NIC Global Summit
Outlook on Decommissioning Market

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State of Play - Nuclear Energy Worldwide

- **At mid-year 2016 , worldwide there are 444 operating power reactors with a combined capacity of 388 GWe and which accounted for 11% of world's electricity**
- **Some 80% of existing nuclear capacity is in OECD countries. Of that more than three-quarters is over 30 years old**
- **By contrast, around half of the capacity in non-OECD countries (excluding Russia) is less than 15 years old**
- **Currently, worldwide there are 62 power reactors under construction with a combined capacity of 66 GWe, 16 reactors in OECD countries and 46 in non-OECD countries**

DECOMMISSIONING OVERVIEW

- **Over the next 20 years and beyond, the IEA estimates that 150 GWs, or more than 200 nuclear plants, are expected to be retired, primed for or begin decommissioning**
- **To date, over 160 nuclear power plants have been shutdown and/or are undergoing decommissioning worldwide (not including test reactors)**
- **Top drivers for plant retirements include:**

  75% -Units that have achieved their expected economic lifetime

  20%- Units which are closed prematurely by political decision or due to regulatory reasons and/or economic difficulties

  5%- Units that are closed following an accident

- **Other key market drivers include:**
  - **Stringent regulations post-Fukushima**
  - **Rising cost of nuclear plant O&M and cap ex**
  - **Low electricity demand growth**
  - **Falling cost of renewables and combined with low natural gas prices**

DECOMMISSIONING OVERVIEW

- **Bulk of worldwide retirements are in the mature markets, i.e. oldest fleets first, reflecting the age profile of their fleets, particularly the by the United States followed by the European Union(led by France, Germany and UK), Japan and Russia.**
- **Rate of retirements picks up in the first half of the 2020s as reactors built in 1970s are taken off-line, and then again in the 2030s, particularly if life extensions in the U.S. are not re-extended for another 20 years.**
- **Average rate of retirements is about 5 GWs per year, compared with new additions of 15 per year**

WORLDWIDE
ESTIMATED MARKET SIZE – NEAR TERM

2016 MARKET SIZE

- **8, 217 MWe**
- **$6,163 - $12,326 Billion**

2020 MARKET SIZE

- **20,604 MWe**
- **$15,453 - $30,906 Billion**

ANNUAL AVERAGE GROWTH RATE: 23 PERCENT

Worldwide Age Profile of Operating Reactors

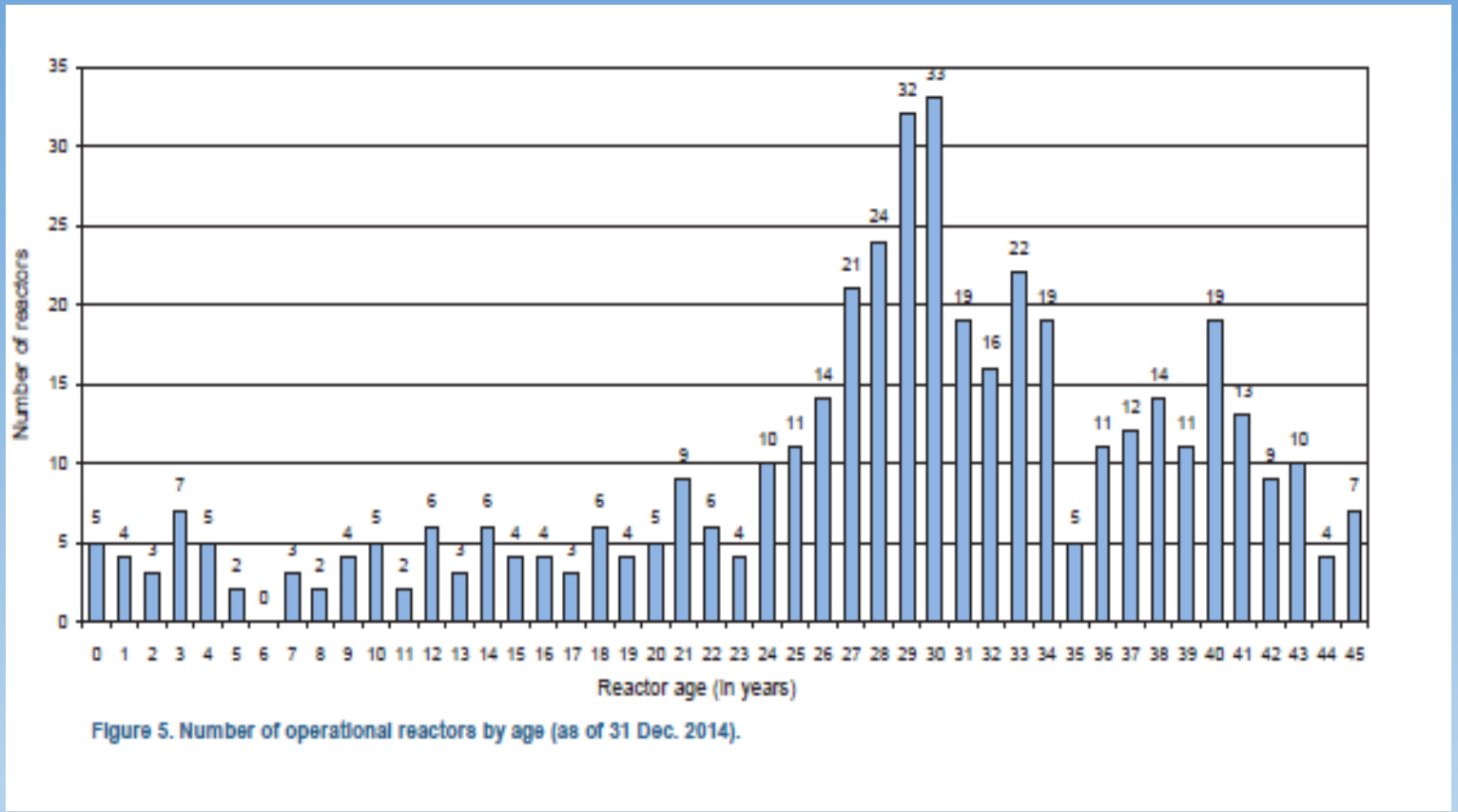
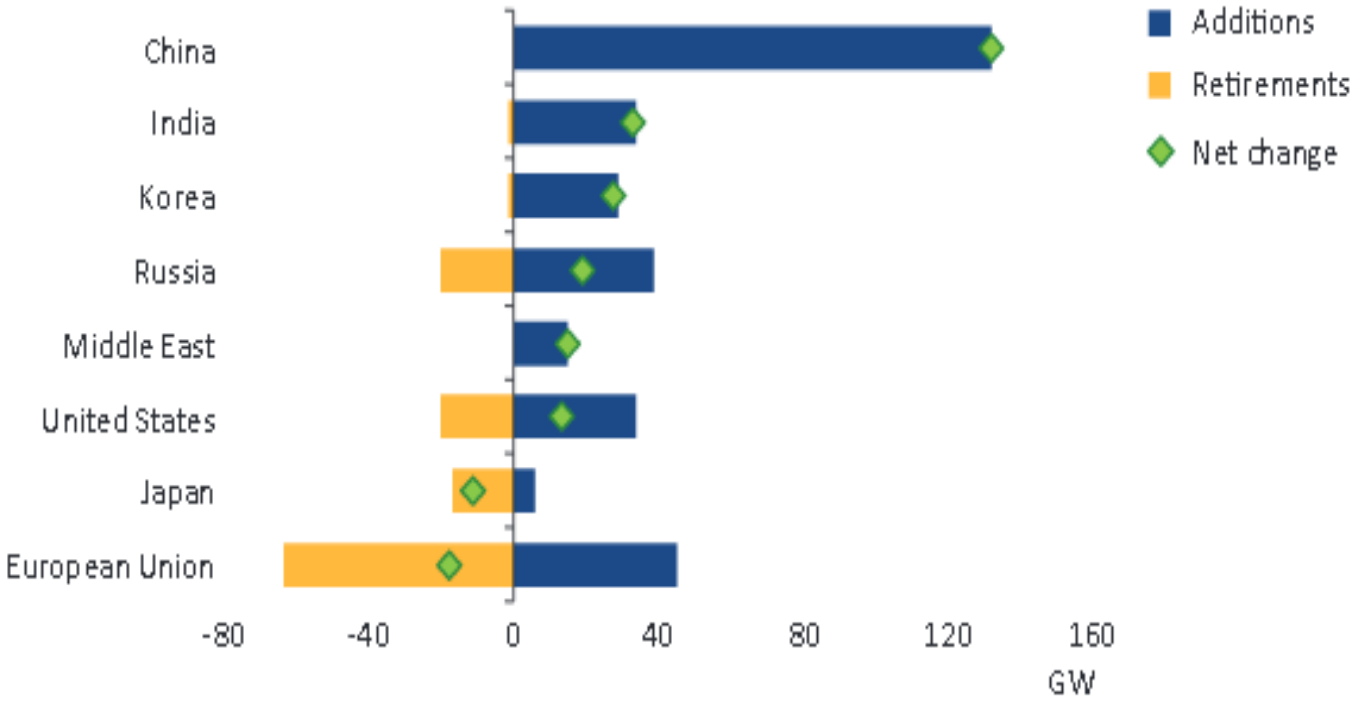


Figure 5. Number of operational reactors by age (as of 31 Dec. 2014).

- Over 20+ years, there are 356 reactors
- Over 30+ years, there are 220 reactors
- Over 40+ years, there are 65 reactors

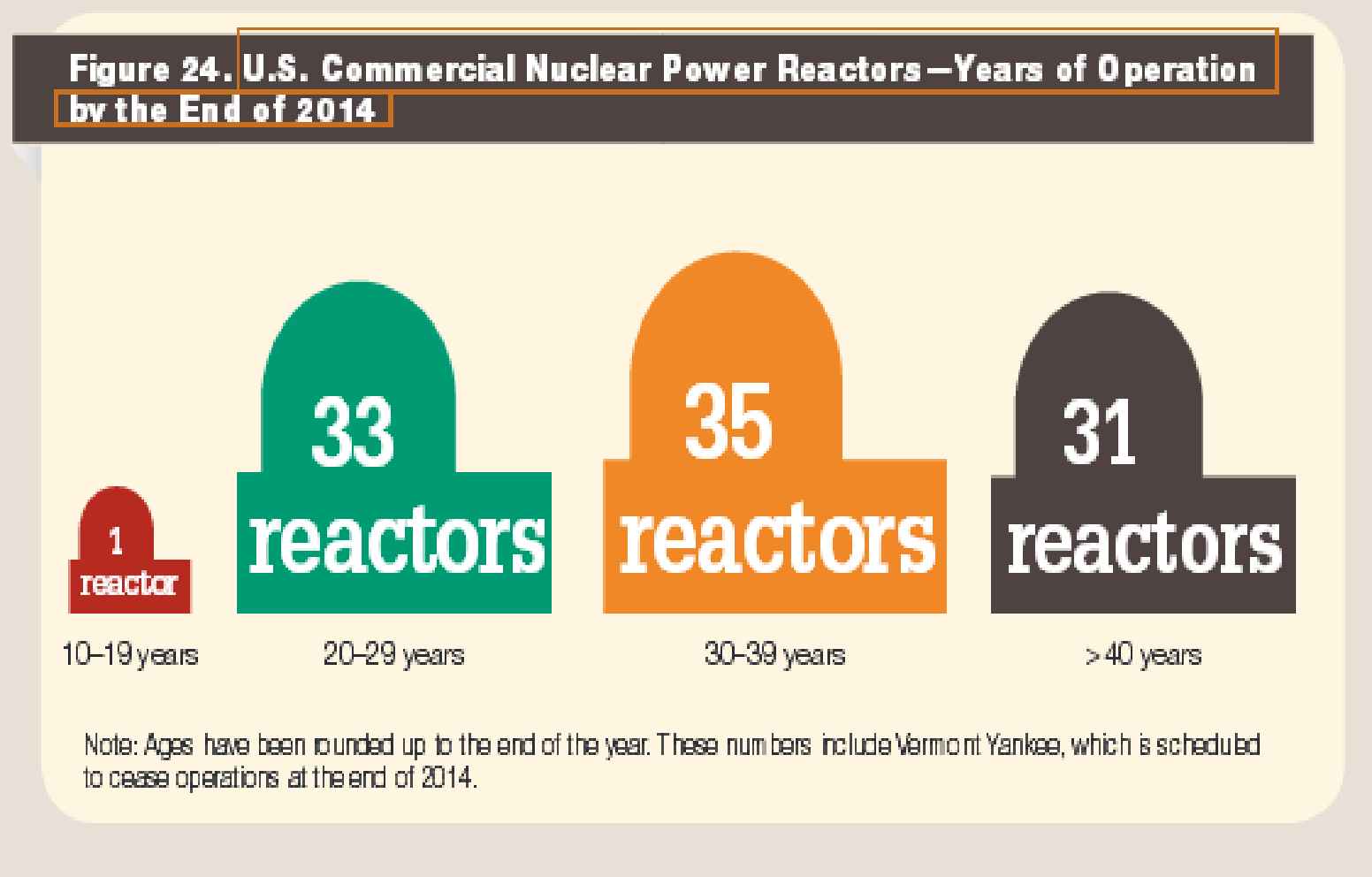
Distribution of Planned Additions/Retirements

Figure 11.4 ▷ Nuclear power capacity additions and retirements by key region in the New Policies Scenario, 2014-2040



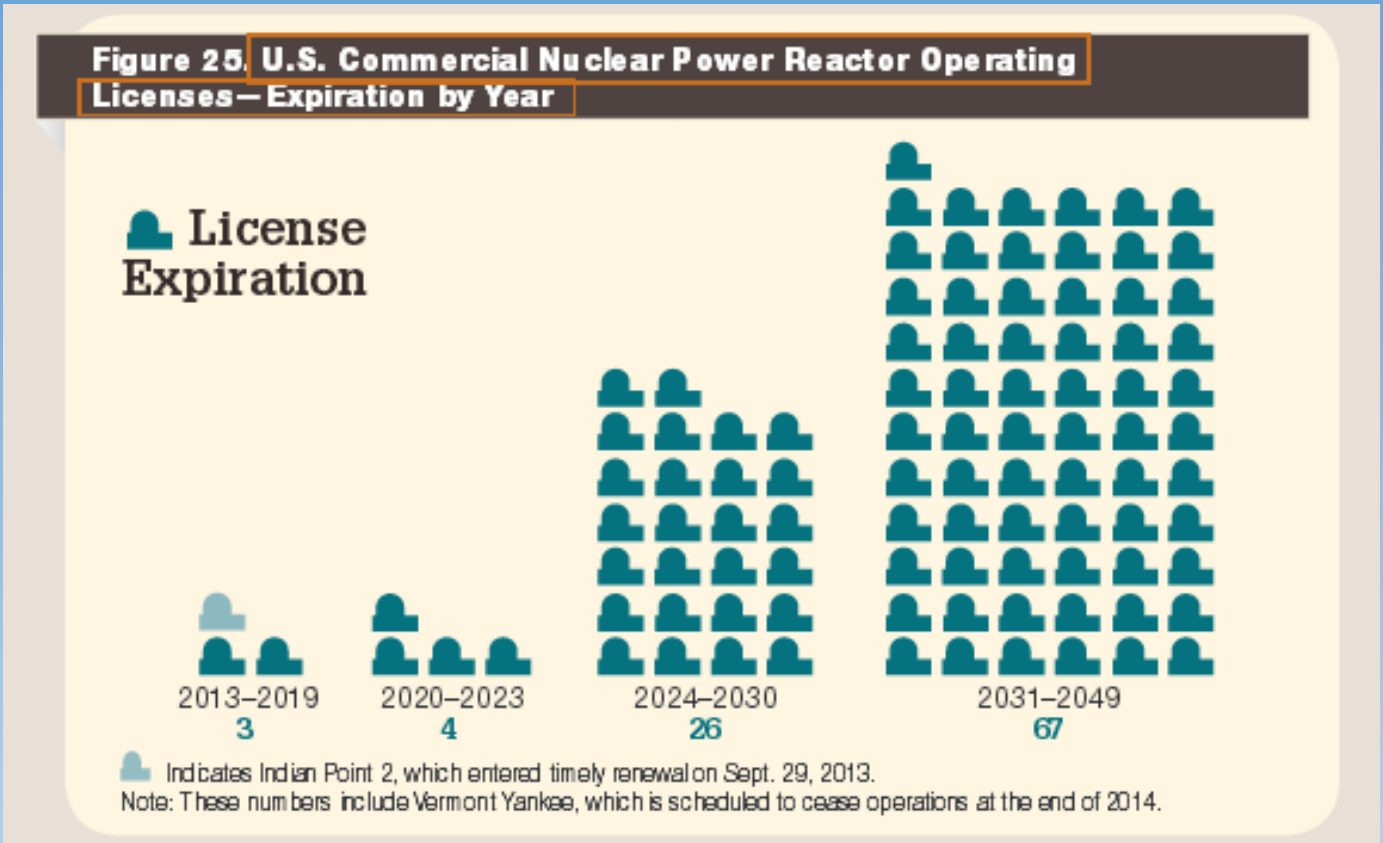
- Around 150 GW of nuclear capacity is retired thru 2040, equivalent to 38% of the current installed capacity or 44% of the existing operating world fleet

U.S. Nuclear Plant Age Distribution



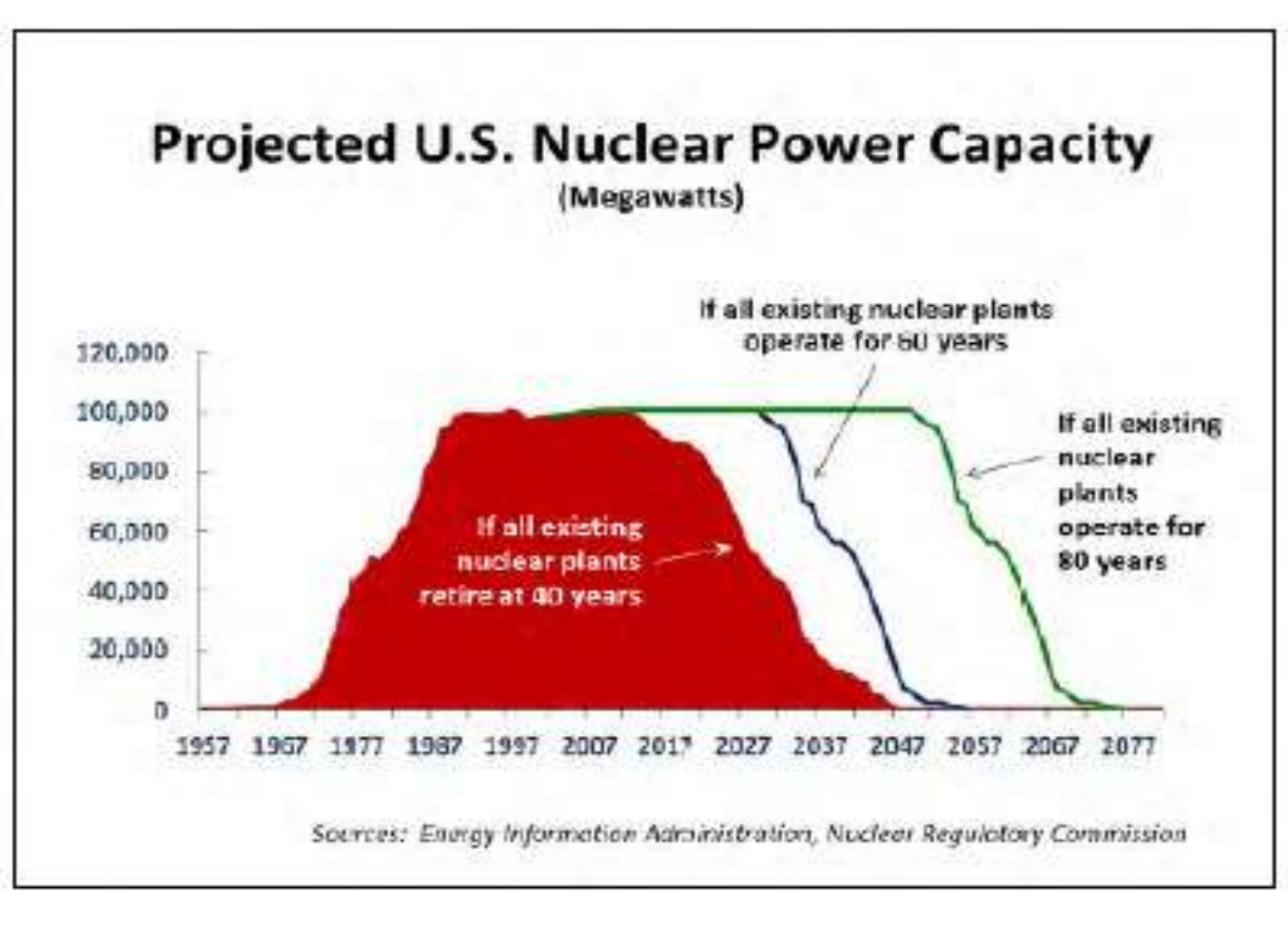
- US nuclear fleet is the oldest in the world and averages 33 years
- 75 U.S. reactors have a 20 year life extension

Expected U.S. Reactor Retirements



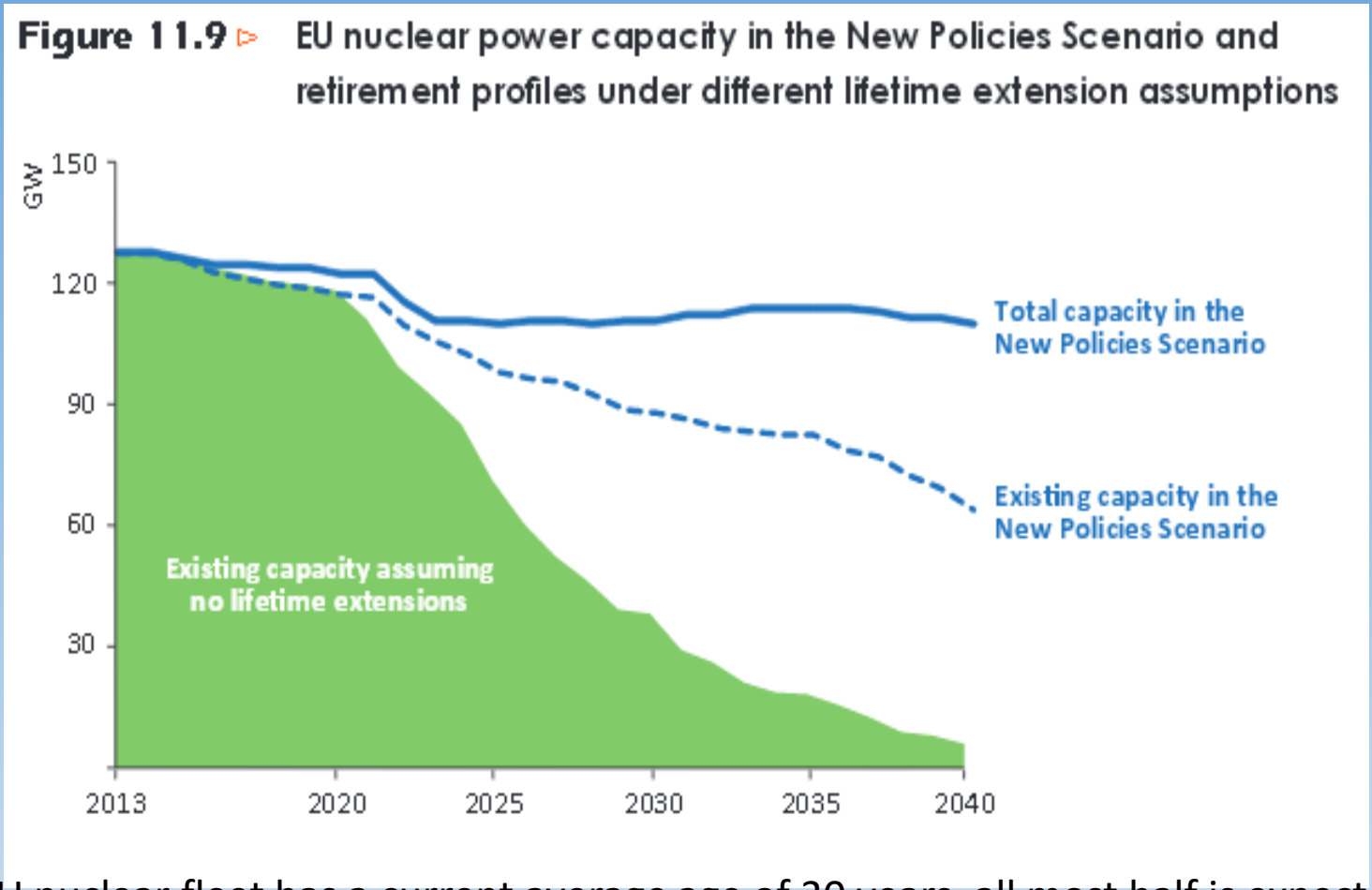
- Recent news reports indicate that first candidates for a second 20-year extension to 80 years are Dominion Resources Surry Plant in Virginia, Exelon's Peach Bottom Plant in Pennsylvania and Duke Energy's Oconee plant in South Carolina

Projected U.S. Nuclear Plant Capacity



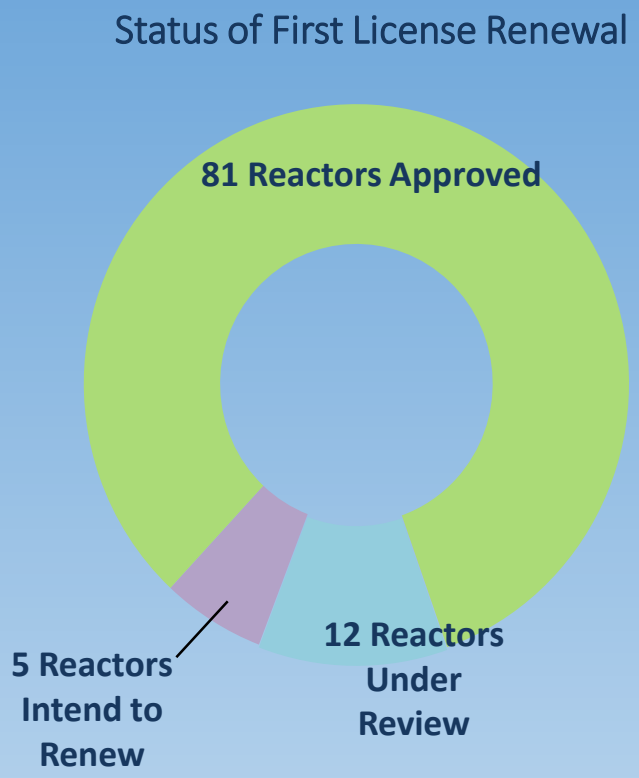
- Without additional new builds beyond those currently underway, total U.S. installed capacity begins to decline starting around 2027

EU Nuclear Capacity Outlook



- EU nuclear fleet has a current average age of 30 years, all most half is expected to be retired by 2040

U.S. License Renewal Efforts



Source: Nuclear Regulatory Commission

- Forty reactors have passed 40-year mark
- Approximately 31,000 MW of nuclear capacity will reach 60 years between 2029 and 2035
- Approximately one-half U.S. nuclear capacity will reach 60 years by 2040
- For second license renewal, NRC regulatory process stable, well-understood; existing regulations adequate
- In November 2015, Dominion Virginia Power announced intent to file second license renewal application for Surry nuclear plant. Exelon has followed and announced its attention at Peach Bottom
- Decision to renew a second time depends on whether market conditions justify capital investment required

Premature Nuclear Plant Shutdowns

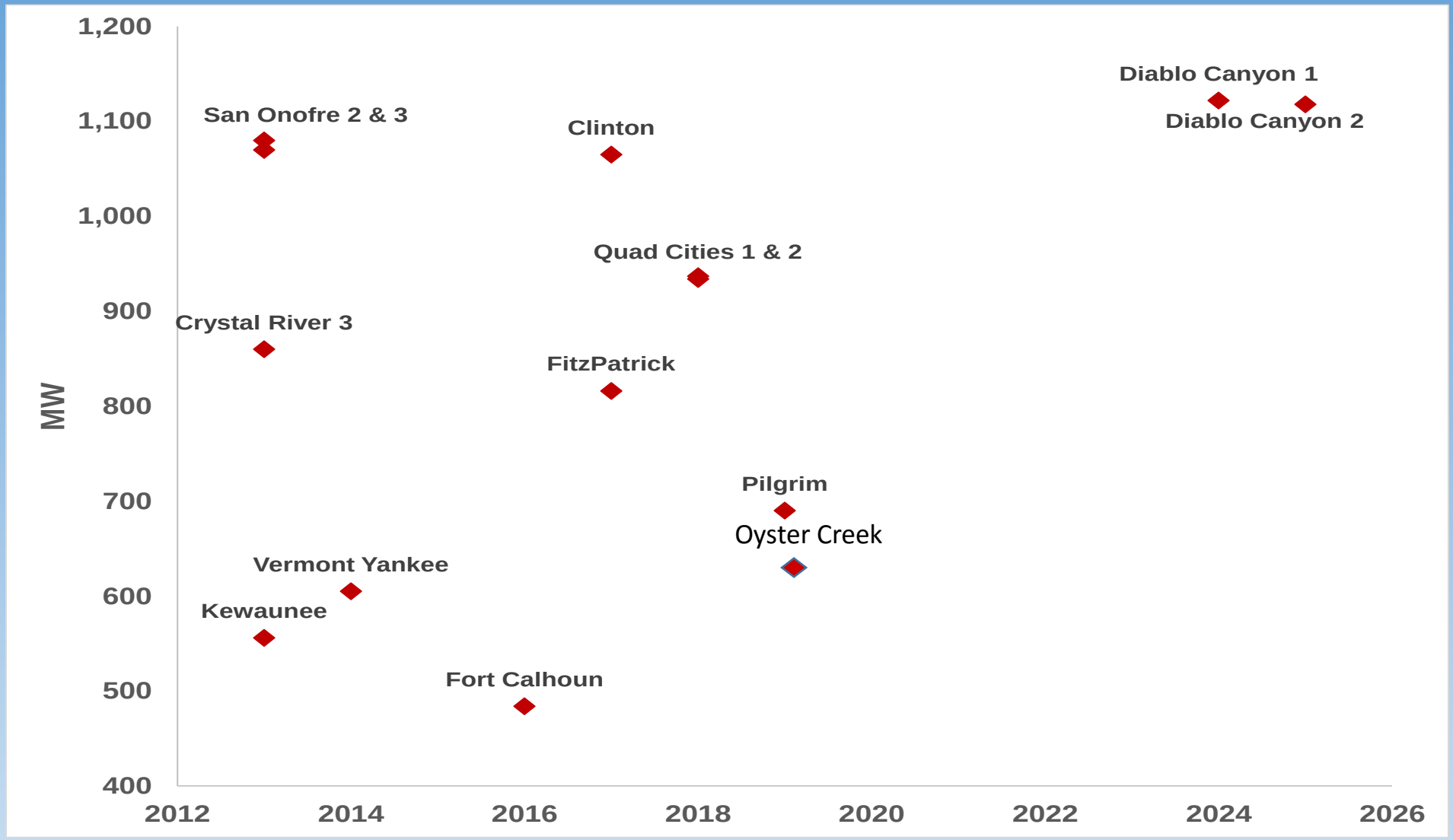
Plant	MWe	Reason	Closure Year	Latest Electricity Generated (bkWh/year)	Latest CO2 Emissions Avoided (million tons/year)
Crystal River 3	860	Mechanical	2013	7.0	5.3
San Onofre 2 & 3	2,150	Mechanical	2013	18.1	8.8
Kewaunee	566	Market	2013	4.5	4.8
Vermont Yankee	620	Market	2014	5.1	2.7
Fort Calhoun	479	Market	2016	3.5	3.7
FitzPatrick	852	Market	2017	7.4	3.9
Clinton	1,065	Market	2017	8.7	9.2
Quad Cities 1 & 2	1,819	Market	2018	15.6	13.2
Pilgrim	678	Market	2019	5.0	2.6
Oyster Creek	610	Policy	2019	5.3	4.4
Diablo Canyon 1 & 2	2,240	Combination	2024-2025	18.5	8.3

- 11,939 MWe of baseload capacity
- 67 million short tons of CO_2 avoided
- 16% of Clean Power Plan's 2030 414-million-ton target
- Approximately 9,000 direct jobs

Plants Declared at Declared at Risk/or at Risk

- **Additional plants that have been declared at risk include:**
  - **Davis Besse: 894 MWe**
  - **Three Mile Island 1: 805 MWe**
  - **Ginna: 582 MWe**
  - **Nine Point 1 637 MWe**
- **Deemed at Risk:**
  - **Indian Point 2 1028 MWe**
  - **Indian Point 3 1041 MWe**
- **Total Capacity at Risk: 4,987 MWe**

U.S. Announced Early Plant Retirements



Source: NECG

Decommissioning Costs

- **Decommissioning cost estimates vary**
- **Based on U.S. data, decommissioning cost estimates are in the range of $750 million to $1 billion per 1000 megawatt plant**
- **Decommissioning options include:**
  - **Immediate dismantling is the prompt removal and processing of all radioactive material**
  - **Deferred dismantling (Safe Store) is the process of allowing radioactive decay to occur before starting the dismantling process**

Decommissioning Costs as a function of time from shutdown

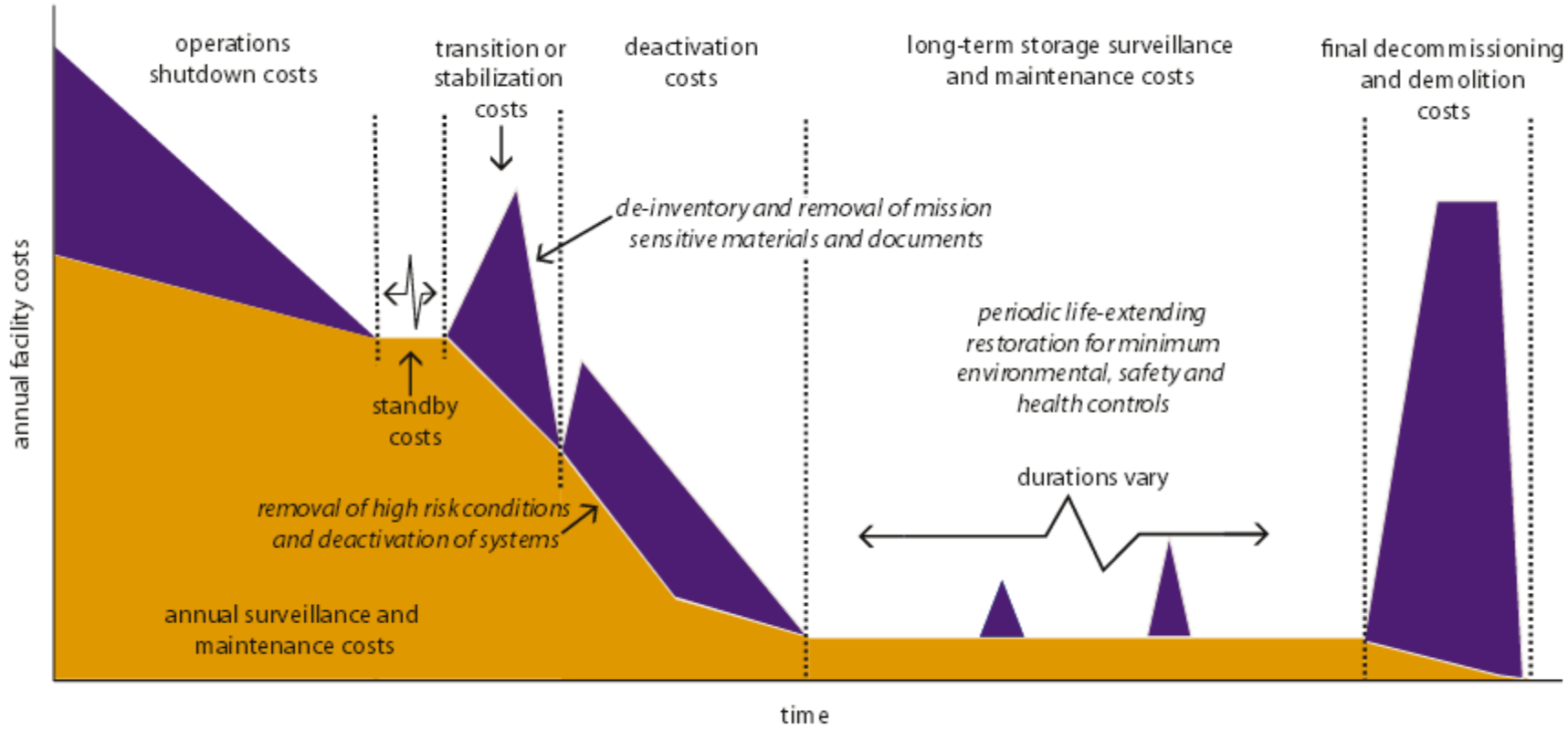


Figure 8: Decommissioning a nuclear power plant takes many years and costs vary widely. The highest costs will be incurred during the initial shutdown and final decommissioning and demolition. Any intervening period of standing by will be less expensive. These factors may influence decisions on how rapidly decommissioning will take place. *Source: United States Department of Energy (2010)*

Investor-Owned Decommissioning Per Plant Cost Estimates

Investor-Owned Utilities

	Company	Lic Exp	[Avg Yrs]	MW Nuclear Capacity	Decommissioning Cost Estimate ($mm) Cost Est	Amt/KW	Cost or $798/KW	Fund Balance ($mm)	Pro Forma Fund Shortfall ($mm)	Annual Contribution ($mm) Current Amount	Pro Forma Amou Shortfall/Avg Yr
1	Ameren Corporation[1]	2024	[11]	1,190	$754	$634	$950	$494	$456	$7	$41
2	American Electric Power Company[2]	2034-2037	[22]	2,069	$1,375	$665	$1,651	$1,932	-$281	$10	-$13
3	Constellation Energy Nuclear Group[3]	2029-2046	[22]	3,853	$3,677	$954	$3,677	$1,570	$2,107	$0	$96
4	Dominion Resources[4]	2032-2045	[22]	6,553	$4,161	$635	$5,229	$3,903	$1,326	$2	$60
5	DTE Energy Company[5]	2025	[11]	1,085	$1,600	$1,475	$1,600	$1,172	$428	$13	$39
6	Duke Energy Corporation[6]	2030-2046	[22]	8,958	$7,503	$838	$7,503	$5,132	$2,371	$79	$108
7	El Paso Electric Company	2045-2047	[33]	622	$381	$612	$496	$214	$282	$5	$9
8	Energy Future Holdings Corporation[2]	2030-2033	[18]	2,406	$1,319	$548	$1,920	$791	$1,129	$16	$63
9	Entergy Corporation[2,7]	2013-2038	[14]	8,223	$5,899	$717	$6,562	$4,519	$2,043	$39	$146
10	Exelon Corporation[2,8]	2022-2040	[15]	17,122	$11,553	$675	$13,663	$8,071	$5,592	$24	$373
11	FirstEnergy Corporation[9]	2017-2047	[15]	4,697	$3,368	$717	$3,748	$2,209	$1,539	$5	$103
12	Great Plains Energy[1]	2043	[31]	545	$296	$543	$435	$184	$251	$3	$8
13	Green Mountain Power Corporation	2045	[32]	21	$11	$524	$17	$8	$8	$0	$0
14	MidAmerican Energy Company[2]	2032	[19]	444	$329	$740	$354	$394	-$40	$2	-$2
15	NextEra Energy	2030-2043	[20]	5,552	$4,500	$811	$4,500	$4,708	-$208	$0	-$10
16	NRG Energy[2]	2027-2028	[14]	1,126	$554	$492	$899	$551	$348	$5	$25
17	Pacific Gas and Electric Company[10]	2024-2025	[11]	2,303	$3,590	$1,559	$3,590	$2,665	$925	$23	$84
18	Pinnacle West Capital Corporation	2045-2047	[33]	1,146	$701	$612	$915	$642	$273	$17	$8
19	PPL Corporation[2]	2042-2044	[29]	2,268	$1,245	$549	$1,810	$864	$946	$0	$33
20	Public Service Company of New Mexico	2045-2047	[33]	402	$246	$611	$321	$223	$98	$5	$3
21	Public Service Enterprise Group[2]	2033-2046	[26]	3,622	$2,180	$602	$2,890	$1,701	$1,189	$0	$46
22	San Diego Gas and Electric Company[11]		[0]	430	$867	$2,015	$867	$907	-$40	$8	N.A.
23	SCANA Corporation[2]	2042	[29]	644	$697	$1,082	$697	$101	$596	$3	$21
24	Southern California Edison[11]	2045-2047	[9]	2,304	$3,756	$1,630	$3,756	$4,237	-$481	$23	-$53
25	Southern Company	2034-2049	[27]	3,667	$2,817	$768	$2,926	$1,480	$1,446	$3	$54
26	Westar Energy[1]	2045	[31]	545	$296	$543	$435	$176	$259	$3	$8
27	Xcel Energy	2030-2034	[19]	1,594	$2,884	$1,809	$2,884	$1,627	$1,257	$21	$66
	Investor-Owned Utilities Totals			83,391	66,558	$798	$74,294	$50,475	$23,819	$315	$1,314

See Appendix page 14 for footnotes.

IEA Decommissioning Costs thru 2040

Table 11.2 ▷ Cumulative global investment and associated costs in nuclear power in the New Policies Scenario, 2014-2040 ($2013 billion)

	Investment in nuclear plants*	Associated costs		Total capacity additions (GW)
		Fuel cycle	Decommissioning	
China	345	191	-	132
European Union	301	220	51	45
United States	247	236	15	33
Korea	103	78	1	29
India	96	37	1	34
Japan	37	54	10	6
Rest of world	406	161	27	101
Total	**1 533**	**977**	**104**	**380**

IEA estimate of $104 billion is based on 150 GW of plant retirements at $693 million per GW. At $1B per GW, estimate is 150 billion and at $1.5B per plant, the worldwide market is $225 billion.

Order of Magnitude Estimates Decommissioning Costs thru 2040

Decommission Market Segment	Estimate of Decommissioning Costs
U.S.	$30 billion
France	$25 billion
Russia	$15 billion
U.K.	$20 billion
Germany	$30 billion
Japan	$30 billion
Total	$150 billion

- Decommissioning market size is in the range of $100-$150 billion thru 2040
- Decommissioning costs are in the order of 10 percent of the investment in new nuclear capacity over the period

SUMMARY

- **Plant Decommissioning has become and will continue to be an increasing important segment of the nuclear energy industry**
- **Existing nuclear plant fleets are approaching "mid-life" and future nuclear plant retirements are "around-the-corner", and are the logical consequence of plants reaching their economic life and design expectancies**
- **Nuclear plant decommissioning costs vary significantly and depend on decommissioning approach, in-country requirements and regulation and industry practices**
- **Nuclear plant decommissionings are expected to be concentrated in the oldest fleets, led by the U.S. and EU, as well as those underway in Germany and those that may take place in Japan as a resulted of the Fukushima accident**

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Backup Slides

State of Play - Nuclear Energy Worldwide

- **In 2015, WNA reports that 10 new reactors began commercial operations (+9497 MWe), while internationally eight reactors were shutdown for decommissioning (-4582 MWe)**
- **Four U.S. reactors (Crystal River 3, San Onofre 2&3, Vermont Yankee) were declared has permanently shutdown (-3479 MWe)**
- **Germany shutdown 1 reactor, Grefenrheingeld of 1345 MWe, Japan permanently closed 5 reactors: Genka 1, Mihama 1, Miahama 2, Shimane 1, and Tsuruga 1 representing a total of 2099, Sweden closed 1 reactor Oskarshamn of 648 MWe and Britain closed 1 reactor Wylfa of 490 MWe**
- **Total: 110 commercial reactors 46 experimental or prototypes, and 250 research reactors and number of fuel cycle facilities have been permanently shutdown. Some of these facilities have been fully dismantled.**

U.S. New Capacity Required Maintain Relative Fuel Share

Figure 2

New Nuclear Generating Capacity Needed If All Reactors Retire After 60 Years of Operation

Year	Total Electric Generation (bkWh)	Nuclear Capacity (GW)	Nuclear Generation (bkWh)	Nuclear Fuel Share	New Generation Needed to Meet Fuel Share (GW)	
					20%	25%
2025	4,622.3	104.0	820.0	17.7%	13.2	42.6
2030	4,815.1	100.0	788.0	16.4%	22.2	52.7
2035	5,004.3	72.4	570.4	11.4%	54.6	86.3
2040	5,219.7	57.5	453.2	8.7%	74.9	108.0

Data Source: Energy Information Administration, Annual Energy Outlook 2014