Nuclear Energy Overview

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Office of Nuclear Energy
U.S. Department of Energy
Nuclear Energy: A National Strategic Asset

• Recognition of the importance of nuclear – today and in the future
  – Energy Security
  – National Security
  – Economic Prosperity
  – Environmental Sustainability

• Concern about the financial viability of some currently operating plants, yet benefits from keeping them running

• Increased interest in nuclear in domestic and international markets to address climate change and ensure reliable, resilient power

• Innovators and utilities looking at advanced nuclear as a way to move beyond electricity

• Secretary Perry: Make Nuclear Energy Cool Again!

• President Trump: Revive, Revitalize and Expand

“If you really care about this environment that we live in… then you need to be a supporter of this [nuclear energy] amazingly clean, resilient, safe, reliable source of energy.”
Secretary Rick Perry at Press conference, May 10th

• 20% of electricity (56% of non-emitting)

• 92% capacity factor

• Supports 475,000 jobs

• $10B in federal & $2.2B in state taxes annually
Global Growth and Market Opportunity

Potential Nuclear Power Expansion

- 35 countries taking steps to develop nuclear power
- 30 countries with operating reactors developing expansion plans

~450 reactors operating
11% of electricity / 40% of clean electricity

- ~60 reactors under construction in 15 countries (20 in China)
- ~170 reactors planned in over 25 countries, worth as much as $700 billion over the next 5-10 years
- ~370 reactors proposed in 36 countries, worth as much as $1.6 trillion over the next 10-25 years

Source: IAEA/PRIS & WNA
## Nuclear Power Plants Shutting Down Prematurely

<table>
<thead>
<tr>
<th>Year</th>
<th>Retirements</th>
<th>MW</th>
<th>Operator</th>
<th>State</th>
<th>License Expiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>Crystal River 3</td>
<td>890</td>
<td>Duke</td>
<td>FL</td>
<td>2016 (40)</td>
</tr>
<tr>
<td></td>
<td>San Onofre 2 &amp; 3</td>
<td>2,254</td>
<td>SoCal Edison</td>
<td>CA</td>
<td>2023 / 2024 (40)</td>
</tr>
<tr>
<td></td>
<td>Kewaunee</td>
<td>560</td>
<td>Dominion</td>
<td>WI</td>
<td>2033 (60)</td>
</tr>
<tr>
<td>2014</td>
<td>Vermont Yankee</td>
<td>563</td>
<td>Entergy</td>
<td>VT</td>
<td>2032 (60)</td>
</tr>
<tr>
<td>2016</td>
<td>Fort Calhoun</td>
<td>502</td>
<td>Omaha Power</td>
<td>NE</td>
<td>2033 (60)</td>
</tr>
<tr>
<td>2018</td>
<td>Oyster Creek</td>
<td>610</td>
<td>Exelon</td>
<td>NJ</td>
<td>2029 (60)</td>
</tr>
<tr>
<td></td>
<td><strong>Total Closed since 2013</strong></td>
<td><strong>5,276</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>Pilgrim</td>
<td>678</td>
<td>Entergy</td>
<td>MA</td>
<td>2032 (60)</td>
</tr>
<tr>
<td></td>
<td>Three Mile Island 1</td>
<td>803</td>
<td>Exelon</td>
<td>PA</td>
<td>2034 (60)</td>
</tr>
<tr>
<td>2020</td>
<td>Davis-Besse*</td>
<td>908</td>
<td>FirstEnergy</td>
<td>OH</td>
<td>2037 (60)</td>
</tr>
<tr>
<td></td>
<td>Duane Arnold</td>
<td>601</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2021</td>
<td>Perry*</td>
<td>1,268</td>
<td>FirstEnergy</td>
<td>OH</td>
<td>2026 (40)</td>
</tr>
<tr>
<td></td>
<td>Indian Point 2 &amp; 3**</td>
<td>2,061</td>
<td>Entergy</td>
<td>NY</td>
<td>2013 / 2015 (40)</td>
</tr>
<tr>
<td></td>
<td>Beaver Valley 1 &amp; 2*</td>
<td>1,872</td>
<td>FirstEnergy</td>
<td>PA</td>
<td>2036 / 2047 (60)</td>
</tr>
<tr>
<td>2022</td>
<td>Palisades</td>
<td>789</td>
<td>Entergy</td>
<td>MI</td>
<td>2031 (60)</td>
</tr>
<tr>
<td>2024-25</td>
<td>Diablo Canyon 1 &amp; 2*</td>
<td>2,240</td>
<td>PG&amp;E</td>
<td>CA</td>
<td>2024 / 2025 (40)</td>
</tr>
<tr>
<td></td>
<td><strong>Total Pending Closures</strong></td>
<td><strong>11,220</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>FitzPatrick***</td>
<td>852</td>
<td>Entergy</td>
<td>NY</td>
<td>2034 (60)</td>
</tr>
<tr>
<td></td>
<td>Ginna***</td>
<td>582</td>
<td>Exelon</td>
<td>NY</td>
<td>2029 (60)</td>
</tr>
<tr>
<td></td>
<td>Clinton***</td>
<td>1,065</td>
<td>Exelon</td>
<td>IL</td>
<td>2026 (40)</td>
</tr>
<tr>
<td>2017-18</td>
<td>Nine Mile Point 1 &amp; 2***</td>
<td>1,937</td>
<td>Exelon</td>
<td>NY</td>
<td>2029 / 2046 (60)</td>
</tr>
<tr>
<td>2018</td>
<td>Quad Cities 1 &amp; 2***</td>
<td>1,819</td>
<td>Exelon</td>
<td>IL</td>
<td>2032 (60)</td>
</tr>
<tr>
<td></td>
<td><strong>Total Saved</strong></td>
<td><strong>6,255</strong></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

* Pending review and approval by PJM
** One reactor will shut down in 2020, and the other will shut down in 2021.
*** Closures averted by state policy actions.
## Combined Construction and Operating Licenses (COLs)

<table>
<thead>
<tr>
<th>SITE/LOCATION</th>
<th>UTILITY</th>
<th>REACTOR TECHNOLOGY/ NO. UNITS</th>
<th>COLA DATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vogtle GA</td>
<td>Southern Nuclear</td>
<td>AP1000 2</td>
<td>3/28/2008</td>
</tr>
<tr>
<td>V.C. Summer SC</td>
<td>SCE&amp;G</td>
<td>AP1000 2</td>
<td>3/27/2008</td>
</tr>
<tr>
<td>Fermi MI</td>
<td>DTE Energy</td>
<td>ESBWR 1</td>
<td>9/18/2008</td>
</tr>
<tr>
<td>South Texas Project TX</td>
<td>STPNOC</td>
<td>ABWR 2</td>
<td>9/20/2007</td>
</tr>
<tr>
<td>Levy FL</td>
<td>Duke Energy</td>
<td>AP1000 2</td>
<td>7/30/2008</td>
</tr>
<tr>
<td>Turkey Point FL</td>
<td>Florida Power and Light</td>
<td>AP1000 2</td>
<td>6/30/2009</td>
</tr>
</tbody>
</table>

- 18 COLs have been docketed by the NRC since 2007
- 8 (totaling 14 reactors) have been approved
- 10 (totaling 14 reactors) were suspended and/or withdrawn
Congressional Support for Nuclear Energy

Nuclear energy has strong bipartisan support from Congress

**Advanced Reactor Concepts**
- Support for advanced reactor concepts
- Micro-reactors for national security locations
- Advanced fuels

**DOE Infrastructure**
- FY 2019 Appropriations ($1.3B)
- Authorized construction of the Versatile Test Reactor

**Streamline Innovation**
- Regulatory reform
- Licensing cost-sharing for advanced reactor concepts
- Accessibility to DOE facilities
- Export control reform

Over 20 bills introduced, five reported out of committee, four passed House or Senate, and two signed into law (FY19 DOE Appropriations and the Nuclear Energy Innovation Capabilities Act)
Office of Nuclear Energy Mission Pillars

- Existing Fleet
- Advanced Reactor Pipeline
- Fuel Cycle Infrastructure
- Global Competitiveness
Sustaining the Existing Fleet

• **Improving Performance and Reducing Costs**
  – LWRS – subsequent license renewal and technical improvements
  – Accident Tolerant fuel – enhanced performance and safety
  – CASL – Energy Innovation Hub for M&S
  – Non-electric applications to improve flexibility and increase revenue generation

• **Policy and Market Reform Support**
  – Level the playing field with technology neutral policies
  – Ensure critical attributes are properly valued
  – Risk-informed, performance-based regulation

• **State and Local Technical Assistance, Education and Outreach**
• Millennial Nuclear Caucuses
• Learning lunches
• Traditional media relations
• Social media
• Infographics and videos
Nuclear Beyond Electricity – Advanced Reactors

NOW

Baseload Electricity Generation

FUTURE

Flexible Electricity Generation

Advanced Reactors

Large LWRs

SMRs

Non-Water Reactors

Large LWRs

SMRs

Chemical Processes

Hydrogen Production

Clean Water

Industrial Applications

Heat
Small Modular Reactors

Greater affordability
- Easier financing for public power entities
- Lower capital investment
- Factory fabrication, shorter construction times

New standard of passive nuclear safety

Energy and environmental benefits
- Greenhouse gas and air pollution avoided
- Grid benefits: stability, security, quality, availability, reliability
- Siting flexibility
- Hybrid energy systems and flexible integration with renewables

Importance to National Security

Economic development and job growth
- Manufacturing jobs and supply chain opportunities in the United States
Micro Reactors

Designed for Specialized Applications

- Siting flexibility including near population centers
- Micro-grids
- Remote Operating Bases
- Data Centers
- Disaster Relief (FEMA)
- Specialized Non-electric Applications
Non-Water Advanced Reactors

Gas Reactors

X-Energy Xe-100

General Atomics
Energy Multiplier Module, EM2

Fast Reactors

GE Hitachi PRISM

TerraPower TWR

Advanced Reactor Concepts LLC ARC-100

Molten Salt Reactors

Terrestrial Energy USA IMSR

TerraPower MCFR

Elysium USA MCSFR

Kairos Power UCB PB-FHR

General Atomics

Xenon-100 Gas Reactors

GE Hitachi PRISM

TerraPower TWR

Advanced Reactor Concepts LLC ARC-100

Terrestrial Energy USA IMSR

TerraPower MCFR

Elysium USA MCSFR

Kairos Power UCB PB-FHR
Gateway for Accelerated Innovation in Nuclear (GAIN)

A private-public partnership framework aimed at rapid and cost-effective development of innovative nuclear energy technologies towards market readiness

**Mission**

Provide the nuclear energy industry with access to technical, regulatory and financial support necessary to move innovative nuclear energy technologies toward *commercialization* in an accelerated and cost-effective fashion.

@GAINnuclear    https://gain.inl.gov
Transient Reactor Test (TREAT) Facility

- 100 kW Steady-state power with 19 GW Peak Transient Power
- Core: ~1.2 m high x 2 m. dia.; surrounded by 0.25 m graphite reflector
- 19 x 19 array of 10 x 10-cm. fuel and reflector assemblies
- Fuel: 0.2 wt.% high enriched UO2 dispersed in graphite
- 12 steady-state and 8 transient control rods
- Instantaneous, large negative temperature coefficient (self protecting driver core)

TREAT Experimental Facility Restarted in 2017
Versatile Advanced Test Reactor

• **Goal:** An Operational Versatile Advanced Test Reactor by 2026, to support accelerated development of advanced fuels and materials for U.S. advanced reactor vendors, as well as to provide the capability for testing those fuels and materials to support licensing by the Nuclear Regulatory Commission.

• A Versatile Advanced Test Reactor with a high fast neutron flux will revitalize our research infrastructure and remove a critical impediment for U.S. developers of advanced nuclear energy technologies.
Most advanced reactor concepts require HALEU for startup cores (15-19.75% - u-235)

- Expected demands for HALEU are very significant
  - A typical start-up core requires 4 MT HALEU

- In addition, there are other national missions that require a reliable supply of enriched uranium

- DOE-NE is working towards addressing these needs
Advanced Manufacturing

Vision
• To improve the methods by which nuclear equipment, components, and plants are manufactured, fabricated, and assembled by utilizing practices found in industries such as oil, aircraft, and shipbuilding

Goal
• To reduce cost and schedule for new nuclear plant construction
• To make fabrication of nuclear power plant (NPP) components faster, cheaper and more reliable
Bilateral, Multilateral and Commercial International Cooperation

• **Bilateral Engagement**
  – R&D coordination and integration with advanced fuel cycle countries, e.g., bilateral action plans, International Nuclear Energy Research Initiatives (I-NERIs), and R&D agreements
  – Technical and policy support for civil nuclear energy working groups and bilateral MOUs

• **Multilateral Engagement**
  – Coordination and leadership for NE’s engagement in multilateral organizations such as the International Atomic Energy Agency (IAEA), Generation IV International Forum (GIF), the International Framework for Nuclear Energy Cooperation (IFNEC), OECD’s Nuclear Energy Agency (NEA), and the International Energy Agency (IEA)

• **International Commercial Engagement**
  – Promotion of U.S. civil nuclear energy policy and technical objectives through engagement on international commercial nuclear matters
  – Advancement of issues associated with developing commercial options for the safe and secure management of used fuel, including regional and international disposal, to support the growth of nuclear power
Nuclear Innovation: Clean Energy Future (NICE Future)

Official Launch:
At the 9th Clean Energy Ministerial (May 2018, Denmark) NICE Future was launched by the United States, Canada and Japan to spotlight nuclear energy in the international clean energy community.

Overview:
NICE Future focuses on nuclear power as a clean energy option for reliable and resilient baseload electricity, and non-electric applications especially when deployed as hybrid nuclear-renewable systems.

Areas of Work:
1) Evaluations of innovative systems, technology, storage, uses
2) Policy-maker and Stakeholder Engagement
3) Economics
4) Communicating nuclear energy’s role in clean energy systems
Team USA: Whole-of-Government Strategy

- Financing for:
  - Feasibility Studies
  - Reverse trade missions

- Standards
- Licensing
- Bilateral cooperation

- RD&D
- Infrastructure
- Fuel Cycle
- Licensing
- Nonproliferation
- International Cooperation
- Safeguards
- Emergency Preparedness

- Foreign Policy
- Nonproliferation
- 123 Agreements
- Infrastructure

- Industry & Analysis
  - Trade Promotion Coordinating Committee (TPCC)
  - Commercial Liaisons

- Global Markets
  - Advocacy
  - Foreign Commercial Service

- Bureau of Industry and Security
  - Dual-Use Licensing

- Industry Advisory Committee (CINTAC)

- Financing Policy
- Export Credit Financing
Summary

• The demand for domestically-generated, reliable, resilient and clean sources of baseload electricity will continue to drive many countries toward nuclear energy as part of their energy security and national economic and environmental calculus.

• Profound opportunity for new nuclear growth exists:
  – Strong global market interest
  – Growing need for increased global access to electricity
  – Support energy security, economic and environmental goals
  – U.S. leadership to ensure safety & nonproliferation are as important as ever

• The Administration is committed to advancing nuclear energy in the U.S. and abroad.
Questions?