Synergies Between Generation-IV and Advanced Fusion Power Plant R&D Programs

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Outline

- Background
  - Gen IV Program
  - Fusion Power Plant Programs
- Materials
- Environmental Impact
- Economics & Energy Products
- Summary/Recommendations

New Era of Nuclear Power Research

- Energy policy that includes nuclear fission and fusion

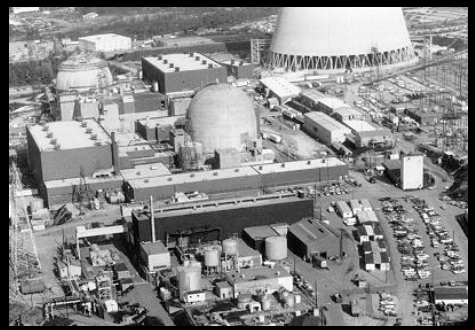
- Gen-IV: New vision/direction for fission research
- Funding levels rebounding

- New fusion power plant design efforts
- Return to ITER

Generation IV

Generation I

Early Prototype Reactors



- Shippingport
- Dresden,Fermi-I
- Magnox

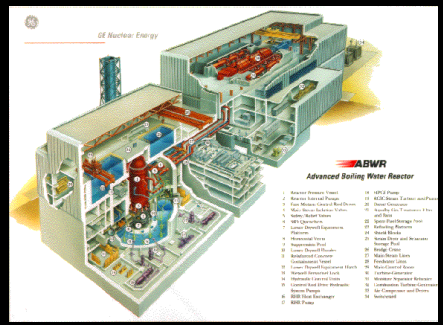
Generation II

Commercial Power Reactors

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

Generation III

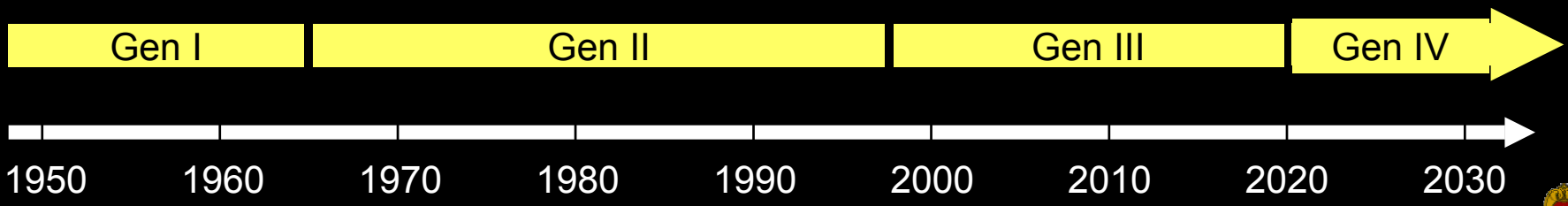
Advanced LWRs



- System 80+
- EPR
- AP600
- ABWR

Generation IV

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



Generation IV

- International process to evaluate contributed concepts and develop roadmap
- Six design concepts chosen
  - VHTR – high temperature H_2 production
  - SCWR – improved economics with similar tech.
  - GFR – actinide management
  - LFR – small modular "battery"
  - SFR, MSR – greater consideration in other countries
- Fission research budget steered towards these concepts

Advanced Fusion Power Plants

- ARIES
  - Long history of studying many concepts including Tokamaks, Stellarators, and IFE
- HAPL (High Average Power Lasers)
  - Inertial fusion energy reactor design program
- ZP3 (Z-Pinch Power Plant)
  - Low rep-rate z-pinch driven reactor design program

Fusion & Fission Materials

- Probably most important technical obstacle
- Fusion environment has necessitated search for low activation steels tolerant to radiation damage
- Fission has had it easy, relatively…(on paper)
  - Many challenges have arisen in operation
- Gen IV fission has environment similar to fusion in many ways

Materials

	Fission	Fusion	Gen IV
Coolant	H_2O, CO_2	H_2O, He, Li, PbLi, FLiBe	H_2O(SC), He, Pb, PbBi, Na, FLiBe
Particle Energy	< 1-2 MeV	< 14 MeV	< 1-2 MeV
Temperatures	<400 °C	300-1000 °C	300-1000 °C
Max. displacement damage		~ 200	15-200
He/dpa	~0.1 appm/dpa	10 appm/dpa	~0.1 appm/dpa
Stresses	Moderate, nearly constant	Moderate, nearly constant	Moderate, nearly constant

Computational Materials

- Experimental programs cannot provide data for breadth of materials and irradiation conditions
- Emerging multi-scale modeling capability
  - Model individual radiation-induced events
  - Model accumulation of microstructural changes
  - Model changes in engineering properties due to these changes
- Requires experimental data for validation
  - Limited resources require careful selection of experimental scenarios

Environmental Impact

- Gen IV & Fusion both recognize potential risk to environment and public health
  - Safety goals and requirements
  - Waste minimization
  - Regulatory reform

Safety

Common safety goal/criterion

No offsite evacuation plan required

- Defined as requirement for fusion in 1996
- Defined as goal of Gen IV program in 2000

- Challenge to demonstrate and develop public and regulator confidence

Waste Minimization

- Qualitative and quantitative difference in waste streams
  - HLW
    - Fusion has set design requirement of no HLW
    - Fission cannot avoid HLW
      - Advanced Fuel Cycle Initiative (AFCI) aims to minimize this
  - LLW
    - Comparable quantities
  - Clearable material
    - Some Gen IV designs will reduce fission to similar to fusion

Regulatory Framework

- Modern nuclear power plant regulation is strongly focused towards light water reactors
- Future (pre-Gen-IV) fission plants will already be driving changes
  - Changed fuel forms and source terms
  - Alternative coolants and relaxed containment requirements
- Fusion will benefit from process of change AND particular changes

Economics & Energy Products

- Similar financial profiles
  - Capital intensive
  - High operating costs - low fuel costs
  - Available for many energy products
- Future economic environment uncertain
  - ? Prices of competing energy sources
  - ? Impact of environmental regulations
  - ? Capital markets and interest rates
  - ? Relative importance of energy products
  - ? **Real cost of nuclear construction**

Nuclear Hydrogen

- H_2 identified for important role in long-term energy security
- Nuclear Hydrogen Initiative
  - Research underway for high temperature thermo-chemical cycles to be coupled to high temperature fission plants
  - Fusion offers similar high temperatures
- Could spark major industrial interest in nuclear technology

Summary

- Gen-IV and fusion power research programs have common goals and promise
  - Energy security
  - Environmental stewardship
- Gen-IV and fusion power research programs have similar obstacles and issues
  - Advanced materials for extreme environments
  - Regulatory reform for non-LWR reactors
  - Economic uncertainties and profiles

Recommendations

- Consider Gen IV fission systems as a stepping stone to a future that includes fusion
- Increased interaction between fission and fusion communities
- Formal leveraging of common research priorities