Perspectives on Advanced Nuclear Energy Systems

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Workshop on Molten Salt Reactor Technologies

Oak Ridge National Laboratory, Oak Ridge TN
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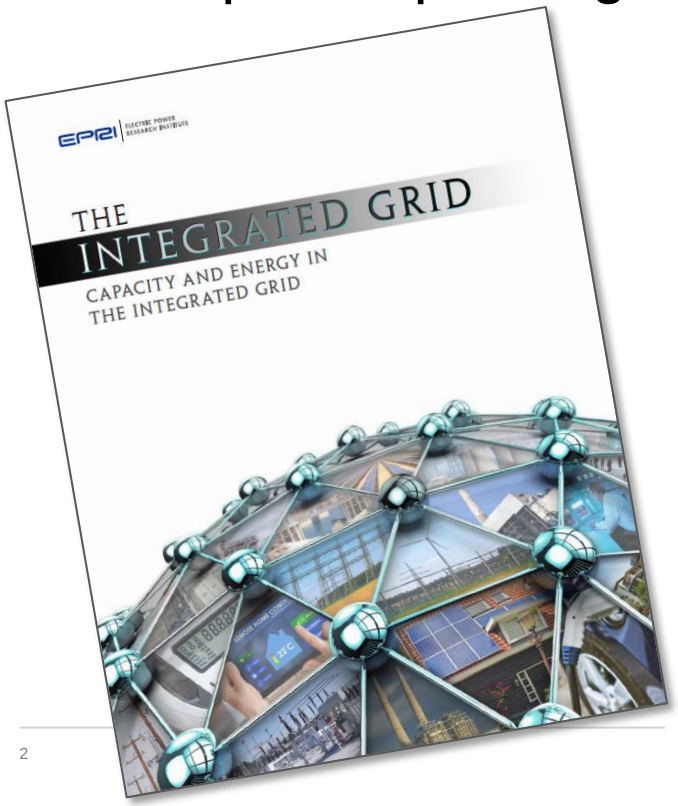
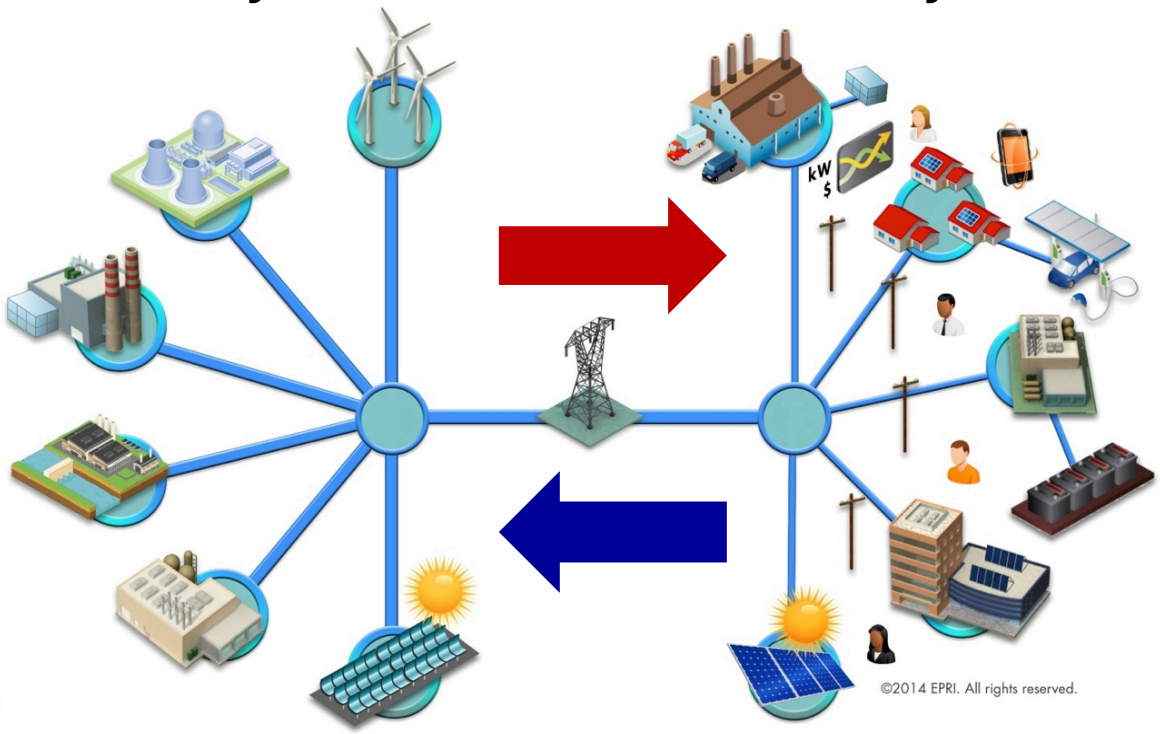
The Commercial Environment for Nuclear is Changing

- Developed energy markets must adapt large, aging infrastructures to maintain adequate energy and capacity
- Developing energy markets face challenge and opportunity of “clean slates” and new choices
- New power paradigm: flexibility, resilience, connectivity





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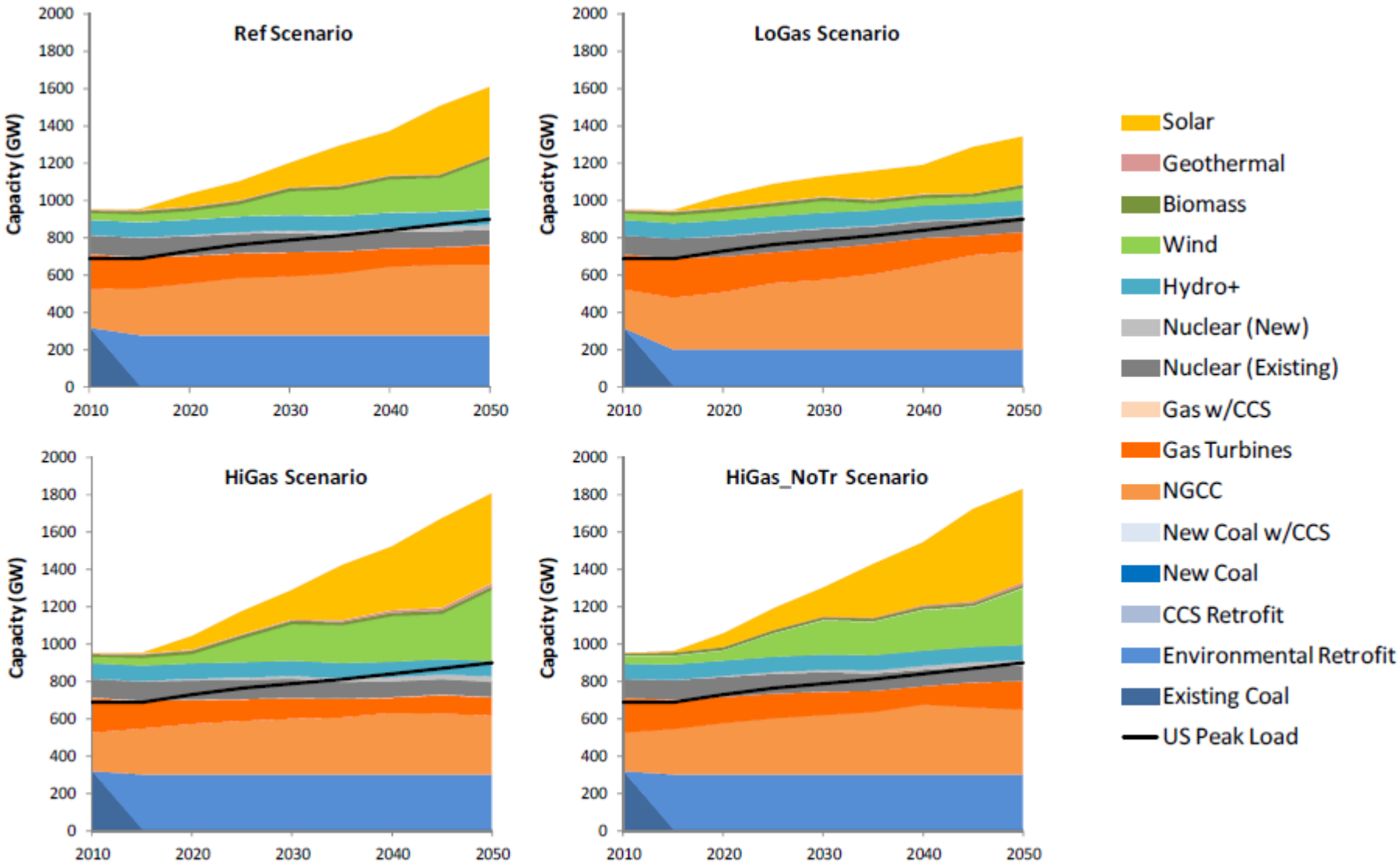
2050: U.S. Generation Capacity by Technology



Program on Technology: Fossil Fleet Transition with Fuel Changes and Large Scale Variable Renewable Integration. EPRI: 2015. 3002006517.

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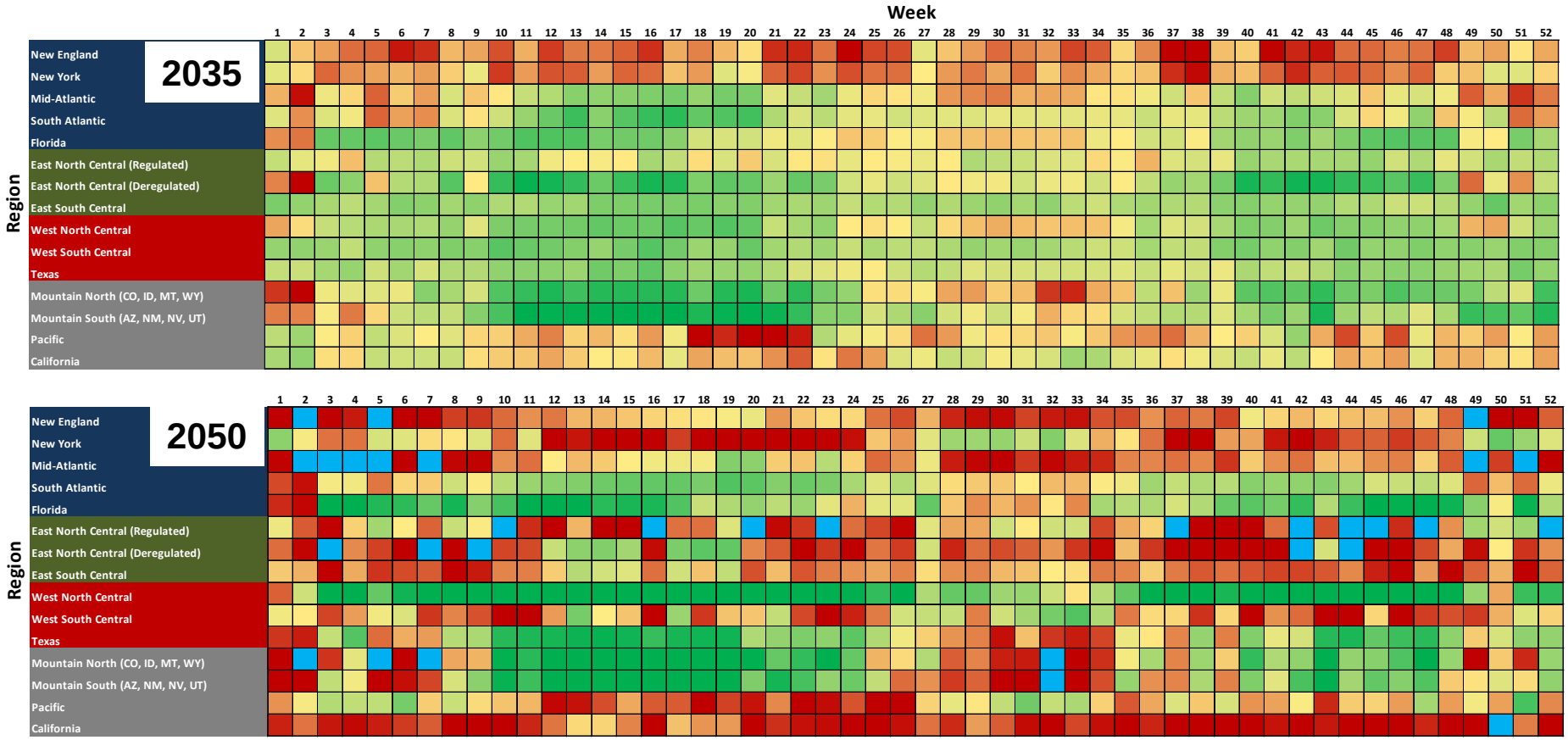
Increasing Grid Variability – Loss of Reliability in 2050



Green = Good

Red = Bad

Blue = Extreme

Factors

- Early retirement of fossil plants
- Renewable portfolio standards take effect in 2025 to 2030
- Modest growth in demand
- Continued lowering cost of renewables as technology improves

Program on Technology: Fossil Fleet Transition with Fuel Changes and Large Scale Variable Renewable Integration. EPRI: 2015. 3002006517.

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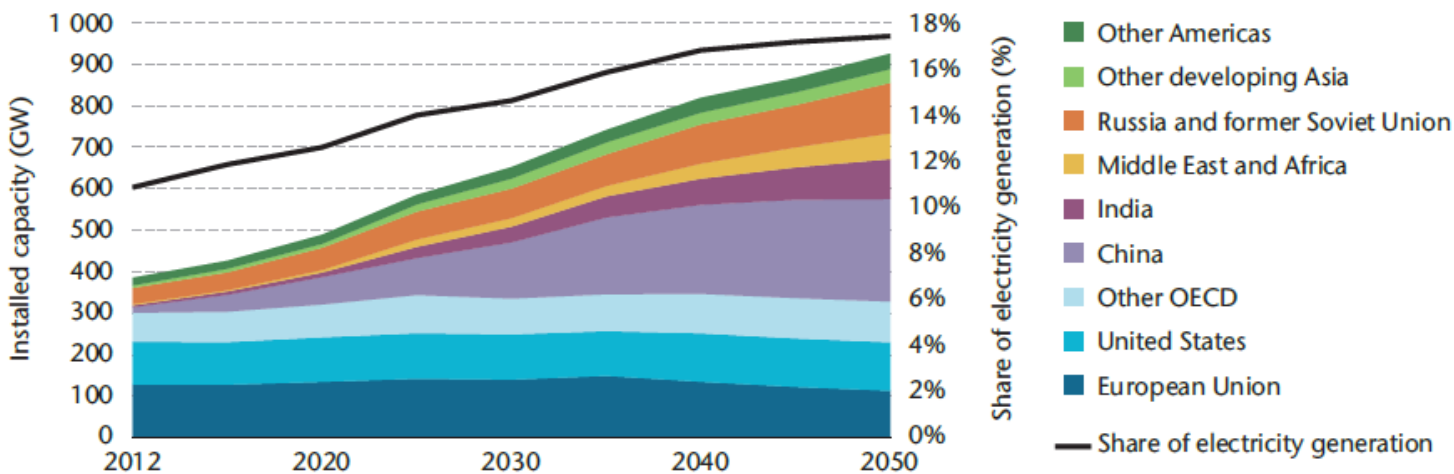
21st Century Role for Current Nuclear Technology

- Light water reactor fleet provides nuclear generation backbone for meeting capacity needs and emission goals
- Once-through fuel cycle remains favorable economic option for foreseeable future for most fleets:
  - uranium resources not limiting in near-term
  - Pu-recycle not economically compelling solely for fuel substitution
- Challenging market, regulatory and policy environments are placing nuclear role at risk in some countries

Projected Global Nuclear Generation for 2DS Scenario

Source: IEA 2015. Technology Roadmap



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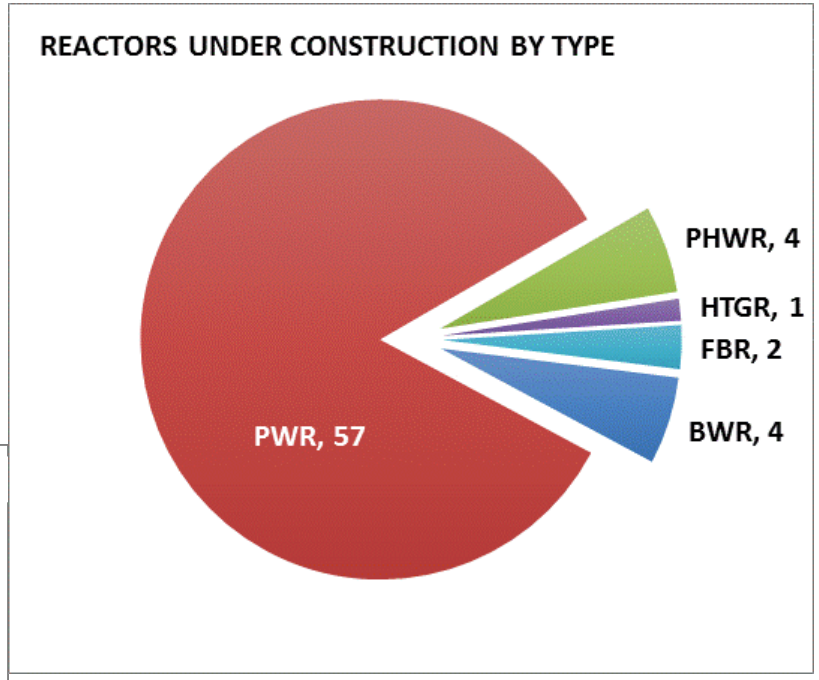
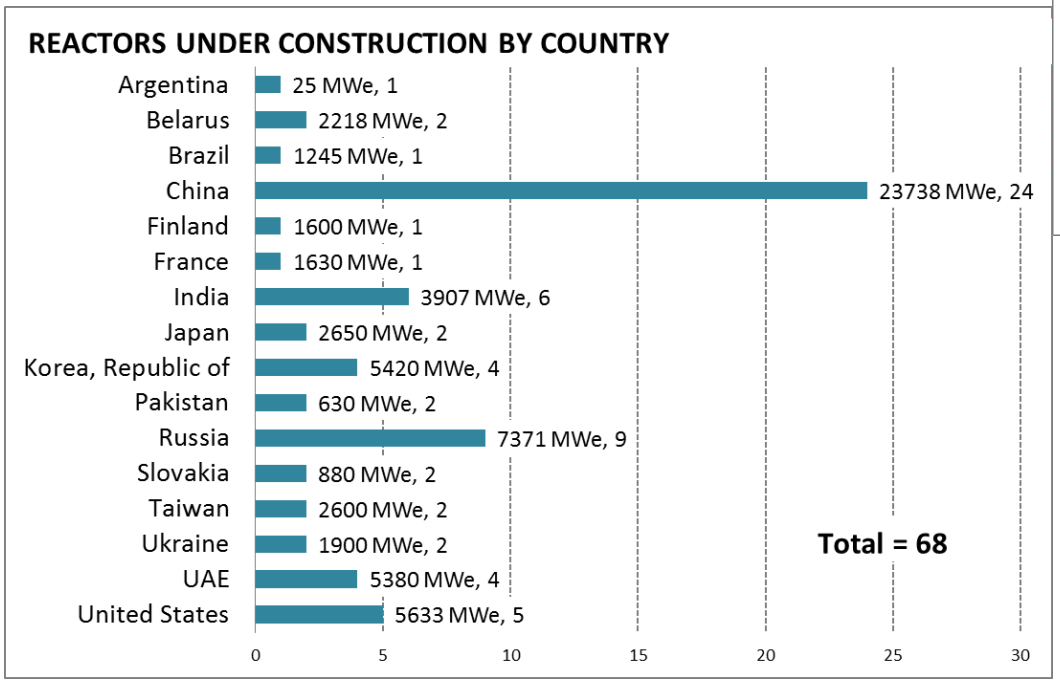
Robust International Market for New Build

- 67 GWe under construction, including non-LWRs
- Operation of new plants will span the century



Source: IAEA PRIS Database. Updated 29 Sept 2015



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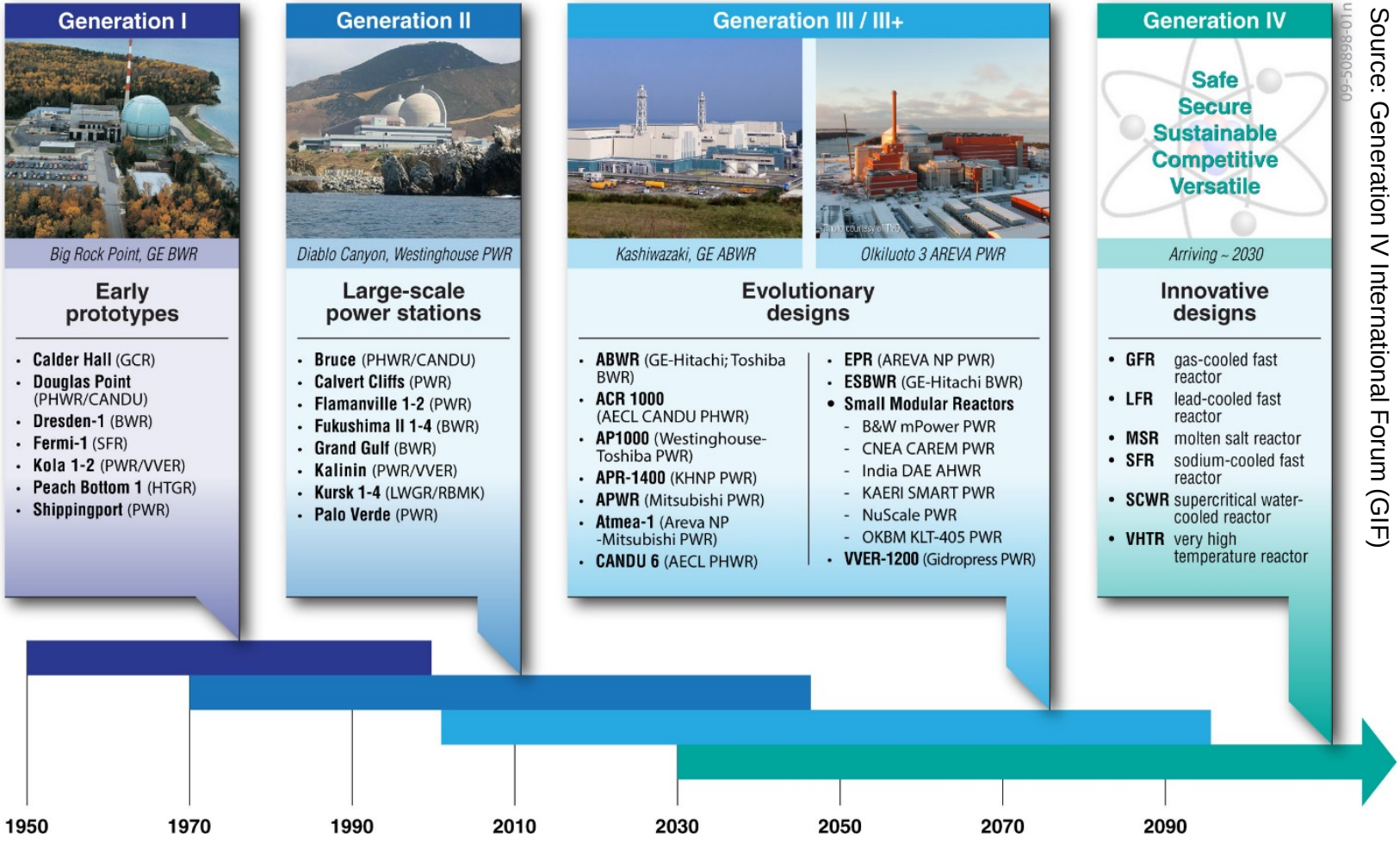
Generation IV: *The Next Generation?*



Source: Generation IV International Forum (GIF)

Most concepts demonstrated at some scale decades ago during era of active national RD&D (ca. 1950s – 1970s)

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Role of Advanced (GEN IV) Nuclear in 21st Century

- No Generation IV without healthy Generation II/III
- Sustained future role for nuclear energy in many countries, markets will require more compelling business cases derived from GEN IV technology attributes:
  - enhanced passive safety from inherent attributes
  - natural resource amplification via high conversion or breeding
  - actinide burning for waste management services
  - **asset flexibility: deployment, operations and products**
- Utilities are looking for options, not silver bullets:
  - *"Options have value…The larger the uncertainty, the larger the value of options." [Tennessee Valley Authority]*

Compelling commercial drivers and owner/operator requirements need to be articulated.

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Snapshot: Global Advanced Reactor Status

- Demos & prototypes operating in China, India, and Russia (primarily SFR, HTGR)*
- Active design, licensing, or construction underway in China, France, India and Russia for additional prototypes & new designs
- National objectives for commercial operation in China, France, India, Japan, and S. Korea ~ 2030-50
- Russia marketing BN-800 for export
- China poised for commercial offering of HTR-PM in 2020s

Russia's 800 MWe BN-800

India's Kalpakkam 500 MWe PFBR

*Japan's two experimental/demo fast reactors remain shutdown for maintenance, repairs and RD&D program review.

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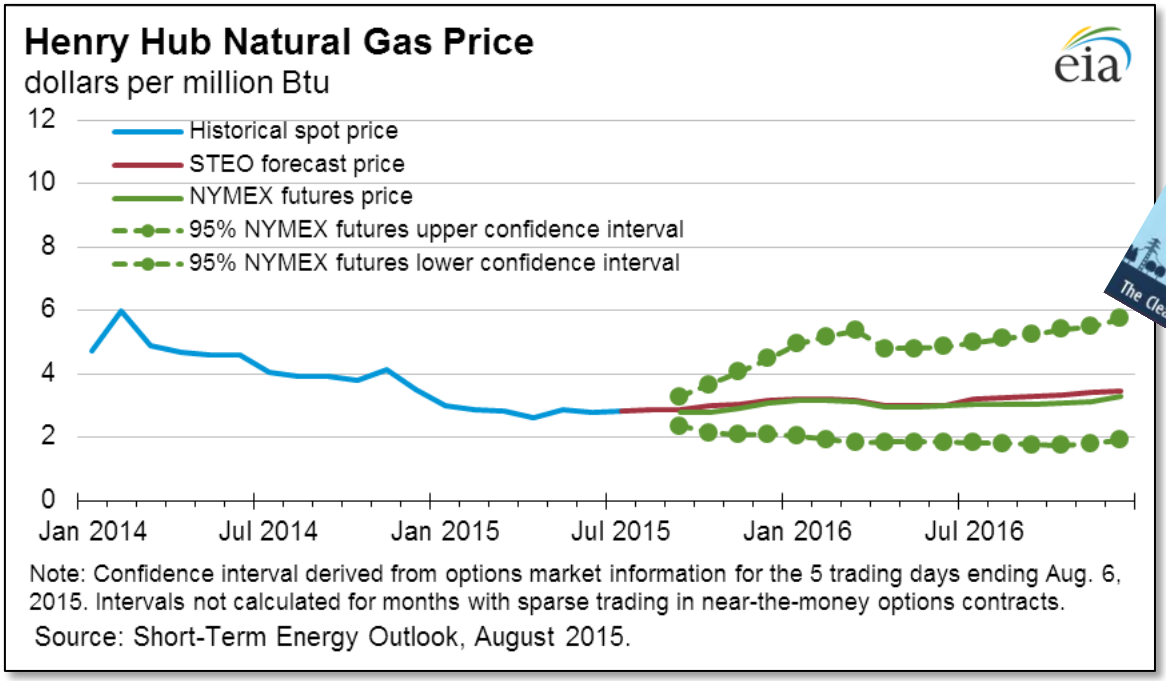
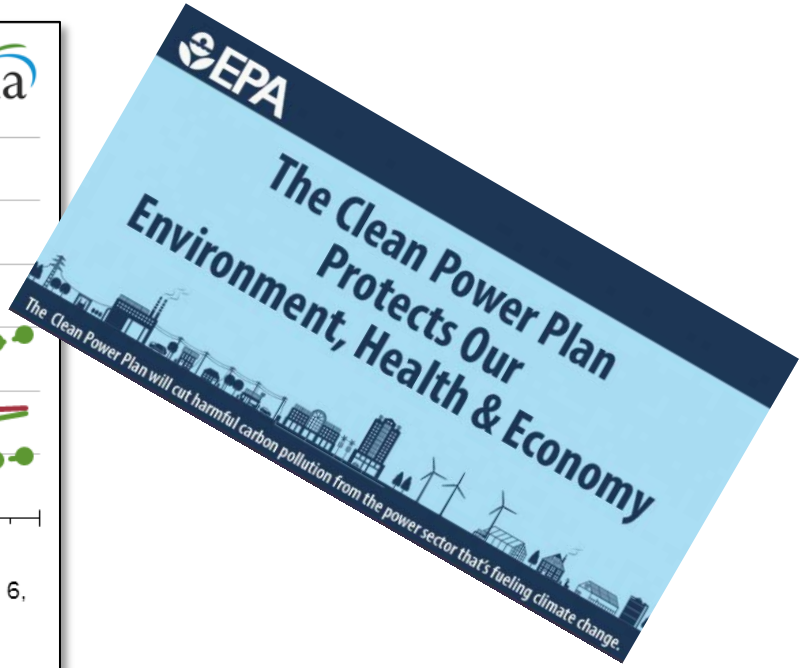
Disruptive Competition, Distributed Generation, Regulation





Utility Dive

How utilities think they will make their money in the future

Execs say distributed generation and the customer relationship will be the new revenue centers

By Robert Walton | February 9, 2015

Facing an evolving power industry and Americans' changing relationship with the electric grid, utilities have been forced to alter traditional ways of thinking and are increasingly seeking growth in new areas.

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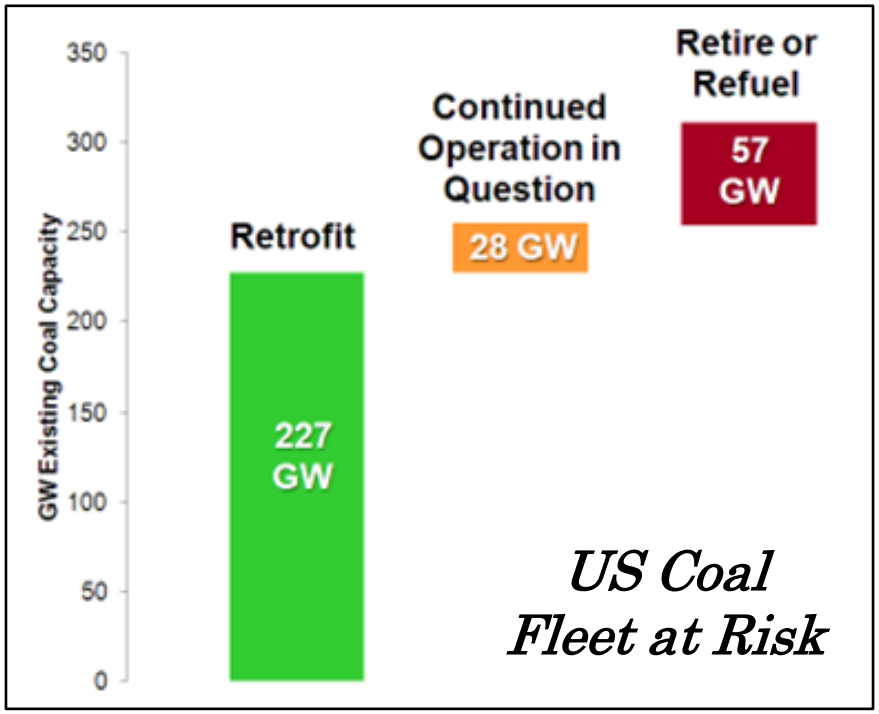
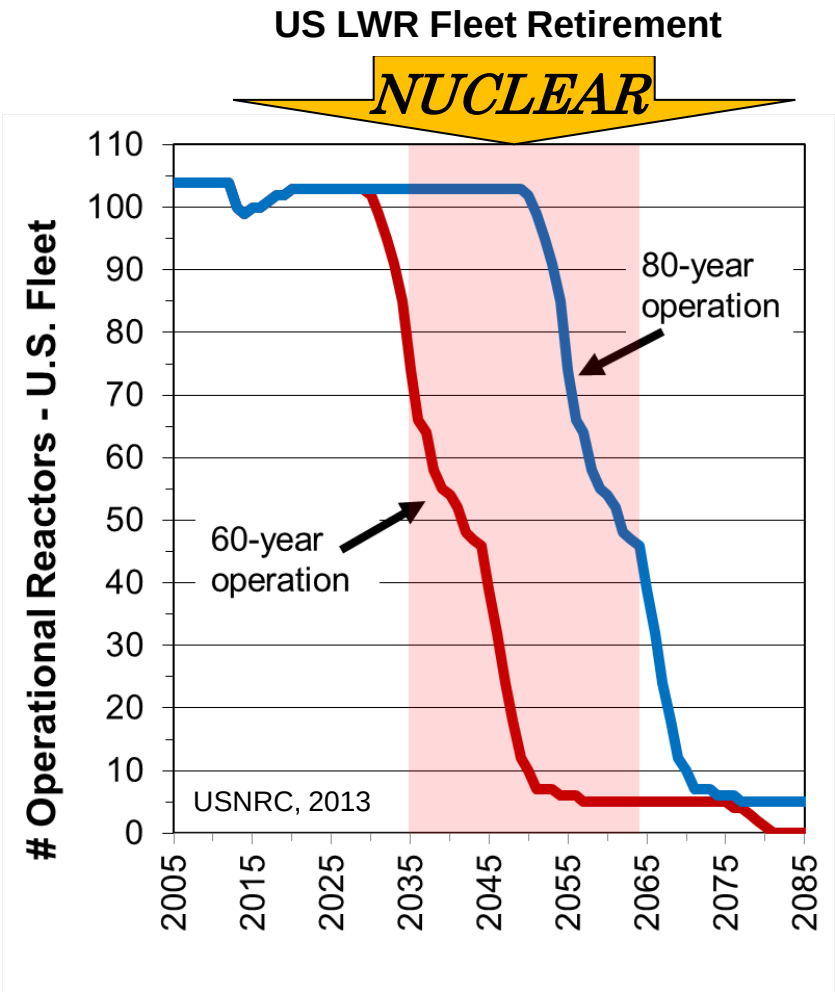
Uncertainty and Opportunity: Drivers for New Nuclear?



EPRI (2102) 1026743. PRISM 2.0: The Value of Innovation in Environmental Controls - Summary Report.



Challenge and Opportunity: $2 trillion in coal and nuclear generation at risk in the United States alone.

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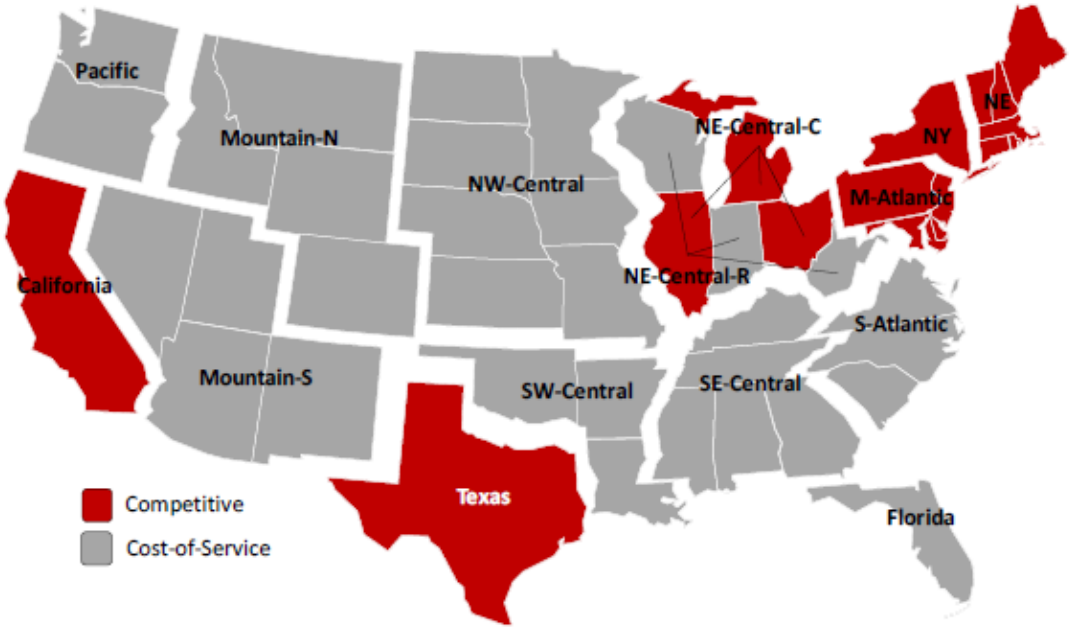
One Size Does NOT Fit All…

- Energy policy, market conditions, energy needs vary by country, region
- Business case for advanced reactors will vary accordingly
- What makes sense for France, UK, South Korea may not translate to US
- What makes sense for the southeastern US may not work for the Northeast



Basis for retail electricity prices by region

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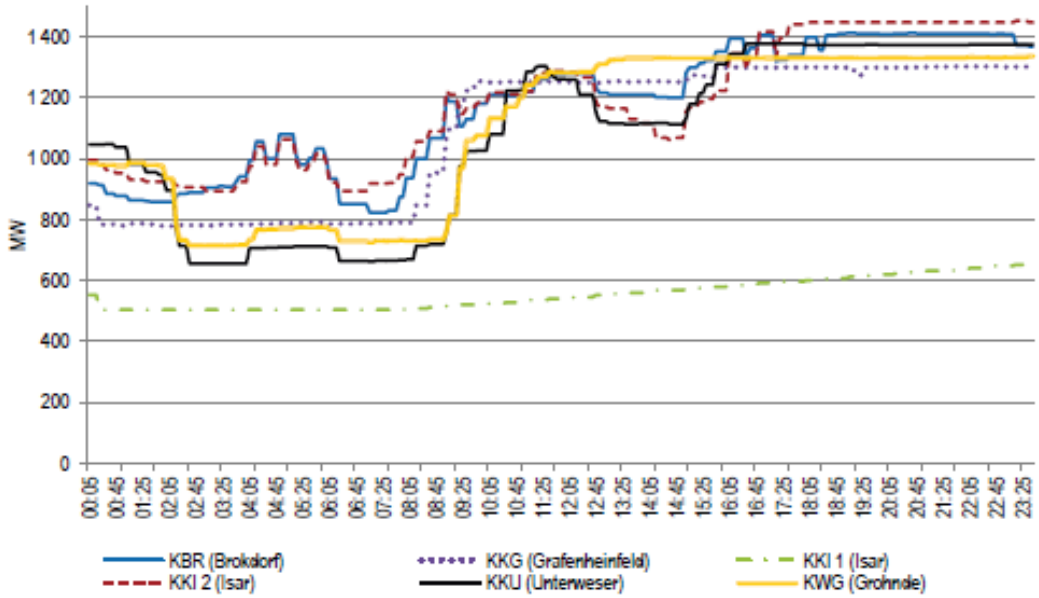
Growing Need for Flexible Operation of Current Nuclear Fleet with Increasing Renewable Penetration

- In the US, pre-planned and agreed upon power ramping:
  - Seasonal
  - Time-of-day
  - Time-of-week
- Extensive experience ir France and Germany:
  - Primary and secondary frequency response
  - 2-5% rated power/min within a limited band



Courtesy of E.ON Kernkraft

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Expanding the Concept of Flexibility for GEN IV

- Operational Flexibility: operation under a wide range of external conditions:
  - maneuverability
  - fuel use
  - cogeneration
  - island operation
- Deployment Flexibility: deployment under a wide range of external conditions:
  - scaling
  - siting
  - construction
- Product Flexibility: diversification of revenue generating products:
  - electricity
  - process heat
  - radioisotopes

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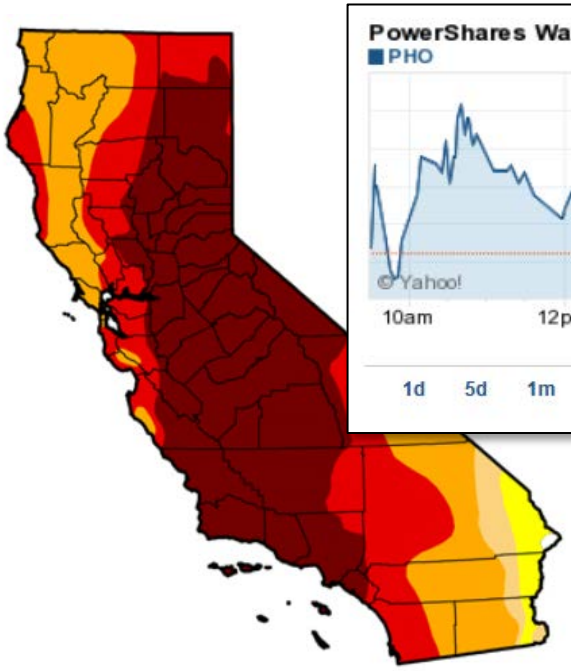
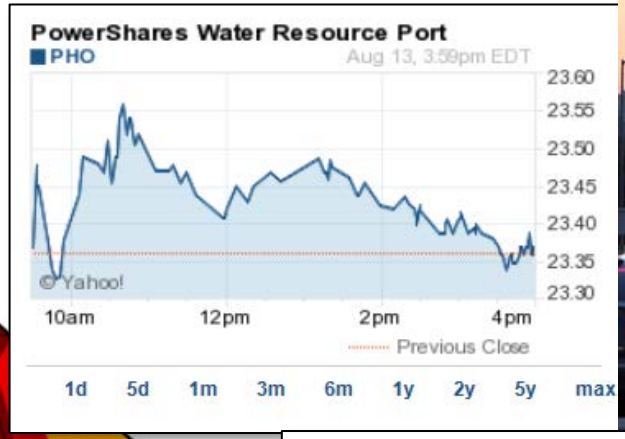
Are Storable Commodities and New Markets the Future Play for Advanced Nuclear?

- Potable water as the "oil" of the 21st century?
  - ~50% of world's population within ~200 km of coast; trend increasing
  - fresh water comprises only 2.5% of earth's water; of this only 1% is readily accessible for use
  - trading of water as a commodity has begun

AP File Photo/Richard Vogel





Water ETFs: The Next Commodity?

By ETFtrends.com
March 19, 2013 9:50 AM

The long term outlook for potable water remains uncertain, but the prospects for water becoming a valued commodity is not a matter of if, just a matter of when as the global population rises.

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EPRI Is Launching GEN IV Strategic Focus Area

- Long history of EPRI evaluation of advanced technology
- Development of decision analysis supporting tools for independent fuel cycle technology assessment since 2010
- Focus now shifting from to reactor technology
- Gathering input from stakeholders, advisors this week: Advanced Reactor RD&D Workshop
  - 40 total attendees from 29 different companies, representing developer, vendors, utilities, DOE, national Labs, EPRI, and others
  - formation of EPRI technical advisory group
- Roll-out of 5-year program to support new Long-Term Research Imperative on flexible generation
- Proposed activities, products: technology scouting, owner/operator requirements, industry RD&D roadmap

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