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Fuel Cycle Research and Development: Moving to a Long-Term, Science-Based, Goal-Oriented Program

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Outline

- **NE Context – mission, budget, five imperatives, fuel cycle options**
- **FCR&D Technical Areas, budget**

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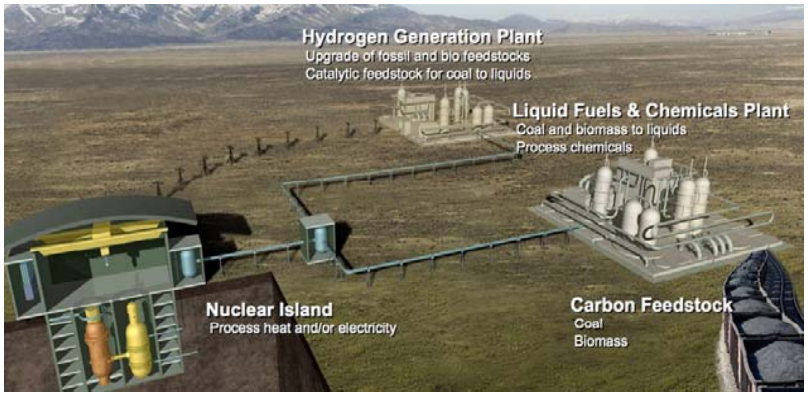
Office of Nuclear Energy Mission



- **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)

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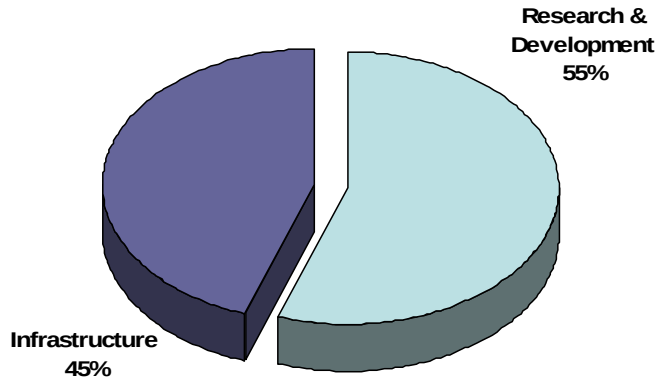
FY2011 Budget Request Breakdown ($K)

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 Funding

Total: $912,252



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

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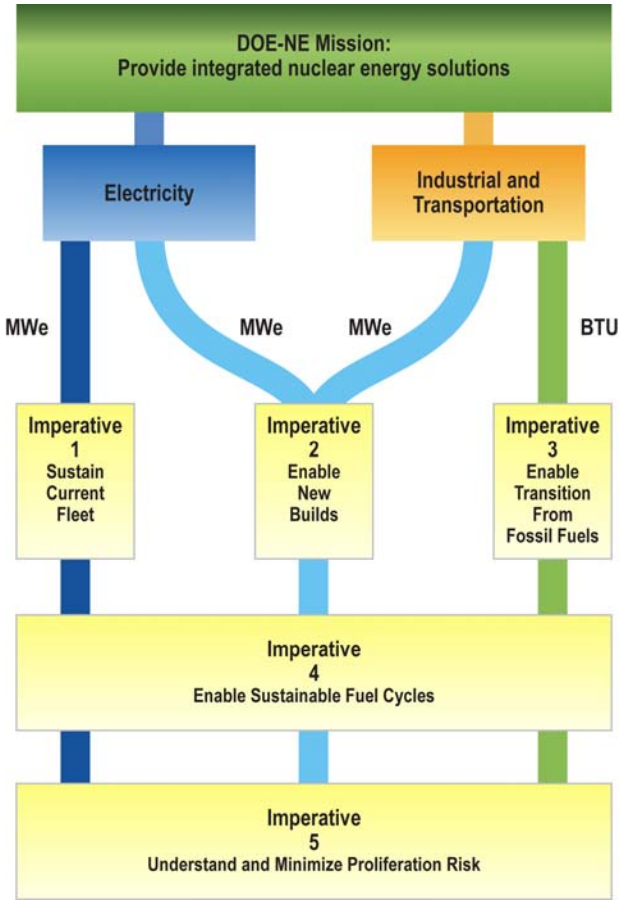
Nuclear Energy Imperatives

- **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 transition away from fossil fuels in the transportation and industrial sectors**
- **4. Enable sustainable fuel cycles**
- **5. Understand and minimize proliferation risk**



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Fuel Cycle Options

- **Once-Through Fuel Cycle – One pass through reactor, used fuel directly disposed in a geologic repository.**
- **Modified Open Cycle – No or limited separations and processing applied to used fuel to extract more energy.**
- **Full Recycle – All actinides important for waste management are recycled in thermal or fast spectrum systems to reduce radiotoxicity and more fully utilize uranium resources.**

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Fuel Cycle Details

- **Once-Through Fuel Cycle**
  - 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
- **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
  - Appropriate when major constraint is on repository capacity (e.g., heat loading, geologic media)
  - Appropriate when actinide loading is not a show stopper
- **Full Recycle**
  - Multiple reprocessing steps and transmutation of actinides
  - “Complete” uranium utilization (with breeder)
  - Appropriate for a high-price uranium future
  - Appropriate when repository capacity and/or actinide loadings are show stoppers

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FCR&D Technical Areas

- **Separations and Waste Forms**
- **Advanced Fuels**
- **Modeling and Simulation**
- **Materials Protection, Accounting, and Control for Transmutation**
- **Used Nuclear Fuel Disposition**

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Separations and Waste Forms

Today's Technology Challenges

- Meeting current air emission requirements
- Economical recovery of transuranic elements for recycle/transmutation
- Minimal waste generation

Grand Challenges

- Near-zero radioactive off-gas emissions
- Simplified, single-step recovery of transuranic elements
- Significantly less process wastes

Development Path

- Develop fundamental understanding of separation process and waste form thermodynamics
- Understand underlying separation driving forces
- Exploit thermodynamic properties to effect separations
- Elucidate microstructural waste form corrosion mechanisms

Transformational Result

- Predictive capability for separation and waste form performance over a broad range of operational conditions
- Novel separations technologies

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Advanced Fuels

Today's Technology Challenges

- Fuels with variable compositions
- Understanding and predicting fuel behavior and performance
- Reliably fabricating fuel with zero defects and with minimal process losses

Grand Challenge

- Fast reactor fuels with multi-fold increases in performance over previous generation fuels, with very low fabrication losses, and that permit high transmutation of radiotoxic elements

Development Path

- Develop a microstructural understanding of fuels and materials
- Closure of combined transport and phase-field equations
- Separate effect testing and properties measurement at sub-grain scale
- Effect of nano-scale implantations
- Innovative clean and reliable fabrication techniques with tightly controlled microstructures tailored to desired performance

Transformational Result

- Predictive capability for fuel process and in-pile behavior for a variety of initial and boundary conditions
- Novel fuel forms

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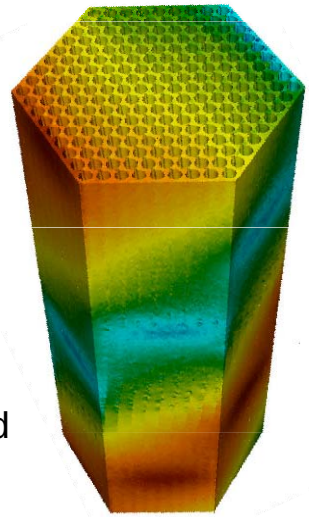
Modeling and Simulation

Today's Technology Challenges

- Current generation of nuclear modeling and simulation tools are empirically based
- Limited to use only for conditions very close to those experiments



Grand Challenge

Rapidly create and deploy "science" (first principles) verified and validated modeling and simulation capabilities essential for the design, implementation, and operation of future nuclear energy systems with the goal of improving U.S. energy security.

Development Path

- Create teams focused on developing Integrated Performance and Safety Codes
- Support smaller projects developing atomistic scale models and methods for upscaling to integrated codes
- Develop and implement methodologies for verification, validation and uncertainty quantification
- Ensure capability transfer pathways to users of modeling and simulation capabilities (labs, industry and regulatory agencies
- Provide supporting computational technologies

Transformational Result

Develop modeling and simulation that is on par with theory and experiment to implement a modern science based approach for fuel cycle technologies.

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Materials Protection, Accounting, and Control for Transmutation
(Fuel cycle systems and reactors)

Today's Technology Challenges

- Large throughput facilities require shutdown for periodic inventory
- New reactor designs require new nuclear material management approach – safeguards by design
- Move from reactive to preventive systems approach

Grand Challenge

Develop online, real-time, continuous, accountability instruments and techniques that permit an order of magnitude improvement in the ability to inventory fissile materials in domestic fuel cycle systems, in order to detect diversion and prevent misuse

Development Path

- **Next generation instrumentation**
  - High sensitivity and specificity
  - Enabled by new physics data
  - New sensor materials
- **Integration of disparate data in quantitative manner**
  - Real time assessments
  - Probability basis with uncertainties
- **Predictive modeling and simulation at atomistic and plant level**

Transformational Result

Real time nuclear materials management with continuous inventory in fuel cycle facilities

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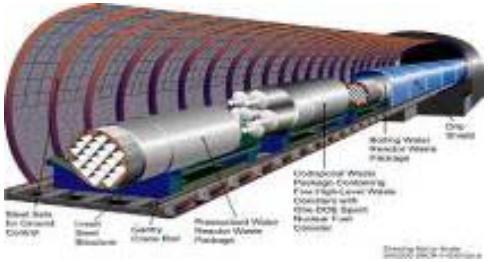
Used Nuclear Fuel Disposition

Today's Technology Challenges

- Storing and disposing UNF, HLW, GTCC, and LLW from a range of fuel cycles
- Understanding and predicting geologic repository performance
- Safe, secure, and cost effective storage, transportation and disposal

Grand Challenge

Integrated waste management with near zero radionuclide release from storage and disposal system



Development Path (with RW, EM)

- Develop an understanding of geologic repository performance
- Review extensive technical basis developed in the U.S. and internationally over the past several decades including recent work by SNL and LANL on a generic salt repository
- Explore a range of potential geologic settings, including granite, salt, clay, and tuff, and range of disposal concepts, including shaft-room, ramp-drift, and deep boreholes
- Investigate storage concepts for UNF and a range of waste streams
- Develop an integrated waste management strategy applicable to a range of fuel cycle options

Transformational Result

Predictive capability for performance of storage and disposal options for a range of fuel cycles

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FY 2011 FCR&D Budget Request

Budget Summary
$ in thousands

Program Element	FY 2010 Approp	FY 2011 Request
Separations and Waste Forms	41,615	31,324
Advanced Fuels	29,651	40,000
Transmutation R&D	4,288	0
Modeling & Simulation	26,009	15,570
Systems Analysis & Integration	14,783	15,664
Materials Protection, Accountancy & Controls for Transmutation	6,826	7,814
Used Nuclear Fuel Disposition	9,124	45,000
Modified Open Cycle	0	40,000
SBIR/STTR	3,704	5,628
Total:	**136,000**	**201,000**

Mission

- Research and develop nuclear fuel and waste management technologies that will enable a safe, secure, and economic fuel cycle.

FY 2011 Planned Accomplishments

- Examine 3 fuel cycle strategies: once-through, modified open, and full recycle.
- Continue to develop advanced concepts for electrochemical processing and alternative waste forms.
- Begin to develop innovative fuel systems that support advanced fuel cycles.
- Provide technical expertise to inform decision-making for storage, transportation, and disposal of used nuclear fuel and radioactive waste.

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Future of Nuclear Energy: National Repository Plans

ANTICIPATED START OF REPOSITORY OPERATIONS	
COUNTRY	**DATE**
United States	No decision made.
Belgium	Anticipated in roughly the 2040 time-frame.
Canada	No decision made.
China	Anticipated in roughly the 2050 time-frame.
Finland	2020
France	2025
Germany	No decision made.
Japan	No decision made.
Republic of Korea	No decision made.
Spain	No decision made.
Sweden	2023
Switzerland	No sooner than 2040
United Kingdom	No decision made.

"The future ain't what it used to be."
Yogi Berra

From: NWTRB Survey of National Programs, October 2009