

Outlook for U.S. D&D and License Renewal

U.S. Nuclear Infrastructure Council

Third Japan-U.S Fukushima Forum

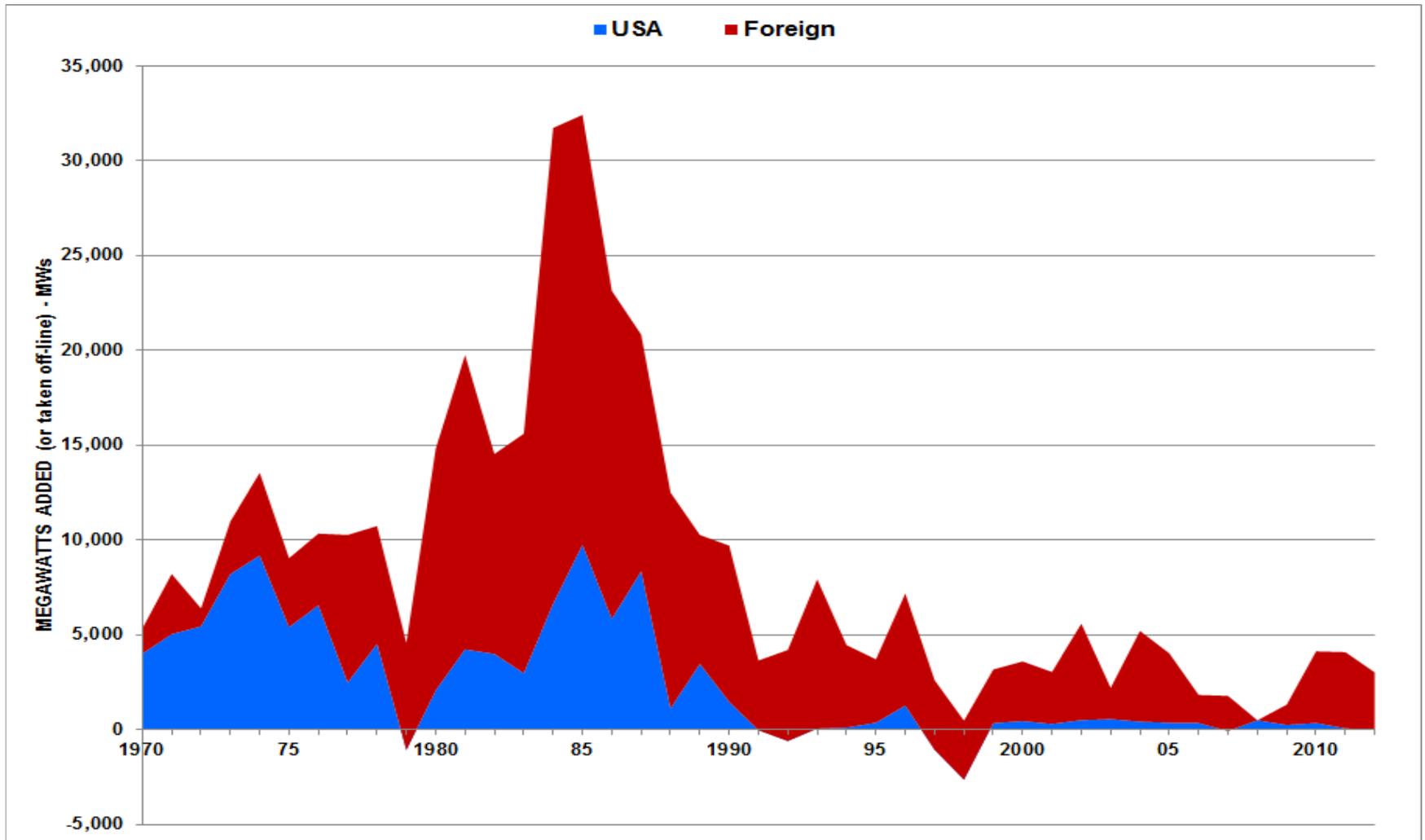
24 February 2016

Tokyo

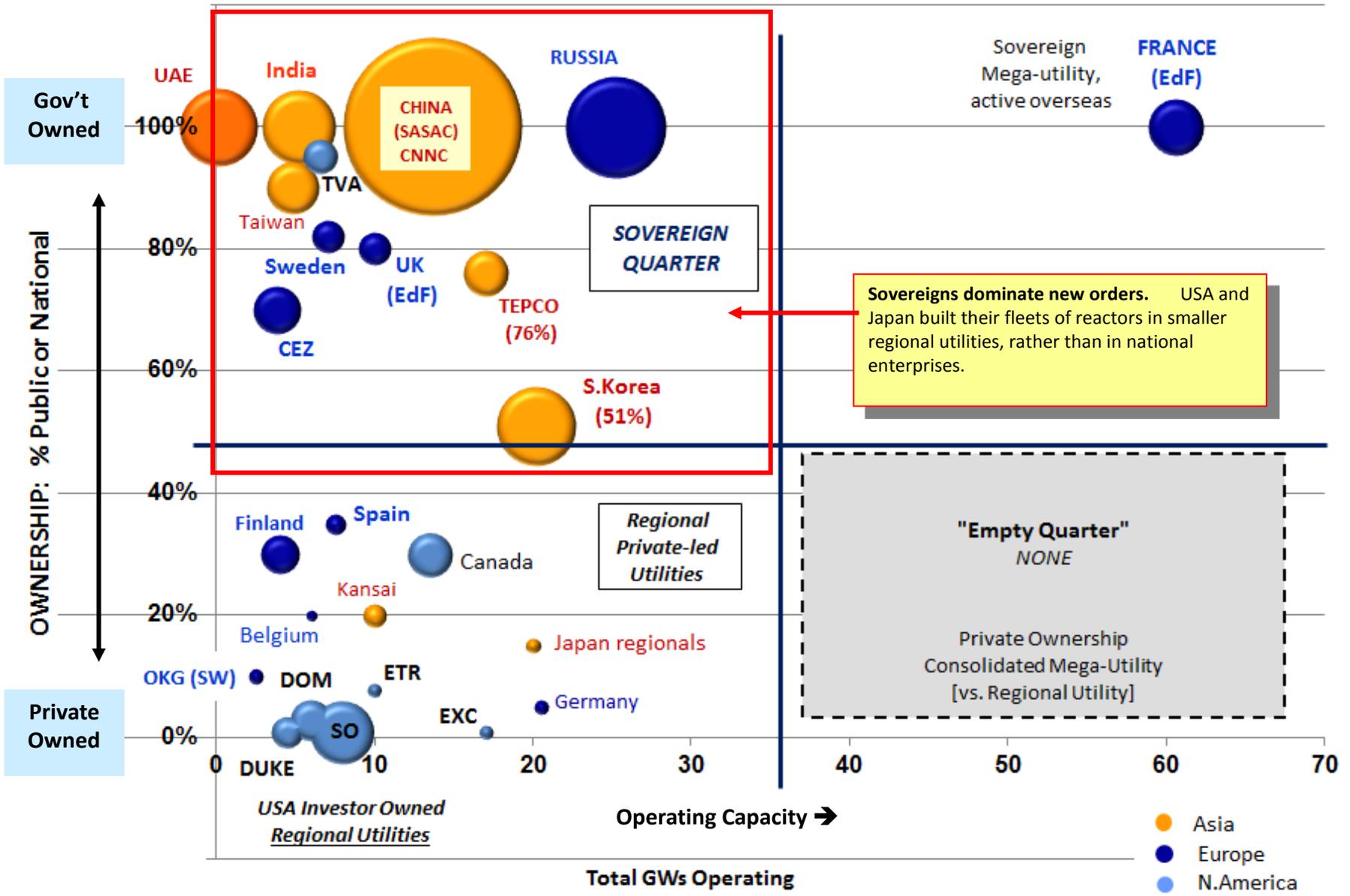
U.S. Nuclear Snapshot

- Debut of five new U.S. reactors (2015-20)
- Eight reactors closing before end of reactor license
- Window of opportunity for replacement of outgoing coal baseload
- Looming nuclear plant retirements
- Competition with natural gas as the clean energy baseload to meet increased demand
- Limited Clean Power Act impacts
- Leader in new Passive Safety Designs – AP1000, ESBWR, NuScale
- Small Modular Reactor Trail Blazing
 - DOE cost-share for Design & Pre-Licensing
 - Deployment in mid-2020s
- Advanced Reactors in progress
 - An estimated 40 U.S. companies in the hunt
- Global market for reactors and supply-chain

New Reactors Brought on Line



Nuclear Entities: Ownership, Operating GWs + Under Construction (bubble size)

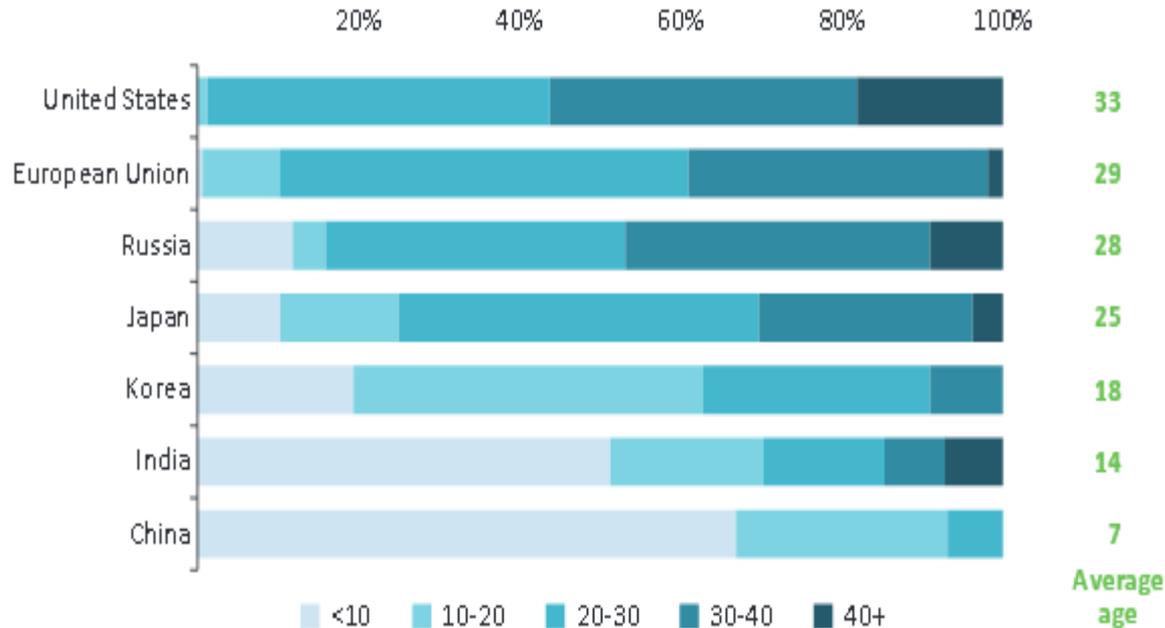


Decommissioning Overview

- 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

Age Profile of Operating Reactors

Figure 10.2 ▶ Age profile of nuclear capacity by selected region (years)



Sources: IAEA PRIS; IEA analysis.

- 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

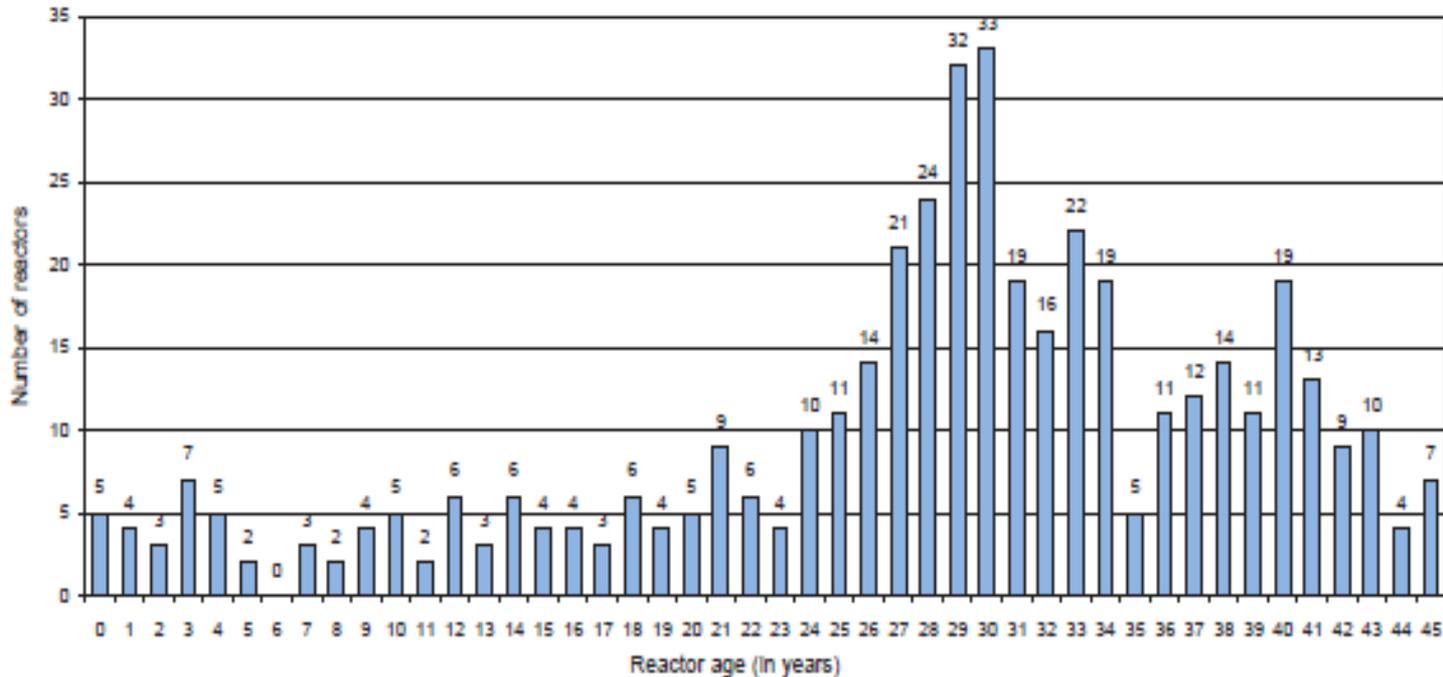
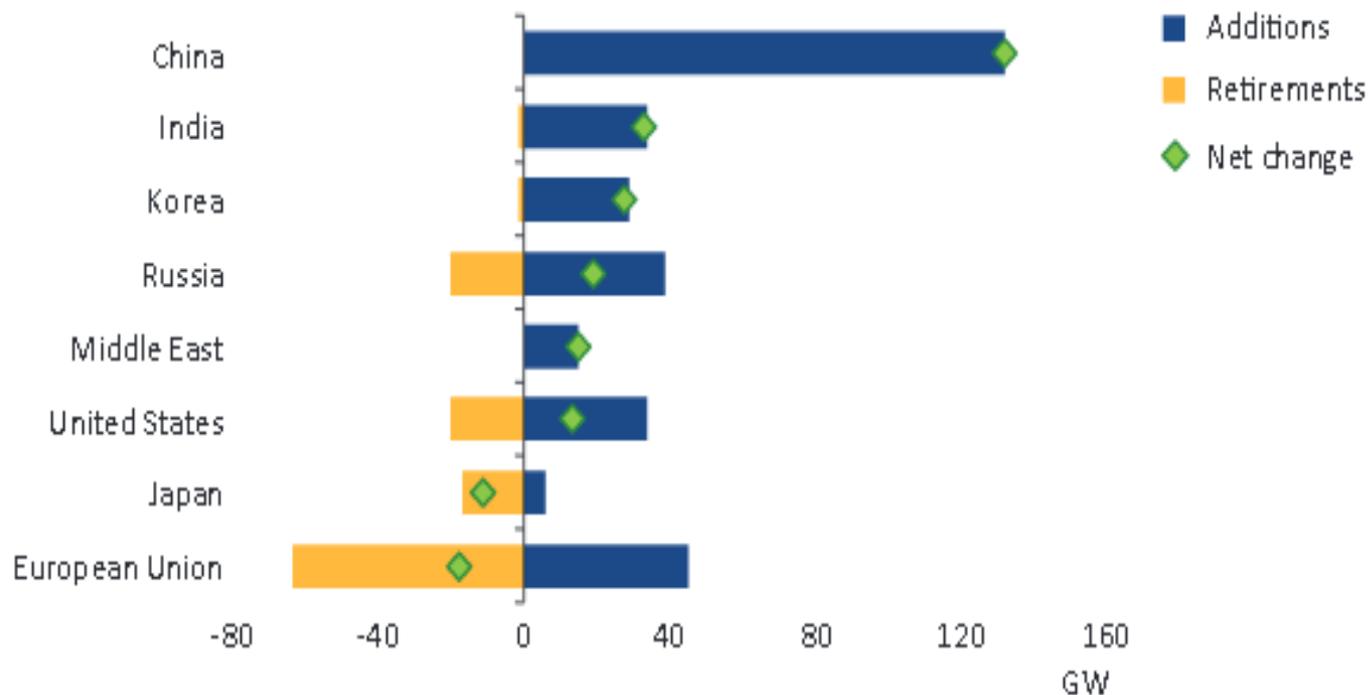


Figure 5. Number of operational reactors by age (as of 31 Dec. 2014).

- 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



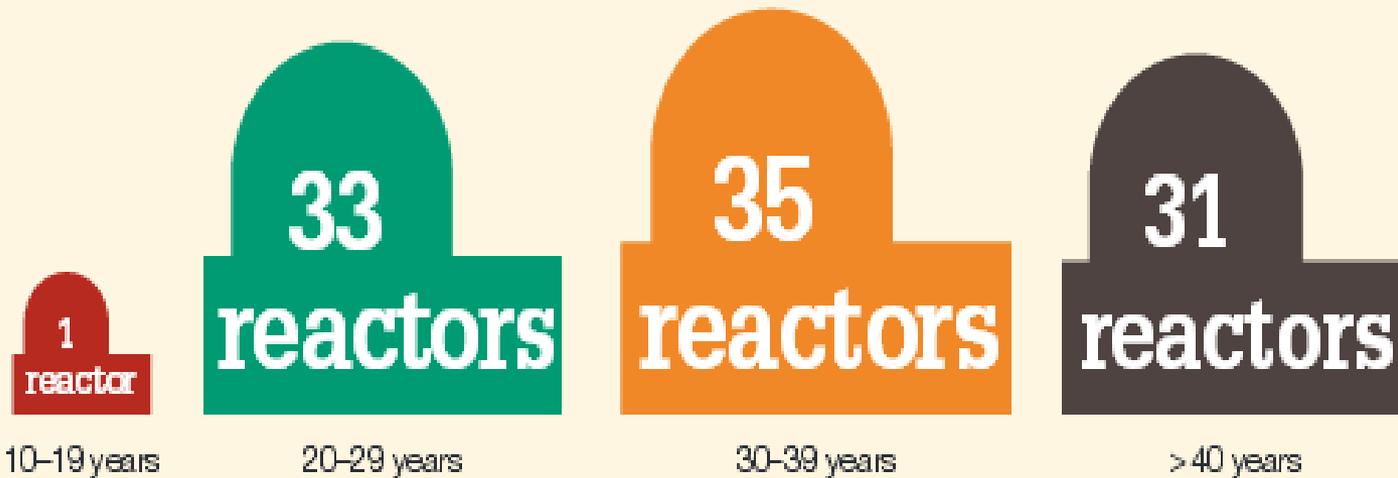
- Around 150 GW of nuclear capacity is retired thru 2040, equivalent to 38% of the current installed capacity or 44% of the existing operating world fleet

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

U.S. Nuclear Plant Age Distribution

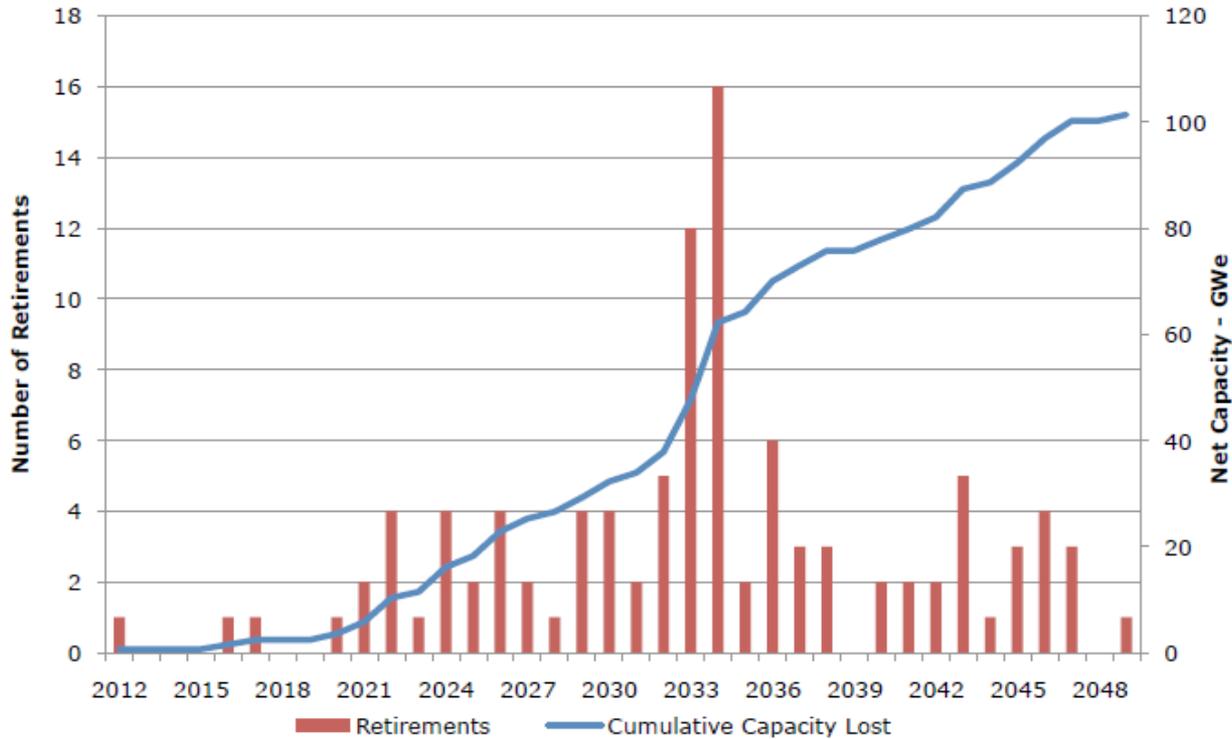
Figure 24. U.S. Commercial Nuclear Power Reactors—Years of Operation by the End of 2014



Note: Ages have been rounded up to the end of the year. These numbers include Vermont Yankee, which is scheduled to cease operations at the end of 2014.

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

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

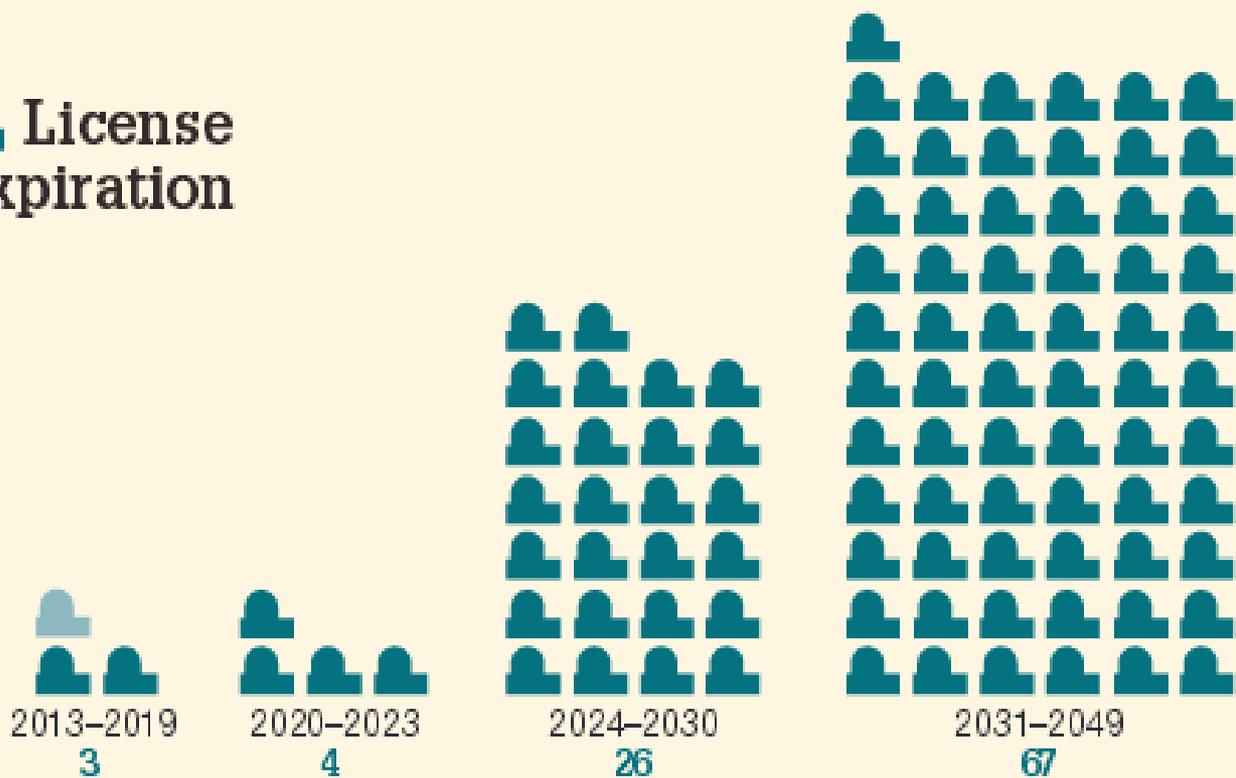


Note: This figure assumes all reactors that have received license extensions and all those with applications currently under review operate for a full 60 years, with no additional extensions.

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

Figure 25. U.S. Commercial Nuclear Power Reactor Operating Licenses—Expiration by Year

 License Expiration



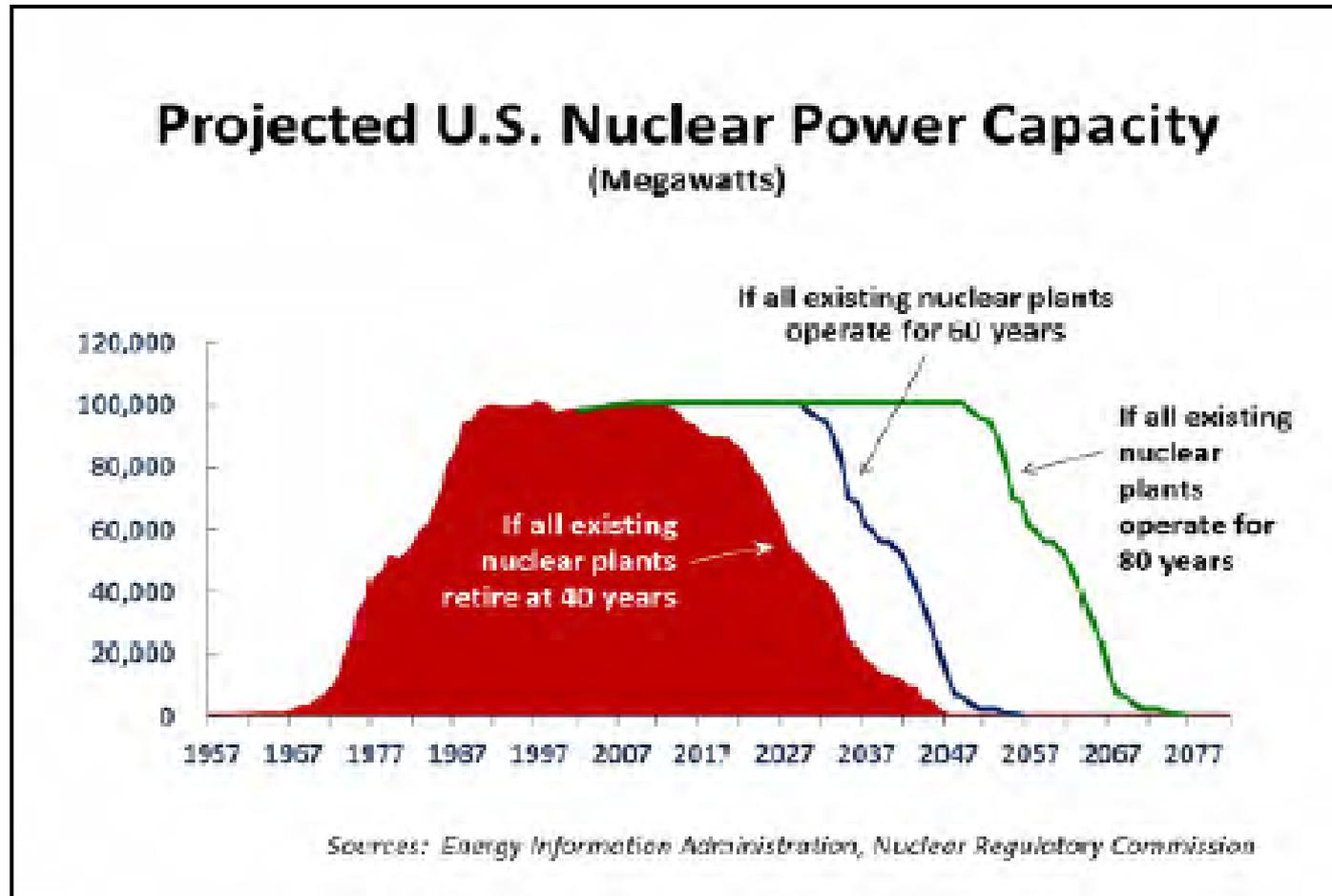
 Indicates Indian Point 2, which entered timely renewal on Sept. 29, 2013.

Note: These numbers include Vermont Yankee, which is scheduled to cease operations at the end of 2014.

Life Beyond 60

- Three US utilities have signaled intent to seek a second license renewal
 - Dominion – Surry (Virginia)
 - Exelon – Peach Bottom (Pennsylvania)
 - Duke – Oconee (South Carolina)
- US NRC has defined as “Subsequent License Renewal” and has initiated its program
- “General Aging Lessons Learned” Now Out for Comment

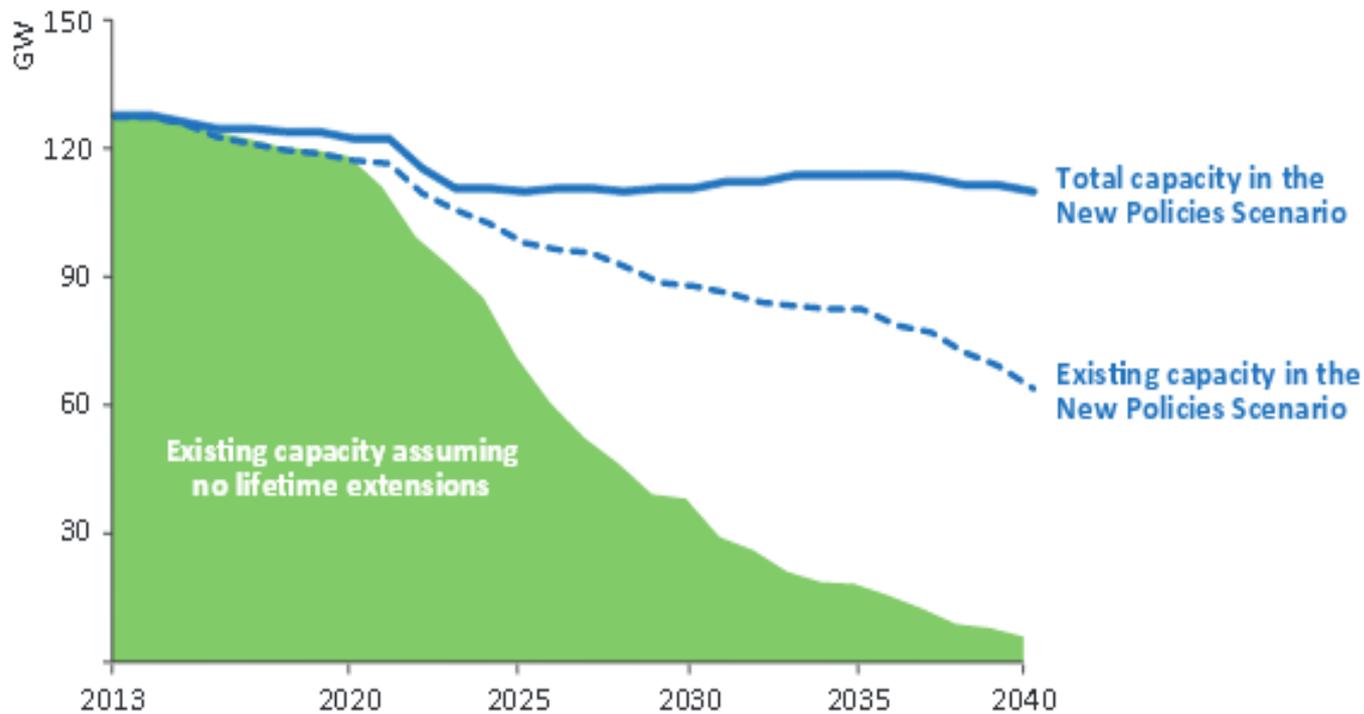
Projected U.S. Nuclear Plant Capacity



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

EU Nuclear Capacity Outlook

Figure 1 1.9 ▶ 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

IEA Decommissioning Costs thru 2040

Table 1 1.2 ▶ 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

Decommissioning Market Takeaways

- Decommissioning beginning in the mid-2020s will become an increasingly 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 decommissioning is 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 will take place in Japan as a result of the Fukushima accident