DC Section Meeting

American Nuclear Society

ANS Initiatives

- K-12 initiative with Discovery
- Increase value of ANS to all members
- “Connecting” parts of ANS
- Grand Challenges
- Incorporation in Illinois
- Enabling then future leaders in Nuclear

Perspectives on the Future of Nuclear Power in the United States

DC Section Meeting
Rockville MD

John E. Kelly
Vice-President/President-Elect
American Nuclear Society
May 8, 2018

Nuclear Energy
A Presidential Priority

"Begin a complete review of U.S. nuclear energy policy to secure domestic energy independence and to revive and expand the U.S. nuclear energy sector by preserving the nuclear fleet, paving the way for deployment of advanced nuclear designs, and stimulating exports abroad"

Make Nuclear Cool Again

ANS

"If you really care about this environment that we live in… then you need to be a supporter of this [nuclear energy] amazingly clean, resilient, safe, reliable source of energy."

Secretary Rick Perry at Press conference, May 10, 2017

Near Term Challenges for Nuclear Power in the U.S.

- Keep current fleet operating
- Resolve cost and schedule for new builds
- Investment/finance for new builds
- Grid of the future
- Waste management
- Achieving national security objectives thru the supply chain
- Advanced SMR deployment
- Gen IV development and demonstration

Decarbonization of Electricity Production by 2050

ANS

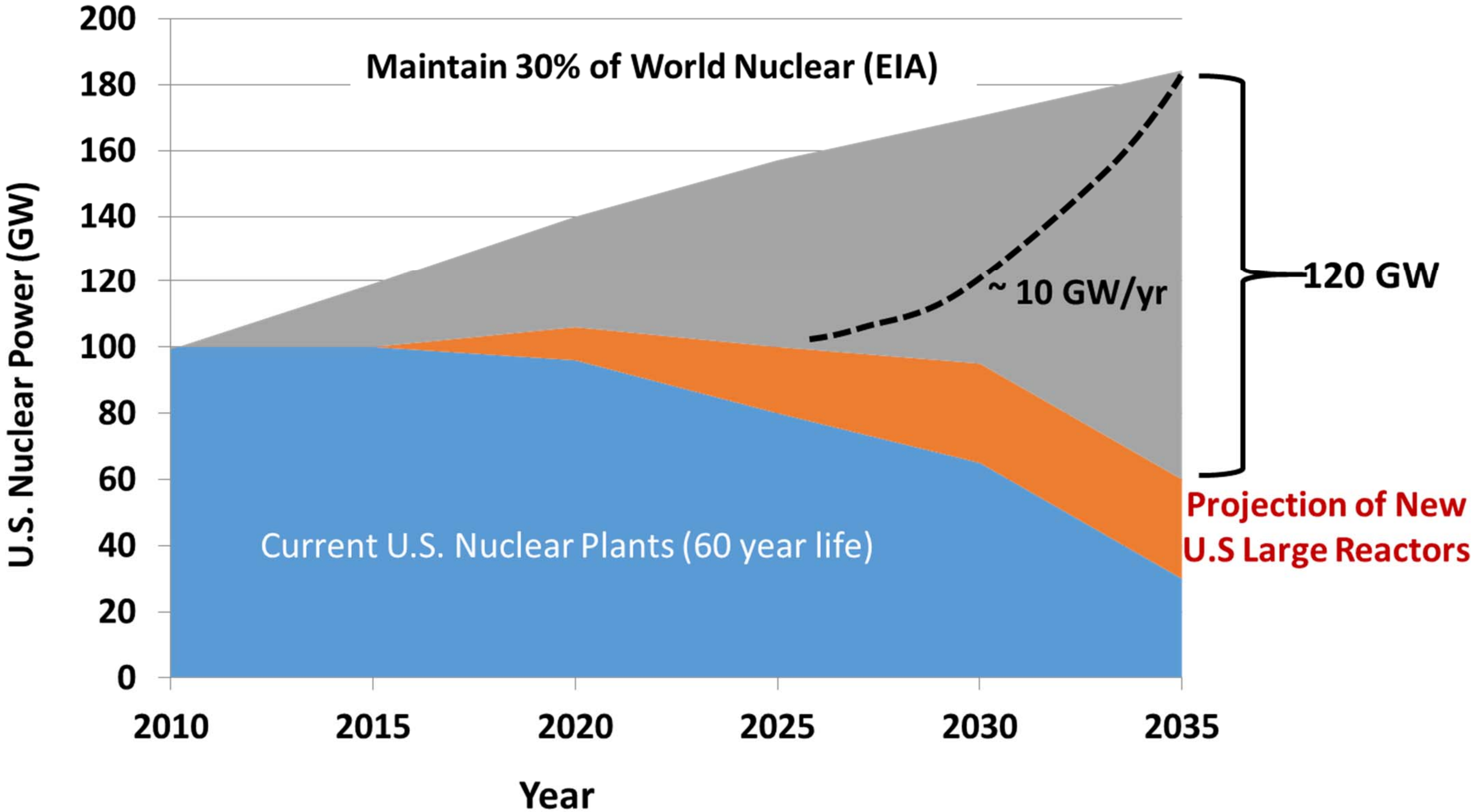
Source	2010 **Elect (TWhr)**	2010 **CO_2 (Gton)**	2035 **Elect (TWhr)**	2035 **CO_2 (Gton)**		2050 Elect (TWhr)
Natural Gas	1000	0.44	~~1520~~	~~0.51~~	**~0**	
Coal	1730	1.58	~~1800~~	~~1.66~~	**~0**	
Fossil (CCS)	0	0	?	0		1600
Nuclear (Large)	790	0	870	0		900
Nuclear (SMR)	0	0	?	0		700
Hydro	325	0	300	0		300
Renewable	200	0	440	0		2100
Petroleum/Other	50	0.04	~~40~~	~~0.03~~	**~0**	
TOTAL	4095	**2.05**	4970	~~**2.2**~~	**~0**	5600

Projections to 2050
CE= 100%

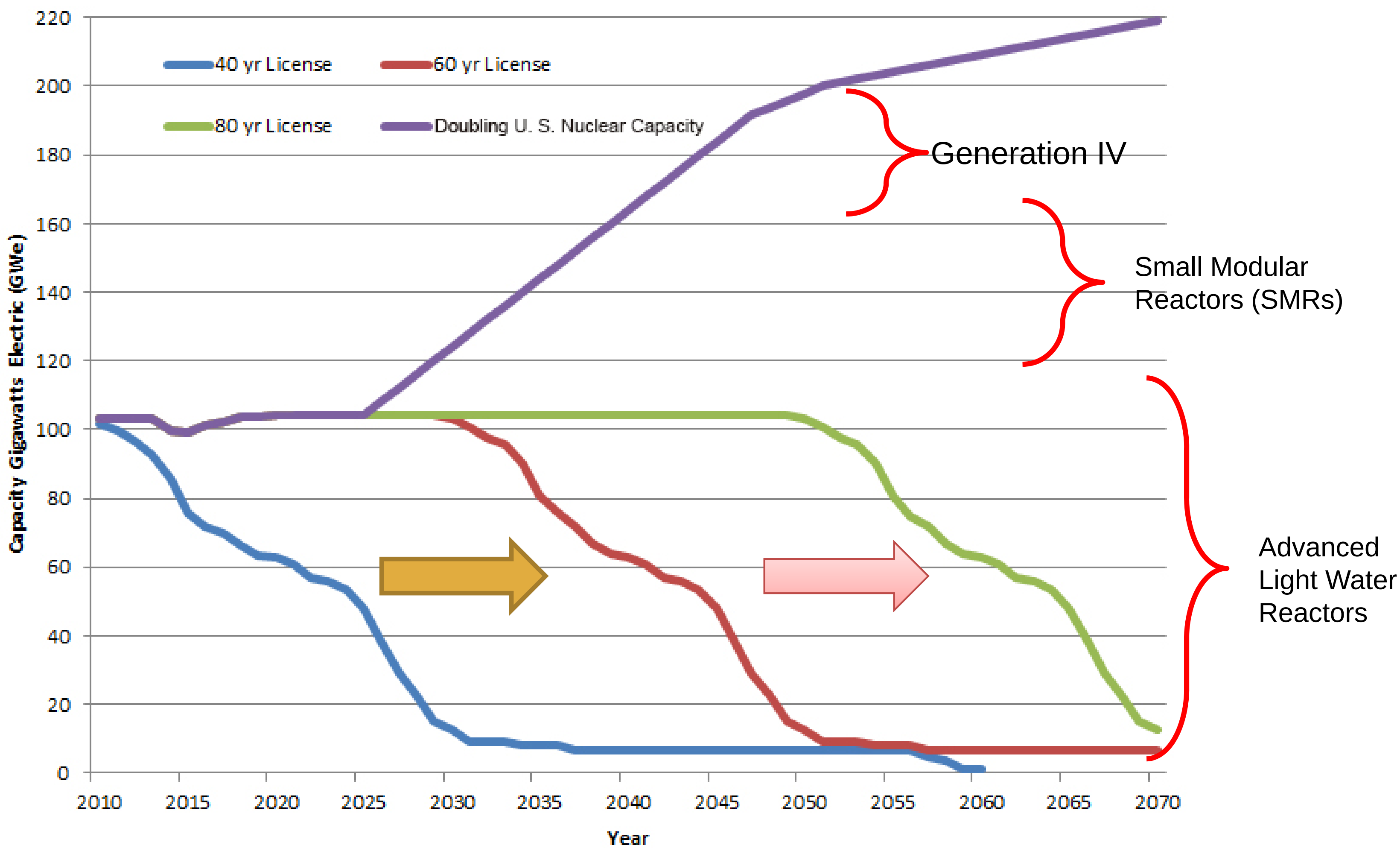
2013 U.S Electricity Consumption and CO_2 Emissions. *EIA* *CE=32%*

Source: EIA, Annual Energy Outlook 2013

Global Leadership in Nuclear Power



Nuclear Power Capacity Needed to Meet Future Electricity Demand



Keeping the Current Fleet Operating

- **Future of US nuclear industry is very dependent on keeping the current fleet operating**
  - **Revenues**
  - **Sustainability of supply chain**
  - **Workforce development**

- **Complex Situation**
  - **Reform market policies and structure**
  - **Utilities seeking near term support from States**
  - **Reduce operating costs**
  - **Subsequent License Renewal**

Nine Mile Point ~ Courtesy Exelon

Enhanced Accident Tolerant Fuel

Develop a new fuel/clad system that would be more tolerant to accident conditions

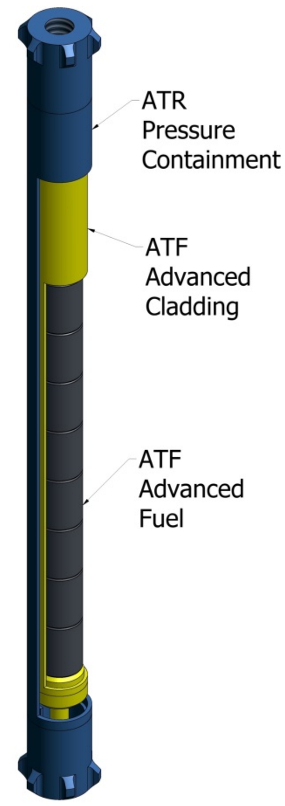
- Eliminate or reduce hydrogen production
- Withstand higher temperatures

3 vendors

- Framatome
- Westinghouse
- GE

Range of concepts

- Coatings on Zr
- New cladding material
- Higher thermal conductivity fuel
- Si-C cladding



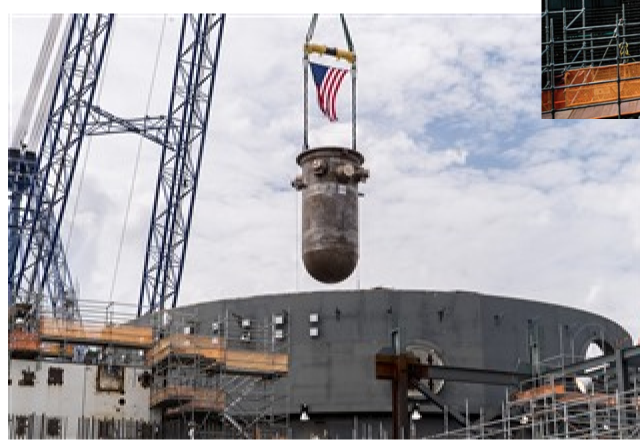
Schematic drawing of the capsule-rodlet assembly for the new accident tolerant fuel experiment in the Advanced Test Reactor (6.2 inches long, 0.4 inches in diameter).

New Builds in U.S.

Will these be sufficient to overcome existing plant retirements?

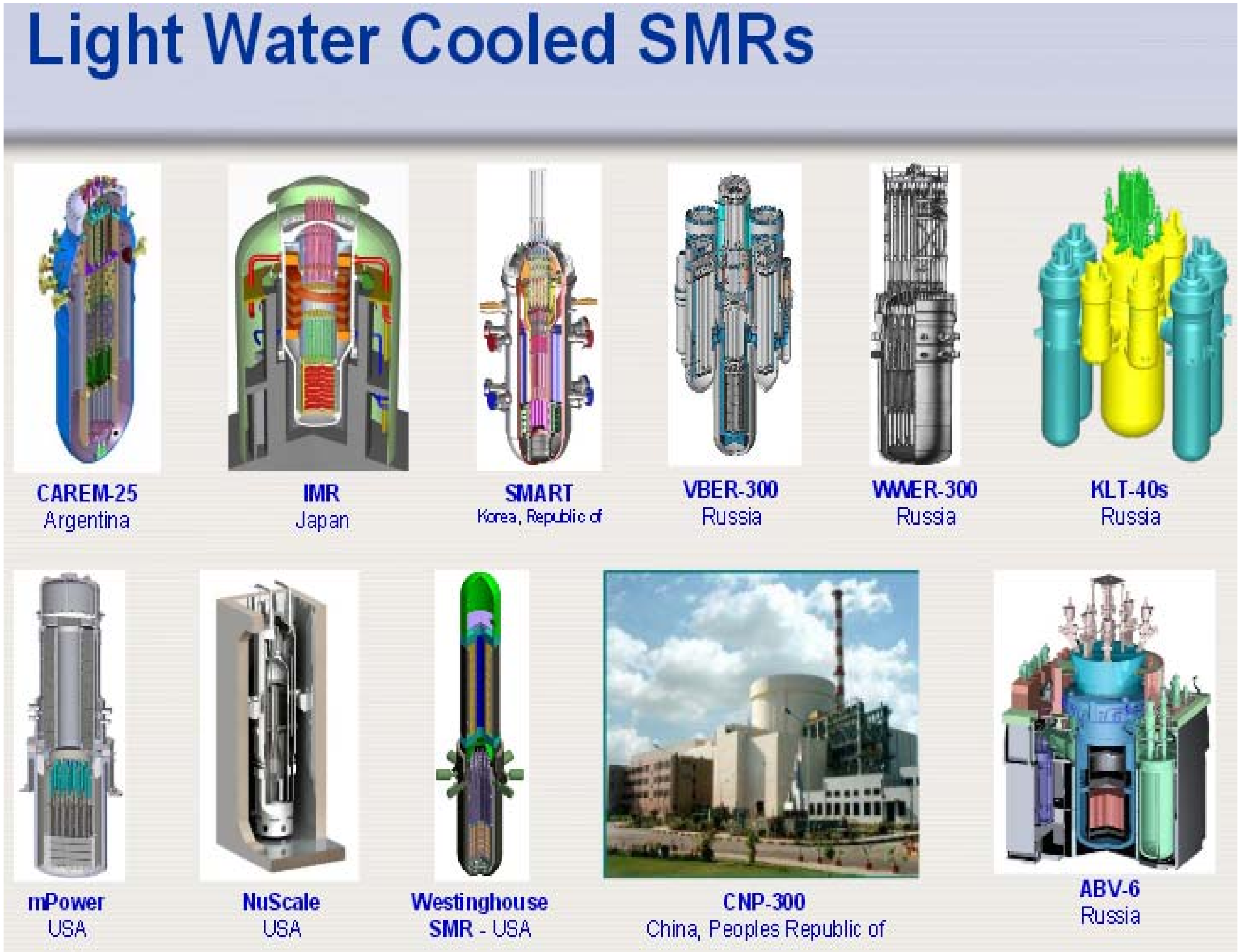
- **First new reactors being built in U.S. in 30 years**
  - Facing first-of-a kind challenges
- **Nuclear construction**
  - Vogtle
  - V.C. Summer?
- **Challenges for nuclear deployment**
  - High capital cost
  - Lower electricity demand
  - Low natural gas prices
  - Market structure issues

Vogtle Unit 3
Courtesy of Georgia Power



V.C. Summer Unit 2
Courtesy of SCANA

Small Modular Reactors



IAEA definition:
< 300 MWe

Potential Benefits:
- Factory fabrication
- Reduced onsite construction
- More flexible siting
- Modular expansion
- Faster return on investment

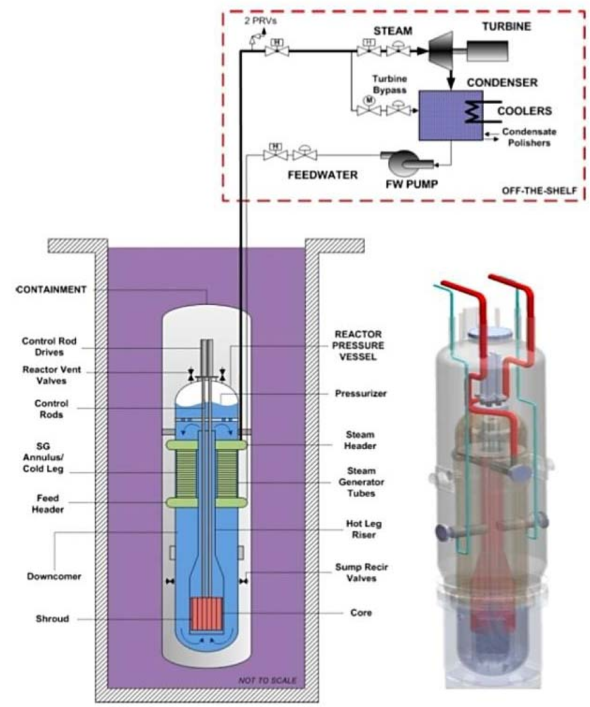
Why the Interest in SMR Technologies?

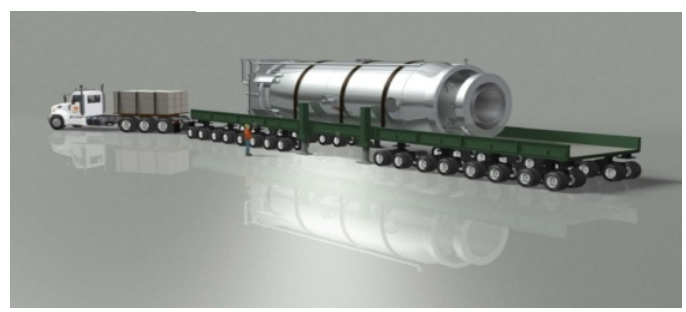
Potential Benefits

- Enhanced safety and security
- Reduced capital cost makes nuclear power feasible for more utilities
- Shorter construction schedules due to modular construction
- Improved quality due to replication in factory-setting
- Meets electric demand growth incrementally
- Domestic job creation potential very high

Potential Markets

- Domestic and international utility markets
- Non-electrical (process heat/desalination) customers





Current Status of SMRs in the US

NuScale

- Design Certification Application (DCA) submitted to the NRC in January 2017
  - NRC accepted and docketed March 2017
  - DCA review and approval expected in 2021

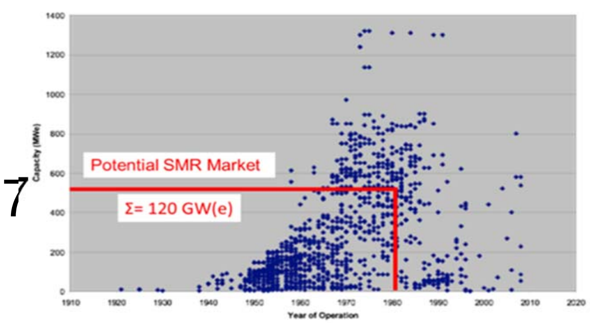
NuScale/UAMPS Siting

- Site use agreement for a site on the INL
  - Preferred site identified in August 2016

TVA Siting

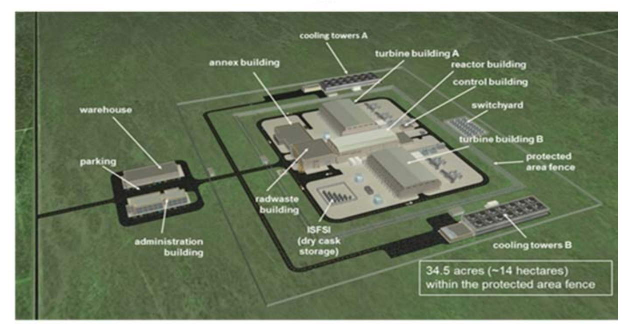
- Submitted Early Site Permit Application to NRC
  - Review commenced January 2017, completed in approximately 30 months

Clean Energy Option



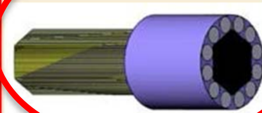
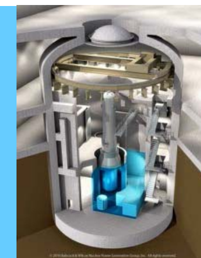
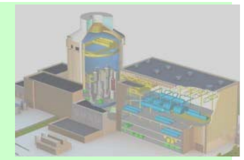
U.S. Coal Plant Capacity vs. Age

Microgrids



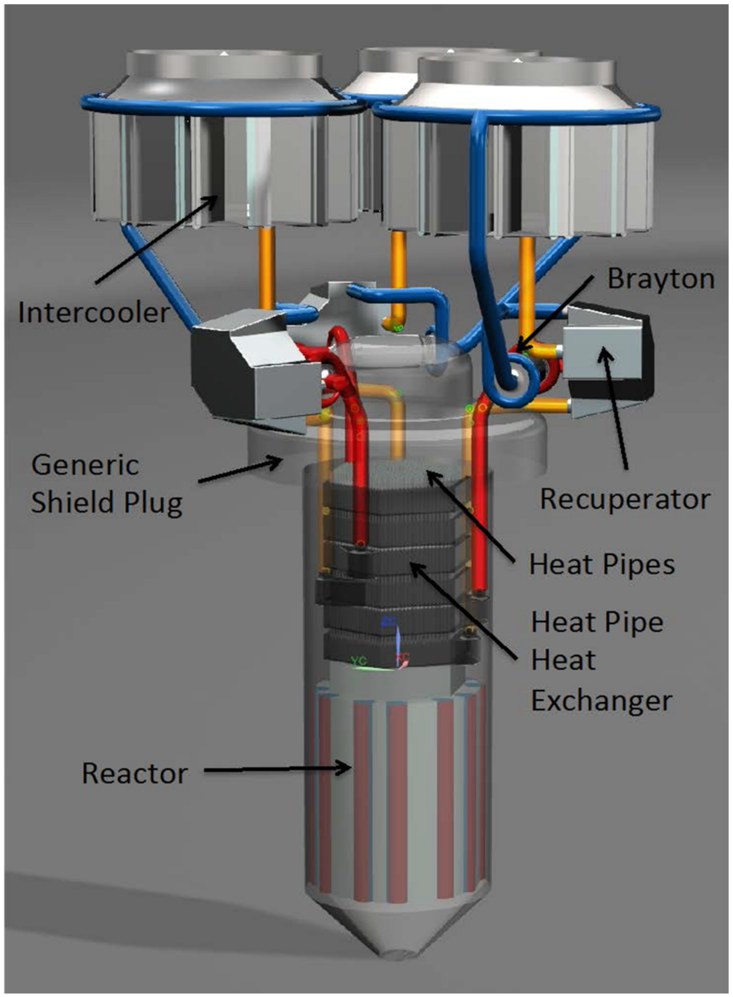
Factory Fabrication

Growing interest in Micro Reactors

					
0.5 to 10 kW Non-LWR	10 to 100's kW Non-LWR	0.1 to 10 MW Non-LWR	10 to 50 MW Non-LWR	50 to 300 MW LWR Focus	1000 MW LWR Focus
Factor built, assembled. Licensing based on prototype.					
Deep Space Power Military Ops	Space propulsion & planetary surface power; Med Isotopes Military Ops	Military Bases; Distributed Hybrid Power; Disaster Relief	Power to Grid; Large Military Bases; Process Heat	Power to Grid; Small Cities, Burning of actinides	Power to Grid 4 units under construction in US

⟵ Micro Reactors ⟶ ⟵ Small Modular ⟶

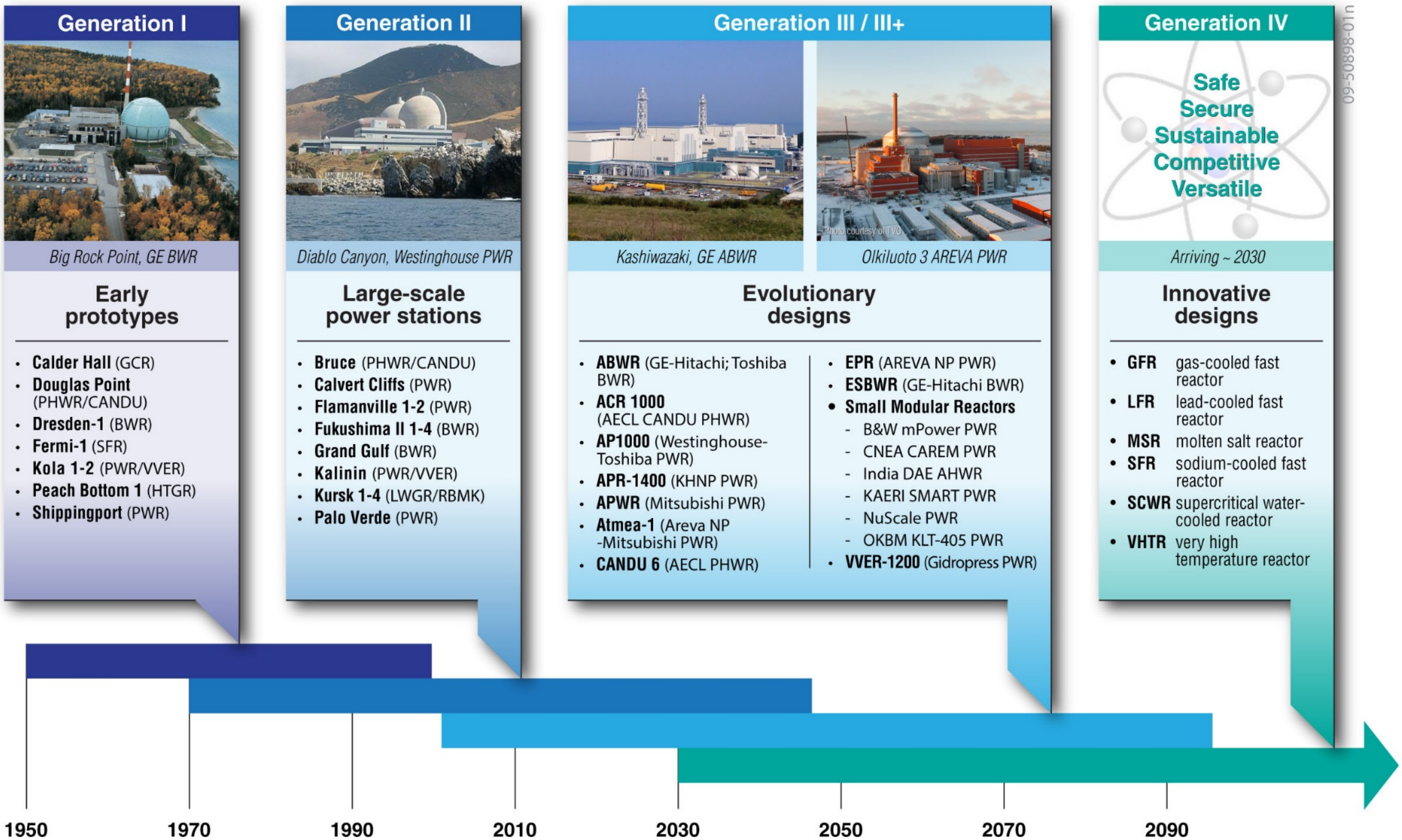
LANL MegaPower Reactor Design



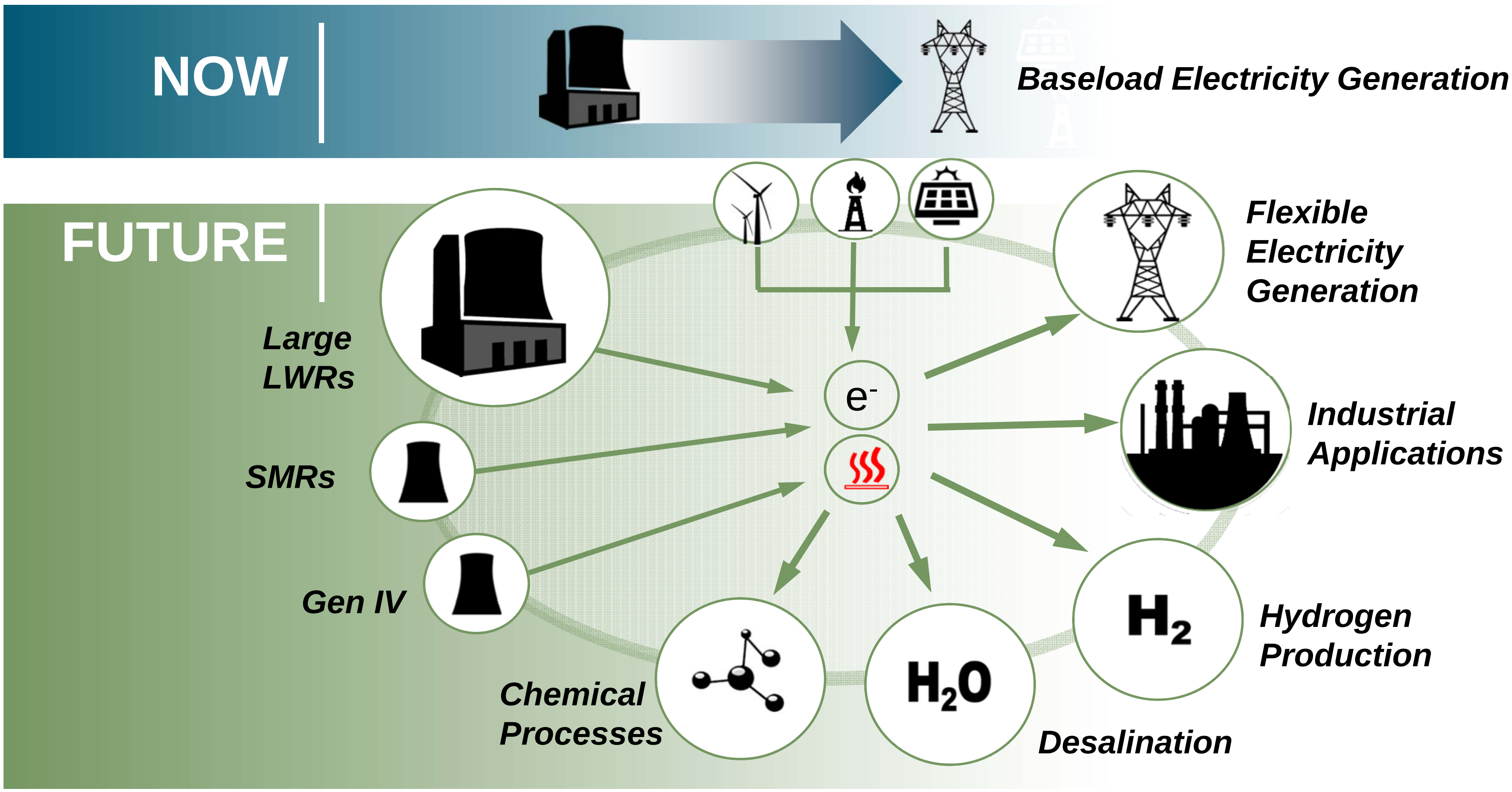
- 0.5-5 MW electric (DoD Base)
- No moving parts or high pressure
- Heat pipe cooled (no water)
- Encapsulated in armored transport cask
- LE-UO_2 fuel (16-19% enriched)
- Different Power Conversions Systems

GEN IV International Forum℠

ANS



Nuclear Energy Beyond Electricity



Flexible Generators ❖ Advanced Processes ❖ Revolutionary Design

GIF Education and Training Task Force

- Formed to develop education and training materials related to Generation IV systems

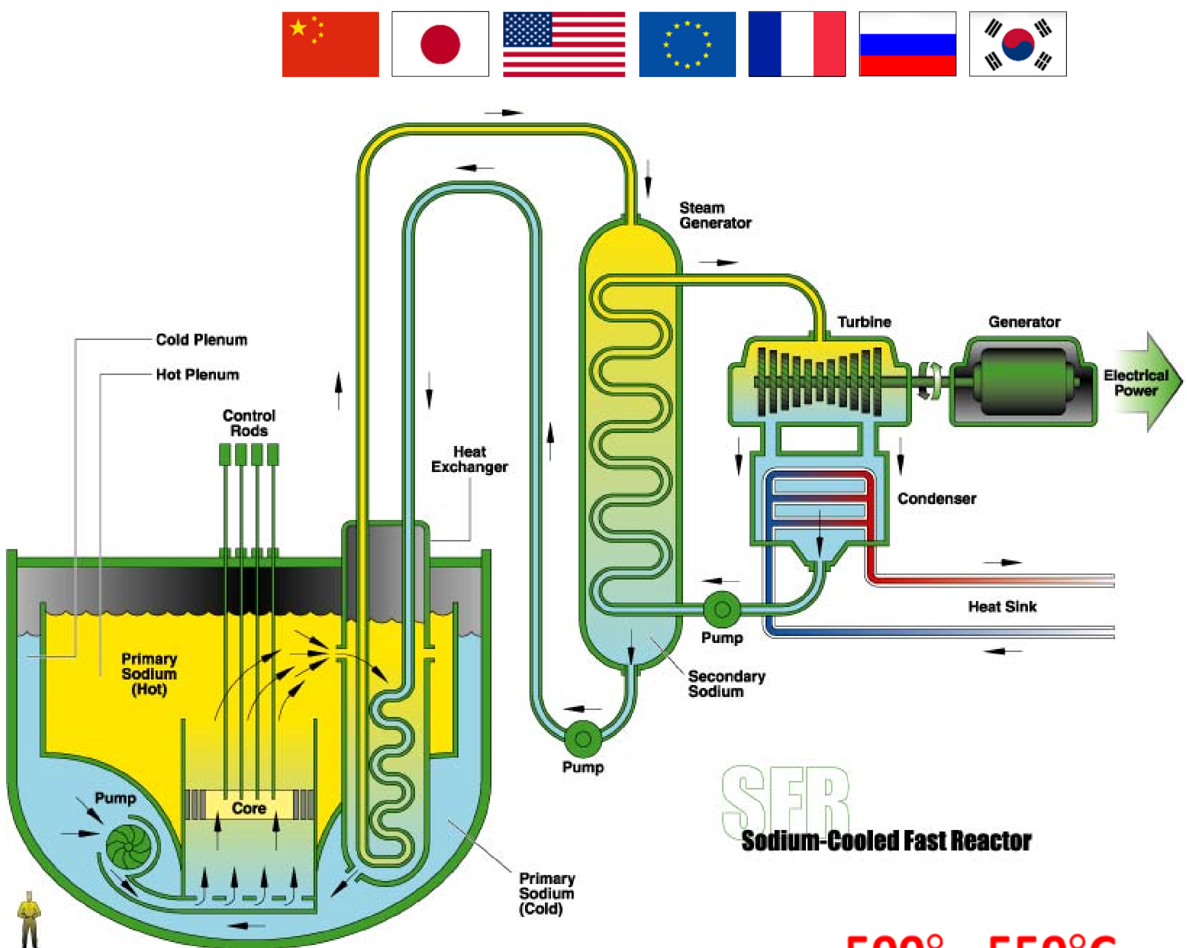
- Created a webinar series (monthly) to provide presentations for the general public on the Gen IV systems and cross-cutting topics
- **See www.Gen-4.org**

- Connecting with other nuclear education organizations to share information on educational opportunities and Summer Schools

Sodium Fast Reactor

- Major features
  - Fast neutron spectrum
  - Low pressure liquid metal coolant
  - Flexible fuel cycle applications

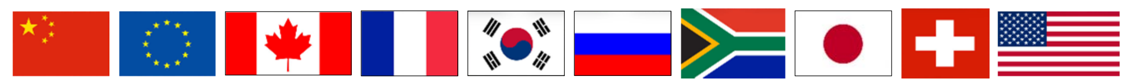
- SFR design activities
  - ASTRID (France)
  - JSFR (Japan)
  - PGSFR (Korea)
  - BN-1200 (Russia)
  - ESFR (European Union)
  - AFR-100 (United States)
  - CFR-1200 (China)

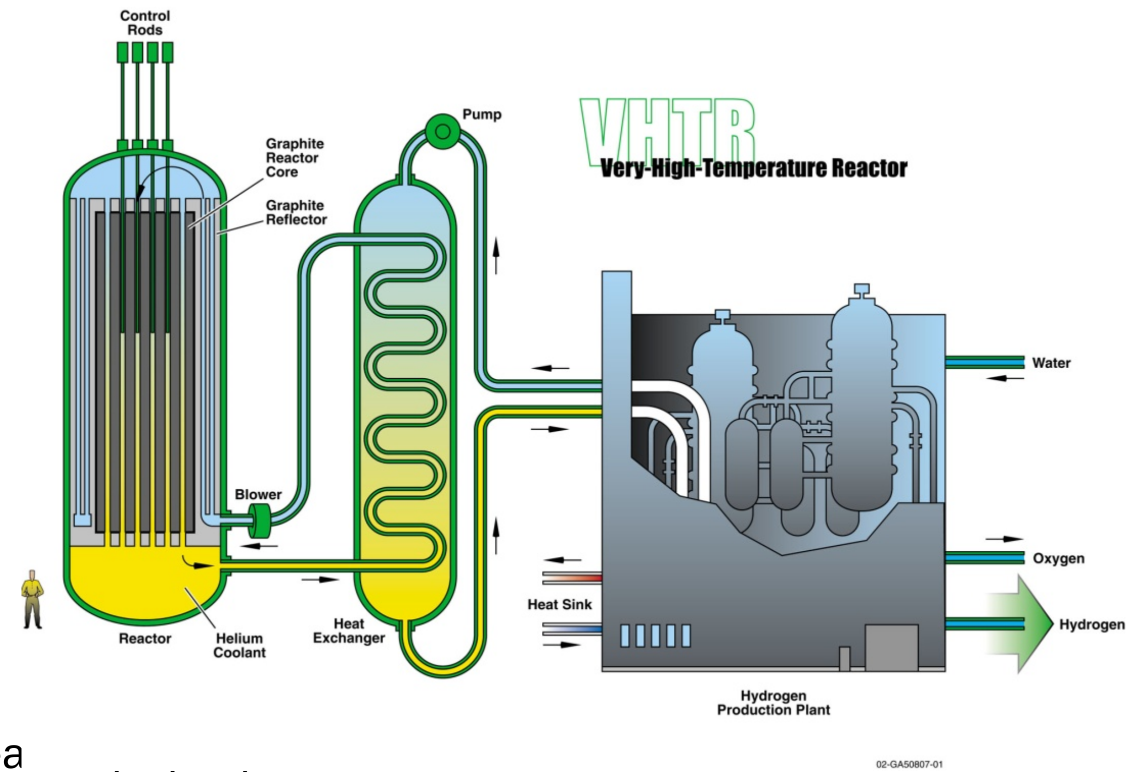


500° - 550°C

Very High Temperature Reactor

- Major features
  - Inert helium coolant
  - Unique TRISO fuel
  - Thermal neutron spectrum
  - Exceptional safety
  - Very high temperature operation
  - Non-electric applications



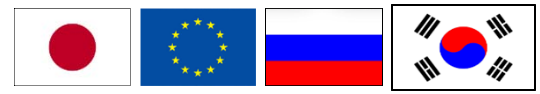


- VHTR Design Activities
  - HTR-PM demonstration plant under construction (China)
  - Next Generation Nuclear Plant (United States)
  - Naturally Safe High Temperature Reactor (Japan)
  - Clean Burn High Temperature Rea
  - Multi-purpose HTGR (Japan and Kazakhstan)
  - PBMR (South Africa)

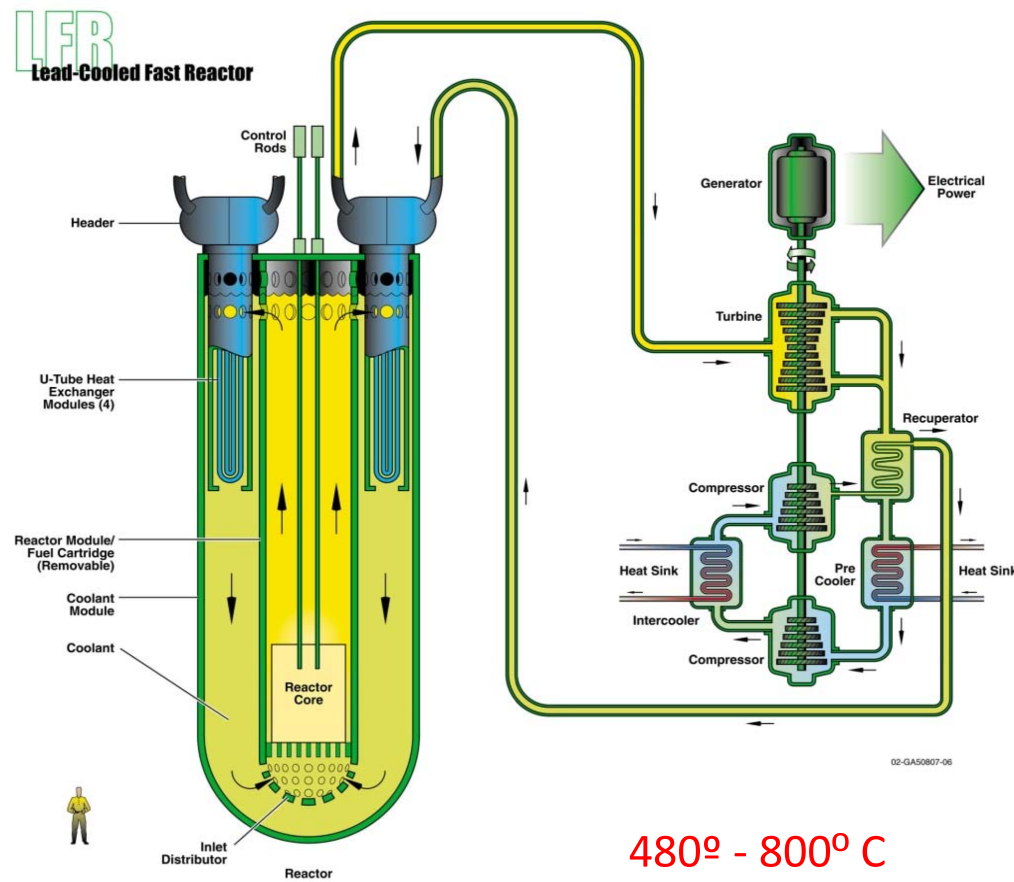
900° - 1000°C

Lead-cooled Fast Reactor

- ❑ Major features
  - – Liquid metal coolant that is not reactive with air or water
  - – Lead or lead-bismuth eutectic options
  - – Fast neutron spectrum



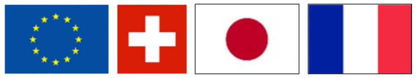
- ❑ LFR design activities
  - – BREST (Russia)
  - – SVBR-100 (Russia)
    - – Lead-bismuth
  - – ALFRED (European Union)
  - – ELFR (European Union)
  - – SSTAR (United States)
  - – MYRRHA (European Union)
    - – Accelerator driven system

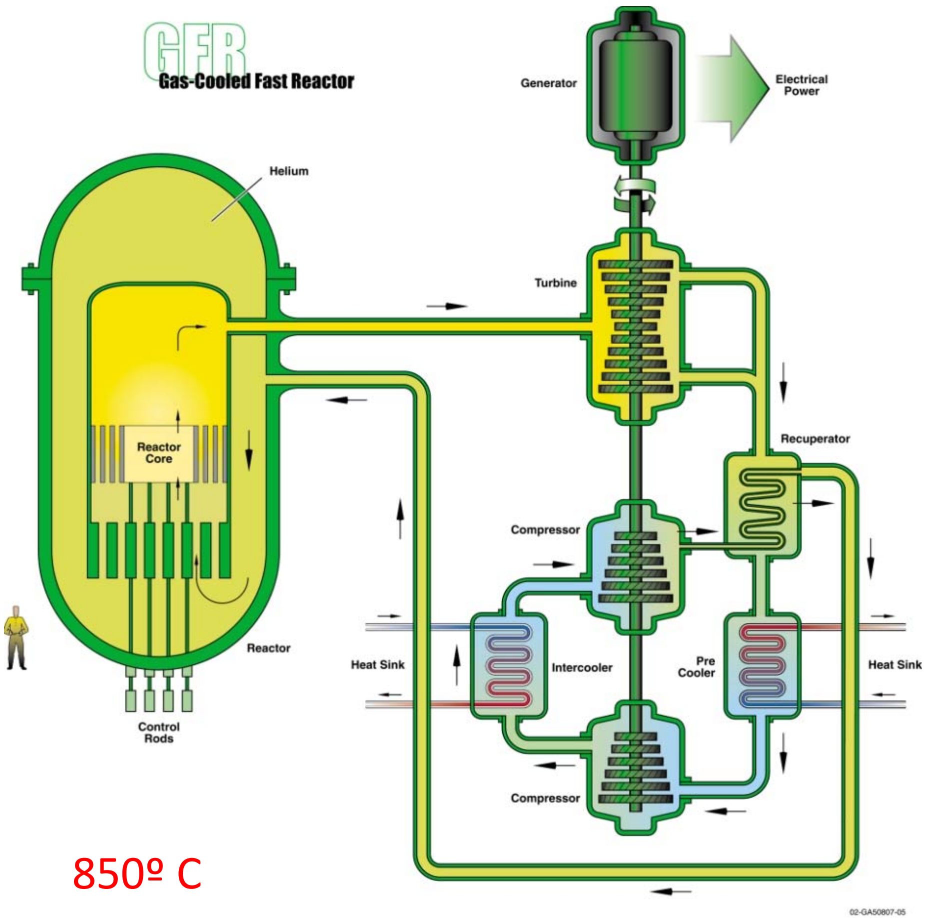


480º - 800º C

Gas-Cooled Fast Reactor

- Major features
  - Fast neutron spectrum
  - Inert helium coolant
  - Very high temperature operation
  - Fuel cycle and non-electric applications
  - Significant development challenges for fuel, safety and components





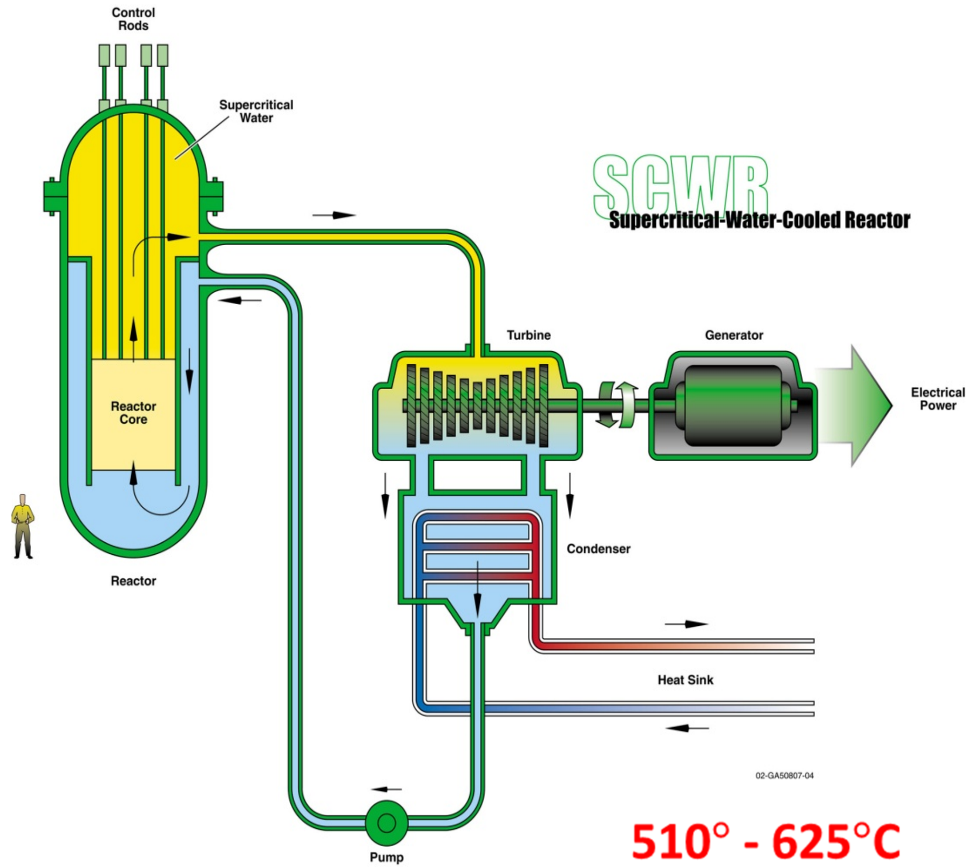
- GFR design activities
  - Allegro (European Union)

850º C

Supercritical Water - Cooled Reactor

- Major features
  - Merges LWR or PHWR technology with advanced supercritical water technology used in coal plants
  - Operates above the thermodynamic critical point (374º C, 22.1 MPa) of water
  - Fast and thermal spectrum options

- SCWR Design Activities
  - First design effort 1957
  - Pre-conceptual design of SC PHWR (Canada)
  - Pre-conceptual SC LWR design activities (Japan and European Union)

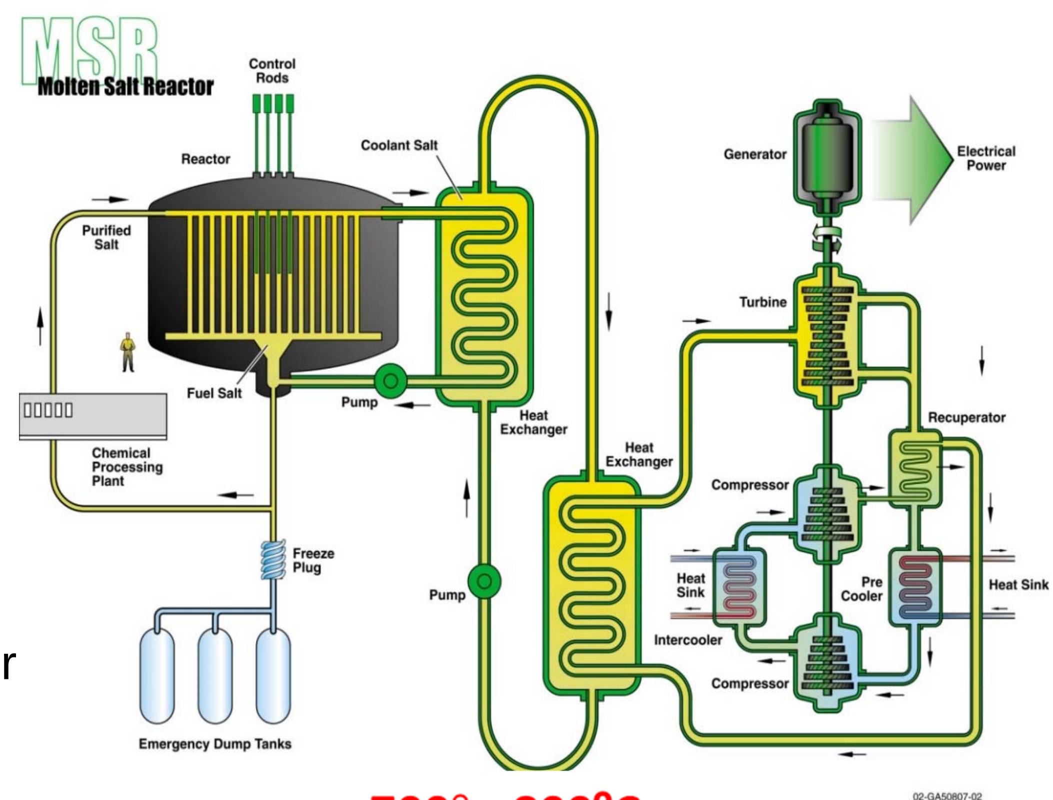


510° - 625°C

Molten Salt Reactor

- Major features
  - Molten salt eutectic coolant
  - High temperature operation
  - Thermal or fast spectrum
  - Molten or solid fuel
  - On-line waste Management

- Design Activities
  - 2-MWt FHR test reactor (China)
  - Pre-conceptual designs to guide R&D planning
    - Molten Salt Actinide Recycler and Transmuter (MOSART)
    - Molten Salt Fast Reactor (MSFR)



700° - 800°C

Over 20 Advanced Fission Reactor Designs in the United States

Sodium Fast Reactor

- TerraPower, General Electric, OKLO, etc

High Temperature Gas Reactor

- X-Energy, AREVA, TerraPower, Hybrid Energy, Ultra Safe, etc

Molten Salt Reactor

- TerraPower, Transatomic, Terrestrial, Elysium, FLIBE Energy, Kairos, etc

Lead Fast Reactor

- Westinghouse, Gen IV Energy, Lake-Chime, etc

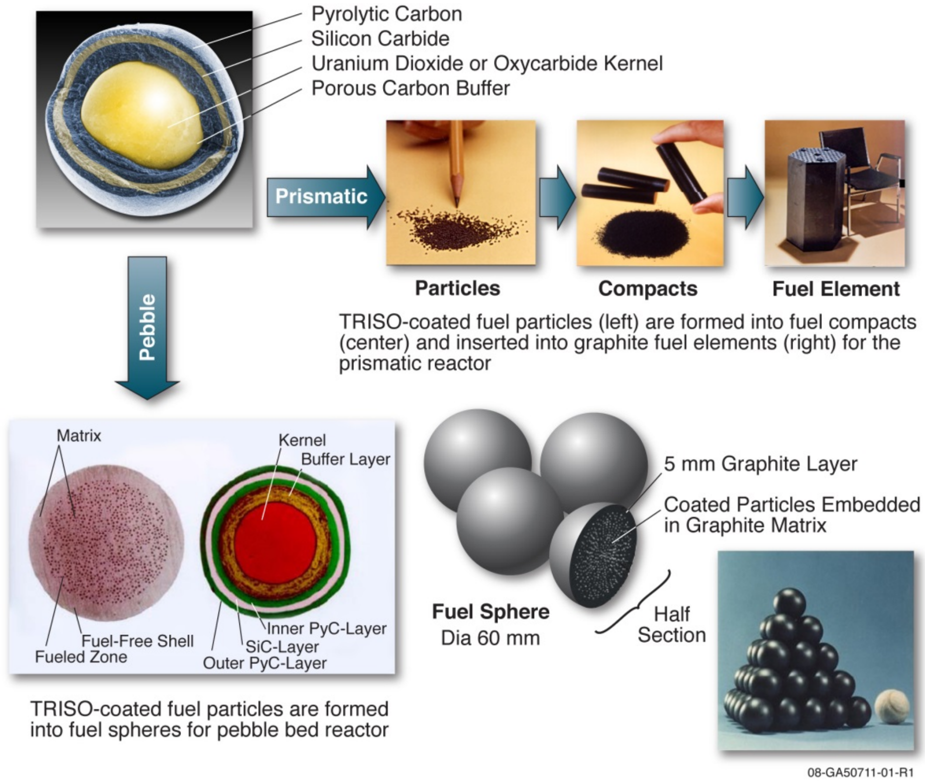
Gas Fast Reactor

- General Atomics

High Temperature Gas Reactor TRISO Fuel

Key aspects of TRISO Fuel:

- German industrial experience demonstrated TRISO-coated particle fuel can be fabricated to achieve high-quality levels with very low defects.
- Fuel is very robust with no failures anticipated during irradiation and under accident conditions.
- Fuel form retains fission products resulting in a high degree of safety.

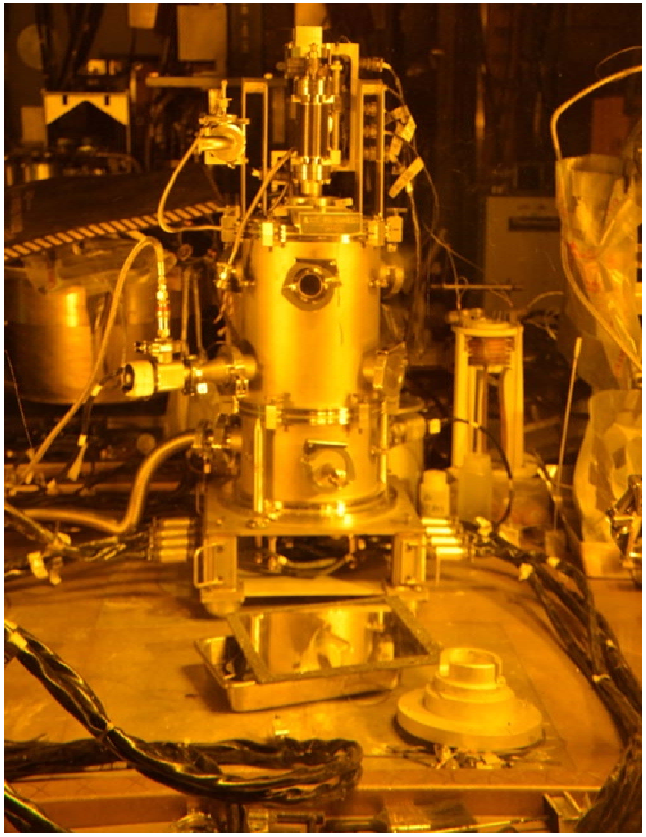


TRISO-coated fuel particles (left) are formed into fuel compacts (center) and inserted into graphite fuel elements (right) for the prismatic reactor

TRISO-coated fuel particles are formed into fuel spheres for pebble bed reactor

Fast Reactor Fuels

- Advance the scientific understanding and engineering application of fuels for use in future fast-spectrum reactors, including:
  - fuels for enhanced resource utilization (including actinide transmutation),
  - support for driver/startup fuel concepts.
- Advanced fabrication methods including remote fabrication.
- Demonstrate acceptable performance of fast reactor fuels including
  - recycled metallic fuels
  - ultra high burnup
- Support development and validation of an advanced fuel performance code.



Remote casting furnace in HFEF

Summary

- Nuclear power must be a major source of our energy production to meet global future energy needs
- Continue the safe and reliable operation of the current fleet
- Deploy SMRs in mid-2020’s
- Track emerging interest in Micro Reactors
- Develop Generation IV reactor technologies for deployment in the 2030’s

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