U.S. DEPARTMENT OF ENERGY | Nuclear Energy

U.S. Nuclear Energy Research and Development: Moving to a Long-Term, Science-Based, Goal-Oriented Program

11th Information Exchange Meeting on Actinide and Fission Product Partitioning and Transmutation
San Francisco, CA

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For Fuel Cycle Technologies

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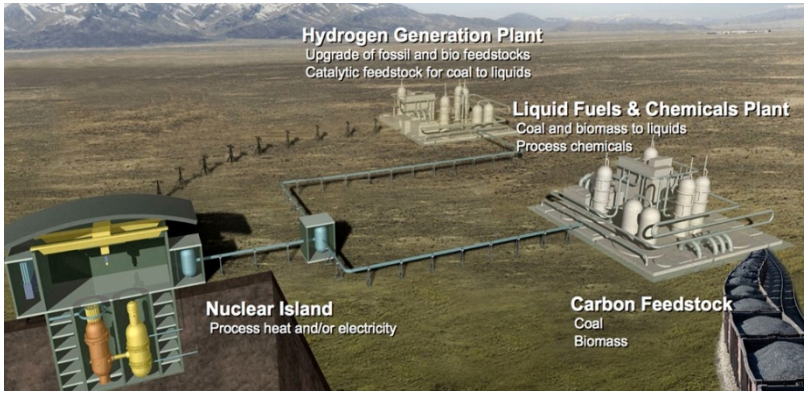
Office of Nuclear Energy Mission



- **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 (MWe)
  - Process heat (BTUs)

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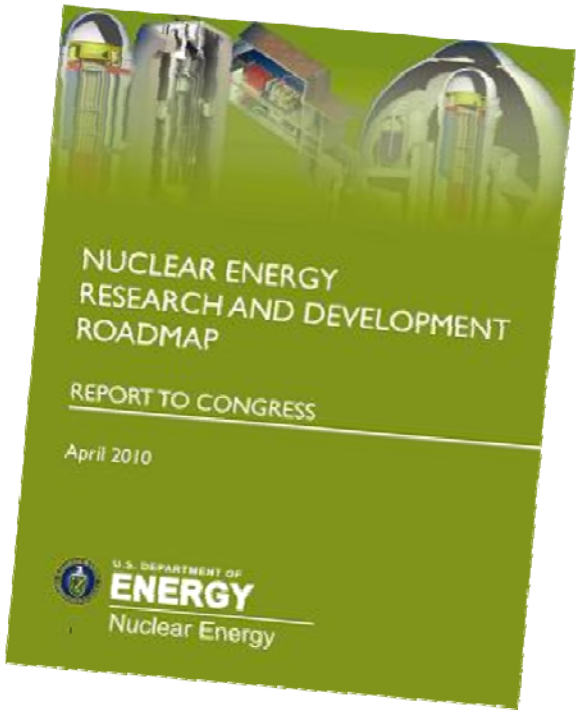
Nuclear Energy R&D Roadmap

- **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.**

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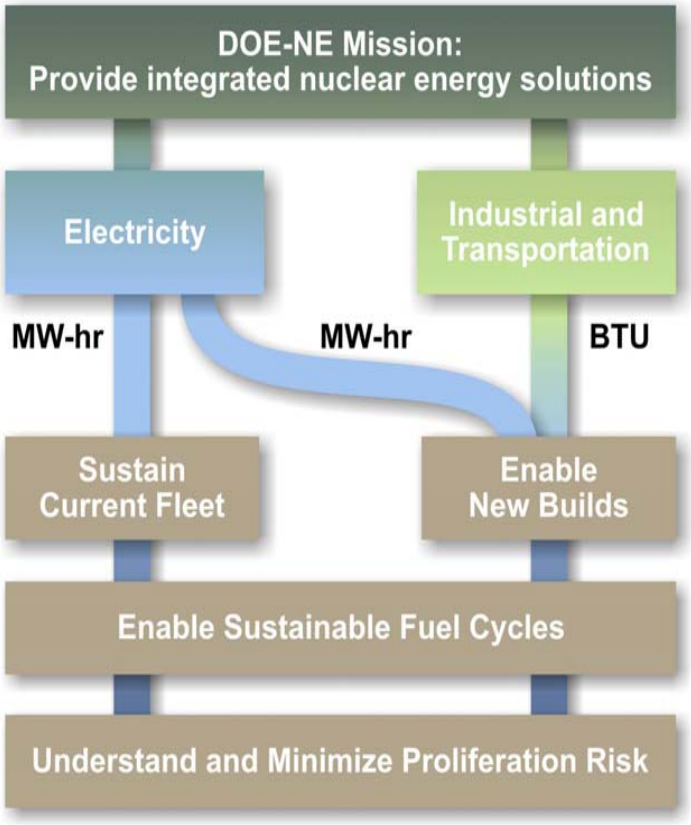
Nuclear Energy R&D Objectives

1. **Extend life, improve performance, and sustain health and safety of the current fleet**
2. **Enable new plant builds and improve the affordability of nuclear energy**
3. **Enable sustainable fuel cycles**
4. **Understand and minimize proliferation risk**



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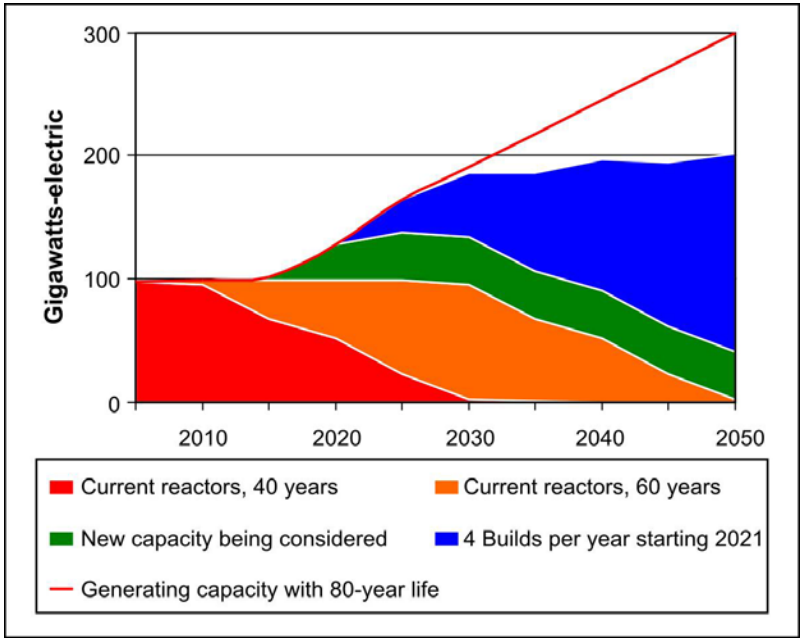
Objective 1: Life Extension

- **Goal is to provide technical basis 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



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Objective 2: New Nuclear Builds

- **Goals**
  - Facilitate development and demonstration of advanced manufacturing and construction technologies
  - Develop and demonstrate next generation advanced plant concepts and technologies
  - Includes Gen IV concepts (VHTR, SFR) and small modular reactors

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

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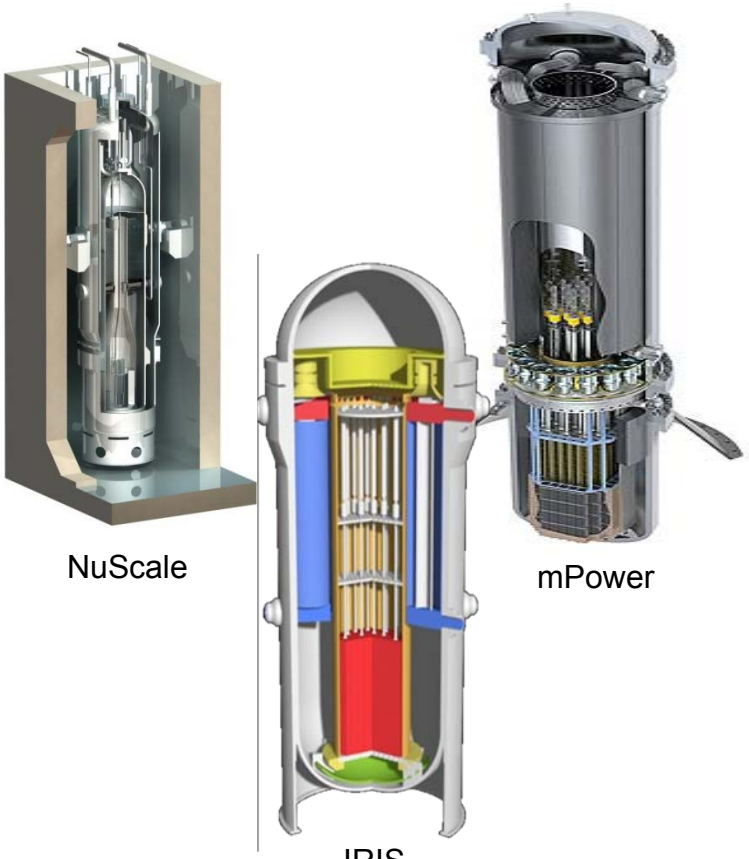
Small Modular Reactors

- Explore advanced SMR concepts and develop advanced technologies that enable/enhance new SMR designs
- Establish cost-share partnerships with industry for LWR-based SMR designs which can be NRC licensed in the near-term
- Emphasis on simplified operation and maintenance, enhanced functionality, and increased proliferation resistance and security
- Major areas of R&D will include:
  - Basic physics, materials, fuels, I&C, and fabrication research and testing
  - Modeling and simulation of reactor systems and components
  - Probabilistic risk analyses of innovative design features and safety systems



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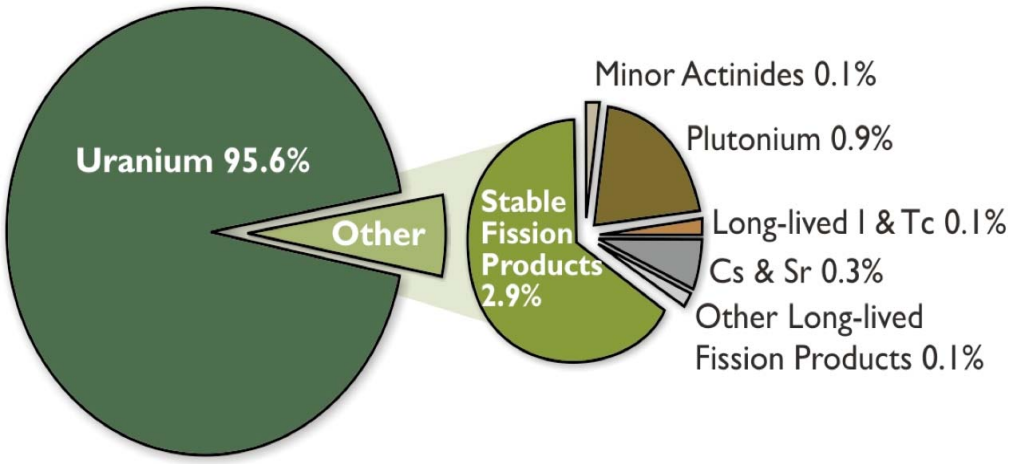
Objective 3: Sustainable Fuel Cycles

- **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 options for further development
  - By 2050, deploy preferred sustainable fuel cycle

- **Challenges**
  - Develop high burnup fuels 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



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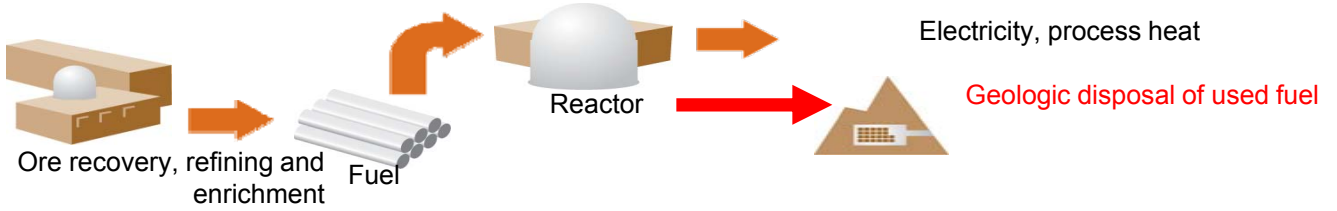
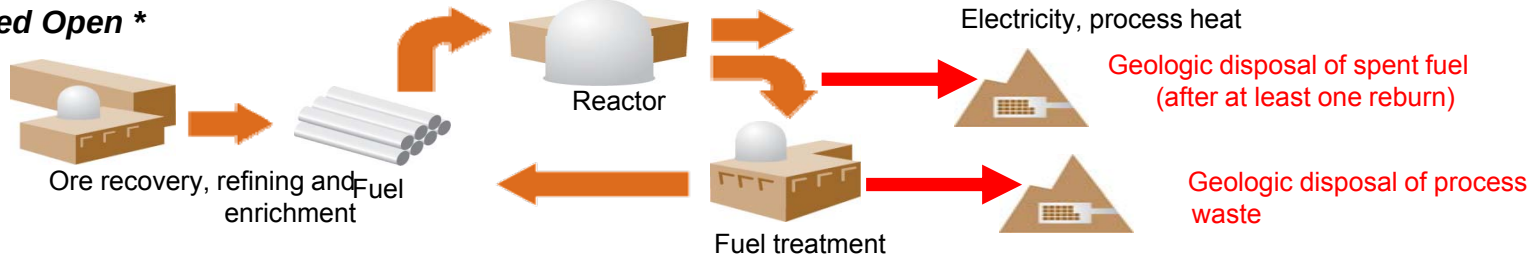
Potential Fuel Cycle Strategies

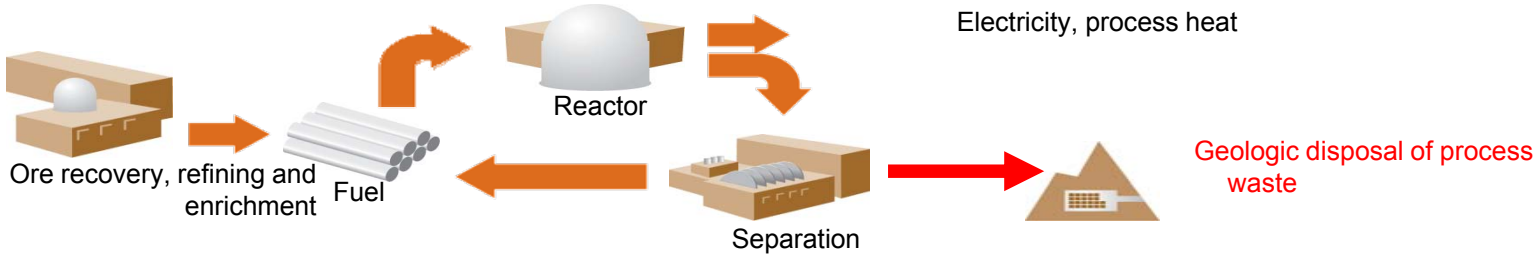
Once-Through (Open)



Modified Open *



Full Recycle (Fully Closed) *



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

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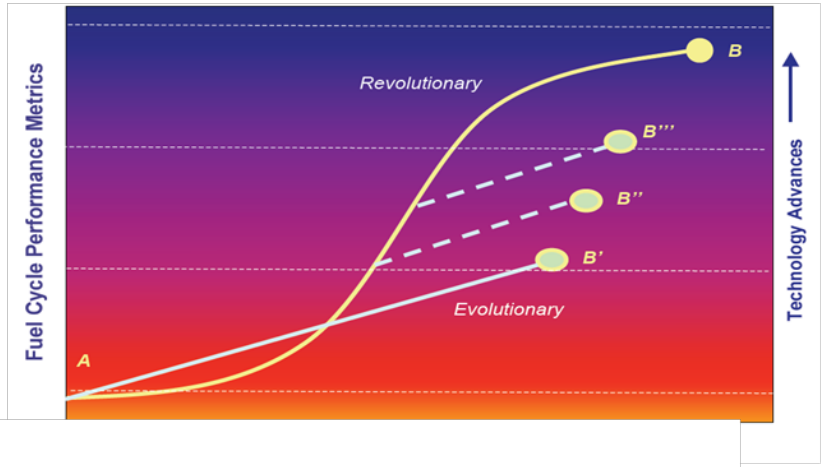
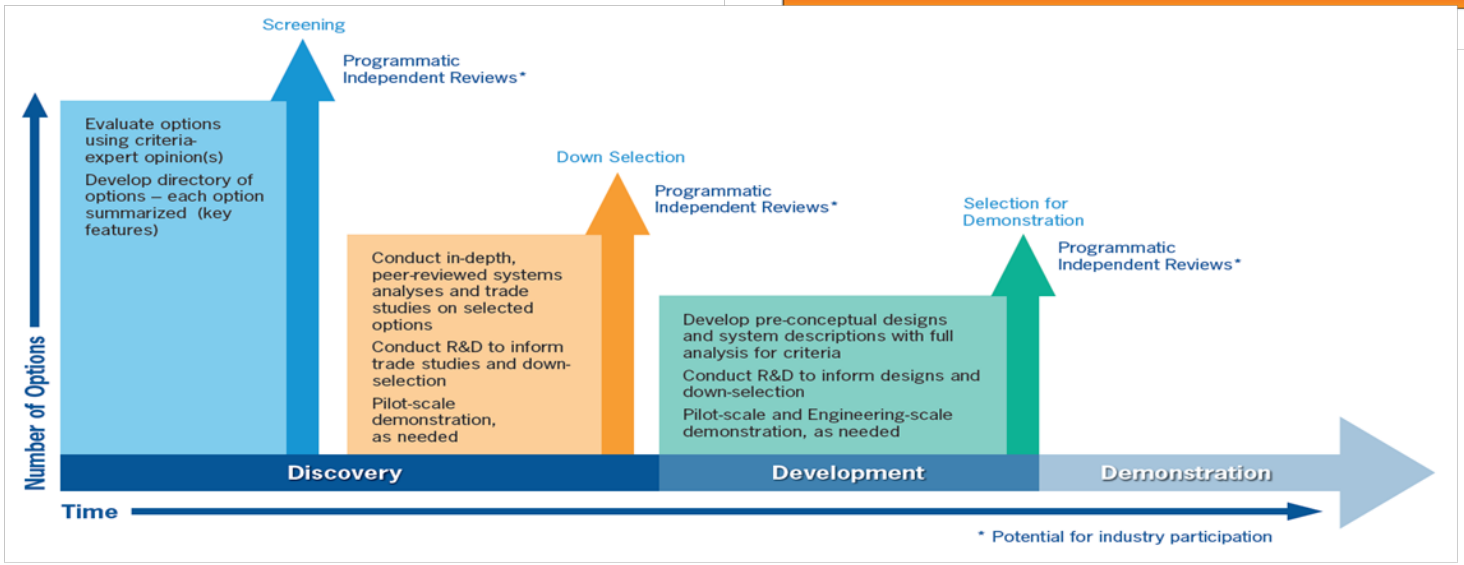
Implementation Strategy

- **A dual-path approach for technology development simultaneously pursuing evolutionary and revolutionary tracks. >>>**
- **A science-based approach for conducting R&D.**
- **Integration through application of systems engineering tools.**





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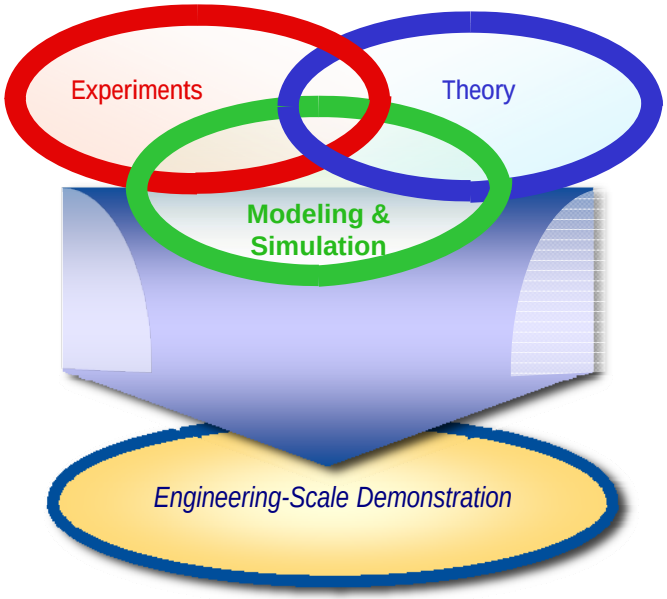
Science Based Approach to Nuclear Energy Development

- ***Experiments*** **– Physical tests done to develop understanding of single effects or integrated system behaviors.**
- ***Theory*** **– Creation of models (i.e., theories) of physical behaviors based on understanding of fundamental scientific principles 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-a-kind system demonstrations that provide top-level validation of integrated system technical and financial performance.**



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Fuel Cycle R&D - Systems Engineering and Analysis

- ***Systems engineering approach to manage technology options and prepare for down selection***
  - *Functions and requirements for fuel cycle technology systems*
  - *Comprehensive catalog of fuel cycle options*
  - *Evaluation criteria and methodology for option screening and down selection*
  - *Risk and opportunity management*

- ***Systems analysis***
  - *Conduct systems analyses, optimization, and trade off studies*
  - *Develop and maintain analysis and communications tools*
  - *Develop an advanced fuel cycle simulator to support decision making, communications, and education*

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Fuel Cycle Research and Development

- ***Separations and Waste Forms***
  - *Explore advanced aqueous, pyrochemical and new innovative separations R&D*
  - *Minimize reprocessing, waste generation, and potential for material diversion.*
  - *Develop waste forms for different waste streams and disposal environments.*

- ***Advanced Fuels***
  - *Achieve multi-fold improvements in fuel and fabrication process performance.*
  - *Challenges: higher burnups, better clads, TRU bearing fuel forms*

- ***Transmutation Research and Development***
  - *Convert long-lived radioactive isotopes into shorter-lived elements*
  - *Increase resource utilization*
  - *Includes nuclear data, non-reactor options*

- ***Materials Protection, Accounting and Control Technology***
  - *Develop technologies and analysis tools for future fuel cycles to prevent diversion or misuse.*

- ***Fuel Resources***
  - *Identify and implement actions to assure that economic nuclear fuel resources remain available in the United States.*
  - *Focusing on uranium extraction from seawater*

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Used Nuclear Fuel Disposition R&D

- **Conduct research to enable long term storage and subsequent transportation of existing and future spent fuel and waste forms.**
- **Develop a fundamental understanding of the performance of potential storage system concepts over many decades for a variety of used nuclear fuel types and radioactive waste forms.**
- **Develop a fundamental understanding of disposal system performance in a range of geologic media for potential wastes that could arise from future nuclear fuel cycle alternatives.**

Potential Disposal Options

- Surface storage
- Near surface disposal
- Deep borehole disposal
- Mined geologic disposal
  - Hard rock, unsaturated
  - Hard rock, saturated
  - Clay/shale, saturated
  - Salt, saturated
- Other (subseabed, carbonate)

Potential Waste Forms

- Used fuel
- Glass
- Ceramic/glass ceramic
- Metal alloy
- LLW, GTCC
- Other (molten salt, new waste forms)

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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

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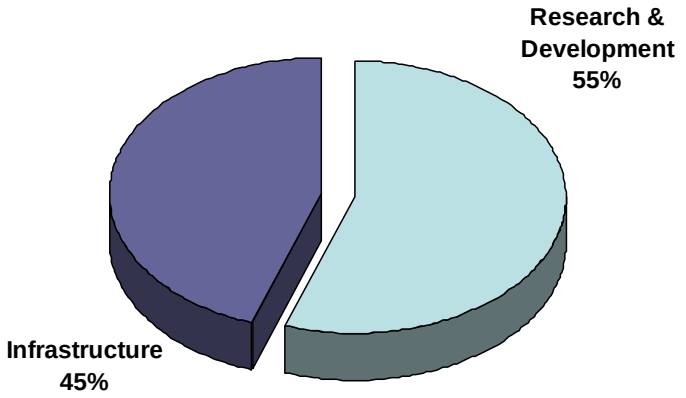
FY 2011 Budget Request
Office of Nuclear Energy

Program:	FY 2010 Approp	FY 2011 Request
Research & Development		
Nuclear Energy Enabling Technologies	0	99,300[a]
Integrated University Program	5,000	0
Re-Energyse	0	5,000
Reactor Concepts RD&D	0	195,000[a]
Generation IV Nuclear Energy Systems	220,137	0
Nuclear Power 2010	105,000	0
Fuel Cycle Research and Development	136,000	201,000[a]
International Nuclear Energy Cooperation	0	3,000
Infrastructure		
Radiological Facilities Management	72, 000	66,818
Idaho Facilities Management	173,000	162,482
Idaho Sitewide S&S	83,358	88,200
Program Direction	73,000	91,452
Congressionally Directed Projects	2,500	0
Total NE:	**869,995**	**912,252**

FY 2011 Request

Total: $912,252



a) up to 20% of R&D funds are competitively awarded to universities

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Mechanisms for International Cooperation

Bilateral:

- Peaceful Uses of Nuclear Energy Agreements (123 Agreements)
- Research and Development (R&D) Agreements
- Science and Technology (S&T) Agreements
- International Nuclear Energy Research Initiatives (I-NERI) with Republic of Korea, France, Japan,, Canada, and Euratom
- Memoranda of Understanding (MOUs)

Multilateral:

- Generation IV International Forum (GIF)
- International Framework for Nuclear Energy Cooperation (IFNEC) (infrastructure development and reliable nuclear fuel services working groups)
- International Atomic Energy Agency (IAEA)
- Nuclear Energy Agency (NEA)
- International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO)

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U.S. Direction on Future Fuel Cycles

- U.S. has decided that used nuclear fuel storage in dry casks is safe for many decades. Therefore the U.S. has no immediate need to implement used fuel reprocessing or geologic disposal.
- A "Blue Ribbon Commission" has been established to provide advice and recommendations on a broad range of technical and policy options concerning the future nuclear fuel cycle and disposal of high level waste.
- A geologic repository will be needed for high level waste disposal for all fuel cycle options
- DOE has established a goal-oriented, science based research and development program to provide used fuel management options to future decision makers.
- If the U.S. chooses to recycle, deployed technologies must be cost effective, safe, environmentally sound and have low proliferation and security risk.