Advanced Nuclear Energy - Nuclear Innovation Alliance

24 March 2022

Energy and Utilities Finance and Policy Committee

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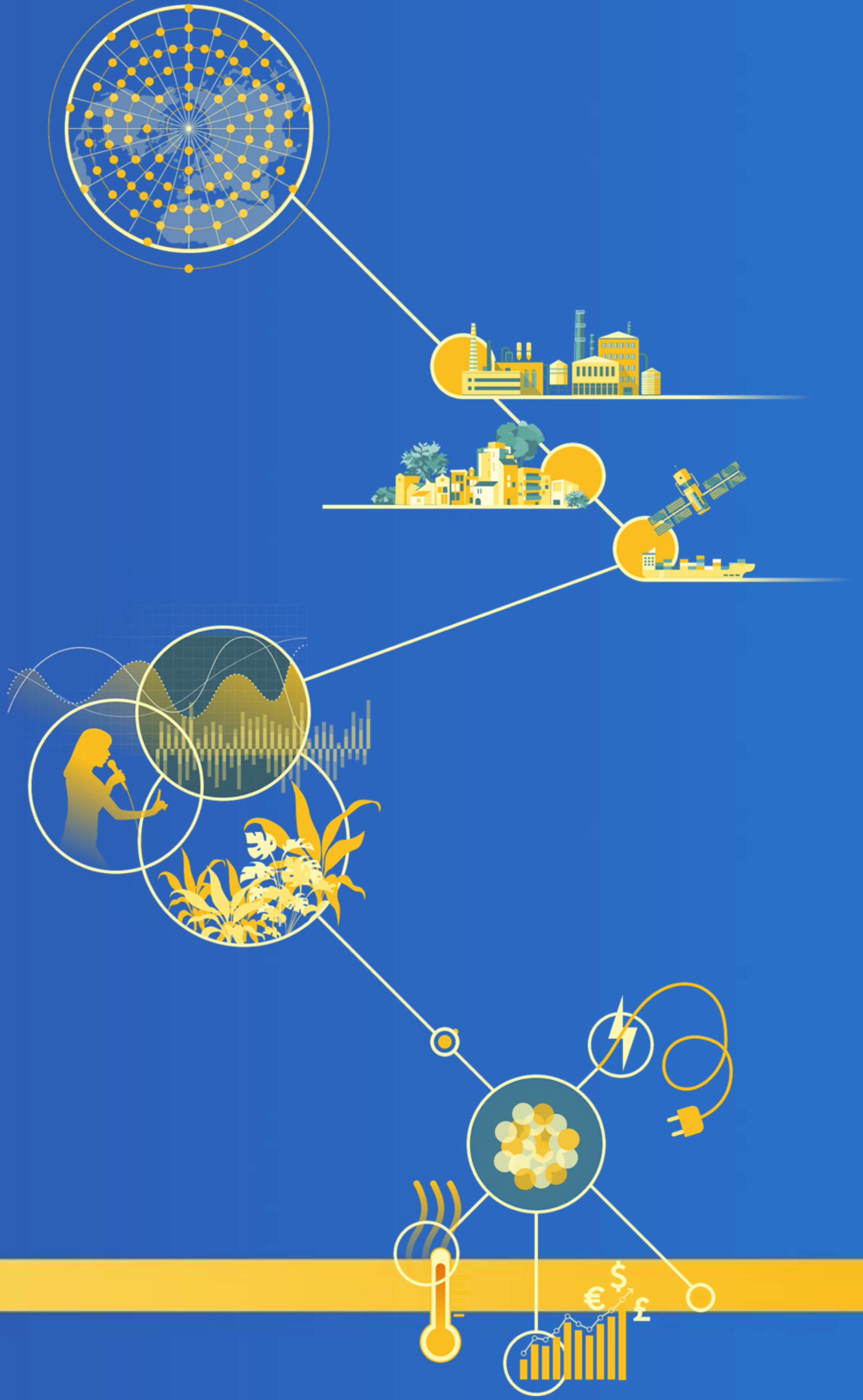
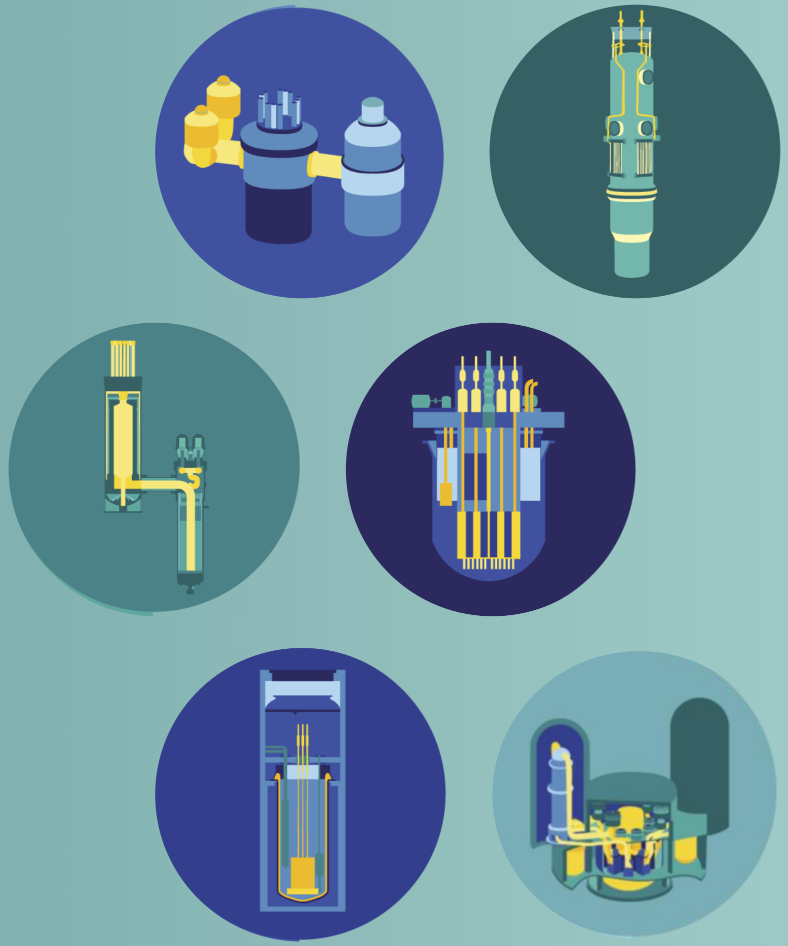


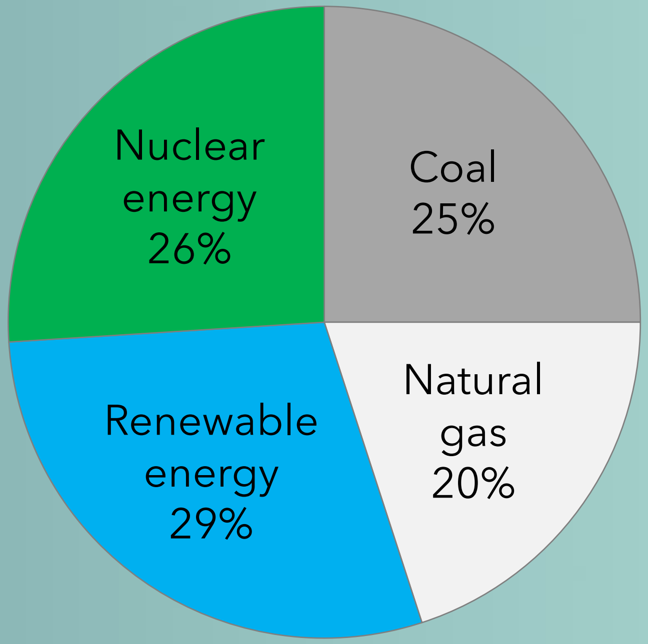
Advanced nuclear energy can play a key role in achieving environment, climate, and energy goals

- NIA is a “think-and-do” tank working to ensure the conditions for success for advanced nuclear energy to be a key part of the climate solution
- Advanced nuclear energy can ensure and accelerate progress towards achieving deep decarbonization goals



Why do we need advanced nuclear energy for deep decarbonization?

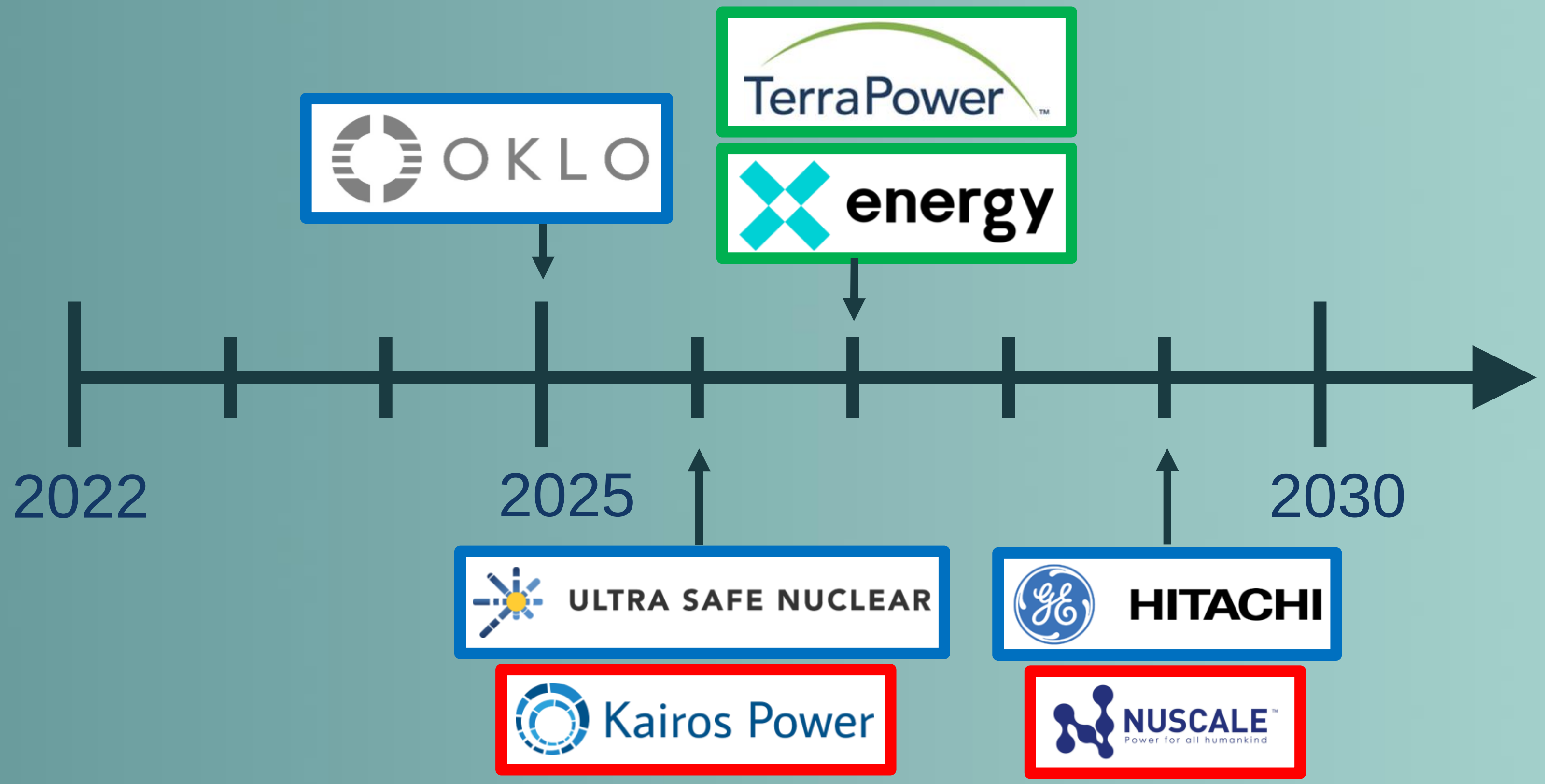
- We need to pursue a portfolio of promising technological options to provide the best chance of success
- The electricity system needs a variety of energy resources in order to be reliable, affordable and zero-carbon
- In particular, the electricity system needs clean firm resources like advanced nuclear energy to balance variable clean resources
- Deep decarbonization studies show that firm energy sources like nuclear energy make it more likely to achieve deep decarbonization and reduce decarbonization costs



Minnesota Electricity Generation Mix (2020)

Commercial advanced reactor deployment is underway for several technology developers in the United States

Technology development is being supported by both federal and private investments



Development and deployment of advanced nuclear energy has climate, domestic, and international benefits

American leadership

- Re-establish American global leadership in nuclear technology and decarbonize emerging economies.

Decarbonizing power & non-electric sectors

- Complement renewables to reach 100% carbon-free electricity.
- Provide district heating, power industrial facilities, and produce hydrogen.
- Replace existing fossil fuel infrastructure.

Economic advantages

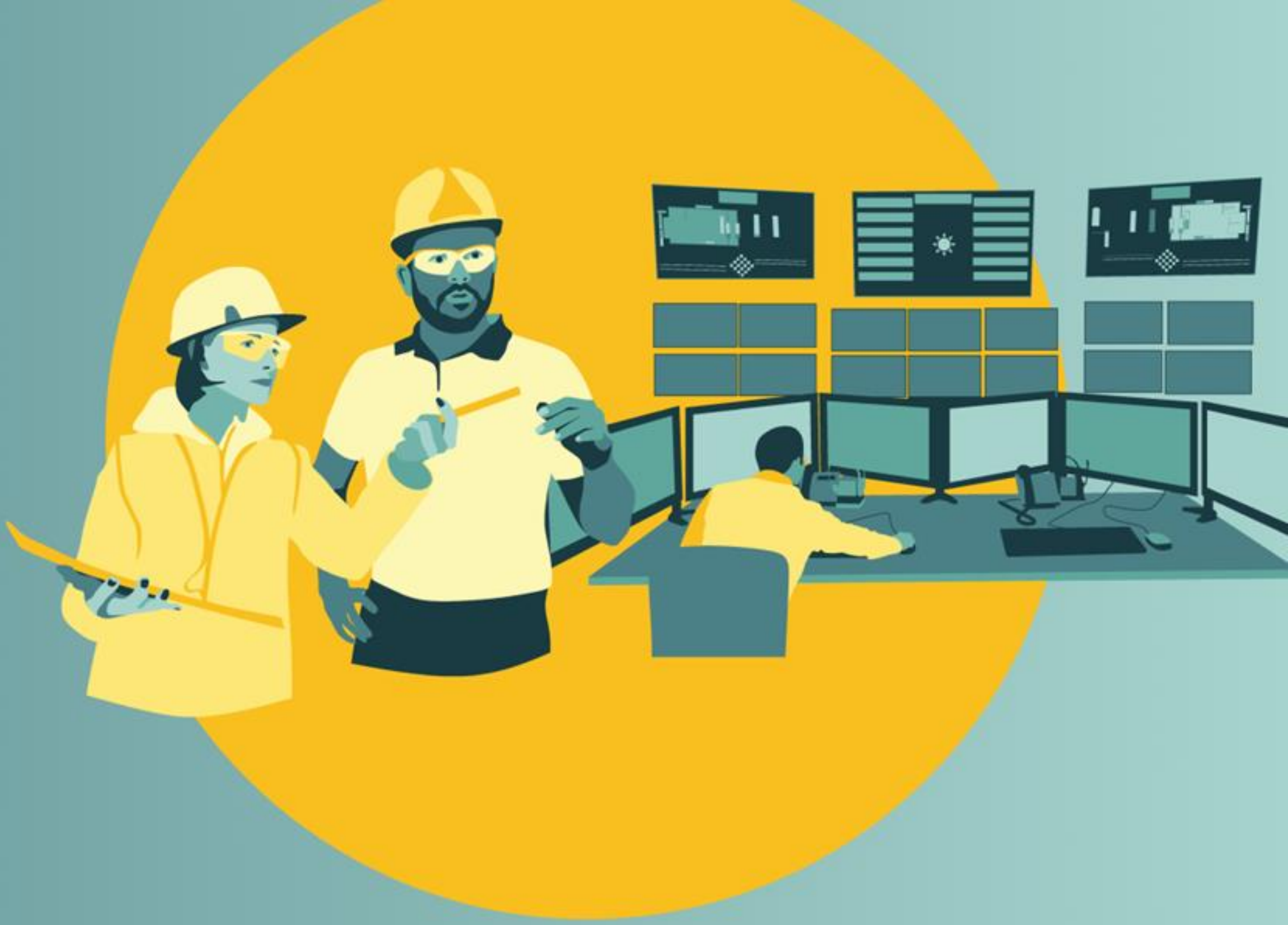
- Create a new industry and support economic growth with high-paying construction and operations jobs.
- Reduce costs and increase flexibility.

Safety improvements

- Innovative designs enable inherently safe reactors that don't require electricity or operator action to shutdown safely.

Replacing retiring power plants

- Coal power plants provides 25% of total electricity in Minnesota in 2020.
- Nuclear plants provide 26% of MN electricity and half of its clean electricity
- These plants will need to be replaced with clean energy as plants retire.



What is advanced nuclear energy?

Advanced nuclear energy adds flexibility and versatility in comparison to conventional nuclear through innovative design

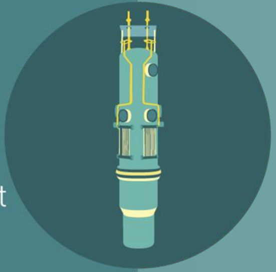
Conventional Nuclear Energy		Advanced Nuclear Energy
Predominantly Large: More than 500 MW_e	Reactor Size	Versatile: 1.5 MW_e to 300+ MW_e
Predominantly Light-Water Reactors	Reactor Technology	Wide Variety of Reactor Technologies
Primarily Baseload Generation	Generation Type	Flexible and Dispatchable Generation
Designed with Active Safety Systems	Safety Approach	Designed with Inherent Safety Systems
Exclusively Low Enriched Uranium Fuel Rods	Fuel & Efficiency	Variety of Proposed Fuels

Definition of advanced nuclear energy includes a variety of nuclear technologies with different advantages

Thermal Fission

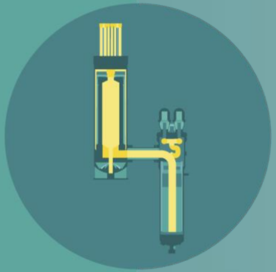
Advanced Light-Water Reactors

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



Thermal or Fast Fission

Molten Salt-Fueled Reactors (MSRs)

Using molten salt for coolant and a fuel form, MSRs can bring significant safety benefits

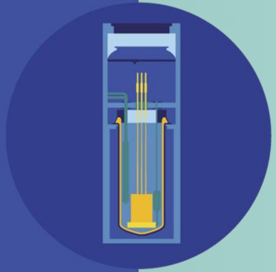
Fast Fission

Gas-cooled fast reactor (GFR)

An evolution of HTRs, GFRs operate at very high temperatures while using a more sustainable fuel cycle

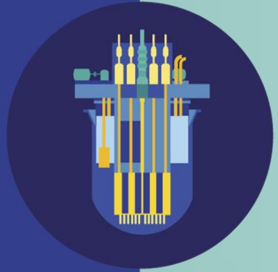
Sodium-cooled fast reactor (SFR)

With many existing experimental reactors, SFRs offer increased fuel efficiency, reduced waste, and passive safety features

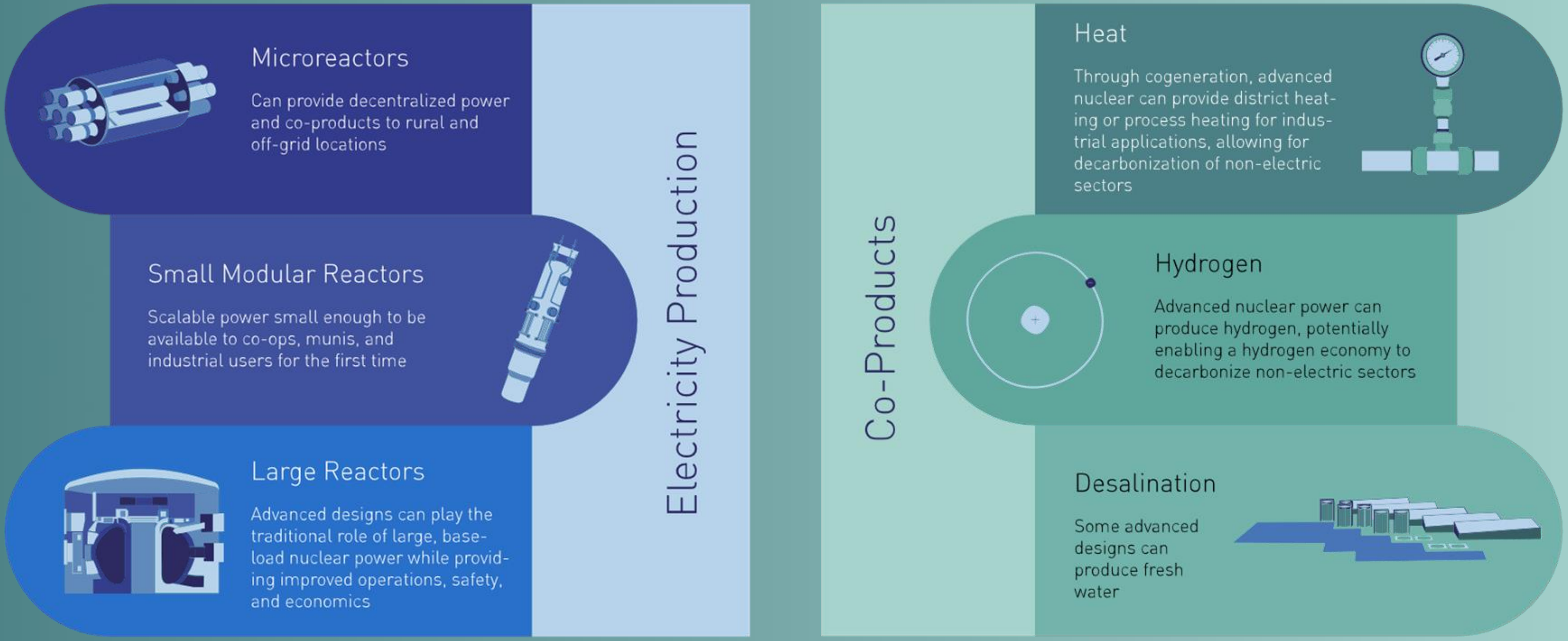


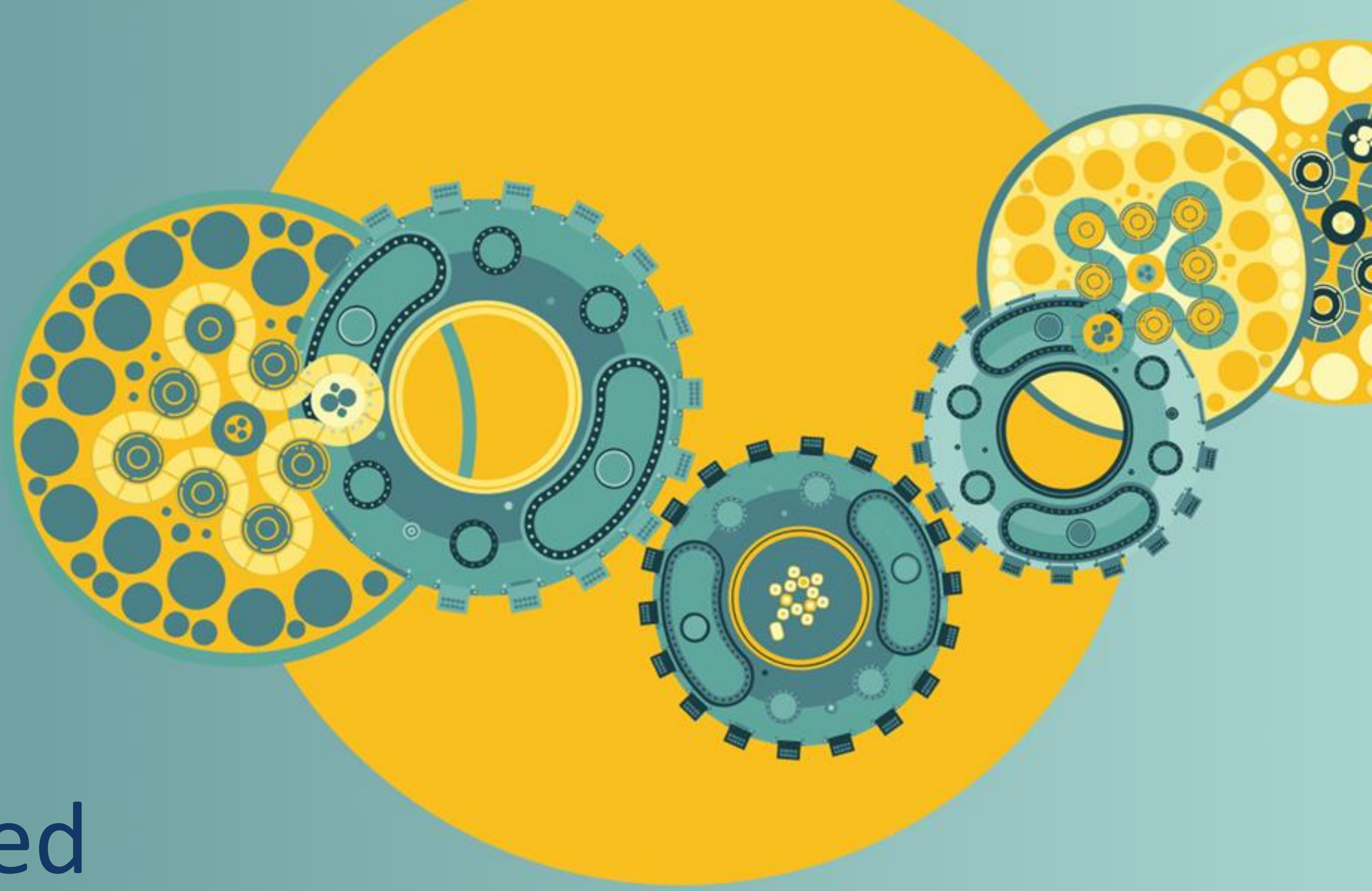
Lead-cooled Fast Reactor (LFR)

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





Licensing Advanced Nuclear Energy

Nuclear Regulatory Commission (NRC) licenses all commercial nuclear facilities in the United States

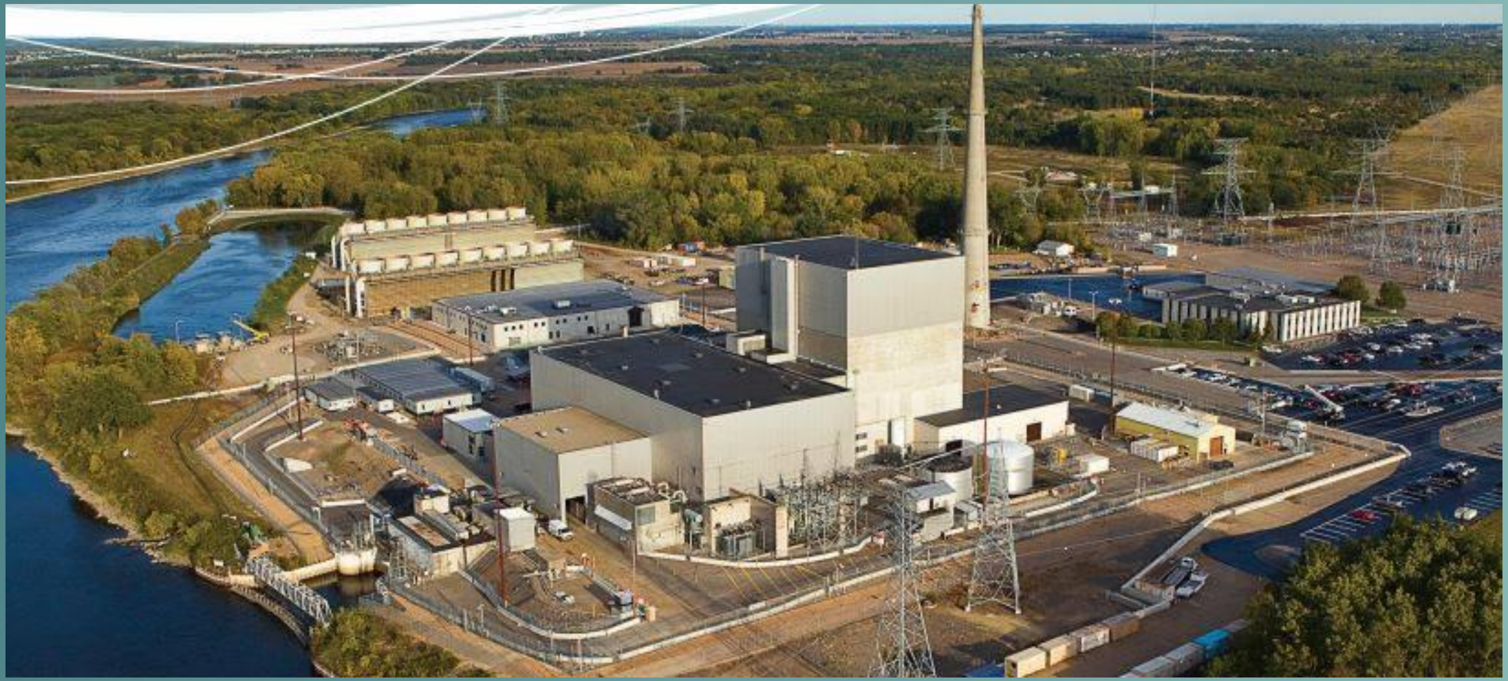
Design and Testing

Manufacturing and Construction

Operation and Maintenance

Decommissioning and Disposal

Existing regulatory frameworks for nuclear energy are optimized for today’s operating nuclear reactors



Monticello Nuclear Generating Plant, Monticello, Minnesota

- Predominantly Large: More than 500 MW_e
- Predominantly Light-Water Reactors
- Primarily Baseload Electricity Generation
- Designed with Active Safety Systems
- Low Enriched Uranium Fuel Rods

Image source: North Wright County Today

Regulatory modernization activities are underway to effectively and efficiently license novel advanced reactors

Risk-Informed
"Focus on probability and consequence"

Modern Nuclear Regulation

Performance-Based
"Focus on outcomes, not design features"

Technology-Inclusive
"Focus on rules applicable to any reactor technology"

Advanced reactors developers are making progress in licensing, with developers starting NRC pre-application and application activities for specific facilities, sites, and designs

NRC Applications (Site or design)

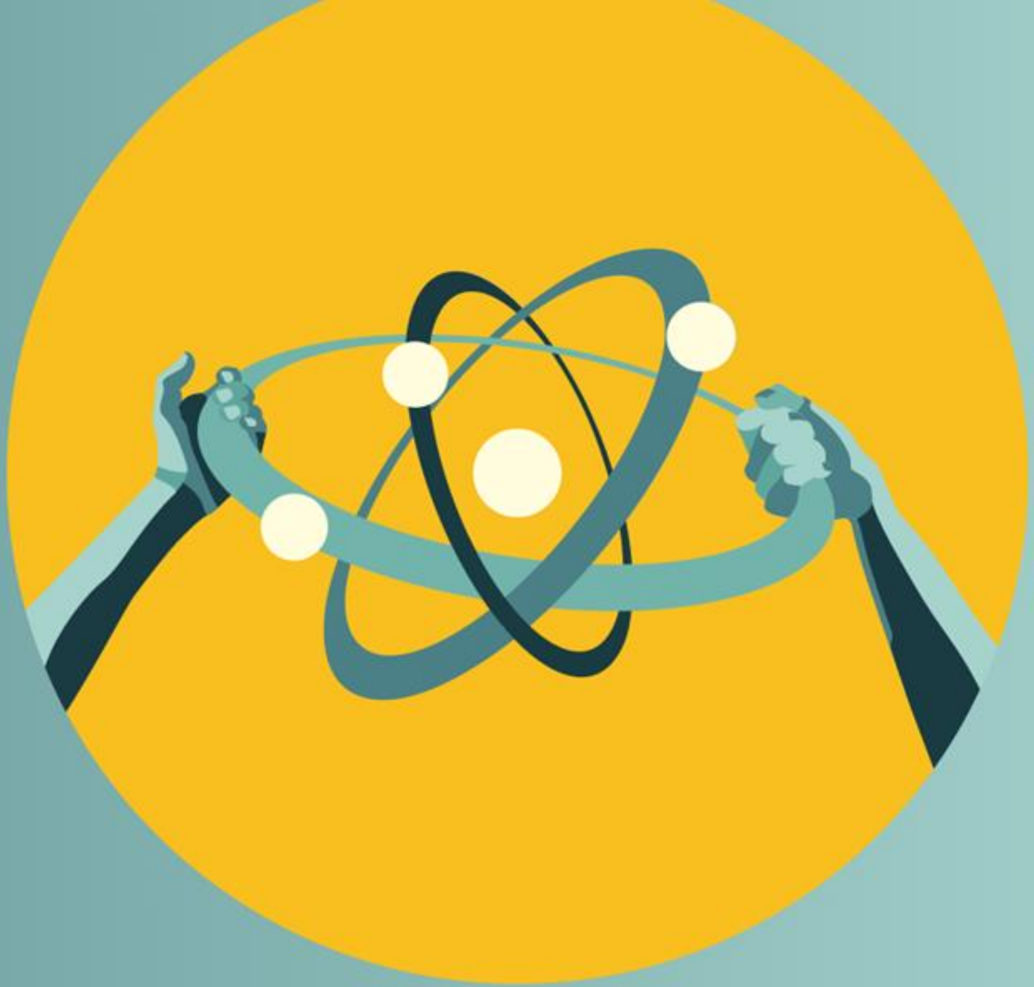
- NuScale (UAMPS)
- Kairos Power (Hermes)

NRC Pre-applications (Site identified)

- X-Energy (Xe-100)
- TerraPower (MCFR)
- TerraPower/GE (Natrium)
- USNC/UIUC (MMR)
- Oklo (Aurora)
- GEH (BWRX-300)

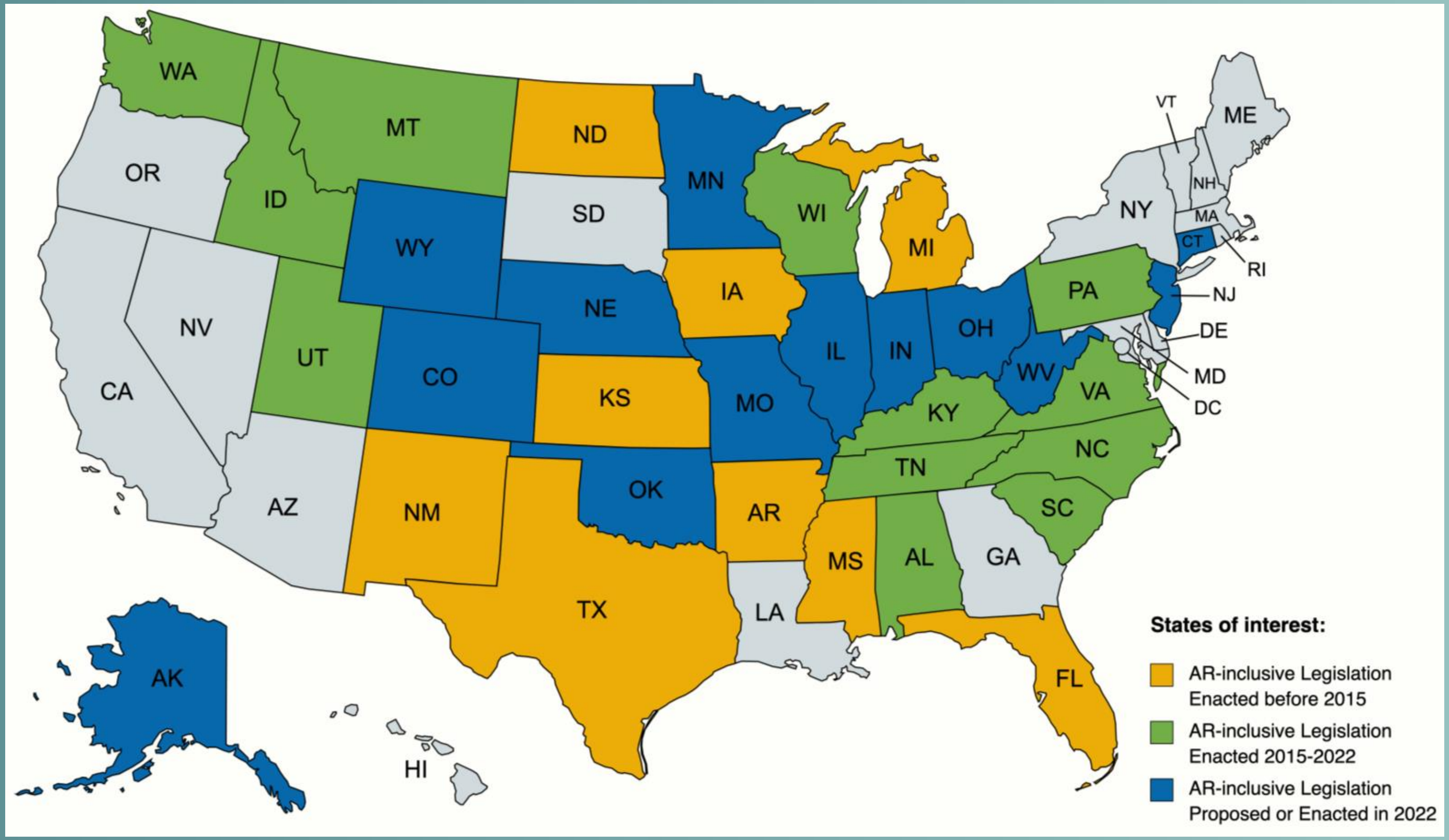
NRC Pre-applications (Site independent)

- General Atomics (EM^2)
- Westinghouse (eVinci)
- Kairos Power (KP-FHR)
- Holtec (SMR-160)
- Terrestrial Energy (IMSR)



State of Play on Advanced Nuclear Energy State Actions

States are exploring and taking action to encourage deployment of advanced nuclear energy



Advanced Nuclear Energy: The Takeaways

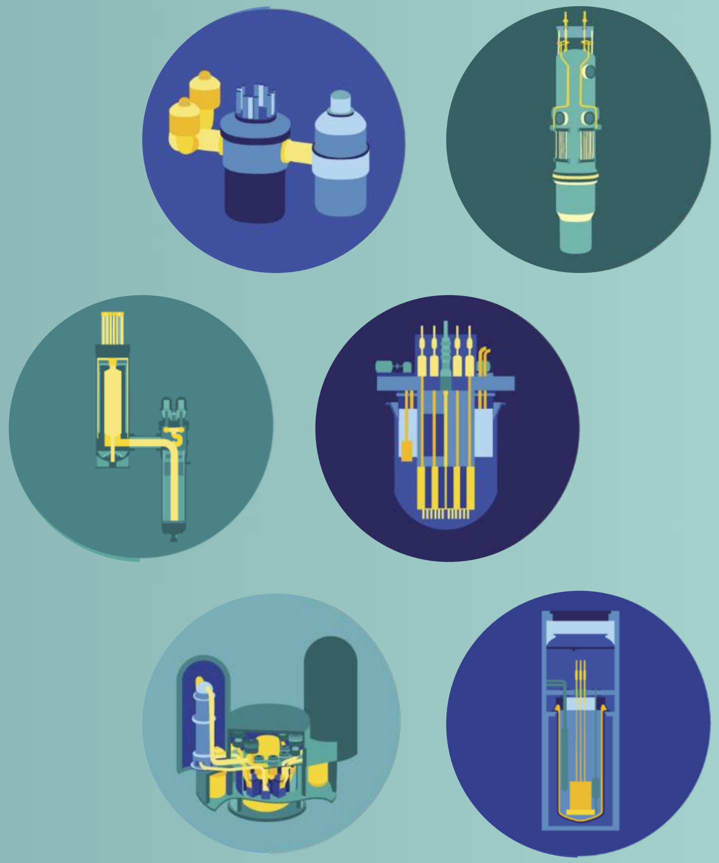
Nuclear energy is an important tool for climate change mitigation

Advanced nuclear energy can help play a unique role in decarbonization

Development of advanced nuclear energy is already underway in the US

NRC regulatory modernization and federal investment in technology innovation are enabling advanced reactor development

State legislative policy changes can catalyze technology deployment



For More Information and Follow-up:

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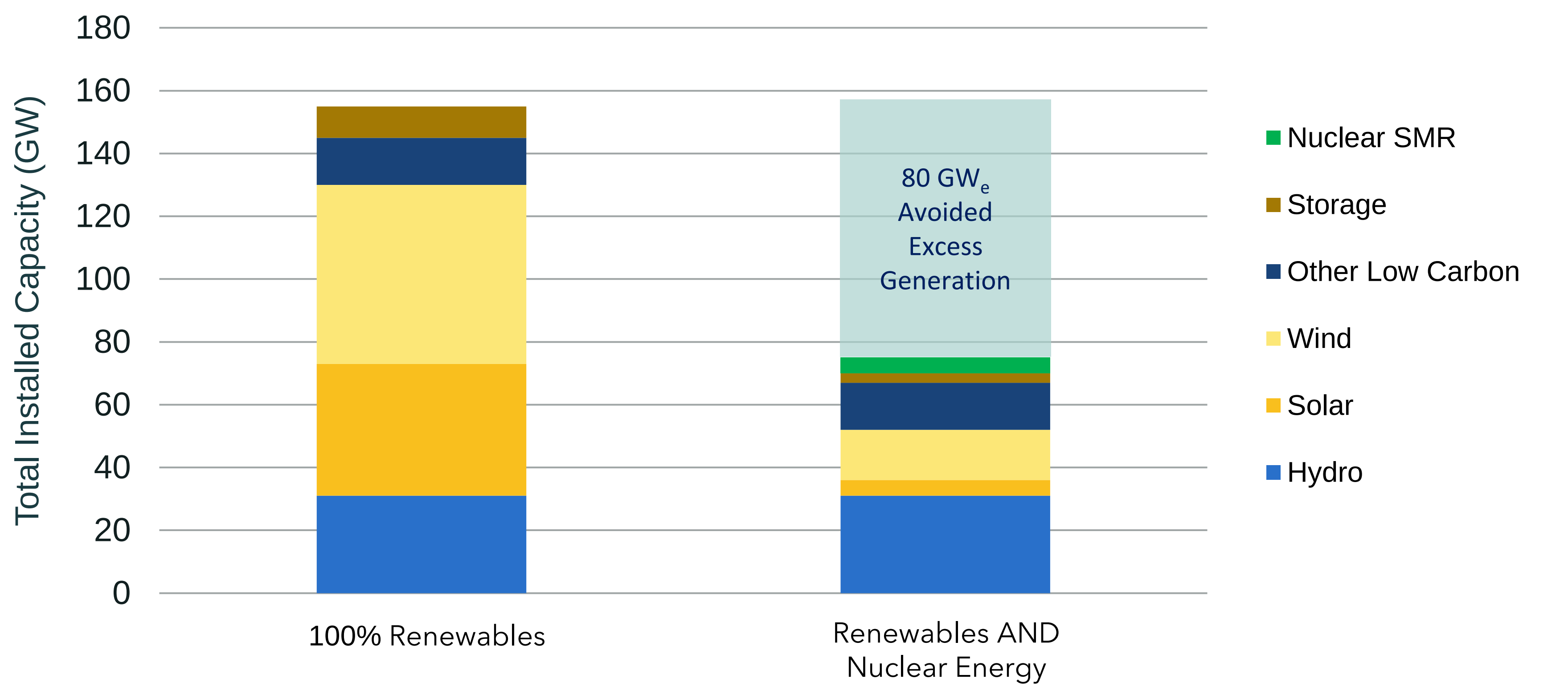
Additional/Back-up Slides

Utilizing advanced nuclear energy increases the likelihood of achieving deep decarbonization and reduces costs



Local case study of Pacific Northwest show that baseload low carbon energy resources (like nuclear) can help offset the cost of deep or full decarbonization. Source: Energy+Environmental Economics

Innovative technology and design strategies help ensure the safety of advanced reactors

Inherent Safety Methods

Advanced reactor are designed with new inherent safety features:

- Replacing active safety systems with inherent safety systems
- Minimal reliance on emergency electric power and operators to ensure safe shutdown

Reduced Advanced Reactor Hazards

Advanced reactor designs reduce inherent hazards:

- Lower reactor power reduces post-shutdown cooling demands
- Smaller reactors have smaller radiological inventories that reduce accident consequences

New and Robust Forms of Fuel

Advanced reactor designs utilize a variety of special fuel forms that:

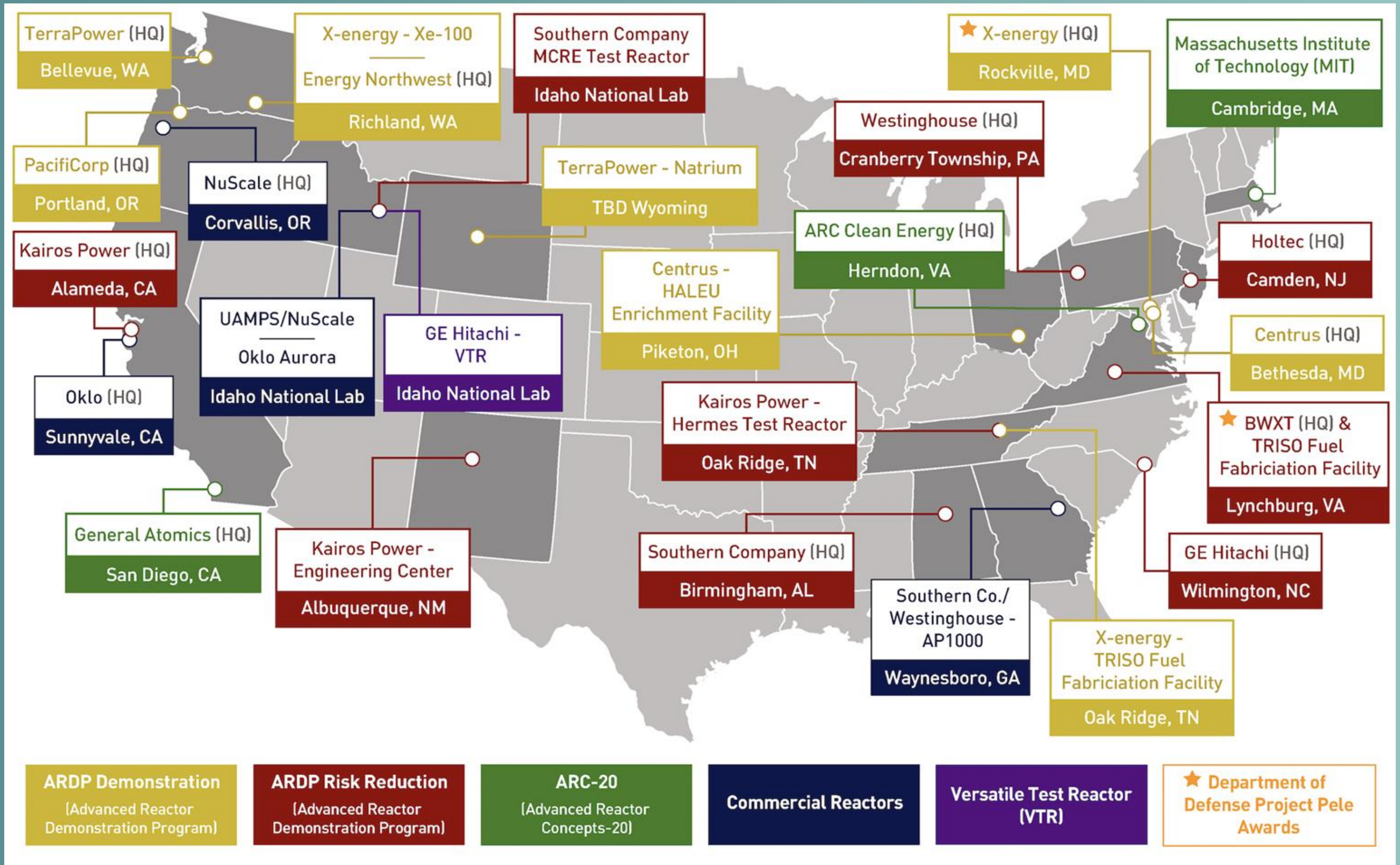
- Survive high temperatures (TRISO fuel forms)
- Maintain operation stability in a liquid form (molten salt reactors)
- Quickly dissipate excess heat (metal fuel forms)

New Reactor Siting Paradigms

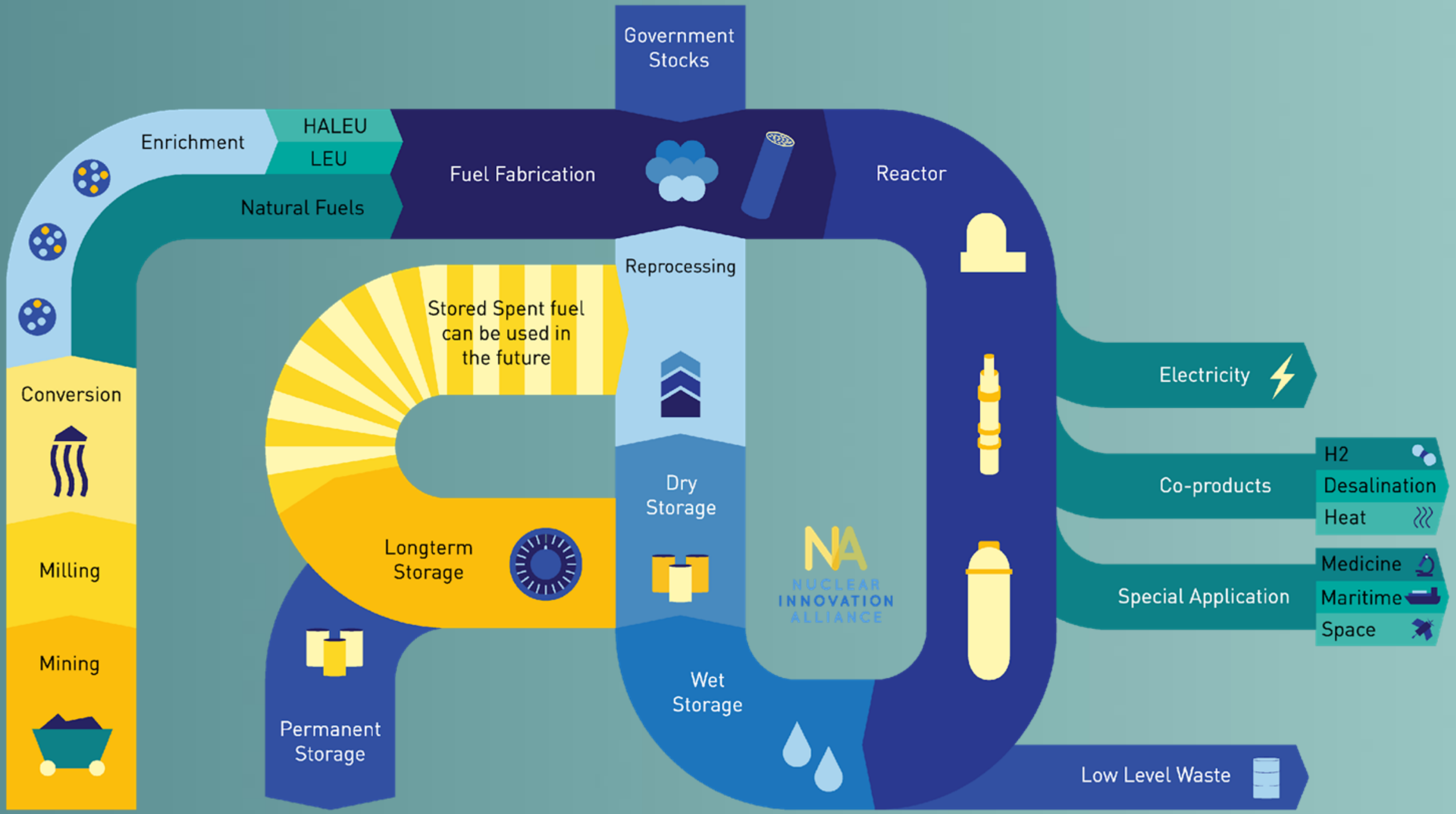
Advanced reactor designs can utilize new approaches to siting :

- Placing reactors underground to reduce natural or man-made risks
- Eliminating off-site accidents and reducing community emergency planning requirements

New, competitive advanced reactor industry is growing nationwide



Reimagining the advanced nuclear fuel cycle can improve the long-term sustainability of nuclear technology



Advanced reactor developers are working with NRC to both use existing rules and help inform future licensing rules

Near-term licensing reform:
10 CFR Part 50 and Part 52

Effectively use existing licensing processes for first-of-a-kind advanced reactor projects

Longer-term licensing development: 10 CFR Part 53

Inform NRC rulemaking on new licensing process for future advanced reactors

Use and help inform NRC rulemaking on environment, siting, and decommissioning

On-going regulatory reform:
Risk-informed, performance-based regulations

NIA's *U.S. Advanced Nuclear Energy Strategy*

State Level Recommendations:

Recognize the Opportunity of Advanced Reactors	Early Movers Support Demo Projects	Innovation Hubs Support Economies	Decarbonization of Power Sector at Scale	Decarbonization At Other Sectors
Advanced reactor will bring high paying jobs and economic development to areas. Restrictions must be eased for reactors to be sited.	Early adopters of advanced nuclear demonstrations projects can support rapid commercialization of advanced reactor.	Advanced reactors can serve has hubs that will develop supply chain and systems that bring broad and other economic benefit to areas.	Advanced nuclear energy can complement renewable energy and serve as a strong, baseload energy source to achieve a 100% carbon free electric sector.	Advanced reactors will be able to produce hydrogen, power desalination plants, and decarbonize other industries like steel making and cement.