Commercializing Advanced Nuclear Energy

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EESI Briefing: The State of Play for Nuclear Energy in the United States

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Who is Nuclear Innovation Alliance (NIA)?

- NIA is a “think-and-do” tank working to ensure advanced nuclear energy can be a key part of the climate solution.

- NIA identifies barriers, performs analysis, engages with stakeholders and policy makers, and nurtures entrepreneurship through its Nuclear Innovation Bootcamp.
Takeaways on Commercializing Advanced Nuclear Energy

- Nuclear energy can play a major role in creating a clean energy economy
- Advanced reactors have a wide array of different commercial use cases
- Developers are leveraging DOE support to accelerate reactor deployment
- Continued federal support and incentives can catalyze private investments
Advanced nuclear energy is an important complementary clean energy source to help fully decarbonize U.S. energy production.
Large (and growing) group of private companies are developing advanced nuclear energy to meet clean energy needs.
Utility partners and industrial energy users have expressed interest in deploying advanced nuclear energy
Public-private partnerships are accelerating the demonstration and deployment of first-of-a-kind advanced reactors.

Federal Partnerships with Private Companies

- Advanced reactor demonstration award
- Advanced reactor development award
- Enabling technology development award

Timeline:
- 2023
- 2025
- 2030
Developers are preparing to submit a large number of formal license applications for review to the NRC in FY23

**Site-Specific Applications**
- Kairos: Hermes (*in progress*)
- ACU: NEXT MSR (*in progress*)
- X-energy: Xe-100
- TerraPower: Natrium
- GEH: BWRX-300
- Oklo: NCSFR-1
- Oklo: NCSFR-2

**Design-Specific Applications**
- NuScale: VOYGR (*complete*)
- NuScale: NPM-20 (*in progress*)
- Terrestrial Energy: IMSR
- Westinghouse: eVinci

**Pre-Application Interactions**
- NuScale: UAMPS (COL)
- Holtec: SMR-160 (CP)
- GA: EM2 (CP)
- BWXT: BANR
- FLiBe: LFTR (ESP)
- ARC: ARC-100
- Radiant Energy: Kaleidos
- USNC: UIUC MMR (CP)
- TerraPower: MCFR
- GA: FMR (CP)

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Pathway from first-of-a-kind to widespread deployment requires an orderbook, on-time and on-budget delivery, and supply chains.

Figure from 2023 DOE Report *Pathways to Commercial Liftoff - Advanced Nuclear*

Example: BWRX-300

Link: BWRX-300 Partnership Announcement
Successful commercialization could dramatically increase demand for advanced nuclear energy for a wide variety of applications.

2022 Nuclear Energy Institute survey of 19 member utilities:

- More than 300 new SMRs deployed for electricity generation by 2050
- More than 90 GW of new nuclear generation by existing owners alone
- Evaluations of sites that currently host operating or retired coal plants for new nuclear reactors

Figure from 2023 DOE Report Pathways to Commercial Liftoff - Advanced Nuclear
Continued federal support and incentives can catalyze private investments in advanced nuclear energy

- **Inflation Reduction Act (IRA) Funding for HALEU**
  - Reactor Development Funding: $650M
- **IRA Nuclear Hydrogen Production Credits**
  - Demonstration Reactor Support: $4600M
  - Non-electric Deployment Incentives: $3.00/kg H₂
- **Advanced Reactor Licensing at the Nuclear Regulatory Commission**
  - DOE ARC 20 Risk Reduction Awards in Appropriations: $700M
  - Commercial Deployment Incentives: 2.5¢/kWh* OR 30% of costs*
- **Infrastructure Investment and Jobs Act (IIJA) Funding and Appropriations**
  - Non-electric Deployment Incentives: 2.5¢/kWh* OR 30% of costs*

Effective, Efficient, and Predictable Regulation

IRA Nuclear Production and Investment Tax Credits (see NIA Fact Sheet for Details)
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Back-up Slides
Advanced nuclear energy adds flexibility and versatility in comparison to conventional nuclear through innovative design.

<table>
<thead>
<tr>
<th>Conventional Nuclear Energy</th>
<th>Advanced Nuclear Energy</th>
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<tbody>
<tr>
<td>Predominantly Large: More than 1000 MW&lt;sub&gt;e&lt;/sub&gt;</td>
<td>Versatile: 1.5 MW&lt;sub&gt;e&lt;/sub&gt; to 300+ MW&lt;sub&gt;e&lt;/sub&gt;</td>
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<tr>
<td>Predominantly Light-Water Reactors</td>
<td>Wide Variety of Reactor Technologies</td>
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<tr>
<td>Primarily Baseload Generation</td>
<td>Flexible and Dispatchable Generation</td>
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<td>Designed with Active Safety Systems</td>
<td>Designed with Inherent Safety Systems</td>
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Definition of advanced nuclear energy includes a variety of nuclear technologies with different advantages.

**Thermal Fission**
- **Advanced Light-Water Reactors**
  Evolutionary design from existing reactors with inherent safety features.

**High-temperature reactors (HTRs)**
- High temperatures drive high efficiency, well-suited for process heat or hydrogen production. Uses TRISO fuel.

**Molten Salt-Fueled Reactors (MSRs)**
- Using molten salt for coolant and a fuel form, MSRs can bring significant safety benefits.

**Fast Fission**
- **Gas-cooled fast reactor (GFR)**
  An evolution of HTRs, GFRs operate at very high temperatures while using a more sustainable fuel cycle.

- **Sodium-cooled fast reactor (SFR)**
  With many existing experimental reactors, SFRs offer increased fuel efficiency, reduced waste, and passive safety features.

- **Lead-cooled Fast Reactor (LFR)**
  Similar in design to SFRs, LFRs are advantageous as lead is operationally safer than sodium.
Variety of reactor sizes and low-carbon products enable integration of advanced nuclear into future energy systems

**Microreactors**
Can provide decentralized power and co-products to rural and off-grid locations

**Small Modular Reactors**
 Scalable power small enough to be available to co-ops, munis, and industrial users for the first time

**Large Reactors**
Advanced designs can play the traditional role of large, base-load nuclear power while providing improved operations, safety, and economics

**Electricity Production**

**Co-Products**

**Heat**
Through cogeneration, advanced nuclear can provide district heating or process heating for industrial applications, allowing for decarbonization of non-electric sectors

**Hydrogen**
Advanced nuclear power can produce hydrogen, potentially enabling a hydrogen economy to decarbonize non-electric sectors

**Desalination**
Some advanced designs can produce fresh water
Both NRC and companies play a role in improving licensing under current rules and creating a new regulatory framework.

Optional Licensing Tools

- Preapplication Interactions
- Topical Reports
- Early Site Permits
- Standard Design Approvals
- Standard Design Certifications

Licensing Path 1 ("Part 50")
Licensing Path 2 ("Part 52")
Licensing Path 3 ("Part 53")
Advanced reactor commercialization requires coordination and planning across all stages of a sustainable fuel cycle.
Some advanced reactor technologies will require nuclear fuel cycles with higher uranium enrichment levels

- **Natural Uranium**
  - 99.3% U-238
  - 0.7% U-235

- **Low-Enriched Uranium (LEU)**
  - 95% U-238
  - 5% U-235

- **High-Assay, Low-Enriched Uranium (HALEU)**
  - 80% U-238
  - < 20% U-235

- **High-Enriched Uranium (HEU)**
  - > 10% U-238
  - < 90% U-235

- **LWR Reactor Fuel**
  - 95% U-238
  - 5% U-235

- **Advanced Reactor Fuel**
  - 80% U-238
  - < 20% U-235

- **Historic Research Reactor Fuel**
  - > 10% U-238
  - < 90% U-235
Advanced reactors that require HALEU or recycled fuels will need new fuel cycle infrastructure and facilities.
Stakeholders can get up to speed on advanced nuclear energy and engage with policymakers on clean energy deployment.