ENERGYGPS LLC

Market Impacts of Spill and Lower Snake River Dam Removal

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Brief Review of History

Dams and Smelters Grow Together

Small Number of Large Coal Plants Added to Mix

Capacity and Energy Surplus – Excess Sold to California as Available

Reliability Maintained Because:

- **Smelters were significant, curtailable, load**
- **Large portion of sales to CA were as-available**
- **Region was over-supplied from a capacity perspective and managed uncertain energy production via smelters and exports.**

Two periods of scarcity:

- **Perception of scarcity in 1970's leads to 1980 NW Power Act and WPPS.**
- **Extremely low water year in 2001 contributes to Western Electricity Crisis. Results in the loss of almost all smelter load.**
- **Otherwise the region has been flush.**

What Has Changed?

Thermal retirements throughout WECC

Renewable additions throughout WECC

Limitations on the hydro system

Key Questions

Quantify Lost Production Due to Spill Rules or LSRD Removal

- Rely on historic hourly outflow and spill data for relevant dams.
- LSRD Removal is Easy: all MWh and MW go away.
- Spill: Requires "diverting" available water from turbine to spillway. Constrained by minimum operating flows and TDG limits. Received input from BPA for these variables.

Characterize Current State of WECC and PNW Markets

- Historic electricity and natural gas prices.
- Forward electricity and natural gas prices.
- Strong evidence of increased scarcity.

Understand:

- Where will replacement energy come from?
- During times of scarcity, what could happen if we lose access to certain hydro resources due to spill or dam removal.

Lost Average Energy Due to Proposed Spill Rules

Figure 48: 2017-2021 Lost Average MW by Month and Hour to Proposed Spill Rules

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Grand Total
1	326	314	198	612	649	483	138	187	229	166	242	283	320
2	321	308	194	602	654	479	133	184	218	157	236	276	314
3	318	311	194	597	651	477	131	184	213	157	235	275	313
4	324	319	200	606	658	495	130	186	215	161	241	280	319
5	357	342	208	566	565	444	134	189	226	185	258	303	315
6	442	400	208	720	725	484	142	199	257	250	317	387	377
7	497	425	205	880	1,063	567	151	227	339	338	388	469	462
8	505	426	197	891	1,095	587	153	229	351	356	391	476	472
9	507	424	197	837	1,054	610	152	230	356	353	390	475	465
10	503	421	207	745	963	612	162	230	365	363	379	460	451
11	483	413	210	647	896	603	163	237	376	348	343	429	429
12	453	392	216	619	861	632	164	238	388	338	320	410	420
13	437	378	217	680	978	762	168	254	395	328	308	396	443
14	430	369	219	699	965	771	173	269	406	322	303	392	445
15	433	371	218	685	979	797	178	280	413	326	303	395	450
16	465	393	219	693	992	800	183	291	419	341	331	426	464
17	502	420	219	729	1,115	822	197	302	429	365	388	467	498
18	505	424	221	843	1,337	882	209	312	435	398	431	480	542
19	507	429	221	1,025	1,551	920	205	313	447	408	443	485	582
20	505	427	218	1,064	1,540	907	202	311	445	408	438	484	582
21	505	429	218	1,032	1,432	830	196	300	447	400	431	478	561
22	493	423	219	944	1,223	758	189	284	438	364	407	470	519
23	415	381	218	708	730	543	161	218	335	269	301	380	389
24	349	336	211	642	652	509	145	191	262	198	263	315	340
Grand Total	441	386	211	753	972	657	165	244	350	304	337	404	436

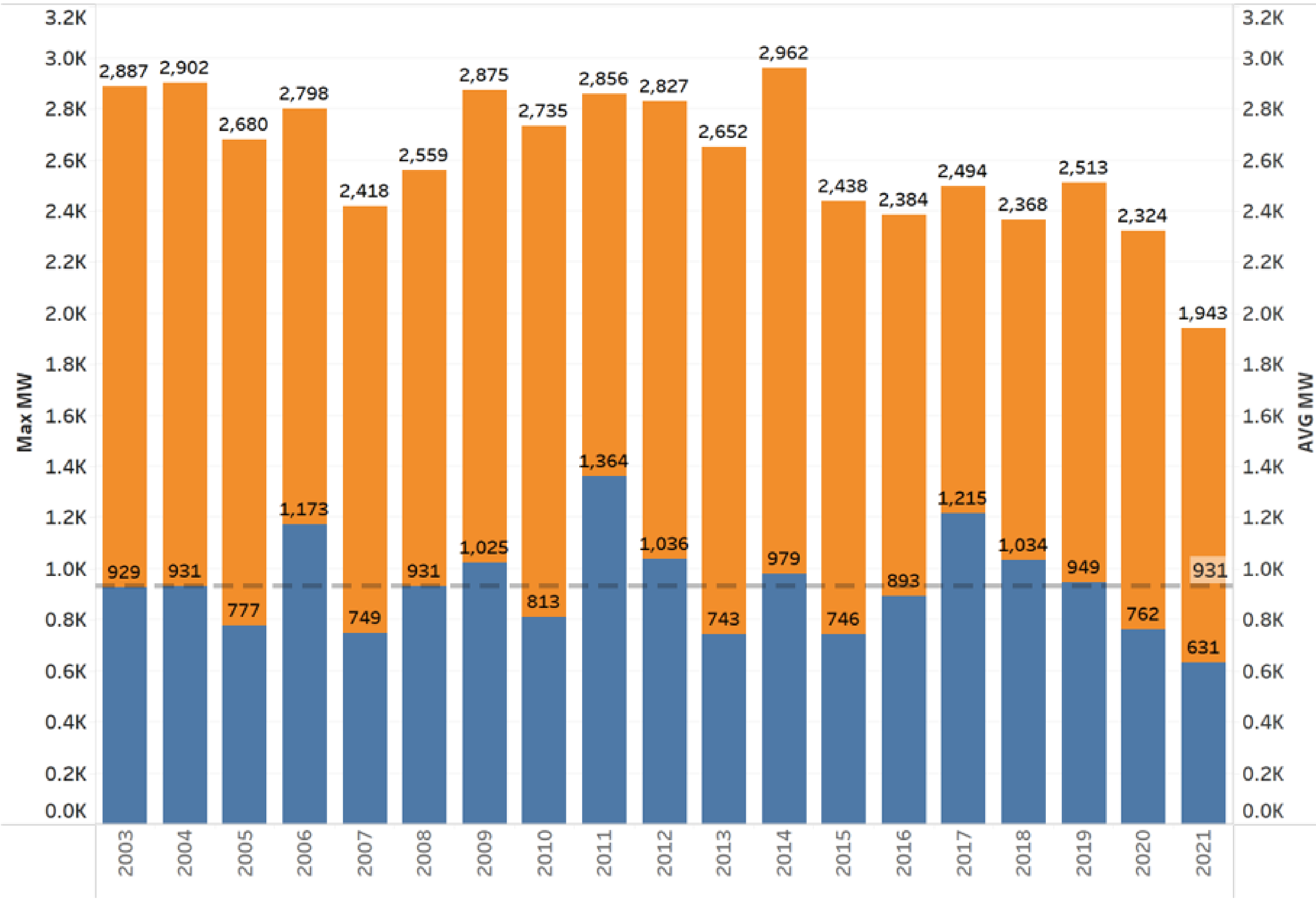
Lost Max MW Due to Spill Rules

Figure 49: 2017-2021 Lost Max MW by Month and Hour to Proposed Spill Rules

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Grand Total
1	534	547	299	2,433	2,233	2,631	457	903	452	423	485	489	2,631
2	540	547	298	2,424	2,268	2,596	497	912	474	399	487	491	2,596
3	535	546	299	2,401	2,269	2,662	474	921	474	359	487	491	2,662
4	538	547	302	2,400	2,245	2,668	450	911	475	378	486	519	2,668
5	540	543	303	2,127	1,979	2,482	441	922	466	416	485	521	2,482
6	543	541	303	2,197	2,397	2,514	459	926	478	483	485	524	2,514
7	543	539	303	2,602	2,597	2,373	406	1,048	478	507	476	538	2,602
8	543	539	302	2,390	2,574	2,273	469	1,016	468	477	477	533	2,574
9	543	539	303	2,375	2,552	2,216	284	1,030	489	469	475	534	2,552
10	543	540	304	2,307	2,407	2,141	346	1,048	468	478	487	534	2,407
11	542	540	311	2,291	2,509	2,158	367	1,042	468	489	498	534	2,509
12	545	541	307	2,283	2,528	2,134	369	1,057	482	477	465	538	2,528
13	541	539	305	2,639	2,385	2,508	443	1,183	481	469	461	533	2,639
14	541	538	317	2,730	2,263	2,585	464	1,266	480	467	461	534	2,730
15	542	539	317	2,730	2,152	2,517	466	1,282	492	470	464	535	2,730
16	541	539	317	2,752	2,068	2,618	466	1,333	490	470	467	543	2,752
17	540	540	316	2,803	2,294	2,617	462	1,412	496	472	477	569	2,803
18	544	538	319	2,766	2,863	2,622	483	1,400	496	474	479	539	2,863
19	548	543	317	2,992	2,945	2,697	502	1,370	498	490	485	543	2,992
20	548	543	317	2,920	2,880	2,698	499	1,386	498	491	486	541	2,920
21	552	544	317	2,755	2,776	2,679	495	1,361	498	493	486	556	2,776
22	547	547	317	2,691	2,863	2,733	484	1,366	502	483	485	586	2,863
23	542	539	308	2,565	2,604	2,737	475	1,037	479	482	485	527	2,737
24	525	537	332	2,553	2,218	2,725	456	906	477	478	486	522	2,725
Grand Total	552	547	332	2,992	2,945	2,737	502	1,412	502	507	498	586	2,992

Lost Avg Energy and Capacity – Dam Removal

Figure 50: LSRD Max Annual Output (Orange) and Avg Annual Output (Blue) MW



Energy, Capacity, and Carbon Impacts of Lost Hydro
-- Before Clean Replacement Occurs --

Table 1: One-Year Impacts on Lost Resources, Costs, and Carbon Emissions

	Units	One Year 2023 Cost Increased Spill	One Year 2023 Cost LSRD Removal	One Year 2023 Cost LSRD Spill + LSRD
Energy Value				
ICE Price All Hours	$/MWh	$66.49	$66.49	$66.49
Volume-Weighted Value	$/MWh	$58.80	$60.90	$61.21
Avg Lost Energy	MW	435	919	1133
Replacement MWh	MWh	3,808,066	8,048,174	9,923,614
Replacement Energy $	$	**$223,899,194**	**$490,160,831**	**$607,414,401**
Capacity Value				
Lost Winter Capacity	MW	515	2,284	2,556
Lost Summer Capacity	MW	930	1,644	1,809
Replacement Capacity	MW	723	1964	2183
Capacity Price	$/kW-Mo	$7.00	$7.00	$7.00
Replacement Capacity $	$	**$60,690,000**	**$164,976,000**	**$183,330,000**
2023 Replacment Cost	$	**$284,589,194**	**$655,136,831**	**$790,744,401**
Increased CO2 Emissions	Tons	**1,629,852**	**3,444,618**	**4,247,307**

Replacement Capacity Estimates Max Lost Winter and Max Lost Summer Capacity

ICE Price All Hours Based on Forward Market Prices Published by the InterContinental Exchange (ICE)

Capacity Price Based on Recent WECC Capacity Price Quotes from Brokers

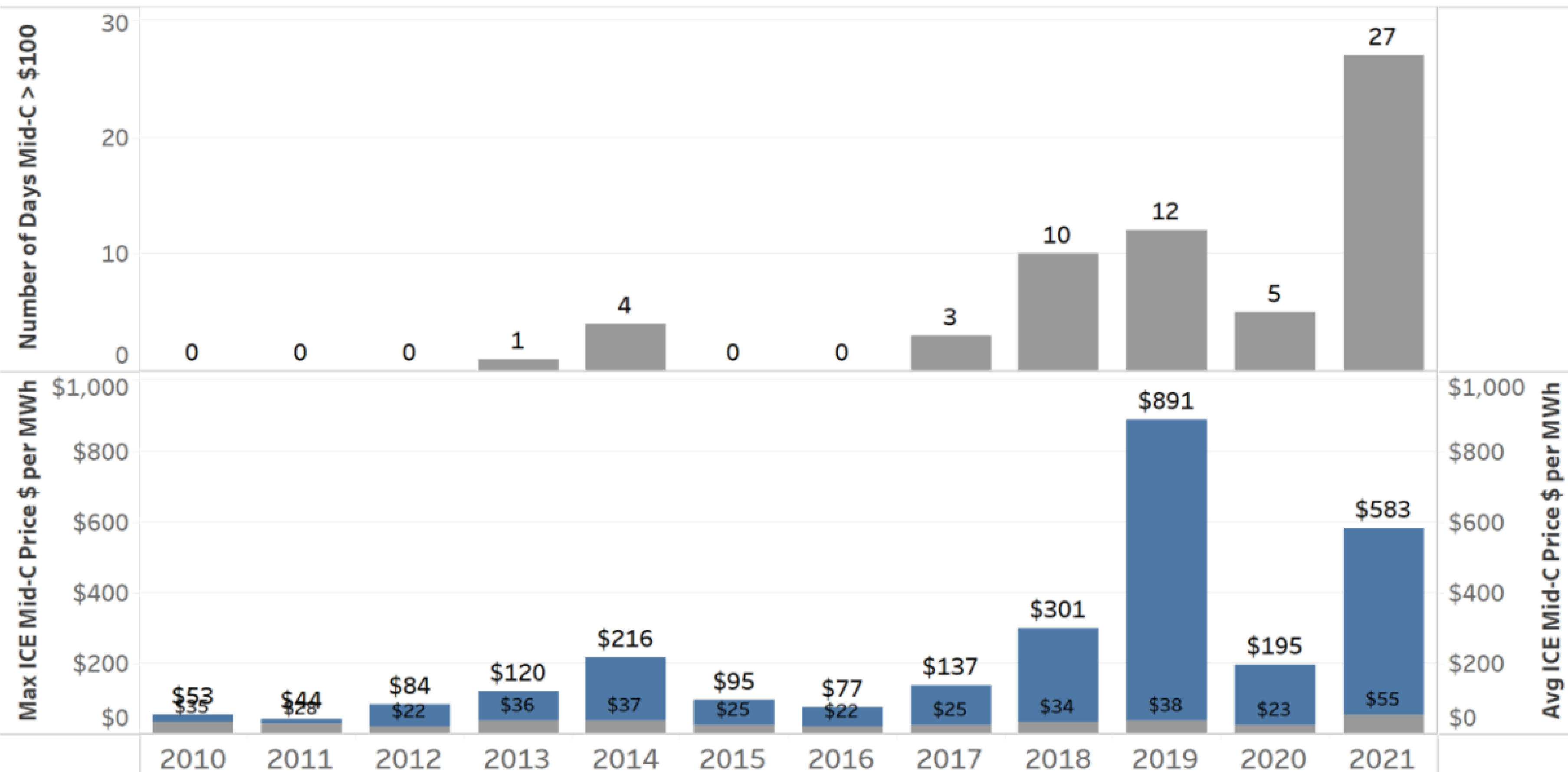
Carbon emissions assume 0.428 tons of carbon per MWh of electricity

Reliability Concerns

- Scarcity events are increasing.
- Natural gas pipeline infrastructure has experienced challenges throughout the WECC.
- Imports are key to meeting reliability. No contractual guarantees. Wildfire risk.
- Evolving grid – thermal replaced by renewable plus storage – not clear what reliability challenges will face the region.

Scarcity Events at the Mid Columbia Are Rising

Figure 1: Days Per Year When Mid-C Price > $100, Max and Avg Annual Mid-C Prices



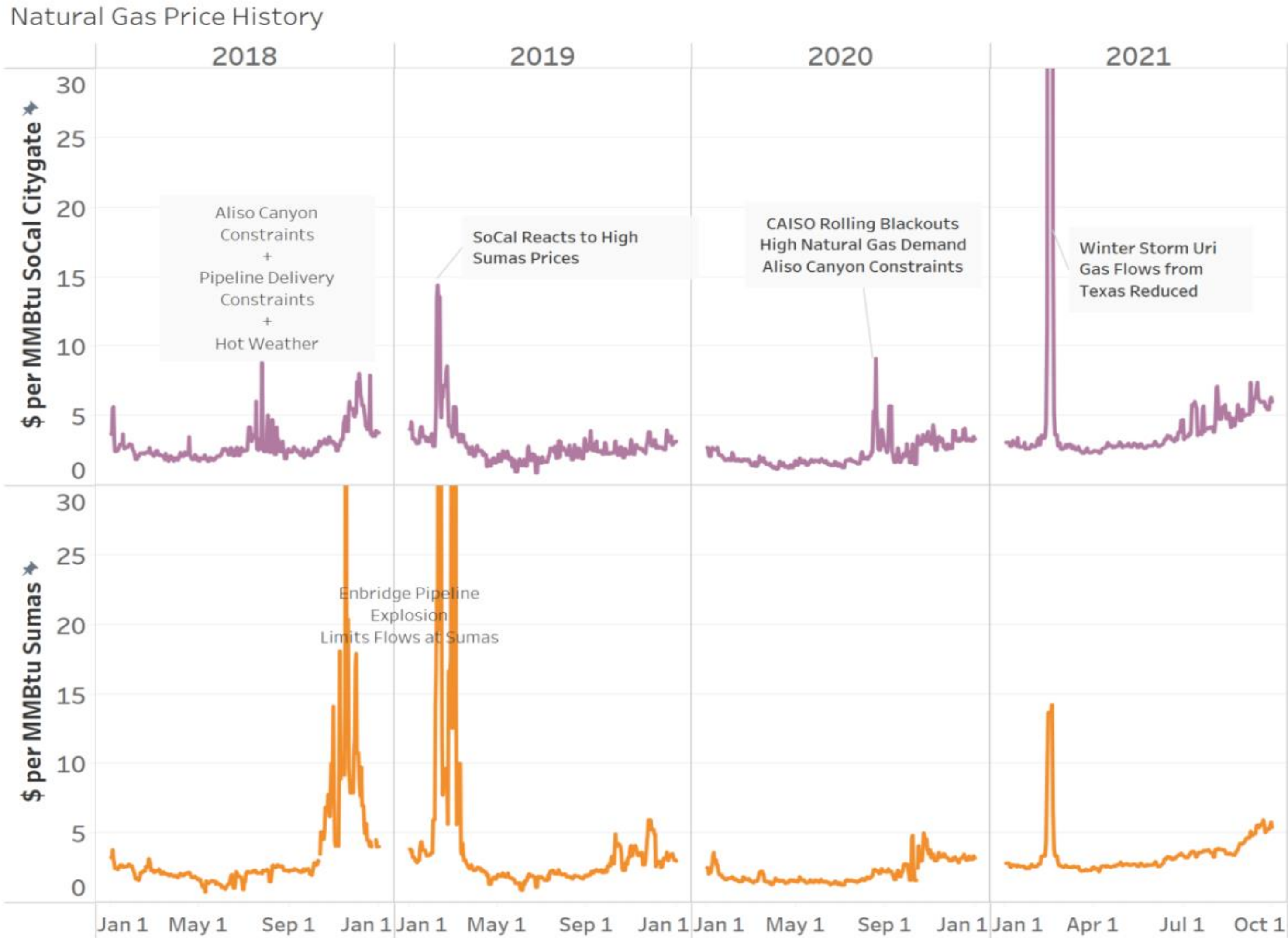
- Rare through 2017
- Common in 2021. Both average price and max price going up.

Mid Columbia Forward Price Has Been Going Up

Figure 2: Mid-C 2023 Peak Price as Traded on the InterContinental Exchange

Natural Gas Prices in West are Prone to Spikes

Figure 3: Natural Gas Price History, 2018-2021

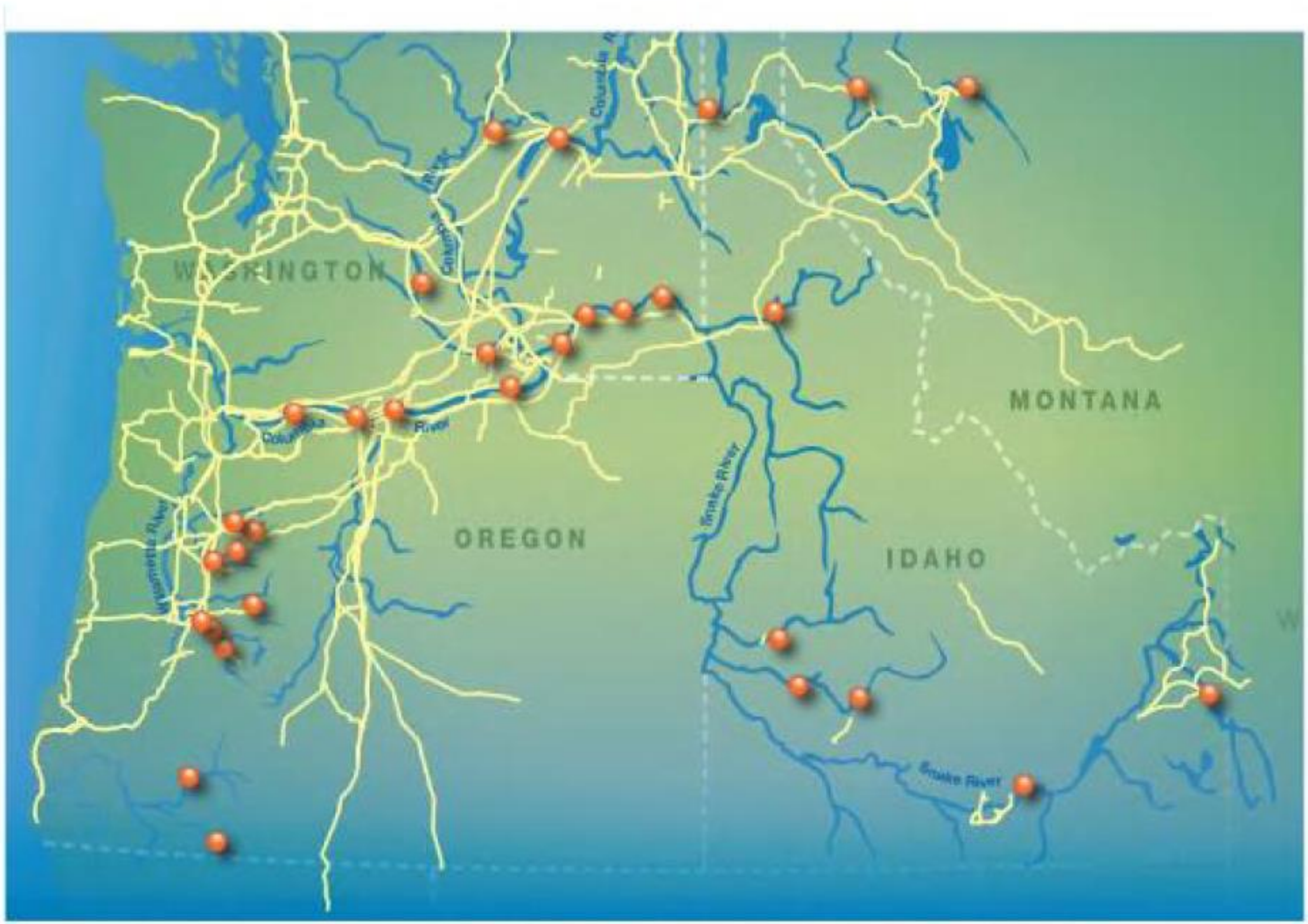


Market/Reliability Analysis

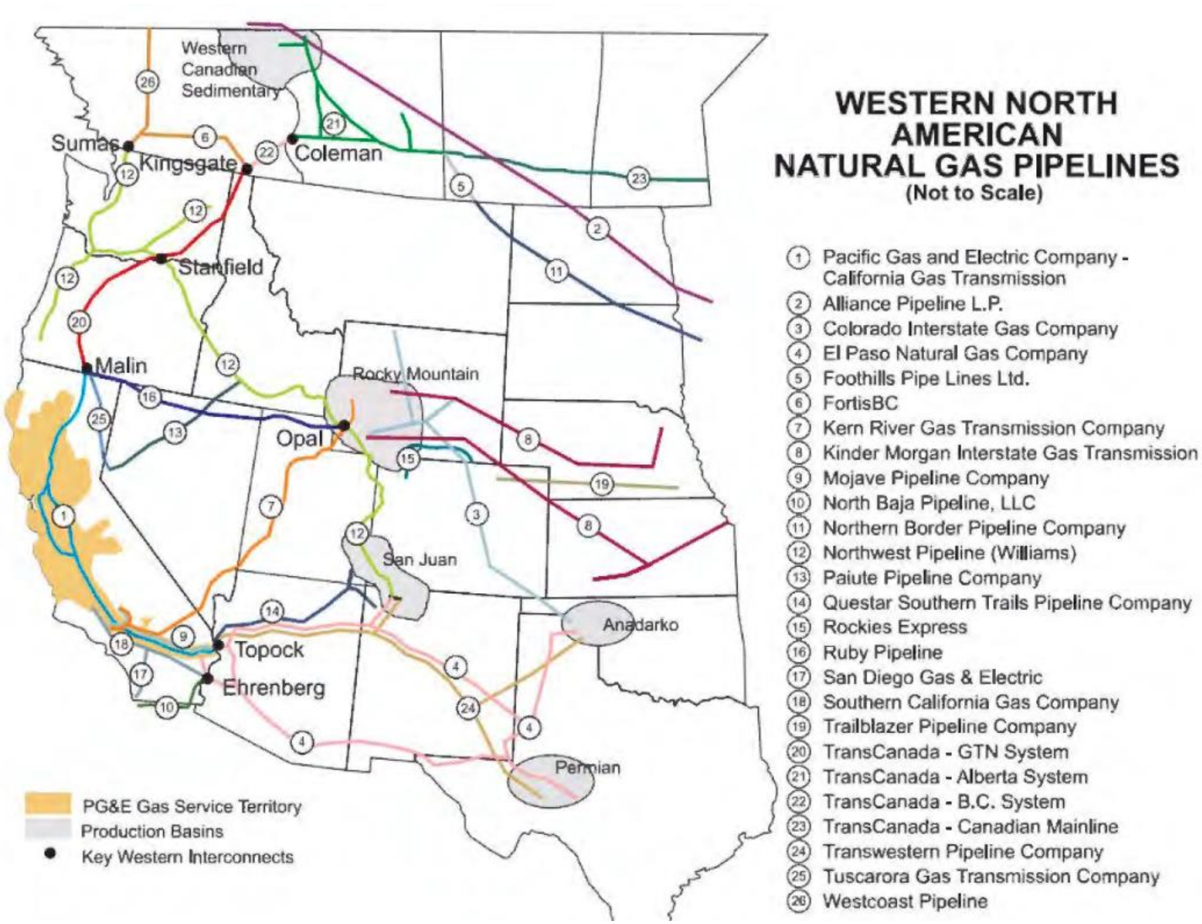
Where is the lost hydro production going to come from during scarcity events?

Location of Hydro and Transmission

Figure 15: Map of BPA Dams and Transmission System [16]



WECC Gas Pipeline Infrastructure



WECC Gas Pipeline Infrastructure

Table 4: Natural Gas Pipelines Serving the WECC [33]

Owner	Pipelines	Capacity MMcf/day	% Total	Running % Total
El Paso	CO Interstate, El Paso, Mojave, WY Interstate	10,690	46%	46%
Williams	Northwest Pipeline	3,500	15%	61%
TransCanada	Gas Transmission NW, North Baja	3,400	15%	76%
Questar	Questar Pipeline, Questar Southern Trails, Overthrust	2,180	9%	85%
Mid American	Kern River	1,700	7%	92%
Other	Transwestern, TransColorado, Tucarora	1,773	8%	100%
Total		23,243	100%	

OR and WA Gas Pipeline Infrastructure

Figure 34. Map of Northwest Pipeline system in I-5 Corridor

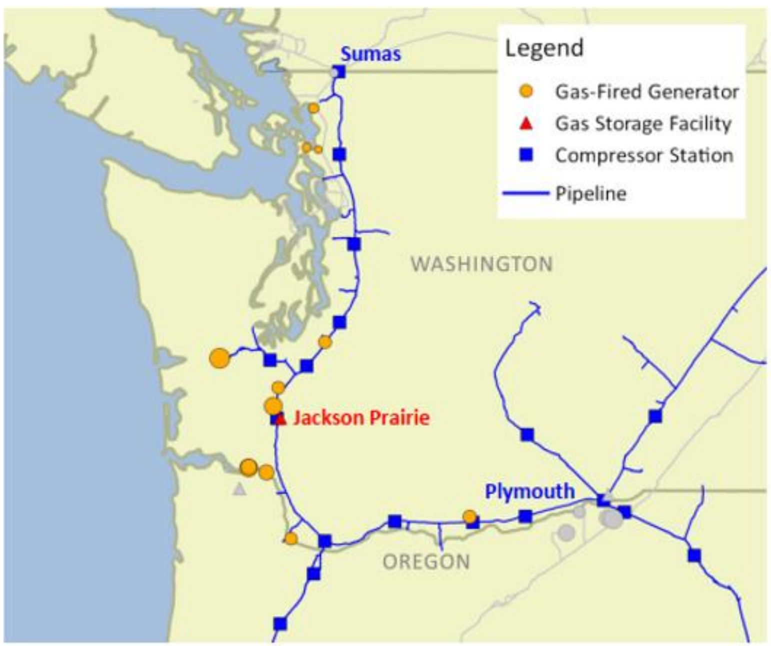
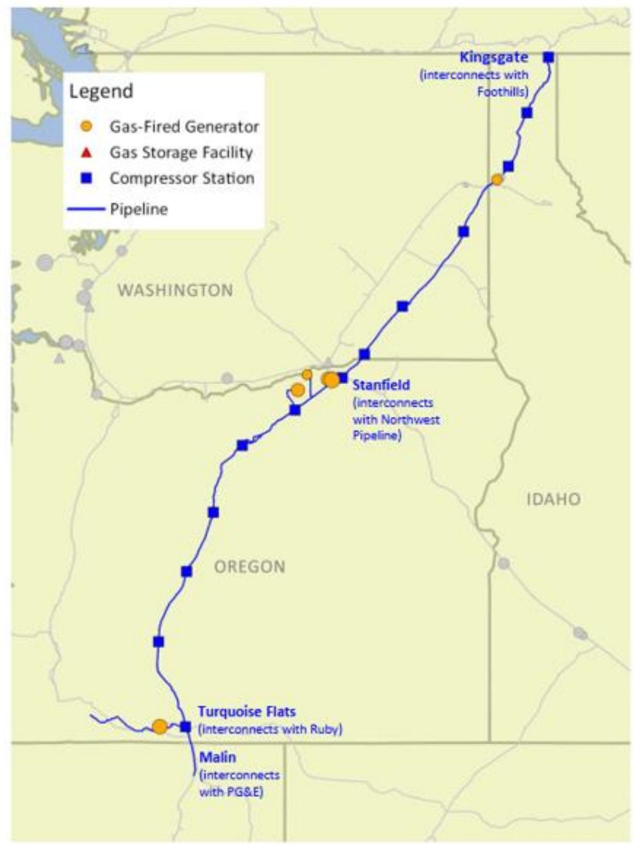
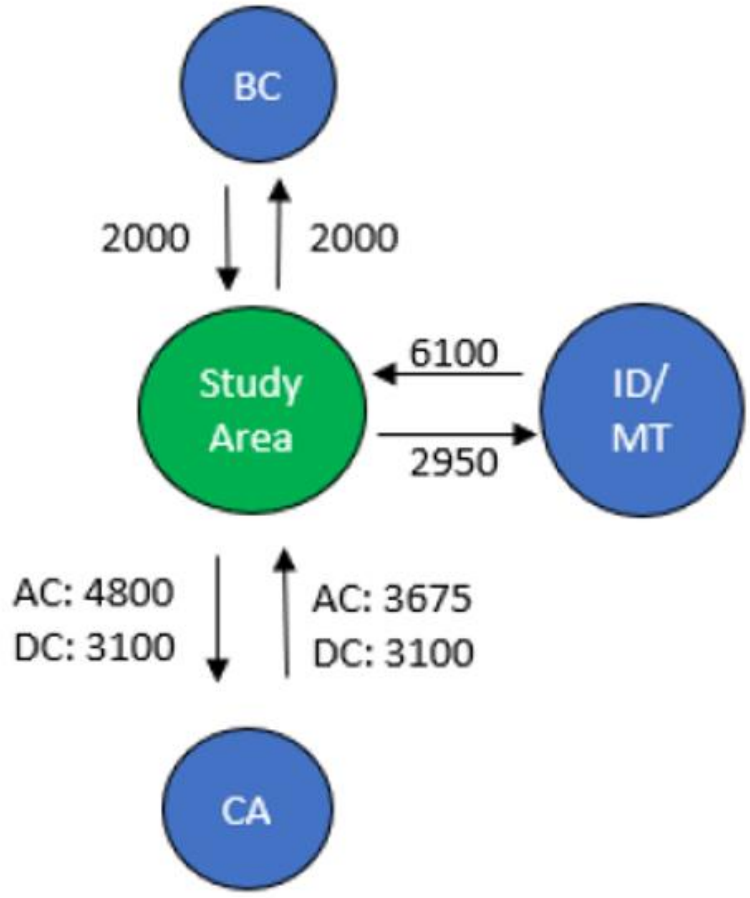


Figure 42. Map of GTN system



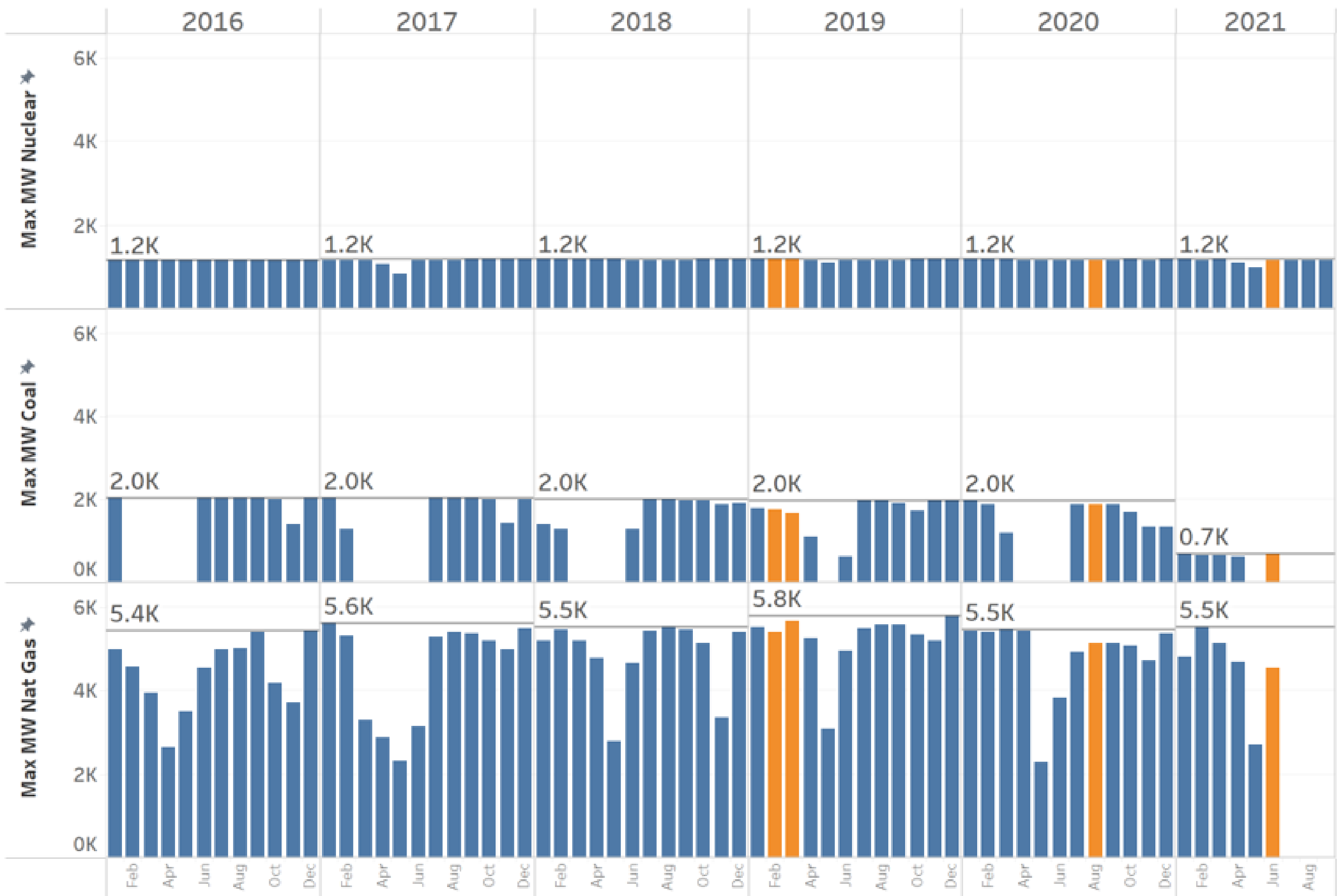
PNW = Oregon + Washington



- Measure: Nuke + Coal + Gas + Wind + Hydro + Load within study area.
- Measure: Imports and Exports

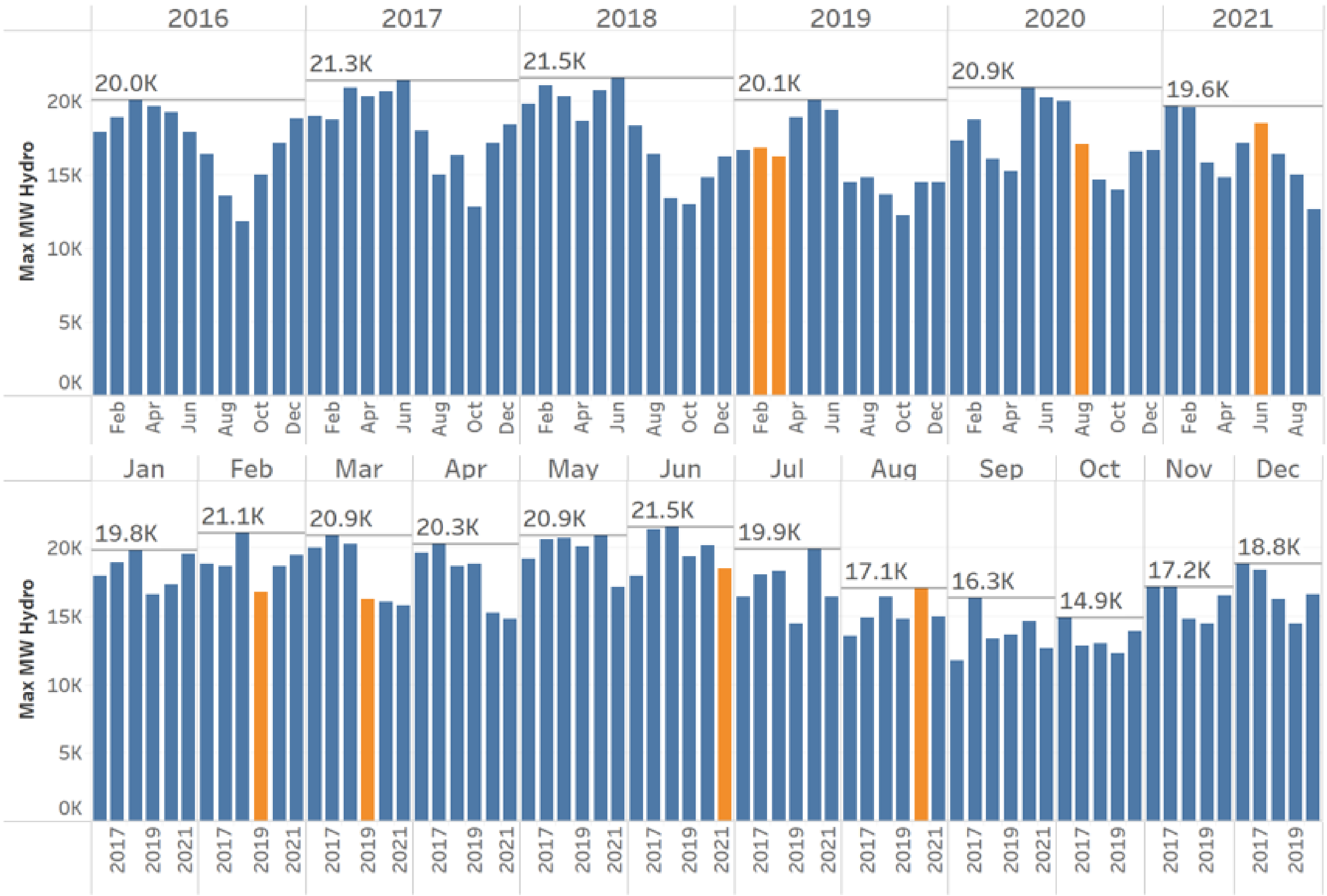
OR and WA Thermal Fleet

Figure 59: Maximum Monthly Supply for Thermal Resources in PNW Market Area



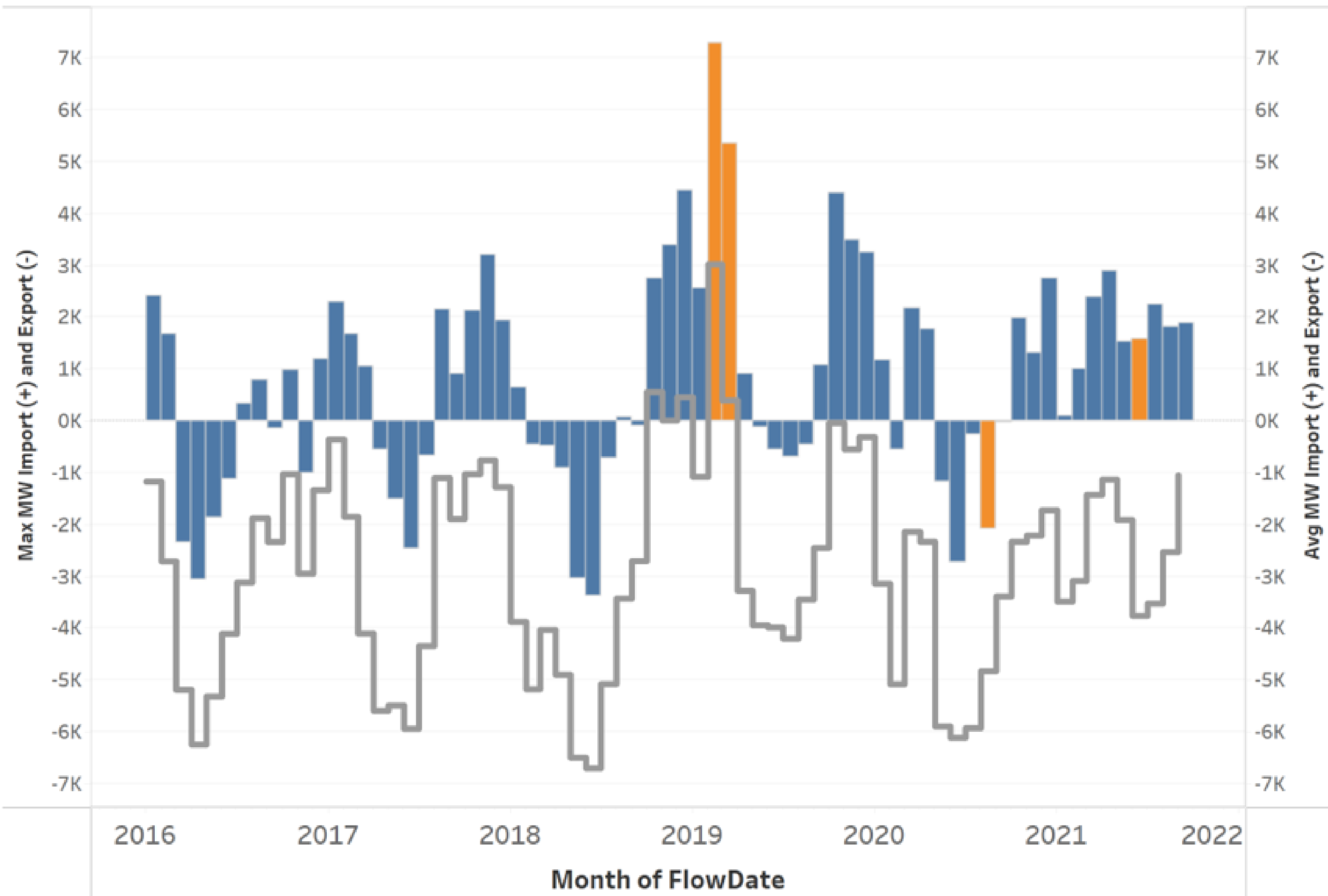
PNW 60 Dam Fleet

Figure 60: Maximum Monthly Hydro Production, Chronologically and by Calendar Month



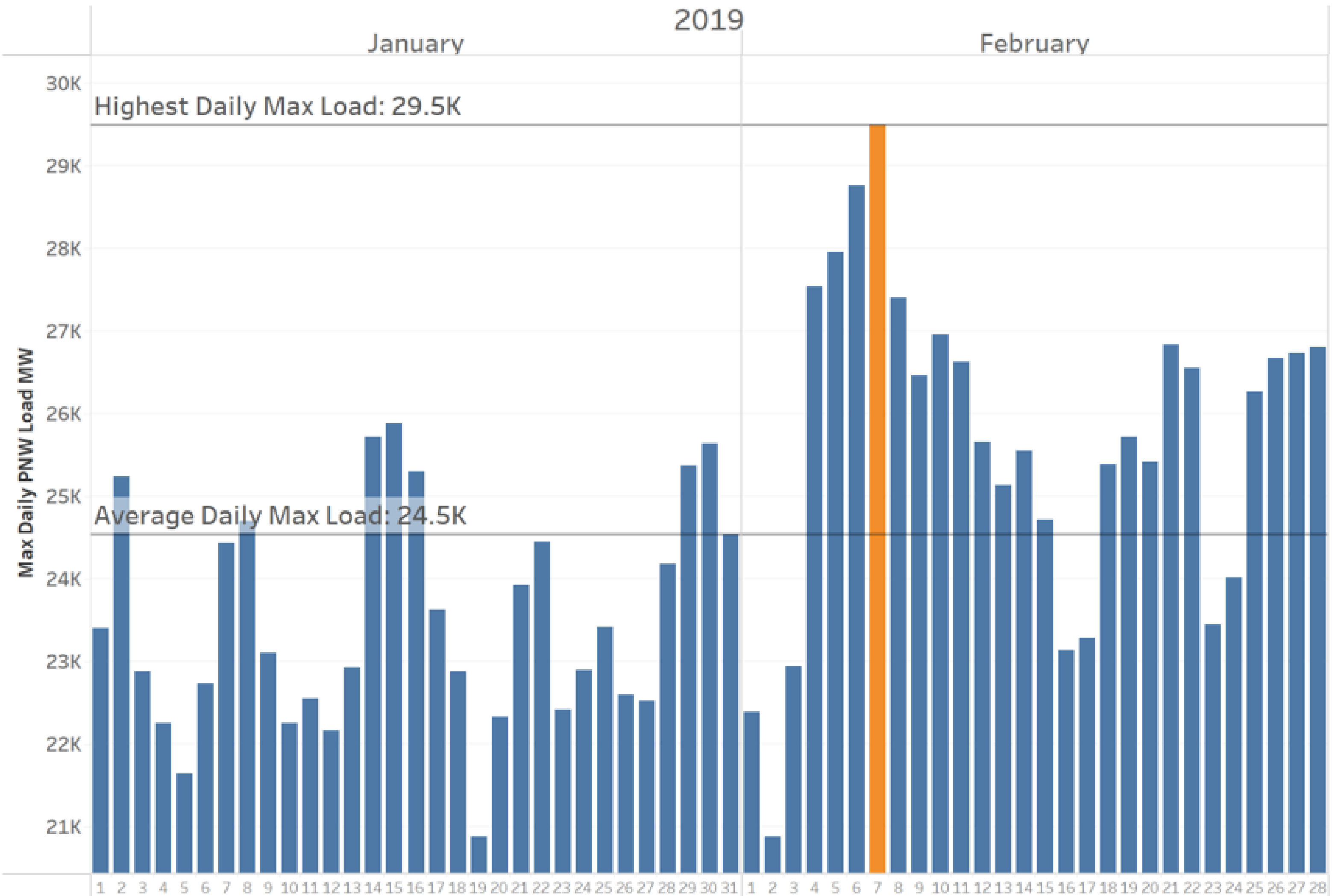
PNW Imports and Exports

Figure 61: Maximum and Average Imports (+) / Exports (-) by Month



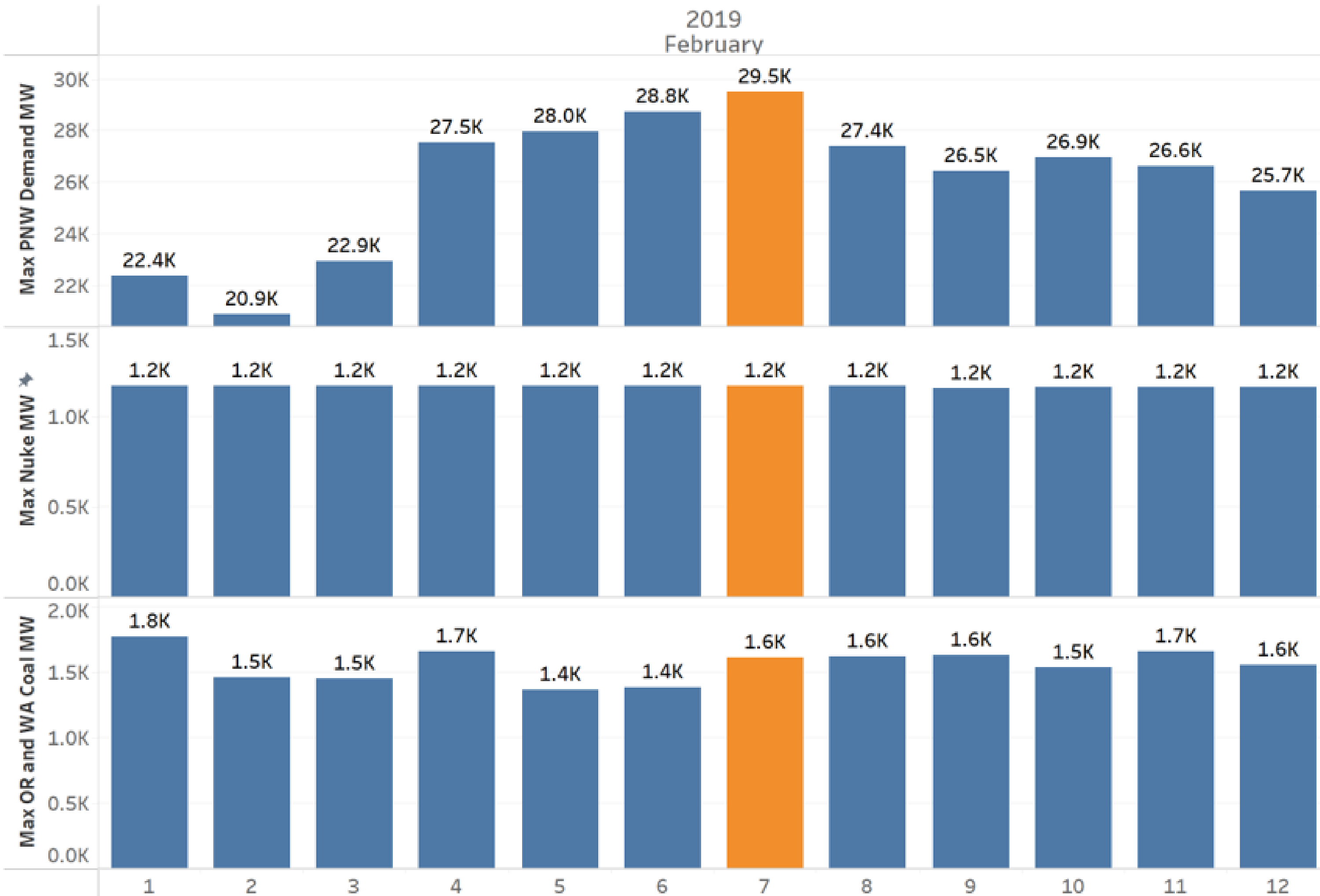
Feb 2019 Scarcity Event
OR and WA Load (PNW)

Figure 63: Maximum Daily PNW Load for Jan and Feb 2019



Feb 2019 Scarcity Event
OR and WA Nuke and Coal

Figure 64: Maximum Daily Demand, Nuclear and Coal Output

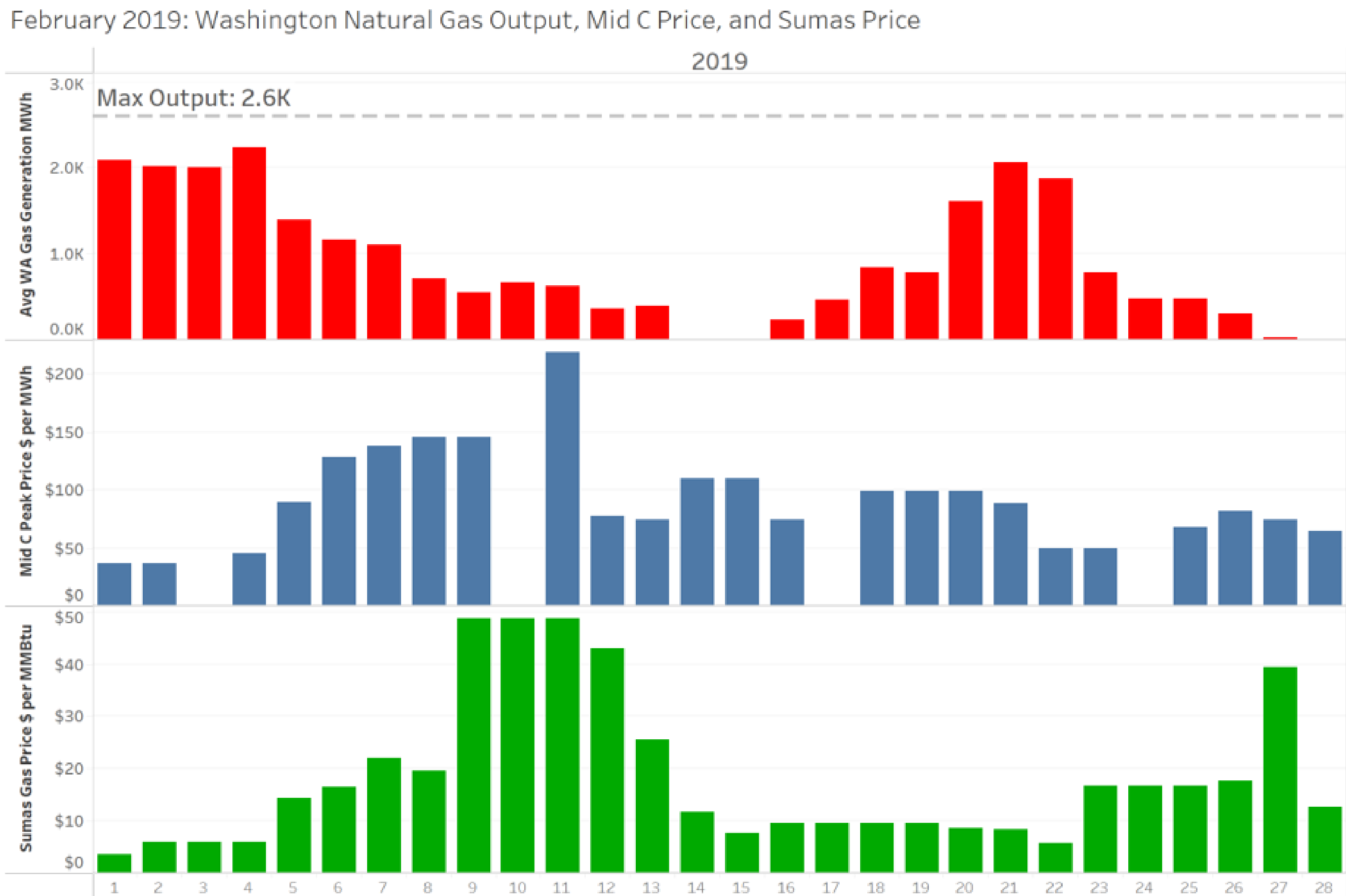


Feb 2019 Scarcity Event
OR and WA Natural Gas

Figure 65: Maximum Daily Demand, Natural Gas Output in Washington and Oregon

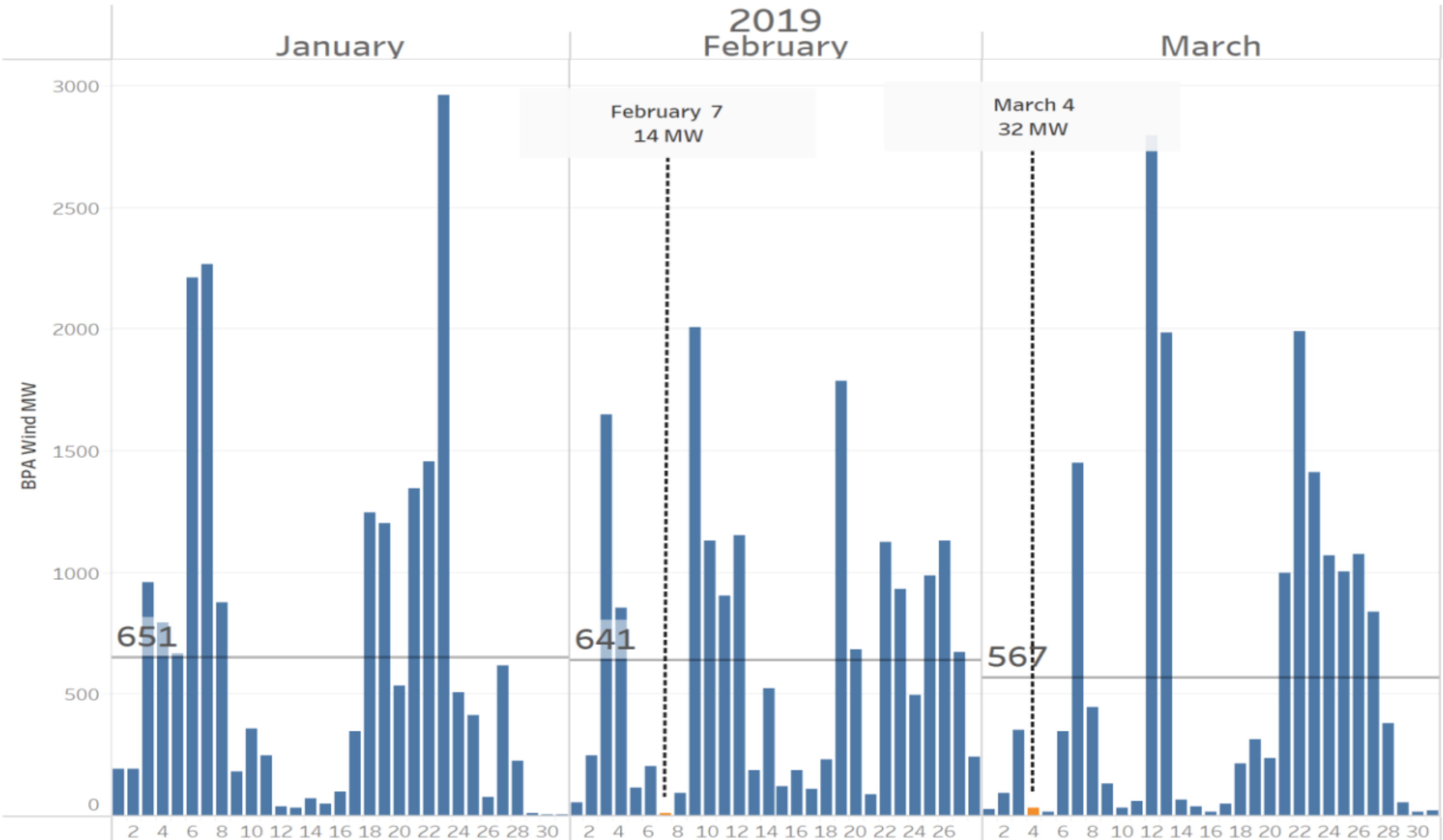
Feb 2019 Sumas Pipeline Constraints Reduce Gas Available for Electricity Generation

Figure 37: Natural Gas Constraints in the Electricity Market, February 2019



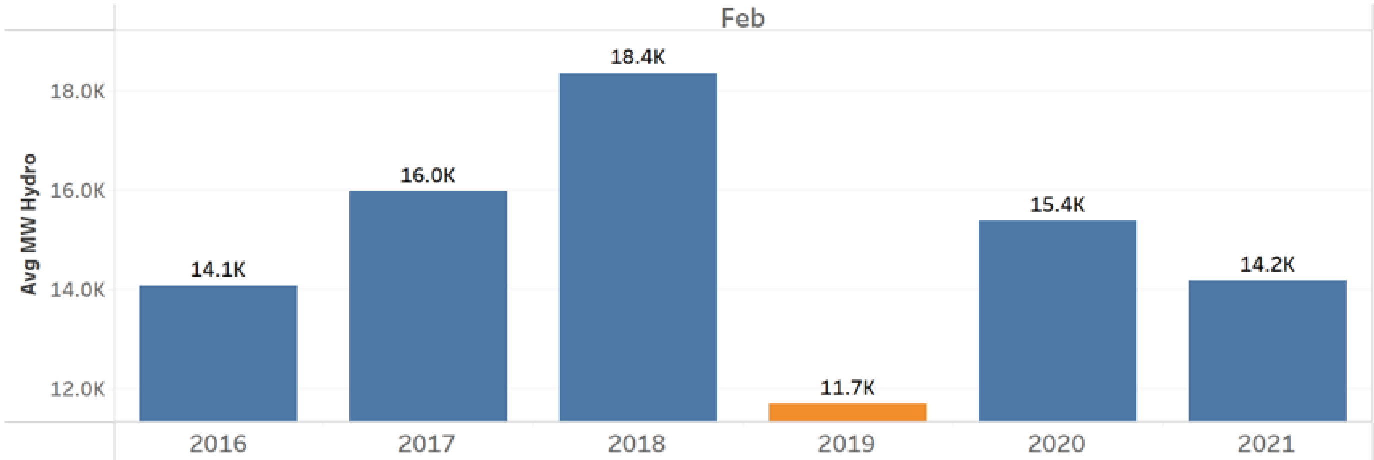
Performance of BPA Wind During Winter Cold Spikes

Figure 4: BPA Maximum Daily Wind Generation (MW)

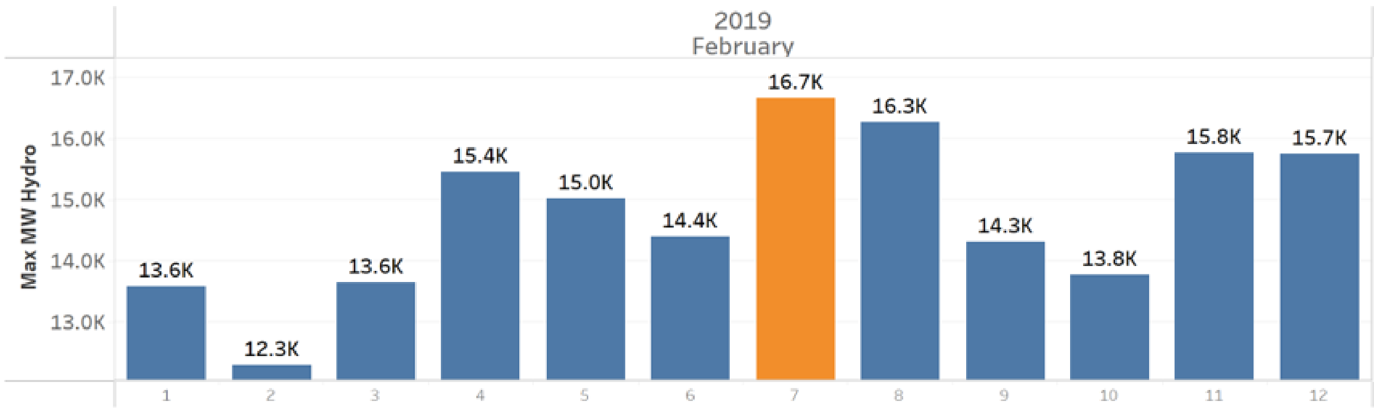


Feb 2019 Scarcity Event
Hydro System Ramps Up

Figure 67: Comparison of Average February Hydro Production to Max Production During Scarcity Event

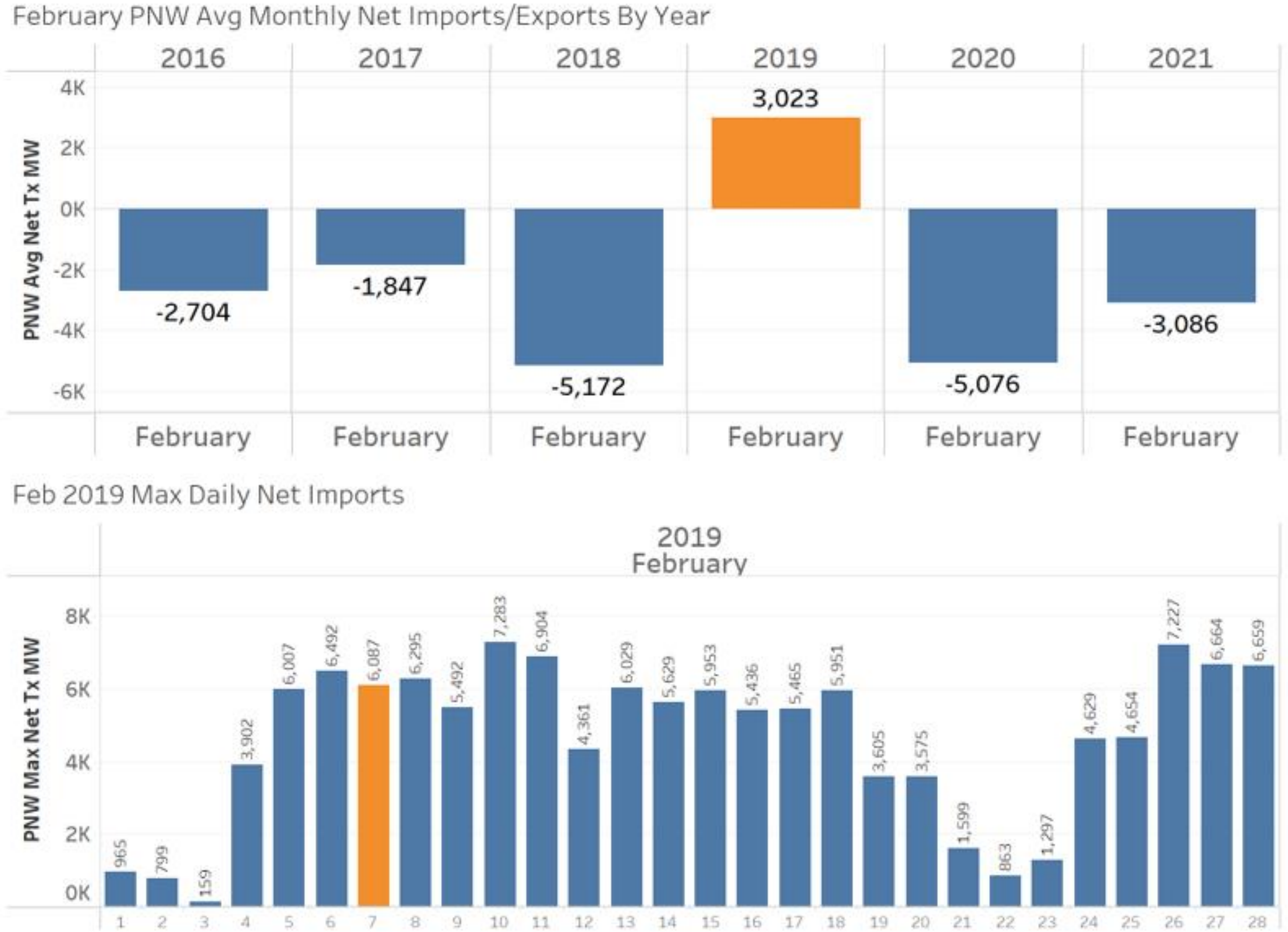


Feb 2019 WA Hydro



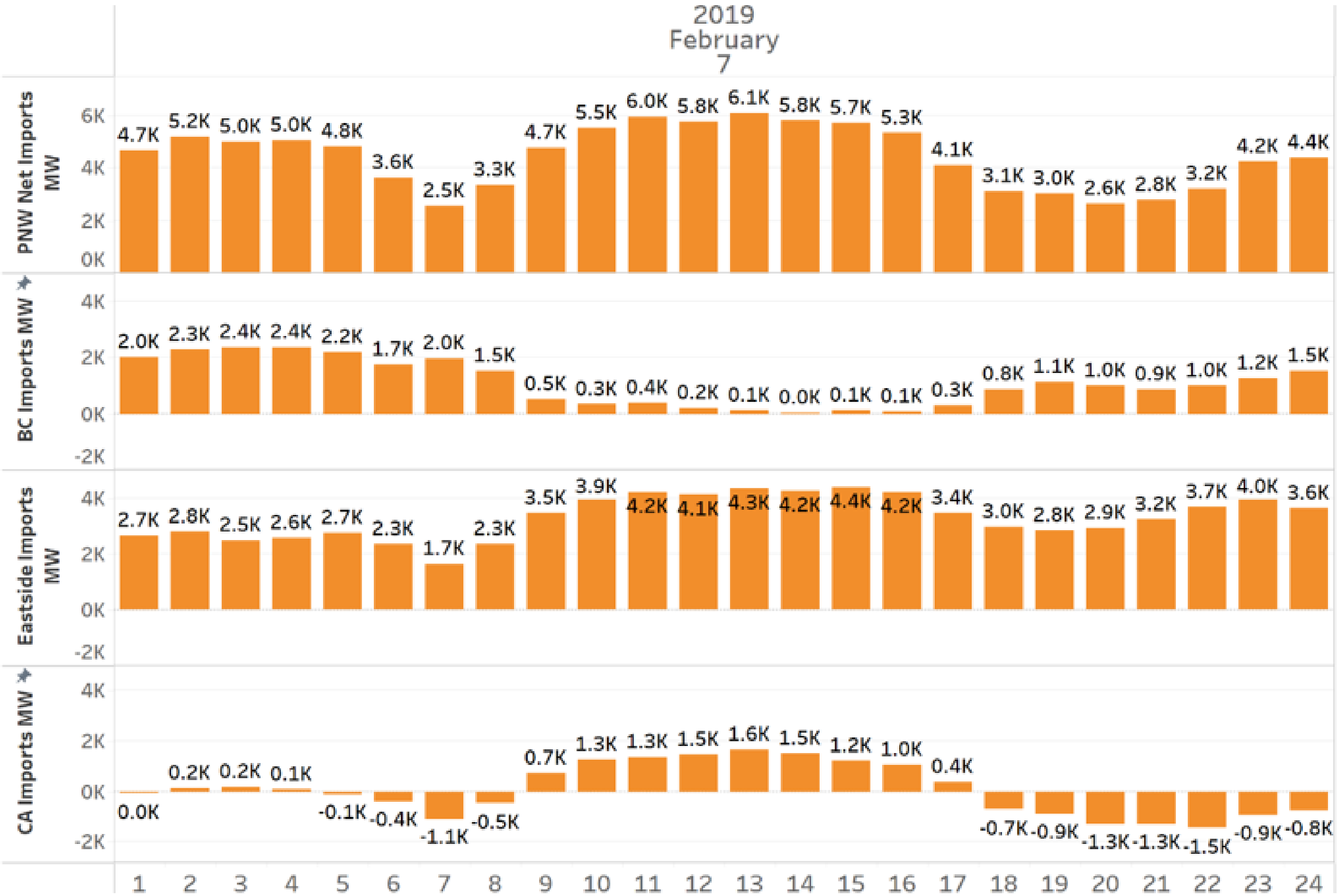
Feb 2019 Scarcity Event
Imports Ramp Up

Figure 68: PNW Net Transmission (MW) – Average by Month and Max by Day



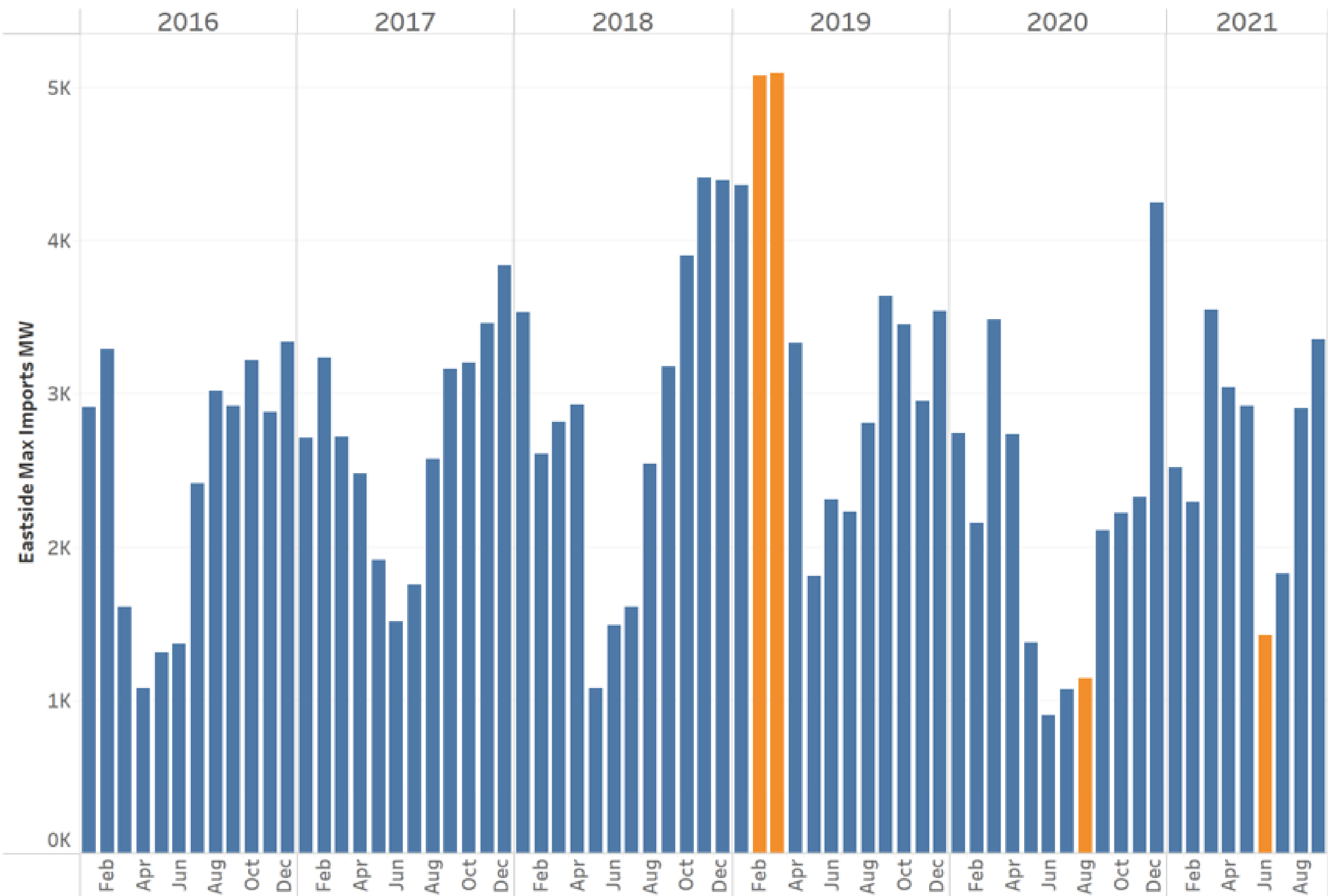
Feb 2019 Scarcity Event
Imports Ramp Up – East Side

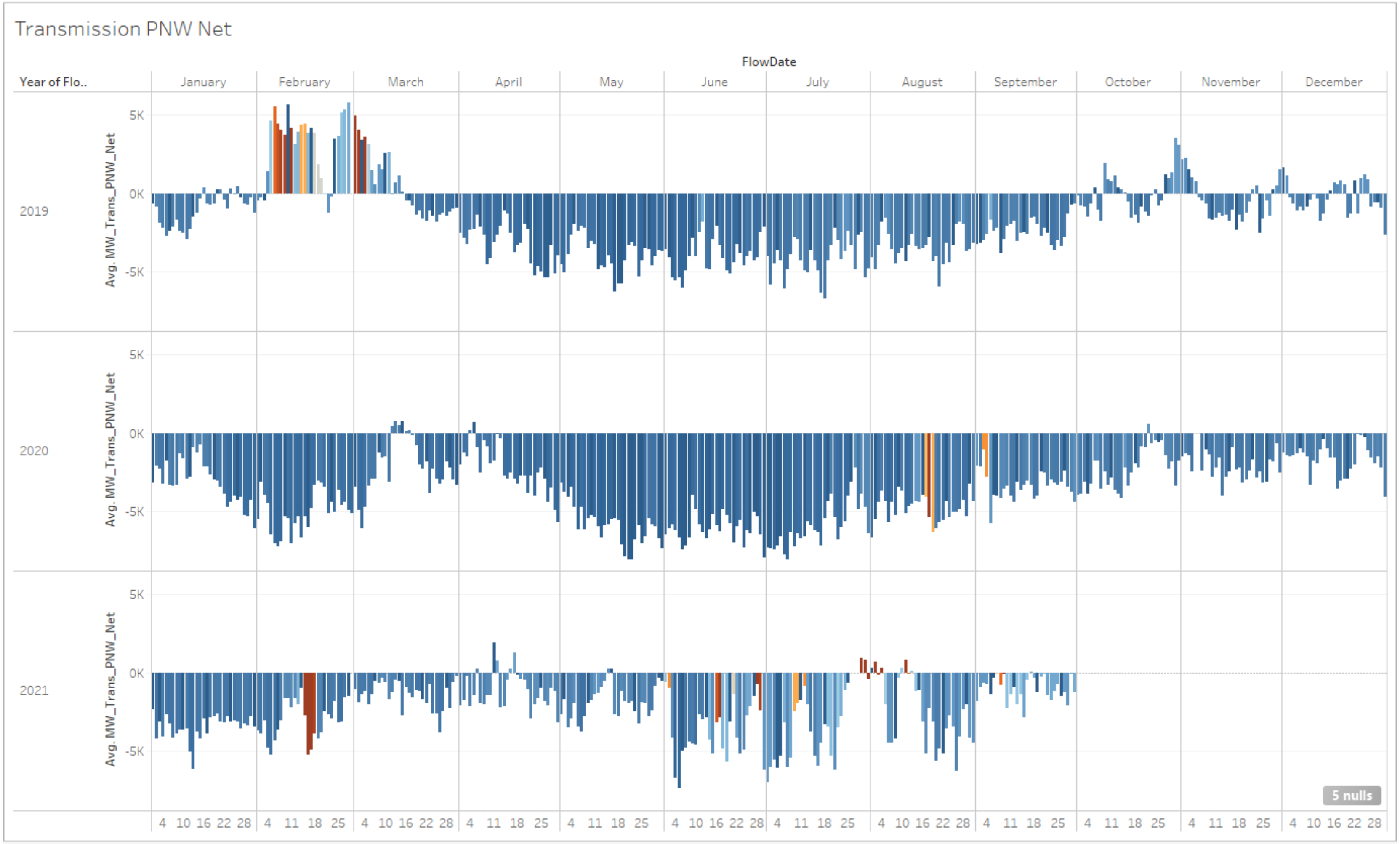
Figure 69: Hourly Imports by Region for February 7, 2019 (MW)



East Side Imports - History

Figure 70: Maximum Imports from East Side by Month, 2016 to 2021

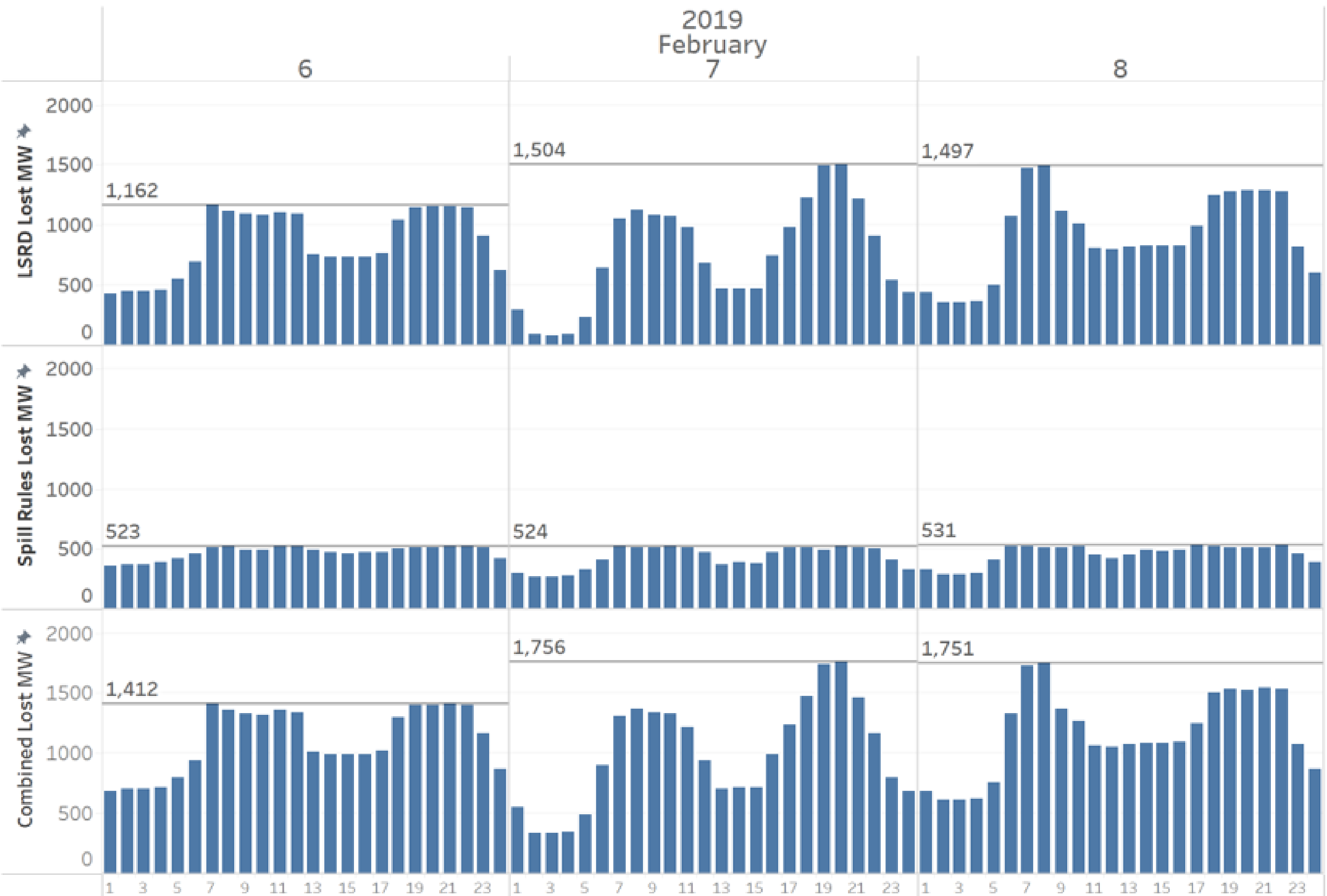




Transmission PNW Net
FlowDate
Year of Flo..
January
February
March
April
May
June
July
August
September
October
November
December
2019
2020
2021
Avg. MW_Trans_PNW_Net
5K
0K
-5K
5 nulls
4 10 16 22 28 4 11 18 25 4 10 16 22 28 4 11 18 25 4 11 18 25 4 10 16 22 28 4 11 18 25 4 10 16 22 28 4 11 18 25 4 11 18 25 4 11 18 25 4 10 16 22 28

Spill and Dam Removal Lost Hydro During Feb 2019

Figure 72: Lost Hydro Generation from New Spill Rules and Removal of LSRD (February 2019)



Feb 2019 Punchline

8.3.7 Case Study 1 Conclusion

In summary, high demand during the critical days in February 2019 happened during a month with relatively low hydro production. Natural gas plants in Washington were not able to produce at maximum output because reduced flows on the Sumas pipeline limited the supply of natural gas, and that limited supply was required to meet heating demand. Other thermal resources in Oregon and Washington enjoyed strong performance, but these resources are limited in total capacity. (Further, with the coal retirements that have happened already coupled with the retirment of Centralia in a few years, this thermal stack in the PNW will be that much thinner.) Wind provided virtually no supply on these critical days.

But for the flexibility of the hydro system and unprecendented imports from other regions, it is not clear how the PNW would have balanced supply and demand. Removal of the LSRD and increased spill obligations would have removed about 1,700 MW of supply from the region. With all other sources of supply maxed out (and declining in the future), it is not clear how the system would have balanced without this 1,700 MW of hydro supply.

Table 2: Summary of Scarcity Event Case Study Analysis

	Case 1 Feb 2019	Case 2 Mar 2019	Case 3 Jun 2021	PJM Polar Vortex Jan 2014	CAISO Blackouts Aug 2020	Texas Blackouts Feb 2021
Trigger	Cold snap	Cold snap	Heat dome	Cold snap	Heat	Winter storm Uri
Mid-C Price	$138	$890	$334	n/a	$51	n/a
PNW Demand	29,500 MW	27,300 MW	28,400 MW	n/a	24,700 MW	n/a
Baseload (Coal and Nuclear)	Performed well	Performed well	Still some outages	Generator outages	Nuclear performed well.	Under-performed
Natural Gas	4,600 MW Limited: supply competed with heating needs	3,400 MW Limited: supply competed with heating needs	4,200 MW Limited: generator outages	Generator outages and supply issues	Under-performed	Failures throughout the natural gas supply and generation systems
Imports	+6,000 MW. Record import level.	+4,500 MW.	+1,600 MW.	Under-delivered	PNW Exported Under-delivered: transmission de-rated	n/a: few interconnections to Texas grid
Renewables	Extreme low wind event	Extreme low wind event	Low wind event	n/a	Under-performed	Underperformed
Hydro Max	16,700 MW	15,600 MW	17,100 MW	n/a	17,082	n/a
Hydro Daily Flex	7,200 MW	5,900 MW	3,200 MW	n/a	6,600 MW	n/a
Proposed Policy: Lost Hydro Capacity	-1,700 MW (combined)	-1,778 MW (combined)	-992 MW (combined)	n/a	-1,944 MW (combined)	n/a

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Unsolicited Quote from Energy GPS Staff Who Did Not Work on this Project

“Oh, and BTW, the west is teetering on a true blow up if the Pacific Northwest has a normal water year and heaven forbid a low one like 2021.”

2021 Flows at The Dalles

Columbia River - The Dalles Dam (TDAO3) [141057001 Observed Runoff]

	HB5 ID	OBS DATE	WY	CURR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Oct1-Oct1	Jan1-Oct1	Apr1-Oct1
RUNOFF	TDAO3	2021/10/01	2021	5038.6	5879.8	7775.2	8318.5	10488.7	8862.0	7739.1	8742.0	13231.2	12919.5	9073.3	7816.7	5038.6	105884.4	83911.0	56821.2
AVERAGE	TDAO3	2021/10/01	2021	6418.9	6981.4	7824.0	9598.5	10508.6	10007.1	11566.2	12547.5	16632.3	16319.2	11026.8	8402.7	6418.9	127833.1	103429.4	71347.4
PCT AVG	TDAO3	2021/10/01	2021	78.5	84.2	99.4	86.7	99.8	88.6	66.9	69.7	79.6	79.2	82.3	93.0	78.5	82.8	81.1	79.6

2001 Flows at The Dalles

141057001 169 COLUMBIA R AT THE DALLES (ADJ = UNREG)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
OBSD VOLUME	6590.	7384.	8500.	7719.	6737.	7150.	6739.	8230.	7685.	5270.	5902.	4850.
30 YR. AVG.	5283.	5437.	5797.	6044.	6435.	8708.	13346.	25963.	29584.	15819.	8477.	5722.
ADJ. VOLUME	4843.	3718.	3522.	3302.	2986.	4684.	6614.	17678.	13696.	9227.	5575.	3463.
PCT. AVG.	92.	68.	61.	55.	46.	54.	50.	68.	46.	58.	66.	61.
ACCUM. VOL.	4843.	8561.	12083.	15385.	18371.	23055.	29669.	47348.	61044.	70271.	75845.	79308.
ACC. AVGS.	5283.	10720.	16517.	22561.	28996.	37704.	51050.	77013.	106597.	122415.	130892.	136614.
PCT. AVG.	92.	80.	73.	68.	63.	61.	58.	61.	57.	57.	58.	58.
ACCUM. VOL.	0.	0.	0.	3302.	6288.	10972.	17586.	35265.	48961.	58187.	63762.	67225.
ACC. AVGS.	0.	0.	0.	6044.	12480.	21187.	34534.	60496.	90080.	105899.	114375.	120097.
PCT. AVG.	0.	0.	0.	55.	50.	52.	51.	58.	54.	55.	56.	56.
ACCUM. VOL.	0.	0.	0.	0.	0.	0.	6614.	24293.	37989.	47216.	52790.	56253.
ACC. AVGS.	0.	0.	0.	0.	0.	0.	13346.	39309.	68893.	84711.	93188.	98910.
PCT. AVG.	0.	0.	0.	0.	0.	0.	50.	62.	55.	56.	57.	57.

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