U.S. DEPARTMENT OF ENERGY | Nuclear Energy

The Role of the U.S. Department of Energy for Sustainable and Innovative Nuclear Technology

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Role of U.S. Department of Energy for Sustainable and Innovative Nuclear Energy

Conduct Research, Development, and Demonstration to:

- Reduce regulatory risk
- Reduce technical risk
- Reduce financial risk and improve economics
- Manage nuclear waste
- Minimize the risks of nuclear proliferation and terrorism
- Foster international and industry collaboration

Vogtle – April 2013

Source: Southern Co.

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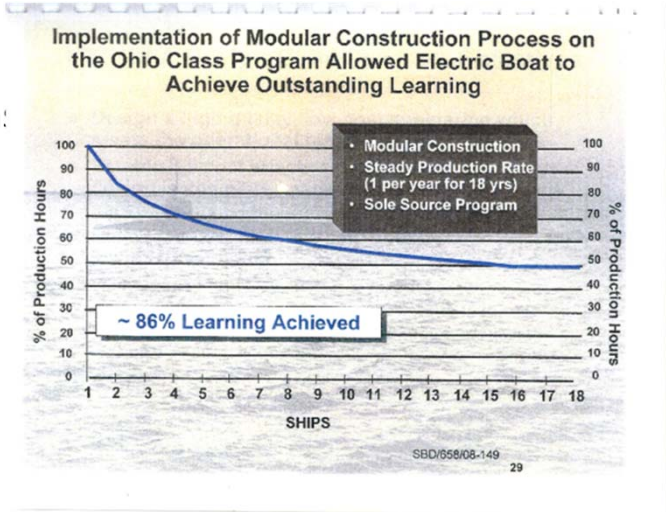
Cost and Regulatory Risk Reduction: Opportunities and Government Incentives

Cost drivers

- High capital cost – commodities, schedule, quality/rework, design changes
- High financing cost – large capital/principal, long schedule duration, risk premiums
- Limited standardization, technology or regulatory risk

Cost reduction opportunities:

- Design simplification, commodity reduction, improved material performance
- Use of advanced high-performance computing, modelling and simulation
- Advanced systems and components , advanced energy conversion options
- Reduced licensing risk / uncertainty
- Modular and factory fabrication
- Reduced Operations & Maintenance costs (e.g., in-service in diagnostic/prognostic sensors)



Collaboration with the Nuclear Regulatory Comm.

Government incentives:

- Loan guarantees, production tax credits

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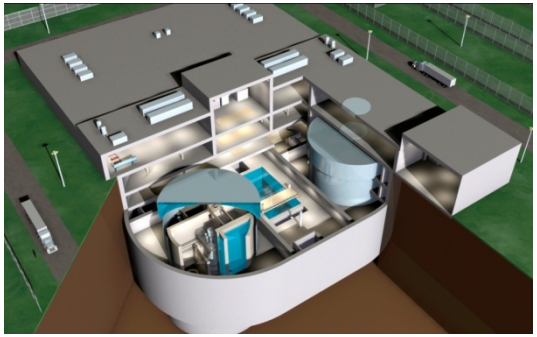
Cost Sharing with Industry: SMR Licensing Technical Support Program

- **Facilitates & accelerates commercial development & deployment of U.S.-based SMR designs**
- **Provides financial assistance for design, certification & licensing of promising SMR technologies**
- **Currently 5 year/$452 M program but FY14 budget request extends to 6 years; min of 50% industry cost share**
- **Modeled after successful NP2010 Program**
- **First Funding Opportunity Announcement**
  - Single award to Generation mPower team (B&W, Bechtel, & Tennessee Valley Authority)
  - Focus on SMRs that can be expeditiously deployed
- **Second Funding Opportunity Announcement**
  - Emphasizes innovation and improved technologies
  - Expands licensing horizon to technologies deployed in 2025 timeframe



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Generation mPower: Progress on Certification & Licensing

- **Cooperative Agreement with mPower signed on April 12, 2013**
- **mPower Team**
  - B&W – Design of primary components and systems
  - Bechtel International – Design of secondary side and plant layout
  - TVA – Site characterization and licensing for deployment at Clinch River Site
- **mPower Design**
  - 530MWt iPWR
  - Next generation passive safety design philosophy
  - 4-Year fuel cycle
- **Design Certification Application (DCA) development well underway**

Success of this project will be an enabling factor for the follow-on programs and policies supporting broader SMR deployment

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Examples of U.S. DOE RD&D Programs

- **Support for licensing and deployment of advanced non-light water SMR designs**
  - Instrumentation, Controls and Human-Machine Interface
  - Materials, Components and Technology Development
  - Safety, Regulatory Framework, and Safeguards
  - SMR Assessments (Performance and Economic Analysis and Evaluation)
- **Advanced reactor technologies and subsystems to improve nuclear power performance including sustainability, economics, safely and proliferation resistance**
  - Fast Reactor R&D
  - High Temperature Gas-cooled Reactor R&D (NGNP)
  - Advanced Energy Conversion
  - Fluoride Salt High-Temperature Reactor (FHR) Concept
- **Advanced fuel cycle technologies**
- **Modeling and Simulation – CASL, NEAMS, MELCOR applied to Fukushima**
- **Light Water Reactor Sustainability**
- **Aging phenomena in used fuel in dry casks**
- **Uranium extraction from seawater**

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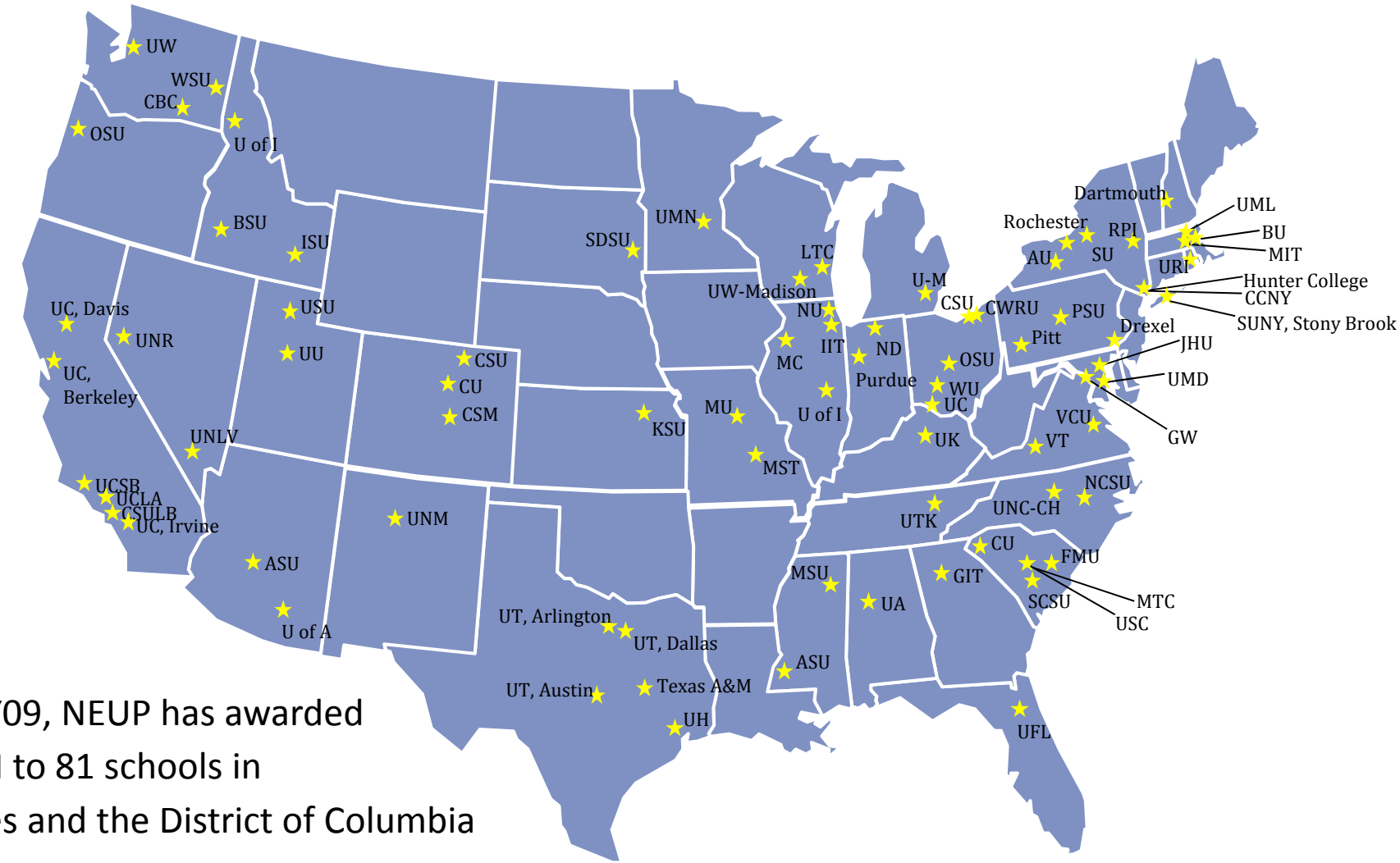
NEUP Award Recipients FY09 – FY12



Since FY09, NEUP has awarded
$233 M to 81 schools in
34 States and the District of Columbia

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International Cooperation

- **U. S. DOE supports technical collaboration through bilateral Action Plans, Working Groups, and the International Nuclear Energy Research Initiative**

- **Bilateral**
  - Peaceful Uses of Nuclear Energy Agreements (123 Agreements)
  - R&D Agreements
  - International Nuclear Energy Research Initiatives with South Korea & Euratom
  - Memoranda of Understanding (MOUs)

- **Multilateral**
  - International Framework for Nuclear Energy Cooperation (IFNEC)
  - Generation IV International Forum (GIF)
  - International Atomic Energy Agency (IAEA)
  - International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO)
  - Nuclear Energy Agency (NEA)

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Conclusion

- **Meeting energy demands, protecting the environment and making the world safe for future generations are global issues**
- **Nuclear Energy is an important part of the energy mix**
- **RD&D can address factors that may inhibit the growth of nuclear energy**
- **Government role: enable nuclear energy by supporting RD&D programs for:**
  - Reducing Regulatory Risk
  - Reducing Technical Risk
  - Reducing Financial Risk and Improving Economics
  - Managing Waste
  - Fostering International and Industry Collaboration

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Backup Slides

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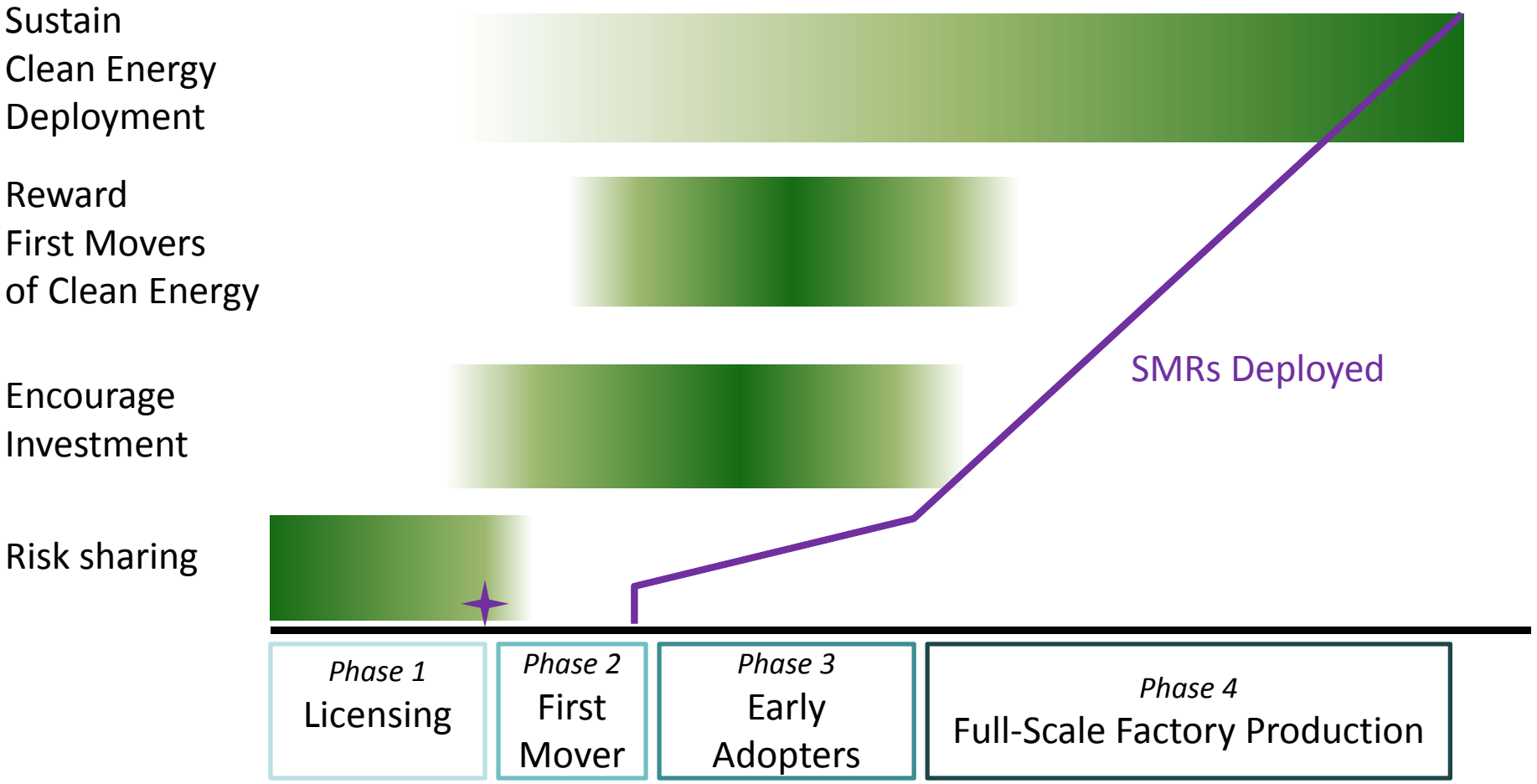
Examining Policies and Programs to Facilitate Broader SMR Deployment



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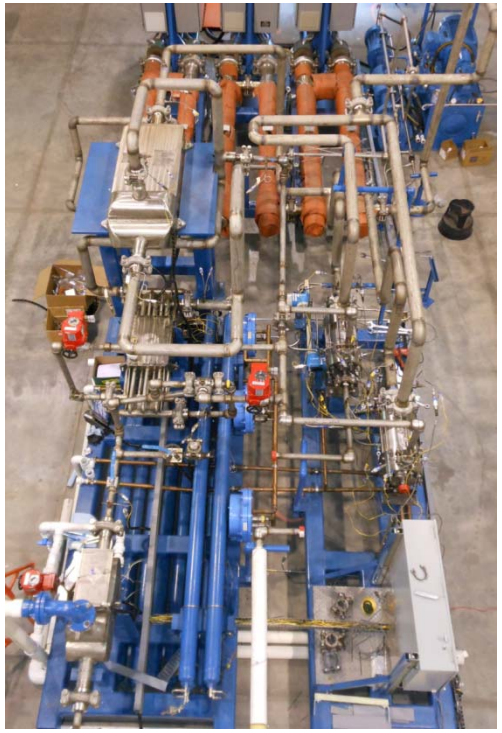
Performing R&D on Advanced Reactor Concepts

- **Research to develop advanced reactor technologies and subsystems to improve nuclear power performance including sustainability, economics, safety and proliferation resistance**

- **Focus Area**
- **F**ast Reactor R&D
  - High Temperature Gas-cooled Reactor R&D (NGNP)
  - Advanced Energy Conversion
  - Fluoride Salt High-Temperature Reactor (FHR) Concept

- **Broader applications**
  - Process heat applications
  - Improved economic competitiveness
  - Transportable/mobile
  - Waste management
  - Long-lived cores



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Accident Tolerant Fuel Focus Area

- U.S. DOE fuel development program was exploring the development of next generation of LWR fuels enhanced performance.
  - Increased burnup – reduced waste volume
  - Increased reliability – reduced failures
  - Higher power density – power upgrades
- After the unfortunate events in Fukushima (March 2011), the U.S. Congress directed the DOE to focus efforts on development of fuels with enhanced accident tolerance.
- Accident Tolerant Fuel development program is being implemented as a collaborative effort among U.S. national laboratories, industry and universities
- International collaboration can also be beneficial.

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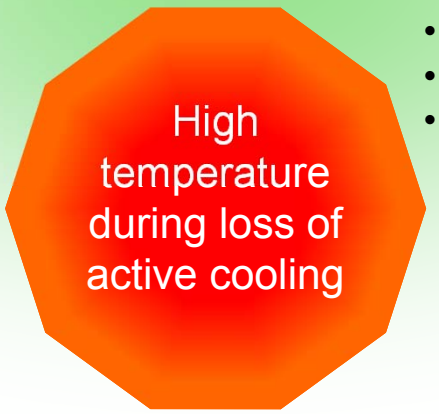
Major attributes of accident tolerant fuels are associated with the behavior of fuel and cladding at high temperatures.

Fuels with enhanced accident tolerance are those that, in comparison with the standard UO_2 – Zircaloy system, can tolerate loss of active cooling in the core for a considerably longer time period (depending on the LWR system and accident scenario) while maintaining or improving the fuel performance during normal operations.

To demonstrate the enhanced accident tolerance of candidate fuel designs, metrics must be developed and evaluated using a combination of design features for a given LWR design, potential improvements and the design of advanced fuel/cladding system.



Improved Reaction Kinetics with Steam
- Heat of oxidation
- Oxidation rate

Slower Hydrogen Generation Rate
- Hydrogen bubble
- Hydrogen explosion
- Hydrogen embrittlement of the clad

Improved Fuel Properties
- Lower operating temperatures
- Clad internal oxidation
- Fuel relocation / dispersion
- Fuel melting

Improved Cladding Properties
- Clad fracture
- Geometric stability
- Thermal shock resistance
- Melting of the cladding

Enhanced Retention of Fission Products
- Gaseous fission products
- Solid/liquid fission products

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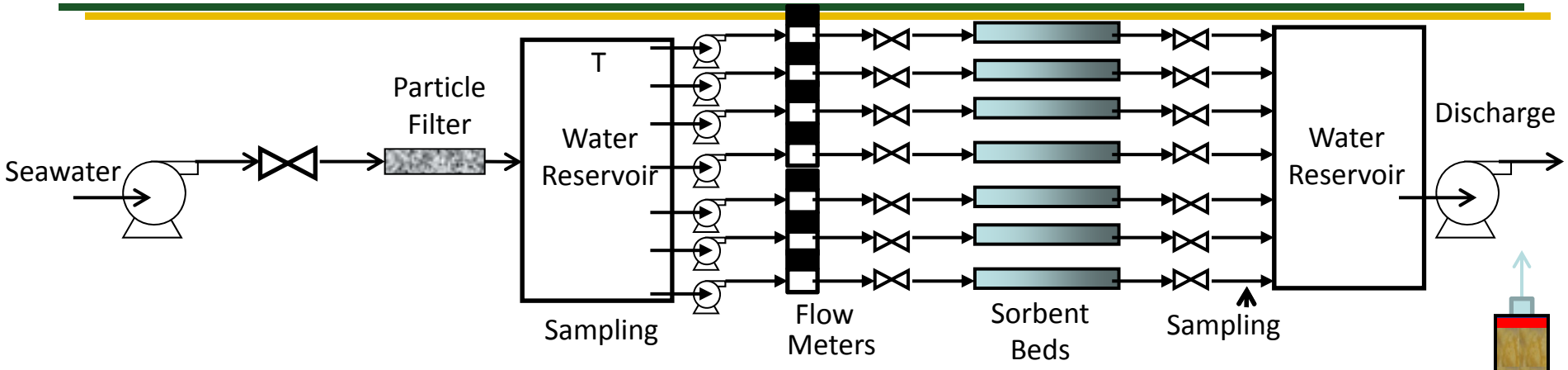
Recovery of Uranium from Sea Water– Initiate Testing at Marine Sciences Laboratory



- **Investigating the next generation of advanced adsorption technologies that enable an economic recovery of uranium from seawater.**
- **Recovering this resource at an economically competitive cost is a technical challenge but this value sets an upper limit in the uranium market price.**

Functionalized fibers

Fixed bed

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Performing R&D on the Next Generation Nuclear Plant

- **Demonstrate high-temperature gas-cooled reactor (HTGR) technology to produce electricity and high temperature process heat**
- **Focus Areas:**
  - Provide non-electric applications
  - Fuels Development R&D
  - Materials Development R&D
  - Design and Safety Methods Development
  - NGNP Licensing Framework Development

Kernel Forming and Drying

Industrial Scale 6 inch CVD Coating (2 kg charge)

Dry Mix and Jet Mill Matrix

Granurex Overcoat and Dry

Hot Press Compact

Carbonize + Heat Treat in a Sequential Process

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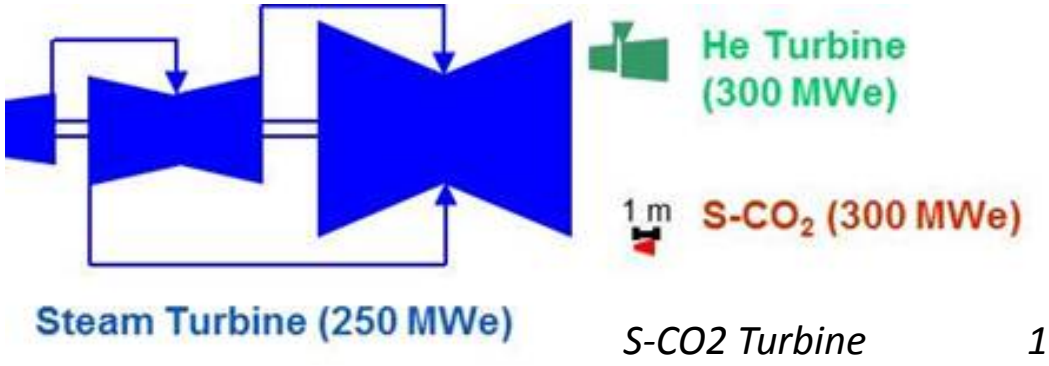
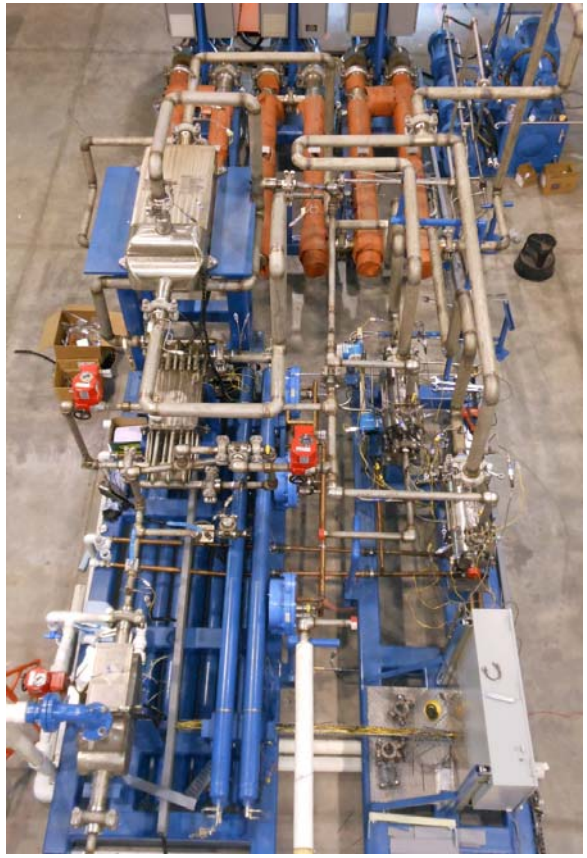
Increasing Efficiency: Supercritical CO_2 Brayton Conversion Cycle

- **R&D has demonstrated this system's capability at the lab level (1MW)**
- **DOE's Sun Shot program is funding ramp up to the 10MW level**
- **U.S. industry has shown interest in this technology**



S-CO2 Turbine 1 M
He Turbine 3 M
Steam Turbine 22 M



Sandia National Lab
Brayton Cycle Test Loop

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Office of Nuclear Energy Research and Development Objectives

- Develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors
- Develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals
- Develop sustainable nuclear fuel cycles
- Understand and minimize the risks of nuclear proliferation and terrorism