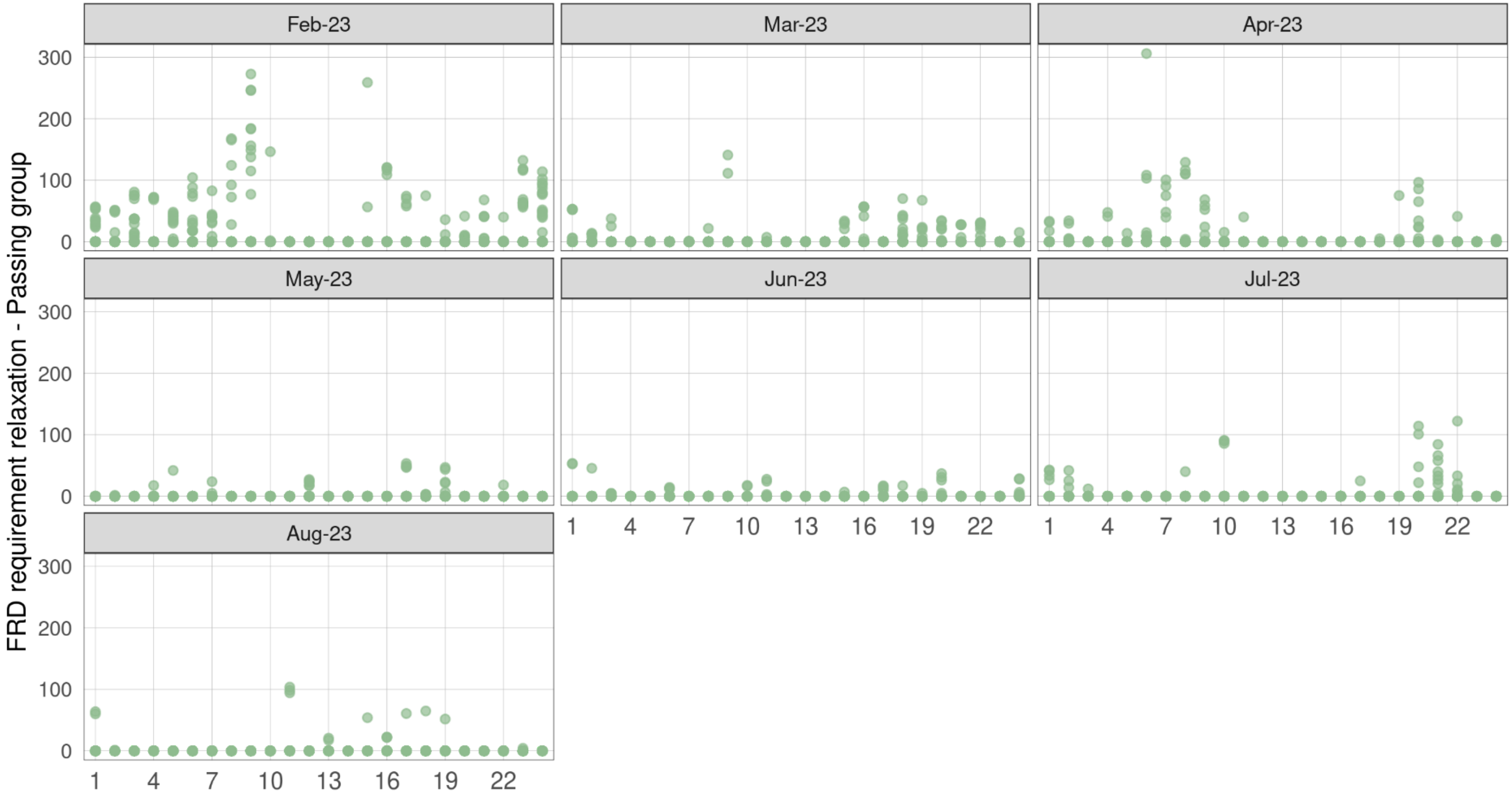
The frequency of FRP procurement relaxation is low and tends to be concentrated for peak hours



ISO PUBLIC

California ISO

The frequency of FRP procurement relaxation is low and tends to be concentrated for peak hours



The effectiveness of the FRP product can be assessed with how FRP is utilized when uncertainty realizes

- Estimate utilization

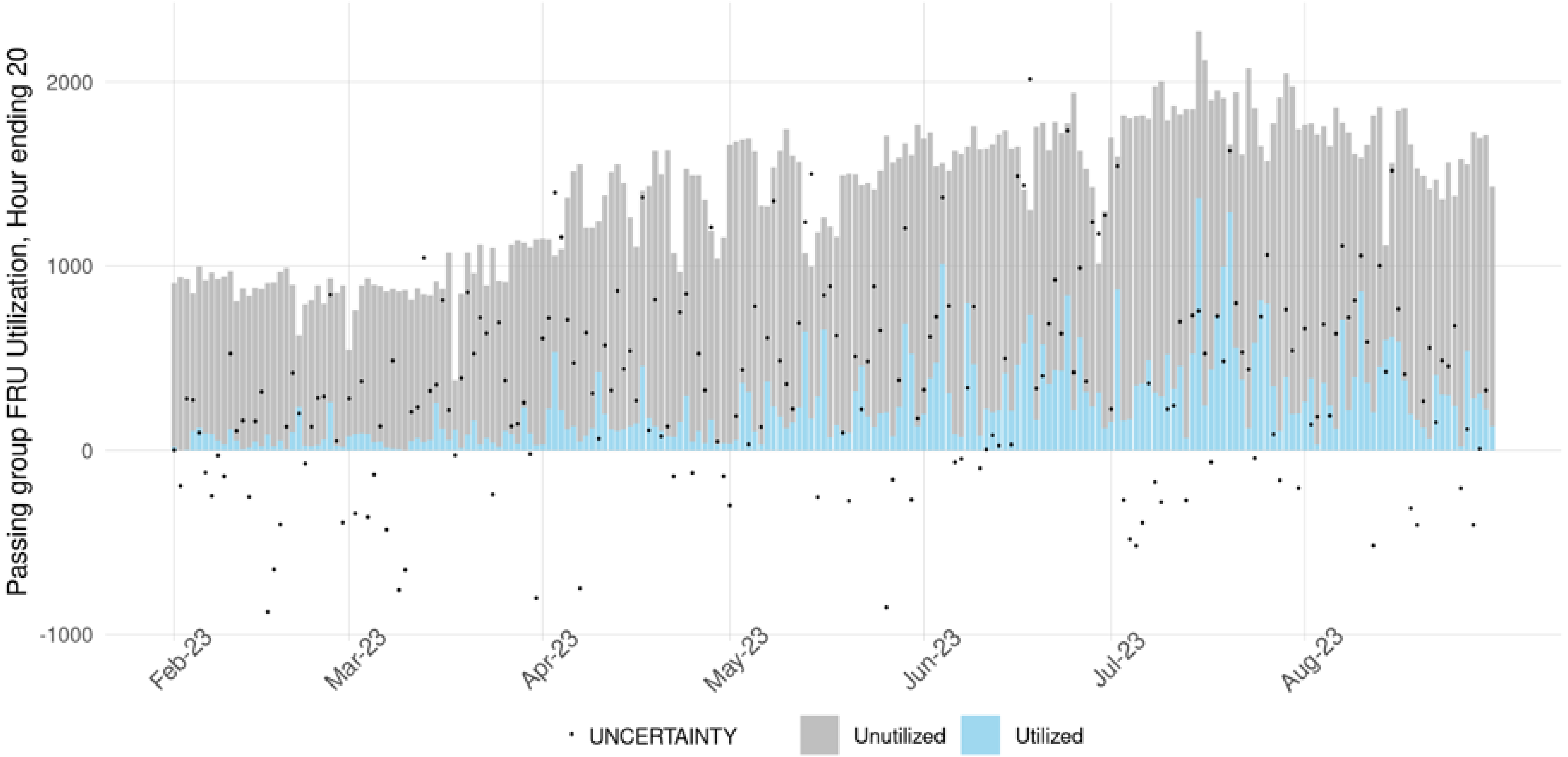
$$Utilized\ FRU = \min \begin{Bmatrix} FRU\ Award, \\ \max(Realized\ uncertainty, 0) \end{Bmatrix}$$

- There are three main reasons for which FRP may not be utilized
  - Economics. Capacity is available but not dispatched because it is not in merit
  - Congestion. Capacity is not deliverable due to being stranded behind transmission constraints. This led to the nodal approach
  - Resource constraints. Any resource limitation that may prevent the deployment or availability of FRP

In pursue of an estimation of FRP utilization

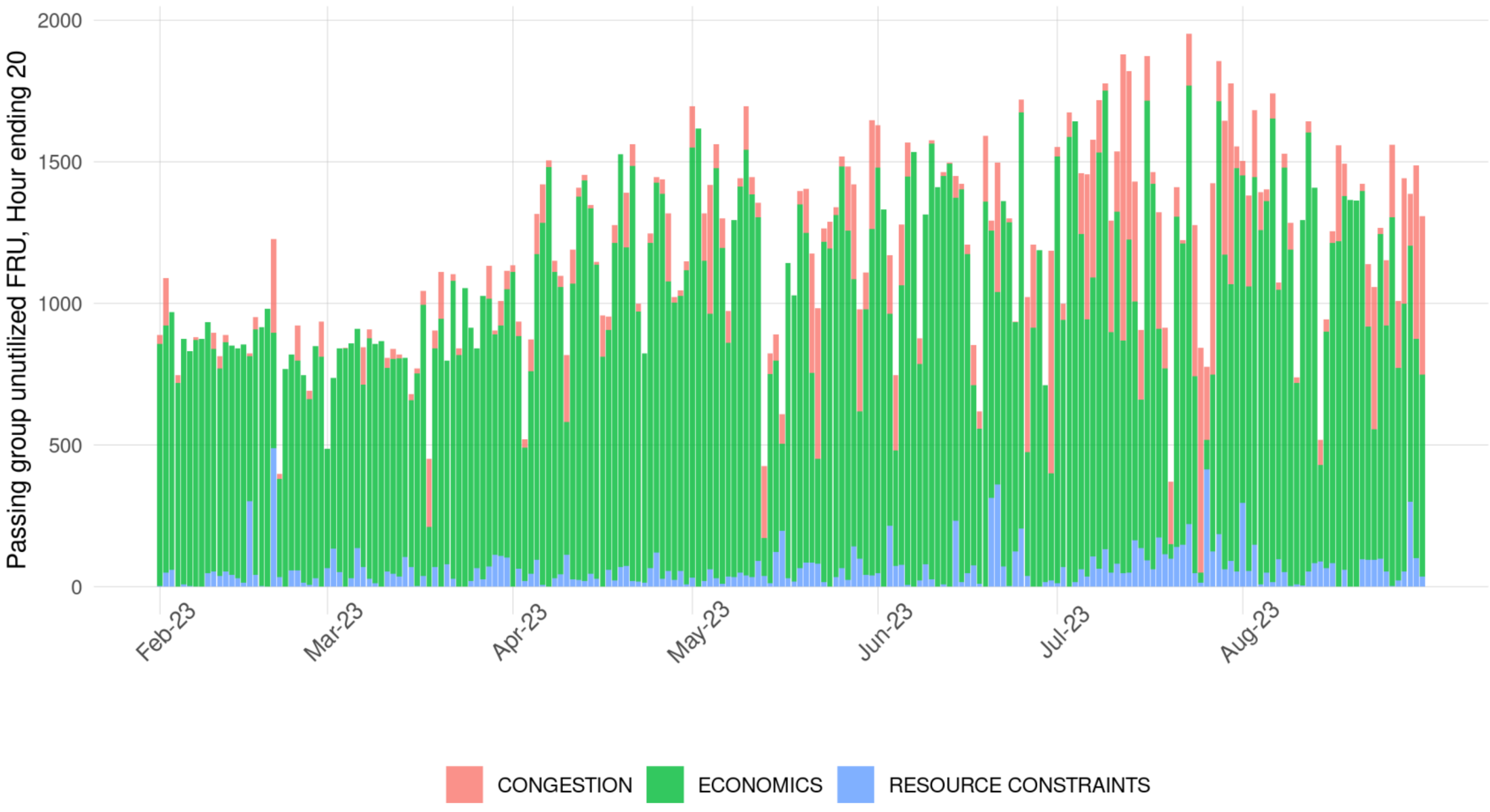
- There should not be an expectation that FRP will be fully utilized all the time
- If no uncertainty realizes then FRP does not need to be utilized
- If uncertainty realizes, it may be at lower levels than FRP was procured for, so FRP may not need to be fully utilized
- If uncertainty realizes in one direction (i.e., downward), then FRP will not need to be utilized for the opposite direction (i.e., upward),
- If uncertainty realizes, FRP may not be utilized if prices are not high enough to make the FRP capacity in merit
- Nothing prevents FRP to be utilized, even when no uncertainty realizes, to absorb other system changes

HE20 example of FRP utilization showcases a variety of scenarios

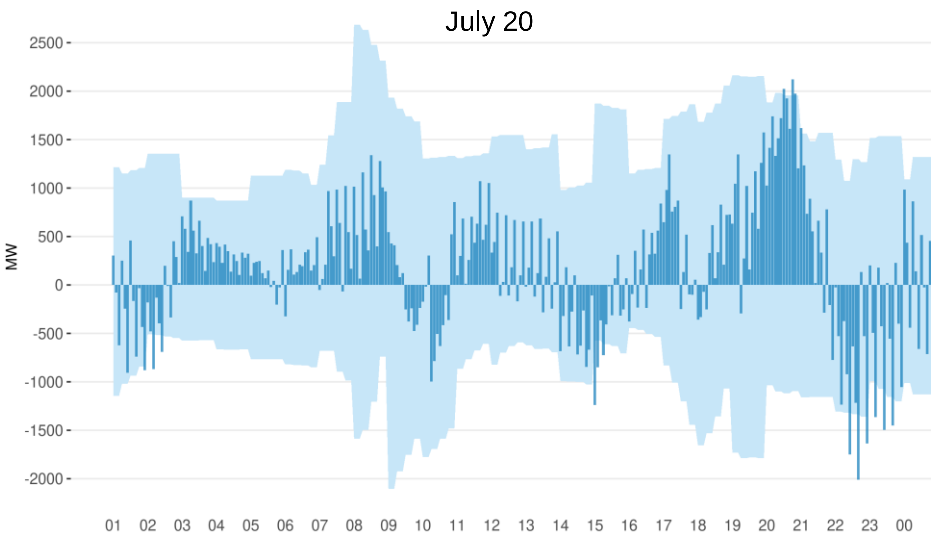


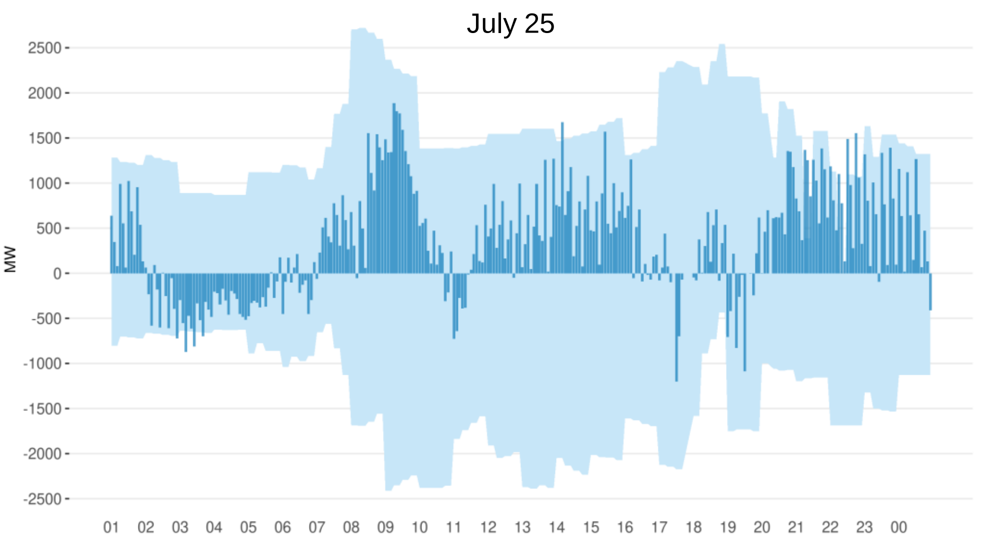
Cases where FRP utilization is greater than actual uncertainty.
Cases where actual uncertainty is in the downward direction but FRU is utilized
Cases where FRP is utilized below the level of actual uncertainty and requirement
Cases where actual uncertainty is higher than FRP requirements

The main reason for not using FRP is economics, while there is still a portion related to non deliverability



How did FRP perform during the July 2023 events?



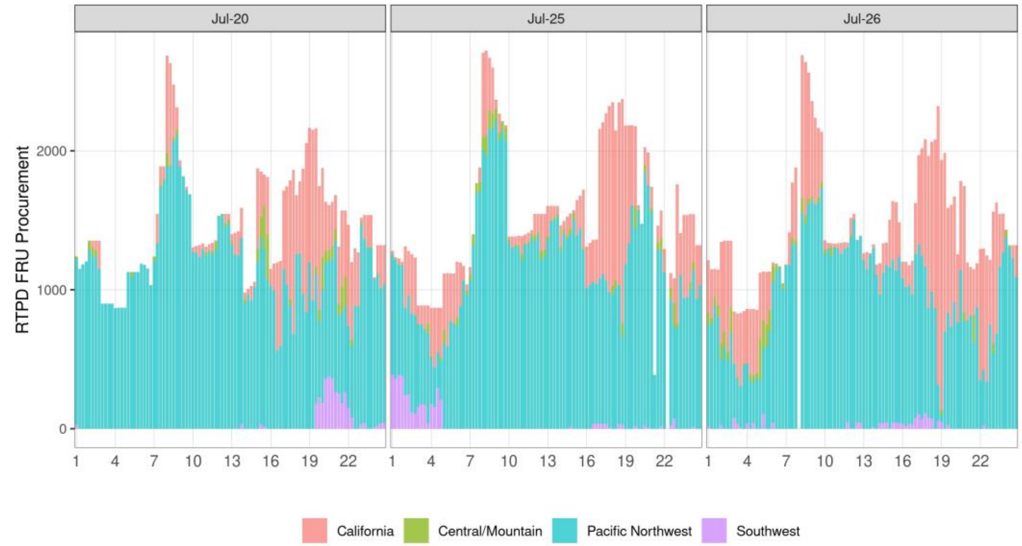


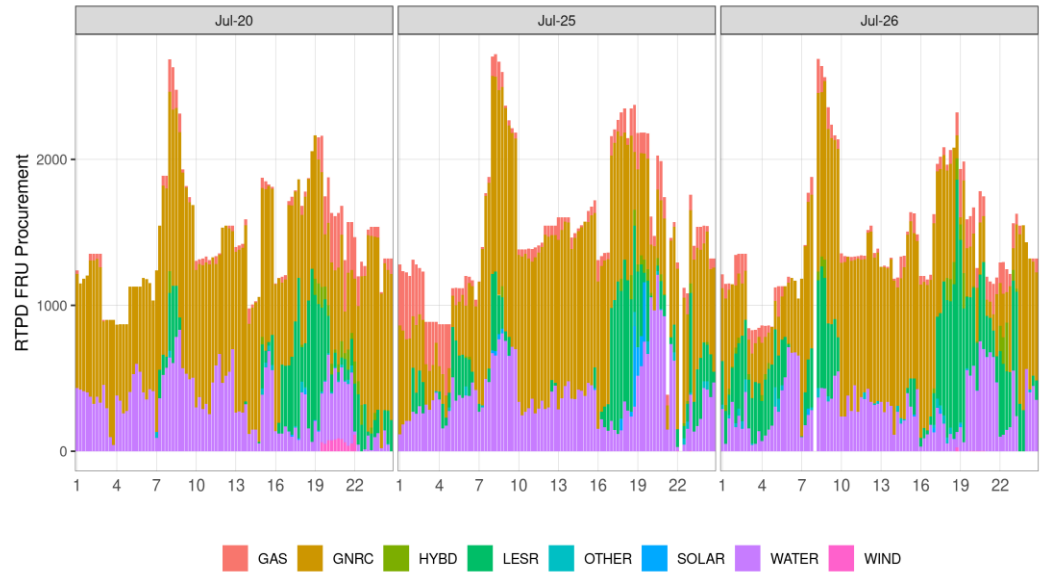
- Actual uncertainty on July 20 of 2,024 slightly greater than FRP procured of 1,957 WM.
- In contrast, actual uncertainty on July 25 was under the FRP requirement of 1905 MW

FRP was procured mainly from the Pacific Northwest

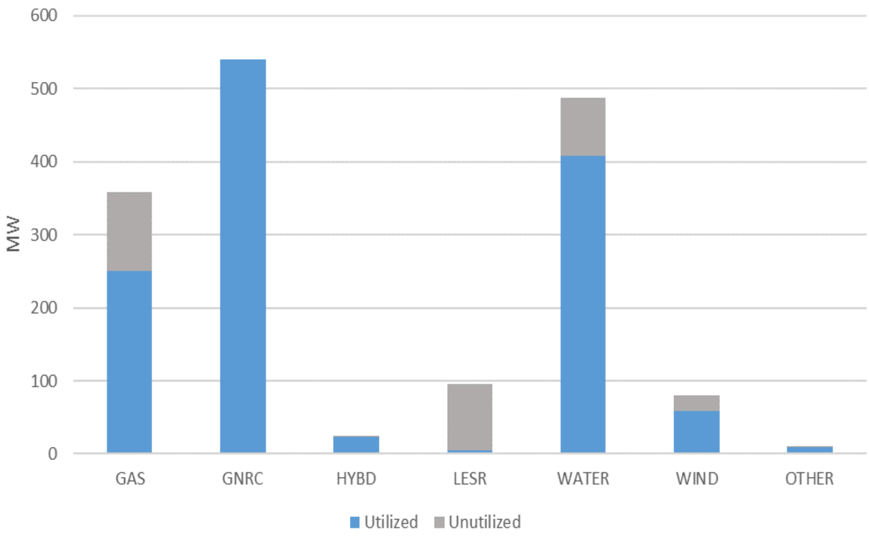
Hydro resources procured a large share

Storage resources in CAISO got FRP awarded for peak hours





FRP had mixed performance during the July events

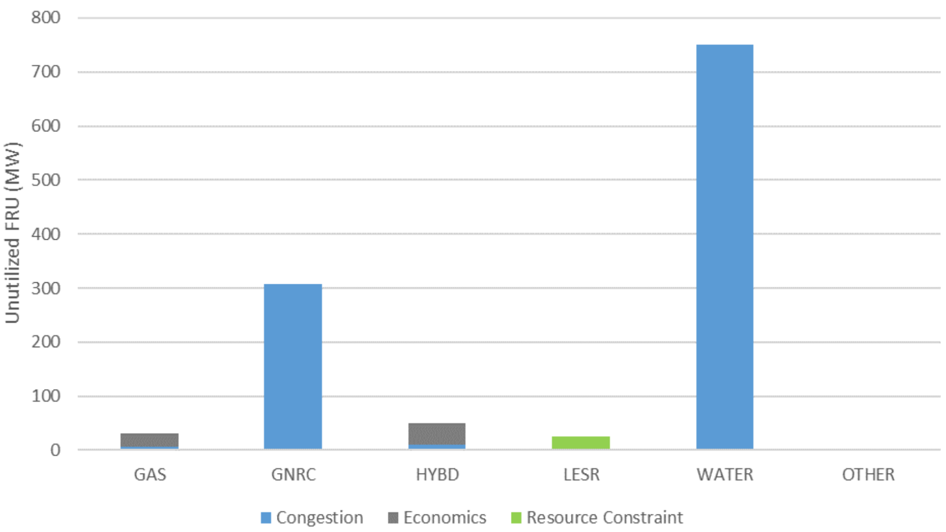


- On July 20 during the critical time, FRP had a good level of utilization

- On July 25 during the critical time, FRP showed a poor level of utilization

- This was due to congestion on nomograms stranding FRP

- Nomograms not enforced at that time; however, if nomogram were enforced, FRP would be relaxed by 1,000MW



Areas for improvement and further assessment

- The results of the T-55 test are now used to determine if an entity pass or not the test for consideration in the run of the first interval of the hour in the real-time market. Tariff language has been revised
- Treatment of negative but negligible FRP requirement shadow prices
- Consideration of energy limits in the FRP procurement for certain energy-limited resources
- FRP demand curve erroneous calculation

Areas for improvement and further assessment

- Enhance logic to account for exceptional dispatches of storage resources in the FRP procurement
- Further assessment of storage resources supporting FRP due to complexities in managing its state of charge, mainly for resources on regulation. FRP procurement does not project SOC utilization if deployed.
- July events show that non-FRP-related variability (non-VER deviations, outages/derates, imports/exports underperformance) can realize concurrent with FRP-related uncertainty and thus FRP is not designed to absorb this type and level of variability
- Further assessment of variability in the requirements and its trade-offs. In the end, the uncertainty is inherently variable as measured by error of net loads between FMM and RTD markets.