

white paper

Nuclear Costs in Context

Prepared by the
Nuclear Energy Institute
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NUCLEAR ENERGY INSTITUTE

The Nuclear Energy Institute is the nuclear energy industry's policy organization.

This white paper and additional information about nuclear energy are available at *nei.org*.

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Total Generating Costs

In 2015, the average total generating cost for nuclear energy was \$35.50 per megawatt-hour. Total generating costs include capital, fuel and operating costs – all the costs necessary to produce electricity from a nuclear power plant. Cost information for the U.S. nuclear fleet is collected by the Electric Utility Cost Group with prior years converted to 2015 dollars for more accurate historical comparisons.

2015 Cost Summary (\$/MWh)

Category	Number of Plants / Sites	Fuel	Capital	Operating	Total Operating (Fuel + Operating)	Total Generating (Fuel + Capital + Operating)
All U.S.	58*	6.91	7.97	20.62	27.53	35.50
Plant Size						
Single-Unit	23	7.10	10.26	27.15	34.25	44.52
Multi-Unit	35	6.85	7.31	18.74	25.60	32.90
Operator						
Single	12	7.49	9.30	22.05	29.54	38.84
Fleet	46	6.74	7.58	20.21	26.95	34.53

* Costs exclude shutdown plants. Also excludes Fort Calhoun, Fitzpatrick, and Pilgrim because no data was provided for 2015.

Source: Electric Utility Cost Group (EUCG)

Three-quarters of nuclear power in the U.S. comes from plants with multiple reactors. The ability to spread costs over a greater amount of electricity production means that the generating cost at multi-unit sites is generally lower than at single-unit plants. In 2015, the total generating cost at multi-unit plants was \$32.90 per megawatt-hour compared to \$44.52 for single-unit plants.

The 2015 generating costs were 2.4 percent lower than in 2014 and almost 11 percent below the 2012 costs. Prior to the 2012 peak, nuclear generating costs had increased steadily over the previous decade. Between 2002 and 2015, fuel costs increased 21 percent, capital expenditures by 103 percent, operating costs by 11 percent (in 2015 dollars per megawatt-hour). Total generating costs are up 26 percent in the last 13 years.

U.S. Nuclear Plant Costs (2015 \$):

Year	Fuel	Capital	Operating	Total
2002	5.73	3.92	18.61	28.27
2003	5.60	4.94	18.87	29.40
2004	5.29	5.66	18.56	29.50
2005	5.02	5.81	18.97	29.80
2006	5.05	5.56	19.23	29.85
2007	5.13	6.12	19.09	30.35
2008	5.36	6.77	19.53	31.66
2009	5.94	8.92	20.52	35.38
2010	6.77	9.17	20.66	36.59
2011	7.10	10.07	21.91	39.08
2012	7.47	10.77	21.50	39.75
2013	7.74	8.21	20.95	36.91
2014	7.22	8.19	20.95	36.35
2015	6.91	7.97	20.62	35.50
2002-2015 Increase	21%	103%	11%	26%
2010-2015 Increase	2%	-13%	0%	-3%

Capital

Industrywide capital spending increased from \$4.4 billion a year in 2006 (2015 dollars), peaked at \$8.7 billion in 2012, and dropped to \$6.25 billion in 2015.

Capital investment took a step change up in about 2003, leveled off for several years, then took another step change in 2009 and has declined over the last two years. These inflections are the result of a few major items: a series of vessel head replacements, steam generator replacements and other upgrades as companies prepared their plants for operation after the initial 40-year license, and power uprates to increase output from existing plants. As a result of these investments, 81 of the 99 operating reactors have received twenty-year license renewals and 92 of the operating reactors have been approved for uprates that have added over 7,000 megawatts of capacity.

Capital spending on uprates and items necessary for operation beyond 40 years should moderate as most plants complete these efforts. Capital investments in uprates peaked at \$2.5 billion in 2012 but declined to \$315 million in 2014. This decline has been offset in other areas where spending has increased. Capital spending to meet regulatory requirements was around \$1 billion in 2007 and 2008 before jumping to \$1.8 billion in 2010 and holding near that level until reaching a peak of almost \$2 billion in 2014. This increase began with significant investments post-9/11 to enhance security, followed by expenditures for post-Fukushima items, which totaled \$1 billion in 2014. As the industry completes Fukushima-related safety upgrades, regulatory capex should also moderate, and revert toward 2007-2008 levels. A further breakdown of capital costs for 2015 will be available at a later date.

Operations

Operations costs increased over the last twelve years from \$18.59 per megawatt-hour in 2002 to \$20.92 per megawatt-hour in 2014. Operations costs have declined 4 percent from the peak in 2011.

This increase in operations costs was not driven by any single category. Operations costs in the 2002-2008 periods are similar to where money was being spent in the 2009-2014 period. However, operations costs have remained flat compared to the past decade. Between 2006 and 2010, operations costs increased 16 percent while, over the past five years, the increase was only 1 percent. A further breakdown of operations costs for 2015 will be available at a later date.

Fuel

Fuel costs represent 15-20 percent of the total generating cost. Fuel costs experienced a relatively rapid increase from 2009 to 2013. This was largely the result of an escalation in uranium prices that peaked in 2008. Since uranium is purchased far in advance of refueling and resides in the reactor for four to six years, the effect of this commodity price spike persists for a long time after the price increase actually occurred.

Economic Pressures Facing Nuclear Plants

Since 2013, five nuclear reactors (Crystal River 3 in Florida, San Onofre 2 and 3 in California, Kewaunee in Wisconsin, and Vermont Yankee) have shut down permanently. Entergy announced in October 2015 that it would close its Pilgrim plant in Massachusetts by June 2019, and possibly sooner. And in February 2016, Entergy announced that it would shut down its FitzPatrick nuclear plant in upstate New York in early 2017.

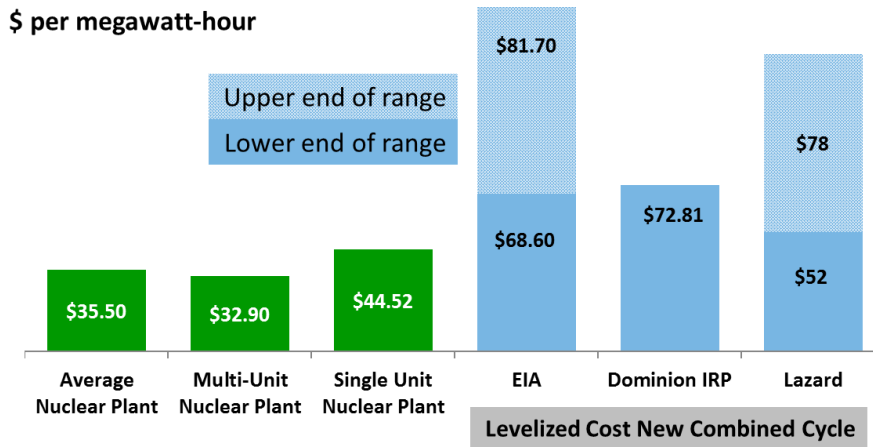
Crystal River and San Onofre shut down due to failed steam generator replacements – unique situations that are unlikely to be repeated. Since the Surry nuclear power plant in Virginia replaced its steam generators in the early 1980s, approximately 110 reactors around the world have replaced their steam generators (including 57 reactors in the United States), in what has become a routine practice.

Kewaunee, Vermont Yankee, Pilgrim and FitzPatrick – all in competitive markets – fell victim to a combination of market-related factors (and, in some cases, a combination of several factors), including:

- Sustained low natural gas prices, which are suppressing prices in wholesale power markets, and will continue to do so.
- Relatively low growth (in some markets, no growth) in electricity demand due partly to subpar economic performance since the 2008 recession, partly to greater efficiency.
- Federal and state mandates for renewable generation, which suppress prices, particularly during off-peak hours (when wind generation is highest and the electricity is needed the least). For example, the federal production tax credit allows wind producers to bid negative prices, which places baseload plants at a disadvantage. Some nuclear plants in Illinois see negative prices as much as 10-11 percent of the off-peak hours and 5-6 percent of all hours.
- Transmission constraints, which require a power plant to pay a congestion charge or penalty to move its power on to the grid. Certain nuclear plants at particularly congested points on the grid pay a penalty of \$6-9 per megawatt-hour to move their power out.
- Market designs that do not compensate the baseload nuclear plants for the value they provide to the grid, and market policies and practices – e.g., reliance on out-of-market revenues – that tend to suppress prices.

The Kewaunee, Vermont Yankee, Pilgrim and FitzPatrick nuclear plants are the only casualties to date, but there are other nuclear stations at risk.

Better Deal for Consumers ... Existing Nuclear or New Combined Cycle Gas?



Sources: Existing nuclear costs are 2015 total generating costs (fuel, O&M, capital) from Electric Utility Cost Group. Gas-fired combined cycle costs are levelized costs from (1) Energy Information Administration, *Annual Energy Outlook 2015*; (2) Dominion Virginia Power 2015 Integrated Resource Plan; (3) Lazard, *Levelized Cost of Energy Analysis*, 9.0, 2014.

Economic Impact of Nuclear Plant Closures

Kewaunee and Vermont Yankee were both highly reliable plants with high capacity factors and relatively low generating costs. Allowing these facilities to close will have long-term economic consequences: replacement generating capacity, when needed, will produce more costly electricity, fewer jobs that will pay less, and more pollution.

In 2015, on average, U.S. nuclear power plants produced electricity for almost \$36 per megawatt-hour. The smaller single-unit plants like Kewaunee and Vermont Yankee were a little more costly – about \$44 per megawatt-hour. The larger, multi-unit sites were less costly – in the \$33 per megawatt-hour range. The electricity these plants produces will likely be replaced with either combined cycle gas-fired capacity at a levelized cost of over \$70 per megawatt-hour (see graph, “Better Deal for Consumers ... Existing Nuclear or New Combined Cycle Gas?”).

