U.S. Department of Energy Innovative Generation IV and Advanced Fuel Cycle Initiative Research Programs

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U.S. DOE

1st COE-INES International Symposium

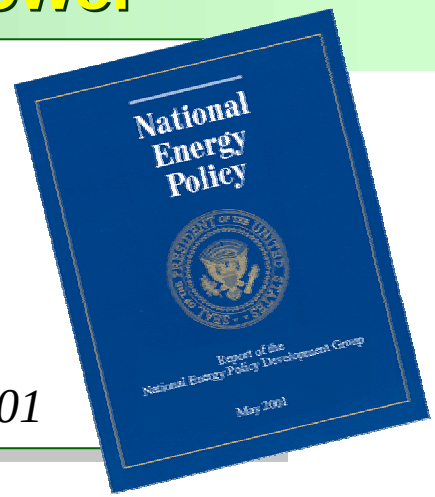
Tokyo, Japan

November 1, 2004

The National Energy Policy and Nuclear Power

"The NEPD Group recommends that the President support the expansion of nuclear energy in the United States as a major component of our national energy policy."

Report of the National Energy Policy Development Group, May 2001



Calvert Cliffs Nuclear Power Plant

Recommendations:

- Support expansion of nuclear energy in the United States
- Develop advanced nuclear fuel cycles and next generation technologies
- Develop advanced reprocessing and fuel treatment technologies

U.S. DOE currently has a number of initiatives to promote the growth of nuclear energy

Nuclear Power 2010

- Explore new sites
- Develop business case
- Develop Generation III+ technologies
- Demonstrate new licensing process

Advanced Fuel Cycle Initiative

- Recovery of energy value from SNF
- Reduce the inventory of civilian Pu
- Reduce the toxicity & heat of waste
- More effective use of the repository

Nuclear Hydrogen Initiative

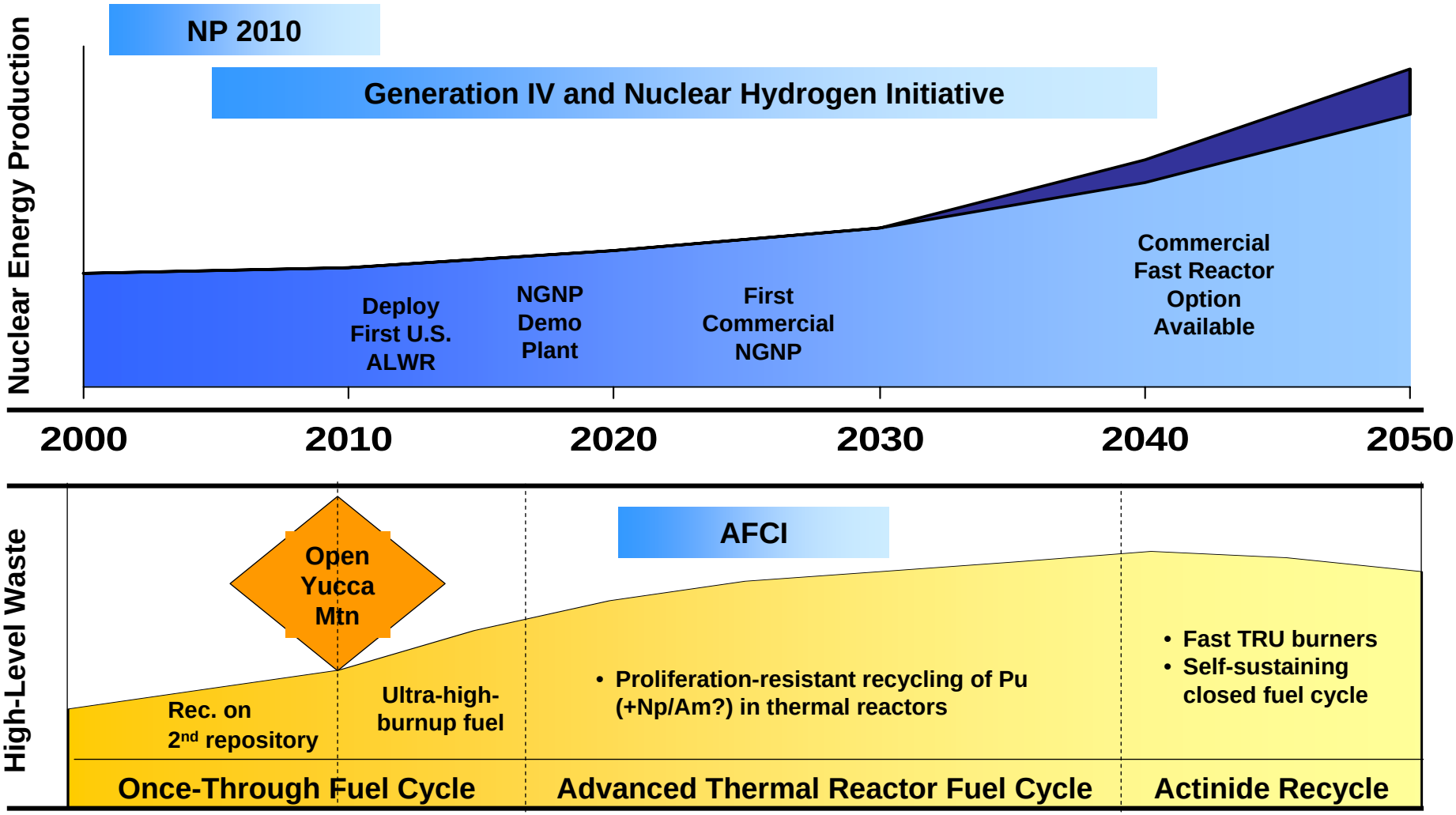
Develop technologies for economic, commercial-scale generation of hydrogen.

Generation IV

Better, safer, more economic nuclear power plants with improvements in

- safety & reliability
- proliferation resistance & physical protection
- economic competitiveness
- sustainability

A Long-Term U.S. Strategy for Nuclear Energy



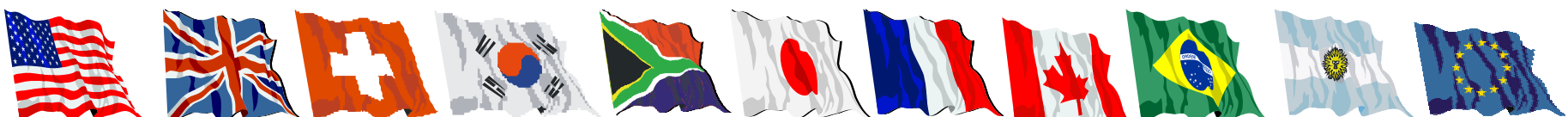
NP 2010 Initiative will help industry pave the way toward construction of new nuclear plants in the next decade

- Completed scoping studies for 2 commercial sites and 3 federal sites
- Completed Independent Business Case analysis
  - Starting point for Congressional considerations of financial assistance
- Participating with industry to usher in Generation III+ technologies through NRC design certification process
- Filed 3 early site permit (ESP) applications with NRC
  - Approval expected mid-2006 for Virginia, Illinois, and Mississippi
- Next step is to demonstrate the “one-step licensing” process for construction and operation

Generation IV Initiative -- Purpose and History

- **Generation IV Initiative was established by DOE in 2000**
  - Initiative designed to lead development of Gen IV reactor systems and bring them to a state of maturity allowing for commercial deployment after 2010 but before 2030
- **Generation IV International Forum (GIF) formed in 2001**
  - The Gen IV Initiative is an international effort, with the U.S. serving as the lead. R&D efforts are being coordinated with other GIF nations.
- **In cooperation with GIF, DOE's Nuclear Energy Research Advisory Committee (NERAC) issued the Gen IV Technology Roadmap in 2002**

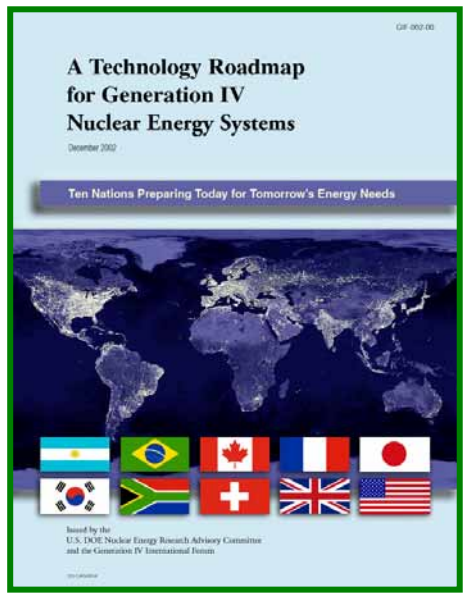
GIF Countries



Gen IV Technology Roadmap

- Discusses the benefits, goals and challenges, and the importance of the fuel cycle
- Introduces six Generation IV systems chosen by the Generation IV International Forum for further development
  - Gas-cooled Fast Reactor (GFR)
  - Lead-cooled Fast Reactor (LFR)
  - Sodium-cooled Fast Reactor (SFR)
  - Molten Salt Reactor (MSR)
  - Supercritical Water-cooled Reactor (SCWR)
  - Very High Temperature Reactor (VHTR)
- Surveys system-specific R&D needs for all six systems
- Collects crosscutting R&D needs
  - Design and evaluation methods, materials, energy conversion
- Recognizes the need for and likelihood of nearer-term deployment, but specifies complete R&D activities

December 2002



http://nuclear.gov/nerac/FinalRoadmapforNERACReview.pdf

U.S. Generation IV Implementation

Gen IV Top Priority

VHTR + H_2 ⟶ NGNP

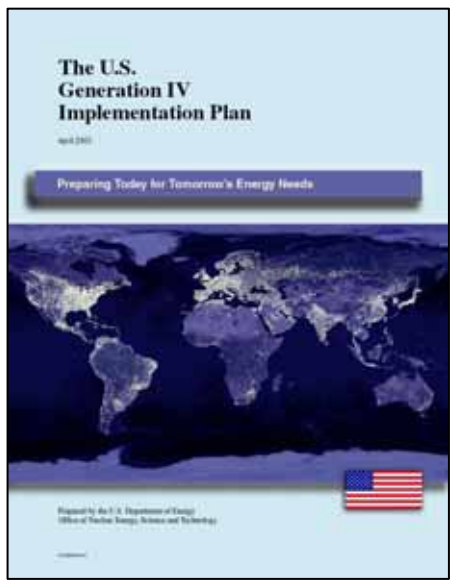
Next-Generation Nuclear Plant

- Collaborative with international community
- Collaborative with industry, especially utilities
- Demonstrate H_2 and direct-cycle electricity production
- Result in a commercially viable plant design

Gen IV Second Priority

- GFR
- LFR
- SFR

U.S. Fast Reactor
Closely coordinated with Advanced Fuel Cycle Initiative

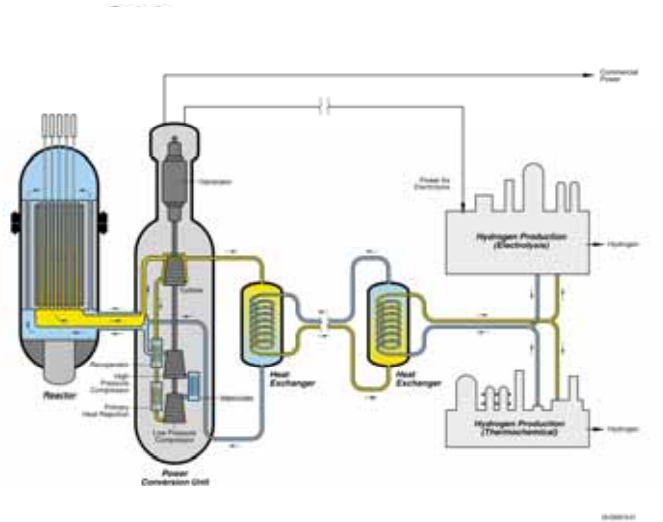


Lower Priority

- SCWR
- MSR

Generation IV 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



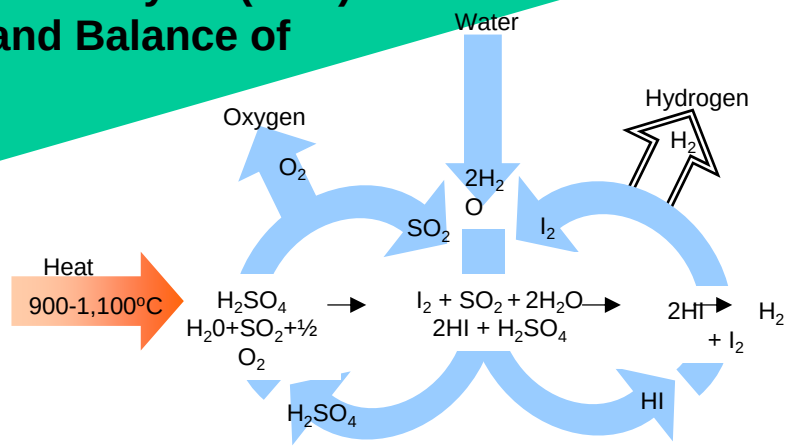
- **Modular construction**
  - 600 MW_{Th}
  - At 50% efficiency, could produce up to 200 MT of H_2 a day, the equivalent of 200,000 gallons gasoline per day.

- **Objective: build NGNP demo plant in Idaho by 2017**

Scaling Up Hydrogen Production Processes

Research and Development

- Thermochemical (TC)
- High Temperature Electrolysis (HTE)
- Systems Interface and Balance of Plant



Bench & Lab Scale, and Materials Testing

Integrated Lab Scale

Pilot Plant Scale

5 MWt Thermochemical
0.5 MWt HTE

Engineering (commercial) Scale

50 MWt Thermochemical
1-5 MWt HTE

10 x

Demonstration

Advanced Fuel Cycle Initiative

Mission

- ***Develop proliferation-resistant spent nuclear fuel treatment, fuel and transmutation technologies to enable the transition from the once-through fuel cycle to a stable, long-term, environmentally, economically, and politically acceptable advanced closed fuel cycle.***

Goals

- ***Develop advanced fuel and fuel cycle technologies for application to current operating commercial reactors and next-generation reactors***
- ***Develop technologies to reduce the cost of geologic disposal of high level waste from spent fuel, enhancing repository performance***

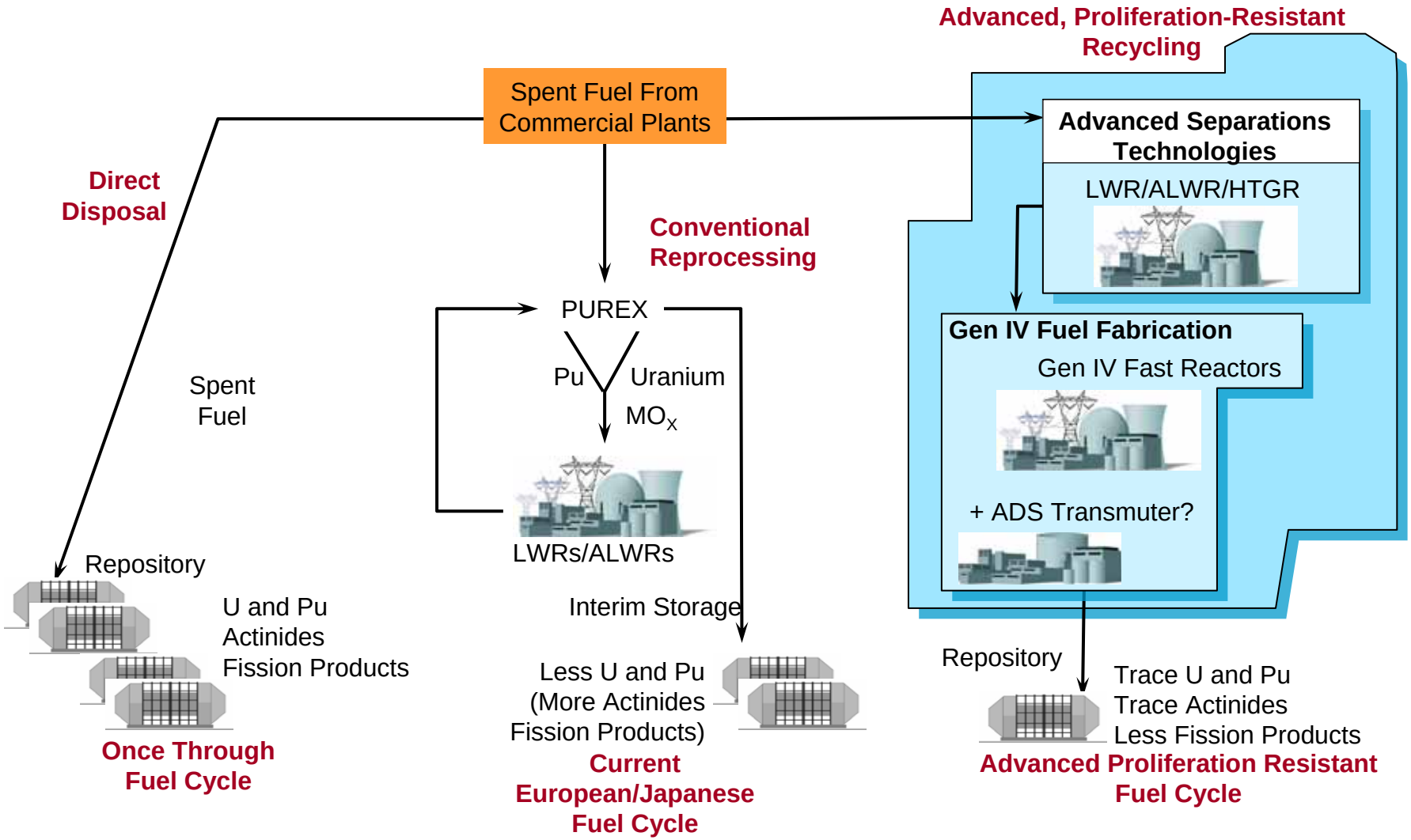
AFCI Benefits

- **Achieving AFCI program goals could:**
  - **Reduce civil plutonium inventories, reducing proliferation risk**
  - **Extract valuable energy from spent fuel components**
  - **Retain nuclear energy as a major component of the U.S. energy mix, ensuring energy security in the 21st century**
  - **Significantly reduce volume, heat load and radiotoxicity of high-level waste from spent fuel, delaying any near-term need for a second geologic repository in the U.S.**

AFCI Research Areas:

- **Advanced aqueous and pyroprocessing spent fuel treatment technologies**
- **Advanced fuels for thermal and fast reactor systems**
- **Transmutation Engineering**
  - Physics
  - Materials
  - Accelerator-Driven Systems (ADS)
- **Systems Analysis and Modeling**

AFCI Approach to Spent Fuel Management



AFCI Long-Range Strategy

2020 2030 2040 2050 2060 2070

Phase 1
Separations for Waste Management

- Uranium disposal as LLW
- Cs/Sr extracted for decay storage
- All TRUs and remaining FPs to HLW or Interim Storage

Phase 2
Thermal Recycle of Pu/Np

- Uranium disposal as LLW
- Cs/Sr extracted for decay storage
- Pu/Np and possibly additional MAs recovered for thermal recycle
- Remaining MAs and FPs to HLW

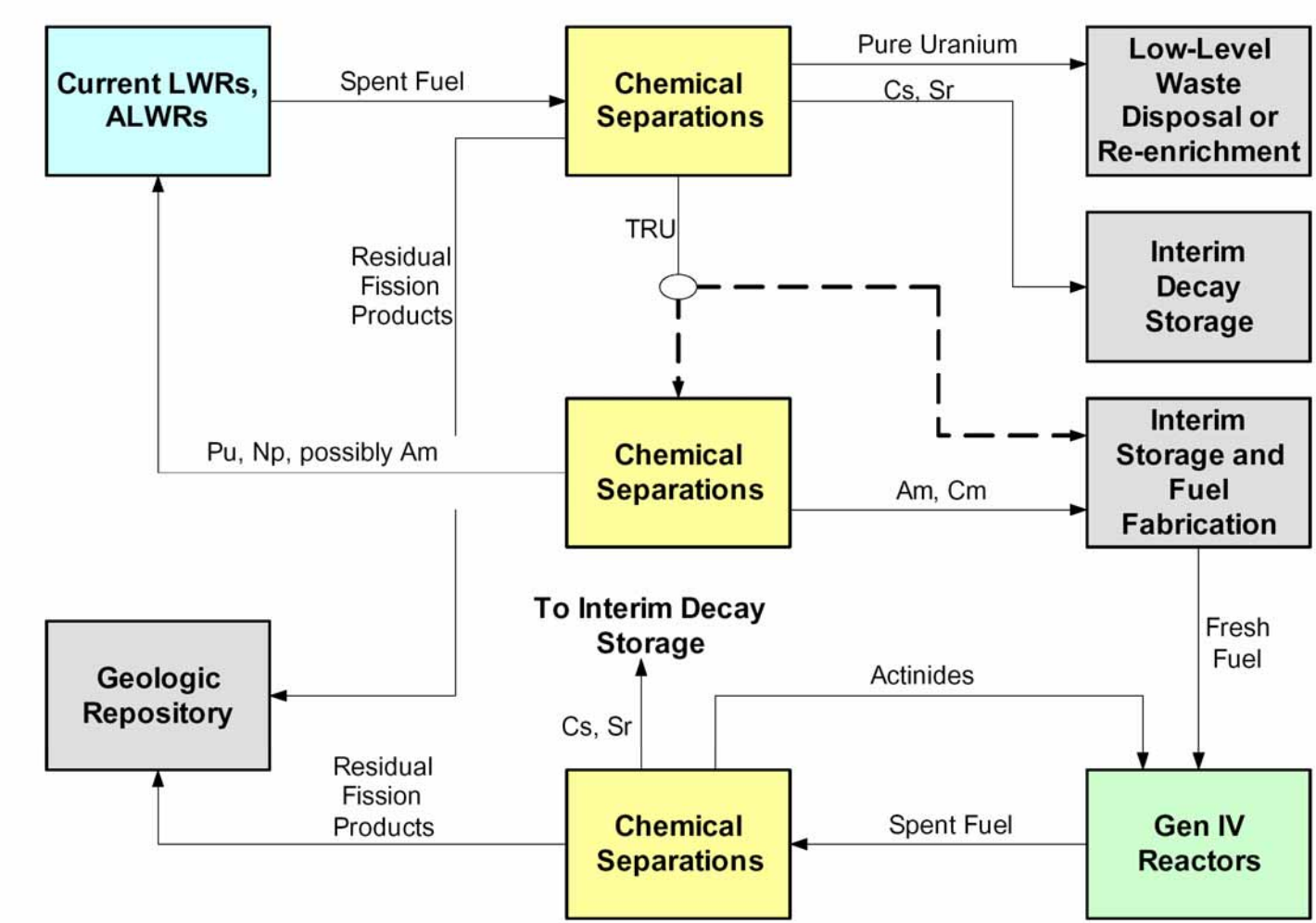
Phase 3
TRUs to Dedicated Burners

- Uranium recovery for re-use
- Cs/Sr extracted for decay storage
- TRUs directed to dedicated burners
- Remaining FPs to HLW

Phase 4
Entry into Gen IV Economy

- Uranium recovery for re-use
- Cs/Sr extracted for decay storage
- Actinide recycle to Gen IV reactors

AFCI Vision for Future Nuclear Energy System



Separations – Current Approach

- Aqueous separations process development (UREX+1, UREX+2) with laboratory-scale experiments
- Process technology development (equipment, process integration, process control and instrumentation, safeguards instrumentation, etc.)
- Development of waste forms and storage forms (including performance testing)
- Evaluation of advanced processing methods and validatation of promising candidates at laboratory-scale

Separations Technology Development in 2005

- **Large centrifugal contactor tests**
  - Scaleup issues, remote operation/reliability/maintainability
  - Process sampling and analysis, process control
- **Dissolution studies**
  - Optimize for most complete dissolution of TRU and compatibility with subsequent separations steps
- **Feed clarification experiments**
  - Efficiency of different methods
- **Alternative head-end process development**
  - Voloxidation process
  - Off-gas recovery and treatment
- **Uranium crystallization process development**
  - Maximizing purity of separated uranium
  - Carbonate dissolution process

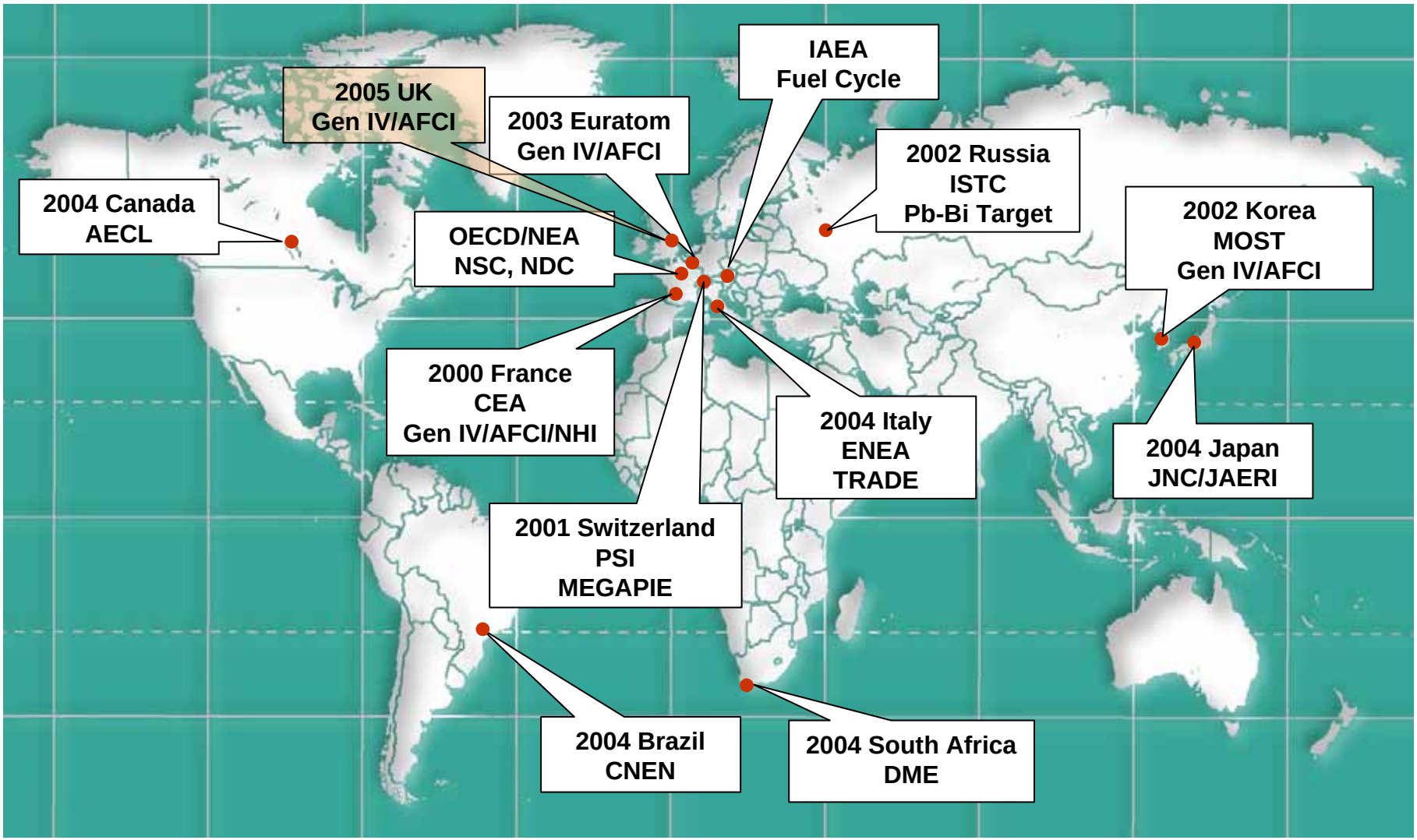
Advanced Fuels Research

- **NGNP particle fuel**
  - UCO, SiC coating
  - High temperature requirement (1000 ° C)
- **LWR Recycle Fuel**
  - Mixed Oxide
  - Pu + Np + Am? + Cm?
  - Inert Matrix
  - Intrinsic proliferation resistance
- **Fast reactor Fuels**
  - Metal, Nitride, Oxide, Dispersion
  - Optimize transmutation

Materials Research

- **Coolants for Generation IV fast reactors and Accelerator Driven Systems**
  - **Lead, lead-bismuth for LFR, ADS**
  - **Helium, supercritical CO2 for GFR**
- **Structural materials for high-temperature, high fast neutron flux performance**
- **Fuel matrix materials for very high-burnup fast reactor and transmutation fuels**

International Collaborations



We have a new vision today to establish *Atoms for Prosperity* for future generations.

The last 50 years saw the realization of Eisenhower's vision of *Atoms for Peace*

"Peaceful power from atomic energy is no dream of the future. That capability, already proved, is here now - today."
-President Eisenhower

- Nuclear power: an energy source of choice worldwide for many decades to come
- Clean, safe, reliable and sustainable energy essential for world's peace and prosperity and for environmental integrity
- U.S. and others want to reduce dependence on foreign energy sources by increasing domestic supplies of clean energy
- In the U.S., a number of forward-looking nuclear energy initiatives are ongoing
- AFCI and GEN IV initiatives are enjoying strong International Collaboration
- *It is becoming imperative for developed nations to promote the peaceful use of nuclear energy while developing a joint strategy for nuclear materials management worldwide*