



ANS

Innovating for a Sustainable Nuclear Future

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Major Objectives of US Nuclear Industry

- ✓ Preserve the existing fleet
 - 98 reactors in operation
 - Providing 19.3% of total US electric generation and over 55% of country's emissions-free electricity
 - Achieving 92.3% average capacity factor
- ✓ Develop light-water small modular reactors (SMRs) and advanced reactors for commercial deployment

Momentum of current fleet is needed to ensure commercial viability of next generation of SMRs and advanced reactors

Premature Nuclear Plant Closures and Announced Shutdowns

Plant	MWe	Closure Year	Reason	Final Year Generation Generation (billion kWh per year)	Final Year CO2 Avoided (M tons/year)
Crystal River 3	860	2013	Mechanical	7.0	3.8
San Onofre 2 & 3	2,150	2013	Mechanical	18.1	8.0
Kewaunee	566	2013	Market	4.5	3.8
Vermont Yankee	620	2014	Market	5.1	2.4
Fort Calhoun	478	2016	Market	3.4	3.3
Oyster Creek	625	2018	Policy	5.4	4.0
TOTAL	5,299			43.5	25.3
Three Mile Island 1	803	2019	Market	6.9	5.0
Pilgrim	678	2019	Market	5.1	2.3
Davis-Besse	908	2020	Market	7.9	5.7
Duane Arnold	619	2020	Market	5.2	5.0
Indian Point 2 & 3	2,061	2020-2021	Market & Policy	15.3	7.1
Beaver Valley 1 & 2	1,872	2021	Market	15.3	11.1
Perry	1,268	2021	Market	9.8	7.1
Palisades	789	2022	Market	6.1	5.3
Diablo Canyon 1 & 2	2,240	2024-2025	Policy	17.9	6.9
TOTAL	11,238			89.5	55.5

Source: Emissions avoided are calculated using regional and national fossil fuel emissions rates from the U.S. Environmental Protection Agency and latest plant generation data from the U.S. Energy Information Administration. Updated: September 2018.

Efforts to Prevent Premature Closure

✓ Internal Focus

- Collaboration among operators through Delivering the Nuclear Promise initiative
 - Utilizing Minor Maintenance (EB 16–15b)
 - Critical Component Reduction (EB 16–25)
 - Value Based Maintenance (EB 17–03)
 - Standardized Performance Indicators (EB 17–24)
- Innovation
 - Electronic Work Packages
 - New Digital Worker

✓ External Focus

- State and federal level advocacy for policy changes
- Designed to level playing field among generation alternatives
- Rewards zero emissions attribute

U.S. Nuclear Plant Costs (\$/MWh in 2017 dollars)

Year	Fuel	Capital	Operating	Total
2002	5.93	4.06	19.25	29.24
2003	5.79	5.11	19.51	30.41
2004	5.47	5.85	19.19	30.51
2005	5.20	6.01	19.62	30.83
2006	5.22	5.76	19.90	30.88
2007	5.31	6.33	19.74	31.39
2008	5.54	7.00	20.21	32.75
2009	6.14	9.22	21.22	36.58
2010	7.00	9.48	21.37	37.84
2011	7.35	10.42	22.66	40.42
2012	7.77	11.21	22.37	41.35
2013	8.01	8.49	21.67	38.17
2014	7.47	8.47	21.67	37.60
2015	7.10	8.24	21.56	36.91
2016	6.90	6.89	20.87	34.65
2017	6.44	6.64	20.43	33.50
2002-2017 Change	8.6%	63.5%	6.1%	14.6%
2012-2017 Change	-17.2%	-40.8%	-8.7%	-19.0%

Source: Electric Utility Cost Group
Updated: September 2018

Nuclear Plants Saved from Premature Closure

Plant	MWe	Projected Closure Year	Reason for Potential Shutdown	Electricity Generated in 2017 (billion kWh per year)	CO ₂ Emissions Avoided in 2017 (Million metric tons/year)
Clinton	1,065	2017	Market	8.3	8.1
Fitzpatrick	852	2017	Market	6.2	2.9
Ginna	582	2017	Market	4.7	2.2
Hope Creek	1,172	~2020	Market	10.6	7.7
Millstone 2 & 3	2,096	~2020	Market	16.5	7.4
Nine Mile Point 1 & 2	1,770	2017-2018	Market	16.0	7.4
Quad Cities 1 & 2	1,819	2018	Market	15.4	11.2
Salem 1 & 2	2,328	~2020-2021	Market	18.0	13.1
TOTAL	11,683			95.7	60.0

11,683 MWe baseload capacity

More than 7,400 direct jobs saved

More electricity generation than all U.S. utility solar in 2017

60.0 million metric tons of CO₂ avoided

Source: Emissions avoided are calculated using regional and national fossil fuel emissions rates from the **U.S. Environmental Protection Agency** and latest plant generation data from the **U.S. Energy Information Administration**. Updated: August 2018.

Reactor Technology Evolution

Light Water Reactors (LWR)



Existing fleet

Passive LWR



LWR Small Modular Reactors (SMR)



Developers
Westinghouse
GE-Hitachi

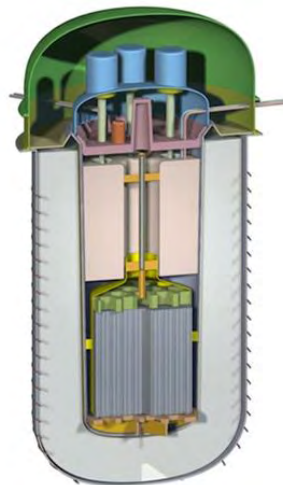
Developers
NuScale
GEH
Holtec

Fusion Reactors



Developers
Helion
Tri-Alpha
General Fusion
Lockheed Martin
FusionOne

Molten Salt and Fast Reactors



Developers
Terrestrial
TerraPower
Flibe
Elysium
Oklo
Westinghouse
UPower

High Temperature Gas-cooled Reactors (HTGR)



Developers
PBMR Ltd
Gen Atomics
Areva
Urenco
X-energy

Light-Water SMR Development

✓ NuScale Power

- 12-pack of 60MWe reactors (720Mwe total)
- Design Certification application under review by NRC
- Potential construction by Utah-based municipalities

✓ GEH

- 300MWe reactor
- Based on approved design of ESBWR
- Recently announce plans to pursue NRC approval

✓ Holtec

- 160MWe
- Expansion of dry cask expertise
- Pursuing regulatory approval in Canada

Advanced Reactor Activity

- ✓ Three Technology Working Groups (TWG)
 - High Temperature Reactors
 - Molten Salt Reactors
 - Fast Reactors
- ✓ Regulatory Challenges
 - Phased approach to licensing to support investment decisions
 - Regulatory framework changes needed to accommodate non-LWRs
- ✓ Federal Government Support
 - Gateway for Accelerated Innovation in Nuclear
 - Rolling funding opportunity from DOE
 - Strong, bi-partisan support in Congress
 - Department of Defense interest in microreactors

Innovation and Collaboration

✓ Innovation

- Optimizing combinations in salt formulas for MSR's
- Customizing design to optimize operational staffing
- Exploring additive manufacturing

✓ Collaboration

- Among design competitors through TWG's
 - Addressing generic regulatory and technical issues
- With international stakeholders
 - Exploring opportunities to share Virtual Test Reactor
 - Continuing communication between National

Innovation and collaboration are key to ensuring that
breakthrough technologies are competitive with other
generation alternatives