

# What's on the Horizon – Overview of Advanced Nuclear

National Governor's Association Learning Collaborative November 10, 2021 Ashley E. Finan, Ph.D., NRIC director ashley.finan@inl.gov

### U.S. Advanced Reactors

- Categorized in terms of capacity
  - Microreactors: <10 MWe
  - Small reactors: 10 MWe <300MWe (SMRs use modular construction)
  - Medium reactors: 300MWe 700 MWe
  - Large reactors: > 700 MWe
- Variety of coolants (gas, sodium, salt, lead, water, etc.)
- Clean, high availability
- Diverse markets
- Improved safety, waste, security, and target economics



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# Meeting Emissions Goals with Nuclear: Example Case

- E3 study for Energy Northwest on achieving 100% carbon free by 2045:
  - Firm zero-emitting resources like nuclear reduce costs up to \$8B per year
  - Adding 6.5GW firm avoids 91GW nonfirm



Pacific Northwest Zero-Emitting Resources Study, Energy and Environmental Economics, Inc. https://www.ethree.com/wp-content/uploads/2020/02/E3-Pacific-Northwest-Zero-Emitting-Resources-Study-Jan-2020.pdf

#### Flexible Nuclear-Industrial System Industrial **Processes** Heat Water Treatment Nuclear Reactor **Transportation Fuels** \*May be coupled with Steam renewable generators in **Chemical Feedstock** the regional grid Electricity balancing area. **Polymers & Plastics** Metals 1. Steam Methane $CH_4$ Hydrogen Reforming Minerals 2. Steam Electrolysis Forest & Paper Products Syngas 3. Steam and CO<sub>2</sub> $CO_2$ **Co-Electrolysis** Food & Beverages RIC

# Historical Context

#### Reactor Demonstration Programs

- Atomic Energy Commission
- National Reactor Testing Station
- Production Reactors
- Cooperative Power Reactor Demonstration Program
- International Development
- NGNP

#### Recent Policy Actions

- Nuclear Energy Innovation Capabilities Act
- Nuclear Energy Innovation Modernization Act
  Advanced Reactor Demonstration Program
- Energy Act of 2020



# WE'RE GOING TO DO IT AGAIN

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## ADVANCED REACTORS Select U.S. DOE Efforts & Partnerships

Advanced Reactor Demonstration Program	Microreactor Demonstration	NRIC & GAIN National Reactor Innovation Center & Gateway for Accelerated Innovation in Nuclear	Advanced Construction Technology Initiative	Integrated Energy Systems
- 10 cost-shared projects including 4 demonstration reactors - Fuel supply	- MARVEL reactor at INL - DOD and NASA projects	- Demonstration Platforms/Test beds - Regulatory & execution support	Technology to address cost & schedule	Demonstrate zero carbon systems
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#### Accelerating Advanced Reactor Demonstration and 2030 Deployment TerraPower HITACHI UAMPS Kairos Power NUSCALE Power for all humankind TerraPower. 🗙 energy Southern Company OKLO C C MARVEL NRIC National Reactor Innovation Center 9





- Demonstration Resource Network
   Regulatory Risk Reduction
  - Test beds & Demonstration Sites
  - Experimental & Fuel Facilities
    - Irradiation & Characterization
    - Component testing (sodium, helium, molten salt, lead, etc.)
- 💥 NRIC

- Virtual Test Bed
- NRIC Resource Team

# Addressing Cost and Markets

- Advanced Construction Technologies
- Digital Engineering & Construction Readiness
- Integrated Energy Systems
- Repowering opportunities











## Projected U.S. Coal Plant Retirements

(nearly 100 GW from 2020 to 2030, nearly 50%)



Source: Energy Information Administration, Annual Energy Outlook 2021, Reference Case (link)

NRIC is a National Program and Central Integrator for Partners and Collaborators





# Thank you! **Questions?** 17

# Background Information



#### **ARDP** Projects

# **Risk Reduction**





**Natrium Reactor** 

energy storage system

TERRAPOWER

Xe-100 Sodium-cooled fast reactor + molten salt High-temperature gas reactor

X-ENERGY



**KP-FHR** Fluoride salt-cooled high-temperature reactor KAIROS POWER



eVinci Heat pipe-cooled microreactor WESTINGHOUSE NUCLEAR



**BWXT Advanced Nuclear Reactor (BANR)** High-temperature gas-cooled microreactor BWX TECHNOLOGIES



**SMR-160** Advanced light-water small modular reactor HOLTEC INTERNATIONAL



**Molten Chloride Fast Reactor** SOUTHERN COMPANY

#### Concept Development





Advanced Sodium-Cooled **Reactor Facility** ADVANCED REACTOR CONCEPTS

**Fast Modular Reactor** GENERAL ATOMICS



**Horizontal Compact High-Temperature Gas Reactor** MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Slide content courtesy of U.S. DOE-NE



#### Demonstration Pathway Selected Technologies

- TerraPower LLC Natrium Reactor
  - SFR that leverages decades of fast reactor and metallic fuel development
  - High temperature reactor coupled with thermal energy storage for flexible electricity output
  - New metal fuel fabrication facility
  - Visit: <u>https://natriumpower.com/</u>
- X-energy Xe-100 reactor
  - HTGR that leverages decades of reactor and robust TRISO fuel form development
  - Provides flexible electricity output and process heat for a wide range of industrial heat applications
  - Commercial scale TRISO fuel fabrication facility
  - Visit: <u>https://x-energy.com/</u>





#### Natrium Reactor

Sodium-cooled fast reactor + molten salt energy storage system TERRAPOWER



Xe-100 High-temperature gas reactor X-ENERGY

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#### Risk Reduction Pathway Selected Technologies

Prime Recipient	Commercial Target Reactor Type and Fuel	Risk Reduction Project Key Deliverables		
Kairos Power. LLC	KP-FHR - 140 Mwe thermal spectrum fluoride salt-cooled MSR, TRISO annular pebble fuel	Design, construction and operation of Hermes reduced-scale test reactor (precursor to commercial- scale KP-FHR)	KP-FHR Fluoride salt-cooled high-temperature reactor KAIROS POWER	eVinci Heat pipe-cooled microreactor WESTINGHOUSE NUCLEAR
Westinghouse	eVinci - 4.5 MWe heat pipe- cooled microreactor, TRISO UCO compact HALEU fuel	Technical risk reduction for moderator design, wick manufacturing, refueling and licensing.	<	Constantion of the second
BWXT	BANR - 50 MWt transportable microreactor HTGR with UN TRISO	Maturation of technology, including the development of UN TRISO fuel, to improve the commercial viability of BANR	BWXT Advanced Nuclear Reactor (BANR) High-temperature gas-cooled microreactor	SMR-160 Advanced light-water small modular reactor
Holtec	SMR-160 - 160 MWe LW-cooled natural circulation PWR	Early stage design, engineering, and licensing activities for the SMR-160.	BWX TECHNOLOGIES	HOLTEC INTERNATIONAL
Southern Company	Molten Chloride Fast Reactor – 180 MWt pool-type MSR fast reactor with liquid salt fuel	Design, construction and operation of Molten Chloride Reactor Experiment (MCRE)	Molten Chloride Fast Reactor	

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eVinci<sup>™</sup>

#### ARC-20 Selected Technologies

NRIC

Prime Applicant	Commercial Target Reactor Type	ARC-20 Project Key Deliverables		
Advanced Reactor Concepts	ARC-100 100 MWe pool type sodium-cooled fast reactor	Conceptual and preliminary design of a seismically isolated advanced sodium-cooled reactor facility	Advanced Sodium-Cooled Reactor Facility	actor
General Atomics	GA-EMS 50 MWe gas-cooled fast modular reactor	Conceptual design of the GA-EMS 50 MWe FMR, increase TRL on systems and components, develop prelim. cost estimates	ADVANCED REACTOR CONCEPTS	
MIT	Modular Integrated Gas- cooled High Temperature Reactor (MIGHTR)	Conceptual design for MIGHTR and support for future commercialization as a safe and cost-competitive HTGR concept	Horizontal Compact High-Temperature Gas Reactor MASSACHUSETTS INSTITUTE OF TECHNOLOGY	

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