Nuclear Energy Development in the USA

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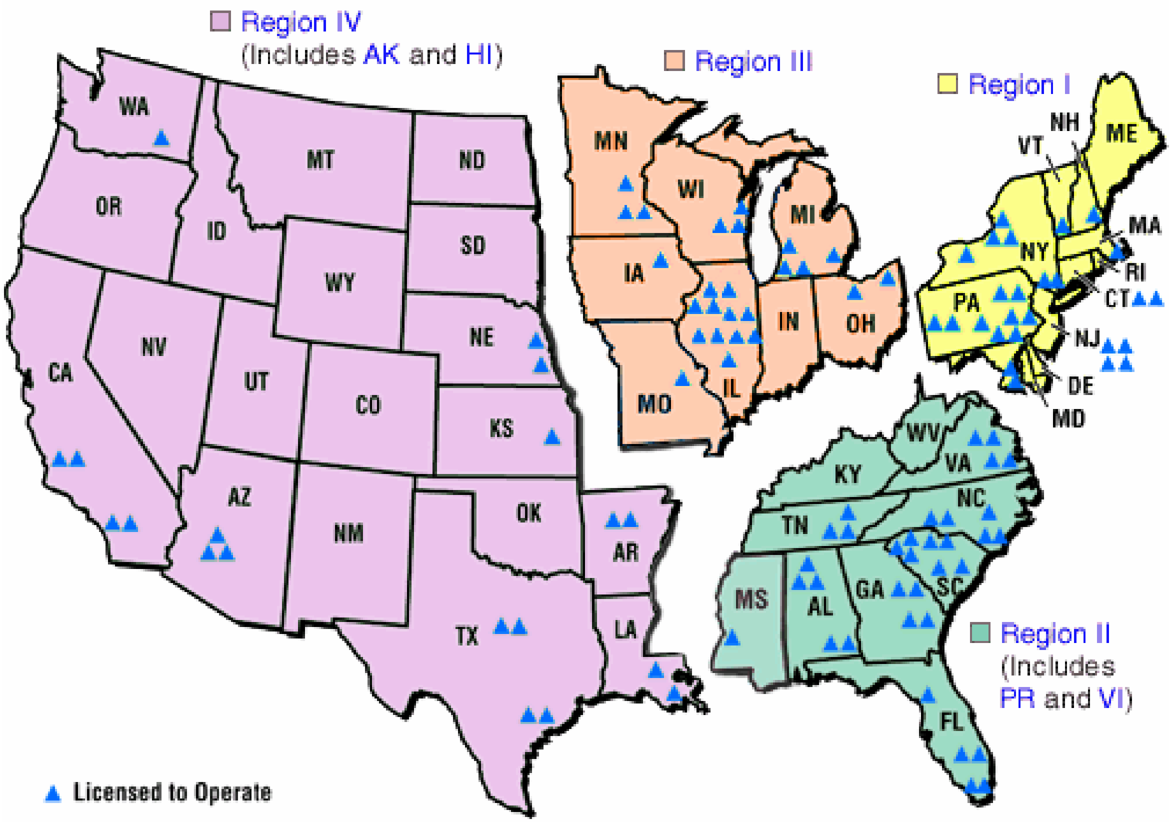
Outline

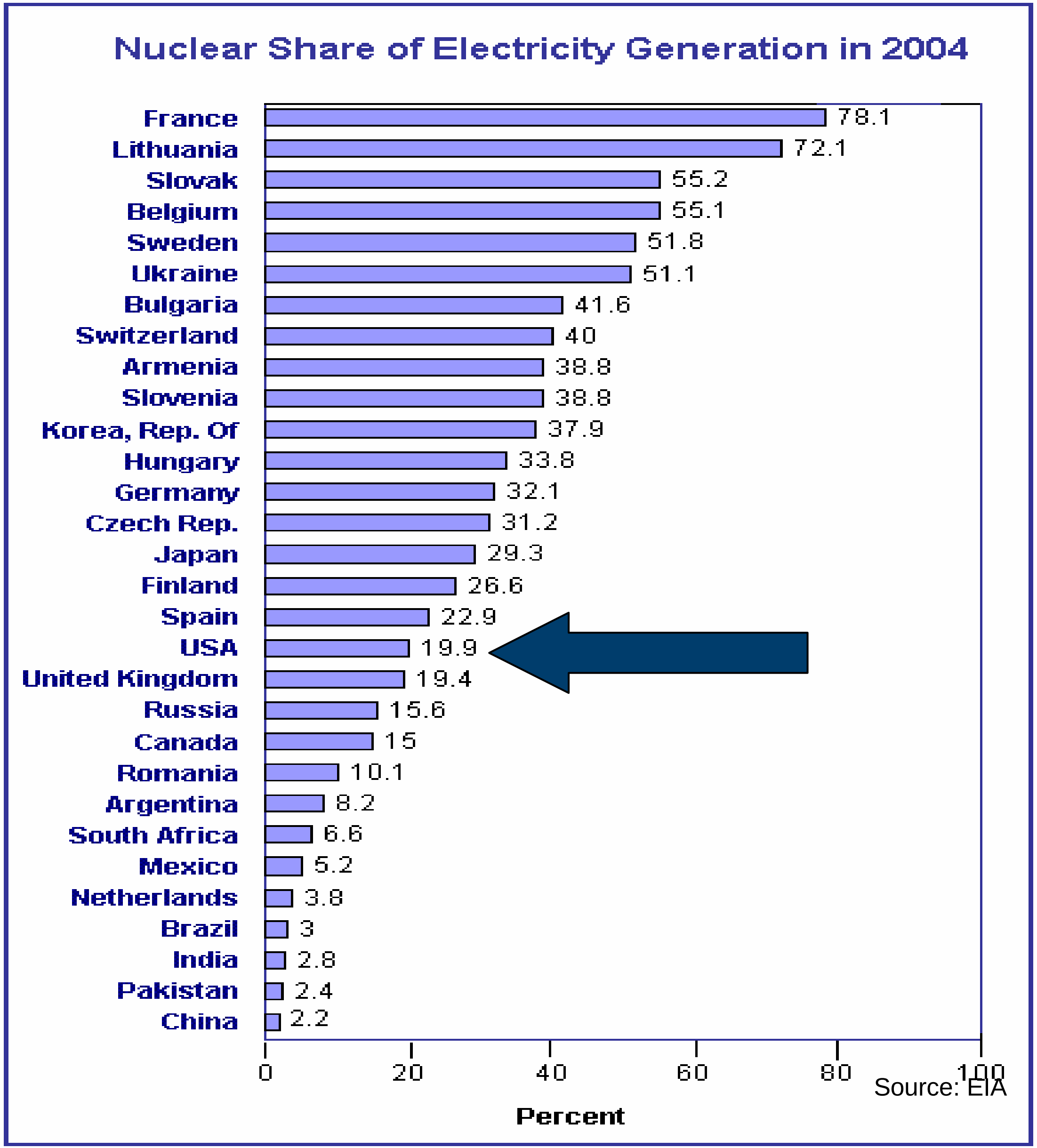
- **Present and Near Term:**
  - **Overview of US Commercial Nuclear Industry**
- **The future:**
  - **Global Nuclear Energy Partnership (GNEP)**
  - **Next Generation Nuclear Plant (NGNP)**

Nuclear Power is Alive and Well in the US!

- **Currently 104 Operating LWRs**
  - **69 Pressurized Water Reactors**
  - **35 Boiling Water Reactors**



The US Produces 20% of it’s Electricity by Nuclear Power



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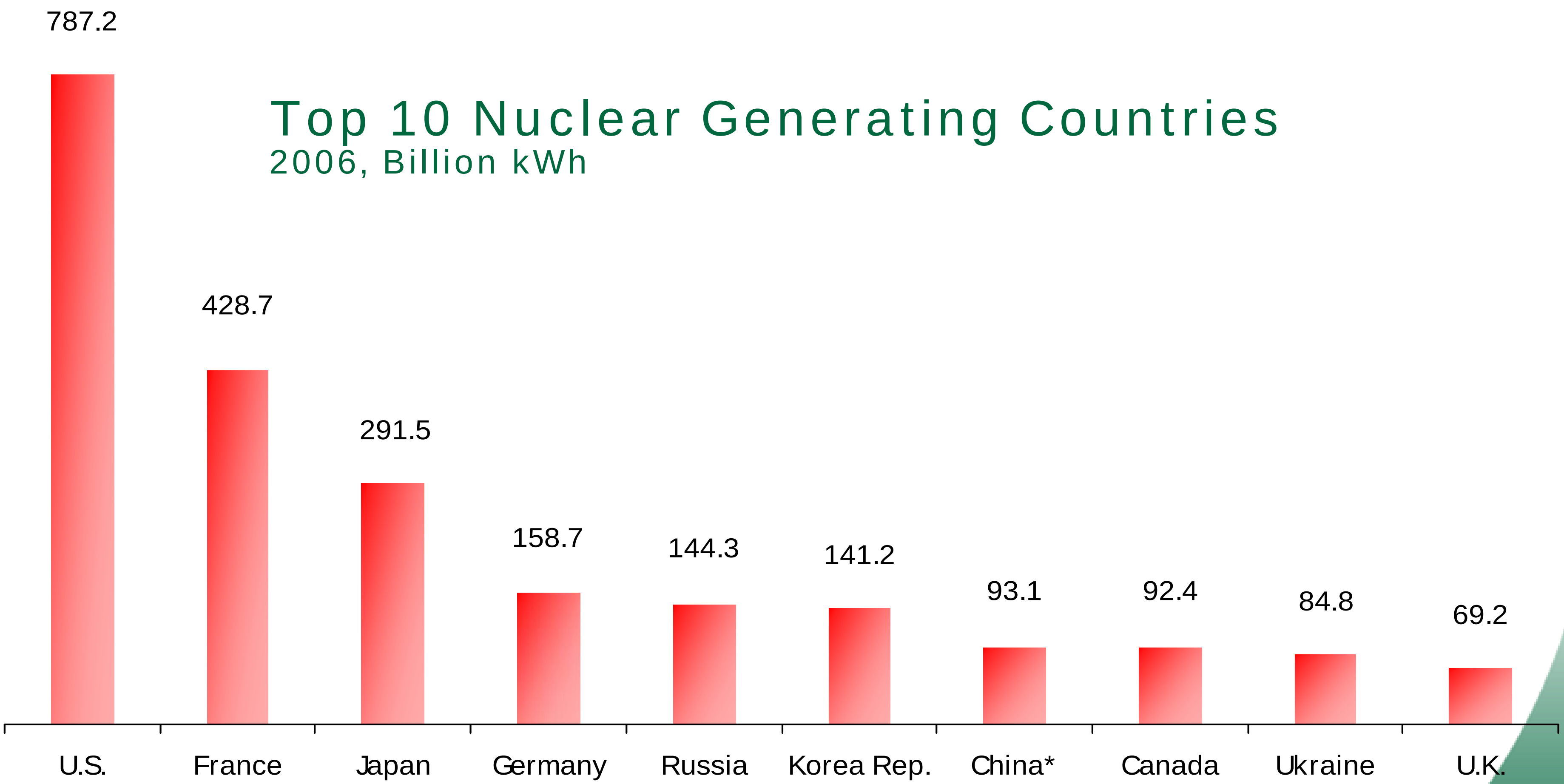
In Absolute Terms, the US is the World's Largest Nuclear Electricity Producer

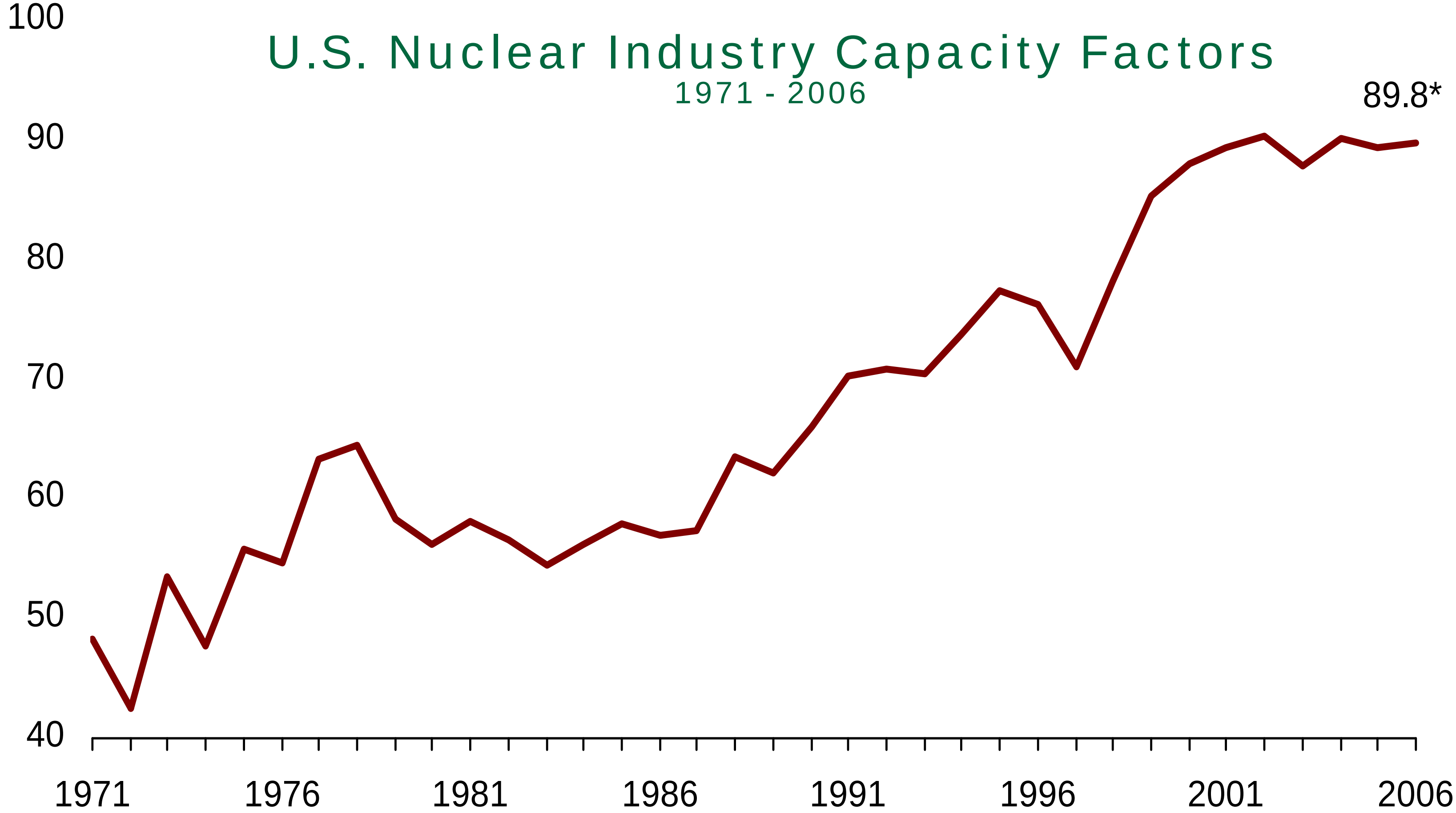


* Includes Taiwan, China

Source: NEI, International Atomic Energy Agency and World Nuclear Association

Updated: 5/07

Plant Performance has Consistently Improved

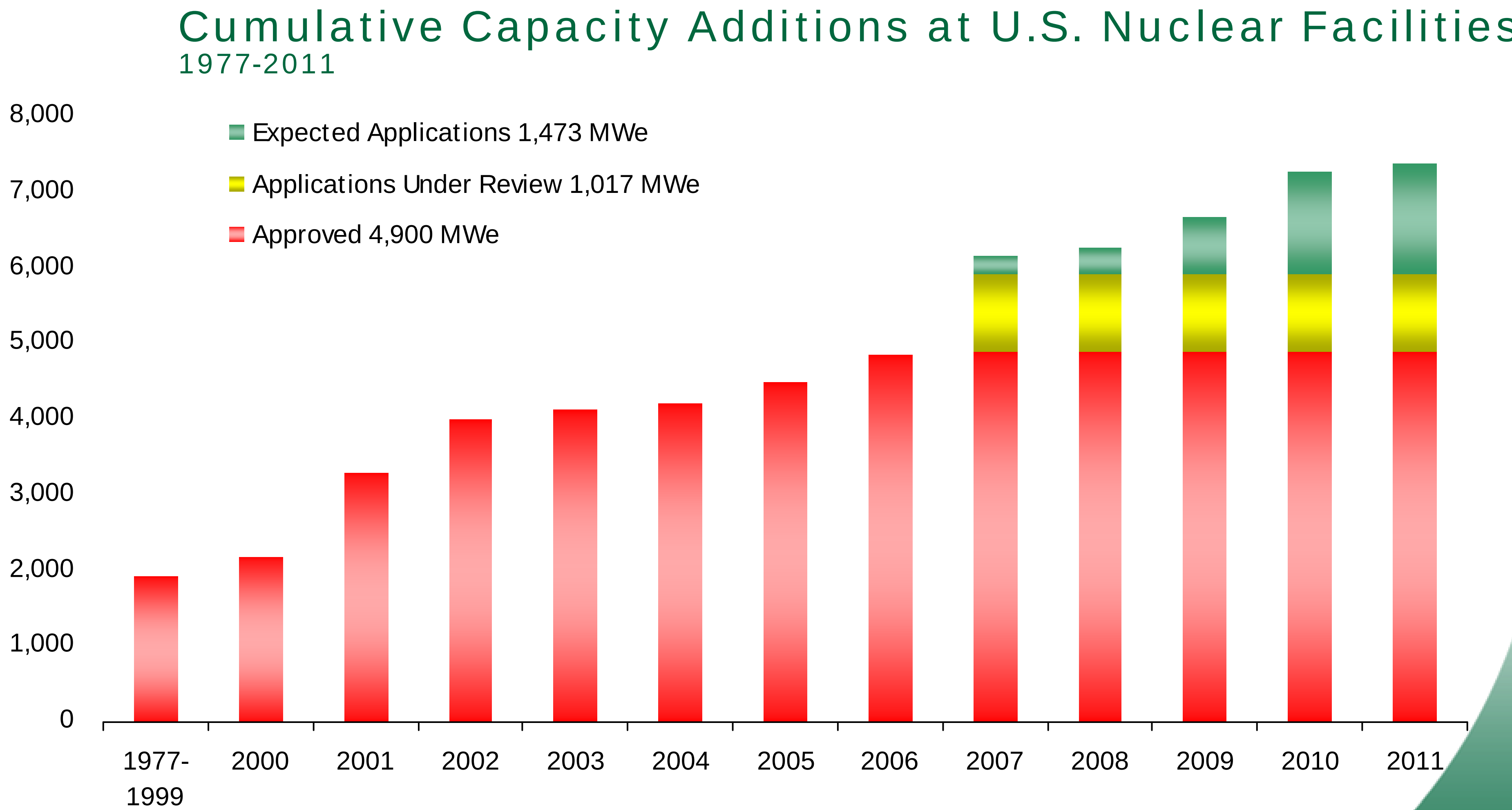


* Preliminary

Source: NEI (Global Energy Decisions / Energy Information Administration)

Updated: 6/07

Significant Capacity Added Through Plant Power Uprates



Source: Nuclear Regulatory Commission

Updated: 5/07

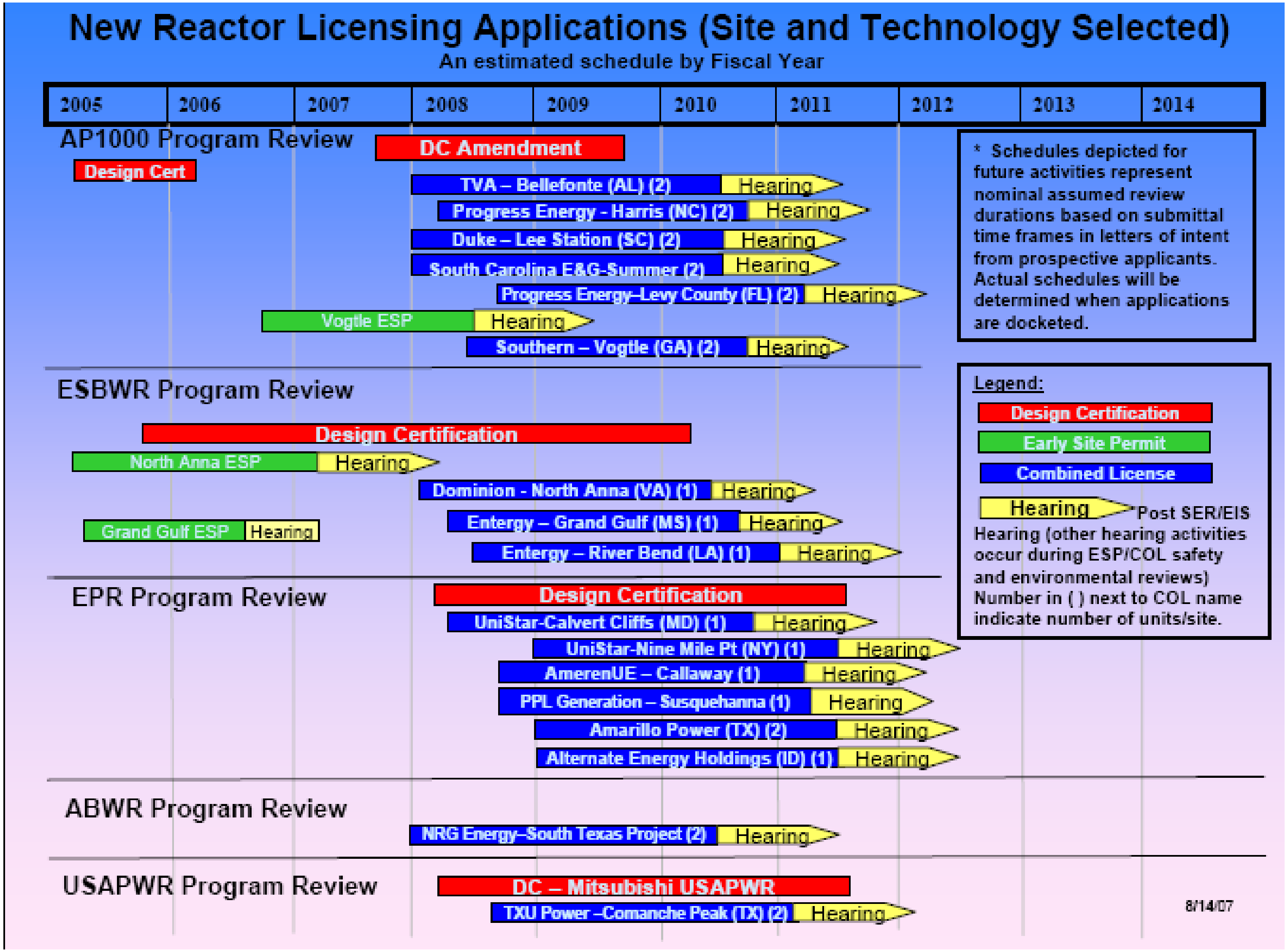
Plant Life Extensions and Additions

- **NRC License Renewals (20 year extensions)**
  - **48 extensions granted**
  - **37 Pending and publicly announced**
- **Browns Ferry 1 (TVA) restart in May 2007 most recent addition to grid (shutdown in 1985).**
- **TVA has announced plans to complete Watts Bar Unit 2 (construction halted in 1988)**

On the Verge of New Plant License Applications

- **Supported by provisions in the Energy Policy Act of 2005 and the DOE NP2010 Program**
- **New License Approach – 10 CFR 52**
  - **Early Site Permits**
  - **Standard Design Certification**
  - **Combined Construction/Operating License**
- **Reactor Design Certification**
  - **General Electric Advanced Boiling Water Reactor - Approved**
  - **Westinghouse AP1000 – Approved**
  - **General Electric ESBWR – under review**
  - **Areva U.S. US EPR – pre-licensing review**
  - **MHI US-APWR – pre-licensing review**

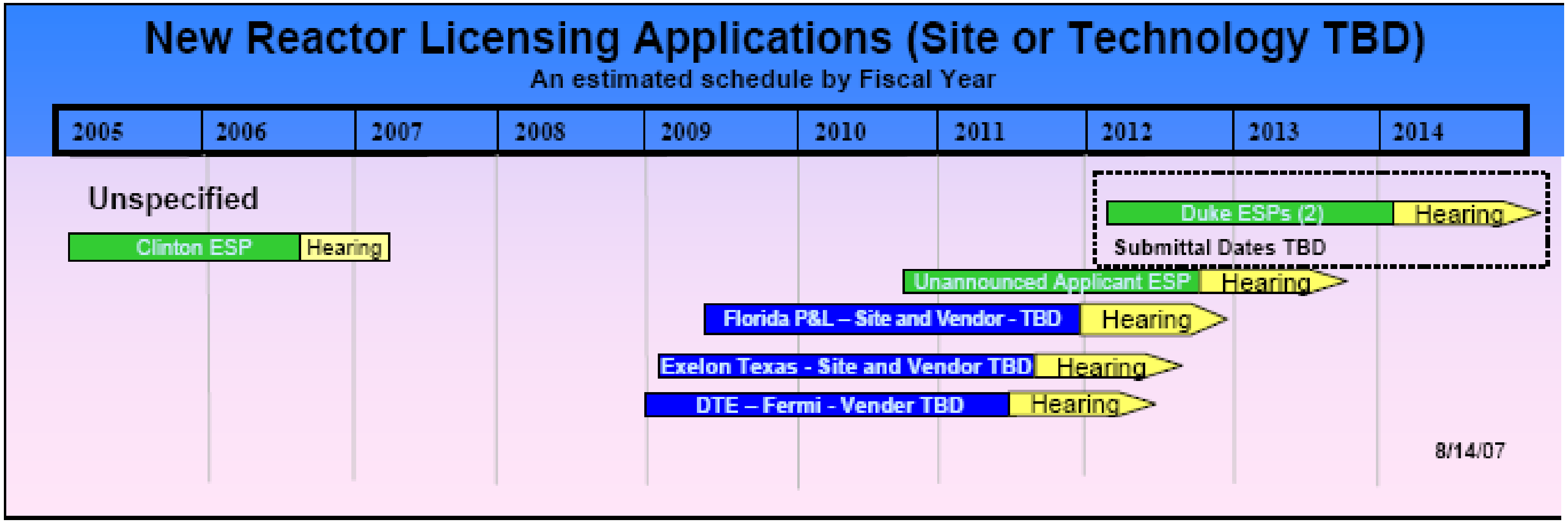
New Reactor Application Schedule



Source: NRC

Managed by UT-Battelle
for the Department of Energy

New Reactor Application Schedule (cont)



- **A total of 19 applications expected in 2007-2009 representing 27 units.**

Longer-Term Nuclear Research and Development

- **Global Nuclear Energy Partnership**
  - **Create a sustainable fuel cycle**
  - **Minimize proliferation concerns**
  - **Address waste issues**
- **Next Generation Nuclear Plant**
  - **Higher-efficiency electricity production**
  - **High-temperature heat source for Nuclear Production of Hydrogen**
  - **Enhanced safety**

GNEP: Objectives

- **Expand nuclear power in a sustainable manner**
- **Develop, demonstrate and deploy advanced technologies for recycling spent fuel that:**
  - **Do not separate plutonium**
  - **Reduce nuclear waste to ensure the need for only one repository through the end of the century**
- **Develop, demonstrate, and deploy advanced recycling reactors**
- **Establish fuel supply agreements among nations to provide reliable fuel services**

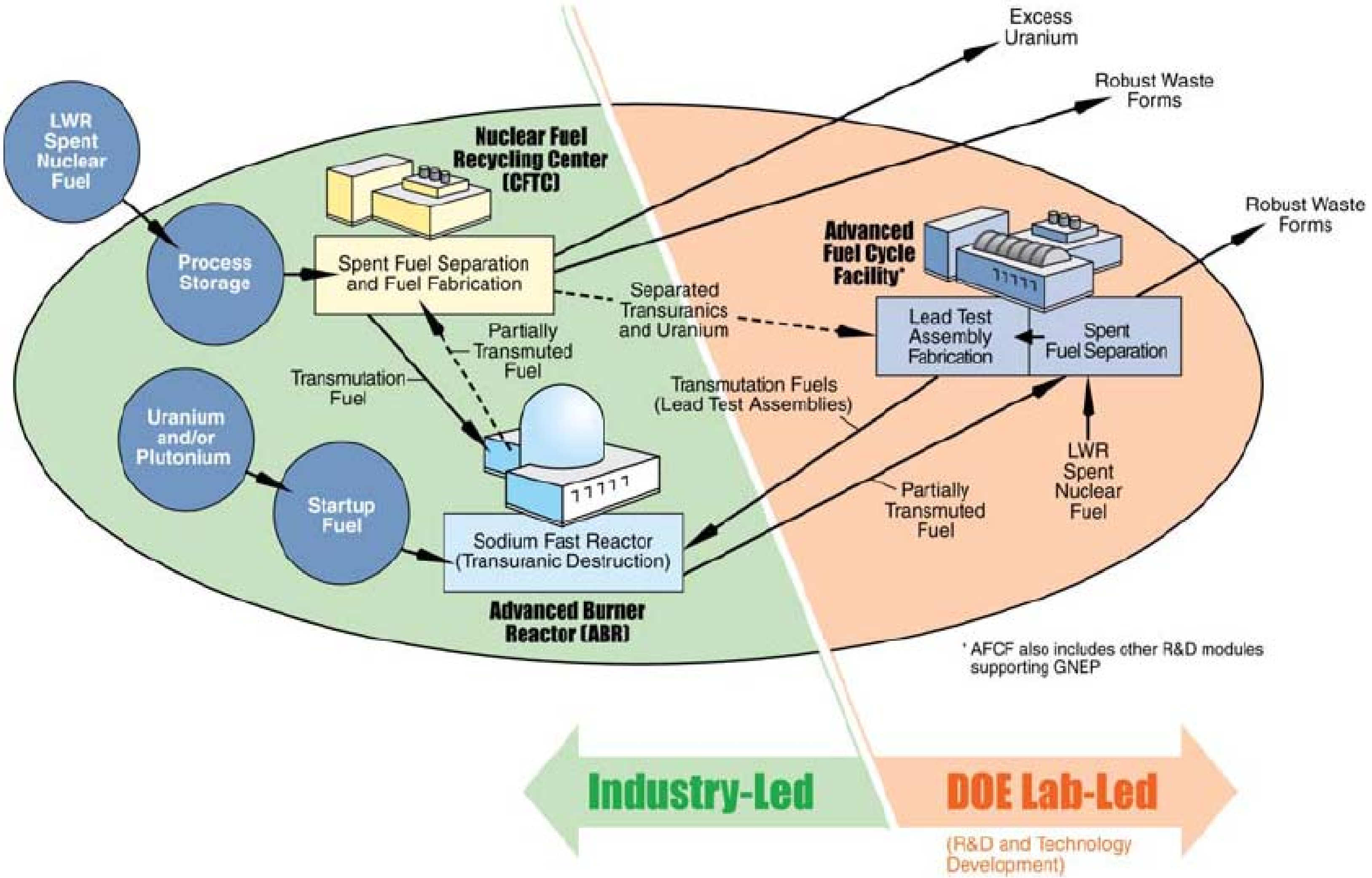
GNEP: Objectives (cont)

- **Develop, demonstrate, deploy advanced proliferation-resistent nuclear power reactors appropriate for power grids of developing countries and regions**
- **In cooperation with the IAEA, develop enhanced nuclear safeguards**

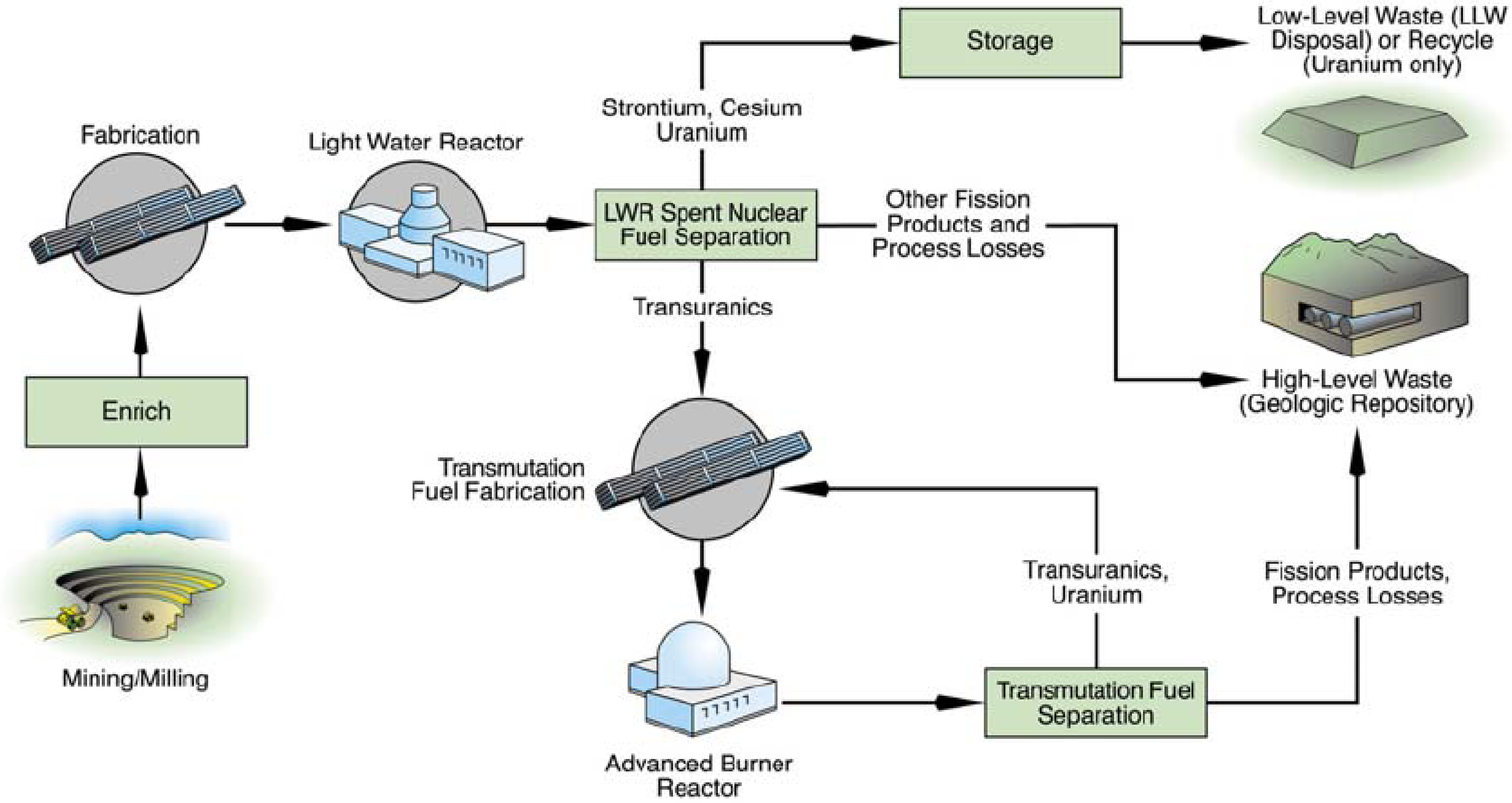
Domestic Implementation Model

- **Government/Industry Partnership**
- **Three primary facilities for initial implementation:**
  - **Advanced Separations Facility (Consolidated Fuel Treatment Center)**
  - **Advanced Recycling Reactor (also known as Advanced Burner Reactor)**
  - **Advanced Fuel Cycle Facility (AFCF) – fuels development and fuel cycle R&D center**

Domestic Implementation Model (cont)



Initial Deployment System Architecture



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Deployment Infrastructure Comments

- **All existing US reactors are commercial LWRs producing 2000 MT of spent fuel per year**
- **Current emphasis is on the use of fast reactors for burning spent LWR fuel and recycled ABR fuel**
- **The use of a single tier approach different from France and Japan, which already have an established commercial MOX infrastructure**
- **Complete Yucca Mountain Repository for 63,000 MT of existing spent fuel. Implement GNEP to avoid future repositories.**

Key Schedule Milestones

- **Secretarial decision – June 2008**
- **Timing of GNEP facilities :**
  - **FY 2020 – initial operation of LWR spent nuclear fuel separations center (CFTC)**
  - **FY 2022 – Startup of prototype fast spectrum reactor to demonstrate transuranic destruction (ABR)**
  - **FY 2020 – Commence operations of the multipurpose separations and transmutation fuel fabrication research center (AFCF)**
  - **Dates subject to change based on programmatic decisions, requirements, and other acquisitions.**

Program Structure

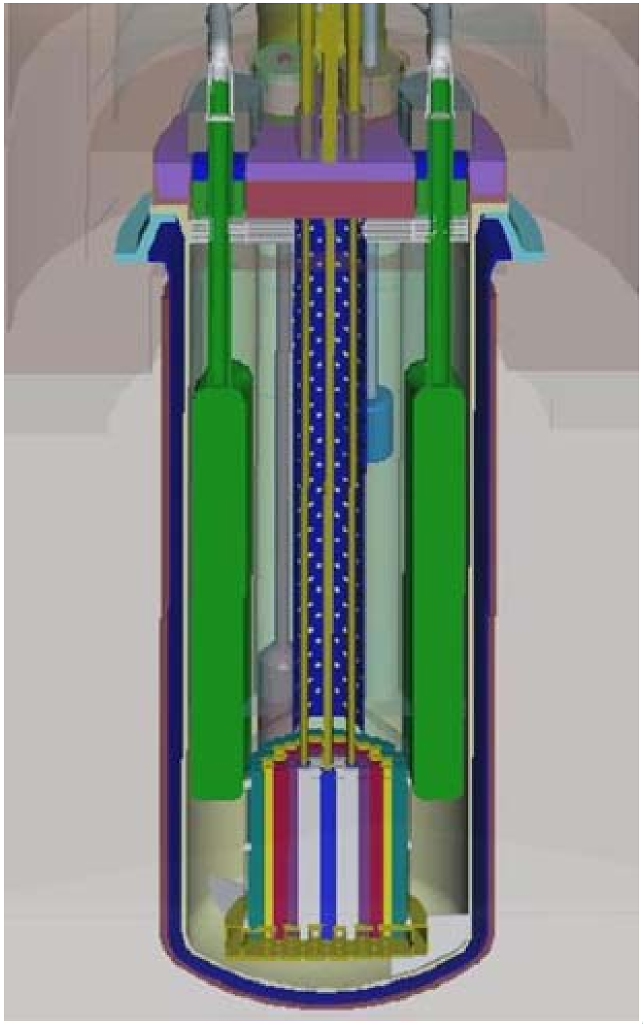
- **Directed by Department of Energy Office of Nuclear Science & Technology**
- **Organized by a Technical Integration Office at the Idaho National Laboratory**
- **Work organized into Six working areas:**
  - **1) Systems Analysis**
  - **2) Separations**
  - **3) Fuels**
  - **4) Reactor**
  - **5) Safeguards**
  - **6) Waste Forms**
- **With Two Cross Cutting Areas:**
  - **1) Advanced Modeling and Simulation**
  - **2) Regulation and Safety**

Fast Reactor Technology Development

- **Four needs have been identified:**
  - **Closed fuel cycle demonstration – The application of transmutation fuels containing the entire mix of transuranics with recycle must be demonstrated.**
  - **Establish a domestic infrastructure – Reinvigorate US domestic sodium fast reactor (SFR) capabilities.**
  - **Capital cost reduction – Reduce implementation cost and commercial attractiveness of SFRs.**
  - **Reactor safety validation and licensing – Develop basis for US NRC licensing of SFRs.**

Advanced Burner Reactor Prototype

- **Sodium-cooled fast-reactor reference technology**
- **Currently developing a reference concept for deployment as a ABR prototype**
- **Startup fuel form (oxide vs metal) still to be determined**
- **Memorandum of understanding with NRC on discussion of licensing issues**



Technology Development for Next-Generation Advanced Recycling Reactor

- **Goal is to remove barriers for wide-spread deployment of advanced recycling reactors**
  - **Improved economics**
  - **Licensing and safety**
- **R&D plans include:**
  - **Advanced materials**
  - **Advanced power conversion systems**
  - **Development of advanced simulation tools**
  - **Improved nuclear data**

LWR Fuel Separations Technologies – Performance Objectives

- **Recover Uranium from spent fuel at a sufficient purity for storage for future use**
- **Separate the transuranics as a group in a solid product form – for use as transmutation fuel**
- **Separate short-lived isotopics (Cesium & Strontium) – avoid heat load in repository**
- **Recover and immobilize Technetium and Iodine – to reduce long-term repository site-boundary dose**
- **Recover and immobilize other fission gases – to mitigate environmental issues**
- **Provide robust waste forms – for long term repository storage**

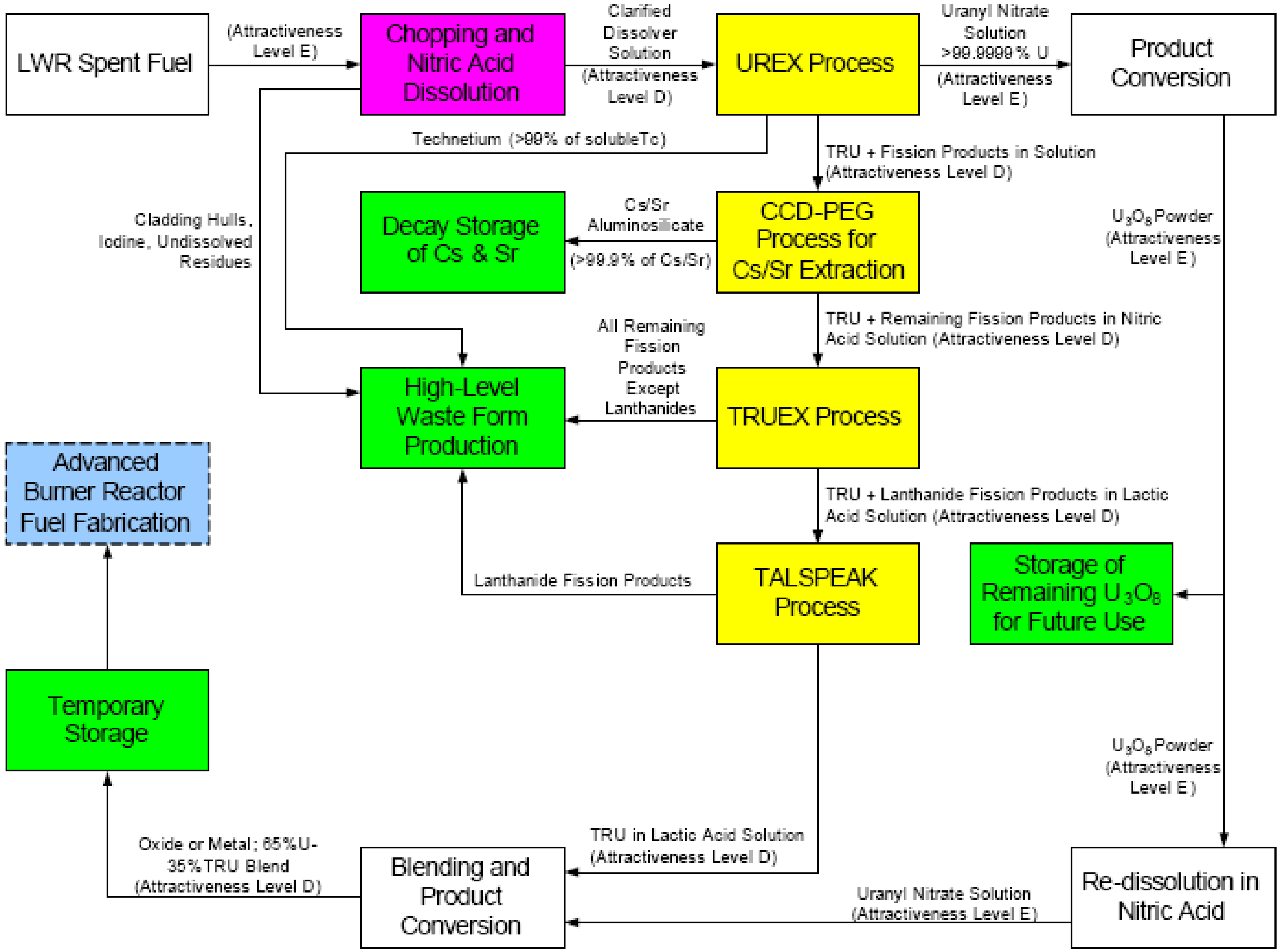
Suite of UREX+ Processes

Process	Prod #1	Prod #2	Prod #3	Prod #4	Prod #5	Prod #6	Prod #7
UREX+1	U	Tc	Cs/Sr	TRU+Ln	FP		
UREX+1a	U	Tc	Cs/Sr	TRU	All FP		
UREX+2	U	Tc	Cs/Sr	Pu+Np	Am+Cm+Ln	FP	
UREX+3	U	Tc	Cs/Sr	Pu+Np	Am+Cm	All FP	
UREX+4	U	Tc	Cs/Sr	Pu+Np	Am	Cm	All FP

Notes: (1) in all cases, iodine is removed as an off-gas from the dissolution process.
(2) processes are designed for the generation of zero liquid high-level wastes

U: uranium (removed in order to reduce the mass and volume of high-level waste)
Tc: technetium (long-lived fission product, prime contributor to long-term dose at Yucca Mountain)
Cs/Sr: cesium and strontium (primary short-term heat generators; repository impact)
TRU: transuranic elements (Pu: plutonium, Np: neptunium, Am: americium, Cm: curium)
Ln: lanthanide (rare earth) fission products
FP: fission products other than cesium, strontium, technetium, iodine, and the lanthanides

UREX+1a Reference Process



Transmutation Fuels and Separation Technologies

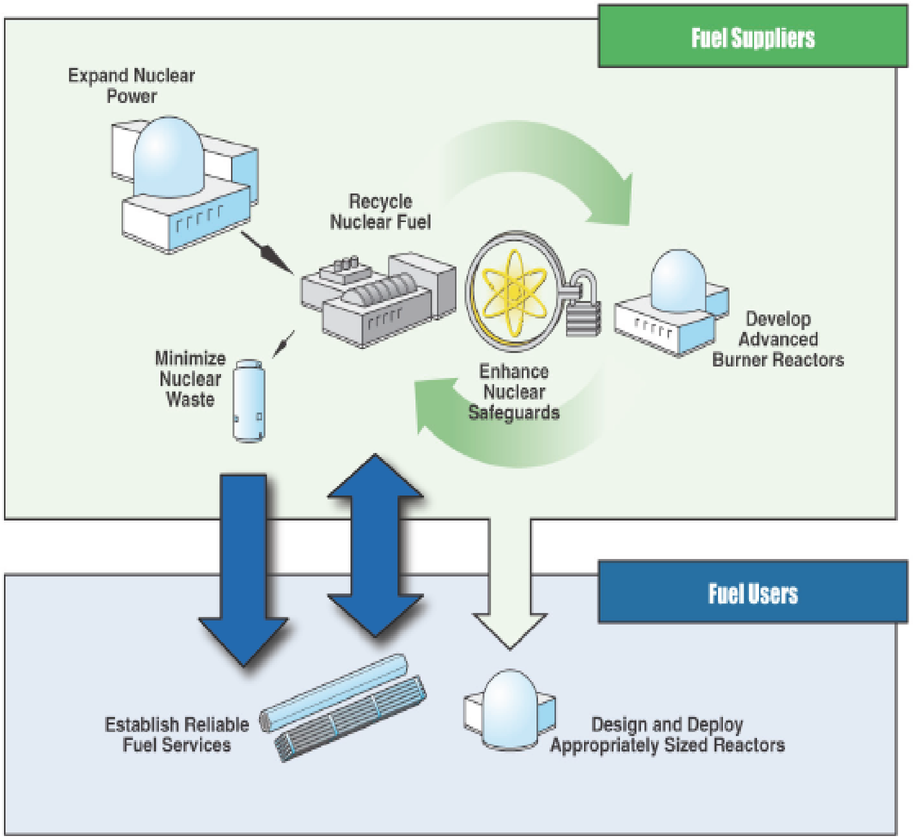
- **Fabrication of SFR fuel from spent LWR fuel and recycled fast-reactor fuel**
- **Considering both aqueous and pyro-processing**
- **Considering oxide and metal TRU fuels, homogeneous and heterogeneous (targets)**
- **Utilizes the AFCF for technology development and demonstration**

Need for Fast-Flux Irradiation Facility

- **Development of transmutations will require a fast-spectrum facility for fuels irradiation**
  - **Desire ~10^{15} n/cm^2-s fast flux (> 0.1 MeV)**
- **The US has no fast reactors to perform such irradiations (last operating facility, FFTF, shut down)**
- **Key area for international collaboration**
  - **Phenix (to be shutdown in 2008-2009) (France)**
  - **JOYO, MONJU (Japan)**
  - **BOR60 (Russia)**
- **Proposed concepts to fill the gap:**
  - **Material Test Station at LANSCE accelerator (LANL)**
  - **Advanced Test Reactor with fast flux booster (INL)**
  - **High Flux Isotope Reactor with thermal shields (ORNL)**

Grid-Appropriate Reactors

- **Support nuclear power in developing countries and regions**
- **Supported with assured fuel supply**
- **Not all locations can accommodate or need 1000 MWe power plants**
- **Have different requirements than large power reactors:**
  - **50 – 350 MWe**
  - **Require minimal nuclear infrastructure**
  - **Safe and secure**
  - **IAEA Safeguards**

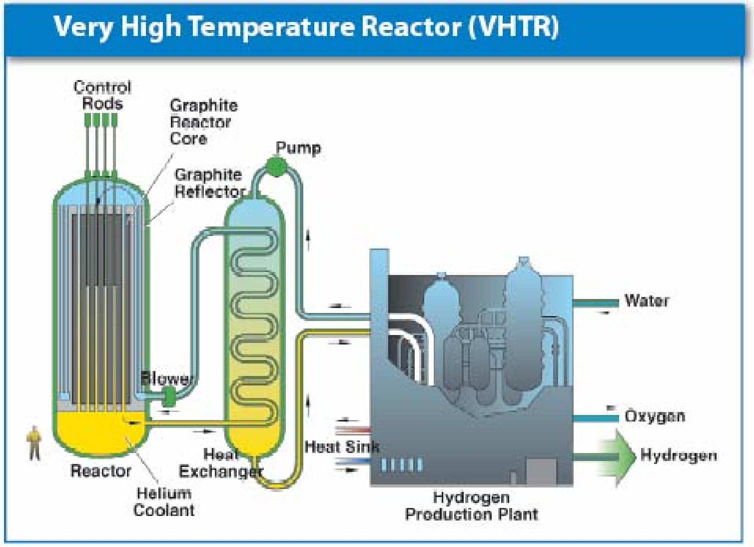


International Collaboration

- Agreements with several countries on joint R&D to support GNEP goals
- Recent joint statement by Peoples Republic of China, France, Japan, Russia, and United States in support of GNEP and nuclear energy cooperation
- Strong desire to share research facilities needed to develop the advanced fuel cycle
- Potential for international development of demonstration facilities.

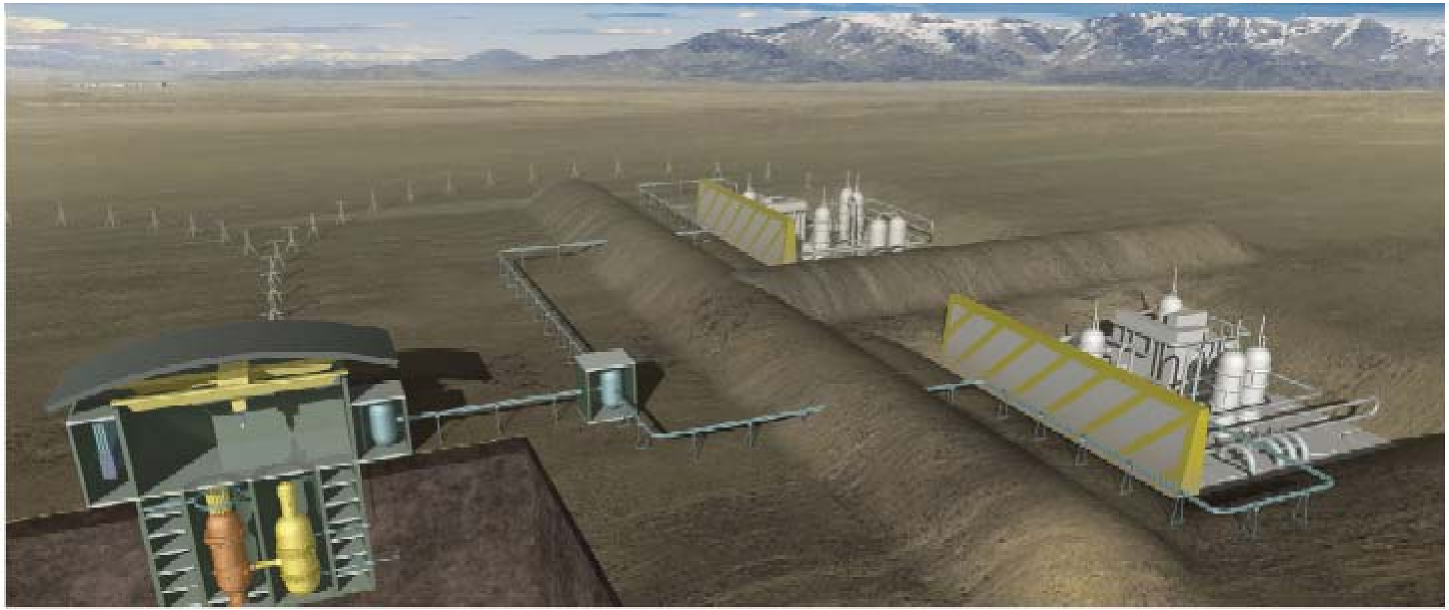
Next Generation Nuclear Plant

- **High temperature, graphite-moderated, gas-cooled reactor**
- **Pebble bed or prismatic core design**
- **Produce high-temperature process heat for electricity production, hydrogen production or other industry applications**
- **R&D Activities:**
  - **High temperature materials**
  - **Nuclear grade graphite**
  - **Coated particle fuels**
  - **High-temperature heat exchangers**



NGNP Current Activities

- **Conducting pre-conceptual design studies**
- **Development of licensing strategy**
- **Irradiation of fuels and graphite**
- **Expanding industrial collaboration**



Summary

- **The US has a strong commercial nuclear power industry with significant potential for near-term growth.**
- **The Global Nuclear Energy Partnership is leading to the development of a closed fuel cycle for:**
  - **Sustainable nuclear power growth**
  - **Minimization of waste and needs for repositories**
  - **Strengthening proliferation resistance**
- **Significant international collaboration is necessary for GNEP to be successfully implemented**
- **NGNP program developing reactor for high-temperature process heat applications**