NIC Global Summit
Outlook on Decommissioning Market

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State of Play - Nuclear Energy Worldwide

- At the end of 2015, world's 382 GW, 441 reactors, of nuclear capacity 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 25 years old
- By contrast, around half of the capacity in non-OECD countries (excluding Russia) is less than 15 years old
- Currently, 67 GW of nuclear capacity under construction, 21 reactors in OECD countries and 46 in non-OECD countries

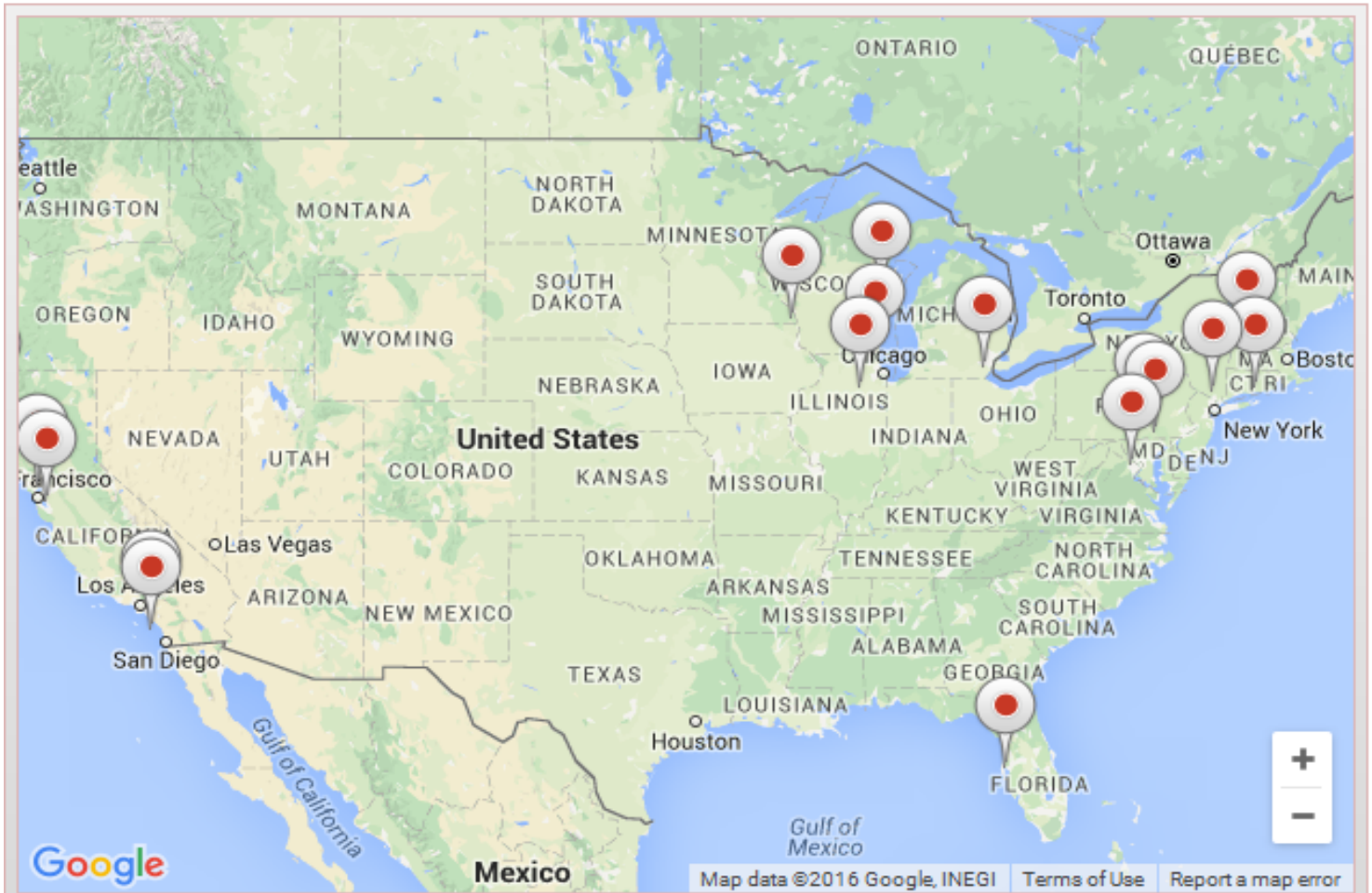
State of Play - Nuclear Energy Worldwide

- 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: 157 reactors have been permanently shutdown

State of Play - Nuclear Energy Worldwide

Locations of Power Reactor Sites Undergoing Decommissioning

The NRC's Office of Nuclear Material Safety and Safeguards (NMSS) has project management responsibilities for 19 power reactors undergoing decommissioning.



State of Play - Nuclear Energy Worldwide

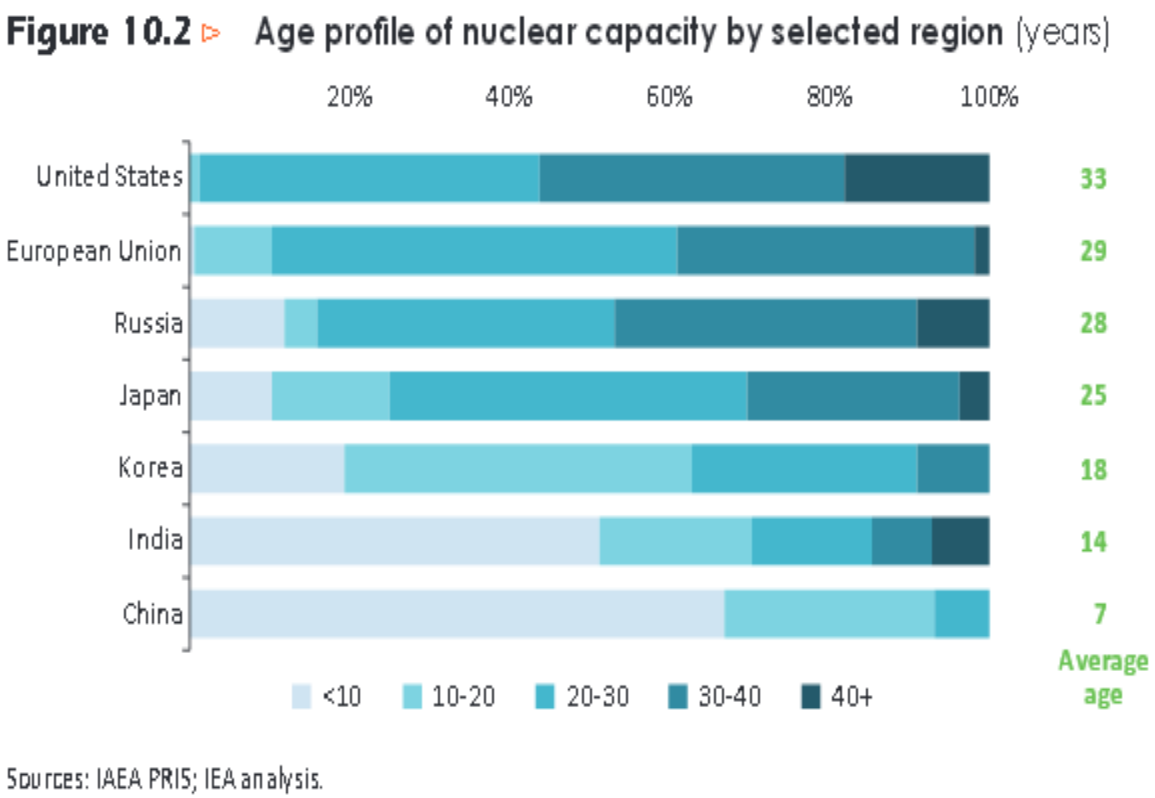
Power Reactor Sites Undergoing Decommissioning

Name	Location
Crystal River – Unit 3	Crystal River, FL
Dresden – Unit 1	Dresden, IL
Fermi – Unit 1	Newport, MI
Humboldt Bay	Eureka, CA
Indian Point – Unit 1	Buchanan, NY
Kewaunee	Kewaunee, WI
LaCrosse Boiling Water Reactor	Genoa, WI
Millstone – Unit 1	Waterford, CT
Nuclear Ship Savannah	Baltimore, MD
Peach Bottom – Unit 1	Delta, PA
San Onofre – Unit 1	San Clemente, CA
San Onofre – Units 2 & 3	San Clemente, CA
Three Mile Island – Unit 2	Middletown, PA
General Electric Co. – ESADA Vallecitos Experimental Superheat Reactor (EVESR)	Sunol, CA
General Electric Co. – Vallecitos Boiling Water Reactor (VBWR)	Sunol, CA
Vermont Yankee	Vernon, VT
Zion – Units 1 & 2	Zion, IL

Retirements – Circle of Life

- 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 157 nuclear power plants have been shutdown and/or are undergoing decommissioning worldwide (not including test reactors)
- Main drivers for plant retirements include:
  - 1. Units that have achieved their expected economic lifetime, 75 %
  - 2. Units that are closed following an accident, 5%
  - 3. Units which are closed prematurely by political decision or due to regulatory reasons, 20%

Age Profile of Operating Reactors



- Global nuclear reactor fleet average age is 27 years
- OECD countries, reactor fleet is over 25 years.
- Half of the capacity in Non-OECD countries is less than 15 years old

Age Profile of Operating Reactors

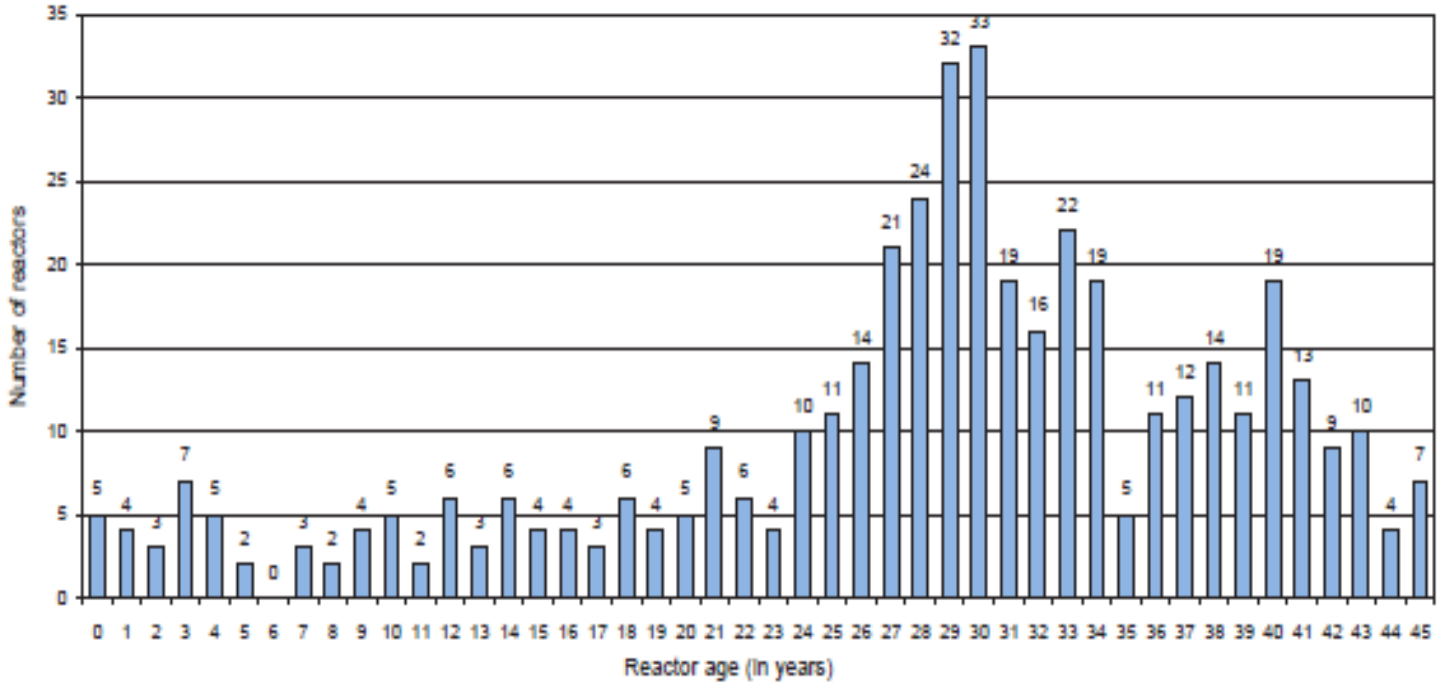
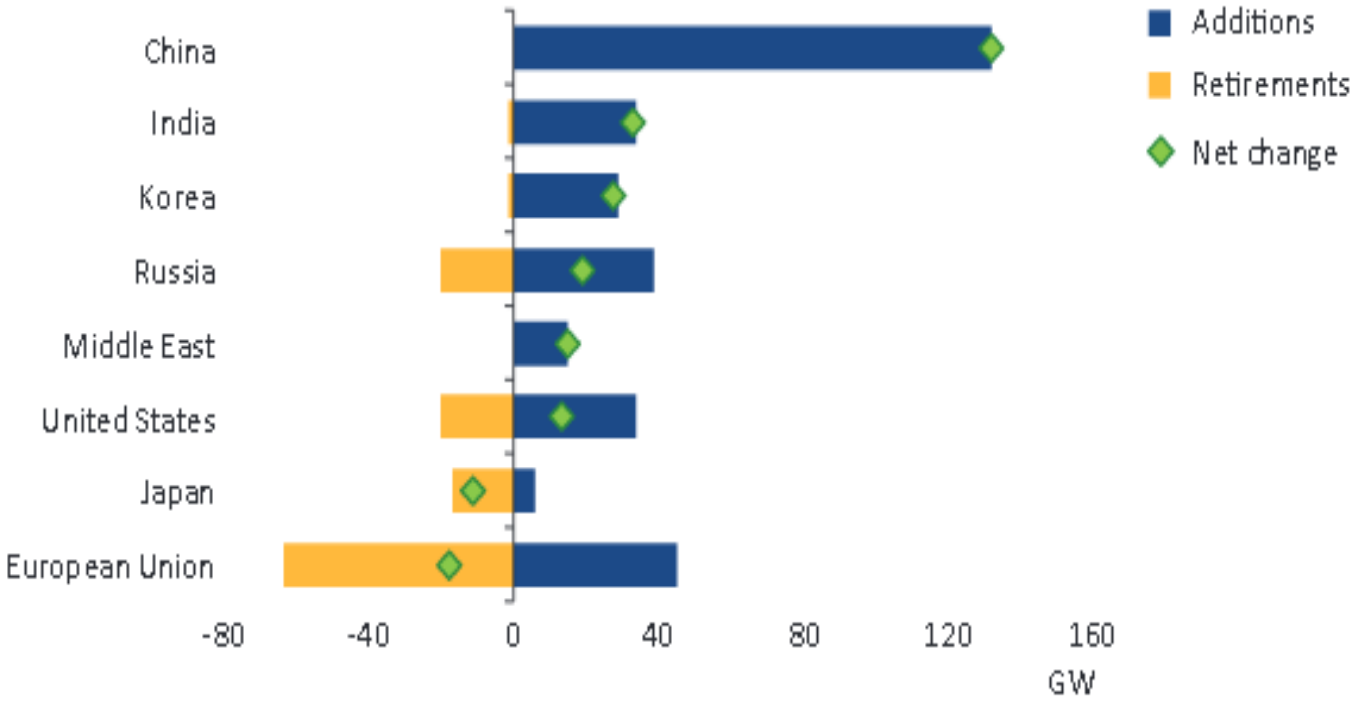


Figure 5. Number of operational reactors by age (as of 31 Dec. 2014).

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

Distribution of Planned Retirements

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

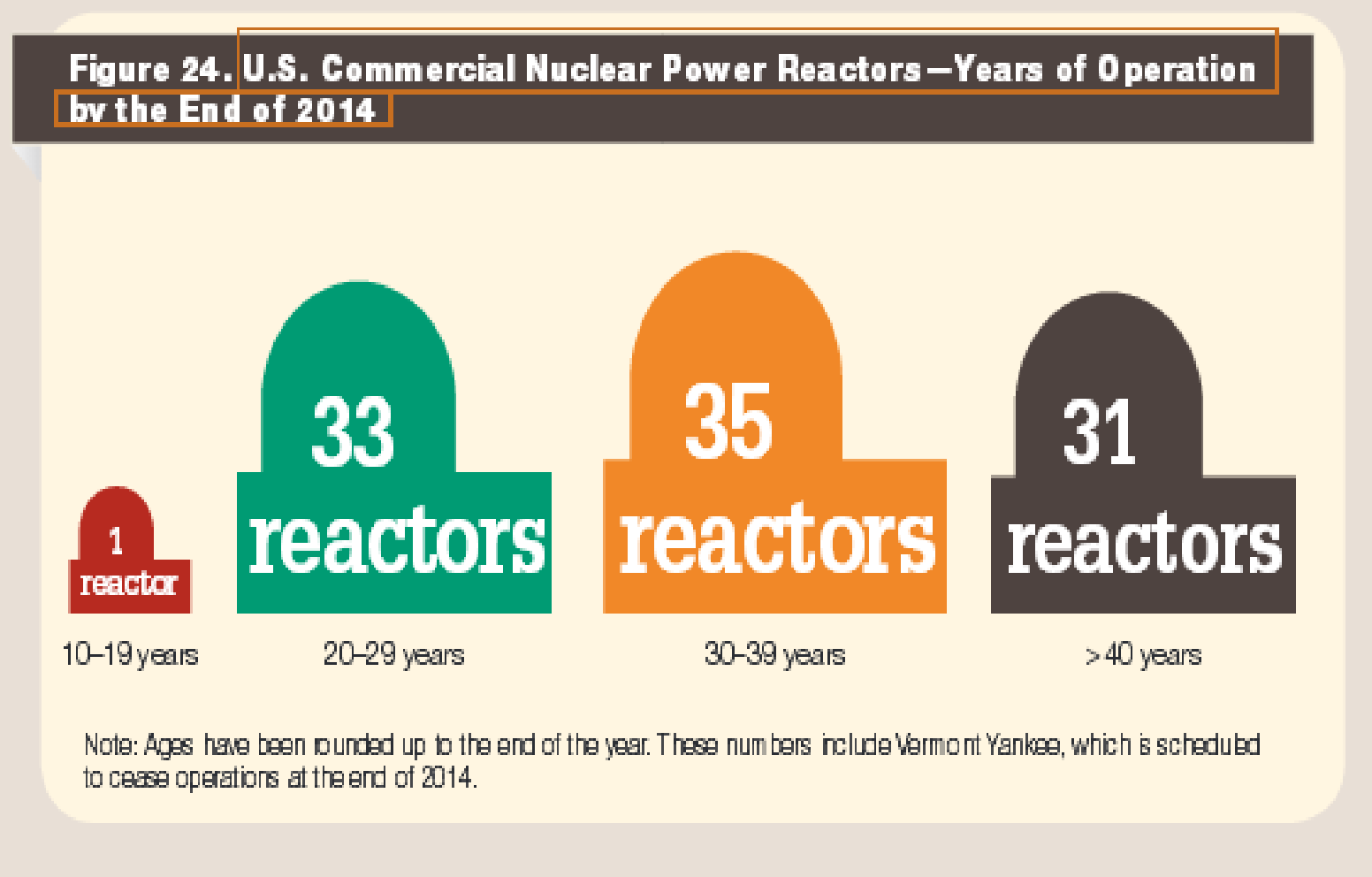


- Around 150 GW of nuclear capacity is retired thru 2040, equivalent to 38% of the current installed capacity or 44% of the existing operating world fleet

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 European Union(led by France, Germany and UK), Russia, Japan and United States**
- **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**

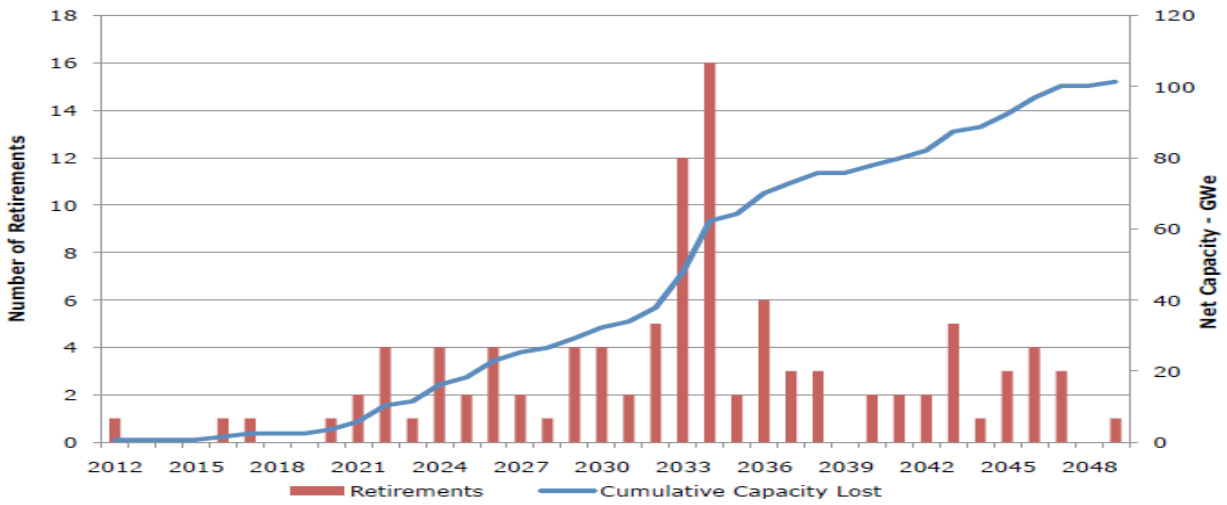
U.S. Nuclear Plant Age Distribution



- 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

Figure 3. Expected U.S. Reactor Retirements and Net Capacity Lost

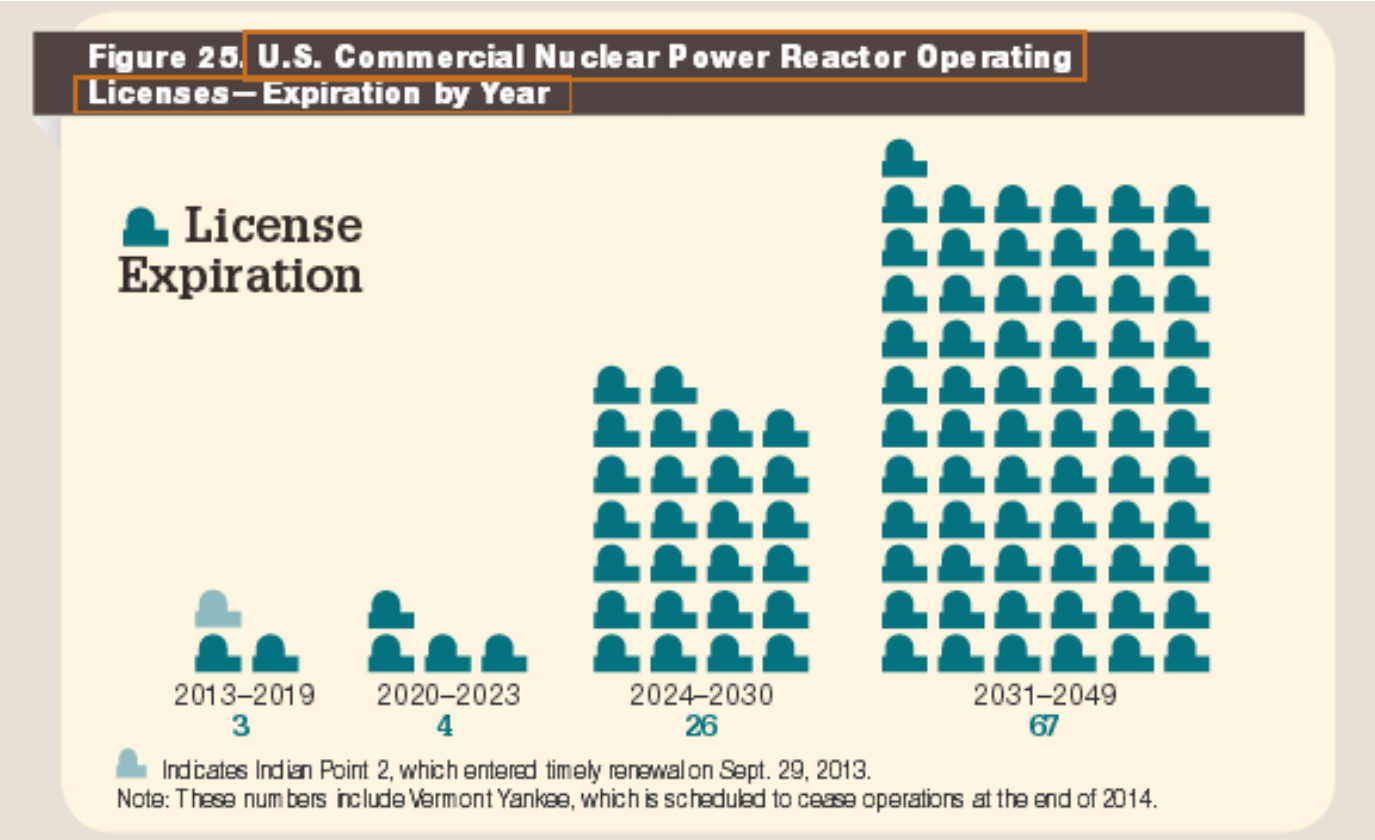


Note: This figure assumes all reactors that have received license extensions and all those with applications currently under review operate for a full 60 years, with no additional extensions.

Source: U.S. Nuclear Regulatory Commission. List of Power Reactor Units. Available at: http://www.nrc.gov/reactors/operating/list-power-reactor-units.html.

- 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

Expected U.S. Reactor Retirements



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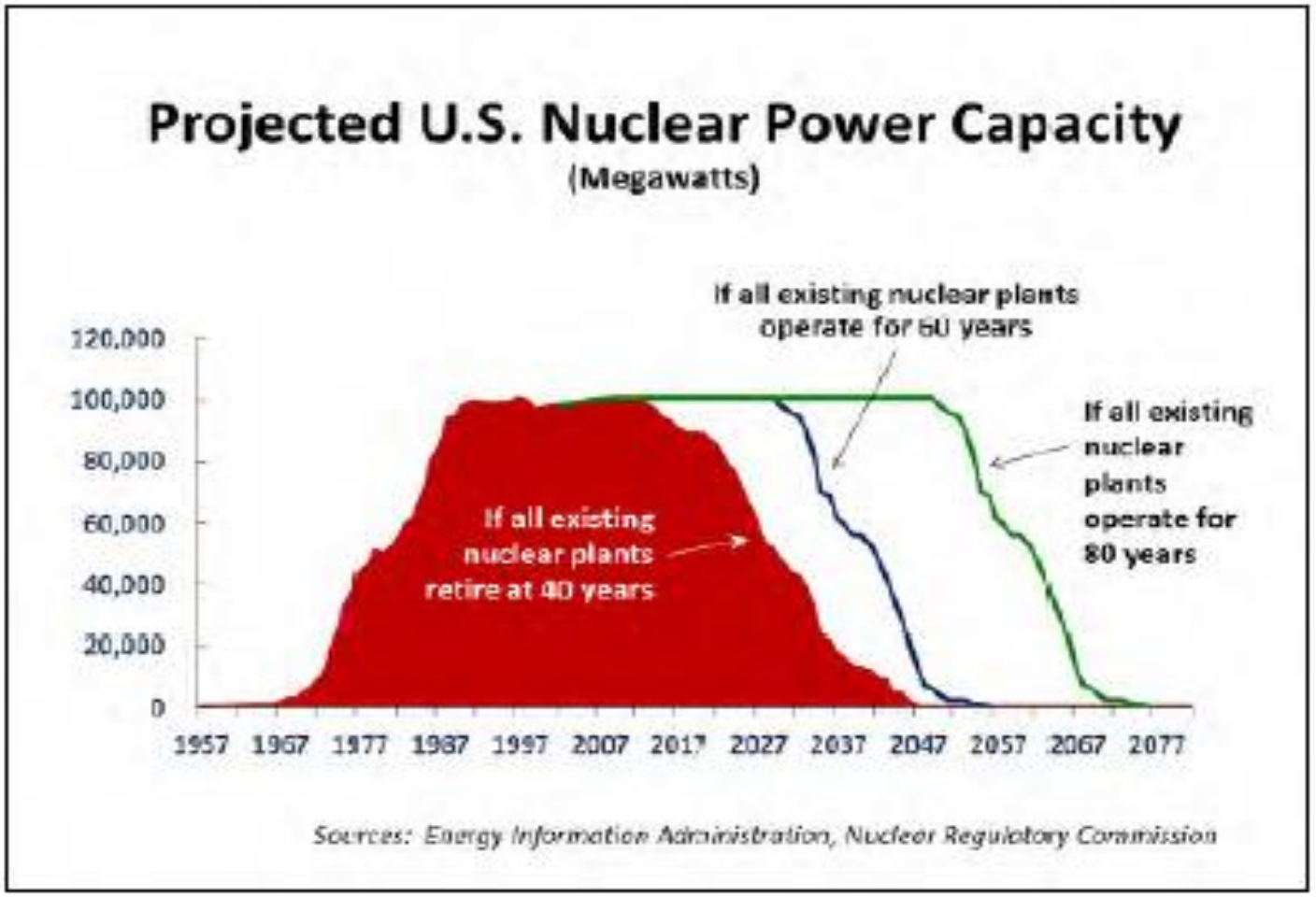
Projected U.S. Nuclear Plant Capacity



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

U.S. New Capacity Required Maintain Relative Fuel Share

Figure 2

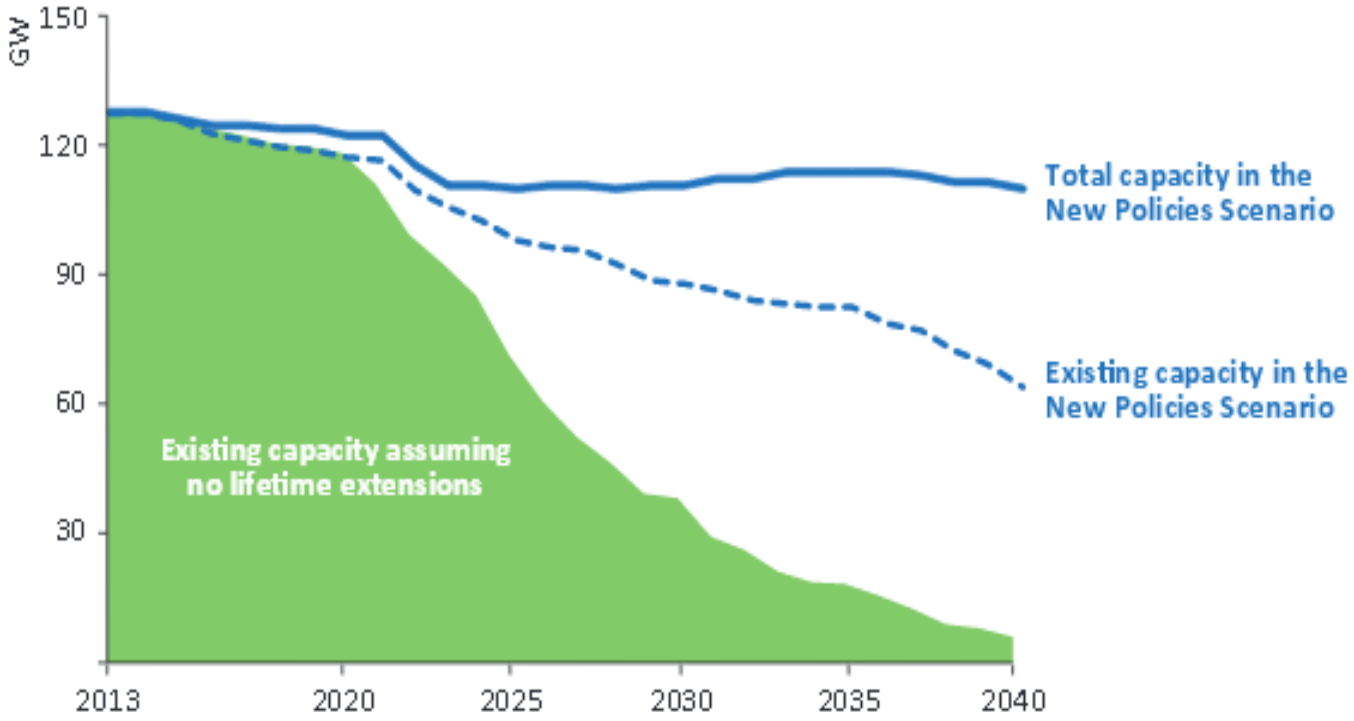
New Nuclear Generating Capacity Needed If All Reactors Retire After 60 Years of Operation

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

EU Nuclear Capacity Outlook

Figure 11.9 ▷ EU nuclear power capacity in the New Policies Scenario and retirement profiles under different lifetime extension assumptions



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

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

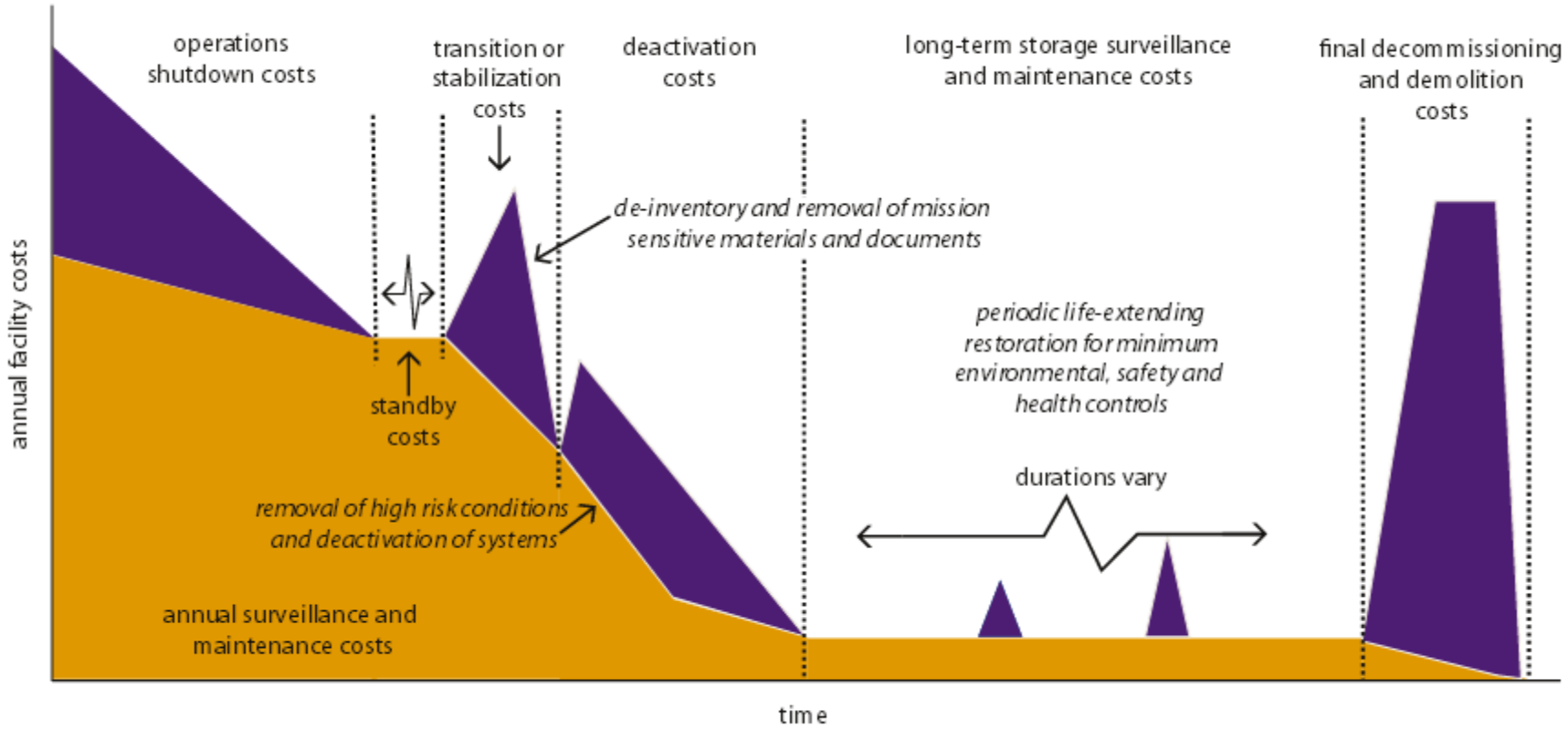


Figure 8: Decommissioning a nuclear power plant takes many years and costs vary widely. The highest costs will be incurred during the initial shutdown and final decommissioning and demolition. Any intervening period of standing by will be less expensive. These factors may influence decisions on how rapidly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

* Investment in new plants and for uprates and refurbishments for life extensions at existing ones.

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

- **Decommissioning beginning in the mid-2020s will become an increasing important segment of the nuclear energy industry**

- **Existing nuclear plant fleet is approaching "mid-life" and future nuclear plant retirements are "around-the-corner" therefore 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**