



U.S. DEPARTMENT OF  
**ENERGY**

**Nuclear Energy**

## **U.S. DOE Nuclear Energy R&D Roadmap Overview**

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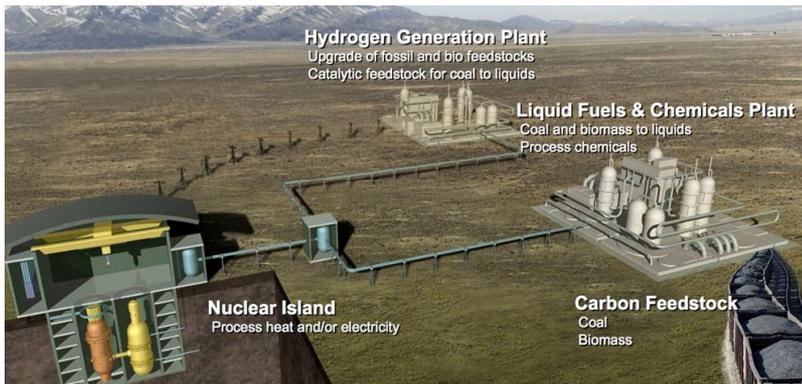


# Office of Nuclear Energy Mission



- The primary mission of NE is to advance nuclear power as a resource capable of making major contributions in meeting the nation's energy supply, environmental, and energy security needs by resolving technical, cost, safety, security and regulatory issues, through research, development, and demonstration (RD&D).

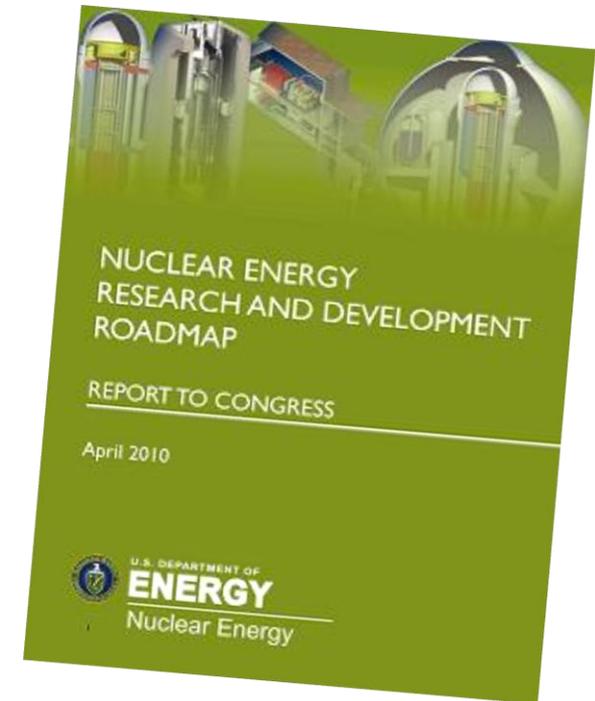
- Objective is to enable the development and deployment of fission power systems for
  - Production of electricity (MWh)
  - Process heat (BTUs)





## Nuclear Energy

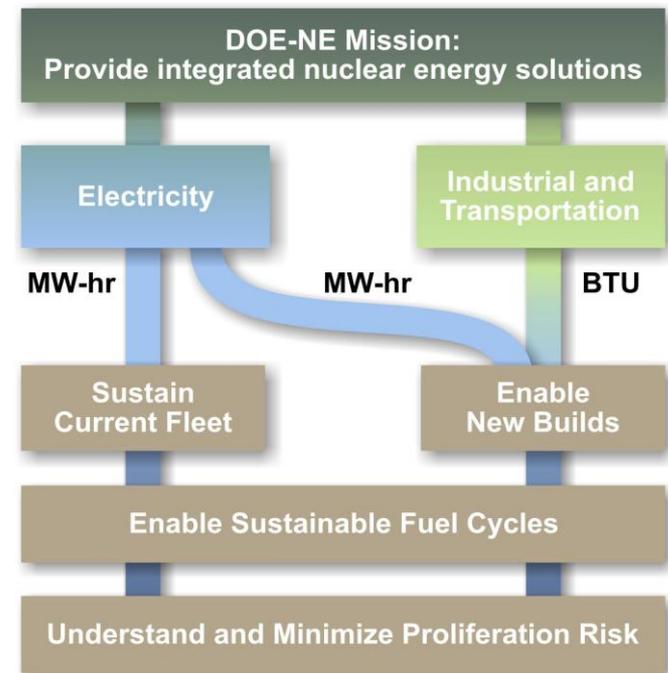
- **Nuclear energy objectives were developed to focus resources on national imperatives for clean energy, economic prosperity, and national security.**
- **Contribution of nuclear power to U.S. energy mix must increase significantly to meet these aggressive objectives.**
  - Internal and external studies project growth on the order of 50 to 100 GWe by 2030.
- **NE Roadmap outlines an integrated approach to meet objectives.**
- **Roadmap addresses transformation of NE programs to a more science-based approach.**





## Nuclear Energy

- **Develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors**
- **Develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals**
- **Develop sustainable nuclear fuel cycles**
- **Understand and minimize the risks of nuclear proliferation and terrorism**

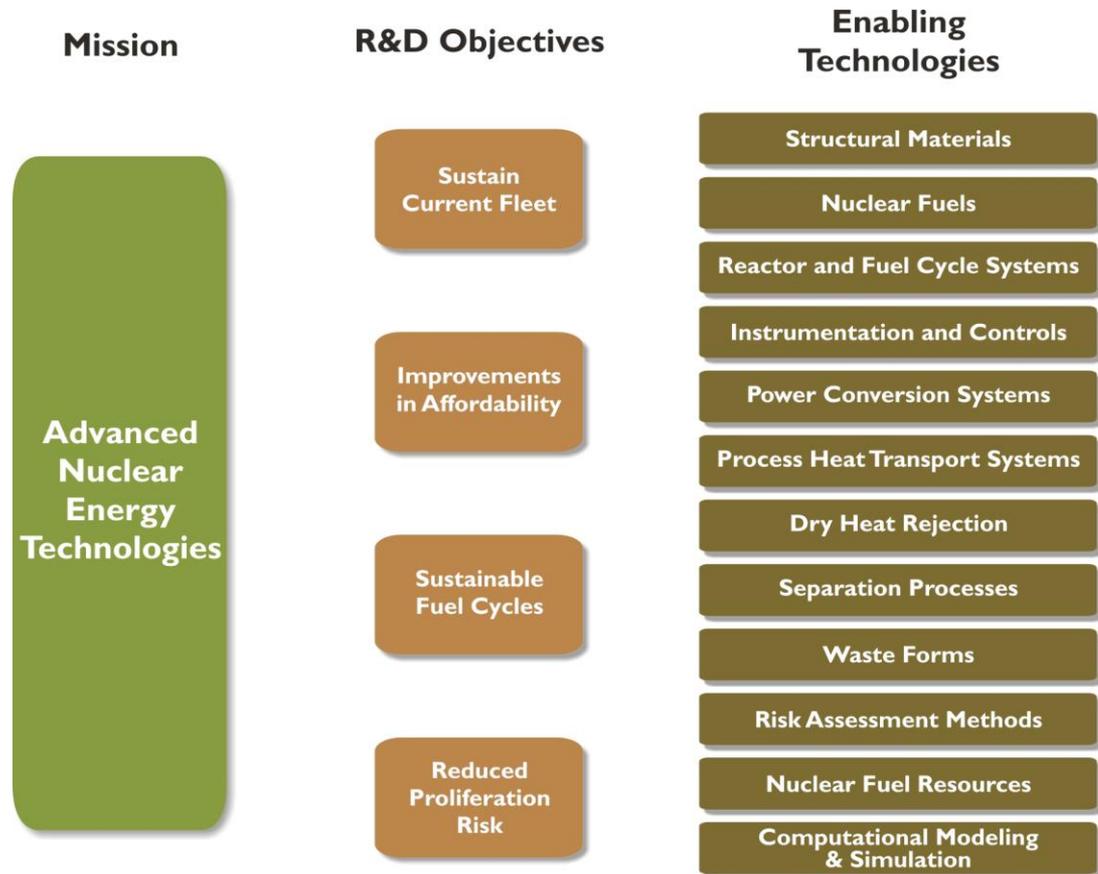


**More detail talks to follow – Reactor Analysis is included in all Objectives**



# Nuclear Energy Research and Development

- Roadmap is objective focused to enable advance nuclear technologies.
- Plan incorporates a portfolio of long-term R&D objectives and a balanced focus on evolutionary, innovative, and high-risk–high-payoff R&D in many diverse areas.

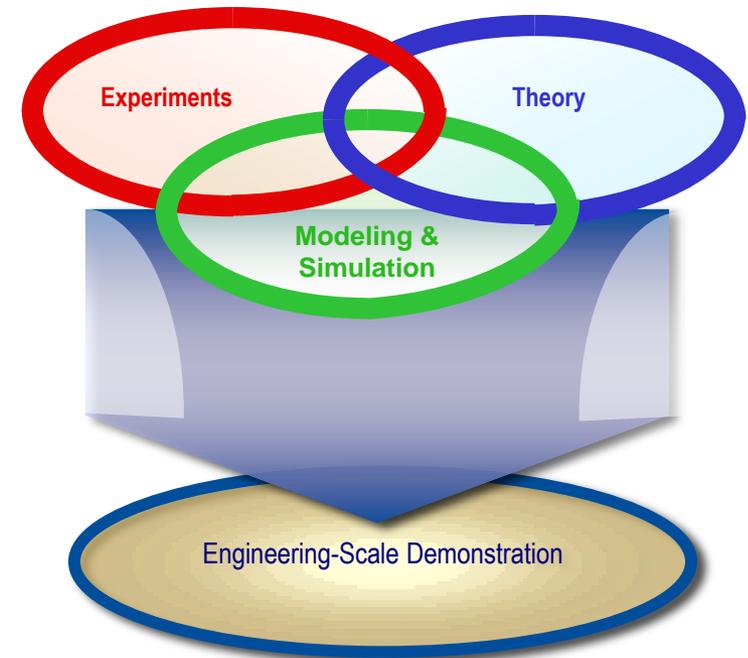




# Science-Based Approach to Nuclear Energy Development

## Nuclear Energy

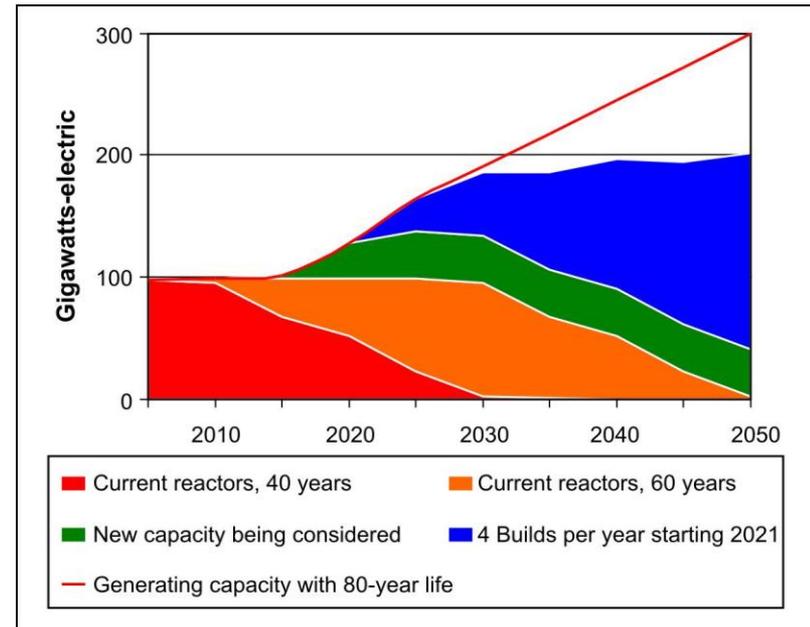
- **Experiments** – Physical tests to develop understanding of single effects or integrated system behaviors.
- **Theory** – Creation of models of physical behaviors based on understanding of fundamental scientific principals and/or experimental observations.
- **Modeling and Simulation** – Use of computational models to develop scientific understanding of the physical behaviors of systems. Also used to apply scientific understanding to predict the behavior of complex physical systems.
- **Demonstrations** – New technologies, regulatory frameworks, and business models integrated into first-of-kind system demonstrations that provide top-level validation of integrated system technical and financial performance.





## Nuclear Energy

- **Goal is to extend plant life beyond 60 years with improved performance**
- **Challenges**
  - Aging and degradation of system structures and components
  - Fuel reliability and performance
  - Obsolete analog instrumentation and control technologies
  - Design and safety analysis tools based on 1980's vintage knowledge bases and computational capabilities





## Nuclear Energy

### ■ Goals

- Demonstrate 10 CFR Part 52 licensing framework
- Facilitate accelerated licensing of small modular reactors
- Facilitate development and demonstration of advanced manufacturing and construction technologies
- Develop and demonstrate next generation advanced plant concepts and technologies



### ■ Challenges

- Financial hurdles associated with new plant
- Deploy small reactors to reduce up front capital costs
- Develop plant designs that address industrial needs
- Develop new regulatory frameworks

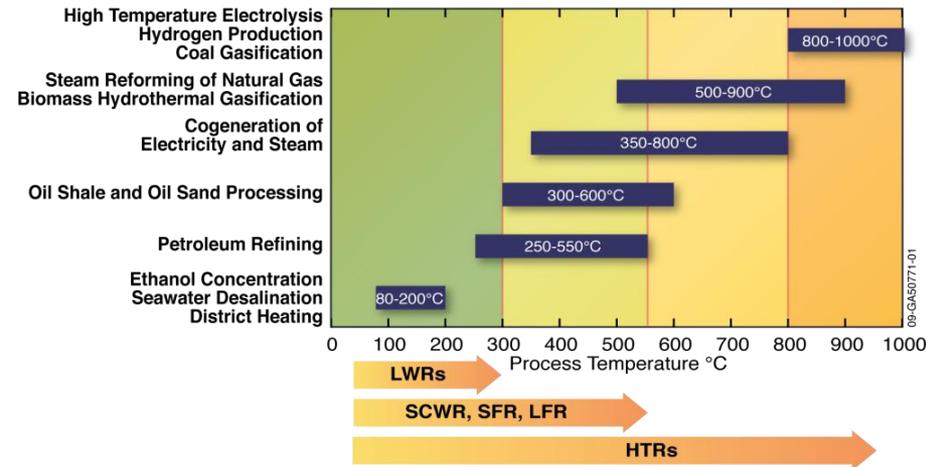


# New Builds to Support Transition from Fossil Fuels

## Nuclear Energy

### ■ Goals

- Use existing technology to reduce greenhouse gas emission
- Develop and qualify technologies to provide process heat
- Develop interfacing systems for industrial and transportation sectors
- Establish basis for licensing high temperature reactors



### ■ Challenges

- Providing process heat to industry will require: Higher temperature reactors, efficient heat transport systems, interface systems for control and isolation, and a robust licensing case.
- Institutional differences exist between transportation, industrial, and electric power sectors.
- High temperature reactors will generate used fuels that are not in the present fuel cycle.



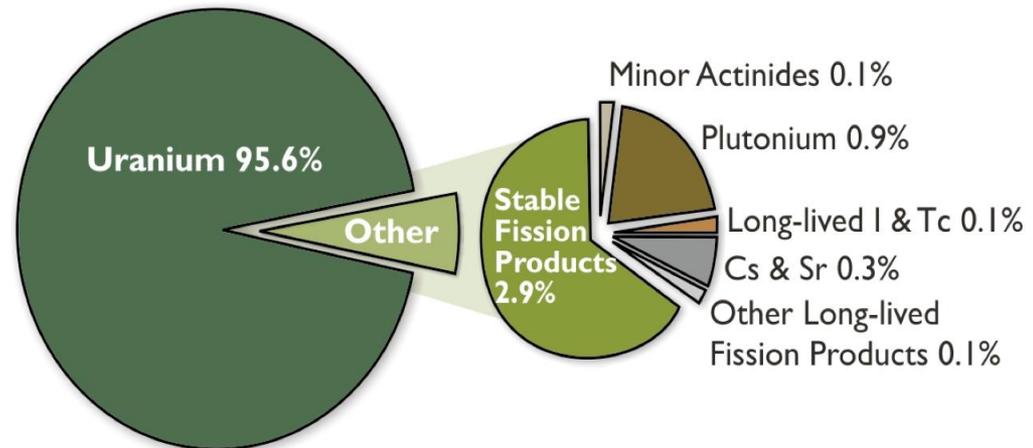
# Objective 3: Sustainable Fuel Cycles

## ■ Goals

- In the near term, define and analyze fuel cycle technologies to develop options that increase the sustainability of nuclear energy
- In the medium term, select preferred fuel cycle option for further development
- By 2050, deploy preferred fuel cycle

## ■ Challenges

- Develop high burnup fuel and structural materials to withstand irradiation for longer periods of time
- Develop simplified separations, waste management, and proliferation risk reduction methods
- Develop optimized systems to maximize energy production while minimizing waste





# Bases for Fuel Cycle Research and Development Program (FCRD)

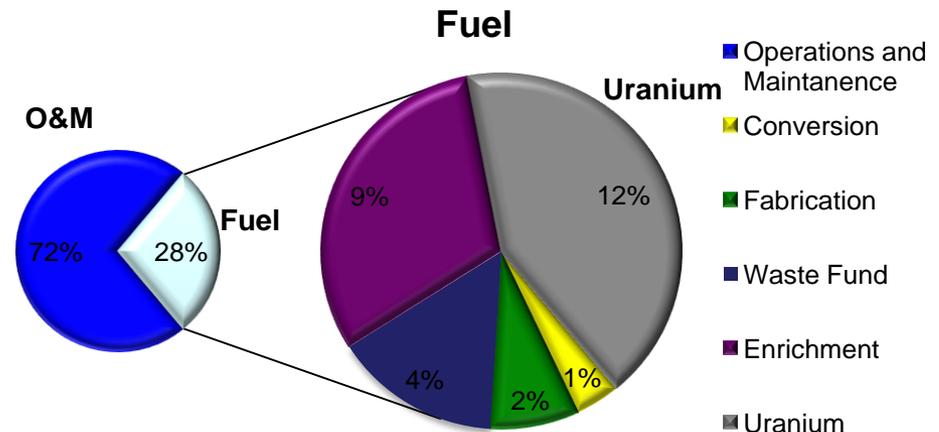
- **Dry cask storage is safe, and used nuclear fuel can be stored for at least 60 years.**
  - R&D includes work on long-term storage.
- **From safety perspective, there is not an urgency to implement a final fuel cycle.**
  - There is time to pursue R&D to assess better approaches.
- **The once-through fuel cycle is the baseline.**
  - Options will be evaluated against the baseline.
  - Final choice may include both once-through and reprocessing.
- **At least one repository will be needed for all options.**
- **Blue Ribbon Commission will provide a policy/planning framework that will guide FCRD.**



## Nuclear Energy

- Technology readiness
- Costs of reactor systems
- Availability/costs of uranium
- Repository issues (capacity, availability, costs, geological media, etc.)
- Proliferation risks
- Social issues (intergenerational equity, resource stewardship, repository siting, etc.)
- Etc.

### Contributions to the Costs of Electricity from Operating Nuclear Power Plants



- Average cost of operating plants is approximately 2 cents per kilowatt-hour (NEI).
- Uranium cost will be a smaller fraction of new plants costs.

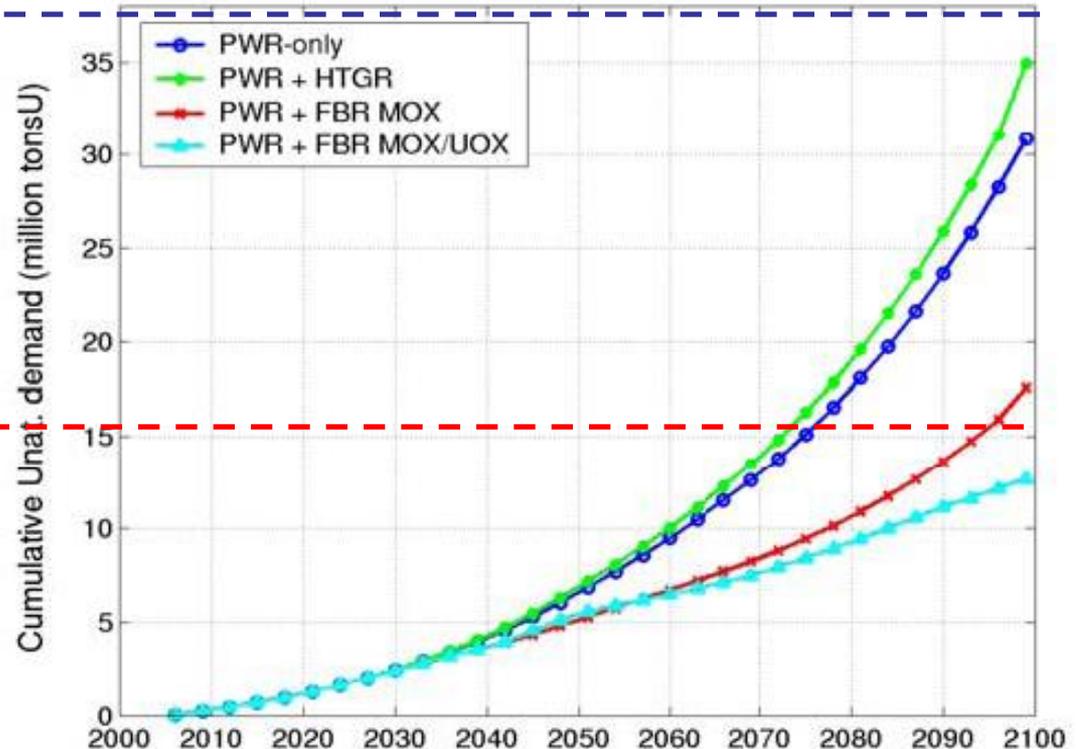


# Uranium Requirements Through 2100

The figure\* presents cumulative **world** uranium consumption for scenarios ranging from once through (30-35 million tons) to a transition to breeders beginning in 2040 (13 million tons).

Redbook Resources  
+  
Phosphates

Redbook Resources

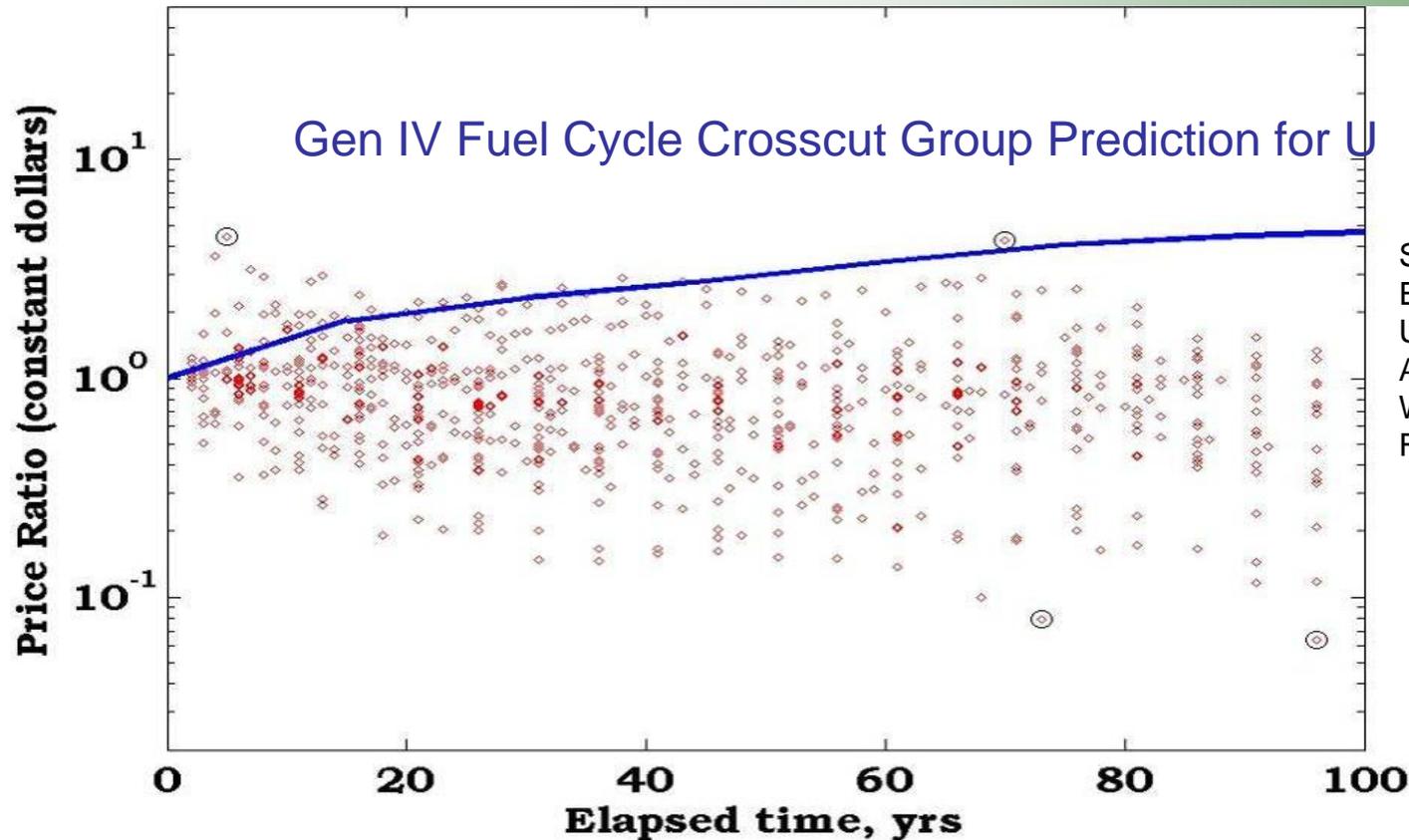


World nuclear power demand obtained from WEC/IIASA "Global Energy Perspectives" A-3 Scenario.

\*Carre and Delbecq, "French Fuel Cycle Strategy and Transition Scenario Studies," Proc. PHYSOR 2006.



# Price For Many (34) Minerals vs. Time...



Slide Material from  
Erich Schneider -  
University of Texas,  
ANTT Meeting,  
Washington, DC,  
February 19, 2009

US Geologic Survey data. Price Ratio = current price of the mineral divided by price of the mineral in year 1 (1900 or first year data are available).

Mineral prices have dropped over the past century.



# Three Potential Fuel Cycle Options

## ■ Once-Through

- No recycling or conditioning of used fuel
- Low uranium utilization
- Appropriate for a low price uranium future
- Appropriate when repository capacity and/or actinide loadings are not show stoppers

## ■ Full Recycle

- Multiple reprocessing steps and transmutation of actinides
- “Complete” uranium utilization (with breeder)
- Appropriate for high price uranium future
- Appropriate when repository capacity and/or actinide loadings are show stoppers

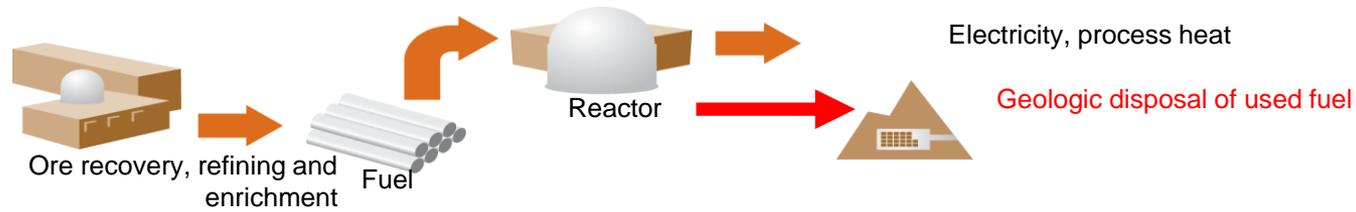
## ■ Modified Open Cycle

- Very limited used fuel conditioning or processing (e.g., recladding)
- High uranium utilization and burnup (i.e., used fuel is spent fuel)
- Appropriate for a high price uranium future or intent to better utilize domestic resources
- Appropriate when major constraint is on repository capacity (e.g., heat loading, geologic media)
- Appropriate when actinide loading is not a show stopper

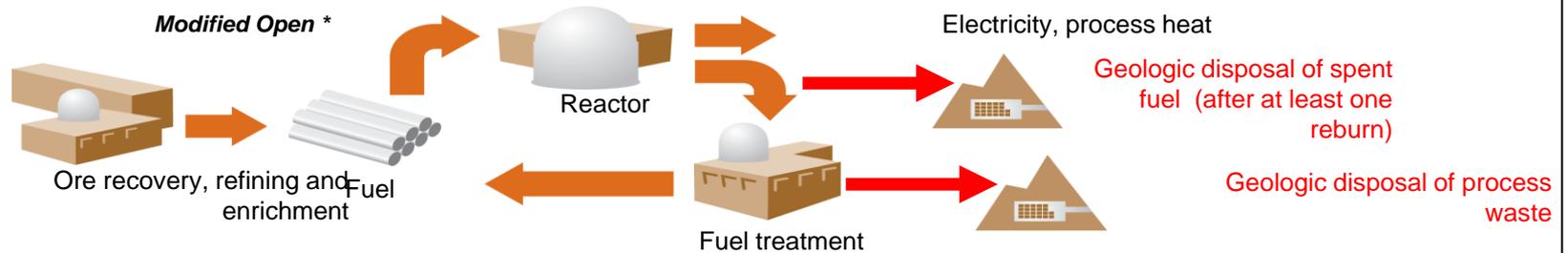


# Three Potential Fuel Cycle Options (cont'd)

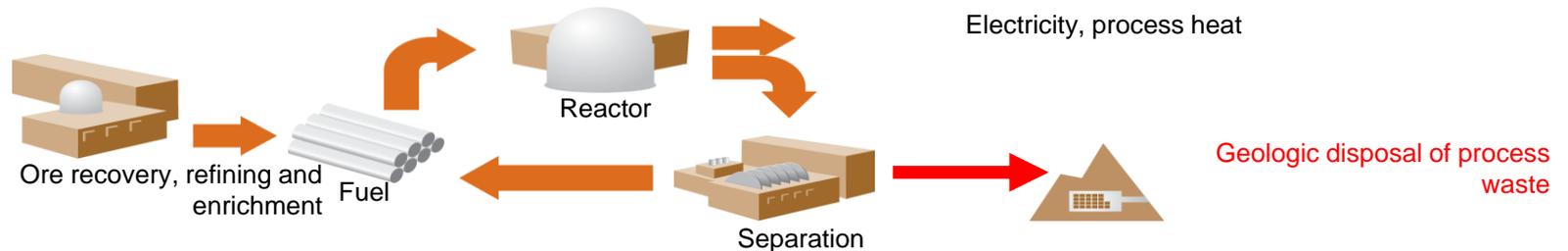
## Once-Through (Open)



## Modified Open \*



## Full Recycle (Fully Closed) \*



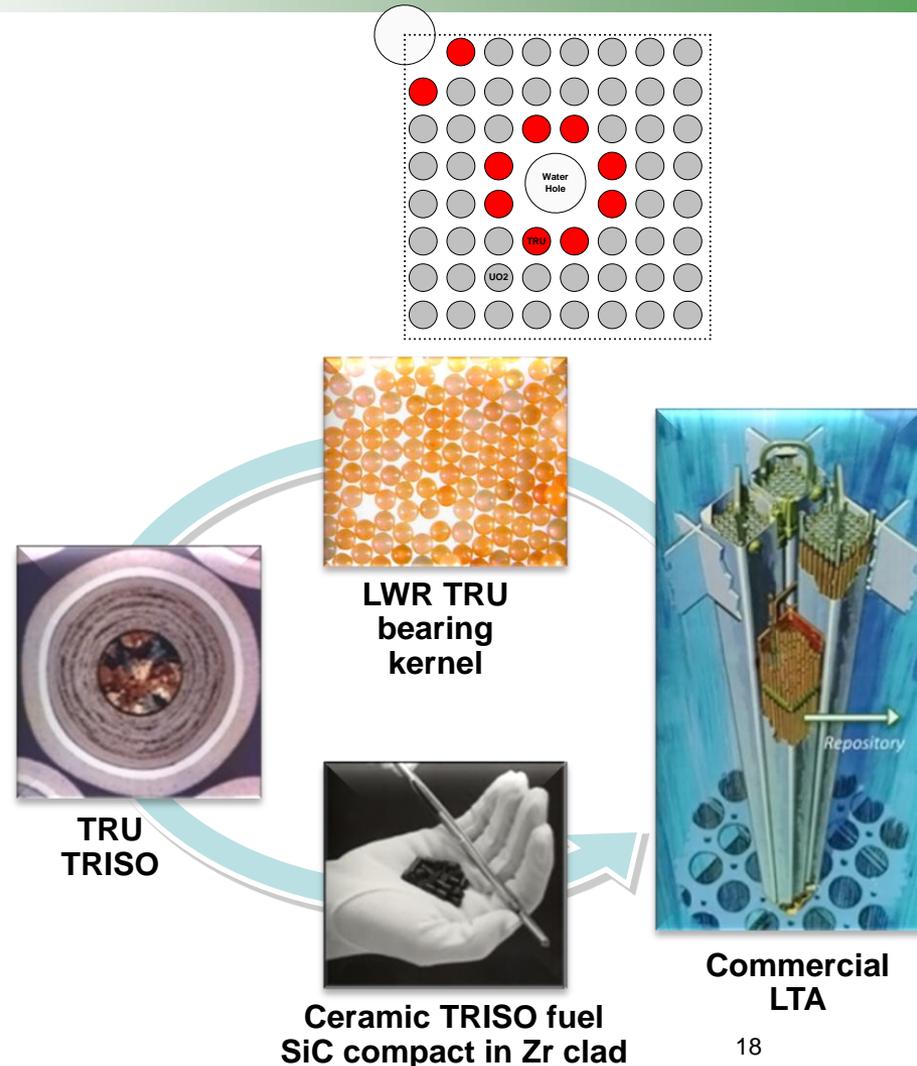
\*A specific fuel cycle strategy may include more than one fuel design, reactor design, or fuel treatment process.





# Example Modified Open Cycle – Deep Burn

- Deep Burn concept is exploring the feasibility of SiC-matrix TRISO fuel to burn transuranics.
- Materials could potentially be burned in existing LWRs or high-temperature gas reactors.
- Fuel from existing LWRs would be reprocessed to recover the transuranics for burning.
- Deep burn will result in some increase in uranium utilization, but total utilization is still low.
- Challenges include
  - High burnup fuels
  - End of life materials management



# Objective 4: Understand and Minimize Proliferation Risk

- **Goal is limiting proliferation and security threats by protecting materials, facilities, sensitive technologies and expertise.**
- **Challenges**
  - Develop proliferation risk assessment methodologies and tools
  - Minimize potential for misuse of technology and materials
  - Develop highly reliable, remote, and unattended monitoring technologies
  - Design improved safeguards into new energy systems and fuel cycle facilities
  - Develop advanced material tracking methodologies



- **Office of Civilian and Radioactive Waste Management to disband as an organization on October 1, 2010.**
- **DOE-NE absorbs the core responsibility for the technical work associated with implementation of the Nuclear Waste Policy Act.**
- **Blue Ribbon Commission recommendations will influence U.S. policy, and any corresponding changes in programmatic direction will influence Nuclear Energy Roadmap.**
- **DOE-NE stands ready to provide requested support to the Blue Ribbon Commission.**