



Future Nuclear Energy Systems: Generation IV

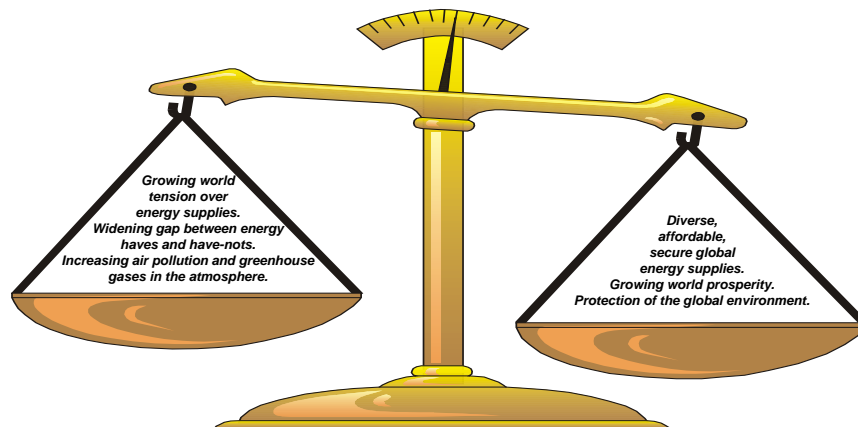
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*50th Annual Meeting of the Health Physics Society
11 July 2005 - Spokane, Washington, USA*



The Legacy of U.S. Energy Leadership



We Will Need More Energy *But Where Will It Come From?*

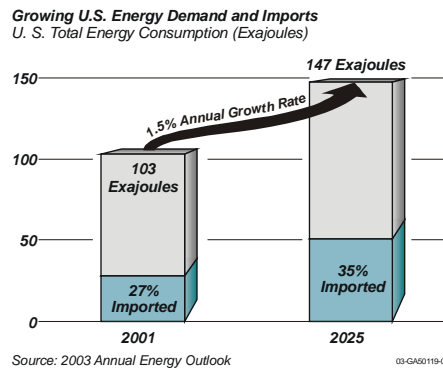
- Oil:
 - U.S. imports 51% of its oil supply
 - Vulnerable to supply disruptions and price fluctuations
- Natural Gas:
 - Today's fuel of choice
 - Future price stability?
- Coal:
 - Plentiful but polluting
- Renewables:
 - Capacity to meet demand?
 - Still expensive
- Nuclear:
 - Proven technology
 - Issues remain

Energy Source	% of U.S. Electricity Supply	% of U.S. Energy Supply	% Imported
Oil	3	39	51
Natural Gas	15	23	16
Coal	51	22	0
Nuclear	20	8	0
Hydroelectric	8	4	0
Biomass	1	3	0
Other Renewables	1	1	0

Source: Energy Information Administration

Forecast for Energy Growth

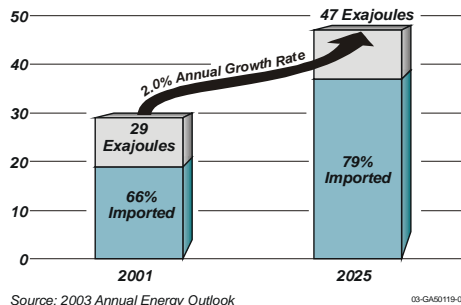
- **Annual outlook is 1.5% growth in U.S. energy to 2025**
- **Most growth is in natural gas and coal**
- **Imports will increase**
- **Nuclear can contribute if deployed in the near-term, but waste will become a major issue for significant growth**



Potential for Nuclear in Transportation

- Transportation sector growth leads electricity & heating
- Outlook is for a disproportionate increase in imports
- Increasing dependence on imports clouds the outlook for energy security and stability
- Hydrogen can contribute if production-distribution-end use issues can be successfully addressed

Growing U.S. Transportation Sector Energy Demand and Imports
U. S. Transportation Sector Energy Consumption (Exajoules)



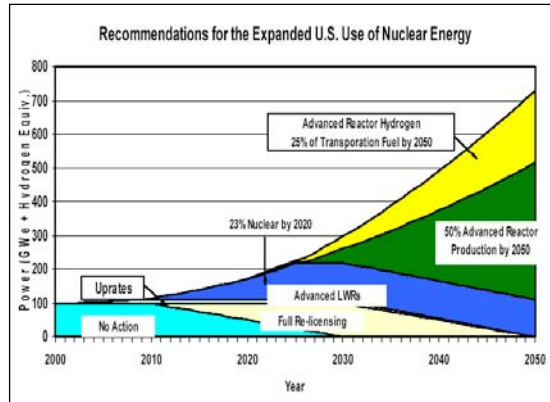
Nuclear Power *The Indispensable Option*

- Reliable, domestic base-load energy
- No carbon emissions
- Sustainable, long-term energy supply
- Supports use of advanced energy infrastructures to
 - Increase the efficient use of energy
 - Reduce overall environmental impacts
 - Deal with transportation fuel needs through production of hydrogen

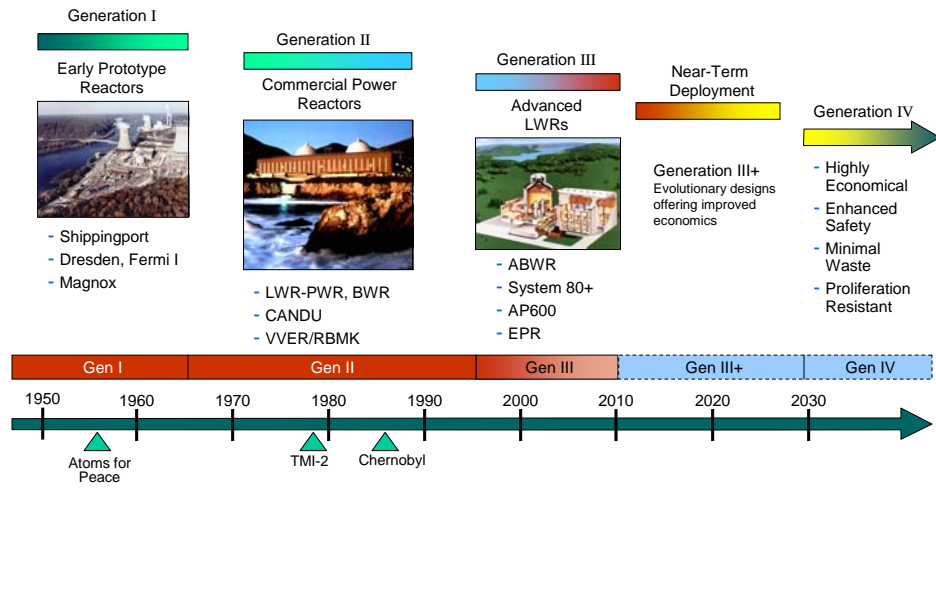


The Potential for Nuclear Energy is Tremendous

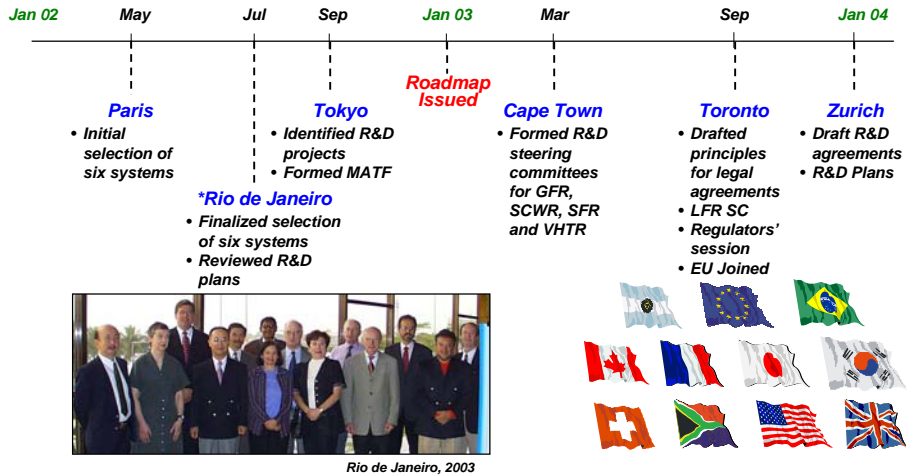
- 50% of U.S. electricity produced by nuclear power by 2050
- 25% of U.S. transportation fuel produced by nuclear energy (nuclear-produced hydrogen) by 2050
- Demonstrate a closed fuel cycle system by 2020
- Demonstrate a global nuclear energy system consisting of intrinsic and extrinsic safeguards that reduces proliferation risk



The Evolution of Nuclear Power



GIF: 2002 – 2004



International Collaborations Benefit Gen IV

GIF Member Interests in System R&D

GFR				◆	◆	◆	◆	◆	◆	◆	◆
LFR				◆		◆	◆		◆		◆
MSR											
SFR				◆	◆	◆	◆			◆	◆
SCWR			◆			◆	◆		◆		◆
VHTR			◆	◆	◆	◆	◆	◆	◆	◆	◆

Red Letter: Co-chair

GFR -- Gas-cooled fast reactor

LFR -- Lead-cooled fast reactor

MSR -- Molten salt reactor

SFR -- Sodium-cooled fast reactor

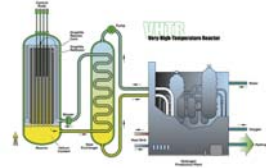
SCWR -- Supercritical water-cooled reactor

VHTR -- Very high temperature reactor

A Long-Term Strategy for Nuclear Energy *Generation IV Nuclear Energy Systems*

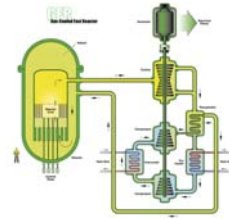
Generation IV Thermal Reactors

- **Thermal neutron systems**
- **Advanced, high burnup fuels**
- **High efficiency, advanced energy products**
- **Available by 2020**



Generation IV Fast Reactors

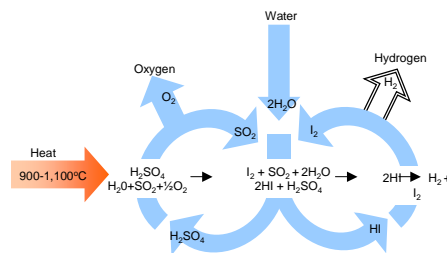
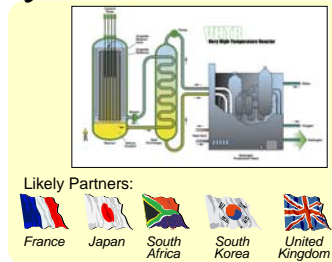
- **Fast neutron systems**
- **Proliferation-resistant closed fuel cycles**
- **Minimize long-term stewardship burden**
- **Available by 2030 to 2040**



Generation IV Nuclear Energy Systems *Thermal Systems*

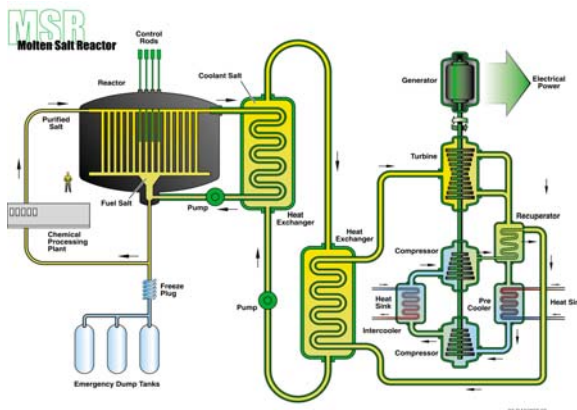
Example: *Very High Temperature Reactor (VHTR)*

- **Thermal neutron spectrum and once-through cycle**
- **High-temperature process heat applications**
- **Coolant outlet temperature above 1,000°C**
- **Reference concept is 600 MWth with operating efficiency greater than 50 percent**
- **Advanced Energy Production**
 - **High efficiency electricity generation**
 - **High efficiency hydrogen production via thermochemical water cracking or high temperature electrolysis**



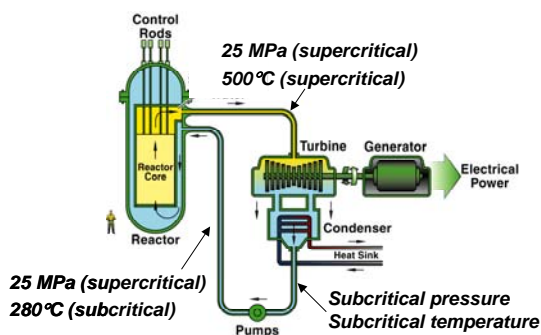
Molten Salt Reactor - MSR

- Molten/liquid fuel reactor
- High outlet temperatures
- Operates at atmospheric pressure
- Flexible fuel: no cladding



Supercritical Water-Cooled Reactor - SCWR

- LWR operating above the critical pressure of water, and producing low-cost electricity.
- The U.S. program assumes:
 - Direct cycle,
 - Thermal spectrum,
 - Light-water coolant and moderator,
 - Low-enriched uranium oxide fuel,
 - Base load operation.

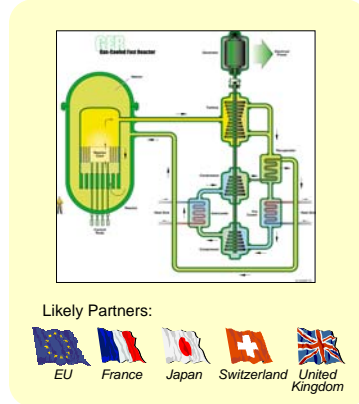


Generation IV Nuclear Energy Systems

Fast Systems

Example: *Gas-Cooled Fast Reactor (GFR)*

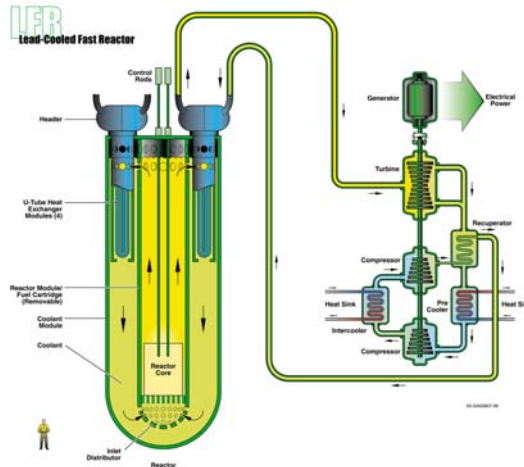
- Fast neutron spectrum and closed fuel cycle
- Efficient management of actinides and conversion of fertile uranium
- Coolant outlet temperature of 850°C
- Reference concept is 600 MWth with operating efficiency of 43 percent; optional concept is 2,400 MWth



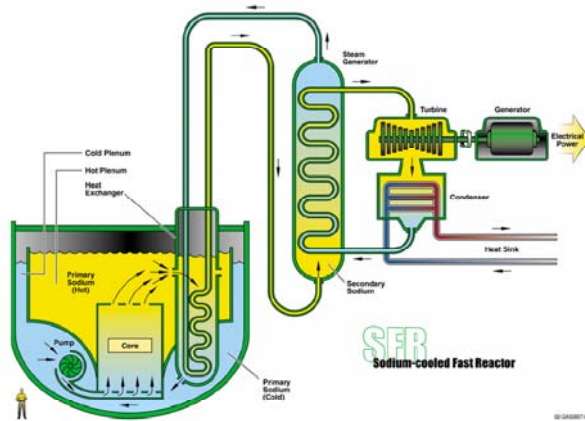
- Advanced Energy Production
 - High efficiency electricity generation
 - Good efficiency for hydrogen production via thermochemical water cracking or high temperature electrolysis

Lead Cooled Fast Reactor - LFR

- Deployable in remote locations without supporting infrastructure (output, transportation)
- High degree of proliferation resistance
- 15 to 30-yr core lifetime
- Passively safe under all conditions
- Capable of self-autonomous load following
- Natural circulation primary
- Fuel cycle flexibility
- Options for electricity, hydrogen, process heat & desalination
- Licensable through testing of demonstration plant



Sodium-cooled Fast Reactor - SFR



Pool-type design example

- Pool and loop designs
- Modular and monolithic designs
- Thermal efficiency about 40%
- Low pressure system

Advanced Fuel Cycle Initiative *The Path to a Proliferation-Resistant Nuclear Future*

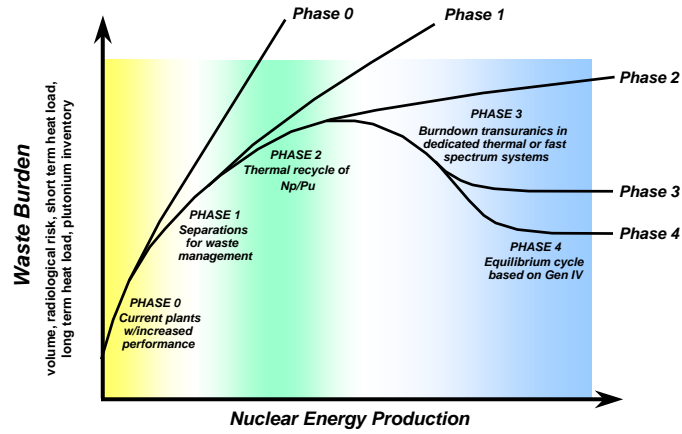
- Develop fuel cycle technologies that:
 - Enable recovery of the energy value from commercial spent nuclear fuel
 - Reduce the toxicity of high-level nuclear waste bound for geologic disposal
 - Reduce the inventories of civilian plutonium in the U.S.
 - Enable more effective use of the currently proposed geologic repository and reduce the cost of geologic disposal

January 2003

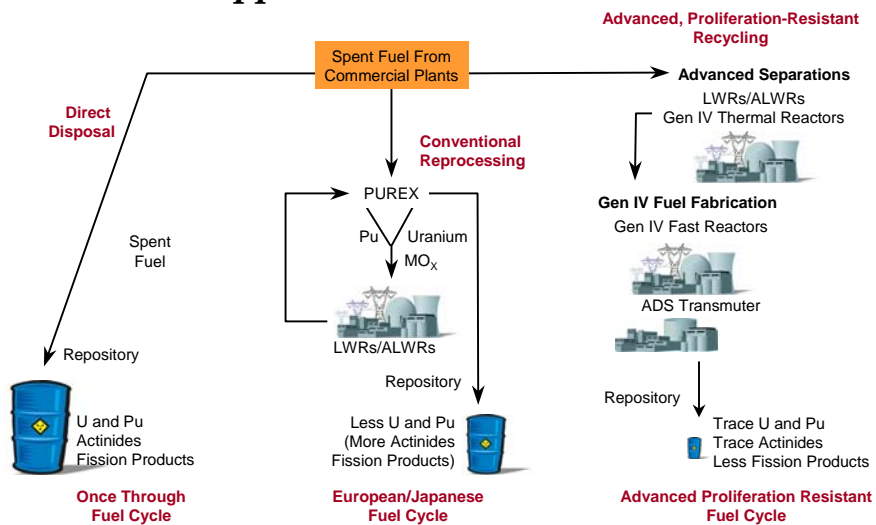


http://www.nuclear.gov/AFCI_RptCong2003.pdf

Generation IV and Spent Fuel Options



Advanced Fuel Cycle Technologies *Application to Fast Reactors*



Summary

- ***Developing and demonstrating advanced nuclear energy systems that meet future needs for safe, sustainable, environmentally responsible, economical, proliferation-resistant, and physically secure energy***
 - ***Innovation in nuclear energy systems to meet future needs***
 - ***A new look at advanced fuel cycles to better manage waste***

