Fuel Cycle Research and Development

Funding Profile by Subprogram

(dollars in thousands)

	FY 2009 Current Appropriation	FY 2009 Current Recovery Act Appropriation	FY 2010 Current Appropriation	FY 2011 Request
Fuel Cycle Research and Development	142,652	0	136,000	201,000

Public Law Authorizations:
P.L. 111-8, Omnibus Appropriation Act (2009)
P.L. 111-85, Appropriation Act (2010)

Mission

The mission of Fuel Cycle Research and Development (R&D) program is to research and develop nuclear fuel and waste management technologies that will enable a safe, secure, and economic fuel cycle. Beginning in FY 2010, the program shifted from a near-term technology development and deployment program to a long-term, science-based R&D program which has the potential to produce beneficial changes to the way the fuel cycle, and particularly spent fuel, is managed. The program will examine three fuel cycle approaches: once-through fuel cycle, modified open fuel cycle, and full fuel recycle. Examination of this full range of approaches is critical to provide future decision-makers with information needed to make decisions on how best to manage used fuel. In addition, the Office of Nuclear Energy (NE) will leverage transformative and crosscutting R&D activities carried out by the Nuclear Energy Enabling Technologies program, complementing the R&D carried out in this program. NE will oversee on-going responsibilities under the Nuclear Waste Policy Act. Within the Fuel Cycle R&D program, these include activities associated with nuclear waste management.

Benefits

The Fuel Cycle R&D program supports long-term technology development activities and will:

- Develop high burn-up and other fuels for use in reactors that could help reduce the amount of used fuel for direct disposal for each megawatt-hour of electricity produced;
- Investigate fuel forms, reactors and fuel/waste management approaches that could dramatically increase utilization, if economically competitive, of fuel resources and reduce the quantity of long-lived radiotoxic elements in the used fuel to be disposed (per megawatt-hour). Technologies will be considered that require at most limited separation steps and minimize proliferation risks; and
- Develop techniques that will enable long-lived actinide elements to be repeatedly recycled. The ultimate goal is to develop a cost-effective and low-proliferation-risk approach that would significantly decrease the long-term challenges posed by the waste and reduce uncertainties associated with its disposal.

The goal is to perform R&D within each of the three tracks above to advance fuel cycle technologies and waste management strategies to inform decision-making.

Annual Performance Results and Targets

The Fuel Cycle R&D program's performance measure aligns to the Secretary's Goal of *Energy: Build a Competitive, Low-Carbon Economy and Secure America's Energy Future* and to the GPRA Unit Program Goal of New Nuclear Generation Technologies. The Fuel Cycle R&D performance measure aligns to these goals by tracking progress on researching and developing nuclear fuel and waste management technologies that will enable a safe, secure, and economic fuel cycle. This will involve identifying gaps in knowledge and uncertainties that require resolution and making progress toward key technology challenges and goals. The program will help create a safe and sustainable path forward and help to optimize the nuclear fuel cycle. Developing these advanced technologies decreases the fuel cycle risks associated with nuclear power plants, increasing the likelihood that new nuclear power plants will be deployed, thus contributing to greenhouse gas abatement efforts.

Fuel Cycle R&D Annual Performance Targets and Results

Secretarial Goal: Energy

GPRA Unit Program Goal: New Nuclear Generation Technologies

FY PY-3	FY PY-2	FY PY-1	FY PY	FY CY	FY BY	FY BY+1	FY BY+2	FY BY+3	FY BY+4
FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
FY 2011 Efficiency Performance Measure: *Maintain total administrative overhead costs in relation to total R&D program costs of less than 8 percent.*									
T: < 8% A: Met	T: < 8% A: Met	T: < 8% A: Met	T: < 8% A: Met	T: < 8% A:	T: < 8% A:	T: < 8% A:	T: < 8% A:	T: < 8% A:	T: < 8% A:
Fuel Cycle R&D FY 2011 Effectiveness Performance Measure: Demonstrate progress toward the long-term mission to develop options to the current commercial fuel cycle management strategy by establishing long-term strategic plans for the program, identifying gaps in knowledge and uncertainties to resolve, and beginning the path to achieve the program's grand challenge goals. FY 2010: Demonstrate progress toward the long-term mission to develop options to the current commercial fuel cycle management strategy by establishing long-term strategic plans for the program, identifying gaps in knowledge and uncertainties to resolve, and beginning the path to achieve the program's grand challenge goals. FY 2009: Support the development of advanced technologies to close the fuel cycle by performing specific used fuel separations, transmutation fuels and fast reactor research and development activities in support of the AFCI. FY 2008: Create a technology development document on recycling technology options, including their readiness and risks, the state of technology development achieved to date, future research and development, and economic evaluations needed to achieve the Global Nuclear Energy Partnership vision. FY 2007: Complete research and development activities, focused on advanced fuel separations technology development and demonstration, to support the Secretary of Energy's determination of the need for a second geologic repository for spent nuclear fuel by FY 2008. FY 2006: Complete research and development activities that allow the Advanced Fuel Cycle Initiative (AFCI) program to support the Secretary of Energy's determination of the need for a second geologic repository for spent nuclear fuel by FY 2008.									
T: 1 A: 1 (Met)	T: 1 A: 1 (Met)	T: 1 A: 1 (Met)	T: 1 A: 1 (Met)	T: 1 A:	T: 1 A:	T: 1 A:	T: 1 A:	T: 1 A:	T: 1 A:

Means and Strategies

The Fuel Cycle R&D program will use various means and strategies to achieve its GRPA Unit Program Goal. However, various external factors may impact the ability to achieve these goals. The program also performs collaborative activities to help meet its goals.

The Department will implement the following means:

- Conduct long-term science-based R&D through small-scale experiments, theory development, modeling and simulation, validation experiments, and development of transformational technologies that have the potential to produce beneficial changes in the way the nuclear fuel cycle, and particularly nuclear waste, is managed.
- Conduct R&D needed for the Department to provide input into the Administration's development of a National nuclear waste management strategy and to support the planned Blue Ribbon Commission.
- Leverage transformative and crosscutting R&D activities carried out by the Nuclear Energy Enabling Technologies program, complementing the R&D carried out in this program.

The Department will implement the following strategies:

- NE's R&D programs will partner with the private sector, national laboratories, universities, and international partners to develop advanced nuclear technologies.
- Programs will also engage the international community in pursuit of advanced nuclear technology that will benefit the United States in terms of enhanced safety, improved economics, and reduced production of wastes.

These strategies will result in efficient and effective management of the program, thus putting the taxpayers' dollars to more productive use.

The following external factors could affect the program's ability to achieve its strategic goal:

- Nuclear energy research programs rely on data produced through collaborations with foreign nations. Should vital data from foreign partners prove unavailable, U.S. efforts would need to be re-evaluated.

In carrying out the program's mission, the program performs the following collaborative activities:

- The Fuel Cycle R&D program is undertaking long-term R&D on fuel cycle technologies to provide the U.S. government with information on and options for the long-term disposition of spent nuclear fuel. Interdependencies with the Office of Environmental Management include collaboration on spent fuel treatment technologies and waste forms to avoid duplication of effort.
- Interdependencies with National Nuclear Security Administration (NNSA) include coordination of advanced material control and accountability monitoring technology development, and safeguards and security aspects of advanced fuel cycle technologies.
- Interdependencies with the Office of Science (SC) include providing the basic science tools that can be used to close technology gaps that currently impede the implementation of fuel cycle technologies. Interfaces in basic energy sciences including actinide chemistry and materials, nuclear physics, and development of advanced simulation and modeling tools must be coordinated between NE and SC.
- The Department and the NRC coordinate program planning to assure that their R&D activities are complementary, cost effective, and not duplicative.
- Participation in international experiments related to the development of advanced fuel cycle technologies is being performed in support of Fuel Cycle R&D program objectives.

Validation and Verification

NE conducts various internal and external reviews and audits to validate and verify program performance. Periodic program reviews evaluate progress against established plans. NE holds monthly, quarterly, semi-annual, and annual reviews, consistent with program management plans and project baselines, to ensure technical progress, cost, and schedule adherence, and responsiveness to program requirements. Internally, NE provides continual management and oversight of its R&D and vital infrastructure programs. Examples of NE's R&D programs include Reactor Concepts Research, Development and Demonstration (RD&D) and Fuel Cycle R&D. NE infrastructure programs, such as the Radiological Facilities Management program and the Idaho Facilities Management program, are managed using similar oversight techniques.

NE engages its stakeholders to help define the appropriate scope of NE's program activities to support nuclear energy's role in meeting the Nation's energy security and environmental goals. NE's programmatic activities are also subject to periodic external reviews by Congress, GAO, the Department's IG, NRC, the EPA, state environmental and health agencies, and the Department's Office of Engineering and Construction Management. In addition, NE solicits the advice and counsel of external agencies such as Nuclear Energy Advisory Committee and National Academy of Sciences.

Fuel Cycle Research and Development

Funding Schedule by Activity

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
Fuel Cycle Research and Development			
Separations and Waste Forms	40,355	41,615	31,324
Advanced Fuels	28,975	29,651	40,000
Transmutation Research and Development	28,394	4,288	0
Modeling and Simulation	24,845	26,009	15,570
Systems Analysis and Integration	20,083	14,783	15,664
Materials Protection, Accountancy, and Controls for Transmutation	0	6,826	7,814
Used Nuclear Fuel Disposition	0	9,124	45,000
Modified Open Cycle	0	0	40,000
SBIR/STTR	0	3,704	5,628
Total, Fuel Cycle Research and Development	142,652	136,000	201,000

Benefits

The program focus has been re-directed from near-term technology deployment to long-term, results-oriented, science-based R&D which has the potential to produce beneficial changes to the way the fuel cycle, particularly used nuclear fuel, is managed. The program will research and develop technologies for each of three fuel cycle management approaches (once-though fuel cycle, modified open fuel cycle, and full fuel recycle).

The Fuel Cycle R&D program is an integrated program to research, develop, and improve fuel cycle and waste management options and technologies. It involves small-scale experiments coupled with theory development and advanced modeling and simulation with validation experiments. This science-based R&D program will provide a more complete understanding of the underlying science supporting the development of advanced fuel cycle and waste management technologies and, therefore, help provide a sound basis for future decision-making. The program will also conduct scientific research and technology development to enable storage, transportation, and disposal of used nuclear fuel and all radioactive wastes generated by existing and future nuclear fuel cycles.

NE programs allocate R&D funding to those entities (e.g., industry, laboratories, and universities) that are best qualified to carry out the work in support of NE's mission. Consistent with NE's commitment to support R&D activities at university and educational research institutions, NE programs competitively award funds that support both mission-specific and mission-related activities. NE designates up to 20 percent of funds appropriated to its R&D programs for work to be performed at university and research institutions, through open, competitive solicitations for investigator-led projects. The national laboratories are encouraged to partner with universities to conduct R&D.

The Fuel Cycle R&D program also collaborates with nuclear industry and, where appropriate, international partners from other countries with advanced fuel cycles to leverage U.S. research

investments and pursue common goals towards advanced fuel cycles that are economic, minimize waste, and reduce proliferation risk. The program provides technical support to NE's international mission via participation in meetings, seminars, related publications, and international technical cooperation agreements. Fuel Cycle R&D continues to pursue and seek new international cooperation activities that leverage the program's activities for mutual benefit and provide access to facilities not available in the United States, such as fast spectrum test reactors for advanced fuel testing.

Detailed Justification

	(dollars in thousands)		
	FY 2009	FY 2010	FY 2011
Separations and Waste Forms	**40,355**	**41,615**	**31,324**

The mission of the Separations and Waste Forms technical area is to develop the next generation of used fuel separations and waste management technologies that enable a sustainable fuel cycle with minimal processing, waste generation, and potential for material diversion. Challenges in separations and waste forms include: 1) develop separations technologies and systems with reduced proliferation risk, very low process losses, and minimal undesirable waste streams; and 2) develop waste forms with predictable, long-term behavior and enhanced resistance to long-term degradation suitable for a variety of potential storage or geologic repository environments.

In FY 2009, the Department:

- Continued to research advanced aqueous separations processes with an increasing emphasis on simplification of the process steps including investigating alternate extraction processes to minimize the number of different solvents needed.
- Continued research on electrochemical processing technologies with a focus on improving process throughput and process control and monitoring technologies.
- Investigated safeguards issues related to special material accountability.
- Continued R&D to optimize the stability of waste forms and the efficiency of waste form production through laboratory-scale demonstration of solidification processes for both glass and metal waste forms.
- Characterized waste forms resulting from separations processes and investigated their potential performance in a variety of geological settings.
- Evaluated metal waste forms to understand and define waste loading performance.
- Prepared the first metal waste form using surrogate undissolved solids.

In FY 2010, the Department is:

- Researching innovative methods for the separation of americium or americium/curium in a single process step.
- Researching innovative methods to capture off-gasses such as iodine and krypton from the head end processes and immobilize the captured gasses.
- Developing advanced concepts for electrochemical processing to recycle salt for waste minimization, advanced methods for transuranic recovery, and novel product consolidation methods.
- Developing alternative waste forms that are tailored to specific radionuclides and potential geologic media.
- Characterizing waste forms and assessing their performance in a variety of potential geologic

media.
- Investigating new waste forms for electrochemical process inactive metals and spent salt streams.
- Evaluating current methodologies for assessing proliferation risk and developing a plan for integrating new and existing concepts into analytical tools for evaluating proliferation risks associated with fuel cycle concepts. Probabilistic risk assessment approaches will be included in the evaluation.
- Developing advanced fuel cycle instrumentation that will provide for online/at-line, near real-time, active and passive nondestructive monitoring of electrochemical and aqueous processes.
- Developing advanced safeguards approaches, including formalization of requirements, for advanced fuel cycles.
- Developing modeling and simulation approaches to support radiation transport and detection, materials behavior in harsh environments, development of radiation and non-radiation based signatures, performance assessments/optimization, virtual inspector presence, and data visualization.

In FY 2011, the Department will:
- Continue to research innovative methods for the separation of americium or americium/curium in a single process step.
- Continue to research innovative methods to capture off-gasses such as iodine and krypton from the head end processes and immobilize the captured gasses.
- Continue to develop advanced concepts for electrochemical processing to recycle salt for waste minimization, advanced methods for transuranic recovery, and novel product consolidation methods.
- Continue to develop alternative waste forms that are tailored to specific radionuclides and potential geologic media.
- Continue to characterize waste forms and assess their long-term stability.
- Continue to investigate new waste forms for electrochemical process inactive metals and spent salt streams.

Advanced Fuels **28,975** **29,651** **40,000**

The mission of the Advanced Fuels technical area is to perform R&D on fuel systems and fabrication processes to achieve multi-fold improvements in fuel and fabrication process performance. This will be in direct support to NE's imperatives of extending plant lifetimes, enabling new reactor builds, and developing sustainable fuel cycles through advanced transmutation fuels. One challenge in advanced fuels is to develop nuclear fuels and/or targets for thermal and fast reactors with multi-fold increases in performance over previous generation fuels. Fuel research under Fuel Cycle R&D is specifically motivated by fuel cycle challenges.

Within the context of long-term (40+ years) waste management technology R&D investigated by the Fuel Cycle R&D program, the design and development of advanced fuels that could ultimately be utilized in fast reactors would be pursued. These activities would include investigating conceptual design modifications to fast reactor concepts to accommodate advanced fuels developed by the program. The Advanced Fuels technical area will also initiate R&D on fuel resources that may improve the

sustainability of nuclear energy in the long term and enhance the security of the fuel supply.

In FY 2009, the Department:

- Initiated post-irradiation examination of Advanced Test Reactor (ATR) test fuel pins removed from the test reactor in FY 2008.
- Continued irradiation and testing of metal and oxide transmutation fuels in the ATR.
- Researched fuel fabrication processes evaluating advanced cladding materials.
- Completed irradiation of U.S. origin transmutation fuels in the French Phénix fast reactor. This reactor was permanently shutdown in FY 2009.
- Continued to prepare transmutation-related feedstock material needed for national and international fuels irradiation testing.
- Continued international collaborations on innovative fuel development.
- Continued development of instrumentation and controls for safeguarding nuclear materials during the fuel cycle and waste management process.
- Initiated development of safeguards related tools and methods for advanced integration and control to enable knowledge extraction of facility operation.
- Investigated safeguard issues related to special material accountability in metal fuel fabrication systems.

In FY 2010, the Department is:

- Exploring innovative fuel designs including transmutation fuels with long-term high performance payback such as composite dispersion fuels with microstructural properties targeted for specific characteristics.
- Continuing to develop advanced fabrication techniques that provide the desired control on fuel microstructure with the inclusion of strategic additives if needed.
- Performing analyses to investigate potential transformational advances in advanced fuels development.
- Initiating small-scale experiments needed to verify specific features of modeling development needs.
- Continuing post-irradiation examination of irradiated experiments from the Fast Flux Test Facility and ATR, as required for input to fuel performance modeling and initiating plans for the return of the U.S. material irradiated in Phénix.
- Developing initial plans for the development of advanced Light Water Reactor (LWR) fuels and claddings in coordination with the LWR Sustainability activity within the Reactor Concepts RD&D program, industry, and universities.
- Continuing irradiation experiments at ATR for the development of advanced oxide and metal fuels and initiated plans for future separative effects testing to support advanced model development.

In FY 2011, the Department will:

Modeling & Simulation (M&S) Support

- Provide advanced fuels requirements input to the M&S program and seek clarification on what M&S parameters need experimental verification in the fuels program.
- Support development and fabrication of experimental techniques that are closely coupled to

M&S development needs, including advanced instrumented irradiation assembly designs for use in ATR and High Flux Isotope Reactor.
- Initiate design and fabrication of an instrumented test assembly for use in ATR to permit parameter uncertainty reductions needed in M&S code development.
- Continue to support performance-modeling development via small-scale experiments to investigate important separate effects.

Post-Irradiation Examination (PIE)
- Initiate destructive PIE on fuel pins from the shutdown Fast Flux Test Facility. These mixed oxide pins, and their associated HT-9 clad material, are the highest burn up fast spectrum reactor fuel in the world, and are of significant national and international interest.
- Transfer irradiated U.S.-origin fuels and materials from Phénix and initiate PIE.
- Continue supporting plans for developing needs and requirements for the Idaho Transient Reactor Test Facility which will be needed for licensing related testing of any new fuel to be used in a nuclear power reactor in the United States. There is significant international interest (France, Japan) in this facility due to its unique testing capabilities.
- Continue to expand the use of new, highly advanced, post-irradiation devices as they become available. Additional post-irradiation characterization equipment will be radiation hardened (e.g. focused Ion Beam) so they can be used on irradiated samples.

Fabrication
- Continue fabrication and characterization development of metal fuels, with the capability to transmute large quantities of minor actinide bearing fuel so its technology readiness level is made comparable to oxide-based mixed oxide fuel. Fabrication process heat modeling will be continued in support of this activity and also to support ceramic development as needed.
- Continue fabrication, characterization, testing, and modeling of ceramic fuels having the capability to transmute large quantities of minor actinides and fission products.
- Continue to develop advanced fabrication techniques that provide the desired control on fuel microstructure with the inclusion of strategic additives if needed.

Other Fuel Activities
- Initiate development of innovative fuel systems that possibly support alternative fuel cycles to the current UOx once-through fuel cycle with the potential for dramatic performance and waste minimization potential.
- Initiate development of advanced high performance particle based fuel systems including the thermal “deep burn” concept.
- Continue pursuit of fuel cladding material development for both thermal and fast reactor use to achieve major increase in irradiation tolerance characteristics, opening the door to overall “deep burn” concepts.
- Collaborate with the Advanced Reactor Concepts program on nuclear data measurements and validation activities that support advanced fuel development activities.
- Continue to explore innovative fuel designs with long-term, high performance.
- Continue the development of transmutation fuels in coordination with long-term separations R&D and systems analysis.

(dollars in thousands)		
FY 2009	FY 2010	FY 2011

- Initiate R&D on fuel resources including uranium and thorium resource estimates, advanced exploration methods, and methods to improve resource recovery efficiencies.
- Complete an analysis to characterize long-term uranium resources, including economic considerations and technical barriers. This study would also include an evaluation of the utilization of low-grade or unconventional resources (e.g., phosphates, seawater, etc.).

Transmutation Research and Development **28,394** **4,288** **0**

The mission of the Transmutation technical area was to convert long-lived radioactive isotopes into shorter-lived elements. Transmutation can lower the long-term radiotoxicity of used nuclear fuel to below that of mined uranium ore by reducing the time for decay from hundreds of millennia to as little as centuries.

In the context of long-term waste management technology R&D, this activity supported research on advanced instruments and measures as well as analyses of highly accurate nuclear data such as neutron fission and captures cross-sections for elements of interest to the Fuel Cycle R&D program. Improved accuracy of nuclear data is important to a variety of activities including transmutation performance analysis, safeguards instrumentation design, high-burnup fuel development, waste package performance, and development of advanced models and simulation codes. Nuclear data research will be performed in collaboration with SC.

In FY 2009, the Department:

- Continued R&D activities on high precision measurements of nuclear data, sensitivity analyses to reduce uncertainty, and development of advanced measurement techniques.
- Continued the development of advanced materials that will significantly improve the performance of nuclear systems.
- Continued to work collaboratively with the international community to efficiently leverage existing infrastructure.

In FY 2010, the Department is:

- Continuing R&D activities on high precision measurements of nuclear data, sensitivity analyses to reduce uncertainty, and development of advanced measurement techniques.
- Updating nuclear data libraries to include reduced uncertainties based on new data in the fast neutron region of the spectrum.

In FY 2011, the Department will:

- Focus on separations of fast reactor fuels, transmutation fuels, and systems analysis of fuel cycles containing fast reactors and be funded under those technical areas.

Modeling and Simulation **24,845** **26,009** **15,570**

The mission of Modeling and Simulation within NE is to create and deploy science-based, verified and validated modeling and simulation capabilities essential for the design, implementation, and operation of all aspects of nuclear energy systems and their nuclear fuel cycles to improve U.S. energy security. Program activities encompass the micro-behavior level of fuels and materials in Fuel Cycle R&D, to the macro-behavior level of reactor systems (e.g., LWRs and advanced reactors in Reactor Concepts RD&D)

and their fuel cycles. The successful application of these advancements will enable the use of computer simulation in a fundamentally new way for design, licensing, and operation of nuclear systems.

These activities differ from those conducted in conjunction with the Energy Innovation Hub for Modeling and Simulation within the Nuclear Energy Enabling Technologies program. While modeling and simulation activities carried out in the Reactor Concepts RD&D and Fuel Cycle R&D programs are focused on building new advanced modeling and simulation capabilities in the areas of nuclear fuels, separations processes, material safeguards, waste forms, and repositories for near-term, mid-term, and long-term nuclear power system concepts, the Hub will have a narrower focus of validating and demonstrating the application of modeling and simulation capabilities through the virtual modeling of an existing operating reactor. Additionally, the Hub will be managed by an independent consortium and while the Hub activities may complement those in the NE program, they are not directly linked to the activities proposed under Fuel Cycle R&D and Reactor Concepts RD&D.

In FY 2009, the Department:

- Expanded code team efforts to develop a fast reactor design code to couple thermal-hydraulics, neutronics and structural mechanics with three-dimensional capabilities.
- Improved the fidelity of thermo-mechanical codes used for fuel modeling and improving the models of multi-component materials used in reactor fuels.
- Developed code architectures and methods to model the performance of advanced waste forms in adverse geological environments for very long-term storage and disposition.
- Initiated the development of simulation codes to model the used nuclear fuel recycling process to improve our understanding of what is needed to better design recycling processes with integrated advanced safeguards.
- Developed a Unified Markup Language specification for a modeling and simulation interoperability framework that will facilitate the transfer of capabilities from the research environment to the engineers who will design, build, and operate the new nuclear energy systems.
- Delivered Fundamental Models and Methods that will allow the understanding of performance of materials on the lower length scales needed to simulate the performance of integrated systems.
- Delivered an initial modeling and simulation integration framework that facilitates capability transfer by allowing interoperability of existing codes, industry codes, and newly developed capabilities.
- Provided a centrally planned, but distributed, set of computational resources that leverages other Department of Energy (DOE) high performance computing programs and is needed to support the application development and use.
- Developed a set of experimental data needs and requirements over the entire spectrum of time- and length-scale for the models.
- Developed the set of validation techniques necessary for demonstrating the quality of the modeling tools and for defining requirements for further development of these tools.
- Issued a competitive solicitation to award mission-specific R&D projects to universities.
- Awarded competitive contracts to enhance university infrastructure and increase human capital developmental programs for nuclear engineers and scientists.

(dollars in thousands)

FY 2009	FY 2010	FY 2011

In FY 2010, the Department is:

- Delivering the first generation of integrated performance and safety codes to provide a limited science based understanding of the performance of nuclear fuels and reactor core and safety systems.
- Establishing projects with universities, industry, and laboratories to deliver fundamental material performance models to the integrated code activities.
- Completing surveys of existing verification, validation, and uncertainty quantification methodologies and beginning to implement the most appropriate ones.
- Creating a prototype application that provides a systematic approach to meeting security requirements by integrating the safeguard systems and separations process.
- Developing an initial three-dimensional, high-resolution, integrated system application to understand and predict the performance of nuclear waste forms in repository environments.

In FY 2011, the Department will:

- Deliver advancements for the integrated performance and safety codes for nuclear fuel that remove empirical based behaviors and replace them with first principle based science.
- Continue projects with universities, industry, and laboratories to deliver fundamental material performance models to the integrated code activities.
- Deliver first generation of codes to simulate waste forms in a repository environment and the operation of safeguard systems in a separations facility.
- Create a prototype application that provides a systematic approach to meeting security requirements by integrating the safeguard systems and separations process.
- Implement advanced verification, validation, and uncertainty methodologies.
- Develop an initial modeling and simulation integration framework that facilitates capability transfer by allowing interoperability of existing codes, industry codes, and newly developed capabilities.
- Provide a centrally planned but distributed set of implemented computational resources that leverage other DOE high-performance computing programs needed to support applications development and use.

Systems Analysis and Integration **20,083** **14,783** **15,664**

The mission of the Systems Analysis technical area is to perform systems engineering and integrating analyses of nuclear energy and fuel cycle systems to inform fuel cycle R&D, programmatic decisions, strategy formulation, and policy development.

The technical integration program element provides support in the areas of technical integration, project controls, quality assurance, document management, knowledge management, and communications. This function ensures the technical consistency of the program, integrated product development, and planning and monitoring of work activities.

In FY 2009, the Department:

- Conducted a study of nuclear fuel cycle management options that was focused on identifying a very broad range of possible options for used fuel storage, recycling, waste disposal (including pathways for options that would require significant scientific breakthroughs), and specified

criteria for each key technical and scientific challenge.
- Designed and assessed specific technical options and trade studies for future fuel cycle systems such as assessment of approaches for minor actinide and heat management.
- Revised quality assurance program to better reflect National Quality Assurance -1 guidance and increased collaborations with industry and universities.
- Began development of knowledge management processes that permit historical sodium reactor data to be available on line to program researchers.

In FY 2010, the Department is:
- Performing systems analyses, optimization studies, and trade studies. Defining sensitivity coefficients with respect to system level assumptions to guide the R&D prioritization effort.
- Providing strategic and program planning support in developing technology roadmaps, integrated schedules, and other planning documents.
- Developing and maintaining a set of tiered models to be used for policy level decision making.
- Expanding knowledge management to include historical fuels data and geologic repository data and reports.
- Developing specifications and requirements for a fuel cycle simulator that can synthesize and visually present multi-variable attributes of potential fuel cycles.

In FY 2011, the Department will:
- Use a systems engineering approach, conduct systems analyses to define and analyze a broad variety of innovative fuel cycle options including analyzing the effects of a variety of alternative disposal geologies to inform R&D prioritization and program planning.
- Develop a directory of innovative fuel cycle options that documents key characteristics.
- Continue knowledge management activities related to historical fuels data and geologic repository data and reports.
- Continue development of a fuel cycle simulator to support future decision making.
- Perform trade studies and systems analyses to develop information and data on newly-defined innovative fuel cycles to inform program planning and R&D prioritization efforts.

Materials Protection, Accountancy, and Controls for Transmutation **0** **6,826** **7,814**

The mission of the Materials Protection, Accountancy, and Controls for Transmutation (MPACT) technical area is to develop technologies and analysis tools to enable next generation nuclear materials management for future U.S. nuclear fuel cycles to prevent diversion or misuse, thereby, reducing proliferation risks and enhancing confidence and acceptance of nuclear energy. One challenge MPACT will focus on is to develop online, real-time, continuous, accountability instruments and techniques that permit at least 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.

Work within this technical area will be closely coordinated with work described in NE's Enabling Technologies program but will focus specifically on informing future fuel cycle and safeguards R&D. Work will continue to be closely coordinated with NNSA programs.

In FY 2010, the Department is:

- Identifying gaps and areas for improving proliferation risk assessments of nuclear fuel cycles and drafting a roadmap outlining the path forward.
- Initiating the development of technologies to provide online, real-time measurement systems, including process-monitoring capabilities for improving material accountancy and reduced proliferation risk associated with advanced fuel cycle systems.
- Initiating the development of methodologies to incorporate safeguards and security systems into advanced fuel cycle systems to reduce proliferation risk, optimize performance, and reduce costs.

In FY 2011, the Department will:

- Based on the roadmap created in FY 2010, continue development of improved proliferation risk assessment tools to evaluate fuel cycle options.
- Continue to develop technologies to provide online, real-time measurement systems, including process-monitoring capabilities for improving material accountancy and reduced proliferation risk associated with advanced fuel cycles.
- Continue to develop methodologies to incorporate safeguards and security systems into advanced fuel cycles to reduce proliferation risk, optimize performance, and reduce costs.
- Develop an integrated safeguards and separations design framework using advanced modeling and simulation to inform and guide safeguards technology development and process design.

Used Nuclear Fuel Disposition **0** **9,124** **45,000**

The mission of the Used Nuclear Fuel Disposition technical area is to identify alternatives and conduct scientific research and technology development to enable storage, transportation, and disposal of used nuclear fuel and all radioactive wastes generated by existing and future nuclear fuel cycles. The challenge for Used Nuclear Fuel Disposition is the development of storage, transportation, and disposal systems resulting in near-zero radionuclide releases. Work in this program element supports all three fuel cycle approaches; once-through fuel cycle, modified open fuel cycle, and full fuel recycle. NE will oversee ongoing responsibilities under the Nuclear Waste Policy Act. Within the Fuel Cycle R&D program, these include activities associated with nuclear waste management.

In FY 2010, the Department is:

- Developing capabilities for analyses and trade studies to evaluate all aspects of storage and disposition scenarios and to provide rapid response capability as needed.
- Developing the technical bases and lessons learned for used nuclear fuel disposition.
- Developing modeling tools and initiating systems modeling for engineered and natural barrier systems and generic disposal concepts in multiple environments.
- Initiating an modeling and simulation experiment and testing program.

In FY 2011, the Department will:

- Provide technical expertise to inform policy decision-making regarding the management of used nuclear fuel and radioactive waste that would be generated under existing and potential future nuclear fuel cycles, in collaboration with Office of Environmental Management.
- Develop commercial used fuel and DOE high-level waste projection databases for consistency

in the amounts, locations, discharges and timeframes for systems analysis for the policy decision process.
- Provide rapid response support for inquiries from the proposed Blue Ribbon Commission.
- Work with the EPA and NRC on to help ensure regulatory frameworks can accommodate waste forms and disposition paths not yet defined.
- Develop a systems model to perform cost-benefit analysis of the variety of waste forms, storage concepts, transportation options, and disposal options to provide to policy makers.
- Develop a lessons learned effort that evaluates the critical components of both the international and the past U.S. policy for nuclear waste to inform decision makers.
- Develop a comprehensive understanding of the current technical bases for storage and transportation of used nuclear fuel and high-level nuclear waste; then identify opportunities for long-term R&D.
- 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 based on simulation and experiment.
- Evaluate and model the effects of a wide range of factors that could impact long term storage including cladding behavior, helium buildup, and marine environments.
- Conduct R&D related to data and modeling needs to ensure security over long periods of storage and future transportation.
- Evaluate technical capability of dual purpose canisters to be transported after long-term storage with consideration of regulatory requirements.
- Investigate techniques for repackaging nuclear materials after long periods of storage.
- Develop and test new techniques for monitoring of nuclear materials during long-term storage and new techniques for non-destructive examination.
- Prepare for qualification of new types of nuclear fuel and new waste forms in shipping casks.
- Develop a features, events, and processes database, beginning with international databases and expanding as required to include additional disposal media and/or disposal concepts.
- Develop enhanced databases and other tools for the management and analysis of activities related to domestic used fuel management.
- Develop a comprehensive understanding of the current technical bases for geologic disposal of used nuclear fuel and high-level nuclear waste; then identify opportunities for long-term R&D.
- Conduct R&D advanced models of disposal options to evaluate a variety of used nuclear fuel and high-level waste forms emplaced in a variety of geologic disposal media such as granite, tuff, deep boreholes, clay, shale, salt, and basalt.
- Initiate validation of these advanced models by measuring the thermomechanical, hydrological, and chemical properties of selected geologic media in laboratory experiments and field tests.
- Evaluate and model the inclusion of low-level waste with various high-level waste disposal options.

Modified Open Cycle **0** **0** **40,000**

The FY 2011 budget expands the focus of the Fuel Cycle R&D program to include fuel cycle strategies beyond a full fuel recycle system. The modified open cycle constitutes a range of technology options in between the once-through and full recycle strategies and could be an important

part of achieving a sustainable fuel cycle. All three fuel cycles need to be studied in order to provide future decision-makers with a full range of options for making decisions on the best way to manage used fuel. Full recycle has been the focus of the Fuel Cycle R&D program to date and the once-through fuel cycle is the current practice in the United States. The modified open cycle has not been studied as thoroughly as the other two options and that is why it is being singled out as a new technical area for FY 2011.

As a potential waste management option in the long-term if economically viable, a modified open cycle could involve limited used fuel conditioning or processing and would have a higher uranium utilization than the once-through cycle, though not as high as the full recycle option. Similar to other fuel cycle approaches, the modified open cycle would still require a repository for disposal of high level waste for hundreds of thousands of years. A key challenge in this area is to accomplish minimum used fuel conditioning or separations in order to keep costs and proliferation risk low.

In FY 2011, the Department will:

- Identify novel fuel forms, ultra-high burnup fuels, thorium-based fuels, deep burn of transuranic-bearing tristructural isotropic fuels, new advanced reactors designed for transuranic burnup such as molten salt reactors and travelling wave reactors, and options to declad and reclad used fuel to allow volatile and gaseous fission products to be removed and captured before recycling.
- Initiate the exploration of limited treatment of used fuel to add more fuel material to the used fuel, remove wastes from the fuel that inhibit the nuclear reactions, and repair or replace the cladding that contains the fuel.
- Initiate systems engineering to define, establish requirements for, and evaluate modified open fuel cycle options.
- Initiate systems analyses to provide needed information on such topics as transuranic management, separations and partitioning efficiency, fission product behavior, materials reuse, and transmutation approaches of modified open fuel cycle systems.
- Initiate the research and analysis of limited fuel treatment processes, waste forms resulting from limited fuel treatment processes, and advanced transmutation concepts.

SBIR/STTR	**0**	**3,704**	**5,628**

The FY 2010 and FY 2011 amounts shown are an estimate of the requirement for the continuation of the SBIR and STTR program.

Total, Fuel Cycle Research and Development	**142,652**	**136,000**	**201,000**

Explanation of Funding Changes

	FY 2011 vs. FY 2010 ($000)
Separations and Waste Forms	
The decrease from $41,615,000 to $31,324,000 reflects:	
▪ The transfer of Experimental Breeder Reactor-II used nuclear fuel treatment to the Idaho Facilities Management program.	
▪ Activities related to materials protection, accountancy, and controls for transmutation have been consolidated into a new activity.	-10,291
Advanced Fuels	
The increase from $29,651,000 to $40,000,000 reflects an increase in scope to expand R&D from primarily transmutation fuels to a multitude of fuel types.	+10,349
Transmutation Research and Development	
The decrease from $4,288,000 to $0 reflects the transfer of this activity to other technical areas such as separations, advanced fuels, and systems analysis.	-4,288
Modeling and Simulation	
The decrease from $26,009,000 to $15,570,000 reflects the transfer of much of the code development and experimental support activities to the technical areas in reactors, fuels, separations and waste forms. In addition, a portion of the Nuclear Energy Advanced Modeling and Simulation support element development will be cost-shared with the Reactor Concepts RD&D program.	-10,439
Systems Analysis and Integration	
The increase from $14,783,000 to $15,664,000 reflects increases to conduct systems engineering and more analyses comparing the three fuel cycle options. These increases are partially offset by sharing the technical integration function with the Reactor Concepts RD&D program.	+881
Materials Protection, Accountancy, and Controls for Transmutation	
The increase from $6,826,000 to $7,814,000 reflects a ramping up of activities related to the development of measurement systems and M&S tools.	+988
Used Nuclear Fuel Disposition	
The increase from $9,124,000 to $45,000,000 reflects a large increase in scope of waste management R&D.	+35,876
Modified Open Cycle	
The increase from $0 to $40,000,000 reflects the introduction of a new technical area to support R&D for the modified open cycle option, one of three fuel cycle options being studied by Fuel Cycle R&D.	+40,000

	FY 2011 vs. FY 2010 ($000)
SBIR/STTR	
The increase from $3,704,000 to $5,628,000 reflects an increase in R&D expenditures subject to SBIR and STTR.	+1,924
Total Funding Change, Fuel Cycle Research and Development	**+65,000**