UT-BATTELLE

Advanced Reactor Development In The United States

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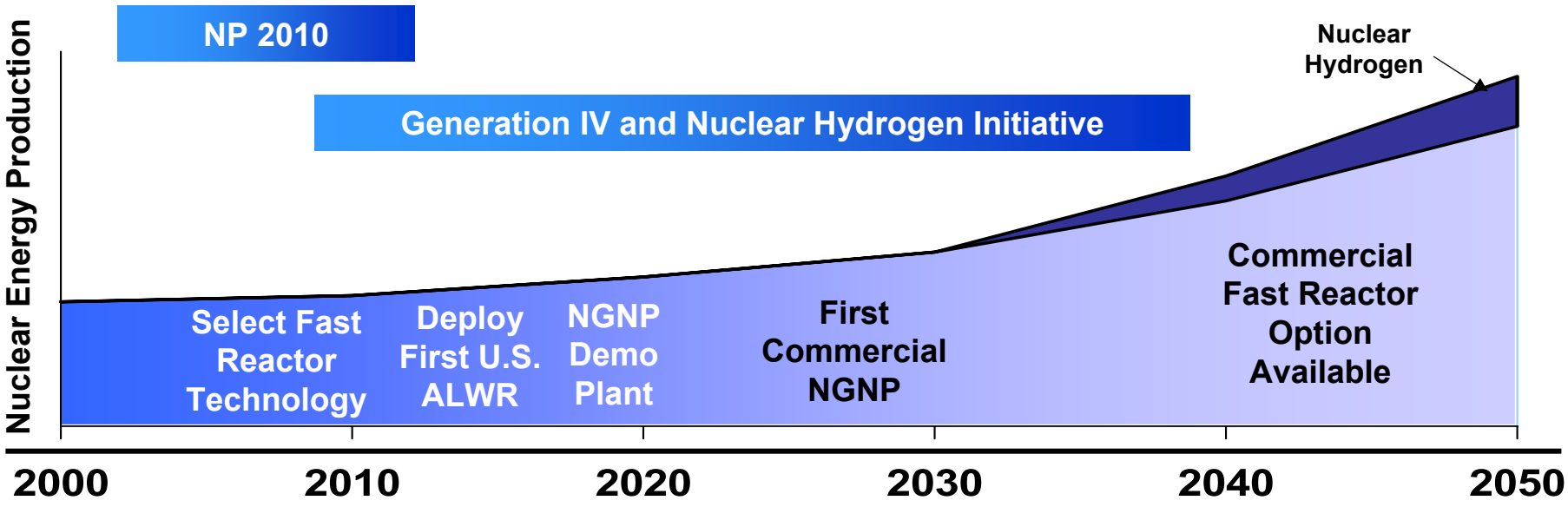
Nuclear Prospects In The U.S.

A Nuclear Renaissance is being driven by:

- Improved performance of existing (Generation II) plants
  - Operating costs are competitive with gas-fired combined-cycle generation (2.0-2.5 versus 3.0-3.5 cents per kilowatt-hour)
  - Exceptional safety record
  - Capacity factors increased from 58% to >90%

- Clean air and global climate change considerations

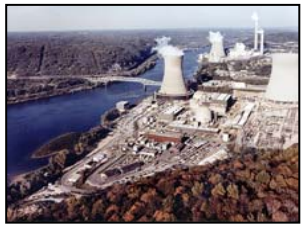
Long-Term U.S. Nuclear Strategy



U.S. Program Is Focused On Generation III and IV Systems

Generation I

Early Prototype Reactors



- Shippingport
- Dresden, Fermi I
- Magnox

Generation II

Commercial Power Reactors

- LWR-PWR, BWR
- CANDU
- VVER/RBMK

Generation III

Advanced LWRs

- ABWR
- System 80+
- AP600
- EPR

Generation III+

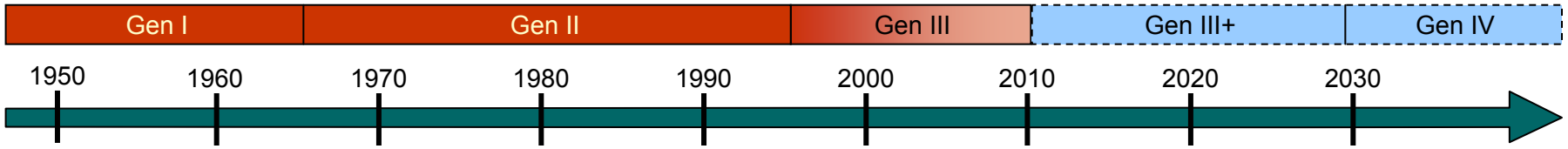
Evolutionary Designs Offering Improved Economics

-AP1000

-ESBWR

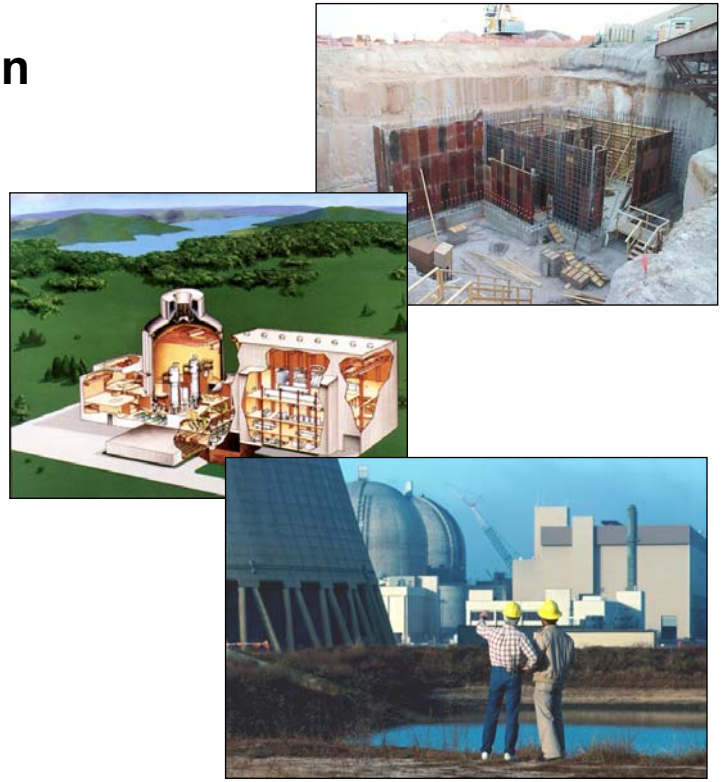
Generation IV

- Highly Economical
- Enhanced Safety
- Minimal Waste
- Proliferation Resistant



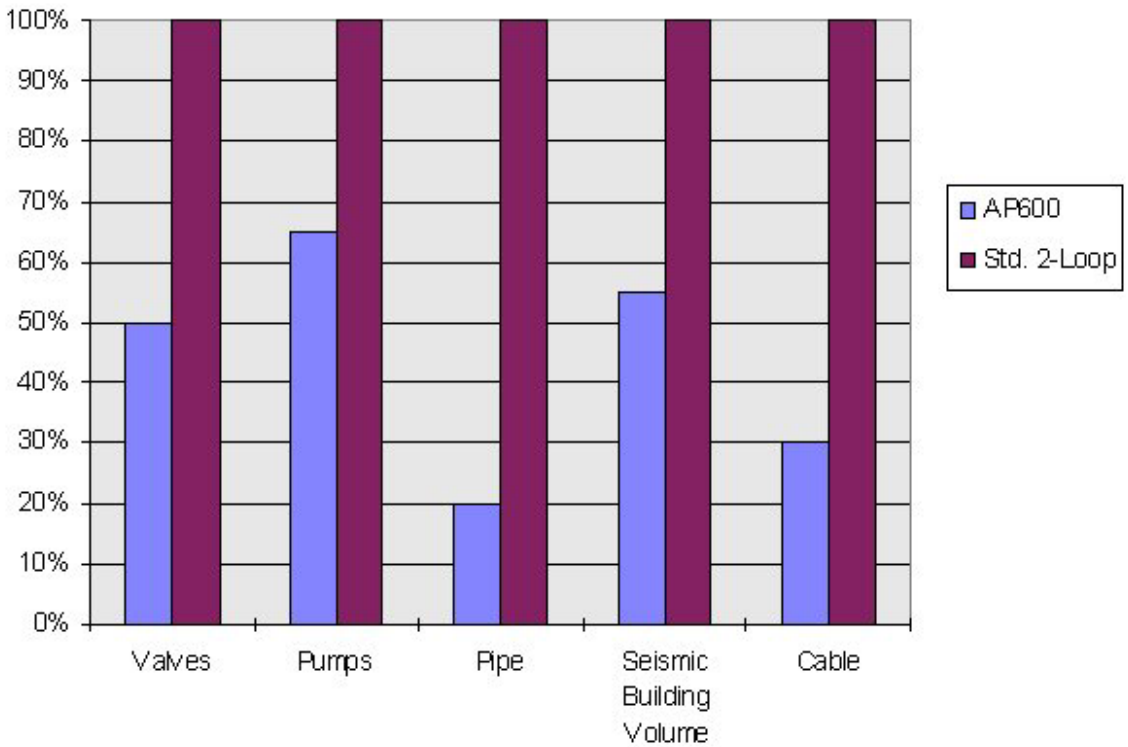
Gen III: Nuclear Program 2010

- Market Driven, Cost-Shared Approach
  - Competitive process -- best proposals win
  - Encourage industry to rally around most promising designs
- Cooperative Activities
  - Early Site Permit (ESP) Application
  - Combined Construction and Operating License (COL)
  - NRC Design Certification (DC)
  - First-of-a-kind engineering for a standardized plant
  - Material, component and system testing
  - Business case and financial incentives
- Risk Mitigation Strategy Development



Improvements For Generation III

- Generation II
  - One of a kind designs
  - Rapidly evolving technology
  - Dynamic regulatory requirements and licensing standards
- Generation III:
  - Standardization
  - Plant simplicity
  - Stable licensing



Number of Components in Simplified Plants versus Current Plants

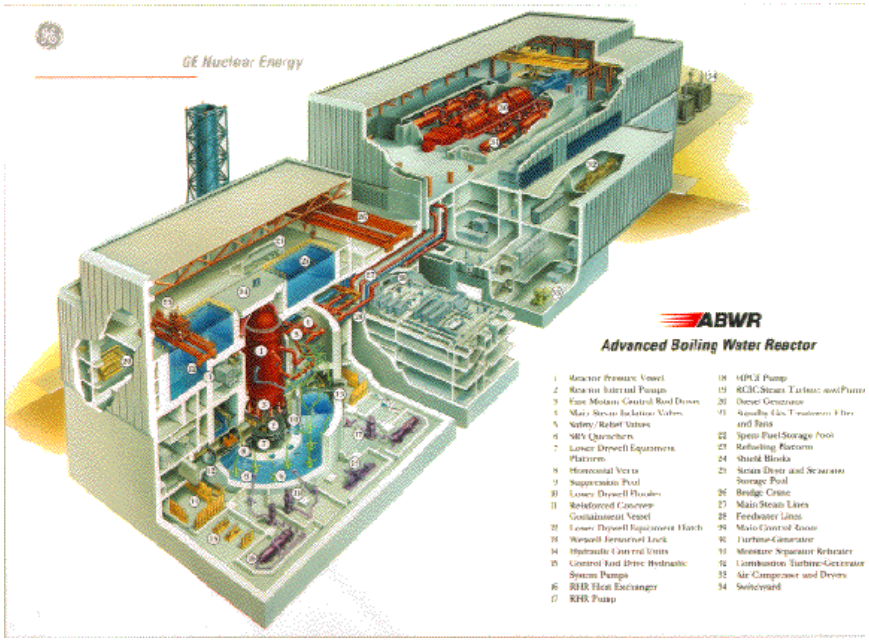
Generation III Designs (cont)

- Passive Designs
  - Stored water and compressed gas
  - Gravity for safety functions as opposed to pumps and motors

- Design certification approval already obtained
  - Advanced Boiling Water Reactor
  - AP-600 & AP-1000
  - System 80+

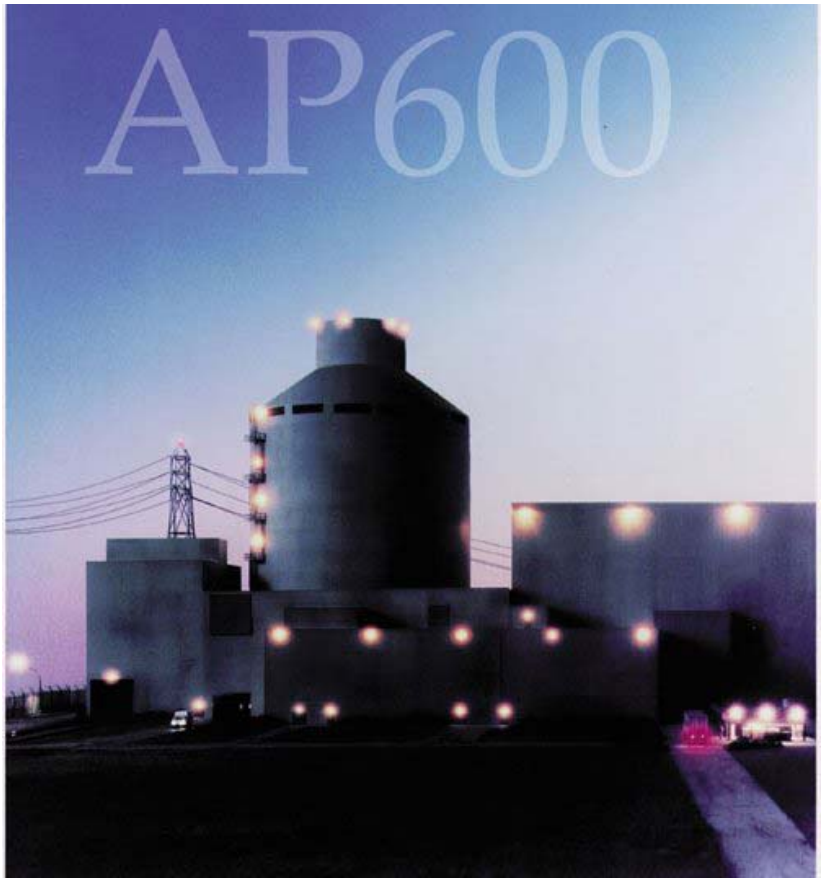
Advanced Boiling Water Reactor

- Single cycle, forced circulation, boiling water reactor
- 1300 MWe
- Control rod drives use screw mechanism instead of step process
- Safety enhancements
  - Containment overpressure protection
  - Core debris flooding capability
  - Independent water makeup system
  - Redundant emergency diesels
  - Combustion turbine as alternate power source



AP-600

- Two-loop 600 MWe
- Upsized to AP-1000
- Safety systems use natural forces
  - Gravity
  - Natural circulation
  - Compressed gas
- Valves fail safe to correct positions
- Passive safety systems include
  - Safety injection
  - Residual heat removal
  - Containment cooling



Generation IV Systems

- Goals
  - Reduced cost (especially capital costs)
  - Improved safety (mainly public perception)
  - Reduced potential for proliferation of nuclear materials
  - Minimization of wastes throughout fuel cycle

- Selected Systems
  - Gas-Cooled Fast Reactor
  - Lead-Cooled Fast Reactor
  - Molten Salt Reactor
  - Sodium-Cooled Fast Reactor
  - Supercritical-Water-Cooled Reactor
  - Very-High-Temperature Reactor

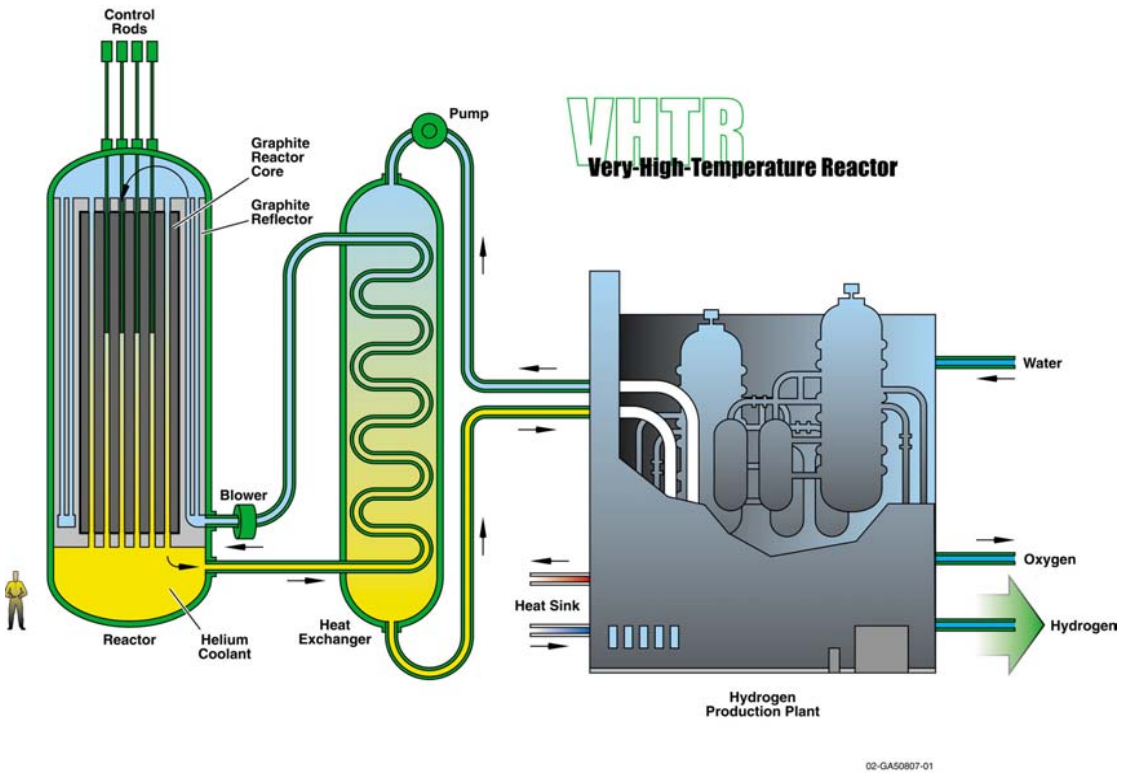
Generation IV Systems -- Summary

	Neutron Spectrum	Fuel Cycle	Size	Applications	R&D
Sodium Fast Reactor (SFR)	Fast	Closed	Medium to Large	Electricity, Actinide Management	Advanced Recycle
Lead-alloy Fast Reactor (LFR)	Fast	Closed	Small to Large	Electricity, Hydrogen Production	Fuels, Materials compatibility
Gas-Cooled Fast Reactor (GFR)	Fast	Closed	Medium	Electricity, Hydrogen, Act. Mgmt	Fuels, Materials, Safety
Very High Temp. Gas Reactor (VHTR)	Thermal	Open	Medium	Electricity, Hydrogen, Process Heat	Fuels, Materials, H_2 production
Supercritical Water Reactor (SCWR)	Thermal, Fast	Open, Closed	Large	Electricity	Materials, Safety
Molten Salt Reactor (MSR)	Thermal	Closed	Large	Electricity, Hydrogen, Actinide Management	Fuel, Fuel treatment, Materials, Safety, Reliability

Very-High-Temperature Reactor (VHTR)

Characteristics

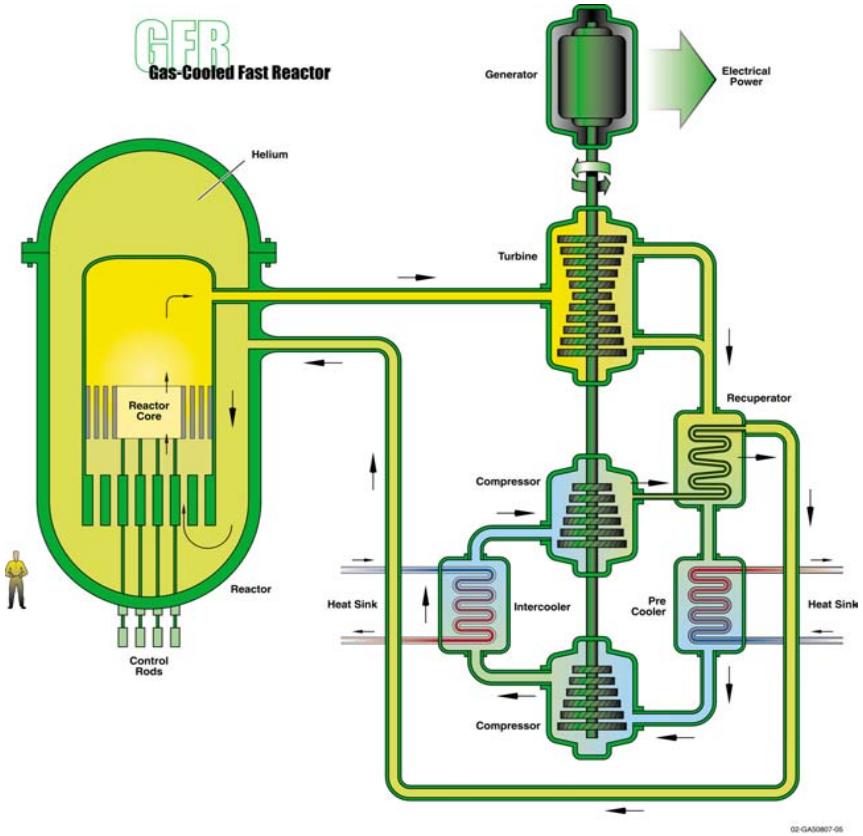
- He coolant, direct cycle
- 1000°C outlet temperature
- 600 MW_{th}, nominally based on GT-MHR
- Coated particle fuel
- Solid graphite block core
- High thermal efficiency
- Hydrogen production
- Passive safety



Gas-Cooled Fast Reactor (GFR)

Characteristics

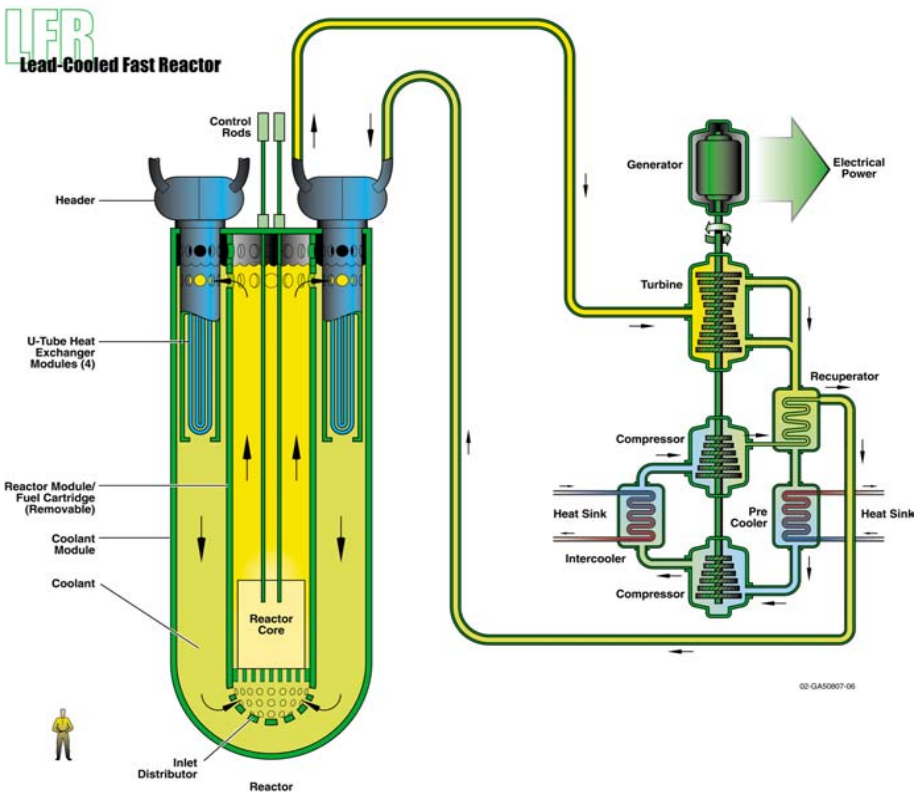
- He (or SC CO_2) coolant, direct cycle gas-turbine
- 850°C outlet temperature
- 600 MW_{th}/288 MW_e
- U-TRU ceramic fuel in coated particle, dispersion, or homogeneous form
- Block, pebble, plate or pin core geometry
- Waste minimization
- Efficient electricity generation



Lead-Cooled Fast Reactor (LFR)

Characteristics

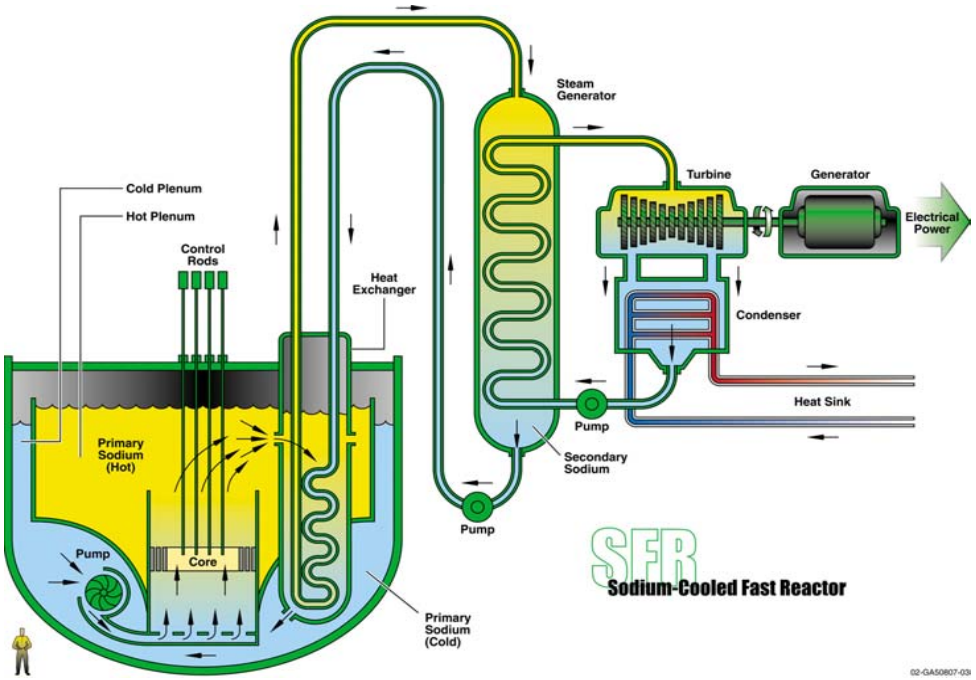
- Pb or Pb/Bi coolant
- 550°C to 800°C outlet temperature
- U-TRU nitride or Zr-alloy fuel pins on triangular pitch
- 120–400 MWe
- 15–30 year core life
- Core refueled as a cartridge
- Distributed energy generation
- Transportable core
- Passive safety and operational autonomy



Sodium-Cooled Fast Reactor (SFR)

Characteristics

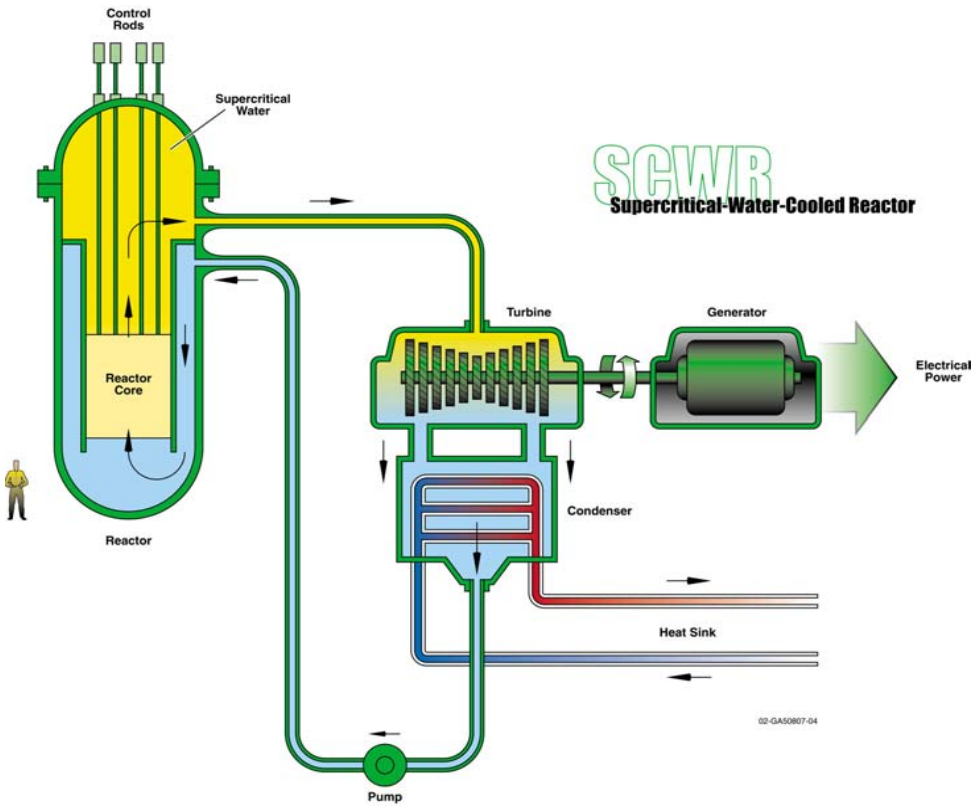
- Sodium coolant, 550°C T_{out}
- 150 to 1500 MWe
- U-TRU oxide or metal-alloy fuel
- Hexagonal assemblies of fuel pins on triangular pitch
- Homogenous or heterogeneous core
- Consumption of LWR discharge actinides
- Efficient fissile material generation



Supercritical-Water-Cooled Reactor (SCWR)

Characteristics

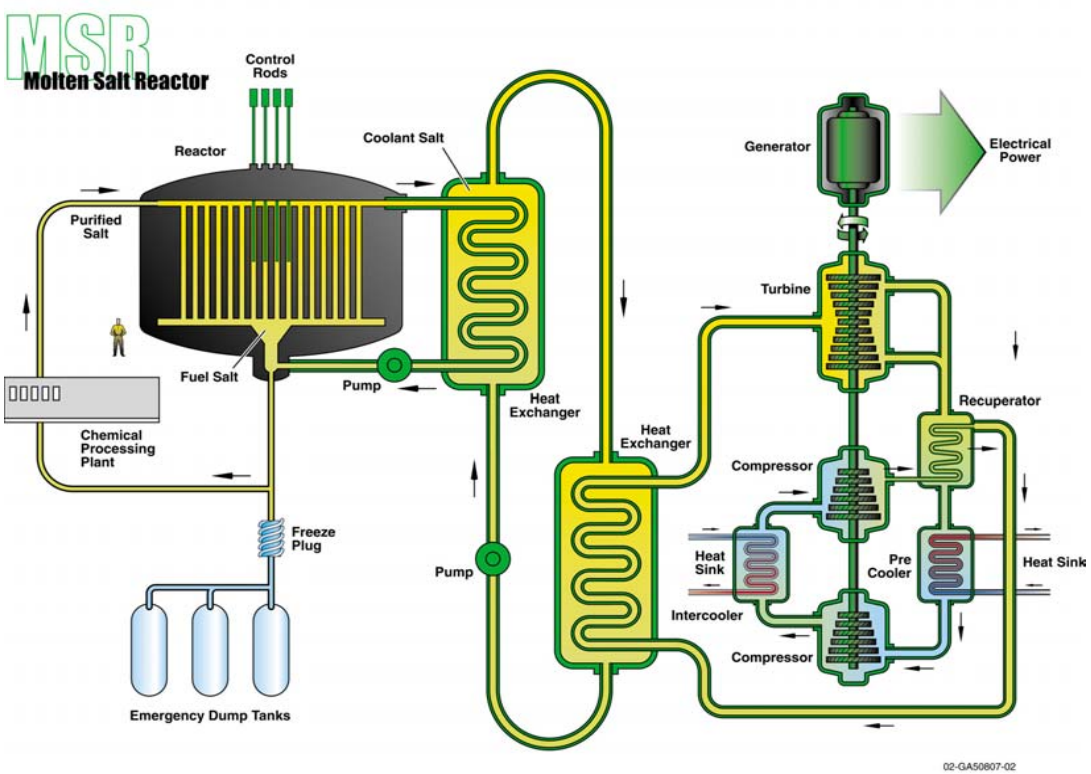
- Water coolant at supercritical conditions (~25 MPa)
- 510°C outlet temperature
- 1700 MWe
- UO_2 fuel, clad with SS or Ni-based alloy
- Square (or hex) assemblies with moderator rods
- High efficiency, compact plant
- Thermal or fast neutron spectrum



Molten Salt Reactor (MSR)

Characteristics

- Molten fluoride salt fuel
- 700–800°C outlet temperature
- 1000 MWe
- Low pressure (<0.5 MPa)
- Circulating actinide-bearing fuel
- Graphite core structure to channel flow
- Actinide consumption
- Avoids fuel development and fabrication



Implementation of Generation IV

Gen IV Top Priority

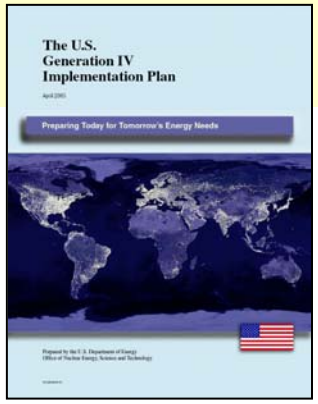
Develop & demonstrate the NGNP

Longer-Term Gen IV

- Fast Reactors
  - Gas-cooled
  - Lead-cooled
  - Sodium-cooled
- Supercritical-water-cooled Reactor

Next-Generation Nuclear Plant

- **Combines high temperature operation with passive safety systems for improved economics and safety**
- **Demonstrates H_2 and direct-cycle electricity production**
- **Collaborative with international community**
- **Collaborative with industry… will be industry led**
- **Result in a commercially viable plant design deployable in the next decade**

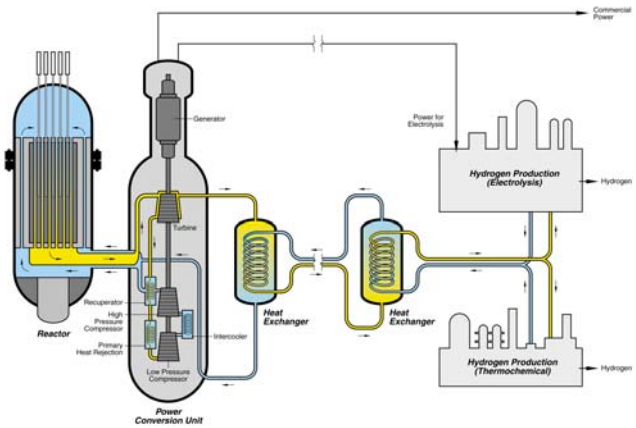


Next Generation Nuclear Plant (NGNP)

- **Generation IV NGNP: Advanced VHTR designed for production of hydrogen and electricity**
  - High outlet temperature (1000°C) allows use of thermochemical and temperature-assisted electrolysis methods for producing hydrogen
  - High electrical conversion efficiency
  - Attractive safety aspects

Objective: Build NGNP demo plant in Idaho by 2017

- **Modular construction**
  - 600 MW_{Th}
  - At 50% efficiency, could produce up to 200 MT of H_2 per day, the equivalent of 200,000 gallons gasoline per day.



Summary

- US Nuclear Industry is focused on supporting existing plants (increased power rating and life extension)
- Passive designs have been certified but not built in US – being studied closely by utilities
- R&D Community is beginning to develop next generation plants and fuel cycles