U.S. nuclear capacity factors: Resiliency and new realities

Once again, the U.S. fleet has achieved a new personal best, even as utilities and operators face formidable challenges.

By Susan Gallier

In the early years of the *Nuclear News* capacity factors survey, any factor over 70 was deemed excellent; any factor under 50 was considered poor. By that standard, all but two operating U.S. power reactors chalked up excellent performance during 2017–2019. A record 809.4 TWh of electricity was generated in the United States from nuclear energy in 2019, according to the U.S. Energy Information Administration (EIA), besting the record of 807.1 TWh set in 2018.

Nuclear News staff developed the capacity factors survey in the early 1980s as a way to identify the most productive reactors in an expanding fleet. Fleet improvement was the industry's self-identified goal, but no one could anticipate the startlingly rapid pace of improvement, spurred by the Institute of Nuclear Power Operations (INPO), which boosted fleetwide performance to highs that continue today.

Not surprisingly, this latest *Nuclear News* capacity factors survey records an increase as well. The median design electrical rating net capacity factor for 2017–2019 is 91.20, up by 0.60 percentage points from the median of 90.60 in 2014–2016.

The fleet has maintained a median capacity factor near 90 percent for over 15 years (see Fig. 1). Data from 30 years ago can remind us just how remarkable this achievement is. In the survey of 1987–1989 capacity factors published in 1990, not one reactor had a capacity factor above 90, and the fleetwide median capacity factor was 68.2 percent (*NN*, May 1990).

Now-retired *NN* writer E. Michael Blake warned that the decade of performance improvements tracked during the 1980s could be reaching a plateau. "A few years ago," he wrote at that time, "it seemed unrealistic to wonder if the median could reach 70 percent; now, it will be a disappointment if the median does not get there, and soon." Blake would go on to witness more steady improvements, and when his plateau did arrive, it was near 90, not 70.

Just 15 years later, as shown in 2002–2004 capacity factor data published in 2005 (*NN*, May 2005), 50 of 104 plants had capacity factors at 90 or above, and just two plants—Davis-Besse and Browns Ferry-1—were below 50. The gains, Blake said, "may suggest that power reactor performance is finally reaching a plateau. In the past, however, this writer has looked ridiculous when making such suggestions, so for now this will not be declared a long-term trend." In hindsight, we can plainly see that with a fleetwide median of 89.77 for 2002–2004, the plateau had been reached, and we give Blake all the thanks he is due for his painstaking tracking of an industry's growing pains.

Continued

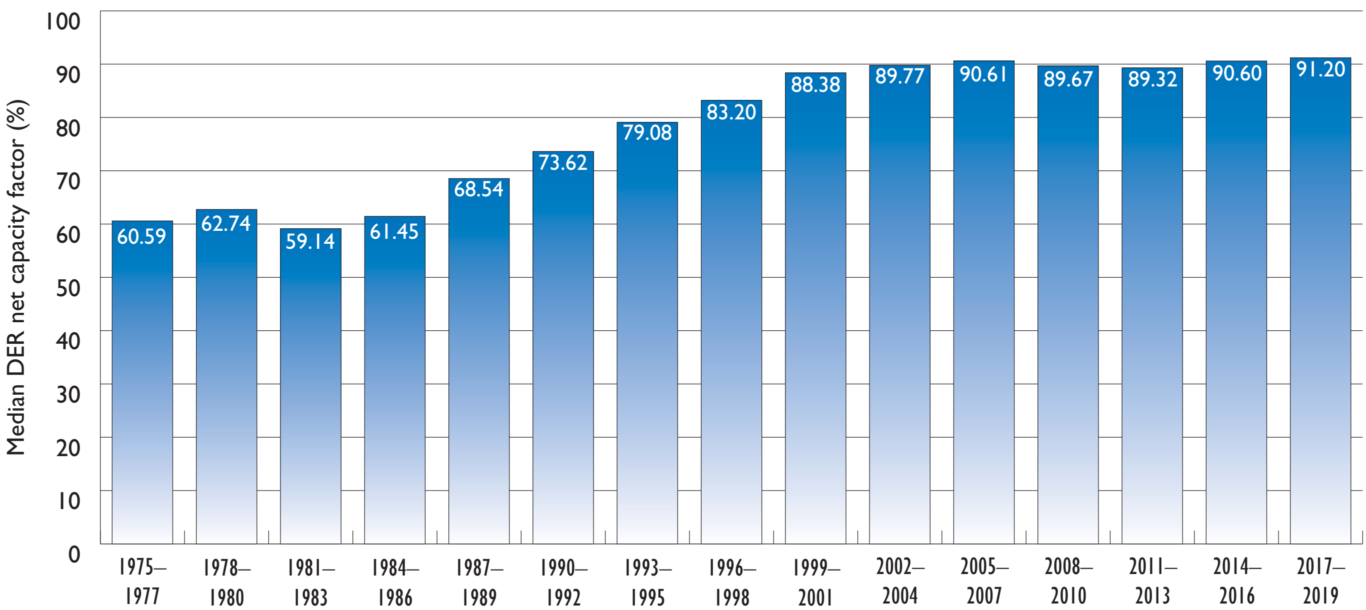

Fig. 1: All reactors. The median DER net capacity factor of the 98 reactors included in this survey for the three-year period 2017–2019 is 91.20 percent, once again the highest ever reported in a *Nuclear News* capacity factors survey. For the five three-year periods between 1999 and 2013 shown above, 104 reactors were in operation. The 2014–2016 capacity factor shown above is that of the 99 reactors remaining in service following the closures of Crystal River-3, Kewaunee, San Onofre-2 and -3, and Vermont Yankee. Oyster Creek, which closed in September 2018, is not included in the 98 reactors represented in the 2017–2019 median DER, but Pilgrim and Three Mile Island-1, which closed in 2019, are included.

Table I. 2017–2019 DER Net Capacity Factors of Individual Reactors

Rank	Reactor	Factor[1]	Rating[2]	Type	Owner[3]
1.	Calvert Cliffs-1	103.73	845	PWR	Exelon
2.	Dresden-3	101.71	879	BWR	Exelon
3.	Calvert Cliffs-2	99.41	845	PWR	Exelon
4.	South Texas-2	98.75	1250.6	PWR	STPNOC
5.	Browns Ferry-1	97.75	1120	BWR	TVA
6.	Farley-2	97.21	855	PWR	Southern
7.	South Texas-1	97.16	1250.6	PWR	STPNOC
8.	Peach Bottom-2	96.80	1330	BWR	Exelon
9.	Davis-Besse	96.79	908	PWR	Energy Harbor
10.	Vogtle-2	96.21	1169	PWR	Southern
11.	Dresden-2	96.20	894	BWR	Exelon
12.	Oconee-3	95.57	881	PWR	Duke
13.	Vogtle-1	95.48	1169	PWR	Southern
14.	Browns Ferry-3	95.35	1120	BWR	TVA
15.	Oconee-1	95.02	865	PWR	Duke
16.	LaSalle-1	94.42	1178	BWR	Exelon
17.	Seabrook	94.39	1248	PWR	NextEra
18.	Byron-2	94.30	1186.4	PWR	Exelon
19.	Farley-1	94.30	854	PWR	Southern
20.	Nine Mile Point-2	94.29	1299.9	BWR	Exelon
21.	Hatch-1	94.10	885	BWR	Southern
22.	Arnold	93.89	621.9	BWR	NextEra
23.	Byron-1	93.86	1213	PWR	Exelon
24.	Susquehanna-1	93.76	1287	BWR	Susquehanna
25.	Comanche Peak-1	93.73	1218	PWR	Luminant
26.	Catawba-1	93.66	1190	PWR	Duke
27.	Ginna	93.60	585	PWR	Exelon
28.	FitzPatrick	93.57	816	BWR	Exelon
29.	North Anna-1	93.51	973	PWR	Dominion
30.	Millstone-3	92.93	1229	PWR	Dominion
31.	McGuire-1	92.92	1199	PWR	Duke
32.	McGuire-2	92.86	1187	PWR	Duke
33.	Quad Cities-2	92.84	957.3	BWR	Exelon
34.	Catawba-2	92.84	1180	PWR	Duke
35.	Point Beach-2	92.80	615	PWR	NextEra
36.	Limerick-1	92.73	1205	BWR	Exelon
37.	Oconee-2	92.73	872	PWR	Duke
38.	Turkey Point-4	92.66	840	PWR	NextEra
39.	Prairie Island-1	92.42	557	PWR	Xcel
40.	Peach Bottom-3	92.26	1331	BWR	Exelon
41.	Wolf Creek	92.21	1200	PWR	Wolf Creek
42.	LaSalle-2	92.11	1178	BWR	Exelon
43.	North Anna-2	92.05	973	PWR	Dominion
44.	Palo Verde-1	91.96	1333	PWR	APS
45.	Surry-2	91.87	874	PWR	Dominion
46.	Turkey Point-3	91.76	844	PWR	NextEra
47.	Nine Mile Point-1	91.70	613	BWR	Exelon
48.	Point Beach-1	91.69	615	PWR	NextEra
49.	Monticello	91.27	656.3	BWR	Xcel
50.	Braidwood-1	91.14	1268	PWR	Exelon
51.	Prairie Island-2	91.13	557	PWR	Xcel
52.	Cooper	91.03	815	BWR	NPPD
53.	Harris	90.75	992	PWR	Duke
54.	Indian Point-2	90.68	1035	PWR	Entergy
55.	Quad Cities-1	90.67	963.99	BWR	Exelon
56.	Susquehanna-2	90.47	1287	BWR	Susquehanna
57.	Palo Verde-3	90.34	1334	PWR	APS
58.	Beaver Valley-1	90.28	963	PWR	Energy Harbor
59.	Surry-1	90.20	874	PWR	Dominion
60.	Clinton	90.09	1062	BWR	Exelon
61.	Three Mile Island-1	90.19	819	PWR	Exelon
62.	Palo Verde-2	89.66	1336	PWR	APS
63.	Diablo Canyon-1	89.64	1138	PWR	PG&E
64.	Beaver Valley-2	89.48	960	PWR	Energy Harbor
65.	Salem-1	89.42	1169	PWR	PSEG
66.	Braidwood-2	89.38	1241	PWR	Exelon
67.	Browns Ferry-2	89.37	1120	BWR	TVA
68.	Hope Creek	89.32	1237	BWR	PSEG
69.	Perry	89.14	1268	BWR	Energy Harbor
70.	Brunswick-1	89.10	983	BWR	Duke
71.	Sequoyah-2	88.90	1177.46	PWR	TVA
72.	Salem-2	88.72	1181	PWR	PSEG
73.	Limerick-2	88.49	1205	BWR	Exelon
74.	Summer	88.13	972.7	PWR	Dominion
75.	Hatch-2	87.86	908	BWR	Southern
76.	Millstone-2	87.71	877.2	PWR	Dominion
77.	Cook-2	87.51	1194	PWR	AEP
78.	Callaway	87.46	1228	PWR	Ameren
79.	Palisades	87.06	805	PWR	Entergy
80.	Columbia	86.81	1174	BWR	Energy Northwest
81.	St. Lucie-2	86.61	1074	PWR	NextEra
82.	Fermi-2	86.11	1150	BWR	DTE
83.	Indian Point-3	85.70	1048	PWR	Entergy
84.	Watts Bar-1	85.64	1173	PWR	TVA
85.	Waterford-3	85.36	1173	PWR	Entergy
86.	Comanche Peak-2	85.27	1207	PWR	Luminant
87.	Sequoyah-1	85.09	1184.37	PWR	TVA
88.	ANO-1	84.96	850	PWR	Entergy
89.	Diablo Canyon-2	84.88	1151	PWR	PG&E
90.	Brunswick-2	84.24	980	BWR	Duke
91.	Robinson-2	84.17	795	PWR	Duke
92.	Cook-1	83.91	1084	PWR	AEP
93.	River Bend	81.33	967	BWR	Entergy
94.	St. Lucie-1	80.71	1062	PWR	NextEra
95.	Watts Bar-2	77.25	1170	PWR	TVA
96.	ANO-2	74.15	1032	PWR	Entergy
97.	Grand Gulf	65.16	1485	BWR	Entergy
98.	Pilgrim	64.33	690	BWR	Entergy

[1]These figures have been rounded. There are no ties. Byron-2 is in 18th place, with 94.2991, and Farley-1 is in 19th place, with 94.2958. Quad Cities-2 is in 33rd place, with 92.8431, and Catawba-2 is in 34th place, with 92.8413. Limerick-1 is in 36th place, with 92.7284, and Oconee-2 is in 37th place, with 92.7258.

[2]This is the design electrical rating (DER) in megawatts (electric), effective as of December 31, 2019. If a reactor's rating has changed during the three-year period, the capacity factor is computed with appropriate weighting.

[3]The owner is also the reactor's operator, except in the case of Cooper, which is operated by Entergy.

Table II. Capacity Factor Change, 2014–2016 to 2017–2019

Rank	Reactor	Change (percentage points)
1.	Davis-Besse	11.96
2.	Wolf Creek	11.51
3.	Prairie Island-1	10.44
4.	Prairie Island-2	9.07
5.	Susquehanna-1	8.66
6.	Salem-2	7.74
7.	Browns Ferry-1	7.70
8.	Arnold	7.70
9.	Monticello	7.67
10.	South Texas-1	6.89
11.	Salem-1	5.93
12.	Fermi-2	5.74
13.	Indian Point-2	5.70
14.	Peach Bottom-2	5.46
15.	Browns Ferry-3	5.41
16.	Calvert Cliffs-1	5.23
17.	St. Lucie-2	5.17
18.	FitzPatrick	4.73
19.	Turkey Point-3	4.48
20.	Oconee-1	4.37
21.	McGuire-1	4.36
22.	Cooper	4.09
23.	Nine Mile Point-2	3.57
24.	Vogtle-1	3.42
25.	Sequoyah-1	3.25
26.	Turkey Point-4	3.25
27.	Surry-2	3.22
28.	Dresden-3	3.18
29.	Limerick-1	2.99
30.	Millstone-3	2.67
31.	Byron-2	2.55
32.	LaSalle-1	2.52
33.	Catawba-1	2.52
34.	Oconee-3	2.43
35.	Farley-2	2.29
36.	Hatch-1	2.27
37.	Quad Cities-2	2.24
38.	Vogtle-2	1.87
39.	Seabrook	1.75
40.	Surry-1	1.68
41.	Comanche Peak-1	1.64
42.	Susquehanna-2	1.56
43.	Harris	1.53
44.	LaSalle-2	1.39
45.	Cook-2	1.39
46.	Sequoyah-2	1.16
47.	Point Beach-2	1.04
48.	Calvert Cliffs-2	1.00
49.	Catawba-2	0.99
50.	North Anna-1	0.91
51.	Byron-1	0.80
52.	South Texas-2	0.76
53.	Brunswick-1	0.71
54.	Palo Verde-1	0.64
55.	Beaver Valley-1	0.63
56.	Braidwood-1	0.54
57.	Point Beach-1	0.36
58.	Farley-1	0.18
59.	North Anna-2	-0.09
60.	Ginna	-0.46
61.	Summer	-0.55
62.	McGuire-2	-0.90
63.	Braidwood-2	-1.33
64.	Dresden-2	-1.59
65.	Diablo Canyon-1	-1.64
66.	ANO-1	-1.77
67.	Cook-1	-1.78
68.	Watts Bar-1	-1.85
69.	Beaver Valley-2	-1.88
70.	Perry	-1.88
71.	Hope Creek	-1.99
72.	Millstone-2	-2.28
73.	Palo Verde-3	-2.45
74.	Palo Verde-2	-2.82
75.	Callaway	-2.90
76.	Columbia	-3.15
77.	Limerick-2	-3.26
78.	St. Lucie-1	-3.32
79.	Clinton	-3.33
80.	Robinson-2	-3.42
81.	Palisades	-3.57
82.	Oconee-2	-3.62
83.	Browns Ferry-2	-4.30
84.	Waterford-3	-4.31
85.	Peach Bottom-3	-4.72
86.	Diablo Canyon-2	-5.01
87.	Nine Mile Point-1	-5.33
88.	Hatch-2	-5.41
89.	Brunswick-2	-5.61
90.	River Bend	-6.11
91.	Grand Gulf	-6.47
92.	Three Mile Island-1	-7.24
93.	Indian Point-3	-7.27
94.	ANO-2	-8.43
95.	Comanche Peak-2	-8.78
96.	Quad Cities-1	-9.36
97.	Pilgrim	-24.79

These figures have been rounded; there are no ties. Watts Bar-2 is not included in this table because it began operation in 2016.

Table III. DER Net Capacity Factor of Multireactor Sites

Rank	Site	Factor	Owner
1.	Calvert Cliffs	101.57	Exelon
2.	Dresden	98.93	Exelon
3.	South Texas	97.95	STPNOC
4.	Vogtle	95.84	Southern
5.	Farley	95.76	Southern
6.	Peach Bottom	94.53	Exelon
7.	Oconee	94.44	Duke
8.	Browns Ferry	94.16	TVA
9.	Byron	94.08	Exelon
10.	FitzPatrick/Nine Mile Point	93.49	Exelon
11.	LaSalle	93.26	Exelon
12.	Catawba	93.25	Duke
13.	McGuire	92.89	Duke
14.	North Anna	92.78	Dominion
15.	Point Beach	92.25	NextEra
16.	Turkey Point	92.21	NextEra
17.	Susquehanna	92.12	Susquehanna
18.	Prairie Island	91.78	Xcel
19.	Quad Cities	91.75	Exelon
20.	Surry	91.04	Dominion
21.	Hatch	90.94	Southern
22.	Millstone	90.76	Dominion
23.	Palo Verde	90.65	APS
24.	Limerick	90.61	Exelon
25.	Braidwood	90.27	Exelon
26.	Beaver Valley	89.88	Energy Harbor
27.	Comanche Peak	89.52	Luminant
28.	Hope Creek/Salem	89.15	PSEG
29.	Indian Point	88.18	Entergy
30.	Diablo Canyon	87.25	PG&E
31.	Sequoyah	86.99	TVA
32.	Brunswick	86.68	Duke
33.	Cook	85.80	AEP
34.	St. Lucie	83.67	NextEra
35.	Watts Bar	81.44	TVA
36.	ANO	79.03	Entergy

Hope Creek and Salem are treated as a single site because they are adjacent and have the same owner; the two-unit Salem had a 2017–2019 factor of 89.07. FitzPatrick, which is adjacent to Nine Mile Point, was purchased by Exelon in March 2017, and the factors of the two plants have been combined in the table above since they now have the same owner; the two-unit Nine Mile Point had a 2017–2019 factor of 93.46.

Sourcing the data

Capacity factor is a measure of how well a reactor is performing up to its potential, represented as a percentage and using a ratio of actual output to maximum possible output over a defined time span. *Nuclear News* presents per-reactor capacity factors averaged over three years and has decades of comparable three-year totals to provide context.

Broadening the data set to include three calendar years of total generation lets readers spot sustained high (or low) performance and lessens the impact of planned and unplanned outages on a single year's capacity factor. *Nuclear News* presents this survey on a near-annual basis, and the three-year span changes each time; the 2017–2019 data are compared to 2014–2016 data and to data from earlier three-year periods, without overlaps.

We measure the electricity produced against a plant's design electrical rating (DER). These data are recorded in monthly operating reports submitted to INPO, which shares the data with the Nuclear Regulatory Commission. The NRC makes the reports public on a quarterly basis, and this survey is based on a compilation of that data (see Table I).

This is the place to note that the DERs for some reactors have not been updated to reflect uprates approved by the NRC. The rank of the two Calvert Cliffs units, for example, would be marginally lower if their DERs reflected uprates approved in 2009. We can expect the three Browns Ferry units to record a higher official DER to bring their stats in line with their licensed generating potential, now that all three units have been upgraded to support 14.3 percent extended power uprates approved in 2017. Peach Bottom, which was approved for 1.66 percent measurement uncertainty recapture uprates in 2017, deserves a commendation for increasing its DER within months of approval.

Here and now

For most of the three-year period 2017–2019, 98 reactors were in operation. Pilgrim and Three Mile Island-1 were permanently closed during 2019—Pilgrim on May 31 and TMI-1 on September 20—reducing the fleet to 96 reactors by the end of 2019.

This survey's set of 98 reactors is being compared to 99 in 2014–2016 and 104 in 2011–2013. There have been nine reactor closures since 2013: Crystal River-3, Kewaunee, San Onofre-2 and -3, Vermont Yankee, Fort Calhoun, Oyster Creek, Pilgrim, and TMI-1. While still operating at this writing, Indian Point-2 was to permanently shut down by the end of April. The Duane Arnold plant is scheduled to close in the fourth quarter of 2020.

Despite the reduced fleet, the median factor of 91.20 for 2017–2019 is up over half a percentage point from the median of 90.60 in 2014–2016 and from 89.32 in 2011–2013. The average factor is up by a similar amount, at 90.41 for 2017–2019, compared to 89.93 in 2014–2016 and 86.03 in 2011–2013 (reflecting a short-term generation dip following the Fukushima Daiichi accident in Japan). In the early days of the capacity factors survey, some poor performers pulled the fleet average several points below the median. Now that the performance gap has narrowed, similar medians and averages serve only to confirm and underscore the fleet's strength.

Fifty-eight reactors had capacity factors in 2017–2019 that were better than those in 2014–2016 (see Table II), a clear majority of the 98 reactors listed. These units deserve a nod of appreciation for their contributions to 2019's record generation.

Table IV. DER Net Capacity Factors of Owners of More Than One Site

Rank	Owner/Operator	Factor
1.	Southern	94.31
2.	Exelon	93.59
3.	Xcel	91.59
4.	Duke	91.42
5.	Energy Harbor	91.18
6.	Dominion	91.03
7.	NextEra	90.12
8.	TVA	88.38
9.	Entergy	79.52

Entergy is the contracted operator of Cooper. With Cooper included, Entergy's factor would be 81.58. Dominion's factor includes Summer, which was owned by SCANA Corporation/South Carolina Electric & Gas Company until January 1, 2019.

The median factor of the 36 multiunit sites was 91.77 for 2017–2019 (see Table III), up from 91.22 in 2014–2016, when only 35 multiunit sites were recorded (Watts Bar is the new addition). The nine fleet owners in 2017–2019 have a median factor of 91.18 (see Table IV), and while the median of 9 data points may have little significance, it is notably higher than in 2014–2016, when the same owners had a median factor of 89.39. The average for 2017–2019 is 90.13, while the average for 2014–2016 was 89.10.

The top and bottom quartiles of the 98 reactors included in this year's survey were also slightly higher in the most recent three-year period than in the one before, at 93.74 and 88.06 (see Fig. 2).

Boiling water reactors edged out pressurized water reactors in 2017–2019 by a slight margin: 33 BWRs had a median ca-

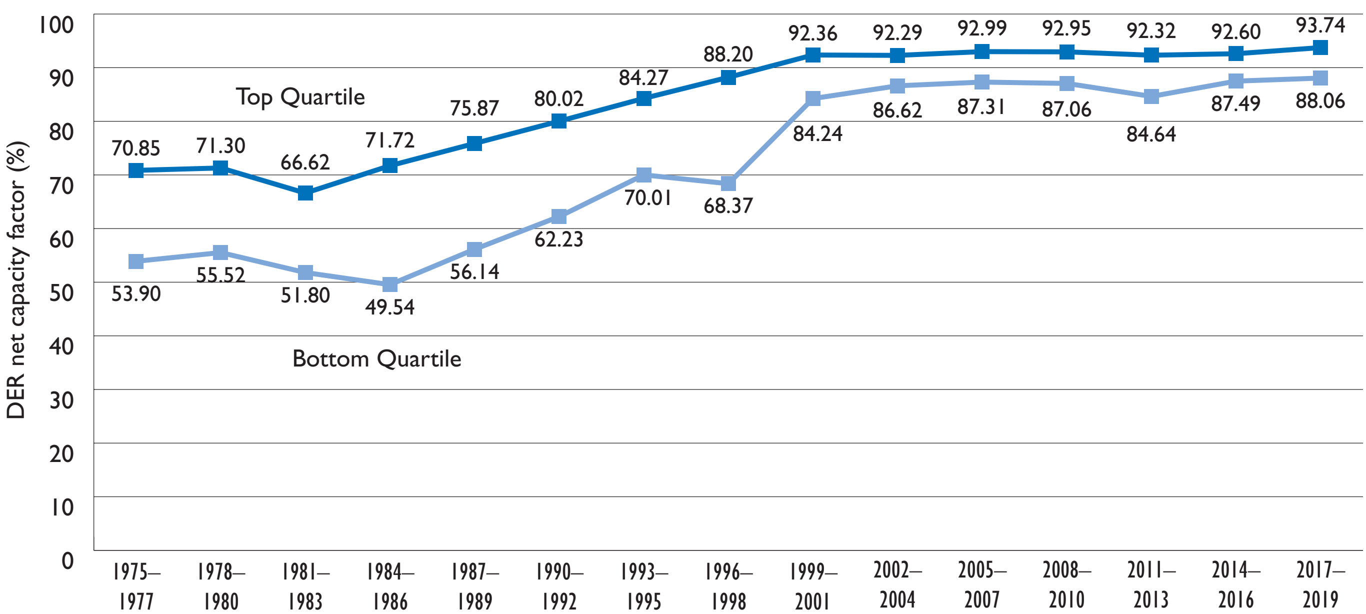

Fig. 2: All reactors, top and bottom quartiles.

pacity factor of 91.27, while 65 PWRs had a median capacity factor of 91.14 (see Fig. 3). In 2014–2016, the 34-BWR median was 90.33, and the 65-PWR median was 90.60.

Watts Bar-2 began operating in 2016, 20 years after Unit 1, and makes its debut in the capacity factors survey this year. Unit 2 had a rough 2017, including a five-month outage because of a steam condenser failure, and that is reflected in its 2017–2019 capacity factor of 77.25. If 2017 is excluded, Watts Bar-2's two-year average capacity factor for 2018 and 2019 would be 91.07.

The closures of Pilgrim and TMI-1 left the U.S. fleet with 32 BWRs and 64 PWRs. We calculated the capacity factors of both reactors as if they were capable of operating throughout 2019. This lowers their factors (perhaps unfairly) but maintains the integrity of our data; the decision to calculate factors of recently closed reactors by assuming a full three years of capacity was made back in 1990. If post-shutdown days are excluded from available capacity, Pilgrim, which lost seven months of generation, would have an improved capacity factor of 79.98 percent, while TMI-1, a perennial strong performer, would be ranked third overall, with a capacity factor of 99.50.

The planned closures of Arnold (a BWR) and Indian Point-2 (a PWR) during 2020 will leave the U.S. fleet with 94 reactors in operation. At least one more unit, Indian Point-3, will have closed by the time Southern Nuclear's Vogtle-3 enters commercial operation, and all bets are off on commercial operation dates for Vogtle's AP1000s, given the as-yet-unquantified impacts of the coronavirus pandemic.

Results during renewal

Previous capacity factor surveys have dissected stats for the fleet's older reactors to uncover the secrets of their longevity, ferret out signs of declining performance, or both. Just one year ago, in our analysis of 2016–2018 capacity factors, only 38 reactors had been operating past their initial 40-year license terms for at least three years. That subset of U.S. reactors now numbers 43. Six reactors—Beaver Valley-1, Browns Ferry-3, Brunswick-1, Calvert Cliffs-2, Salem-1, and St. Lucie-1—joined the group, while one, Oyster Creek, has departed the fleet.

Table V shows the capacity factors of those 43 reactors in each of the last four three-year periods as they approached and surpassed 40 years of operation. The 2017–2019 median factor of these units is 91.70, slightly higher than the 91.20 median for all 98 operating reactors, and 24 are above the 91.20 median.

Parsing the list of 43 mature reactors still further, at this writing the NRC has been notified of planned or submitted subsequent license renewal applications for 11 of these reactors, which would permit them to operate for 80 years by adding 20 more years to the 60 years already permitted following initial license renewal. The average 2017–2019 capacity factor for the 11 reactors is 93.17, which, on the incremental scale of nuclear capacity factor comparables, is quite high. Of those 11 reactors, which represent five plants—North Anna, Oconee, Peach Bottom, Surry, and Turkey Point—four (Turkey Point-3 and -4 and Peach Bottom-2 and -3) have already received subsequent license renewal approval. Clearly, utilities that have already invested in their plants and have seen those investments pay off are prepared to invest more. Maybe the U.S. fleet's older reactors are not so much "over the hill" as "king of the mountain."

Market impact

Calls for relief from unfavorable market pricing conditions for nuclear generators continue to be made. Progress on zero emissions credits (ZEC) means that some plants have gained an extra measure of protection in the past three years.

In July 2019, Ohio's Clean Air Act established a ZEC program, allowing that state to join four states with programs of their own—Connecticut, Illinois, New Jersey, and New York—and benefiting Energy Harbor's Davis-Besse and Perry plants. Pennsylvania Gov. Tom Wolf announced in October 2019 that his state would join the Regional Greenhouse Gas Initiative, and Energy Harbor credited that move as essential to the continued operation of the Beaver Valley plant in western Pennsylvania.

These protections are tenuous, however, because of legal challenges and a lack of control over outside circumstances, including the Federal Energy Regulatory Commission's December 2019 order to PJM Interconnection to extend the minimum offer price rule to include nuclear resources within PJM's territory that receive state subsidies such as ZECs. Unless the affected plants—in Illinois, New Jersey, and Ohio—can find a way to opt out of PJM's capacity market, the plants could lose their legislated ZEC benefits.

We depend on electricity being there when and where we need it. Housebound office workers with full Zoom calendars need reliable Wi-Fi that isn't plagued with intermittent drops, and the same goes for electricity. Intermittent renewables are threatening the stability of the grid, and of reliable generators like nuclear, but that threat could be mitigated through long-term power purchase agreements,

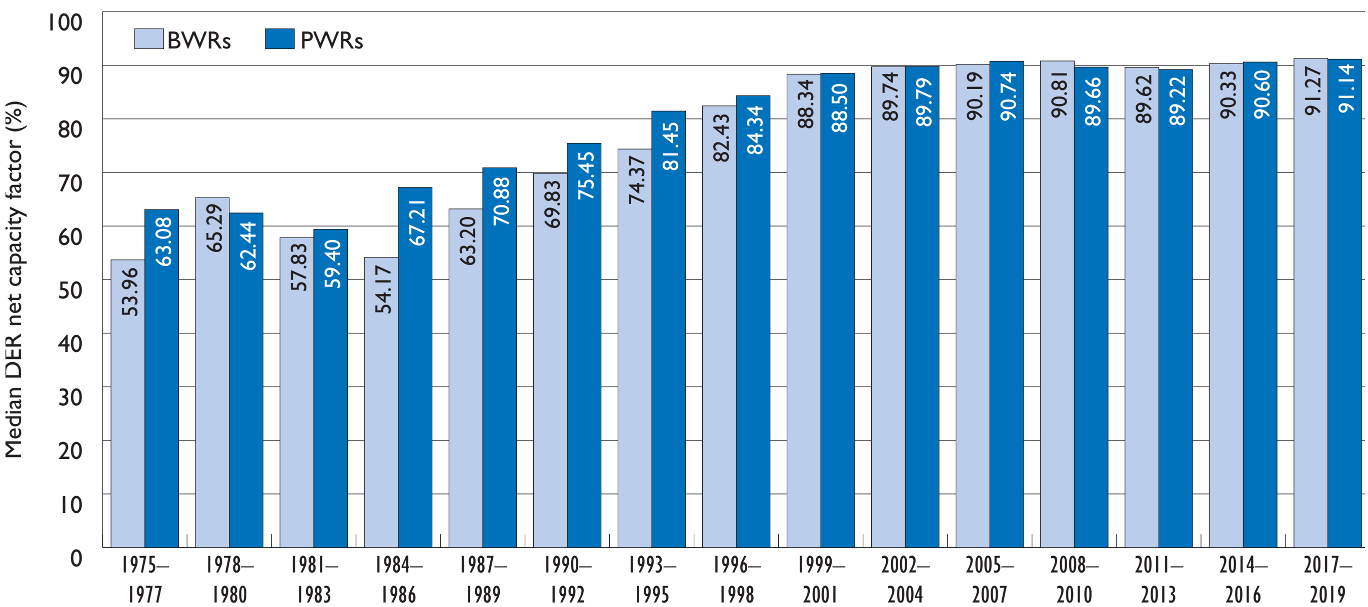

Fig. 3: Reactors by type. In the most recent seven periods, both pressurized water reactors and boiling water reactors have contributed to the U.S. fleet's performance.

Table V. DER Capacity Factors of Reactors With At Least Three Years of License Renewal

Reactor	2008–2010	2011–2013	2014–2016	2017–2019
ANO-1	89.67	81.76	86.73	**84.96**
Arnold	88.70	90.98	86.19	**93.89**
Beaver Valley-1	93.00	91.97	89.65	**90.28**
Browns Ferry-1	84.94	90.80	**90.05**	**97.75**
Browns Ferry-2	88.53	85.86	93.67	**89.37**
Browns Ferry-3	82.44	87.18	89.94	**95.35**
Brunswick-1	84.57	87.51	88.39	**89.10**
Brunswick-2	86.37	80.34	89.85	**84.24**
Calvert Cliffs-1	96.47	96.41	98.50	**103.73**
Calvert Cliffs-2	97.97	93.50	98.42	**99.41**
Cook-1	48.08	86.94	85.68	**83.91**
Cooper	87.25	85.80	86.93	**91.03**
Dresden-2	96.90	**98.26**	**97.78**	**96.20**
Dresden-3	92.74	97.32	**98.53**	**101.71**
FitzPatrick	95.28	93.90	88.84	**93.57**
Ginna	93.12	**90.37**	**94.06**	**93.60**
Hatch-1	86.49	91.88	91.84	**94.10**
Indian Point-2	89.27	93.45	**84.98**	**90.68**
Indian Point-3	93.79	92.39	92.97	**85.70**
Millstone-2	87.39	88.52	89.99	**87.71**
Monticello	86.92	**71.26**	**83.61**	**91.27**
Nine Mile Point-1	96.77	**88.45**	**97.03**	**91.70**

Reactor	2008–2010	2011–2013	2014–2016	2017–2019
Oconee-1	85.70	84.33	**90.66**	**95.02**
Oconee-2	88.96	89.22	**96.35**	**92.73**
Oconee-3	91.52	92.54	93.14	**95.57**
Palisades	90.66	84.35	**90.63**	**87.06**
Peach Bottom-2	92.77	94.92	**91.34**	**96.80**
Peach Bottom-3	94.43	91.15	96.98	**92.26**
Pilgrim	94.67	84.23	**89.12**	**64.33**
Point Beach-1	86.04	**86.75**	**91.34**	**91.69**
Point Beach-2	89.21	84.10	**91.76**	**92.80**
Prairie Island-1	87.43	85.51	**81.98**	**92.42**
Prairie Island-2	91.08	74.64	82.06	**91.13**
Quad Cities-1	96.52	99.85	**100.04**	**90.67**
Quad Cities-2	94.27	93.40	**90.60**	**92.84**
Robinson-2	77.03	**85.59**	**87.58**	**84.17**
Salem-1	92.34	90.59	83.49	**89.42**
St. Lucie-1	86.31	73.58	84.03	**80.71**
Surry-1	95.01	94.89	**88.52**	**90.20**
Surry-2	96.42	89.71	**88.66**	**91.87**
Three Mile Island-1	92.33	94.73	97.43	**90.19**
Turkey Point-3	88.43	73.02	**87.28**	**91.76**
Turkey Point-4	87.75	75.00	**89.42**	**92.66**

The reactors in this table have operated for at least three full years beyond their original license expiration dates. Green indicates a factor that is greater than or equal to 91.20 (the median for all reactors in 2017–2019), while orange indicates a factor less than 91.20. Twenty-four of the 43 reactors had a factor at or above the median of 91.20. The 2017–2019 median factor of these 43 units is 91.70, which is slightly higher than the median factor for all 98 reactors. The median for the same group of 43 reactors was 89.99 in 2014–2016, 89.22 in 2011–2013, and 89.67 in 2008–2010. **Bold type** allows for a rough comparison of the age of the reactors in this table. A factor is bold if the reactor was operating beyond its original license expiration date for the entirety of a three-year period; reactors with more bold factors are older. For example, Dresden-2, Ginna, Monticello, Nine Mile Point-1, Point Beach-1, and Robinson-2 reached their original license expiration dates in either 2009 or 2010 and are in bold type in the 2011–2013 column.

low-carbon portfolio standards, ZECs, a carbon tax, or capacity market reforms that reward resiliency.

Those risk mitigation strategies assume that nuclear's energy is being sold into an electricity market and that a high capacity factor is the goal. A reactor that can enjoy extended runs at full power and receive a fair price for that electricity has the best of both worlds.

Other options

Intermittent renewable generation causes daily net load and price fluctuations in some electricity markets. Solar generation peaks in the middle of the day, reducing the net load and sometimes pushing prices into negative territory before demand returns in the evening to call for a high ramp rate from dispatchable generation. Wind is less predictable and causes an increasing hourly ramp rate, uncertainty in net load, and increasing ramp range.

Grid operators need to carefully balance generation and consumption around the clock. Some U.S. nuclear operators have already introduced load following, but reactor engineers and operators must ramp power judiciously to avoid unnecessary wear and tear on equipment that can have an impact on maintenance, reliability, and inspections.

Coordinating dispatchable nuclear generation and intermittent renewable generation could allow nuclear plants to profit when electricity prices fall by using a reactor's output to generate hydrogen, industrial process heat, or stored heat.

The Department of Energy is exploring options for generating hydrogen from a nuclear plant's output in both regulated and unregulated electricity markets. Studies are leading to planned demonstrations, including a 1- to 3-MWe low-temperature electrolysis unit to be sited at Energy Harbor's Davis-Besse plant in Oak Harbor, Ohio.

Davis-Besse recorded an excellent capacity factor of 96.79 for 2017–2019, but it wasn't always such a strong performer. Operators discovered significant degradation of the reactor's vessel head in March 2002, and the plant entered a two-year shutdown. A permanent shutdown by May 2020 was threatened in 2018 by then operator FirstEnergy Solutions (which has since emerged from bankruptcy as Energy Harbor). Now, with high capacity factors and a planned hydrogen production demonstration, Davis-Besse may have a new lease on life.

Improving a reactor's economic profile in future hydrogen or process heat markets means less electricity production and lower capacity factors. As utilities assess their options, we may need to assess how we measure performance. Can we cut to the chase and rank reactors by the profit they yield? Count the hours of criticality? Or shall we calculate capacity factors from the demand side, and ask not what a reactor can do for the grid, but what the grid wants from a reactor?

The COVID grid

It is unclear what impact the coronavirus pandemic will have on nuclear capacity factors. Shortages are the danger—shortages of staff, or of personal protective equipment—but could that mean a shortage of nuclear-sourced electricity?

At this writing, operators have put prearranged pandemic plans—first developed in 2006 and recently updated—into practice. But no nuclear plant has been operated during a pandemic before. Plants, and the NRC, will do whatever they need to do, whether that is isolating key staff at plants, shedding unnecessary tasks, delaying refueling, or temporarily curtailing operations.

Low electricity demand brought on by manufacturing slowdowns can tax grid operators just as high demand does. If electricity demand falls, and variable renewables such as wind and solar meet a bigger share of that demand, maintaining grid stability could become more challenging.

COVID-19 has put most industries on a precarious footing. The safety-conscious nuclear community is better prepared than most. This is a time to look back on the past challenges that have spurred the fleet to operating excellence and remember that change is an opportunity for success. NN