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REDACTED VERSION

Energy Imbalance Market Collaborative – Sub hourly Wind

Puget Sound Energy

Power Cost Only Rate Case, Docket UE-200980

PSE PUGET SOUND ENERGY

September 17, 2021

Agenda for today

Review approach | Historical data | Results | Hydro Assumption

- Review PSE's approach for shaping wind sub-hourly
- Discuss alternative approach using historical data
- Consider impact of historical sub-hourly wind shapes on portfolio costs and EIM benefit estimate
- Touch on hydro assumption required for sub-hourly model

PSE proposed interpolating between hourly data to determine sub-hourly wind inputs for modeling

Review approach | Historical data | Results | Hydro Assumption

- Start with hourly wind availability at each PSE-owned resource used in 2020 PCORC based on forecasts from Vaisala
- Sub-hourly wind availability determined by interpolating between hourly values
  - On average, sub-hourly outcomes are identical to hourly values used to establish base schedules
- Underlying assumption that, on average, wind availability ramps up and down smoothly between hours
- Suggestion made in previous workshop to consider using historical generation as an alternative to sub-hourly interpolation

PSE tested use of historical sub-hourly wind data

Review approach | Historical data | Results | Hydro Assumption

1. Historical five-minute wind data from Hopkins Ridge, Wild Horse, and Lower Snake River were gathered for 2015-2018
2. Data was averaged for each fifteen minute Month-Hour-Interval for each project
   - E.g. January – Hour Ending 1 – Minutes 0-15
3. New data set was tested against a smoothed historical sub-hourly shape to determine historical shaping factor for each Month-Hour-Interval
   - For non-PSE-owned wind resources, shaping factors from three PSE-owned resources were averaged
4. Historical shaping factors were applied to interpolated sub-hourly wind forecast shape and input into Aurora model
5. Aurora sub-hourly models were re-run, and results analyzed

PSE tested use of historical sub-hourly wind data

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Historical 2015-2018 five-minute wind data from PSE's resources

Historical generation

Historical Generation (MW)

Year	Month	Day	Hour	Minute	HR	WH	LSR
2017	1	1	0	0	132	188	331
2017	1	1	0	5	122	195	329
2017	1	1	0	10	115	199	327
2017	1	1	0	15	114	190	327
2017	1	1	0	20	119	186	326
2017	1	1	0	25	133	194	324
2017	1	1	0	30	128	196	325
2017	1	1	0	35	128	199	323
2017	1	1	0	40	125	203	326
2017	1	1	0	45	133	202	326
2017	1	1	0	50	137	199	327
2017	1	1	0	55	140	202	323
2017	1	1	1	0	140	203	328
2017	1	1	1	5	139	201	332
2017	1	1	1	10	139	191	332
2017	1	1	1	15	140	182	330
2017	1	1	1	20	139	179	330
2017	1	1	1	25	140	172	329
2017	1	1	1	30	139	176	330
2017	1	1	1	35	140	180	322
2017	1	1	1	40	139	179	322
2017	1	1	1	45	140	163	319
2017	1	1	1	50	140	160	318
2017	1	1	1	55	139	157	321
2017	1	1	2	0	140	169	322
2017	1	1	2	5	139	171	321
2017	1	1	2	10	140	167	325
2017	1	1	2	15	140	168	329
2017	1	1	2	20	140	169	330
2017	1	1	2	25	139	172	331

Average historical data for each minute-hour-interval

Average historical generation

Average Historical Generation (MW)

Month	Hour	Minute	HR	WH	LSR
1	0	0	33	59	60
1	0	15	33	58	61
1	0	30	32	57	61
1	0	45	32	58	61
1	1	0	32	57	60
1	1	15	32	58	60
1	1	30	32	57	61
1	1	45	32	57	61
1	2	0	31	56	61
1	2	15	31	56	60
1	2	30	30	56	59
1	2	45	29	55	57
1	3	0	29	55	56
1	3	15	28	56	54
1	3	30	27	54	52
1	3	45	27	54	51
1	4	0	28	54	50
1	4	15	28	54	54
1	4	30	29	54	56
1	4	45	29	54	59
1	5	0	31	55	62
1	5	15	33	57	61
1	5	30	33	57	60
1	5	45	32	55	60
1	6	0	32	55	60

Determine shaping factor as percentage of smoothed data

Sub-hourly shaping factor

Shaping factor for interpolated results

Month	Hour	Minute	HR	WH	LSR
1	0	0	1.00	1.00	1.00
1	0	15	1.00	1.00	1.01
1	0	30	1.00	0.99	1.02
1	0	45	1.00	1.02	1.01
1	1	0	1.00	1.00	1.00
1	1	15	1.01	1.00	1.01
1	1	30	1.00	1.00	0.99
1	1	45	1.01	1.00	0.99
1	2	0	1.00	1.00	1.00
1	2	15	1.00	0.99	0.99
1	2	30	1.00	1.01	0.98
1	2	45	1.00	1.01	1.02
1	3	0	1.00	1.00	1.00
1	3	15	0.99	1.01	0.99
1	3	30	1.00	1.02	1.01
1	3	45	1.02	1.00	0.99
1	4	0	1.00	1.00	1.00
1	4	15	1.00	1.00	1.00
1	4	30	1.03	0.99	1.03
1	4	45	0.99	1.01	1.00
1	5	0	1.00	1.00	1.00
1	5	15	1.01	0.99	1.02
1	5	30	1.01	1.01	1.01
1	5	45	1.01	1.00	1.00

Apply shaping factors to sub-hourly forecasted wind shapes

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On average, historical sub-hourly wind shapes aligned closely with interpolation method

- 98% of average Month-Hour-Intervals (between 1st and 99th percentile) are within 0.95-1.05 of historical smoothed shape

Historical Shaping Factor	Hopkins Ridge	Wild Horse	Lower Snake River	Average
Maximum	1.23	1.23	1.26	**1.24**
99%	1.05	1.05	1.04	**1.03**
95%	1.03	1.02	1.02	**1.02**
Average	1.00	1.00	1.00	**1.00**
5%	0.97	0.98	0.98	**0.99**
1%	0.95	0.95	0.95	**0.96**
Minimum	0.69	0.75	0.66	**0.70**

Sub-hourly power prices are not materially impacted by using historical sub-hourly wind data

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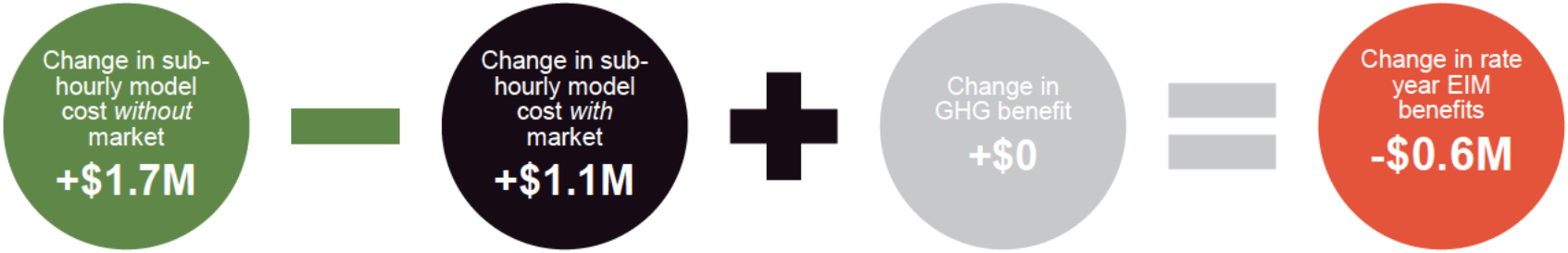
- Shaping sub-hourly wind inputs based on historical PSE-owned wind generation results in small increase to market power prices
  - $0.02/MWh increase annually driven by marginally increased variability in wind shapes

Estimated EIM benefits are not materially impacted by using historical sub-hourly wind data

Review approach | Historical data | Results | Hydro Assumption



- Historical sub-hourly wind shapes add small amount of variability to wind generation, which leads to small increase in total portfolio costs
- Overall impact is immaterial reduction to estimated EIM benefits

Sub-hourly modeling approach requires simplified hydro assumption

PSE and UTC Staff have discussed using median hydro as alternative to running each of 80 historical hydro years individually