Nuclear Energy

Current Trends, the Next Decade, and Beyond!

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Midwest Rural Energy Council

3/12/2010

Advances in Nuclear Power Generation

- Revamped licensing process
- Improved regulatory environment
- Consolidation of nuclear operators
- License Renewal & Power Uprates
- National (Nuclear) Energy Policy
- Why Nuclear?
- Used Nuclear Fuel
- Sustainable Nuclear Fuel Cycles

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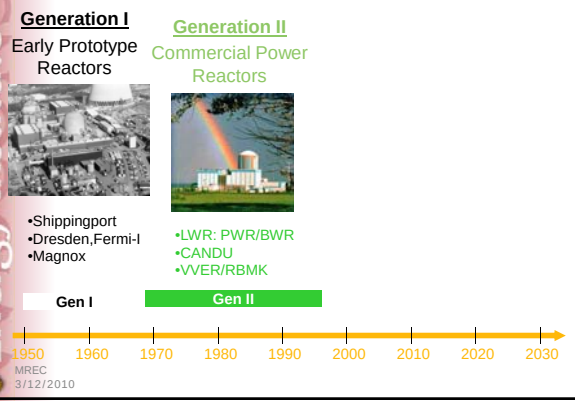
Current Trends



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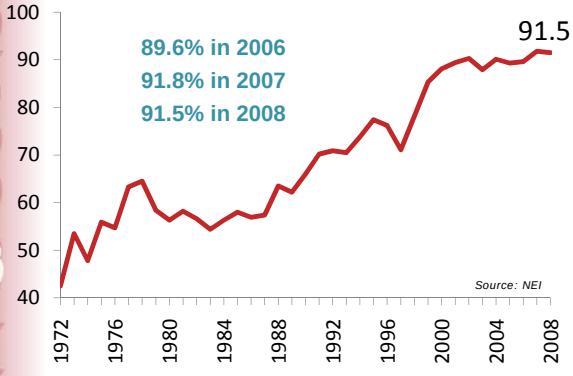
Capacity Factors Improve



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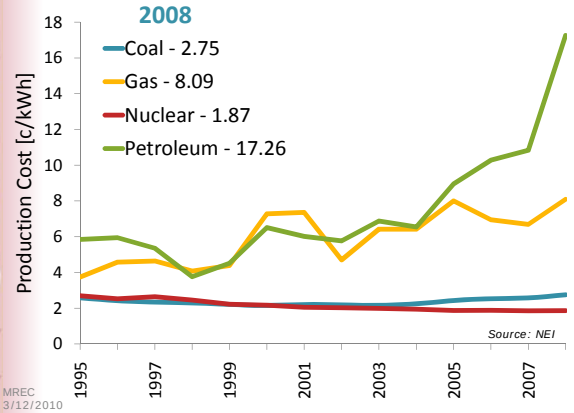
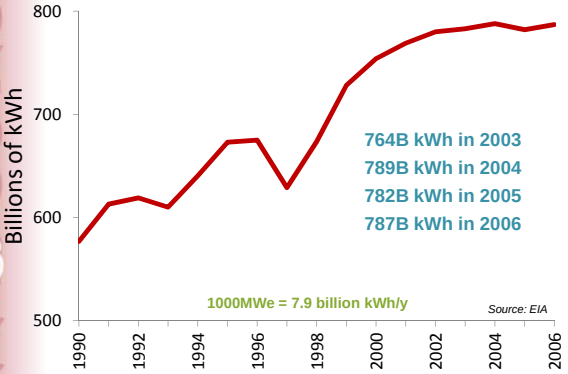
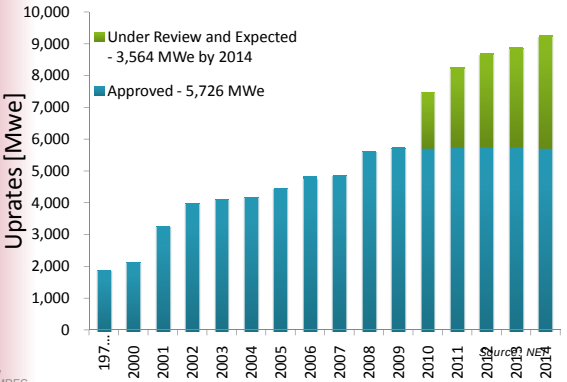
Nation's Lowest Production Costs



Record U.S.Nuclear Electricity Production



Extending Assets: Power Uprates



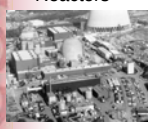
Extending Assets: License Renewals

- License Renewals
  - 20 year license renewals
  - Must demonstrate continued safe operation

59 units renewed
19 units pending
20 anticipated
98 out of 104

… The Next Decade …

Generation I
Early Prototype Reactors



•Shippingport
•Dresden,Fermi-I
•Magnox

Generation II
Commercial Power Reactors

•LWR: PWR/BWR
•CANDU
•VVER/RBMK

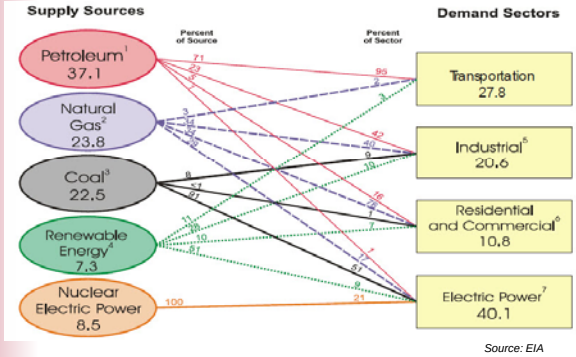
Generation III
Advanced LWRs

•System 80+•AP1000
•EPR •ABWR

Gen I | Gen II | Gen III

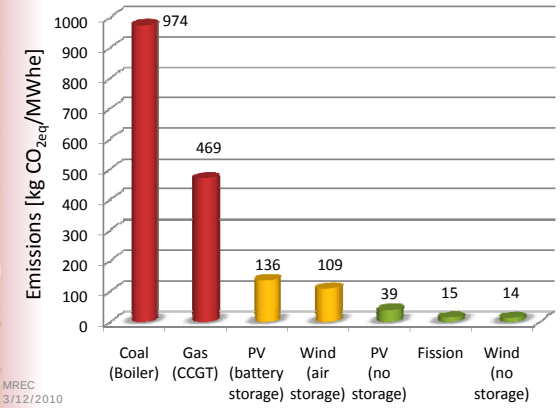
1950 1960 1970 1980 1990 2000 2010 2020 2030

Primary Energy Use in the US

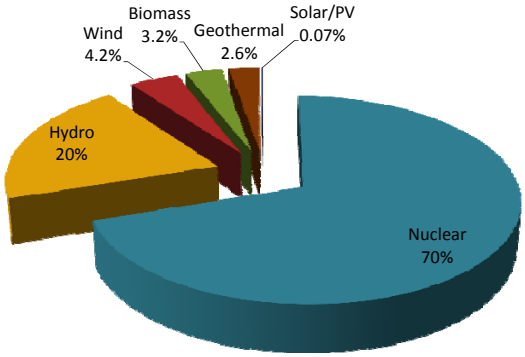


Source: EIA

Life-cycle Emissions



Nuclear Energy Supplies Majority of Low Emmission Electricity



Nuclear Fuel Supply

- Uranium prices relatively stable(?)
- Fuel prices are small fraction of cost
- Uranium imported from stable democracies (Australia & Canada)

Advanced Light Water Reactors

- Evolutionary changes to current reactor designs
- Focus on passive safety systems
- Improved economics (!$!)
  - Modern/modular construction practices
  - Standardized designs
- Currently being built in Pacific Rim, Finland & France

Economic Factors

- Lowest O&M costs of any source
- Reduced capital cost for new plants
- Reduced construction time for new plants
- "Externalities" included
- Large capital investment
- Unproven financial performance
- Large material & labor cost escalation

Nuclear Energy Policy

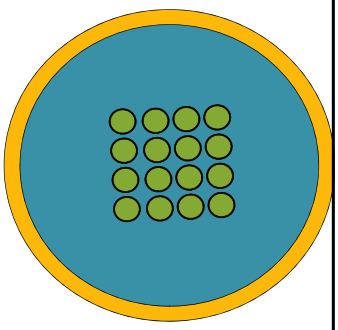
- New Licensing Process (1992)
  - Three steps
    - Design Certification (4 certified designs)
    - Early Site Permit (4 ESP applications issued)
    - Construction & Operation License
- Renewal of Price-Anderson Act (2005)
- Federal loan guarantees (2005)
- Standby insurance (2005)
- Production tax credits (2005)

The 3 C's of Used Nuclear Fuel

- **Compact** … Contained … Cared for
- Imagine all your electricity for an entire lifetime was generated by nuclear energy
  - About 1 million kWh (2006 EIA)
- About 1 soda-can of used nuclear fuel

The 3 C's of Used Nuclear Fuel

- Compact … **Contained** … Cared for
- Fuel itself is solid
- Wrapped in metal
- Stored in pool/ cask



The 3 C's of Used Nuclear Fuel

- Compact … Contained … **Cared for**
- Carefully tracked
- Decades of experience in safe handling
- Easy to detect and monitor
- Paid for in Nuclear Waste Fee

Used Nuclear Fuel Stored at Yucca Mountain

- 1982 – Nuclear Waste Policy Act
  - Establishes Nuclear Waste Fee/Fund
  - Chooses Geologic Disposal
- 1987 – NWPA Amendment
  - Selects Yucca Mountain as preferred site
- 2002 - Site approved by President and selection upheld by congress
  - Based on years of sound scientific & environmental assessment
  - First (political) progress in many years

Used Nuclear Fuel Stored at Yucca Mountain

- Designed to meet EPA limits for 1 MILLION years
- New timeline put DOE on track to (finally) fulfill obligations to utilities
  - License app: filed 06/08, accepted 09/08
- President Obama withdraws support
- March 2010
  - Appoints Blue Ribbon Commission
  - Formally withdraws applications **with prejudice**

Used Nuclear Fuel A Matter of Policy

- We know how to manage this material safely in the short term
- No technical urgency to do anything different
  - Can be stored in current systems for 50-100 years – probably longer
- Some security questions addressed by more $$$
- Intergenerational ethics
  - How long can we wait before having a solution

New Nuclear Plant Status

Company	Site(s)	Design, # of units	Construction / Operating License Submittal Timeline
TVA (NuStart)	Bellefonte (TN)	W: AP1000 (2)	October 2007
South Carolina E & G	Summer (SC)	W: AP1000 (2)	March 2008
Duke	Cherokee County, SC	W: AP1000 (2)	Dec 2007
Progress Energy	Harris (NC) Levy County, FL	W: AP1000 (2) AP1000 (2)	Feb 2008 July 2008
Constellation (UniStar)	Calvert Cliffs (MD) Nine Mile Point (NY) + one other sites	Areva: EPR (1) EPR (1) EPR (1)	March 2008 Sep 2009 TBD
Dominion	North Anna (VA)	GE: ESBWR (1)	Nov 2007
Entergy (NuStart)	Grand Gulf (MS) River Bend (LA)	GE: ESBWR (1) ESBWR (1)	Feb 2008 Sep 2008
NRG Energy (STP)	South Texas Project (TX)	GE: ABWR (2)	Sep 2007
Southern Company	Vogtle (GA)	W: AP1000 (2)	March 2008
Luminant	Comanche Peak (TX)	MHI: APWR (2)	Sep 2008
Detroit Edison	Fermi (MI)	TBD	Sep 2008

Source: NEI 10/2009

>30 reactors planned, 16 COLAs for 25 reactors

New Nuclear Plant Status

Company	Site(s)	Design, # of units	Construction / Operating License Submittal Timeline
Amarillo Power	Near Amarillo, TX	EPR	FY 2009
Florida Power & Light	Turkey Point (FL)	TBD (2)	June 2009
Alternate Energy Holdings	Bruneau, ID	EPR	FY 2009
AmerenUE	Callaway (MO)	EPR	July 2008 (suspended)
Exelon	Matagorda & Victoria County, TX	ESBWR(2)	Sep 2008
Duke	Davie County (NC)	TBD	TBD
Duke	Oconee County (SC)	TBD	TBD
Exelon	Clinton (IL)	TBD	TBD
PSEG	Salem / Hope Creek	TBD	TBD
PPL Corp	Susquehanna, (PA)	EPR	Oct 2008

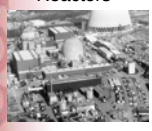
Source: NEI 10/2009

New Reactor Highlights

- Most planned for existing sites
- Most advanced plans in regulated markets
- Vogtle (Southern Company) awarded $8.4B Loan Guarantees
- First license award expected late 2010/early 2011
- Financial issues beginning to appear (??)
  - STP investors disagree on path forward
  - FPL slowing down on plans

… and Beyond

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

- System 80+
- AP600
- EPR
- ABWR

Generation IV

- Highly economical
- Enhanced Safety
- Minimized Wastes
- Proliferation Resistance

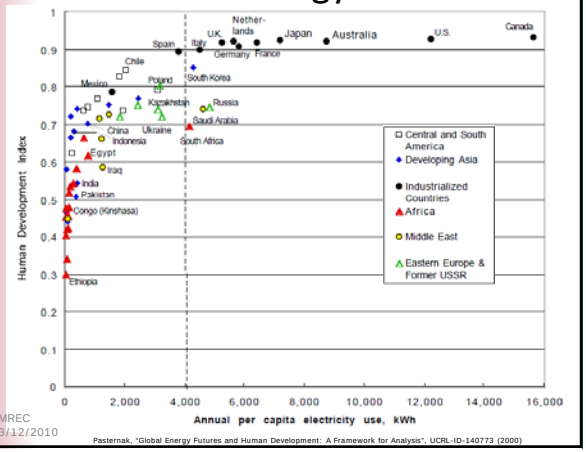
Gen I | Gen II | Gen III | Gen IV

1950 1960 1970 1980 1990 2000 2010 2020 2030

Preparing for Global Energy Needs

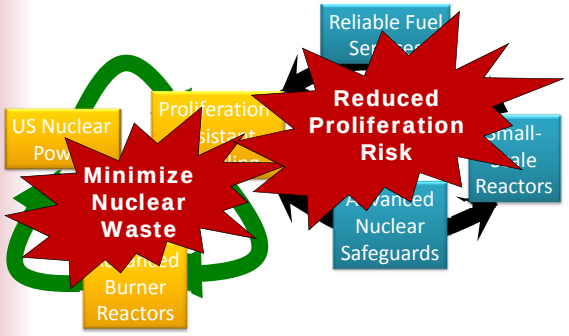
- Improvement in global standard of living will require increased energy/electricity supply
- Even a modest nuclear share requires large global deployment:
  - Differing economic environments & energy products
  - Large spent fuel inventories
  - Proliferation concerns
  - Varying safety cultures

Global Energy Use



Pasternak, "Global Energy Futures and Human Development: A Framework for Analysis", UCRL-ID-140773 (2000)

Global Nuclear Fuel Cycles



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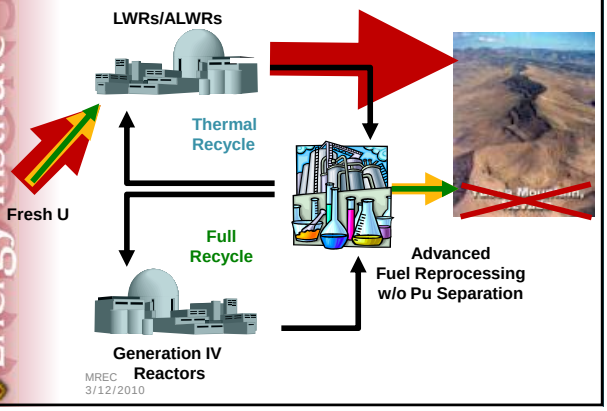
Advanced fuel cycles



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Minimize Nuclear Waste

Nuclear Futures	Legal Limit	Extended License for Current Reactors	Continued Constant Energy Generation	Constant Market Share	Growing Market Share
Total Discharged Fuel by *2100*, MTHM	63,000	120,000	240,000	600,000	1,300,000
Current approach	1	2	4	9	21
Expanded capacity		1	2	5	11
Thermal Recycle			1	2	5
Full Recycle					1

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Reduce Proliferation Risk

- Reliable fuel services
  - Supplier states are most economically attractive option
  - Internationally guaranteed supply
- Small-scale reactors
  - Small size for growing economies with limited access to capital
  - Long life cores to minimize refueling
- Advanced Safeguards
  - Technology & diplomacy

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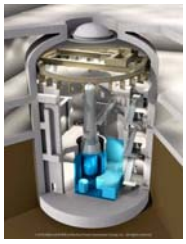
Small Modular Reactors

- Components manufactured in factories
  - Shipped to plant site and assembled quickly



B&W mPower

NuScale

Wisconsin "Moratorium"

- Waste
- Economics

196.493 Construction of nuclear power plants limited.
(1) DEFINITION. In this section, "nuclear power plant" means a nuclear−fired large electric generating facility as defined under s. 196.491 (1) (g).

(2) LIMITS ON CERTIFICATION. The commission may not certify under s. 196.49 (3) (b) or 196.491 (3) any nuclear power plant unless the commission finds that:

(a) A federally licensed facility, or a facility outside of the United States which the commission determines will satisfy the public welfare requirements of the people of this state, with adequate capacity to dispose of high−level nuclear waste from all nuclear power plants operating in this state will be available, as necessary, for disposal of the waste; and

(b) The proposed nuclear power plant, in comparison with feasible alternatives, is economically advantageous to ratepayers, based upon:

1. The existence of a reliable and adequate nuclear fuel supply;

2. The costs for construction, operation and decommissioning of nuclear power plants and for nuclear waste disposal; and

3. Any other factor having an impact on the economics of nuclear power plants, as determined by the commission.

History: 1983 a. 401; 1997 a. 204.
Cross Reference: See also ch. PSC 111, Wis. adm. code.

WI Global Warming Task Force

- Recommendations on energy policy
  - 25% RPS by 2025
  - Relax previous constraints on nuclear build
    - Add new constraints
- Currently being drafted as legislation
  - To be voted on soon

New Construction in WI

- No current plans
  - Not even close
- WI NPPs are owned by nuclear utilities with well-advanced expansion plans elsewhere
  - Dominion @ North Anna, VA
  - FPL @ Turkey Point, FL
- Neither has yet suggested expansion WI!
- Will NRC license for Yucca Mtn meet requirements of WI 196.493 (2)(a)

A Role for Nuclear Energy in WI

- Current Trends:
  - Valuable assets have been transferred to leading nuclear owner/operators
  - Important part of WI low-emission portfolio (76%)
- The Next Decade:
  - Continued supply of reliable electricity
    - Increased electrification, esp. transportation sector(?)
  - New supply of alternative energy products
    - Process heat (ethanol?)
    - Hydrogen

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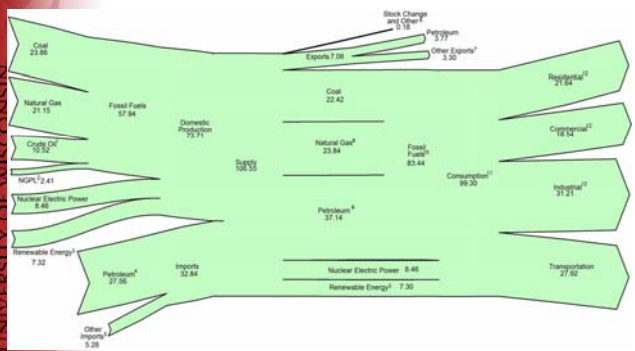
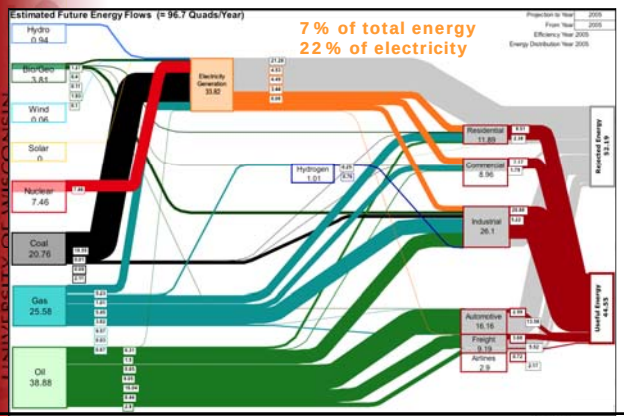
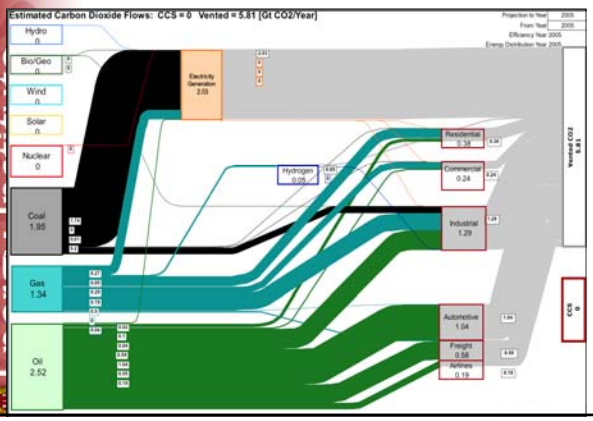
Primary Energy Use in the US



Primary Energy Use in the US



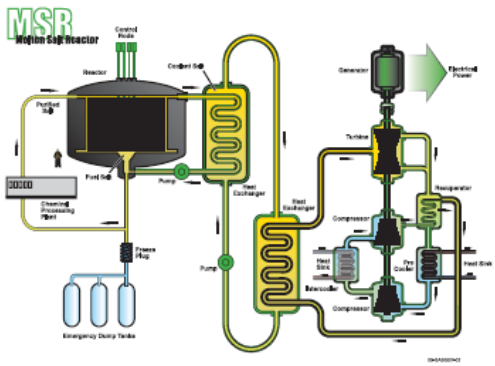
CO_2 Sources from US Energy Consumption



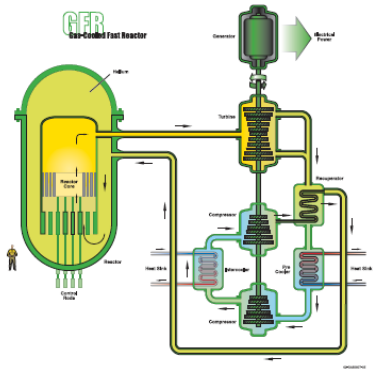
Hydrogen Production

- Strong policy push towards H2 fuel
- H2 must be produced from H2O (or natural gas) requiring energy
  - Energy currency vs energy source
- Nuclear power is the only low-emission energy source that is deployable for large-scale centralized H2 production
- May require high temperatures
  - Low temperature process being explored at UW

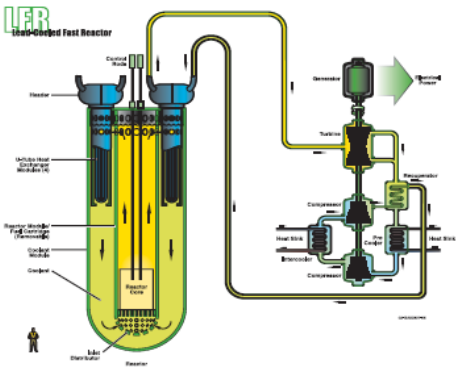
Molten-Salt Reactor



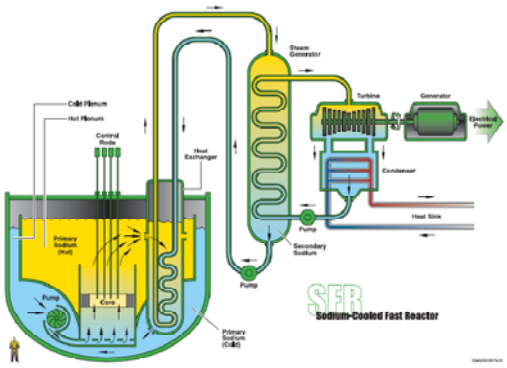
Gas-Cooled Fast Reactor



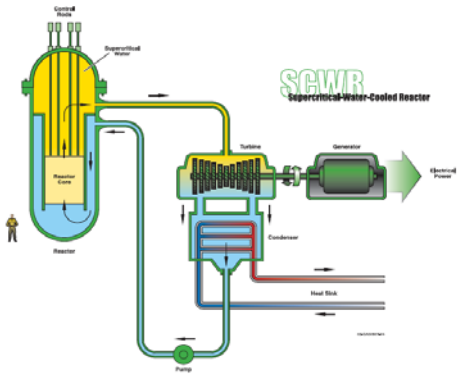
Lead-Cooled Fast Reactor



Sodium-Cooled Fast Reactor



Super-critical Water Reactor



Very High Temperature Reactor