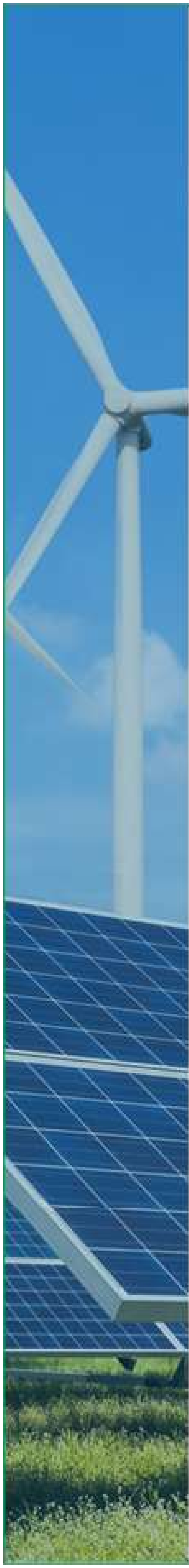


New York ISO
Independent System Operator

Appendix E: New York Renewable Profiles and Variability

2023-2042 System & Resource Outlook

A Report from the New York Independent System Operator

DRAFT for June 7, 2024, ESPWG

Appendix E: New York Renewable Production Profiles

Overview

The NYISO contracted with DNV to produce long-term hourly simulated weather and generation profiles for representative offshore wind (OSW), land-based wind (LBW), and utility-scale solar (UPV) generators. Information about these databases and their production methods were presented to and discussed with stakeholders.[1] DNV provided data for seven OSW locations and nearly 80 LBW and UPV locations throughout the state. The locations were aggregated to the county or zonal level to be put into a format consistent with the capacity expansion modeling framework for use in this Outlook. Capacity weighted aggregation of the site-level net capacity factor (NCF) shapes by technology type in each region was performed in each hour to determine the zonal or county aggregate NCF profiles that the NYISO used as inputs for this Outlook.[2] To align with the weather representation inherent in the demand forecasts used in this Outlook, the renewable generation profiles from 2018 were leveraged from the 20-plus-year database to represent the production from renewable generators in every year of the 20-year study.

Renewable Technologies

While most of the renewable energy generation in the state today is produced by hydroelectric generators, the expected growth of LBW, OSW, and solar—both UPV and behind the meter (BTM) PV—are key factors in achieving the requirements of the CLCPA. The production amounts of each type of generation are considered when determining the representative days selected for the capacity expansion model and are used as hourly generation shapes in the production cost model for this Outlook.

The NYISO acknowledges that advances in technology are continuously occurring and can lead to improved performance among generators built in the later years of the Study Period. Offsetting this effect, however, is that better sites may be utilized before less favorable resource sites leading to older technology on more favorable sites. Moreover, once installed, equipment performance can degrade over time. While these impacts are known, the exact magnitude of the impacts is hard to quantify. Accordingly, this Outlook does not make any assumptions about improved performance of renewable generators built in the later years of the Study Period or performance degradation of

[1] The Offshore Wind Profile Details & Methodology was shared and discussed at the February 7, 2023 ICAP/MIWG/PRLWG meeting, and the Solar and Land-Based Wind Profile Details & Methodology was shared by DNV and discussed at the November 21, 2024 ESPWG/TPAS meeting.

[2] Simulated hourly production profiles for renewable resources for years 2000 through 2022.

generators once in operation.

Data

For this Outlook, the NYISO is employing a multi-year database containing OSW, LBW, and UPV production profiles based on a single weather model run and resource projections. The NYISO contracted with DNV to produce retrospective databases spanning from 2000 to the present of hourly generation output, represented as net capacity factors (NCF), for hypothetical projects sited throughout the state and in the New York Bight on the Outer Continental Shelf.[3] The full suite of site-level shapes across the OSW, LBW, and UPV database were derived from a single weather model run, and the production values in the simulated database are representative of actual historical weather conditions. The increasing weather dependent supply resources and electrified load will necessitate more attention be paid to spatiotemporally correlated renewable generation and loads are models in long-term planning studies.

Offshore Wind Generation Profiles

The OSW database was developed as part of the ICAP market process to provide estimates for OSW capacity values.[4] Hourly NCF values from 2000 to 2021 were provided for seven locations representative of awarded and anticipated lease areas for OSW development by the Bureau of Ocean Energy Management.[5]

Land-Based Wind and Utility PV Generation Profiles

DNV developed LBW and UPV profiles for approximately 160 sites throughout New York that included existing and expected project sites and other locations to capture potential resource variations throughout the state.[6] The database provides hourly NCF values from 2000 to 2022 for each LBW and UPV site under various assumptions about the performance and technology of the individual projects modeled.

Benefits of New Data

With a new catalog of correlated LBW, OSW, and UPV profiles now available for use in the NYISO's planning and other studies, better characterization of the impacts of electrification and renewable energy integration is possible as large structural system changes make the grid more

[3] These profiles can be used to not only simulate production from potential hypothetical projects in the NYISO's long-term planning studies but also for the addition firm resources that will be included in the planning database.

[4] https://www.nyiso.com/documents/20142/36079056/4%2023_02_07_ICAPWG_OffshoreWindProfileDevelopment.pdf

[5] https://www.nyiso.com/documents/20142/36079056/4%20NYISO_OffshoreWind_Hourly_NetCapacityFactor.xlsx/

[6] https://www.nyiso.com/documents/20142/41314645/06_10430908%20DNV%20LBW%20and%20Solar%20Presentation%20for%20NYISO.pdf

weather dependent. Correlating the renewable profiles with load for the same weather year leads to improved representation of potential renewable generation production relative to the expected system demand. In addition, a large catalog of smaller site-level shapes allows for more accurate representation in nodal models where differences in renewable resource production across each of the individual sites will be aggregated to develop representations for larger regions (*e.g.*, county or zone). More granular representation in nodal models will reduce the potential of overestimating the inter-hourly ramps that may become a key constraint in high renewable energy systems.

Renewable Resource Characterization

Resource production profiles can be characterized in various ways to describe interannual variability in, for example, resource output, hourly ramps, variability, and duration of low output. In order to understand the consequences of selecting a single weather year for modeling all future years' system operations and renewable profiles, the NYISO performed a comparison of 2018 statistics to those across the 20-plus-year period.

Based on the granular site-level DNV data, the NYISO developed hourly zonal NCF profiles for integration into the capacity expansion model to represent the output of candidate generators. The NYISO used aggregated zonal profiles to represent OSW, LBW, and UPV generators in the capacity expansion model and site-level and aggregated county-level profiles for existing and new renewable resources modeled in the production cost model, respectively.

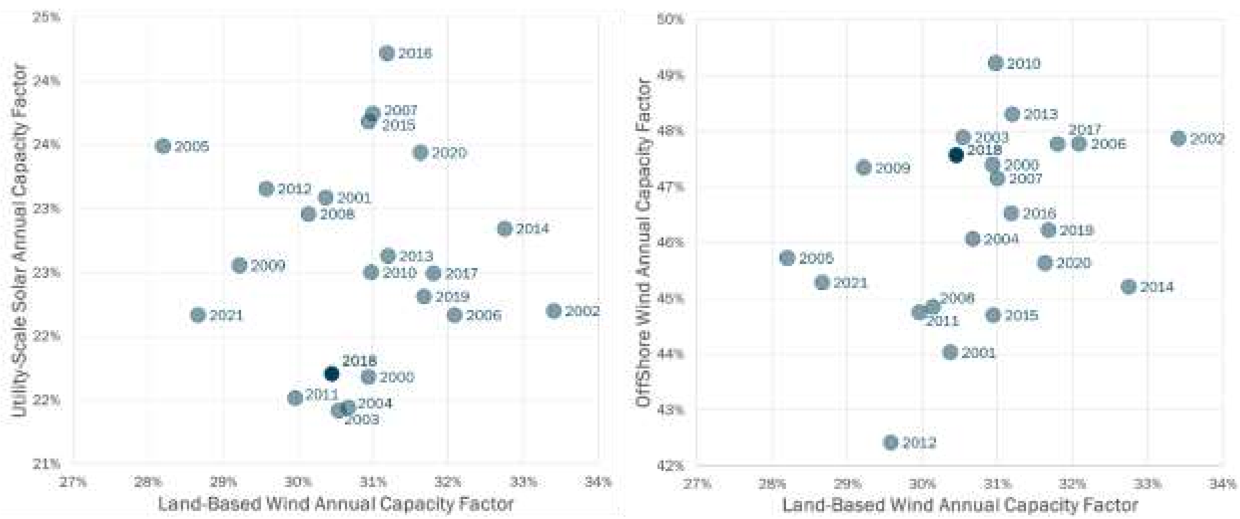
The aggregate zonal NCF profiles and the UPV, LBW, and OSW zonal capacities in several cases were used to model the input renewable generation seen by the model for use in this Outlook. Each technology was aggregated to the NYCA level. However, instead of only reviewing 2018, all years (e.g., 2000-2021) are included in the comparison. In addition, the modeled load shape is used in each case in order to examine details of net load (for purposes of this calculation, net load = load – UPV – LBW – OSW) assuming different weather but the same load shape.

Cases from the study examined in this fashion include the 2030 Contract Case and 2035 Lower and Higher Demand scenarios in the Policy Case. In addition, the NYISO used a baseline case with the actual 2018 load and zonal capacity mix as input to the methodology utilized in the analysis performed for this appendix.

Metrics for Characterizing Renewable Production

Given the variability of the wind and solar resources, characterization of their respective output over the hours and seasons of a single- or multi-year period is challenging. At a macro level, understanding the variation in production over the years by comparing the annual capacity factors by technology type provides an initial indication of the energy impact of the choice of 2018 relative to other years in the DNV database. Relative to the 2000-2021 DNV database, 2018 had low UPV production, slightly below average LBW production, and above average OSW output, as shown below. In addition, LBW and OSW production are more correlated than the LBW and UPV production, as is expected.

Figure xx: Annual Capacity Factor of UPV, LBW, and OSW: 2030 Contract Case

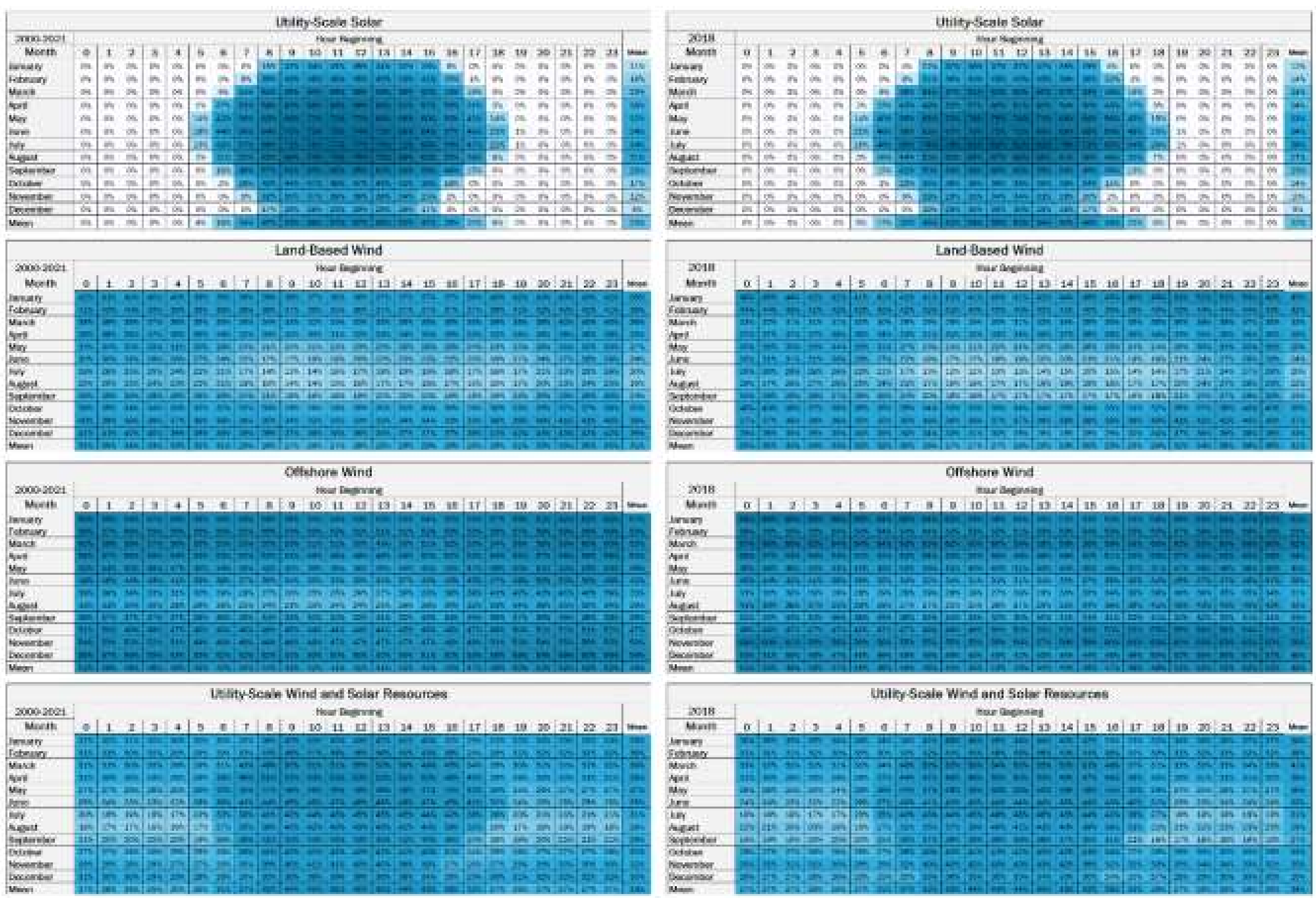


Renewable production profiles can be characterized on a more granular level by examining statistics within individual month and hour bins. Commonly referred to as "twelve by twenty-fours" (12x24), this calculation allows the diurnal and seasonal contributions of different renewable generation types to be accessed from the hourly timeseries. Further comparison of the net load provides insight on when and how much other supply resources are needed across the year and when there is a potential for renewable oversupply (i.e., negative net loads).

The graphics below present the hourly and monthly average NCF by technology type and present the NCF of the capacity weighted aggregation of UPV, LBW, and OSW. The figures on the left hand of the page show the averages over the 22-year period (2000-2021), while the right-hand figures display the averages based on only the 2018 shapes.

A number of salient features of the input data can be observed using this methodology. The concentration of solar generation in the summer and mid-day hours is clearly observed, as well as comparably lower solar generation in the winter months due to shorter daytime periods. In the shoulder months, solar production is slightly higher in the spring relative to the fall. On the other hand, production of both LBW and OSW is concentrated on average to the winter evening hours, with this impact more pronounced for OSW than LBW. Across the board, OSW produces at higher NCF levels than LBW. The combined impact of the wind and solar display clear features of each of the technologies with the highest overall renewable production during the summer mid-day. The lowest production persists during the evening hours in the summer and early fall with fleet capacity factors under 20% on average. Comparison of the 22-year average results to those for 2018 show that the general behavior of these resources is relatively consistent from year to year.

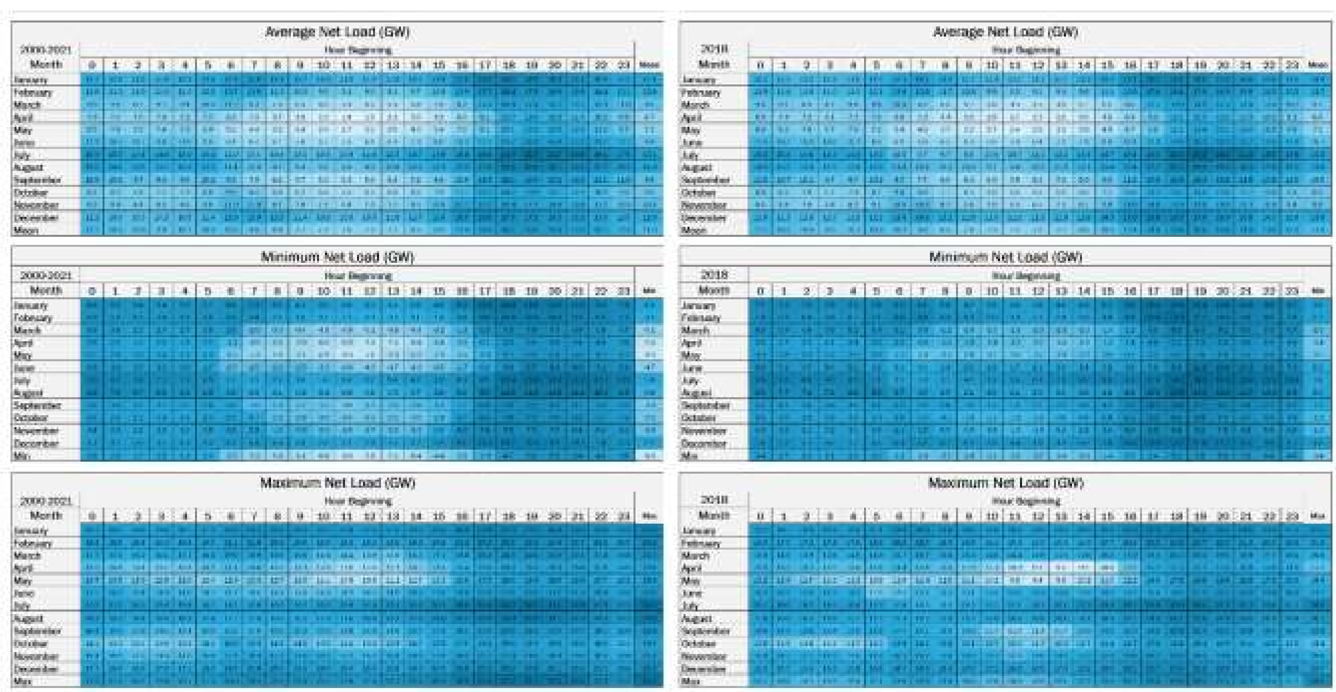
Figure xx: "12x24" Average Net Capacity Factors for UPV, LBW, OSW, and Combined: 2030 Contract Case



Renewable energy supply is better characterized from a timing perspective. By comparing renewable energy supply to the timing of the expected load, the remaining supply resources needed to serve demand (e.g., hydro, nuclear, imports, fossil fuel-fired and other generation, storage, and DEFRs) can be better understood. Using a similar framework to simplify the comparison, the figure below displays the variability in net load by displaying 12x24 charts for average, minimum, and maximum net load in GW. The left-hand figure displays net load over the 22-year period (assuming the same load in each year but varying the renewable energy shapes). The right-hand figure shows net load for only the 2018 renewable data.

Average net loads are highest in the summer and winter evening hours after sunset. This indicates the need for additional supply beyond the assumed wind and solar resources to meet expected demand. Net loads are lowest during the mid-day spring and fall months when loads are lower and renewable energy production is generally high. The minimum net loads, which may be negative, provide an indication of the minimum generation levels needed from the remaining fleet when loads are lowest and renewable output is high. Negative net loads indicate intervals where the renewable energy supplied by wind and solar resources exceeds the demand on the NYCA and coincides with times of low average net load during the shoulder mid-day periods, primarily due to the concentration of solar output. Storage resources would potentially be able to shift a significant amount of this excess mid-day renewable output during the day or across a few days. However, storage resources may not be fully capable of economically addressing the seasonal mismatch between times of low and negative net loads in the shoulder seasons and high positive net loads during peak season after the sun goes down. This impact is only exacerbated as weather-dependent electrified load (e.g., building heating) increases the potential peak load sensitivity of the system during temperature or weather extremes. This results in the requirement for even further supply resources to meet the larger net load peak without significant efforts to mitigate the potential peak load growth impacts.

Figure xx: "12x24" Average, Minimum, and Maximum Net Loads (GW): 2030 Contract Case



An additional feature of the variability of wind and solar output and their relation to load relates to the ramping requirements presented to the remaining (dispatchable) fleet to serve hour to hour changes in net load. Because each renewable generation type has a different hourly profile, they also have different levels of changes of output during different hours across the year. Some may help mitigate hourly changes in load, while others can exacerbate the impact of changes in load creating even larger ramp demands upon the fleet of dispatchable generators.

The following figures compute the average and maximum (extreme) ramp for each renewable technology, the combination of renewable technologies, load, and net load for each hour and month bin over the 22-years of renewable profile data. The ramps are presented for all the renewable profiles and are the negative of the actual production ramps to directly compare their impact to the resultant net load ramps. As shown earlier for the relative timing of net load, several important features are observed from visualizing the separate up and down ramp statistics in this fashion. Displayed here are the capacity mix and hourly loads from the 2030 Contract Case.

Overall, the coherence of the UPV results in significant contribution to upward ramp in the late evening as the sun is setting and downward ramp in the early morning as the sun rises. The timing of the average and extreme ramps changes throughout the course of the year as the days become longer and shorter. The average and extreme ramps for LBW and OSW are more evenly distributed due to the more random nature of the variations in the winds and generally smaller due to the lower geographic and temporal correlation of the wind shapes than the solar shapes. When combined, the renewable energy production contains characteristics of each of LBW, OSW, and UPV; however, the ramps are dominated by the UPV ramp impact.

Changes in load on the other hand are largely driven by the behavior of the many end users of the electricity system. In general, the largest upward ramp intervals occur in the early morning hours of the winter months and the early afternoon hours across the year. The largest downward ramp intervals occur overnight throughout the year and in the mid-morning hours during the winter months.

Figure xx: Contribution to Average Net Load Ramp Binned by Month and Hour: 2030 Contract Case

Average Upramp and Downramp (MW/hr)

Utility-Scale Solar

2000-2021 Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Mean
January	0	0	0	0	0	0	0	0	1	51	91	65	164	253	328	1,841	539	0	0	0	0	0	0	0	139
February	0	0	0	0	0	0	0	0	22	36	141	167	140	281	273	1,347	1,951	120	0	0	0	0	0	0	187
March	0	0	0	0	0	0	0	0	32	32	196	185	145	308	368	775	2,409	1,233	1	0	0	0	0	0	237
April	0	0	0	0	0	0	0	14	33	41	67	126	250	376	408	594	1,620	2,303	293	0	0	0	0	0	255
May	0	0	0	0	0	0	1	14	22	42	80	158	286	339	480	642	1,002	2,265	1,192	4	0	0	0	0	272
June	0	0	0	0	0	0	2	8	23	50	70	118	227	287	454	607	912	1,929	1,872	107	0	0	0	0	278
July	0	0	0	0	0	0	1	7	20	46	56	121	229	319	453	653	967	2,114	1,809	66	0	0	0	0	286
August	0	0	0	0	0	0	0	3	21	37	66	114	255	384	447	668	1,366	2,550	734	0	0	0	0	0	277
September	0	0	0	0	0	0	0	4	41	58	119	116	228	336	385	848	2,565	1,273	9	0	0	0	0	0	249
October	0	0	0	0	0	0	0	1	59	90	152	94	214	312	328	1,788	1,470	31	0	0	0	0	0	0	189
November	0	0	0	0	0	0	0	0	35	78	106	97	220	241	781	1,940	171	0	0	0	0	0	0	0	153
December	0	0	0	0	0	0	0	0	2	52	82	66	181	217	773	1,421	21	0	0	0	0	0	0	0	117
Mean	0	0	0	0	0	0	0	4	26	51	102	119	212	305	457	1,093	1,243	1,157	496	15	0	0	0	0	220

Utility-Scale Solar

2000-2021 Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Mean
January	0	0	0	0	0	0	18	1,609	1,030	223	172	97	72	65	47	0	0	0	0	0	0	0	0	0	139
February	0	0	0	0	0	0	721	2,259	557	367	172	69	166	97	70	0	0	0	0	0	0	0	0	0	187
March	0	0	0	0	0	409	2,465	1,412	383	437	165	95	182	75	54	8	0	0	0	0	0	0	0	0	237
April	0	0	0	0	177	2,123	2,025	583	385	375	229	102	51	25	39	13	1	0	0	0	0	0	0	0	255
May	0	0	0	2	1,144	2,426	1,105	666	455	324	207	86	34	37	22	15	3	0	0	0	0	0	0	0	272
June	0	0	0	20	1,524	2,127	1,027	715	495	288	231	117	48	41	20	12	1	0	0	0	0	0	0	0	278
July	0	0	0	2	1,113	2,439	1,244	771	509	311	242	112	46	42	19	8	1	0	0	0	0	0	0	0	286
August	0	0	0	0	280	2,350	1,868	809	507	397	233	105	42	25	22	6	0	0	0	0	0	0	0	0	277
September	0	0	0	0	2	1,369	2,646	806	397	357	170	85	62	38	40	9	0	0	0	0	0	0	0	0	249
October	0	0	0	0	0	207	2,128	1,222	237	310	115	112	88	65	56	0	0	0	0	0	0	0	0	0	189
November	0	0	0	0	0	0	768	1,923	298	273	148	67	98	86	9	0	0	0	0	0	0	0	0	0	153
December	0	0	0	0	0	0	29	1,432	768	221	153	68	76	67	3	0	0	0	0	0	0	0	0	0	117
Mean	0	0	0	2	355	1,126	1,338	1,178	503	323	186	93	80	55	33	6	1	0	0	0	0	0	0	0	220

Land-Based Wind

2000-2021 Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Mean
January	50	57	53	46	58	45	46	31	60	64	58	41	26	31	40	49	48	12	15	25	35	65	52	60	44
February	52	57	54	50	51	41	47	42	67	59	46	35	24	26	41	48	62	20	22	25	41	63	56	59	45
March	56	63	55	55	55	40	55	63	64	49	31	22	14	17	26	40	70	41	37	26	40	51	61	58	45
April	49	53	54	51	66	56	95	93	56	34	24	16	15	18	25	37	83	73	43	24	26	39	52	50	47
May	35	50	58	58	76	89	146	136	52	25	18	11	10	12	20	35	79	80	29	14	14	23	35	40	48
June	35	55	47	46	61	94	149	123	38	16	11	9	8	13	18	42	81	73	22	8	10	21	32	38	44
July	37	54	53	47	67	73	148	120	36	10	6	7	6	12	14	39	70	54	13	3	8	15	22	39	40
August	37	38	39	46	65	45	122	136	57	23	9	6	5	10	14	40	71	45	8	3	8	20	24	40	38
September	42	43	39	47	60	32	82	156	90	39	20	15	12	14	24	45	73	27	9	6	10	32	37	45	42
October	49	57	44	51	59	29	41	96	82	44	28	21	22	19	37	56	80	27	16	14	24	46	50	49	43
November	46	59	52	57	65	44	41	57	78	65	42	28	30	24	40	46	60	19	20	28	33	51	52	50	45
December	42	57	48	50	60	46	45	36	65	61	44	36	36	30	43	34	49	16	24	34	34	60	55	54	44
Mean	44	53	50	50	62	53	85	91	62	41	28	20	17	19	28	42	69	41	22	18	23	40	44	48	44

Land-Based Wind

2000-2021 Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Mean
January	34	27	31	36	29	35	37	51	28	29	28	37	52	48	40	39	63	121	94	62	43	29	31	31	44
February	40	29	30	31	31	38	34	39	24	29	36	47	58	53	36	35	52	107	95	77	51	39	36	37	45
March	32	23	28	30	28	36	23	25	27	31	43	51	65	54	41	36	34	82	98	101	71	52	41	34	45
April	45	32	29	27	19	24	14	20	33	47	57	63	64	52	42	37	20	46	87	114	95	67	53	46	47
May	48	31	24	20	12	11	5	10	30	51	62	62	58	55	41	28	14	33	93	135	122	83	61	47	47
June	39	27	27	22	11	6	2	4	27	49	62	54	57	47	34	16	10	24	83	133	120	79	64	47	43
July	32	22	20	17	9	9	2	1	18	45	68	52	51	33	31	11	6	18	78	132	109	81	63	42	40
August	29	29	22	16	8	15	2	1	14	26	46	43	48	35	27	11	6	25	103	134	105	71	60	34	38
September	31	30	26	17	12	29	10	2	11	25	34	38	36	32	26	17	14	68	148	145	103	64	55	35	42
October	30	26	29	25	18	41	38	13	21	31	45	51	41	43	27	21	25	94	133	109	75	48	40	33	44
November	29	23	28	31	26	41	44	31	24	27	36	40	36	45	34	38	56	124	120	87	58	40	34	31	45
December	37	30	32	31	28	43	38	46	22	23	34	39	38	47	40	55	69	127	88	63	43	29	32	28	44
Mean	36	27	27	25	19	27	21	20	23	34	46	48	50	45	35	29	31	72	102	108	83	57	48	37	44

Offshore Wind

2000-2021 Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Mean
January	183	190	169	181	146	135	123	118	155	188	188	178	153	121	90	88	87	53	54	60	94	112	158	201	134
February	174	164	186	172	151	136	132	132	198	233	224	181	144	114	96	83	105	73	57	74	104	115	149	210	142
March	184	161	179	197	164	141	141	148	218	219	188	177	152	118	99	84	91	67	61	56	83	81	125	173	138
April	210	193	193	192	188	139	144	145	210	211	194	181	154	109	100	84	89	108	68	72	113	117	137	173	147
May	199	194	177	237	248	197	181	205	215	204	183	150	122	72	69	69	71	88	80	79	99	117	133	170	148
June	228	252	190	265	239	184	179	191	192	162	145	107	86	50	47	69	51	89	79	74	127	156	155	185	146
July	238	219	182	224	190	189	147	155	172	135	105	94	65	37	40	40	43	71	82	101	162	198	170	222	137
August	177	172	157	185	152	215	154	131	132	103	87	83	82	61	51	60	39	64	68	64	110	167	146	164	118
September	142	135	116	167	158	145	130	137	152	171	126	116	128	78	69	93	64	81	68	55	107	153	120	135	119
October	156	154	162	189	180	138	139	128	151	153	149	154	121	79	97	103	74	65	58	77	96	114	88	145	124
November	161	151	158	174	187	143	150	118	128	162	160	156	113	95	111	77	65	52	53	69	96	103	107	150	123
December	165	156	179	189	162	150	123	129	165	168	164	157	131	98	87	61	61	34	56	66	103	124	165	187	128
Mean	185	178	171	198	180	160	145	145	174	175	159	144	121	86	80	76	70	70	65	71	108	130	138	176	134

Offshore Wind

2000-2021 Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Mean
January	105	87	95	92	110	125	145	150	123	111	127	108	115	112	160	166	158	193	229	219	133	150	110	97	134
February	103	109	108	117	128	138	146	178	126	110	109	121	149	150	158	172	126	192	232	217	144	141	121	93	141
March	100	106	100	94	113	123	136	131	86	90	114	113	118	167	179	179	161	180	241	215	161	170	133	98	138
April	101	122	105	105	104	136	120	129	93	97	106	129	152	191	207	218	187	171	220	228	164	166	147	127	147
May	108	102	106	73	69	99	110	94	76	92	101	129	172	260	262	266	228	206	205	197	164	148	140	115	147
June	94	83	102	78	66	86	95	76	75	96	93	156	195	291	289	267	276	205	205	196	128	129	123	99	146
July	63	72	94	67	85	72	95	73	66	89	111	122	168	285	334	277	286	193	170	145	84	99	114	59	134
August	75	76	106	73	100	60	77	73	68	103	104	123	135	176	218	180	231	180	162	154	101	103	107	73	119
September	98	121	136	90	90	86	106	88	82	89	100	90	96	139	151	140	156	141	196	196	116	110	123	109	119
October	96	112	109	85	88	102	120	122	104	108	124	102	118	175	144	145	159	179	188	153	134	115	136	108	126
November	75	83	86	93	82	103	107	123	128	109	110	107	113	129	129	156	169	205	184	177	144	143	120	85	123
December	87	85	83	85	93	107	124	124	106	103	114	131	127	140	129	171	185	244	197	193	128	141	99	90	129
Mean	92	96	102	87	94	103	115	113	94	100	109	119	138	185	197	195	194	191	202	191	133	135	123	96	134

Utility-Scale Wind and Solar Resources

2000-2021 Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Mean
January	211	227	198	202	178	156	137	3	20	192	235	203	239	282	339	1,785	530	41	49	67	108	152	189	241	249
February	201	197	218	201	178	151	29	1	88	169	302	278	169	275	284	1,298	1,945	125	55	74	118	152	186	247	289
March	218	200	210	228	192	72	4	17	156	137	289	272	181	301	341	723	2,385	1,112	72	60	94	106	157	207	322
April	228	218	223	219	158	4	9	73	149	140	168	212	294	358	373	527	1,600	2,274	263	68	109	126	157	194	339
May	202	214	202	267	31	5	16	99	116	136	163	215	285	262	370	511	928	2,204	1,035	65	80	112	133	176	326
June	233	279	209	272	13	9	24	62	84	113	114	146	200	189	313	497	786	1,871	1,696	89	103	148	157	189	325
July	250	248	208	247	15	3	12	45	74	92	82	140	192	204	283	498	818	2,031	1,662	99	127	178	160	235	329
August	189	186	171	209	95	4	4	21	63	63	82	133	235	311	337	599	1,252	2,459	611	42	82	153	142	178	317
September	156	151	130	191	192	6	2	35	126	142	172	163	270	311	353	846	2,536	1,197	48	35	84	152	124	150	315
October	182	187	183	216	219	80	3	25	161	167	233	182	243	267	339	1,790	1,451	78	45	63	88	129	110	168	275
November	181	182	184	202	225	162	34	3	108	185	211	194	249	234	809	1,881	210	47	48	69	105	129	132	175	248
December	184	190	204	217	199	172	132	4	51	172	194	180	235	223	770	1,304	91	27	57	78	117	163	200	221	225
Mean	203	207	195	223	141	68	34	32	100	142	186	193	233	268	410	1,020	1,205	1,127	473	67	101	142	154	198	297

Utility-Scale Wind and Solar Resources

2000-2021 Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Mean
January	117	95	102	105	113	137	169	1,663	985	253	224	162	134	103	128	12	76	289	304	262	156	154	121	108	249
February	119	115	116	126	135	150	751	2,302	509	347	207	133	234	153	138	28	4	211	302	269	168	153	137	107	288
March	110	106	103	100	115	459	2,432	1,375	338	395	196	147	235	153	122	47	11	33	312	294	204	195	145	107	322
April	114	126	110	109	204	2,092	1,929	552	361	372	274	183	142	124	129	79	15	7	168	315	230	204	169	144	340
May	124	103	98	67	932	2,255	907	513	389	333	253	174	130	191	126	75	21	11	33	299	253	204	166	128	324
June	103	83	101	80	1,314	1,950	818	534	428	318	274	238	179	217	136	75	29	9	11	231	214	179	157	112	325
July	69	70	87	60	965	2,261	1,058	608	439	347	335	204	157	196	160	62	32	4	6	205	151	146	146	74	327
August	79	80	104	67	266	2,169	1,674	635	442	426	304	201	119	92	91	26	13	5	67	262	170	140	138	81	319
September	101	124	137	84	77	1,314	2,553	635	334	346	211	128	96	92	91	25	4	24	307	315	186	141	145	114	316
October	103	114	114	87	85	263	2,109	1,157	230	328	189	179	134	141	104	9	12	228	291	233	177	133	148	115	278
November	79	78	88	94	81	119	762	1,905	318	290	197	127	132	132	48	12	139	305	278	236	178	158	127	90	249
December	101	92	92	95	99	127	155	1,440	714	238	206	160	128	133	39	14	214	348	262	235	151	150	112	99	225
Mean	101	99	104	89	367	1,112	1,278	1,103	458	333	239	170	151	144	109	39	48	123	194	263	186	163	143	107	297

Load

2000-2021 Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Mean
January	0	0	8	246	889	1,553	1,123	73	0	2	0	7	247	528	1,235	1,800	1,581	272	0	0	0	0	0	44	400
February	0	0	7	227	843	1,472	869	40	0	0	3	4	144	413	1,053	1,745	1,897	752	0	0	0	0	0	0	394
March	0	0	287	191	795	1,275	475	0	0	0	12	53	176	336	942	1,585	1,698	1,044	224	0	0	0	0	0	379
April	0	0	0	129	582	734	220	14	10	10	12	63	284	499	930	1,378	1,489	930	251	19	0	0	0	11	315
May	0	0	0	58	287	414	308	62	28	19	52	206	429	630	904	1,159	1,169	787	161	20	0	0	0	0	279
June	0	0	0	1	108	315	371	226	121	80	203	442	600	907	1,129	1,256	1,174	652	55	0	0	0	0	0	318
July	0	0	0	0	150	303	503	541	460	422	560	704	910	1,159	1,100	1,248	1,247	678	1	0	0	0	0	5	416
August	0	0	0	0	322	392	336	314	181	221	381	574	797	970	1,115	1,292	1,193	526	1	0	0	0	0	0	359
September	0	0	0	32	472	718	132	47	33	49	117	327	543	660	1,099	1,459	1,137	420	91	0	0	0	0	0	306
October	0	0	0	124	705	1,305	591	1	0	1	13	77	400	536	1,061	1,399	1,118	695	18	0	0	0	0	0	335
November	0	0	1	182	777	1,373	749	8	0	0	0	97	540	787	1,323	1,621	1,261	201	0	0	0	0	0	0	372
December	0	0	0	194	786	1,397	1,049	108	0	0	0	64	375	639	1,164	1,794	1,472	156	0	0	0	0	0	0	383
Mean	0	0	26	115	558	935	560	121	70	68	114	219	456	674	1,088	1,477	1,367	592	67	3	0	0	0	5	355

Load

2000-2021 Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Mean
January	630	353	123	0	0	0	0	45	589	625	492	154	1	0	0	0	0	0	395	679	931	1,433	1,517	1,634	400
February	610	353	126	0	0	0	0	235	631	581	472	228	4	0	0	0	0	0	337	711	996	1,409	1,412	1,393	396
March	609	815	0	1	0	0	29	520	692	549	431	224	41	6	0	0	0	0	0	445	918	1,270	1,340	1,307	383
April	672	403	197	19	3	32	109	377	524	462	290	88	44	2	0	0	0	0	0	79	787	1,159	1,270	1,037	315
May	732	459	246	37	54	112	53	114	240	307	150	18	1	0	0	0	0	0	0	67	532	1,142	1,295	1,077	277
June	909	641	362	115	139	153	31	12	81	171	68	2	3	0	0	0	0	0	47	402	391	1,161	1,486	1,373	314
July	1,087	792	505	178	115	166	13	3	10	22	6	1	0	0	0	0	0	0	333	897	834	1,698	1,654	1,641	415
August	998	711	438	110	33	103	52	30	93	57	1	0	0	0	0	0	0	0	404	464	917	1,344	1,478	1,510	364
September	759	537	295	53	1	3	99	247	311	201	121	24	0	0	0	0	0	0	12	435	881	1,161	1,265	990	308
October	652	419	209	16	0	0	5	411	554	397	279	18	0	0	0	0	0	0	52	641	932	1,191	1,260	976	334
November	277	712	182	0	0	0	0	380	687	529	339	23	0	0	0	0	0	0	447	732	953	1,227	1,271	1,129	370
December	689	399	164	0	0	0	0	38	497	488	298	69	5	0	0	0	0	4	453	745	1,028	1,391	1,453	1,423	381
Mean	720	551	238	44	29	48	33	200	408	364	244	70	8	1	0	0	0	0	207	525	841	1,299	1,392	1,292	355

Net Load

2000-2021 Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Mean
January	27	86	139	393	964	1,576	1,099	4	3	45	77	145	416	725	1,450	3,572	2,036	168	7	1	1	1	1	80	542
February	23	62	156	366	902	1,477	390	1	18	46	133	171	245	583	1,205	3,015	3,838	693	10	7	3	0	1	24	557
March	35	18	433	373	886	975	23	3	32	32	132	209	281	549	1,172	2,262	4,072	2,127	172	11	2	0	0	6	575
April	35	79	132	300	603	103	18	30	48	47	91	213	496	769	1,184	1,828	3,075	3,197	441	55	9	2	3	30	533
May	19	54	97	289	92	30	67	96	74	69	144	355	628	750	1,162	1,598	2,076	2,981	1,187	61	14	4	0	6	494
June	14	50	72	208	19	36	104	134	110	106	226	441	662	902	1,311	1,679	1,931	2,516	1,703	15	30	2	1	3	511
July	4	22	31	154	28	10	87	238	289	338	418	681	956	1,182	1,230	1,685	2,034	2,706	1,353	3	6	1	1	25	562
August	5	15	34	151	281	17	27	105	119	158	296	553	922	1,195	1,361	1,864	2,432	2,980	353	8	3	5	0	6	537
September	10	26	46	182	606	135	4	28	78	108	198	409	734	892	1,363	2,279	3,669	1,599	75	6	2	7	2	13	520
October	19	49	98	297	851	1,135	35	10	37	65	129	224	553	698	1,299	3,180	2,558	573	40	3	2	1	1	6	494
November	74	14	100	340	930	1,417	316	1	15	51	86	251	682	898	2,086	3,490	1,334	130	6	2	4	2	0	4	510
December	17	55	128	368	898	1,446	1,033	6	15	55	100	196	525	743	1,896	3,084	1,350	80	10	5	1	2	0	3	501
Mean	23	44	123	285	586	694	268	55	70	94	170	322	594	825	1,394	2,459	2,524	1,651	448	15	6	2	1	17	528

Net Load

2000-2021 Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Mean
January	563	306	158	50	10	4	7	1,636	1,556	729	558	250	65	18	3	0	2	143	656	876	980	1,435	1,450	1,538	541
February	551	332	174	65	16	4	243	2,497	1,070	804	508	249	170	48	5	0	0	28	594	913	1,049	1,410	1,364	1,277	557
March	537	739	39	54	15	87	2,005	1,881	906	839	459	255	200	71	11	1	0	4	188	690	1,030	1,360	1,328	1,214	580
April	593	390	215	80	68	1,490	1,827	872	774	731	476	210	104	37	10	2	0	0	94	363	916	1,239	1,286	1,006	533
May	672	402	239	68	760	1,978	704	563	558	554	332	125	45	49	14	2	0	1	23	342	719	1,238	1,328	1,036	490
June	794	495	326	130	1,351	1,814	557	392	414	402	251	92	44	23	5	1	1	1	11	558	531	1,194	1,487	1,300	507
July	910	635	415	145	942	2,131	643	263	205	193	117	43	10	15	8	0	0	1	29	1,007	864	1,667	1,641	1,500	558
August	893	620	405	118	162	1,893	1,413	434	410	356	138	47	10	5	1	0	0	1	212	692	1,009	1,336	1,474	1,419	544
September	714	535	349	97	20	728	2,521	827	564	464	240	71	17	13	2	0	0	6	254	721	986	1,157	1,289	968	523
October	592	395	239	60	12	13	1,554	1,553	660	623	351	162	43	36	3	0	0	28	320	814	1,022	1,195	1,299	929	496
November	249	623	185	50	9	2	295	2,275	912	685	411	110	25	9	1	0	2	187	683	901	1,029	1,257	1,267	1,048	509
December	624	355	179	52	11	4	7	1,373	1,175	609	410	181	48	14	1	0	1	249	668	907	1,063	1,380	1,364	1,304	499
Mean	642	486	244	81	282	850	983	1,206	766	581	353	149	65	28	5	1	1	54	310	732	933	1,323	1,382	1,212	528

Figure xx: Contribution to Extreme Net Load Ramp Binned by Month and Hour: 2030 Contract Case

Extreme Upramp and Downramp (MW/hr)

Utility-Scale Solar

2000-2021	Hour Beginning																								
Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Max
January	0	0	0	0	0	0	0	0	103	773	710	729	1,076	1,248	1,645	4,177	2,300	0	0	0	0	0	0	0	4,177
February	0	0	0	0	0	0	0	0	831	781	1,243	1,420	1,124	1,607	1,707	3,834	4,936	920	0	0	0	0	0	0	4,936
March	0	0	0	0	0	0	0	133	1,430	954	1,740	1,464	1,575	1,814	2,358	2,839	5,439	3,929	20	0	0	0	0	0	5,439
April	0	0	0	0	0	0	0	635	1,191	1,101	1,958	1,248	1,987	1,742	2,225	2,758	4,297	5,268	1,496	0	0	0	0	0	5,268
May	0	0	0	0	0	0	281	1,039	1,012	1,016	1,479	1,293	1,792	1,931	2,057	2,182	3,242	5,204	3,464	44	0	0	0	0	5,204
June	0	0	0	0	0	0	490	764	958	1,020	997	1,610	1,747	1,727	2,512	2,213	2,529	3,906	4,108	403	0	0	0	0	4,108
July	0	0	0	0	0	0	269	933	1,334	1,375	1,280	1,214	2,121	1,578	2,267	2,333	2,558	4,293	3,978	332	0	0	0	0	4,293
August	0	0	0	0	0	0	0	510	775	1,010	775	1,149	1,446	1,834	1,856	2,591	3,604	4,862	2,737	3	0	0	0	0	4,862
September	0	0	0	0	0	0	0	709	1,191	1,172	1,225	1,127	1,947	1,977	1,836	3,223	5,244	4,369	190	0	0	0	0	0	5,244
October	0	0	0	0	0	0	0	227	1,056	1,187	1,167	1,041	1,199	1,503	1,989	4,921	4,767	417	0	0	0	0	0	0	4,921
November	0	0	0	0	0	0	0	0	855	863	841	810	1,187	1,359	2,492	5,007	1,143	0	0	0	0	0	0	0	5,007
December	0	0	0	0	0	0	0	0	184	708	943	865	896	2,322	2,440	3,419	116	0	0	0	0	0	0	0	3,419
Max	0	0	0	0	0	0	490	1,039	1,430	1,375	1,958	1,610	2,121	2,322	2,512	5,007	5,439	5,268	4,108	403	0	0	0	0	5,439

Utility-Scale Solar

2000-2021	Hour Beginning																								
Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Max
January	0	0	0	0	0	0	175	4,146	2,595	1,156	1,087	942	755	948	801	0	0	0	0	0	0	0	0	0	4,146
February	0	0	0	0	0	0	2,994	5,202	2,437	1,758	1,544	907	1,658	1,244	1,030	233	0	0	0	0	0	0	0	0	5,202
March	0	0	0	0	0	2,381	5,850	4,647	2,477	1,751	1,645	1,446	1,631	1,290	1,222	595	0	0	0	0	0	0	0	0	5,850
April	0	0	0	0	1,409	5,402	5,225	2,366	2,272	1,608	1,588	1,142	1,132	637	982	897	421	0	0	0	0	0	0	0	5,402
May	0	0	0	24	3,189	5,358	2,904	2,779	2,280	1,899	1,508	1,337	864	928	823	1,033	1,097	0	0	0	0	0	0	0	5,358
June	0	0	0	59	3,627	4,512	2,777	2,818	2,064	1,864	1,584	1,359	961	872	1,163	701	338	0	0	0	0	0	0	0	4,512
July	0	0	0	16	3,204	4,946	2,978	2,387	2,136	1,630	2,068	2,562	1,181	1,392	854	499	336	0	0	0	0	0	0	0	4,946
August	0	0	0	0	1,277	4,869	4,046	2,561	2,016	2,166	1,344	1,017	885	929	692	404	101	0	0	0	0	0	0	0	4,869
September	0	0	0	0	26	3,825	5,392	1,982	1,891	1,665	1,342	1,204	1,129	675	1,106	799	0	0	0	0	0	0	0	0	5,392
October	0	0	0	0	0	1,364	5,220	3,891	1,403	1,504	1,114	1,251	930	869	1,066	20	0	0	0	0	0	0	0	0	5,220
November	0	0	0	0	0	0	2,952	4,675	1,428	1,479	1,092	896	969	948	740	0	0	0	0	0	0	0	0	0	4,675
December	0	0	0	0	0	0	280	3,846	2,455	919	1,026	543	784	921	261	0	0	0	0	0	0	0	0	0	3,846
Max	0	0	0	59	3,627	5,402	5,850	5,202	2,595	2,166	2,068	2,562	1,658	1,392	1,222	1,033	1,097	0	0	0	0	0	0	0	5,850

Land-Based Wind

2000-2021	Hour Beginning																								
Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Max
January	510	385	424	380	445	392	552	415	409	445	501	507	405	457	373	377	425	294	252	288	375	427	348	362	552
February	404	392	387	362	420	323	380	434	526	455	399	448	390	404	506	443	483	334	308	298	378	423	435	410	526
March	498	417	439	469	376	451	376	541	507	434	363	433	377	316	407	424	562	466	411	458	429	413	459	446	562
April	497	494	504	346	484	391	489	589	517	323	349	474	382	304	288	397	511	470	582	432	450	514	418	412	589
May	602	489	410	402	381	457	584	554	356	302	250	279	337	433	526	448	591	560	549	354	340	323	353	455	602
June	429	367	389	503	414	377	633	590	299	286	259	296	285	305	304	368	523	582	368	220	457	477	370	352	633
July	305	347	377	390	382	383	521	444	299	324	311	200	252	168	227	320	475	448	300	147	219	299	272	407	521
August	439	406	293	303	362	313	439	452	322	275	191	161	181	236	258	365	497	360	258	229	258	241	390	425	497
September	492	408	411	527	520	433	403	571	474	436	327	318	240	234	326	348	587	435	346	327	326	405	342	489	587
October	369	401	317	363	355	259	325	461	480	351	449	429	316	269	505	421	603	409	316	324	272	380	524	494	603
November	400	326	360	342	403	429	451	461	453	448	468	405	418	458	504	451	636	453	472	476	468	418	618	351	636
December	352	376	341	347	451	387	412	317	382	473	504	407	495	345	420	512	614	358	427	395	357	385	355	394	614
Max	602	494	504	527	520	457	633	590	526	473	504	507	495	458	526	512	636	582	582	476	468	514	618	494	636

Land-Based Wind

2000-2021	Hour Beginning																								
Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Max
January	405	360	330	364	278	316	383	406	314	460	421	441	410	428	379	413	561	700	596	447	404	370	338	353	700
February	383	425	362	374	352	380	331	360	346	373	397	413	370	392	325	403	674	866	768	542	522	496	391	408	866
March	477	376	390	402	333	454	450	569	430	346	563	515	380	437	332	358	476	605	766	595	562	487	492	494	766
April	596	439	293	334	277	352	357	350	351	505	406	534	375	383	343	390	307	444	801	731	673	513	540	459	801
May	550	440	379	429	425	292	305	271	478	499	368	408	454	365	310	259	284	365	576	733	657	582	480	525	733
June	491	365	354	387	410	241	177	185	355	424	471	508	370	323	284	229	168	333	487	636	637	587	465	462	637
July	308	335	342	236	192	347	218	115	297	376	488	327	295	249	238	195	177	256	522	809	654	499	510	434	809
August	325	302	282	282	308	307	205	181	284	243	380	349	316	334	258	209	178	299	592	682	570	489	540	417	682
September	347	401	319	233	224	324	305	283	331	280	321	376	225	242	267	259	180	470	726	705	555	575	526	370	726
October	375	444	273	401	397	432	447	251	345	420	495	361	459	466	295	256	302	532	751	564	488	486	402	405	751
November	319	310	298	369	354	402	394	341	314	383	453	578	448	417	373	416	519	694	725	455	400	386	362	370	725
December	299	330	320	372	489	597	333	357	271	366	368	451	440	384	360	435	523	630	586	413	395	330	290	298	630
Max	596	444	390	429	489	597	450	569	478	505	563	578	459	466	379	435	674	866	801	809	673	587	540	525	866

Offshore Wind

2000-2021	Hour Beginning																								
Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Max
January	1,614	1,503	1,246	2,022	2,041	1,308	1,529	1,932	1,374	1,397	1,578	1,771	1,686	1,440	1,106	1,336	995	1,086	1,229	1,255	1,145	1,748	1,490	1,458	2,041
February	1,344	1,331	1,540	1,719	1,926	1,305	1,990	1,218	1,904	1,439	1,462	1,708	1,644	1,121	1,092	1,467	1,593	1,732	1,102	1,453	1,312	1,070	1,495	1,716	1,990
March	1,706	1,895	2,350	2,260	2,057	1,418	1,492	1,516	2,204	1,634	2,120	1,658	1,390	1,766	1,863	1,403	1,178	1,183	1,717	1,817	1,340	1,093	1,443	1,747	2,350
April	2,086	1,653	1,641	1,739	1,932	1,355	1,987	1,562	1,695	1,657	2,020	1,682	1,782	1,331	1,451	1,997	1,406	1,356	1,292	1,146	1,509	1,780	2,306	1,655	2,306
May	1,846	1,453	1,488	1,970	1,934	1,592	1,861	1,679	2,059	2,066	2,201	1,898	1,563	1,241	2,331	1,488	1,274	1,268	1,530	1,267	1,446	1,780	1,506	1,788	2,331
June	1,760	1,693	1,901	1,804	1,951	1,215	2,023	2,106	1,357	1,278	1,125	1,940	1,549	2,112	1,152	1,860	1,602	1,524	1,827	1,180	1,725	1,506	1,545	1,310	2,112
July	1,679	1,646	1,793	1,806	1,649	1,543	1,322	1,318	1,364	1,968	1,230	1,373	957	801	964	933	1,124	1,463	1,421	1,681	1,837	2,051	1,602	1,498	2,051
August	1,786	1,541	1,519	1,286	1,855	1,600	1,588	1,157	1,472	1,031	1,157	1,112	1,408	875	976	1,444	769	1,475	1,393	1,326	1,362	1,836	1,358	1,764	1,855
September	1,627	1,587	1,134	1,474	1,454	1,502	1,407	1,278	1,810	1,974	1,319	1,438	1,387	1,201	1,097	1,551	972	1,374	1,807	1,220	1,674	1,989	1,702	1,423	1,989
October	1,607	1,591	1,665	2,055	1,305	1,325	1,354	1,743	1,285	1,500	1,544	1,228	1,272	1,163	1,468	1,264	1,141	1,077	1,033	1,220	1,596	1,336	1,344	1,372	2,055
November	1,562	1,527	2,127	2,005	1,554	1,540	1,474	1,518	1,347	1,432	1,654	1,568	1,284	1,258	1,313	1,757	1,073	1,142	1,006	1,153	1,570	1,919	999	1,162	2,127
December	1,550	1,259	1,620	1,745	2,050	1,266	1,738	2,065	1,501	1,918	1,492	1,458	1,602	1,126	1,180	1,250	1,832	831	1,246	1,314	1,110	1,916	1,474	1,725	2,065
Max	2,086	1,895	2,350	2,260	2,057	1,600	2,023	2,106	2,204	2,066	2,201	1,940	1,782	2,112	2,331	1,997	1,832	1,732	1,827	1,817	1,837	2,051	2,306	1,788	2,350

Offshore Wind

2000-2021	Hour Beginning																								
Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Max
January	1,622	1,558	1,981	1,435	1,642	1,945	2,270	1,508	1,627	1,869	1,562	1,359	1,280	1,549	1,789	1,741	2,169	2,330	2,135	2,089	1,348	1,854	1,759	1,718	2,330
February	1,422	1,553	2,723	1,750	1,552	1,708	1,562	1,907	1,448	1,453	1,328	1,534	1,655	1,824	1,712	1,913	1,562	1,708	1,688	1,959	1,843	2,269	2,350	1,573	2,723
March	1,577	1,756	2,092	1,360	1,529	1,772	1,669	1,925	1,445	1,243	1,818	1,462	1,603	1,781	1,805	2,024	1,483	2,099	2,607	2,191	1,402	1,677	1,726	1,803	2,607
April	1,525	1,419	1,150	1,506	1,653	1,817	2,390	1,705	1,479	1,400	1,595	1,947	1,909	1,797	1,571	1,858	1,748	1,730	1,605	2,105	1,519	2,284	1,878	2,251	2,390
May	2,429	1,502	1,176	1,145	1,612	1,581	1,672	1,702	1,427	1,707	2,055	1,474	2,072	2,091	2,001	1,627	1,997	1,689	1,737	1,752	1,678	1,547	2,547	1,584	2,547
June	1,431	1,166	1,218	908	1,128	1,374	1,235	1,188	965	1,795	1,260	1,797	1,779	2,353	2,145	2,093	2,450	1,820	1,702	2,033	1,666	1,709	1,498	1,542	2,450
July	1,200	1,006	1,248	1,154	1,248	1,296	1,538	1,065	1,029	1,334	1,092	1,232	1,484	1,693	1,880	1,566	2,159	1,479	1,695	1,292	1,181	1,428	1,612	1,280	2,159
August	1,092	1,242	1,063	1,476	1,307	1,478	1,374	1,235	1,733	1,738	1,538	1,164	1,855	1,549	1,623	2,104	1,570	1,557	1,270	1,239	1,498	1,628	1,002	[illegible]	2,104
September	1,361	1,606	1,611	1,229	1,027	1,282	1,269	1,803	1,251	1,436	1,387	1,201	1,478	1,472	1,527	1,522	1,840	2,457	1,806	1,581	2,071	1,365	1,196	1,154	2,457
October	2,162	2,011	1,563	1,052	1,485	1,272	1,741	1,396	1,801	1,160	1,392	2,282	1,313	2,076	1,578	1,550	1,435	1,863	2,119	1,775	2,248	1,747	1,673	1,531	2,282
November	1,391	2,249	1,830	1,710	1,493	1,802	2,393	1,949	2,066	1,517	1,369	1,311	1,459	1,618	1,578	1,611	2,250	1,725	1,487	1,876	1,794	1,479	1,531	1,486	2,393
December	1,758	1,515	1,867	1,796	1,519	1,844	1,460	1,852	1,573	1,267	2,418	1,543	1,815	1,443	1,598	1,802	1,633	2,209	1,704	1,829	1,477	1,966	1,680	1,803	2,418
Max	2,429	2,249	2,723	1,796	1,653	1,945	2,393	1,949	2,066	1,869	2,418	2,282	2,072	2,353	2,145	2,093	2,450	2,457	2,607	2,191	2,248	2,284	2,547	2,251	2,723

Utility-Scale Wind and Solar Resources

2000-2021	Hour Beginning																								
Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Max
January	1,708	1,552	1,325	2,186	2,296	1,469	1,611	804	1,040	1,884	1,741	1,778	2,144	1,862	2,289	5,091	2,528	1,061	1,117	1,237	1,064	1,823	1,612	1,563	5,091
February	1,194	1,484	1,581	1,720	2,181	1,537	1,590	404	1,460	1,613	2,011	1,857	2,366	1,630	1,720	4,634	5,959	2,251	1,151	1,424	1,339	1,279	1,550	1,847	5,959
March	2,050	1,975	2,403	2,277	1,979	1,436	782	1,164	2,515	1,478	2,357	1,947	1,309	2,042	2,603	2,938	5,941	4,236	1,717	1,892	1,437	1,234	1,539	1,623	5,941
April	2,185	1,819	1,771	1,911	1,811	600	1,249	1,795	1,745	1,842	2,318	1,806	1,956	1,835	2,752	2,678	4,919	6,174	2,063	1,144	1,504	1,826	2,316	1,777	6,174
May	1,854	1,499	1,551	2,089	1,398	813	1,145	1,834	1,883	1,715	1,870	2,114	1,828	1,689	2,530	3,479	3,136	5,756	5,086	1,278	1,524	1,770	1,514	1,802	5,756
June	1,932	1,844	1,937	1,776	1,048	896	924	1,488	1,586	1,266	1,074	1,761	1,597	2,259	1,841	2,735	3,156	4,364	4,774	1,219	1,650	1,544	1,645	1,408	4,774
July	1,668	1,681	1,883	1,805	814	485	1,221	1,320	1,258	1,641	1,224	1,394	2,256	1,367	2,468	2,229	2,933	4,707	4,950	1,651	1,765	1,823	1,723	1,546	4,950
August	1,805	1,570	1,562	1,538	1,862	969	784	680	1,851	1,054	982	1,356	1,719	1,681	1,777	2,364	3,715	5,171	2,814	1,294	1,407	1,875	1,330	1,798	5,171
September	1,741	1,654	1,248	1,506	1,547	693	388	1,060	1,700	1,736	1,996	1,739	1,845	1,854	1,938	3,245	5,651	4,338	1,793	1,313	1,777	2,086	1,721	1,523	5,651
October	1,714	1,622	1,792	2,118	1,442	1,343	719	1,764	1,891	1,733	1,621	1,674	1,692	1,385	2,434	5,605	5,014	1,312	1,005	1,114	1,575	1,462	1,378	1,471	5,605
November	1,643	1,621	2,184	2,003	1,710	1,704	1,127	1,047	1,280	1,444	1,657	1,490	1,818	1,701	2,956	5,660	1,696	1,153	1,107	1,203	1,691	2,337	1,193	1,245	5,660
December	1,746	1,361	1,853	1,741	2,173	1,314	1,790	766	1,520	1,785	1,399	1,848	2,347	2,252	3,104	3,535	1,850	748	1,471	1,573	1,184	2,156	1,494	1,872	3,535
Max	2,185	1,975	2,403	2,277	2,296	1,704	1,790	1,834	2,515	1,884	2,357	2,114	2,366	2,259	3,104	5,660	5,959	6,174	5,086	1,892	1,777	2,337	2,316	1,872	6,174

Utility-Scale Wind and Solar Resources

2000-2021	Hour Beginning																								
Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Max
January	1,582	1,727	2,021	1,499	1,704	1,902	2,123	4,183	2,999	1,835	1,736	2,126	1,302	2,017	1,845	1,420	2,363	2,493	2,144	2,005	1,476	1,833	1,833	1,722	4,183
February	1,477	1,596	2,821	1,652	1,452	1,776	2,833	5,429	2,786	2,915	1,754	1,280	2,572	1,598	1,632	968	474	1,858	1,890	2,227	1,897	2,296	2,366	1,542	5,429
March	1,852	1,828	1,895	1,370	1,721	2,506	6,033	4,436	2,464	2,521	1,896	1,757	2,687	2,557	1,787	1,619	1,147	2,183	2,524	2,317	1,524	1,702	1,663	1,816	6,033
April	1,715	1,393	1,344	1,648	2,863	5,666	5,407	3,307	2,461	2,443	1,881	2,608	2,453	1,702	1,687	1,755	954	919	1,550	2,132	1,942	2,289	1,762	2,222	5,666
May	2,463	1,596	1,200	1,061	3,544	5,422	4,015	3,178	2,577	2,341	2,656	1,704	2,115	2,628	1,878	1,515	1,014	1,176	1,398	1,899	1,788	1,504	2,452	1,508	5,422
June	1,424	1,183	1,141	995	4,182	4,948	3,012	2,692	2,479	2,335	1,974	2,264	2,179	2,407	2,241	1,658	1,509	979	682	2,301	1,724	1,741	1,563	1,437	4,948
July	1,191	953	1,229	1,171	4,026	5,191	3,188	2,393	2,468	2,246	2,022	2,844	1,780	2,162	1,962	1,189	1,196	548	1,384	1,625	1,495	1,570	1,580	1,274	5,191
August	1,163	1,230	1,125	867	1,560	5,209	3,908	2,816	2,079	2,413	2,165	2,566	1,926	1,450	1,121	849	794	886	1,544	1,626	1,366	1,450	1,636	1,048	5,209
September	1,333	1,568	1,600	1,194	998	3,761	5,565	2,489	1,992	2,299	1,891	1,561	1,635	1,360	1,184	1,140	789	1,050	1,841	1,779	2,101	1,296	1,114	1,132	5,565
October	2,046	1,883	1,578	1,224	1,604	1,788	5,315	4,028	2,134	1,736	1,693	2,323	2,060	1,843	1,314	598	905	1,872	1,998	1,851	2,263	1,795	1,785	1,576	5,315
November	1,381	2,181	1,791	1,744	1,530	1,795	3,615	5,016	2,428	1,998	1,609	1,298	1,967	1,417	1,446	1,015	2,216	1,968	1,686	2,038	1,770	1,388	1,604	1,560	5,016
December	1,847	1,558	1,935	1,851	1,445	1,881	1,536	3,967	2,760	1,918	2,416	1,786	1,595	1,384	1,518	1,083	1,663	2,687	1,875	1,861	1,595	1,903	1,918	2,102	3,967
Max	2,463	2,181	2,821	1,851	4,182	5,666	6,033	5,429	2,999	2,915	2,656	2,844	2,687	2,628	2,241	1,755	2,363	2,687	2,524	2,317	2,263	2,296	2,452	2,222	6,033

Load

2000-2021	Hour Beginning																								
Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Max
January	0	0	110	375	1,261	2,014	1,490	291	0	60	0	82	542	892	1,644	2,232	2,234	438	0	0	0	0	0	1,354	2,234
February	0	0	101	361	1,091	1,929	1,265	261	0	0	84	55	495	736	1,466	2,177	2,351	1,218	0	0	0	0	0	8	2,351
March	0	0	578	349	1,091	1,783	941	0	0	0	273	458	643	687	1,448	2,024	2,138	1,466	391	0	0	0	0	0	2,138
April	0	0	5	253	920	1,350	699	314	296	227	190	326	703	1,018	1,358	1,800	1,995	1,310	521	135	0	0	0	324	1,995
May	0	0	0	163	587	867	656	351	235	346	367	668	932	1,189	1,481	1,545	1,604	1,239	374	130	0	0	0	0	1,604
June	0	0	0	33	302	777	905	933	506	541	1,145	959	973	1,296	1,506	1,660	1,477	1,117	333	0	0	0	0	0	1,660
July	0	0	0	0	372	702	1,027	1,230	1,250	1,316	1,195	1,372	1,270	1,638	1,519	1,945	1,947	1,644	21	0	0	0	0	157	1,947
August	0	0	0	6	564	867	926	1,055	670	967	1,046	945	1,496	1,278	1,536	1,883	1,643	915	23	0	0	0	0	0	1,883
September	0	0	0	138	797	1,282	477	383	435	435	741	1,058	809	1,020	1,526	1,821	1,449	715	282	0	0	0	0	0	1,821
October	0	0	0	242	963	1,766	1,059	24	0	20	173	356	809	854	1,510	1,828	1,423	916	155	0	0	0	0	0	1,828
November	0	0	35	299	1,026	1,784	1,109	167	0	0	14	334	915	1,164	1,686	1,967	1,428	385	0	0	0	0	0	0	1,967
December	0	0	15	325	1,058	1,821	1,279	483	8	0	9	264	723	1,006	1,505	2,169	1,815	370	0	0	0	0	0	0	2,169
Max	0	0	578	375	1,261	2,014	1,490	1,230	1,250	1,316	1,195	1,372	1,496	1,638	1,686	2,232	2,351	1,644	521	135	0	0	0	1,354	2,351

Load

2000-2021	Hour Beginning																								
Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Max
January	790	814	404	11	0	0	0	332	992	1,058	769	431	20	0	0	0	0	0	515	807	1,119	1,804	1,847	3,838	3,838
February	737	807	296	0	0	0	0	632	1,188	1,023	861	581	70	0	0	0	0	0	517	944	1,323	1,748	1,780	2,531	2,531
March	754	1,301	0	29	0	0	532	894	1,256	1,269	1,086	954	367	185	0	0	0	0	0	626	1,301	1,772	1,542	2,532	2,532
April	867	900	416	130	55	420	750	795	868	782	586	506	719	58	0	0	0	0	0	171	968	1,338	1,416	2,692	2,692
May	847	944	402	209	426	808	464	494	1,017	736	581	197	21	0	0	0	0	0	0	198	682	1,375	1,553	2,106	2,106
June	1,062	1,126	508	298	559	723	261	126	307	415	495	50	85	0	0	0	0	0	239	698	583	1,394	1,722	2,409	2,409
July	1,233	1,294	672	400	515	837	226	104	319	324	199	36	0	0	0	0	0	0	743	1,221	1,317	2,906	3,126	5,022	5,022
August	1,143	1,195	613	296	264	610	470	322	613	307	20	0	0	0	0	0	0	0	727	873	1,694	2,416	2,490	3,058	3,058
September	875	1,003	461	209	21	55	599	763	822	606	637	215	0	0	0	0	0	0	88	754	1,068	1,398	1,588	2,146	2,146
October	767	881	355	124	0	0	102	904	1,128	963	599	149	0	0	0	0	0	0	135	766	1,081	1,385	1,400	1,702	1,702
November	684	1,169	332	0	0	0	0	769	1,115	898	692	230	0	0	0	0	0	0	554	854	1,129	1,426	1,421	1,909	1,909
December	790	832	279	7	0	0	0	178	952	895	810	382	78	0	0	0	0	122	698	1,005	1,304	1,827	1,641	2,846	2,846
Max	1,233	1,301	672	400	559	837	750	904	1,256	1,269	1,086	954	719	185	0	0	0	122	743	1,221	1,694	2,906	3,126	5,022	5,022

Net Load

2000-2021	Hour Beginning																								
Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Max
January	1,022	1,256	1,137	2,469	3,310	3,319	2,977	942	350	1,502	1,349	1,649	2,479	2,664	3,472	6,932	4,251	1,221	620	557	226	353	336	2,038	6,932
February	657	1,200	1,392	1,784	3,169	3,261	2,525	359	1,183	1,096	1,915	1,595	2,677	2,123	2,900	6,646	8,092	2,843	893	750	502	42	289	1,421	8,092
March	1,425	1,243	2,553	2,495	2,569	3,176	1,614	922	2,038	1,028	2,177	1,703	1,819	2,513	3,801	4,687	7,741	5,242	1,920	1,435	477	218	78	772	7,741
April	1,490	1,400	1,578	2,067	2,489	1,898	1,571	1,568	1,366	1,287	2,394	1,929	2,352	2,562	3,308	4,000	6,298	7,146	2,466	1,186	817	976	975	1,310	7,146
May	1,341	1,155	1,338	1,957	1,441	1,110	1,388	1,809	1,806	1,483	1,804	2,336	2,259	2,401	3,456	4,462	4,475	6,691	5,140	1,171	1,175	695	209	622	6,691
June	1,037	1,273	1,720	1,732	1,174	1,365	1,376	1,725	1,723	1,485	2,066	2,129	2,148	2,837	2,834	4,167	4,280	5,119	4,733	700	1,228	433	486	357	5,119
July	891	846	1,258	1,724	1,109	721	2,148	1,937	1,936	2,368	1,869	2,151	3,324	2,810	3,754	3,637	3,859	5,730	4,971	578	670	419	272	1,232	5,730
August	813	1,036	1,060	1,510	2,426	1,573	1,323	1,392	2,007	1,741	1,698	2,146	2,795	2,779	3,026	4,060	4,922	6,025	2,427	972	510	818	68	843	6,025
September	1,052	1,082	939	1,503	2,257	1,720	523	1,022	1,515	1,550	2,737	2,524	2,581	2,735	3,000	4,920	6,761	4,857	1,741	832	782	934	547	1,124	6,761
October	1,205	930	1,766	2,268	2,330	2,769	1,573	1,201	1,650	1,207	1,322	1,704	1,980	2,151	3,786	7,106	6,040	1,958	899	481	677	333	237	560	7,106
November	1,388	915	1,960	2,066	2,515	3,438	2,155	397	969	1,212	1,213	1,587	2,641	2,802	4,348	7,274	3,007	1,318	800	448	671	1,189	0	359	7,274
December	1,083	1,050	1,736	2,022	3,188	3,094	2,594	647	975	1,372	1,347	1,653	2,560	3,193	4,127	5,316	3,617	826	952	734	212	710	118	444	5,316
Max	1,490	1,400	2,553	2,495	3,310	3,438	2,977	1,937	2,038	2,368	2,737	2,524	3,324	3,193	4,348	7,274	8,092	7,146	5,140	1,435	1,228	1,189	975	2,038	8,092

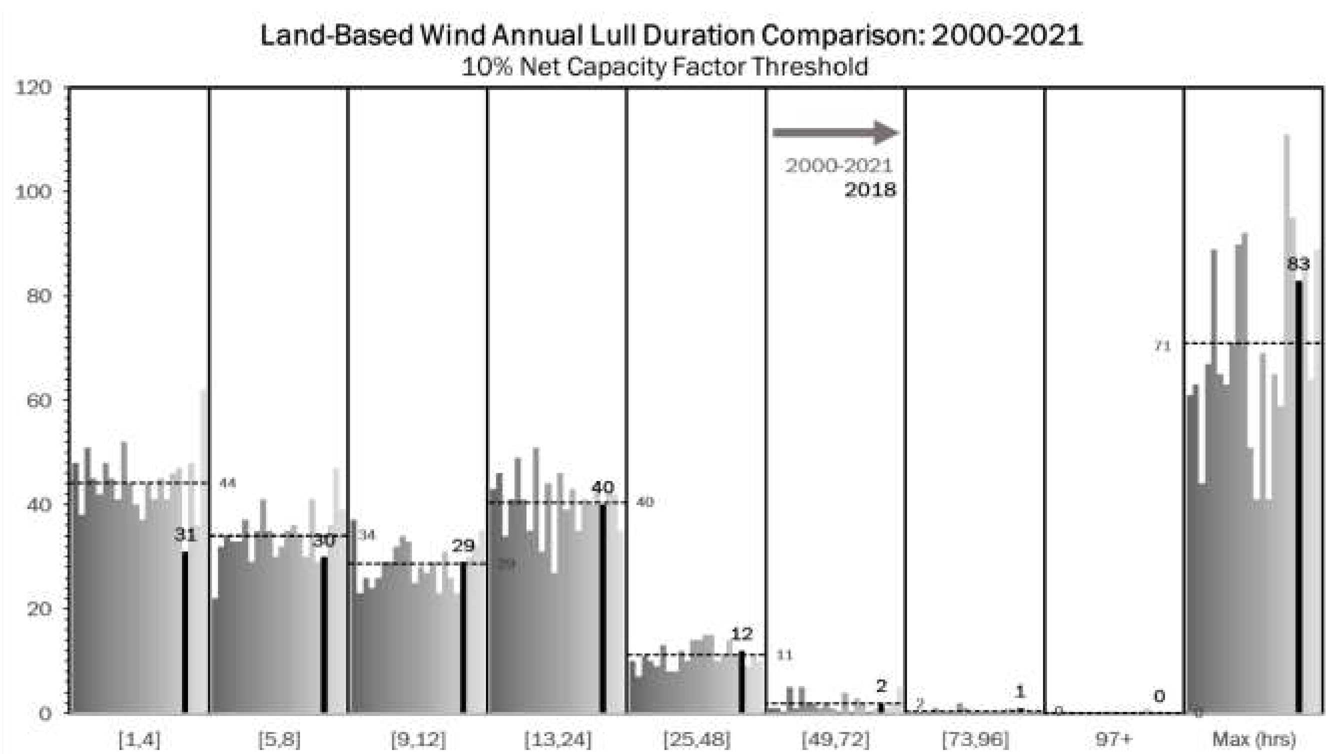
Net Load

2000-2021	Hour Beginning																								
Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Max
January	2,242	2,003	2,166	1,171	642	646	909	4,382	3,802	2,852	2,398	2,226	1,220	1,775	865	0	834	2,057	2,587	2,574	2,395	3,506	3,341	5,560	5,560
February	2,083	2,078	2,981	1,622	973	949	2,182	5,751	3,515	3,811	2,364	1,634	2,502	1,254	529	0	0	1,301	2,319	3,171	2,786	3,582	3,552	3,303	5,751
March	2,451	2,499	1,641	1,124	1,079	2,045	6,125	4,935	3,349	3,183	2,887	2,550	2,413	2,390	948	344	0	1,321	2,286	2,854	2,509	3,122	3,112	3,371	6,125
April	2,474	2,020	1,529	1,493	2,918	6,008	5,069	3,473	2,953	2,992	2,237	2,731	2,111	1,391	1,048	801	0	109	1,395	2,218	2,806	3,566	3,097	3,413	6,008
May	3,095	2,031	1,436	959	3,237	5,569	3,874	3,633	3,069	2,590	2,974	1,542	1,755	2,235	1,238	713	0	462	1,225	1,798	2,381	2,750	3,813	2,960	5,569
June	2,284	2,100	1,540	1,183	4,736	5,252	2,762	2,455	2,348	2,522	2,236	1,743	1,779	1,193	748	516	659	293	725	2,699	2,056	3,044	3,042	3,121	5,252
July	2,129	2,176	1,667	1,486	3,897	5,826	2,919	1,797	2,146	2,201	1,645	1,896	1,025	1,204	1,046	135	100	431	1,365	2,552	2,515	3,955	4,151	5,451	5,826
August	2,219	1,842	1,696	968	1,421	5,288	4,278	2,163	2,003	2,207	1,831	1,898	869	783	245	0	0	357	2,077	2,196	2,838	3,311	3,046	3,682	5,288
September	1,949	2,473	1,863	1,227	843	3,725	5,608	2,607	2,692	2,525	1,980	1,283	1,214	858	451	0	0	750	1,811	2,263	3,115	2,559	2,634	2,805	5,608
October	2,651	2,189	1,878	1,058	1,263	799	5,417	4,371	2,890	2,699	2,293	2,344	1,783	1,312	608	0	0	1,173	2,133	2,588	3,344	2,916	2,911	2,724	5,417
November	1,689	3,340	2,069	1,700	837	954	2,689	5,706	2,903	2,563	1,967	1,261	1,585	839	459	0	950	1,943	2,136	2,649	2,600	2,803	3,007	2,772	5,706
December	2,580	2,390	2,067	1,599	826	827	814	4,131	3,311	2,343	2,810	1,882	1,443	817	318	0	185	2,371	2,439	2,802	2,657	3,354	3,078	3,780	4,131
Max	3,095	3,340	2,981	1,700	4,736	6,008	6,125	5,751	3,802	3,811	2,974	2,731	2,502	2,390	1,238	801	950	2,371	2,587	3,171	3,344	3,955	4,151	5,560	6,125

Characterization of the magnitude and frequency of low output intervals of renewable output is an important consideration when analyzing the impact of serving demand during longer duration events of low renewable production. Different output levels and durations must be considered and one threshold must be selected to perform this analysis on an input renewable generation profile. For this analysis, low output events, or lulls, are defined as continuous durations where the production is below the identified threshold. Events are then binned by the duration of the number of hours for each event for each year. This analysis was performed for LBW, OSW, and a combination of LBW, OSW, and UPV to examine the impact of the combined assumed renewable fleet on the number of lulls of a given set of duration bins.

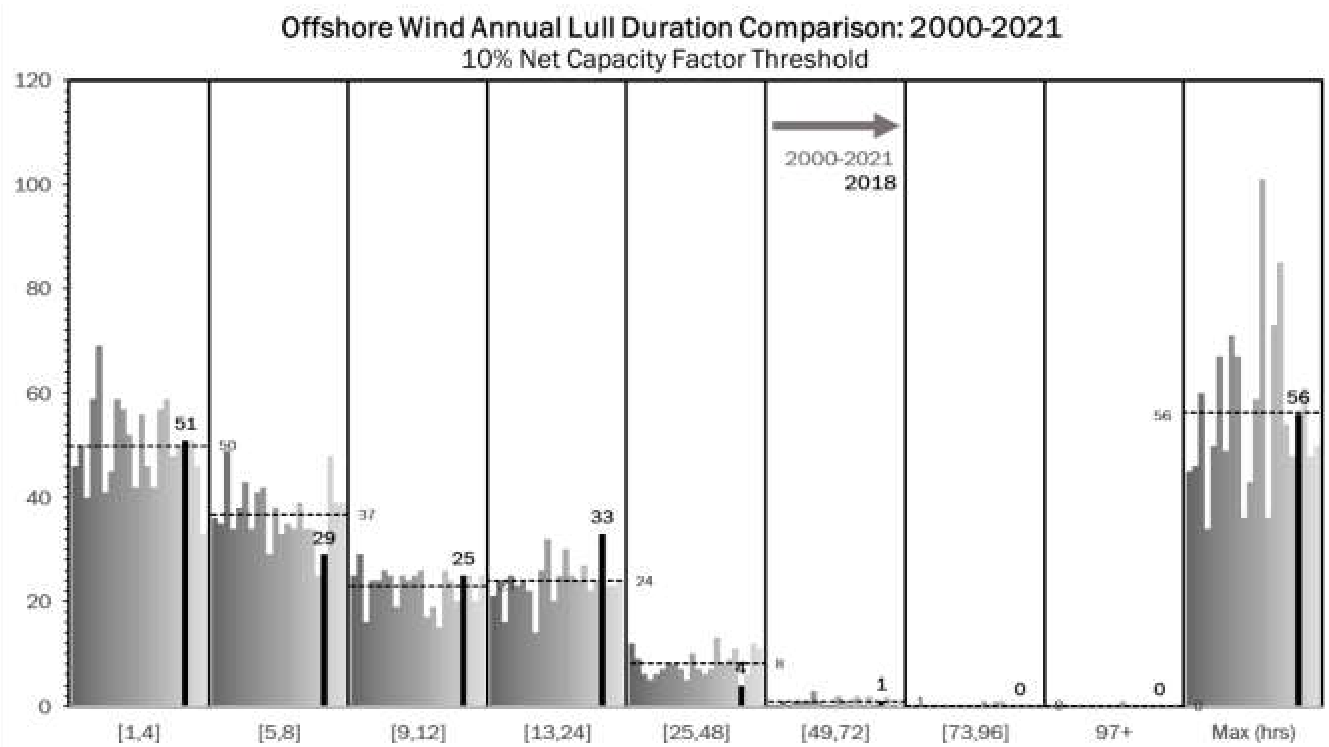
Figure xx presents the results of reviewing the LBW profiles over the 2000-2021 period on an annual basis assuming a 10% hourly NCF threshold (i.e., lull hours are defined as those with a NCF greater than 0.1). The x-axis displays the event duration bins (e.g., "[1,4]" collect all one-to-four-hour events while "97+" collects all events that are 97 hours or longer) except for the last bin that displays the longest duration event in hours during the year. Each bar within a bin going from left to right represents the number of events in each duration bin for one year from 2000-2021, with 2018 labeled with black bars and the corresponding number of events. The dashed line across each bin shows the average value of the number of lulls (and maximum duration) across the 23-year period. The analysis shows that, in 2018, the longest event where LBW output stayed below 10% of capacity across New York was 83 hours long and there were 12 events between 25 and 48 hours long. The chart also shows that there were less short duration LBW lull events in 2018 relative to the 23-year average but that there were in general more lulls longer than on day in duration than in a typical year.

Figure xx: Land-Based Wind Lull Event Duration Statistics assuming 10% NCF threshold: 2030 Contract Case



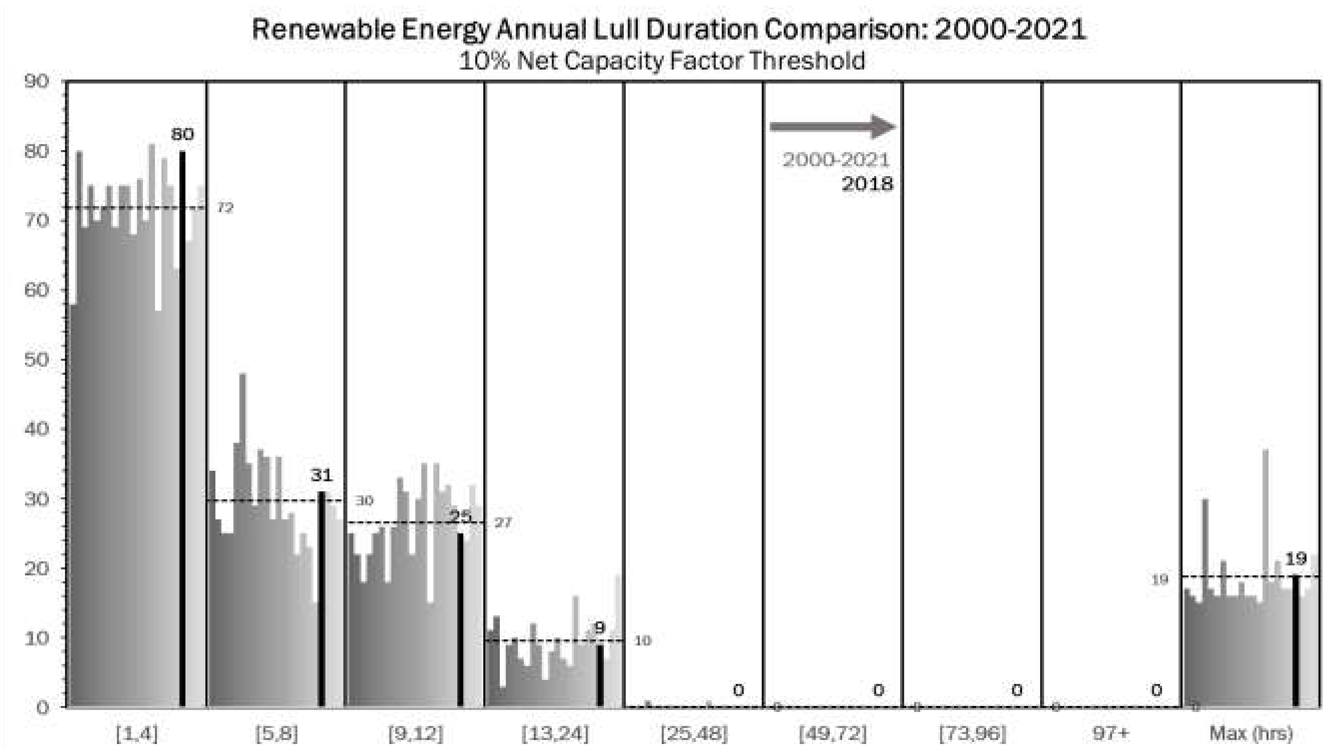
Comparison of the DNV renewable production shapes shows that LBW has more and longer wind lulls than the OSW shapes. This is expected, in part, as OSW has higher average capacity factors as shown in the monthly-hourly analysis earlier in this section.

Figure xx: Offshore Wind Lull Event Duration Statistics assuming 10% NCF threshold: 2030 Contract Case



Combining the LBW, OSW, and UPV shapes on a capacity weighted basis and performing the same analysis results in less lulls of all durations because the diversity in timing of production from the different generation types has the effect removing or splitting longer lulls into more shorter events.

Figure xx: Combined Renewable Generation Lull Event Duration Statistics assuming 10% NCF threshold: 2030 Contract Case



Conclusions

Analysis of the input renewable and load shapes over the course of a single year can provide significant information about when additional resources will most likely be needed to provide additional supply to the system. Using the 22-years of simulated renewable NCF profiles applied to the zonal capacity mix in the 2030 Contract Case provides significant insight into general system characteristics and potential needs for additional supply resources. Comparative review of these metrics for the 2035 Lower and Higher Demand scenarios in the Policy Case shows largely similar features across all of the discussed metrics but with larger impacts due to the higher loads and slightly larger renewable builds present in the 2035 Policy Case relative to the 2030 Contract Case.