U.S. capacity factors: Holding steady into license renewal

So far, reactors operating past the 40-year mark are performing about as well as newer units.

By E. Michael Blake

Whatever the economic prospects may be for power reactors in the United States, performance has remained at the level established at the start of the millennium after steady improvement over the previous 20 years. The 99 reactors in operation throughout the three-year period 2013–2015 had a median design electrical rating net capacity factor of 90.41 percent, up from 89.59 percent in 2010–2012. Because some reactors have closed in the past few years, this survey's ability to compare like with like has gone somewhat awry, so we will note that the median capacity factor of all 104 reactors still licensed in 2010–2012 was 89.56. What is probably most significant is that the vast majority of the power reactor fleet, in various states and with many different owner-operators, continues to perform at a high level.

This has all happened while reactors have been assessed for and, in many cases, put through physical and procedural modifications to comply with Nuclear Regulatory Commission orders and other initiatives related to lessons learned from the 2011 Fukushima Daiichi accident in Japan. In general, structural alterations (such as allowing the place-

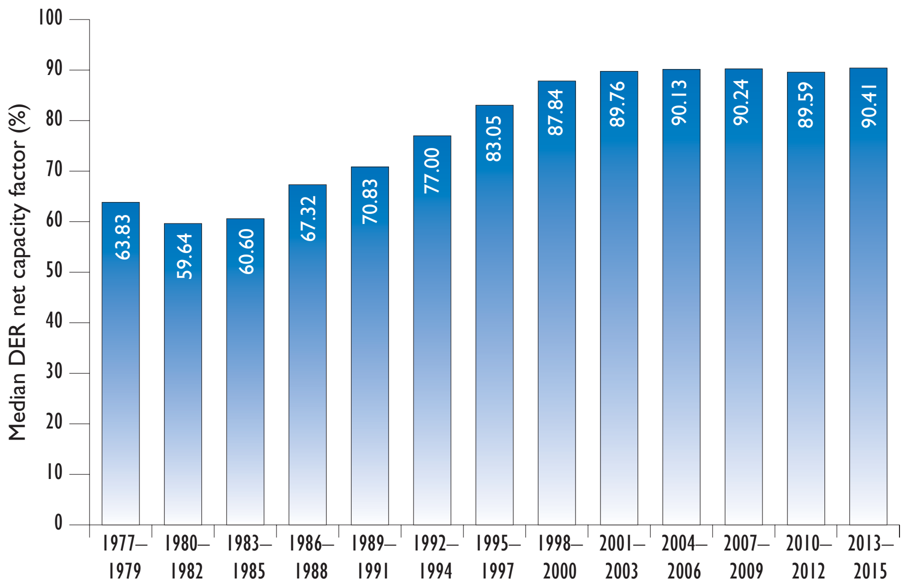

Fig. 1: All reactors. The median DER net capacity factor of the 99 reactors licensed at the end of 2015—90.41 percent—is the highest ever recorded in this grouping of three-year periods (although in the survey for 2006–2008, with different start and end points for the three years, the median was 90.60 percent). The departure of five reactors from the database has not made a significant difference because two of the five performed above the median as their operational eras were ending, and the other three performed below the median. The increase in the median is small, but the improvement trend exists essentially throughout the fleet. There were 43 reactors in the database in 1977–1979, and in subsequent periods there were 53, 60, 77, 97, 102, 103, and 104 in the next four. The capacity factor shown above for 2010–2012 is that of the 99 reactors also in service in 2013–2015; the 104-reactor median in 2010–2012 was 89.56, 0.03 percentage points lower than the 99-reactor median.

Table I.
2013–2015 DER Net Capacity Factors of Individual Reactors

Rank	Reactor	Factor[1]	Rating[2]	Type	Owner[3]
1.	Calvert Cliffs-1	101.40	845	PWR	Exelon
2.	Quad Cities-1	101.27	963.99	BWR	Exelon
3.	Dresden-3	100.66	879	BWR	Exelon
4.	Dresden-2	95.74	894	BWR	Exelon
5.	Farley-1	95.71	854	PWR	Southern
6.	Three Mile Island-1	95.65	819	PWR	Exelon
7.	Farley-2	95.29	855	PWR	Southern
8.	Indian Point-2	95.11	1035	PWR	Entergy
9.	Oconee-3	95.02	881	PWR	Duke
10.	LaSalle-1	94.31	1178	BWR	Exelon
11.	Nine Mile Point-1	94.18	613	BWR	Exelon
12.	Browns Ferry-1	93.88	1120	BWR	TVA
13.	Comanche Peak-2	93.84	1207	PWR	Luminant
14.	Ginna	93.83	585	PWR	Exelon
15.	Calvert Cliffs-2	93.61	845	PWR	Exelon
16.	Byron-1	93.59	1213	PWR	Exelon
17.	Peach Bottom-2	93.52	1308	BWR	Exelon
18.	FitzPatrick	93.50	816	BWR	Entergy
19.	McGuire-2	93.49	1187	PWR	Duke
20.	Seabrook	93.23	1248	PWR	FPL
21.	Nine Mile Point-2	93.20	1299.9	BWR	Exelon
22.	Browns Ferry-3	93.17	1120	BWR	TVA
23.	Braidwood-1	93.06	1268	PWR	Exelon
24.	North Anna-1	92.85	973	PWR	Dominion
25.	Comanche Peak-1	92.82	1218	PWR	Luminant
26.	Byron-2	92.71	1186.4	PWR	Exelon
27.	Quad Cities-2	92.68	957.3	BWR	Exelon
28.	Oconee-1	92.64	865	PWR	Duke
29.	Palo Verde-1	92.58	1333	PWR	APS
30.	Limerick-1	92.52	1205	BWR	Exelon
31.	Hatch-1	92.20	885	BWR	Southern
32.	Beaver Valley-2	92.19	960	PWR	FENOC
33.	Vogtle-2	92.06	1169	PWR	Southern
34.	Catawba-2	92.03	1180	PWR	Duke
35.	Vogtle-1	91.98	1169	PWR	Southern
36.	Braidwood-2	91.94	1241	PWR	Exelon
37.	North Anna-2	91.60	973	PWR	Dominion
38.	Millstone-3	91.59	1229	PWR	Dominion
39.	Point Beach-2	91.57	615	PWR	FPL
40.	Catawba-1	91.52	1174	PWR	Duke
41.	Brunswick-1	91.41	983	BWR	Duke
42.	Clinton	91.39	1062	BWR	Exelon
43.	Palo Verde-2	91.26	1336	PWR	APS
44.	Cooper	91.12	815	BWR	NPPD
45.	Cook-2	90.96	1107	PWR	IMP
46.	Palo Verde-3	90.70	1334	PWR	APS
47.	Oconee-2	90.65	872	PWR	Duke
48.	Millstone-2	90.55	877.2	PWR	Dominion
49.	Salem-1	90.47	1169	PWR	PSEG
50.	Point Beach-1	90.41	615	PWR	FPL
51.	Diablo Canyon-1	90.29	1138	PWR	PG&E
52.	Davis-Besse	90.29	908	PWR	FENOC
53.	Indian Point-3	90.23	1048	PWR	Entergy
54.	Arnold	90.05	621.9	BWR	FPL
55.	Peach Bottom-3	90.04	1179	BWR	Exelon
56.	Hope Creek	89.76	1228.1	BWR	PSEG
57.	Hatch-2	89.63	908	BWR	Southern
58.	Limerick-2	89.60	1205	BWR	Exelon
59.	South Texas-1	89.54	1250.6	PWR	STPNOC
60.	River Bend-1	89.45	967	BWR	Entergy
61.	Watts Bar-1	89.25	1160	PWR	TVA
62.	Oyster Creek	89.13	650	BWR	Exelon
63.	Beaver Valley-1	89.04	963	PWR	FENOC
64.	Surry-2	89.04	874	PWR	Dominion
65.	Susquehanna-1	88.58	1287	BWR	PPL
66.	Browns Ferry-2	88.57	1120	BWR	TVA
67.	Sequoyah-2	88.36	1177.46	PWR	TVA
68.	Diablo Canyon-2	88.19	1151	PWR	PG&E
69.	Grand Gulf-1	88.07	1485	BWR	Entergy
70.	South Texas-2	87.72	1250.6	PWR	STPNOC
71.	Summer-1	87.63	972.7	PWR	SCE&G
72.	Waterford-3	87.45	1173	PWR	Entergy
73.	Surry-1	87.41	874	PWR	Dominion
74.	Callaway	87.23	1228	PWR	Ameren
75.	LaSalle-2	87.23	1178	BWR	Exelon
76.	McGuire-1	87.06	1160	PWR	Duke
77.	Harris-1	86.85	973	PWR	Duke
78.	Columbia	86.20	1153	BWR	Northwest
79.	Palisades	85.99	805	PWR	Entergy
80.	Salem-2	85.85	1181	PWR	PSEG
81.	Sequoyah-1	85.69	1184.37	PWR	TVA
82.	Perry	85.19	1268	BWR	FENOC
83.	Prairie Island-1	85.11	557	PWR	NSP
84.	St. Lucie-1	84.33	1062	PWR	FPL
85.	Susquehanna-2	84.27	1287	BWR	PPL
86.	Robinson-2	84.14	795	PWR	Duke
87.	Cook-1	84.14	1084.37	PWR	IMP
88.	Brunswick-2	83.37	980	BWR	Duke
89.	Pilgrim	83.21	690	BWR	Entergy
90.	Turkey Point-3	83.08	831	PWR	FPL
91.	St. Lucie-2	82.80	1074	PWR	FPL
92.	ANO-2	81.73	1032	PWR	Entergy
93.	ANO-1	81.29	850	PWR	Entergy
94.	Turkey Point-4	80.92	840	PWR	FPL
95.	Wolf Creek	77.37	1200	PWR	WCNOC
96.	Prairie Island-2	75.33	557	PWR	NSP
97.	Fermi-2	72.02	1150	BWR	DTE
98.	Monticello	70.77	666.7	BWR	NSP
99.	Fort Calhoun	59.17	502	PWR	OPPD

[1] These figures are rounded off. There are no ties. For example, Diablo Canyon-1 is in 51st, with 90.2946, and Davis-Besse is in 52nd, with 90.2916.
[2] This is the design electrical rating (DER) in megawatts (electric), effective as of December 31, 2015. If the reactor's rating has changed during the three-year period, the capacity factor is computed with appropriate weighting.
[3] As of December 31, 2015. In most cases this also means the reactor's operator, but Entergy and Exelon are the contracted operators of Cooper and Fort Calhoun, respectively.

ment of emergency power or water supplies outside containment) are scheduled during refueling outages, so there have been no long stretches of downtime associated with Fukushima compliance. There have, however, been expenses beyond what would be associated with normal operation.

Some of the tasks are being completed; in particular, compliance with the NRC's 2012 order regarding reliable spent fuel pool instrumentation has reached the final phases (safety evaluation and inspection) for more than half of the reactors now in operation. Also in progress for many reactors are the conversion to risk-informed fire protection under the National Fire Protection Association's Standard 805, the long-pending potential issue of sump strainer clogging in pressurized water reactors, and the open phase issue on the availability of electrical power. The fire protection change is intended, among other things, to save money and reduce regulatory burden in the long term, but for now it is mainly taking up licensee resources that are not otherwise available for electricity production from uranium fission.

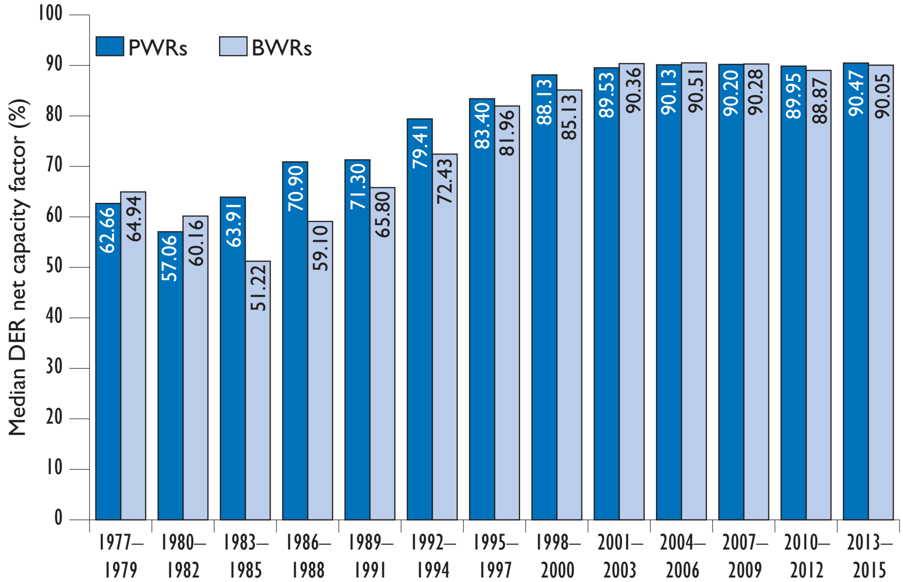

Fig. 2: Reactors by type. Both pressurized water reactors and boiling water reactors showed improvement, compared to the 2010–2012 medians of both the 65 PWRs and 34 BWRs still operating (shown in the graph above) and the 69 PWRs and 35 BWRs licensed at that time. In 2010–2012, the 69-PWR median was 89.86 percent, and the 35-BWR median was 89.01 percent. During the past 15 years, neither reactor type has had an advantage of more than a percentage point over the other.

The economic competitiveness of nuclear power in some markets, and under some pricing conditions, has been covered frequently in these pages, and surely will be covered again. The contributing factors will not be rehashed in this survey, nor will there be excessive hand-wringing over the inherent contradiction of early reactor closures with the effort to reduce carbon dioxide emissions in electricity production. It will merely be stated as relevant information that Entergy plans to close FitzPatrick next year and Pilgrim no later than 2019, and that Exelon has planned for some time not to operate Oyster Creek past 2019, the halfway point of its license renewal. Exelon has also hinted on several occasions that other reactors in its fleet may close early if they are not sufficiently compensated through grid operators' auction processes.

One of the plants said to be at risk is Quad Cities, where Unit 1 had a 2013–2015 capacity factor of 101.27 percent, putting it in second place in Table I. This number is inflated to some extent because a power uprate that was officially declared to be in effect as of last November had been part of the plant's operation much earlier, leading to a capacity factor of 104.50 percent in 2012–2014. In fact, Unit 1's total output for those three years was slightly less than that of Unit 2, which had an earlier established uprate and a factor of 92.68, two places below the top quartile. With Exelon having invested in extended power uprates at Quad Cities, it would seem reasonable that the company would seek several years of return on the investment. The renewed licenses of Quad Cities are in effect until December 2032.

The first sign that a reactor owner might buck the trend of early closure for smaller, older reactors came last year, when Dominion Generation stated that it expects to apply to the NRC in 2019 for second renewals of the licenses of the two Surry reactors in Virginia. It is true that Dominion made the decision regarding the 21st century's first early closure of a fully operable reactor based on purely economic grounds, closing Wisconsin's Kewaunee in May 2013, but this reactor was operated on a merchant basis, and long-term power purchase agreements expired with the term of the first license. Surry is in Dominion's traditional home territory and was licensed by the company that became Dominion.

Second renewal is hardly a new idea. The Department of Energy's Office of Nuclear Energy, through its Light Water Reactor Sustainability Program, has been exploring for several years the issues, needs, and improvements that could allow a reactor designed in the 1960s and first irradiated in the 1970s to continue to operate to its 80-year mark. So far, there is not a vast amount of data on performance by reactors in their first renewals past the 40-year mark, but those data will nonetheless be examined after the basic 2012–2015 information for all reactors, separately and in groups, is summarized.

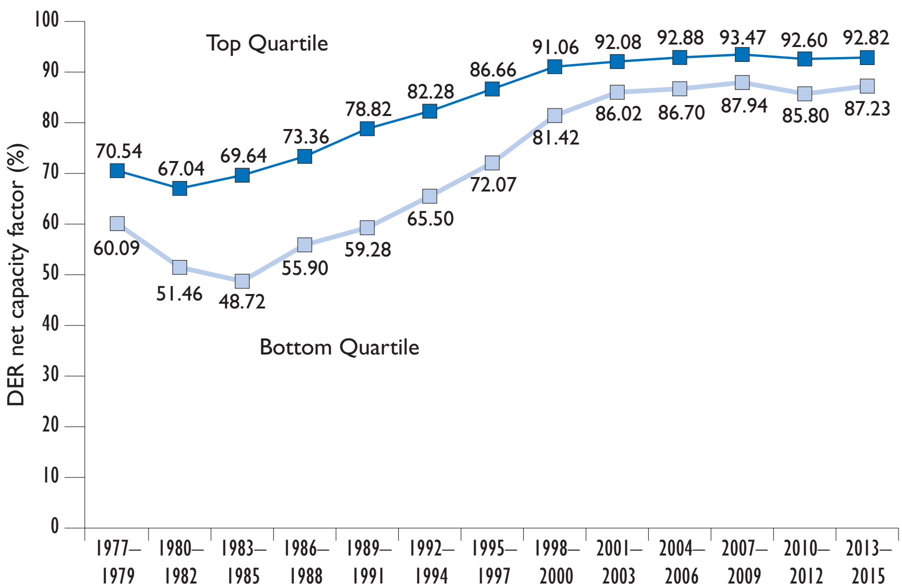

Fig. 3: All reactors, top and bottom quartiles. The top quartile tends not to vary much, because there is only so much room, statistically, between that point and nonstop full-power operation. The bottom quartile might be a better measure of the entire fleet's trend, and in 2013–2015 that figure was close to the best that it has ever been. As with the other graphs, this one shows the current 99 reactors in the last two periods; among all 104 reactors in 2010–2012, the top quartile was 92.60 and the bottom quartile was 85.80, in each case less than a tenth of a percentage point different from what is shown above.

Table II.
Capacity Factor Change, 2010–2012 to 2013–2015

Rank	Reactor	Change (percentage points)	Rank	Reactor	Change (percentage points)	Rank	Reactor	Change (percentage points)
1.	Fort Calhoun	+17.98	34.	Millstone-2	+2.86	67.	Prairie Island-1	-1.49
2.	Susquehanna-1	+12.44	35.	Hatch-1	+2.67	68.	Hope Creek	-1.78
3.	St. Lucie-1	+12.28	36.	Sequoyah-2	+2.56	69.	Cook-1	-2.65
4.	Davis-Besse	+12.08	37.	Braidwood-1	+2.43	70.	Comanche Peak-2	-2.68
5.	Turkey Point-3	+10.96	38.	Watts Bar-1	+2.16	71.	Sequoyah-1	-2.78
6.	Browns Ferry-3	+10.66	39.	FitzPatrick	+1.83	72.	Braidwood-2	-2.81
7.	North Anna-1	+9.98	40.	Cook-2	+1.74	73.	Comanche Peak-1	-2.90
8.	Calvert Cliffs-1	+9.77	41.	LaSalle-1	+1.72	74.	Callaway	-2.94
9.	Seabrook	+9.58	42.	Hatch-2	+1.60	75.	Vogtle-2	-2.96
10.	Columbia	+9.11	43.	Farley-2	+1.50	76.	Summer	-3.03
11.	Point Beach-2	+8.85	44.	Susquehanna-2	+1.14	77.	Wolf Creek	-3.12
12.	Brunswick-1	+8.79	45.	Three Mile Island-1	+1.13	78.	Harris	-3.23
13.	St. Lucie-2	+8.68	46.	Peach Bottom-2	+1.03	79.	Brunswick-2	-3.23
14.	Browns Ferry-1	+7.88	47.	Farley-1	+1.01	80.	McGuire-1	-3.25
15.	Robinson-2	+7.86	48.	Salem-1	0.88	81.	Calvert Cliffs-2	-3.27
16.	McGuire-2	+7.67	49.	Quad Cities-1	0.81	82.	Beaver Valley-1	-3.60
17.	Dresden-3	+7.30	50.	Palisades	0.69	83.	Perry	-3.82
18.	Indian Point-2	+7.05	51.	Catawba-1	0.50	84.	Salem-2	-4.01
19.	Grand Gulf	+6.85	52.	Palo Verde-3	0.46	85.	Clinton	-4.04
20.	Oconee-1	+6.77	53.	Diablo Canyon-1	0.34	86.	Dresden-2	-4.33
21.	Palo Verde-1	+6.12	54.	Millstone-3	0.34	87.	Diablo Canyon-2	-4.43
22.	Limerick-1	+5.98	55.	Byron-2	0.10	88.	River Bend	-4.44
23.	Oconee-3	+5.81	56.	Quad Cities-2	0.08	89.	Indian Point-3	-4.71
24.	Nine Mile Point-2	+5.47	57.	Oconee-2	-0.01	90.	Turkey Point-4	-5.01
25.	Cooper	+5.36	58.	Browns Ferry-2	-0.15	91.	Peach Bottom-3	-5.81
26.	North Anna-2	+5.34	59.	Fermi-2	-0.20	92.	Prairie Island-2	-7.60
27.	Arnold	+4.38	60.	Beaver Valley-2	-0.37	93.	ANO-2	-7.78
28.	Ginna	+3.75	61.	Waterford-3	-0.38	94.	Surry-1	-7.88
29.	Point Beach-1	+3.65	62.	Limerick-2	-0.87	95.	LaSalle-2	-8.64
30.	Oyster Creek	+3.62	63.	Surry-2	-1.02	96.	South Texas-1	-9.22
31.	South Texas-2	+3.26	64.	Palo Verde-2	-1.03	97.	Pilgrim	-9.79
32.	Nine Mile Point-1	+3.18	65.	Vogtle-1	-1.29	98.	ANO-1	-10.17
33.	Byron-1	+3.14	66.	Catawba-2	-1.47	99.	Monticello	-11.24

This time, back over 90

In this survey, power reactor performance is determined entirely by electricity produced for people in general. A reactor's license and the physical limits of how much fuel the reactor can hold and what can be done with the energy released from it dictate the maximum thermal output. The plant's other equipment determines how much electricity can leave the plant. There are several ways to express a plant's capability. This survey uses design electrical rating (DER) as the closest measure of what a reactor is intended to do. For a view of sustained performance, this survey computes DER capacity factor over a period of three calendar years. (Because the survey has been presented each year, the three-year span changes each time; the 2013–2015 data overlap the 2012–2014 data examined in last year's survey but are compared to 2010–2012 data and those of earlier three-year periods, without overlaps.)

A reactor's DER usually changes only for the better, through heat rate improvements or power uprates. Combined with operational revisions and tightening of the time spent in refueling outages, the national fleet has been able to produce about as much electricity with 99 reactors as it did in many earlier years with 104. During 2015, power uprates went into effect as follows: Beaver Valley-1, 963 MWe (from 911); Beaver Valley-2, 960 MWe (from 904); McGuire-2, 1,187 MWe (from 1,163); Peach Bottom-2, 1,308 MWe (from 1,179); and Quad Cities-1, 963.99 MWe (from 866). This can be thought of (or not) as an increase in the country's nuclear capacity of 358.99 MWe, without the addition of any new reactors.

The raw data (each reactor's electricity production and DERs, with the latter's change dates) are recorded as monthly operating reports through the Institute of Nuclear Power Operations, which shares the data with the NRC, which then makes the reports public on a quarterly basis. The survey is made up from the compilation and grouping of the data as needed to produce the results shown here.

As stated above, the median factor in 2013–2015 is up by either 0.82 or 0.85 percentage points from the median in 2010–2012. The average factor is also up by a similar amount, at 89.52 in 2013–2015 compared to the 99-reactor 88.50 in 2010–2012. The 104-reactor average then was 87.17, affected by three reactors that were destined never to restart (Crystal River-3 and San Onofre-2 and -3) and one that eventually resumed operation (Fort Calhoun). In 2007–2009, the 104-reactor average was 89.54. This survey uses the median of a data set to assess performance, but sometimes an average can provide perspective (although that belief may be open to question because the differences are so small).

The improvement in the fleet as a whole is not the result of the removal of closed reactors from the data set. Fifty-six reactors had better capacity factors in 2013–2015 than in 2010–2012 (see Table

Table III.
DER Net Capacity Factor of Multireactor Sites[1]

Rank	Site	Factor	Owner
1.	Dresden	98.18	Exelon
2.	Calvert Cliffs	97.50	Exelon
3.	Quad Cities	96.77	Exelon
4.	Farley	95.50	Southern
5.	Nine Mile Point	93.51	Exelon
6.	Comanche Peak	93.33	Luminant
7.	Byron	93.15	Exelon
8.	Oconee	92.78	Duke
9.	Indian Point	92.65	Entergy
10.	Braidwood	92.50	Exelon
11.	North Anna	92.22	Dominion
12.	Vogtle	92.02	Southern
13.	Browns Ferry	91.87	TVA
14.	Peach Bottom	91.80	Exelon
15.	Catawba	91.78	Duke
16.	Palo Verde	91.51	APS
17.	Millstone	91.15	Dominion
18.	Limerick	91.06	Exelon
19.	Point Beach	90.99	FPL
20.	Hatch	90.90	Southern
21.	LaSalle	90.77	Exelon
22.	Beaver Valley	90.61	FENOC
23.	McGuire	90.29	Duke
24.	Diablo Canyon	89.24	PG&E
25.	Hope Creek/Salem	88.70	PSEG
26.	South Texas	88.63	STPNOC
27.	Surry	88.22	Dominion
28.	Cook	87.58	IMP
29.	Brunswick	87.40	Duke
30.	Sequoyah	87.02	TVA
31.	Susquehanna	86.42	Talen/SN
32.	St. Lucie	83.57	FPL
33.	Turkey Point	81.99	FPL
34.	ANO	81.53	Entergy
35.	Prairie Island	80.22	NSP

[1] Because Nine Mile Point and FitzPatrick have different owners, Nine Mile Point is listed here as a multireactor site, but FitzPatrick is not included, even though the plants are on adjacent properties; combined, Nine Mile Point and FitzPatrick would have a 2013–2015 factor of 93.51. Hope Creek and Salem are treated as a single site because they are adjacent and have the same owner; the two-reactor Salem had a 2013–2015 factor of 88.15.

II), with poorer factors for the other 43; even in a sample of 104, 56 would be a majority. There were some long outages in progress in 2010–2012, and they are all nearly over. Fort Calhoun, forced off line by severe flooding in 2011 and kept down after significant operational and equipment problems were identified, has been back in normal operation for more than two years, and its three-year factor for 2014–2016 might lift it out of last place in Table I. The top and bottom quartiles of the 99 reactors, like the median, were also slightly higher in the most recent three-year period than in the one before (see Fig. 3), and while they did not reach the levels of 2007–2009, the differences are extremely small. (Please excuse the repetition of that point.)

Table IV.
DER Net Capacity Factors of Owners of More Than One Site[1]

Rank	Owner/Operator	Factor
1.	Exelon Generation	93.42
2.	Southern Nuclear	92.69
3.	Dominion Generation	90.63
4.	Duke Energy	89.94
5.	TVA Nuclear	89.77
6.	FirstEnergy Nuclear	88.83
7.	Entergy Nuclear	87.79
8.	FPL/NextEra	86.85
9.	Northern States Power–Minnesota	76.76

[1] Entergy and Exelon are the contract operators of Cooper and Fort Calhoun, respectively. With Cooper included, Entergy's factor would be 88.05. With Fort Calhoun included, Exelon's factor would be 92.67.

Pressurized water reactors retained their slight edge over boiling water reactors in 2013–2015, although both groups improved over their 2010–2012 medians. To the extent that a factor of 90 percent is a benchmark for sufficient performance, 55 of the 99 reactors exceeded it, although there is probably nothing wrong with a factor of 85, given that many reactors began operation with rate-base expectations of 65 percent capacity. The median factor of the 35 multiunit sites was 91.06, up from 90.35 in 2010–2012 (see Table III). With San Onofre included in the latter group, the median was 90.05. The Exelon-Constellation and Duke-Progress mergers make it difficult to compare multisite owners then and now; the nine fleet owners in 2013–2015 have a median factor of 89.77 (see Table IV), while the 11 owners in 2010–2012 had a median of 89.31.

Results during renewal

This survey has focused on older reactors a few times in the past, and it is now possible to look not at how those reactors were doing as they approached their renewal periods, but at how they've done during those periods. With only one new reactor in startup (Watts Bar-2) and four more under construction (Summer-2 and -3 and Vogtle-3 and -4), the nuclear electricity enterprise in the United States will clearly need existing reactors to be productive for many more years to help limit carbon dioxide emissions from the electricity sector until conditions more generally favor new reactor construction. Also, while strong performance did not outweigh economic considerations in the closures of Kewaunee and Vermont Yankee, there may be other plants for which a high capacity factor might tip the scale in favor of continued operation.

Fifteen reactors have operated for at least one full three-year period following the renewal of their licenses. This group includes Quad Cities-1 and -2, which completed 40 years of commercial operation in February 2013 but were licensed in December 1972, so renewal took effect just before the start of 2013. Table V shows the 15 units' capacity factors in each of the last three three-year periods. Numbers in bold are completely in renewal periods; Nine Mile Point-1 and Oyster Creek, which began commercial operation before the end of 1969, have operated for two periods under renewed licenses. The "trend" column shows the survey's perhaps arbitrary judgment of how the reactor has been progressing through these three periods.

While this survey is based on number-crunching, it is our belief that the process is worthwhile only if it allows meaningful conclusions to be drawn. This isn't about statistics for their own sake, and if nothing can be concluded, the exercise should not continue. (Having read far too many published papers with charts showing three data points in error bars as tall as trees through which a wide variety of contradictory curves could be drawn, the author is comfortable with placing qualitative terms in the "trend" column.)

As it happens, the 2013–2015 median factor of these 15 units is 90.41, the same

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

Reactor	2007–2009	2010–2012	2013–2015	Trend
Dresden-2	93.60	100.07	95.74	mixed
Dresden-3	95.77	93.36	100.66	up
Ginna	93.09	90.08	93.83	even
Monticello	83.73	82.02	70.77	down
Nine Mile Point-1	93.48	91.00	94.18	even
Oyster Creek	86.10	85.52	89.13	up
Palisades	88.72	85.29	85.99	down
Pilgrim	90.28	93.00	83.21	down
Point Beach-1	85.04	86.76	90.41	up
Point Beach-2	90.58	82.72	91.57	mixed
Quad Cities-1	93.45	100.46	101.27	even
Quad Cities-2	95.90	92.60	92.68	even
Robinson-2	87.66	76.28	84.14	mixed
Surry-1	94.96	95.28	87.41	down
Turkey Point-3	87.32	72.12	83.08	mixed

as that of all 99 reactors (represented by Point Beach-1, eighth in this group and 50th in Table I). The data set is probably too small for further chopping to be meaningful (the top quartile here would be higher, and the bottom quartile lower, than those of all 99). Ten of the 15 had higher factors in 2013–2015 than in 2010–2012, but three of them were higher by less than a percentage point. Seven of the 15 had higher factors in 2013–2015 than in either 2010–2012 or 2007–2009.

Because the group is so small, one must try to make allowances for the power uprates at Dresden and Quad Cities, and how their official declaration dates may have influenced their factors. We believe that it should be conceded (as noted in the earlier passage on Quad Cities-1) that performance probably has changed to lesser degrees than indicated by these numbers, and also that these plants' adoption of fixes to the steam dryer cracking issue that has affected a number of uprated BWRs must have been effective. By any reasonable adjustment of the capacity factors, Dresden and Quad Cities are performing impressively.

These and other factors have led us to the one-word assessments placed in the "trend" column. The use of three periods shows that most plants have gone up, then down, or down, then up. Only one has gone down, then down, and two have gone up, then up (and one of those two is Quad Cities-1). Thus we have decided that the overall trends of three reactors are mainly up, with four mainly down, four appearing to be even, and four showing mixed results. Over the fleet as a whole, it can certainly not be said that reactors in general just keep getting better and better; that appears to have been the case in the 1980s and 1990s, but since then, performance has been on a plateau (of very high quality). What does appear to be the case, in the still early years of license renewal, is that there does not appear to be a substantial drop off in performance (with the possible exception of Monticello).

From the perspective of a worker at a nuclear plant, there is no sudden shift from the original license to renewal. Much of the aging-management process happens outside of the immediate activities of a control room, with some new procedures and equipment worked in years before a reactor is officially in renewal. Also, it sometimes comes up in conversation that the 40-year license term was based not on firm knowledge of when a reactor should be closed (since at that time no reactor had operated very long) but on a comparable benchmark for aircraft. As plant personnel have learned more through operating experience, it has become possible to determine how power reactors change over time. Whether by this name or some other, aging management is now part of the routine at essentially every reactor, even if the original license still has many years left on it.

This does not mean that age can be denied entirely. The DOE is well aware of pending issues such as the potential degradation of underground cabling, and longer operational tenures may be bringing back attention to the prospect of reactor vessel embrittlement. The hardware may also be picking up stress at greater rates than before. In their early days, many of these reactors went through long stretches of downtime because of various operational and regulatory issues, and periods when they operated well below peak power. A fair number of reactors went through around 20 effective full-power years of operation in their first 30 calendar years. Since then, with so many of the old problems solved and reactors routinely operating nonstop near full power, the second 30 calendar years of those same reactors might include 27 effective full-power years of operation or more. At that point, a reactor would reach the end of its first license renewal, and the decision would already have been made as to whether a second renewal would be worthwhile.

Who should decide?

The nuclear community in the United States is not in widespread agreement about the underlying issues involved in decisions to close reactors before the expiration of licenses, original or renewed. Is a power reactor private property, with its future to be decided entirely by its owners? Or is a power reactor part of a greater public good, necessary to provide large amounts of grid-stabilizing electricity and reduce the combustion of fossil fuels?

On many occasions in the past, the environmental, energy-abundance idealism of nuclear proponents has run counter to the free-market beliefs of . . . nuclear proponents (sometimes with both sentiments contesting within the same person). Whatever the market conditions or grid pricing rules that may be in effect at any given time, a power reactor represents a huge reservoir of longtime added value, and closing a reactor just because of the availability of natural gas that until recently was referred to as "shut-in" seems ludicrous, especially if the only benefit is to one company's bottom line.

The first public-versus-private dispute of this kind has been happening in upstate New York, where Entergy plans to close its FitzPatrick BWR next year, as stated earlier. The New York state government and labor unions involved with the plant and other industries in the region have tried to negotiate a way to keep the plant running, but so far Entergy has refused to budge. (Whether the state can reconcile its position on FitzPatrick with its desire to close Indian Point-2 and -3 is beyond the scope of this article, but that conundrum has already been observed in this publication, and probably will be again in later coverage.)

Here is a point for future discussion: Should governments, or other entities established to uphold the public good, be allowed to take over power reactors from private concerns that no longer want to operate them? In this particular instance, should New York seek to acquire FitzPatrick through eminent domain, place it under the control of a revived New York Power Authority (the state agency that owned FitzPatrick previously), retain all plant personnel, and price the electricity in a way that is not influenced by a corporate bottom line? NN