U.S. capacity factors: Keeping the grid stable

By E. Michael Blake

For about 15 years, power reactors as a whole have maintained high, steady output, but this may not be enough to keep some of them in service.

Nuclear power continues to be a highly productive electricity source in the United States, as it has been so far this century. For the past few years, however, it has not been reasonable to conclude that this is enough for the technology to remain viable in the long term. The litany of concerns has been recited many times in this magazine, and also in this annual survey of power reactor capacity factors, so much so that it might be possible to lose sight of an underlying truth: If nuclear power were not this productive, it would be even more difficult to present it as a key to future power generation. Fossil-fuel combustion must somehow be limited, if not reduced, to improve the chances to avert severe climate change (this statement should not be taken as a political expression, but as a recognition of substantial consensus in the scientific community).

As has been reported here, the federal government's inclusion of nuclear among the "clean power" sources and the Environmental Protection Agency's proposed rule to limit carbon dioxide emissions on a state-by-state basis are at least nominal acknowledgments of the value of existing and forthcoming nuclear power. The real-world situation, however, includes stresses that can overcome an ideal policy position. For many years, reactor owners were able to take advantage of merchant-power economics, as sales of reactors to fleet operators were coupled with license renewal to provide what appeared to be long-term stability for reactors that might otherwise have closed early (as some did, before the turn of the century). In many cases, however, the merchant approach depended on long-term power purchase agreements, usually feeding the electricity into the systems of utilities that had previously owned and operated the reactors. Just as it came time for these agreements to be renewed, "fracked" natural gas suddenly became plentiful at low cost, and many of the power-buying utilities did not want to enter into new long-term purchase agreements on terms that reactor owners considered favorable. Meanwhile, an overall stall in the economy starting in 2008 cut into power demand growth, and renewable sources (especially wind power) became more available, supported to some extent by production tax credits

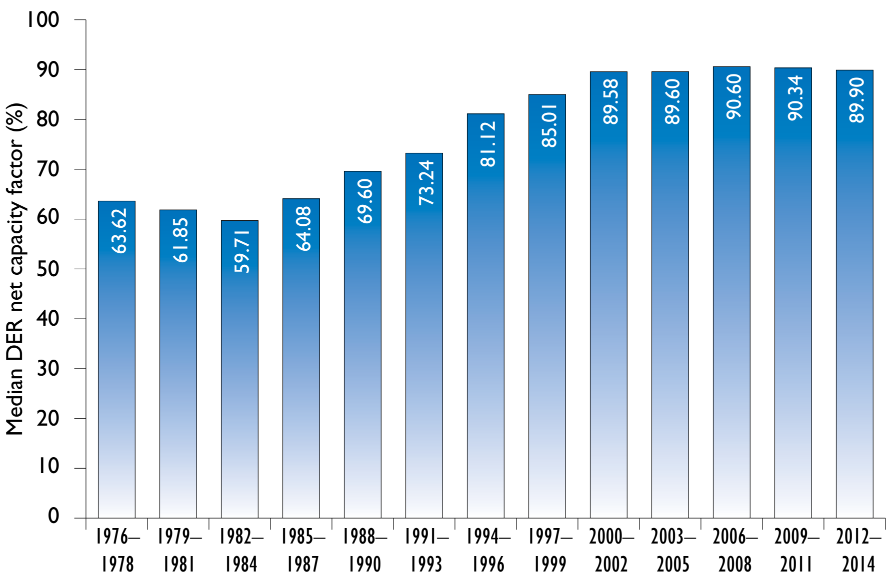

Fig. 1: All reactors. As noted in the text, the two columns at the right side show the medians of a 100-reactor data set. For 2012–2014, these are the 100 reactors in service through essentially the entire three-year period; for 2009–2011, the four reactors that were declared closed in the later period are excluded. For all earlier periods, the medians are for those reactors in service through those periods. Starting from the left, there were 40 reactors, and then 52, 59, 70, 91, 102, 103, and 104 in each of the next four. The adjustment to exclude recently closed reactors does not significantly affect the performance level that has been in effect now for about 15 years.

Table I.
2012–2014 DER Net Capacity Factors of Individual Reactors

Rank	Reactor	Factor[1]	Design Electrical Rating (DER), MWe[2]	Type	Owner[3]	Rank	Reactor	Factor[1]	Design Electrical Rating (DER), MWe[2]	Type	Owner[3]
1.	Quad Cities-1	104.50	866	BWR	Exelon	51.	Oconee-3	89.85	881	PWR	Duke
2.	Dresden-2	99.00	894	BWR	Exelon	52.	Sequoyah-1	89.67	1184.37	PWR	TVA
3.	Three Mile Island-1	98.39	819	PWR	Exelon	53.	Palo Verde-3	89.45	1334	PWR	APS
4.	Dresden-3	96.94	879	BWR	Exelon	54.	Peach Bottom-2	89.44	1179	BWR	Exelon
5.	Farley-1	96.73	854	PWR	Southern	55.	Watts Bar-1	89.42	1160	PWR	TVA
6.	Calvert Cliffs-2	96.35	845	PWR	Exelon	56.	Seabrook	89.20	1248	PWR	FPL
7.	Farley-2	96.21	855	PWR	Southern	57.	Cook-1	88.98	1084	PWR	IMP
8.	Clinton	95.92	1062	BWR	Exelon	58.	Hatch-1	88.82	885	BWR	Southern
9.	Indian Point-3	95.13	1048	PWR	Entergy	59.	McGuire-2	88.74	1163	PWR	Duke
10.	Comanche Peak-2	94.37	1207	PWR	Luminant	60.	Oconee-1	88.64	865	PWR	Duke
11.	Peach Bottom-3	94.16	1179	BWR	Exelon	61.	Diablo Canyon-1	88.55	1138	PWR	PG&E
12.	Calvert Cliffs-1	93.64	845	PWR	Exelon	62.	Millstone-2	88.38	877.2	PWR	Dominion
13.	Nine Mile Point-1	93.44	613	BWR	Exelon	63.	Summer-1	88.20	972.7	PWR	SCE&G
14.	Braidwood-1	93.14	1268	PWR	Exelon	64.	Perry	88.13	1268	BWR	FENOC
15.	Braidwood-2	93.12	1241	PWR	Exelon	65.	Pilgrim	88.00	690	BWR	Entergy
16.	Beaver Valley-2	93.07	904	PWR	FENOC	66.	Callaway	88.00	1228	PWR	Ameren
17.	South Texas-1	93.07	1250.6	PWR	STPNOC	67.	Limerick-1	87.89	1205	BWR	Exelon
18.	River Bend-1	92.85	967	BWR	Entergy	68.	Browns Ferry-3	87.57	1120	BWR	TVA
19.	Catawba-2	92.75	1180	PWR	Duke	69.	FitzPatrick	87.30	816	BWR	Entergy
20.	Ginna	92.65	585	PWR	Exelon	70.	Diablo Canyon-2	87.21	1151	PWR	PG&E
21.	Oconee-2	92.63	872	PWR	Duke	71.	Nine Mile Point-2	87.17	1299.9	BWR	Exelon
22.	Vogtle-2	92.61	1169	PWR	Southern	72.	Harris-1	87.12	973	PWR	Duke
23.	Byron-1	92.49	1213	PWR	Exelon	73.	Davis-Besse	86.89	908	PWR	FENOC
24.	Surry-1	92.42	874	PWR	Dominion	74.	Brunswick-2	86.74	980	BWR	Duke
25.	LaSalle-2	92.29	1178	BWR	Exelon	75.	Cooper	86.48	815	BWR	NPPD
26.	Hatch-2	92.29	908	BWR	Southern	76.	McGuire-1	86.25	1160	PWR	Duke
27.	Vermont Yankee	92.22	617	BWR	Entergy	77.	Oyster Creek	85.79	650	BWR	Exelon
28.	Palo Verde-1	92.16	1333	PWR	APS	78.	Waterford-3	85.67	1173	PWR	Entergy
29.	LaSalle-1	92.02	1178	BWR	Exelon	79.	Sequoyah-2	85.36	1177.46	PWR	TVA
30.	Vogtle-1	91.90	1169	PWR	Southern	80.	Salem-2	85.34	1181	PWR	PSEG
31.	Comanche Peak-1	91.90	1218	PWR	Luminant	81.	ANO-1	85.27	850	PWR	Entergy
32.	Browns Ferry-2	91.84	1120	BWR	TVA	82.	Arnold	84.48	621.9	BWR	FPL
33.	Millstone-3	91.81	1229	PWR	Dominion	83.	ANO-2	84.36	1032	PWR	Entergy
34.	Surry-2	91.80	874	PWR	Dominion	84.	Brunswick-1	84.10	983	BWR	Duke
35.	Indian Point-2	91.78	1035	PWR	Entergy	85.	Robinson-2	83.51	795	PWR	Duke
36.	Limerick-2	91.61	1205	BWR	Exelon	86.	Prairie Island-1	83.09	557	PWR	NSP
37.	Byron-2	91.43	1186.4	PWR	Exelon	87.	Susquehanna-2	82.66	1287	BWR	PPL
38.	Palo Verde-2	91.02	1336	PWR	APS	88.	South Texas-2	81.46	1250.6	PWR	STPNOC
39.	North Anna-1	90.97	973	PWR	Dominion	89.	St. Lucie-2	80.55	1074	PWR	FPL
40.	Salem-1	90.77	1169	PWR	PSEG	90.	Palisades	80.52	805	PWR	Entergy
41.	North Anna-2	90.74	973	PWR	Dominion	91.	Grand Gulf-1	80.12	1485	BWR	Entergy
42.	Browns Ferry-1	90.57	1120	BWR	TVA	92.	Susquehanna-1	79.35	1287	BWR	PPL
43.	Catawba-1	90.50	1174	PWR	Duke	93.	St. Lucie-1	77.94	1062	PWR	FPL
44.	Beaver Valley-1	90.39	911	PWR	FENOC	94.	Turkey Point-4	76.29	840	PWR	FPL
45.	Point Beach-2	90.34	615	PWR	FPL	95.	Wolf Creek	76.16	1200	PWR	WCNOC
46.	Cook-2	90.19	1107	PWR	IMP	96.	Prairie Island-2	75.05	557	PWR	NSP
47.	Hope Creek	90.10	1228.1	BWR	PSEG	97.	Monticello	74.62	666.7	BWR	NSP
48.	Point Beach-1	90.10	615	PWR	FPL	98.	Turkey Point-3	70.00	831	PWR	FPL
49.	Columbia	89.99	1153	BWR	Northwest	99.	Fermi-2	64.78	1150	BWR	DTE
50.	Quad Cities-2	89.94	957.3	BWR	Exelon	100.	Fort Calhoun	32.42	502	PWR	OPPD

[1] These figures are rounded off. There are no ties. For example, LaSalle-2 is in 25th, with 92.2890, and Hatch-2 is in 26th, with 92.2871.

[2] This is the design electrical rating (DER) in megawatts (electric), effective as of December 31, 2014. 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, 2014. In most cases this also means the reactor's operator, but Entergy and Exelon are the contracted operators of Cooper and Fort Calhoun, respectively.

and claiming priority on power grids.

To repeat, as bad as things look now, they would look far worse if the entire nuclear industry had not managed to improve steadily through the 1980s and 1990s and to maintain the level of roughly 90 percent capacity factors up to this day. To the extent that an argument can be made for grids to set policies that value the steady, reliable output of power reactors, this would not be possible at all if the industry were prone to the protracted outages and frequent scrams of earlier days. Even if it becomes necessary to tweak operating practices to reduce the effects of "negative pricing" on some grids (such as Exelon's decision to switch its Clinton reactor in Illinois to a 12-month cycle), there will probably still be times when the best thing a reactor can do for its owner, its customers, and the world in general, is to put together a breaker-to-breaker run at or near full power.

This does not alter the view expressed in this survey last year (*NN,* May 2014, p. 30) that what is presented here may be losing its value. If nothing else, the excellent performance of the vast majority of reactors has become so similar from one three-year period to the next that there seems to be little that can be learned from these sets of numbers. It is, of course, unreasonable simply to assume that the national fleet will keep doing this, faced with how the stresses noted above can influence operations and looking ahead to the possibility of plant modifications resulting from lessons learned from the 2011 Fukushima Daiichi accident in Japan. Strong performance did not prevent the closure of Kewaunee in 2013 and of Vermont Yankee as 2014 was ending. Again, however, without strong performance, there might already have been many more clo-

Table II.
Capacity Factor Change, 2009–2011 to 2012–2014

Rank	Reactor	Change (percentage points)	Rank	Reactor	Change (percentage points)	Rank	Reactor	Change (percentage points)	Rank	Reactor	Change (percentage points)
1.	Cook-1	+33.56	26.	Clinton	+2.15	51.	McGuire-2	-0.90	76.	Sequoyah-2	-4.32
2.	Columbia	+21.74	27.	Robinson-2	+1.76	52.	Summer-1	-0.94	77.	South Texas-1	-4.47
3.	Hatch-2	+14.08	28.	Oconee-2	+1.58	53.	Diablo Canyon-1	-1.01	78.	ANO-2	-4.55
4.	Three Mile Island-1	+9.91	29.	Calvert Cliffs-2	+1.57	54.	Vogtle-1	-1.19	79.	Calvert Cliffs-1	-4.63
5.	Quad Cities-1	+9.57	30.	Limerick-2	+1.55	55.	River Bend-1	-1.23	80.	Brunswick-1	-5.18
6.	Browns Ferry-2	+9.03	31.	Millstone-3	+1.51	56.	Oyster Creek	-1.33	81.	Surry-1	-5.26
7.	Point Beach-2	+8.46	32.	Beaver Valley-2	+1.43	57.	Catawba-1	-1.38	82.	ANO-1	-5.69
8.	Perry	+7.67	33.	Dresden-3	+1.42	58.	Diablo Canyon-2	-1.46	83.	Waterford-3	-5.75
9.	Davis-Besse	+6.48	34.	Nine Mile Point-1	+1.22	59.	Braidwood-2	-1.66	84.	Susquehanna-1	-6.03
10.	North Anna-1	+6.25	35.	Browns Ferry-3	+1.15	60.	Susquehanna-2	-1.71	85.	Comanche Peak-1	-6.45
11.	Brunswick-2	+6.19	36.	Palo Verde-2	+1.07	61.	Oconee-3	-1.87	86.	St. Lucie-1	-6.54
12.	Point Beach-1	+5.94	37.	Sequoyah-1	+1.06	62.	Vogtle-2	-1.87	87.	Wolf Creek	-6.61
13.	Palo Verde-1	+5.32	38.	Cooper	+1.06	63.	Hope Creek	-1.99	88.	Salem-2	-6.96
14.	Farley-2	+4.88	39.	Braidwood-1	+1.03	64.	LaSalle-1	-2.04	89.	Quad Cities-2	-7.14
15.	Indian Point-3	+4.68	40.	Millstone-2	+0.99	65.	Beaver Valley-1	-2.31	90.	Peach Bottom-2	-7.51
16.	Oconee-1	+4.35	41.	Palo Verde-3	+0.64	66.	Pilgrim	-2.43	91.	Nine Mile Point-2	-7.70
17.	St. Lucie-2	+4.13	42.	Indian Point-2	+0.36	67.	Hatch-1	-2.46	92.	Palisades	-9.29
18.	North Anna-2	+4.07	43.	Surry-2	+0.13	68.	Monticello	-2.74	93.	FitzPatrick	-10.64
19.	Browns Ferry-1	+3.64	44.	Salem-1	-0.03	69.	Arnold	-3.38	94.	Turkey Point-4	-10.78
20.	Seabrook	+3.52	45.	Watts Bar-1	-0.12	70.	Comanche Peak-2	-3.54	95.	Grand Gulf-1	-12.08
21.	Dresden-2	+3.27	46.	Byron-1	-0.24	71.	Byron-2	-3.62	96.	South Texas-2	-12.81
22.	Farley-1	+2.92	47.	Catawba-2	-0.34	72.	Limerick-1	-3.67	97.	Fermi-2	-14.95
23.	Peach Bottom-3	+2.84	48.	LaSalle-2	-0.82	73.	McGuire-1	-3.78	98.	Turkey Point-3	-16.84
24.	Cook-2	+2.38	49.	Callaway	-0.85	74.	Prairie Island-1	-3.97	99.	Prairie Island-2	-18.17
25.	Ginna	+2.27	50.	Vermont Yankee	-0.85	75.	Harris-1	-4.18	100.	Fort Calhoun	-36.88

sures, and perhaps less incentive to build new reactors or, as TVA Nuclear has done, restart Browns Ferry-1 and resume the construction of Watts Bar-2.

The nearly-90 normal

The 100 power reactors that operated during the three-year period of 2012–2014 had a median capacity factor of 89.90 percent. Those same 100 reactors had a median factor of 90.34 in 2009–2011. The 104 reactors that were operable in 2006–2008 had a median factor of 90.60. (Yes, the data set has changed, but for now, please accept that the comparisons being made here are reasonable, and everything will be explained later.) The top quartile in 2012–2014 was 92.28, following 93.08 in 2009–2011 and 93.13 in 2006–2008. The bottom quartile was 86.36 in the most recent three years, after 86.84 in the previous three years and 87.82 in the three years before that. The average in 2012–2014 was 88.52; it was 89.23 in 2009–2011, and 89.46 in 2006–2008. It is possible to read this as a downward trend, but only if fractions of a percentage point are given a significance that we believe is not warranted.

The 65 pressurized water reactors in the current data set had a median factor in 2012–2014 of 90.10, a top quartile of 92.52, and a bottom quartile of 85.96. The corresponding numbers from 2009–2011 were 90.02, 92.30, and 87.06. Among the 35 boiling water reactors, the 2012–2014 median was 89.44, the top quartile was 92.29, and the bottom quartile was 86.48; in 2009–2011, they were 91.28, 94.06, and 85.38. As has generally been the case over the years, the capacity factors of multiunit sites were somewhat higher than those of single-unit sites. Because of recent ownership changes affecting several reactors, it is not clear whether fleets with several plant sites have performed better than single-site owners.

As promised, we now address the changed data. For several years, it was possible to draw clear conclusions in this survey because of the stability of the data set. After the reactor closures of the 1990s (some of them, in retrospect, perhaps premature), the United States settled in with 104 licensed units. Browns Ferry-1 was included here all along, despite 22 years off line, because it was still licensed; its resumed operation in 2007 simply ended its long streak in last place in Table I. Now, there are four reactors that have left the data set (Crystal River-3, Kewaunee, and San Onofre-2 and -3), and Vermont Yankee is making its final appearance, with power operation having ended last December 29. We have decided, therefore, that it is reasonable to compare the 100 reactors still in the set with their own past performance, rather than try to compare them to the traditional 104.

It has always been my view that statistics are worthwhile only to the extent that they allow conclusions to be drawn, and that the numbers themselves don't merit attention if the differences involved are extremely small.

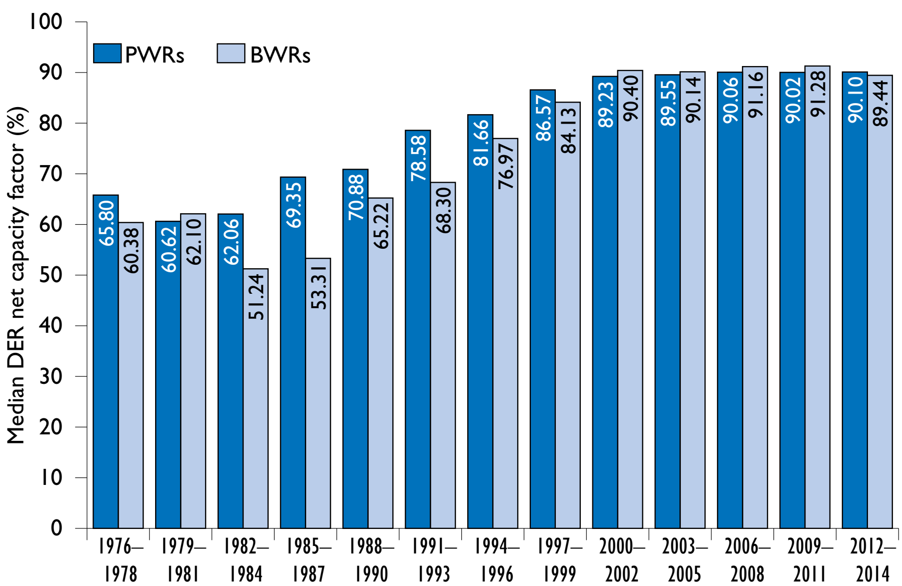

Fig. 2: Reactors by type. Pressurized water reactors, as a group, had a slightly higher median than boiling water reactors in 2012–2014, reversing a recent trend. At no time in recent years, however, has either reactor type had a substantial performance lead over the other.

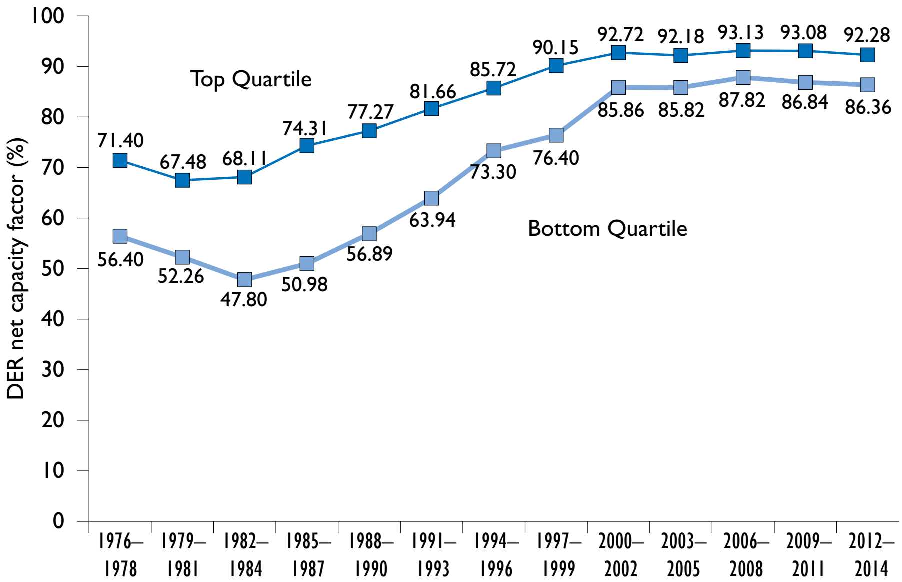

Fig. 3: Top and bottom quartiles. Although the fleet as a whole has not maintained the extreme uniformity of 2006–2008, when the bottom quartile was within six points of the top quartile, the space between the lines on the chart remains narrow, indicating that the median is a fair representation of fleet-wide performance.

The necessity in this survey to compare the 100 reactors that operated through the end of 2014 (or very nearly so; Vermont Yankee lost only two days at the very end) to those same 100 reactors in 2009–2011 leads to one of those extremely small differences, if one were to compare the 100 reactors in 2012–2014 to the 104 reactors in 2009–2011. In the interest of reducing the slew of numbers that readers must already confront, here's a comparison of the reduced data set with the original one: In 2009–2011, the 104 reactors that were licensed at the time had a median capacity factor of 90.18, a top quartile of 93.08, a bottom quartile of 86.75, and an average of 88.60. In that same period, the 100 reactors that are still in the survey now had a median of 90.34, the same top quartile, a bottom quartile of 86.84, and an average of 89.23. Because all of these differences are smaller than two-thirds of a percentage point, I am confident that limiting all comparisons to within the 100-reactor set (and subdivisions thereof) will provide as many meaningful conclusions as these data can provide.

Also, because the differences are small, this survey continues to use the base data for periods before 2009–2011, rather than redefine them to delete Crystal River-3, Kewaunee, and San Onofre-2 and -3. These historical data are based on reactors that were in service during each period, and back then, the four reactors mentioned above were in normal operation. The use of 100 reactors in 2009–2011 more reasonably indicates such normal operation, given that Crystal River-3 was off line for most of 2009–2011 anyway. So, while there may be a nominal inconsistency in this approach to the data, perfect consistency would not provide noticeably different statistics.

If one insists on going beyond glass-half-empty to glass-broken, it will be conceded (for the sake of diligence beyond what is due) that the median factor in 2012–2014 of all 104 reactors that were still licensed at the start of this period would plunge to 89.56, about a third of a percentage point, and the average would understandably drop to 85.74, almost three points below the average of the still-operable reactors. It should also be noted that the glass-half-full view is propped up somewhat by the removal of the closed reactors from the database. The Nuclear Energy Institute announced in January that the capacity factor for all reactors in calendar year 2014 was the highest ever, at 91.9 percent (based on summer peak capacity). The total produced electricity, however, was not as high as it was in four earlier years, when more reactors were in service.

Numbers and their crunching

This leads us to our description of how we obtain the data and what we do with them. Until 2004, power reactor licensees reported electricity production and other operational information to the Nuclear Regulatory Commission, which then made it available to the public. The NRC then decided that it did not have to be directly involved in this process, so the licensees began sending the data to the Institute of Nuclear Power Operations, which then forwarded them to the NRC. The survey in this publication computes capacity factors for three-year periods, to show sustained performance, and bases the factors on each reactor's design electrical rating (DER), as opposed to other measures (such as maximum dependable capacity [MDC] or summer peak). In our view, DER provides the best measure of what a reactor is supposed to be doing. For the same reason, we use net electricity, which leaves the plant, as opposed to gross.

As much as we seek consistency in these numbers, even DERs can change, especially because of power uprates and heat-rate improvements. During 2014, the following reactors were assigned different DERs by their licensees: Braidwood-1, 1,286 MWe (from 1,187); Braidwood-2, 1,241 MWe (from 1,155); Byron-1, 1,213 MWe (from 1,187); Byron-2, 1,186.4 MWe (from 1,155); Catawba-1, 1,174 MWe (from 1,145); Catawba-2, 1,180 MWe (from 1,145); Grand Gulf-1, 1,485 MWe (from 1,279); McGuire-1, 1,160 MWe (from 1166); McGuire-2, 1,163 MWe (from 1,170); Monticello, 666.7 MWe (from 600); Oconee-1, 865 MWe (from 886); Oconee-2, 872 MWe (from 886); Oconee-3, 881 MWe (from 886).

Continued

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

Rank	Site	Factor	Owner	Rank	Site	Factor	Owner
1.	Dresden	97.98	Exelon	19.	Oconee	90.37	Duke
2.	Quad Cities	96.86	Exelon	20.	Point Beach	90.22	FPL
3.	Farley	96.47	Southern	21.	Browns Ferry	89.99	TVA
4.	Calvert Cliffs	95.00	Exelon	22.	Limerick	89.75	Exelon
5.	Indian Point	93.47	Entergy	23.	Cook	89.59	IMP
6.	Braidwood	93.13	Exelon	24.	Nine Mile Point	89.21	Exelon
7.	Comanche Peak	93.13	Luminant	25.	Hope Creek/Salem	88.75	PSEG
8.	Vogtle	92.26	Southern	26.	Diablo Canyon	87.87	PG&E
9.	LaSalle	92.15	Exelon	27.	Sequoyah	87.53	TVA
10.	Surry	92.11	Dominion	28.	McGuire	87.49	Duke
11.	Byron	91.97	Exelon	29.	South Texas	87.27	STPNOC
12.	Peach Bottom	91.80	Exelon	30.	Brunswick	85.42	Duke
13.	Beaver Valley	91.73	FENOC	31.	ANO	84.77	Entergy
14.	Catawba	91.63	Duke	32.	Susquehanna	81.01	PPL
15.	Palo Verde	90.88	APS	33.	St. Lucie	79.23	FPL
16.	North Anna	90.85	Dominion	34.	Prairie Island	79.07	NSP
17.	Hatch	90.57	Southern	35.	Turkey Point	73.15	FPL
18.	Millstone	90.38	Dominion				

[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 2012–2014 factor of 88.64. 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 2012–2014 factor of 88.04.

A glass-half-full view of this would be that the 100 reactors had a total installed capacity in 2014 that was 526.1 MWe greater than in 2013, although more realistically this can be seen as only compensating for most of the lost generation from the closure of Kewaunee in 2013. The loss of Crystal River-3 and San Onofre-2 and -3 took away almost 3 GWe of generation, and 2015 began without the 617 MWe of Vermont Yankee.

The biggest addition was the 206 MWe at Grand Gulf-1, although it took a long time for Entergy to make official the new rating reflected in an extended power uprate that was approved by the NRC in July 2012. Grand Gulf-1 is now, by far, the most powerful reactor in the United States, and its placement in Table I (at 91st) suggests that it has not been easy for this reactor to reach and maintain its new peak power level.

The de-rating of five Duke reactors is unusual, especially at Oconee, where each reactor had a DER of 886 MWe ever since startup. Two Duke uprates give the utility a net gain of 11 MWe, so at least for now there will be no complaints in this survey about interference in what should be a fairly steady indicator of plant performance.

There continue to be three reactors with DERs that for several years have not properly reflected the effects of earlier uprates: Calvert Cliffs-1 and -2 and FitzPatrick. A DER that is not high enough can have the effect of making a capacity factor appear better than it actually is. As noted below, this also appears to be the case for another reactor that previously had not been so obvious.

104.5 percent?

When it comes to the numbers for individual plants, the reactor at the top of Table I inspires some fairly loud throat-clearing. Quad Cities-1 has clearly been a strong performer over the previous three years, but the capacity factor produced by the DER currently used by Exelon is the largest outlier from reality of any reactor in the history of this survey. Both Quad Cities units were approved for 17.8 percent extended power uprates in December 2001, and in terms of licensing, they had equal peak power authorization both before (2,511 MWt) and after (2,957 MWt) the uprates went into effect. The DER of Unit 1, however, is given as 866 MWe, and that of Unit 2 as 957.3 MWe.

Exactly how a thermal uprate will be expressed in electricity output varies from one reactor to another, because of differences in hardware, operational choices, and external conditions (weather, grid connection, etc.). Even collocated reactors that were close to replicates when they were built could diverge over time. Quad Cities had operated for nearly 30 years before the uprates were approved. It was at this plant that the issue of steam dryer cracking in BWRs was discovered as the result of higher-power operation. If a 17.8 percent increase were applied to the pre-uprate DER (789 MWe, for much of each Quad Cities unit's experience), the DER would be 929 MWe, and while (as noted) there is not a linear relationship between the MWt and the MWe, it seems to be an odd circumstance for Unit 1's DER to have risen only by 9.8 percent, while Unit 2's DER climbed by 21.3 percent. If Unit 1 were rated at 957.3 MWe, like Unit 2, the factor would be a highly respectable 92.34 percent, and only a few points above that of Unit 2. In terms of output, there was not a great deal of difference between the two units in 2012–2014. Unit 1 produced 23.25 GWh, which was less than 2.3 percent more than Unit 2's 22.73 GWh. With their current respective DERs, however, the two reactors' capacity factors differ by more than 14 points.

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

Rank	Owner/Operator	Factor
1.	Exelon Generation	93.00
2.	Southern Nuclear	92.97
3.	Dominion Generation	91.06
4.	FirstEnergy Nuclear	89.48
5.	TVA Nuclear	89.06
6.	Duke Energy	88.37
7.	Entergy Nuclear	87.29
8.	FPL/NextEra	82.15
9.	Northern States Power–Minnesota	77.47

[1] Entergy has been the contract operator of Cooper since 2003. Exelon became the contract operator of Fort Calhoun in 2012.

We have attempted to learn Exelon's reasoning for the DERs assigned to the Quad Cities reactors, but had learned nothing when it was time for this article to go to press. Some licensees at multireactor sites prefer to designate one of the reactors as the primary, sometimes extending this to its intended output, but a difference in electrical ratings of more than 10 percent, for comparable units, is new to us.

Seeking a bright side

Because this survey has, for the first time in more than a decade, changed the number of reactors in the data set, the question may be raised more noticeably than before: How many of the reactors in Table I will still be there if there is a survey in 2018 for the three-year period that has just begun? Obviously, Vermont Yankee will not be there, and even if TVA Nuclear's Watts Bar-2 starts up as intended, it will not have completed three years of commercial operation by the end of 2017, and thus would not be included in the survey. We have already entered an era in which the number of licensed reactors has dropped from three digits to two, and there may be some people (on either side of the nuclear debate) who choose to see significance in going from 100 to 99. We see it as just another datum, with the larger issue being the number of nuclear professionals who have lost their employment because five reactors have stopped producing electricity since 2009.

It seems silly in an article about strong nuclear power performance to try to find things that could help people cheer up. For anyone who feels the need, here are a few such things:

- Fort Calhoun resumed power operation near the end of 2013, and in 2014 its capacity factor was 95.16 percent. This spring, the NRC ended the reactor's long stay outside of normal oversight and placed it in the top-level Licensee Response column of the Reactor Oversight Process action matrix (see page 23, this issue). If Omaha Public Power District and contracted operator Exelon have truly learned how to cope with fluctuations in the Missouri River, which provides the plant with its necessary water, there might be no more multiyear outages at this reactor.
- Not every major repair has an outcome like the steam generator replacement wear at San Onofre or the concrete delamination at Crystal River. Cook-1 had to undergo a very long outage after a turbine mishap late in the previous decade, and in 2012–2014, the reactor had a capacity factor of 88.98. Last October, Cook-1 also passed its 40-year mark and entered the term of its renewed license.
- Speaking of the over-40 crowd, when 2015 began, 37 of the 99 still-operable units had entered the extra time on their licenses. (The NRC considers a reactor to be on its renewed license as soon as renewal is approved, and not when the 40-year mark is passed; for the purposes of this article, renewal is considered to take practical effect when a reactor operates past its original 40-year term. Also included here is Indian Point-2, which is in post-40 operation while its renewal is still pending.) The median capacity factor of those 37 reactors in 2012–2014 was 89.44, within half a point of the median for all reactors.

In the wider world, meanwhile, Exelon has made some headway with legislation in Illinois to improve its reactors' profitability, and the Federal Energy Regulatory Commission has taken some initiative to get grid operators to place greater value on the stability provided by baseload nuclear power. Watts Bar-2 might enter service soon, and down the road there should be power generated by at least a few new units licensed under 10 CFR Part 52, and perhaps even small modular reactors. Meanwhile, the reactors now on line, merchant or regulated, over 40 or under, must maintain the performance level that has now been in effect for more than a decade. NN