INL/EXT-11-21639

Five-Year Implementation Plan for Advanced Separations and Waste Forms Capabilities at the Idaho National Laboratory (FY 2011 to FY 2015)

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ACRONYMS

AL	Analytical Laboratory
BCTC	Bonneville County Technology Center
BEA	Battelle Energy Alliance, LLC
CAES	Center for Advanced Energy Studies
CCIM	Cold Crucible Inductive Melter
CFA	Central Facilities Area
CWI	CH2M-WG Idaho, LLC
DOE	Department of Energy
-EM	Office of Environmental Management
-ID	Idaho Operations Office
-NA	National Nuclear Security Administration
-NE	Office of Nuclear Energy
EBR-II	Experimental Breeder Reactor-II
FASB	Fuels and Applied Science Building
FCF	Fuels Conditioning Facility
FCP	Fluorinel Dissolution Process
FCR&D	Fuel Cycle Research and Development
FFTF	Fast Flux Test Facility
FITRS	Fourier Transform Infrared Spectroscope
GPEC	Gas Pressurized Extraction Chromatograph
HFEF	Hot Fuel Examination Facility
HIP	Hot Isostatic Press
ICP-MS	Inductively Coupled Plasma Mass Spectrometer
IEDF	INL Engineering Demonstration Facility
IFM	Idaho Facilities Management
IGPCE	Institutional General Purpose Capital Equipment
IGPP	Institutional General Plant Project
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
IRC	INL Research Center
LDRD	Laboratory-directed Research and Development
LIB	Line Item Building
LTA	Lead Test Assembly
MFC	Materials and Fuels Complex
NEAMS	Nuclear Energy Advanced Modeling and Simulation
RAL	Remote Analytical Lab
RCL	Radiochemistry Lab
REL	Research and Education Laboratory
R&D	Research and Development
RD&D	Research, Development and Demonstration
SEM	Scanning Electron Microscope
SIMS	Secondary Ion Mass Spectrometer

TGA	Thermogravimetric Analyzer
TRU	transuranic
UV-VIS	Ultraviolet-visible

Five-Year Implementation Plan For Advanced Separations and Waste Forms Capabilities at the Idaho National Laboratory (FY 2011 to FY 2015)

1. INTRODUCTION

Nuclear power is a significant contributor to the United States' portfolio of energy providers. As the need for clean energy increases, so will the need for efficient, safe, and secure management of nuclear power resources.

The primary mission of the U.S. Department of Energy (DOE) Office of Nuclear Energy (NE) is to advance nuclear power as a resource capable of meeting the nation's energy, environmental, and national security needs by resolving technical, cost, safety, security, and proliferation resistance issues through research, development, and demonstration (RD&D), as appropriate. The *Nuclear Energy Research and Development Roadmap*, issued in April 2010, outlines the path forward to mission accomplishment. The four main roadmap objectives are (1) develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors; (2) develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals; (3) develop sustainable nuclear fuel cycles; and (4) understand and minimize the risks of nuclear proliferation and terrorism.

Advanced separations and waste form RD&D directly supports NE Roadmap objectives 3 and 4 (i.e., develop sustainable fuel cycle options and minimize proliferation risks). Sustainable fuel options are those that improve uranium resource utilization, maximize energy generation, minimize waste generation, and improve safety. Additionally, understanding separation technologies is critical to assessing proliferation risk and ensuring material is appropriately safeguarded in support of objective 4. (i.e., understand and minimize the risks of nuclear proliferation and terrorism).

DOE-NE separations research is focused today on developing a science-based understanding that builds on historical research and focuses on combining a fundamental understanding of separations and waste forms processes with small-scale experimentation coupled with modeling and simulation. The result of this approach is the development of a predictive capability that supports evaluation of separations and waste forms technologies. The specific suite of technologies explored will depend on and must be integrated with the fuel development effort, as well as an understanding of potential waste form requirements.

Figure 1 shows the progression of INL's capabilities to become world-leading in aqueous and electrochemical separations and waste forms. It also indicates the scale and relative radiological level of the capability. It should be noted that the graded approach proposed here does not require a full suite of capabilities for every scale and every relative radiological level. Through this graded approach, increases in capabilities are strategically targeted to provide the maximum advance for the associated investment.

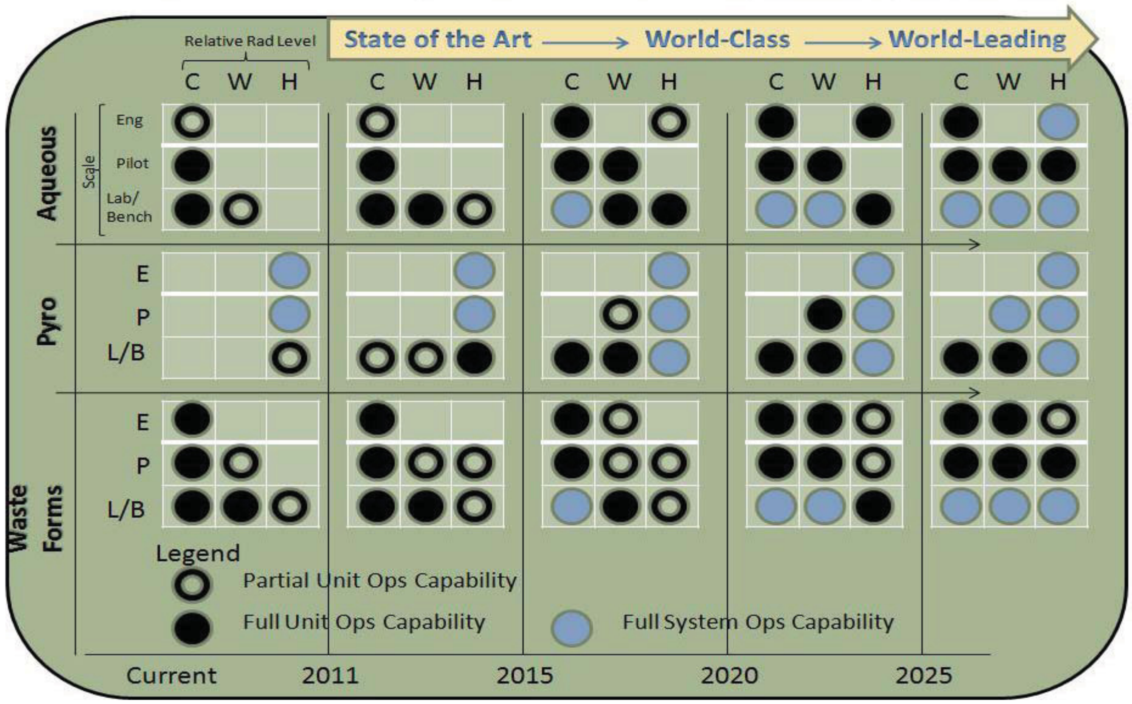

Figure 1. Advanced Separations & Waste Forms RD&D Capabilities Development Timeline

This five-year implementation plan lays out the specific near-term tactical investments in people, equipment and facilities, and customer capture efforts that will be required over the next five years to quickly and safely bring on line the capabilities needed to support the science-based goals and objectives of INL's Advanced Separations and Waste Forms RD&D Capabilities Strategic Plan.

2. CURRENT SEPARATIONS and WASTE FORM CAPABILITIES

Separations and waste form RD&D capabilities are spread out across the INL campus with a major presence at the Materials and Fuel Complex,(MFC), including equipment in the Hot Fuel Examination Facility (HFEF), Analytical Laboratory (AL), Radio-Chemistry Laboratory, (RCL), Fuels Conditioning Facility, (FCF), and the Fuels and Applied Science Building (FASB). Additional capabilities exist at the Central Facilities Area, (CFA, Building 625). These nuclear and radiological facilities, equipment, and expertise are used for warm, transuranics and hot, science-based research and development (R&D) work.

Additionally, the Center for Advanced Energy Studies (CAES), Bonneville County Technology Center (BCTC), INL Research Center (IRC), and INL Engineering Demonstration Facility (IEDF) in Idaho Falls, along with the Water Chemistry and Engineering Laboratory at MFC, are currently used for separations and waste form RD&D work on cold surrogate materials.

- **Hot Fuel Examination Facility (HFEF/MFC)** – Commissioned in 1975, the HFEF is a heavily-shielded Hazard Category 2 nuclear facility suited for remote handling of transuranics and radioactive materials in a shielded hot cell. It has a large air, hot cell along with a bigger inert atmosphere hot cell that is currently used for waste form R&D work. It currently houses the Hot Isostatic Press, (HIP), along with several waste form furnaces at the MFC complex.

- **Analytical Lab (AL/MFC)** – The AL at MFC is a Hazard Category 3 nuclear facility that focuses on the chemical and isotopic characterization of irradiated fuels and materials. Hot aqueous separations R&D work is conducted in a series of small hot cells, fume hoods and glove boxes using Gas Pressurized Extraction Chromatograph equipment, (GPEC). This specialized equipment provides both manual and automated radionuclide separations capabilities in a safe, radiological controlled facility.

- **RadioChemistry Laboratory (RCL/MFC)** – The RCL is MFC's newest facility (2010) and houses state-of the art equipment and instrumentation in five separate laboratories used for aqueous separations RD&D work on radiological materials. The facility provides the capabilities to perform analytical and characterization work along aqueous separation process testing in a safe, radiological controlled facility.

- **Fuels Conditioning Facility (FCF/MFC)** – The FCF at MFC is the primary facility being used today for the electrochemical separations processing of the used Experimental Breeder Reactor (EBR)-II fuel and Fast Flux Test Facility (FFTF) fuel. FCF is a nuclear facility that houses the engineering-scale dispositioning equipment, like the Mark V electrorefiner, cathode processors, and casting furnaces that are utilized for this mission.

- **EBR-II Turbine Deck (Building, 768/MFC)** – The laboratory space at the EBR-II turbine deck at MFC is a non-radiological area currently being used to perform process development work relative to electrochemical separations RD&D on cold surrogate materials. This facility houses engineering-scale processing equipment like the Zeolite roller mill, Zeolite dryer, grinder/classifier, sieve/shaker unit, and a heated V-mixer.

- **Engineering Development Laboratory (MFC Building 789)** – The engineering development laboratory at MFC is a non-radiological facility that is currently used to perform process development work relative to electrochemical separations RD&D on cold surrogate materials. This facility houses engineering and laboratory-scale processing equipment like a V-mixer, inert glove boxes (2), and molten-salt, high-temperature air and inert resistance furnaces.

- **Water Chemistry Laboratory (EBR-II Building 768B/MFC)** – The water chemistry laboratory at MFC is a non-radiological facility that is currently used to perform measurement and characterization work on cold surrogate materials. This facility houses laboratory-scale analytical equipment like, an Inductively Coupled Plasma Mass Spectrometer (ICP-MS), Thermogravimetric Analyzer (TGA), and Auto-density Analyzer along with an inert glove box and a small furnace being used for electrochemical separations research.

- **Fuels & Applied Science Building (FASB/MFC)** – The FASB at MFC is a radiological facility that is currently be used for process development of both aqueous and electrochemical separations RD&D. This radiological facility houses laboratory-scale equipment in room 106 like a Gamma-Cell 220 Irradiator, aqueous test loop with Centrifugal Contactors, and an ultraviolet-visible (UV-VIS) Spectrometer used for gamma radiolysis and aqueous process research. FASB is also used to perform radiological process and equipment development research for electrochemical separations and houses laboratory and engineering-scale equipment, such as a molten-salt and vacuum furnace along with an inert glove box and engineering-scale vacuum induction furnace.

- **Central Facilities Area (CFA/625)** – CFA-625 at INL has two laboratories currently being used for radiological and non-radiological aqueous RD&D process development work. The non-radiological laboratory contains laboratory-scale equipment used to capture and analyze iodine gases and houses an HP 5890 Chromatograph, two bench-top hoods, six gas lines, and gas analyzers. The other laboratory at CFA-625 is used for radiochemistry analysis and measurements and houses radiological laboratory-scale equipment, such as a Gamma Spectrometer, Potentionstat, Beta Spectrometer, UV-Vis Spectrometer, Scintillation Counter, Alpha Spectrometer, and three hoods /inert gloves boxes.

- **Bonneville County Technology Center (BCTC-B6/Idaho Falls)** – The BCTC in Idaho Falls is a non-radiological facility that is currently used for aqueous process and equipment development and demonstration. This facility houses laboratory-, engineering-, and pilot-scale equipment used for aqueous separations and analysis. The BCTC has V2, V5, V10, and a 30-stage cascading contactor platform along with mixer/settlers, pulse column ,and a droplet analyzer all used for aqueous separations RD&D work.
- **INL Research Center, (IRC-B1 and B12/Idaho Falls)** – The IRC, located in Idaho Falls, is a non-radiological facility that is currently used for aqueous chemical R&D and Krypton gas capturing. The B12 laboratory at IRC houses the laboratory-scale Cryostat that is used in the Krypton gas capture process. The B1 laboratory at IRC houses the engineering-scale equipment that is used for aqueous chemical R&D. Some of the R&D equipment in B1 includes: a 6000i Spectrometer, Thermogravameter, Porosity Analyzer, Atom Absorption Spectrometer, and two fume hoods/glove boxes. Non-radiological waste form qualification work is also performed at IRC in multiple laboratories using laboratory-scale equipment, such as: five to six waste form furnaces, X-Ray, Scanning Electron Microscope (SEM), Auge, Gas Chromatography, ICP-MS, Secondary Ion Mass Spectrometer (SIMS), and Fourier Transform Infrared Spectroscope (FTIRS).
- **INL Engineering Demonstration Facility, (IEDF/Idaho Falls)** – The IEDF in Idaho Falls is a non-radiological facility that houses the Cold Crucible Inductive Melter (CCIM), which is a one-of-a-kind laboratory-scale test bed used for waste form development work on cold surrogate materials.

3. IMPLEMENTATION STRATEGY

This five-year tactical implementation plan details all of the activities that will take place between FY 2011 through FY 2016 at INL to ensure that the key objectives and gaps described in the *Separations and Waste Forms Strategic Plan* are met and filled. This implementation plan concisely defines the facilities, expertise, and equipment required to enable INL to deploy integrated solutions to the world's nuclear/industrial materials and fuel cycle challenges and will be the foundation ,that will lead INL to its world-leading vision and grow business opportunities at the Laboratory.

INL Separations and Waste Form Strategic Plan FY 2011 milestones are as follows:

1. Issue an implementation plan that lists specific actions to support the strategic plan in the FY 2011 through FY 2015 time frame by March 31, 2011.
2. Provide support to CH2M-WG Idaho, LLC (CWI) and DOE Office of Environmental Management (EM) efforts to complete Remote Analytical Laboratory (RAL) turnover, including procedure development, training, etc., as required to make RAL available for NE research activities in FY 2012, by September 30, 2011.
3. Procure laboratory-scale electrorefining equipment to support development of new capabilities for uranium and radiological testing, which can be done much more cost effectively than tests performed in hot cells. Complete initial equipment purchases by September 30, 2011.

4. Provide specific recommendations to INL Deputy Lab Director on organizational changes that would consolidate INL waste form R&D capabilities into a single organization, with sufficient capabilities to attract new funding. Complete recommendation by March 31, 2011.

The key objectives, enablers, and activities to becoming world-leading in separations and waste forms as written in the strategic plan are as follows:

- Establish and develop warm/transuranics and hot capabilities for aqueous separations and waste forms bench-, pilot-, and engineering-scale R&D
- Establish and develop cold, warm/transuranics, and hot bench-scale capabilities for electrochemical separations R&D
- Organize waste forms expertise into a unified, collaborative activity that will attract new funding from DOE-NE, other DOE offices, and other agencies.
- Transfer and construct planned RD&D facilities, such as the RAL (at the Idaho Nuclear Technology and Engineering Center [INTEC]), the Research and Education Laboratory, (REL in Idaho Falls), the Fluorinel Dissolution Process (FDP) hot cells (at INTEC), and the FPF (at INTEC/CPP-691).
- Develop critical expertise through professional development and hiring of researchers/scientists who have specialized skills in separations and waste forms science and engineering
- Develop management systems that could be used to support access by a wide range of university, government, industry, and international researchers to INL separations and waste form capabilities.

3.1 Customer Capture and Relationship Plan

As identified in the *Separations and Waste Forms Strategic Plan*, a key objective is the development of "management systems that could be used to support access by a wide range of university, government, industry, and international researchers to INL separations and waste form capabilities." Implementation of this objective is accomplished through the preparation of a customer capture and relationship plan. The *Customer Capture Plan* provides details on potential customers and how collaboration with those customers will enable the achievement of both customer and DOE objectives and identify opportunities for development of capabilities into a research hub and user facility. Development of a *Customer Capture Plan* is estimated to cost $20,000 and should be completed in FY 2011. This capture plan will provide the basis for refining and updating both the strategic plan and this implementation plan.

3.2 Aqueous Separations

The critical capability gap for aqueous separations at INL is the lack of engineering- and pilot-scale capabilities for warm and transuranics materials along with no bench-, engineering-, or pilot-scale capabilities for hot/irradiated materials. These warm and hot capabilities must be developed and deployed in the next five years and are the critical milestone objectives required for advancing INL RD&D capabilities in the field of aqueous separations. Key objectives, enablers, and activities for aqueous separations identified in the strategic plan are as follows:

A. Establish and develop warm/transuranics and hot capabilities for aqueous separations and waste forms bench-, pilot-, and engineering-scale R&D

B. Transfer and construct planned RD&D facilities, such as the REL at INTEC, the REL in Idaho Falls, the FDP hot cells at INTEC, and the FPF at INTEC/CPP-691.

C. Develop integrated and enhanced engineering-scale R&D capabilities for separations

D. Develop critical expertise through professional development and hiring of researchers/scientists who have specialized skills in separations and waste forms science and engineering.

Table 1 shows the developmental capability gaps for aqueous separations at INL.

Table 1. Developmental Capability Gaps for Aqueous Separations

Current	Future	Gaps
REC Laboratory and BCTC – cold surrogate work in Idaho Falls. RCL/MFC – warm, radiological R&D. FASB – warm radiological R&D. CFA-625 – warm radiological R&D.	Expand- laboratory and engineering scale capabilities via radiological and nuclear facilities dedicated to separations (i.e., RAL, REL). Also integrated engineering-scale capabilities with surrogates and nuclear materials. Ability to perform integrated process demonstrations at engineering-scale as well as process various special nuclear materials. Develop integrated modeling and simulation expertise. Expand science-based research capability closely coupled with R&D experiments	1. Hot-cell, integrated, & shielded R&D capability at laboratory/ bench-scale and engineering-scale. 2. Modeling and simulation expertise. 3. Instrumentation to support science-based R&D 4. Additional personnel required for advancing INL's aqueous capabilities.

Other areas of expertise at INL that require investment for increasing our capabilities in aqueous separations are summarized below:

- **Solvent Extraction** – Current expertise exists in the areas of fundamental actinide separations, fundamental Cs/Sr separations, process flow sheet development and demonstration, and solvent extraction equipment design and demonstration. Increased recognition in these areas will require contactor equipment investment to support engineering-scale testing, analytical instrumentation investment and method development, and the strategic hiring of researchers in the areas of analytical instrumentation methods development and radiochemical separations, and chemical engineers with solvent extraction equipment experience. This will be particularly important since much of the existing expertise could be retiring in the next 10 to 15 years. Mentoring of personnel will be critical to maintaining and improving capabilities.

- **Off gas Capture** – Limited expertise currently exists in the aqueous separations and radiochemistry department in the areas of iodine and Kr/Xe capture from used nuclear fuel recycling off gas streams. Process capabilities include a deep bed bench-scale iodine adsorption test setup and a bench-scale Kr capture cryostat setup. Development of additional off gas separations expertise is critical to the growth and recognition in this area.

Development of collaborative efforts with other national laboratories and universities will also support these goals.

- **Separations Process Modeling** – This is a new area being developed at INL that was initiated previously through a solvent extraction dynamic modeling Laboratory-directed Research and Development (LDRD) effort. This has led to limited modeling programmatic funding from the Fuel Cycle Research and Development (FCR&D) Nuclear Energy Advanced Modeling and Simulation (NEAMS) Campaign in FY 2010/2011. As a result, efforts are underway to develop an off gas modeling capability for the program and support solvent extraction modeling efforts. The current separations modeling capability at INL is supported by a few engineers with limited modeling experience. Further development of their expertise, along with the hiring of personnel with modeling expertise, is critical to continued expansion into this growing area of research.

Table 2 shows the detailed breakdown (by fiscal year) of the capital equipment, people, facilities ,and investments required to close the identified gaps and meet objectives over the next five to seven years and advance INL's aqueous separations towards world class. Additionally, investments in state-of-the-art instrumentation and equipment will be necessary to support this goal – particularly in the area of analytical instrumentation. These are specific activities that support milestones identified in the strategic plan.

Table 2. Preliminary Cost Estimates For Advanced Aqueous Separations Capabilities

Obj/ Gap	Activity- (Aqueous Separations)- ($K)	FY11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17
	RAL Operational Readiness							
B / 1	Procedure Development/Pedigree Update		$120K	$120K				
B / 1	Readiness Training		$80K					
B / 1	Administrative Requirements		$80K					
	*Assumption is that CWI/EM will pick up the ~$1.7M needed for facility corrective and preventative maintenance/repair costs for IWITU. (Contains no hot cell costs)							
	FDP/FPF							
	Transition FDP/INTEC from EM to NE for Engineering-Scale Demonstration & Materials Dispositioning						$500K	$1000K
	RCL Instrumentation/Facility enhancements							
A / 3	Hot NMR Instrument							$600K
A / 3	Nano Calorimeter			$100K				
A / 3	FTIR instrument		$100K					
A / 3	FT-Raman instrument			$125K				
A / 3	Laser induced Fluorescence Spectroscopy with IR detection capability					$300K		
A / 3	Additional gamma irradiator		$300K					
A / 3	Bench top fluorimeter. (Electrophoresis equipment)			$75K				
A / 3	General Lab equipment (non-capital)	$30K		$30K		$30K		$30K

Obj/ Gap	Activity- (Aqueous Separations)- ($K)	FY11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17
A / 1	Glove boxes (3)	$60K		$60K		$60K		
A / 1	Redo drain lines			$250K				
A / 1	Continuous emission monitoring stack			$250K				
A / 3	HPLC-MS-MS				$600K			
	Lab/Bench Scale Hot Separations Capability (RAL)							
A / 3	Centrifugal contactor upgrade			$200K	$100K			
A / 3	Support Equipment for Contactors			$50K	$50K			
A / 3	Fuel Dissolution Apparatus		$200K					
A / 3	ICP MS		$200K					
A / 3	Ion Chromatograph		$150K					
A / 3	General lab equipment (non-capital)		$50K	$25K		$25K		$25K
A / 3	Gamma counter		$140K					
A / 3	Liquid scintillation counter			$125K				
A / 3	Alpha spectrometer			$40K				
A / 3	Low energy gamma spectroscopy				$50K			
	Warm Engineering Scale Separations Capability (REL)							
C / 1	5-cm Centrifugal Contactor Pilot Plant (40 stage)					$800K		
C / 1	Individual Engineering Scale Contactors (centrifugal, mixer-settler, columns)				$250K			
C / 3	Laboratory support equipment (centrifuges, balances, titrators, mixers…)(non-capital)			$50K	$50K		$25K	$25K
C / 1	Glove boxes /enclosures				$300K	$700K		
C / 3	liquid scintillation counter				$125K			
C / 3	Alpha/Beta gas proportional counter				$80K			
C / 3	Alpha spectrometer					$40K		
C / 3	Low energy gamma spectroscopy					$50K		
C / 3	ICP-MS				$200K			
	Staff Augmentation(* Dollars shown for year of hire and will need to continue)							
D / 4	Radiochemical Separation Scientist		$300K[a]					
D / 4	Chemical Engineers		$300K			$300K		$300K

[a] LDRD funding requirements are identified in a red font in the table and show the fiscal year where the initial funding is needed to add the necessary expertise to expand INL's aqueous separations capabilities.

Obj/ Gap	Activity- (Aqueous Separations)- ($K)	FY11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17
D / 4	Modeling/Simulation Specialist			$300K				
D / 4	Mass Spectroscopist				$300K			
D / 4	Solvent Extraction Equipment Engineer			$300K				
D / 4	Chemist				$300K			
D / 4	Radiation Chemist			$300K				
D / 4	Technician		$200K		$200K			
D / 4	ICP-MS				$200K			
	Totals by Fiscal Year for Aqueous- ($K)	**FY11**	**FY 12**	**FY 13**	**FY 14**	**FY 15**	**FY 16**	**FY 17**
		$90K	$2,220K	$2,400K	$2,805K	$2,305K	$525K	$1,980K

3.3 Electrochemical Separations

Because of the narrow mission of its existing inert-atmosphere facilities, INL needs additional equipment, infrastructure, manpower, and facilities to enhance our suite of research capabilities to support science based R&D as called for in the DOE NE roadmap, INL TYSP, and INL's Advanced Separations and Waste Forms Strategic Plan. World-leading research in electrochemical recycling requires the capability to test the range of fundamental and applied science associated with the entire process, and the ability to validate the development of fundamental and integrated process models.

The critical path enablers for advancing electrochemical separations RD&D capabilities at INL in the next five years is to establish and enhance lab/bench-scale capabilities for cold, warm, transuranics and hot materials. Today only limited hot bench-scale capabilities exist at INL. Key objectives, enablers and activities for electrochemical separations identified in the strategic plan are:

A. Establishing and developing cold, warm/transuranics, and hot, bench-scale capabilities for electrochemical separations R&D

B. Timely transfer and construction of planned RD&D facilities such as the Remote Analytical Laboratory at (RAL/INTEC), the Research and Education Laboratory, (REL in Idaho Falls), and the retrofitting of existing Fuel Conditioning Facility (FCF/MFC) anterior rooms for warm/transuranic support capabilities.

C. Developing critical expertise through professional development and hiring of researchers/scientists who have specialized skills in separations and waste forms science and engineering

Table 3 shows the developmental capability gaps for electrochemical separations at INL.

Table 3. Developmental Capability Gaps for Electrochemical Separations

Current	Future	Gaps
Fuel Cycle Facility/MFC – First generation electrochemical equipment for treatment of used sodium-bonded EBR-II and FFTF fuel. HFEF/MFC-single, small electrochemical cell with limited access. FASB/MFC- single, small electrochemical cell for radiological testing with limited quantities of radioactive materials. Engineering development laboratory/MFC- single, small electrochemical cell for cold surrogate work.	Complete treatment capability for multiple fuel types – The ability to completely disposition used EBR-II and FFTF fuel, as well as the ability to disposition limited quantities of other fuel types–such as small quantities of fuel brought in for PIE and other programs. The ability to return recovered uranium to the commercial market is also a key future capability. Lab-Scale cold, warm/TRU R&D capabilities. Integrated/enhanced engineering-scale capabilities. Develop integrated modeling and simulation expertise.	1. Electrochemical technology development capabilities – testing laboratories that test smaller scale equipment at cold, warm, and hot radiological levels are necessary to test adaptations to first generation process for additional fuel types. 2. Improved Uranium Product – Modifications to the 1st generation process equipment are necessary to achieve form and purity required for commercial uranium market. 3. Inert glove boxes installed in Radiological facilities. 4. Modeling and simulation expertise. 5. Proliferation resistance analysis. 6. Additional personnel required for advancing INL's electrochemical capabilities.

Table 4 shows the detailed breakdown (by fiscal year) of the capital equipment, people, facilities and investments required to close the identified gaps over the next five to seven years. These are specific activities that support milestones identified in the strategic plan.

Table 4. Cost Estimates For Advanced Electrochemical Separations Capabilities ($K)

Obj/Gap	Activity – (Electrochemical) ($K)	FY11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17
	Non-Rad Glove Box Capability (EDL- 789 & Water Chem Lab)							
A / 1	Argon Atmosphere glove boxes & associated equipment (2)		$250K					
A / 1	Pyrometallurgical furnaces & associated thermal analysis equipment (4)	$575K	$575K					
A / 1	Particle size analyzer	$100K						
A / 1	Sample Prep equipment; microbalances, cutting/polishing/drilling (non-capital)	$50K						
A / 1	General Lab Equipment (non-capital)	$100K						
A / 1	Hot Fuel Dissolution Apparatus-Mock-Up	$150K						
A / 1	ICP-MS	$200K						

Obj/Gap	Activity – (Electrochemical) ($K)	FY11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17
	Actinide-Low Rad Glove Box Capability (FCF Room 20)							
A, B / 3	D&D/Room Prep, (Utilities, HVAC, Infrastructure)		$500K					
A, B / 3	Argon Atmosphere glove boxes & associated equipment (1)			$250K				
A, B / 1	Pyrometallurgical furnaces & associated thermal analysis equipment (1)			$700K				
A, B / 1	Sample Prep equipment; microbalances, cutting/polishing/drilling			$100K				
A, B / 1	General Lab Equipment (non capital)			$100K				
A, B / 1	X-Ray Diffractmeter				$150K			
A, B / 1	SEM with EDAX Capability				$200K			
A, B / 1	X-Ray Fluorescence					$150K		
A, B / 1	Atomic Microprobe					$150K		
	Actinide-Low Rad Glove Box Capability (REL/FCF Room 26)							
A, B / 3	D&D/Room Prep, (Utilities, HVAC, Infrastructure)			$500K				
A, B / 3	Argon Atmosphere glove boxes & associated equipment (2)				$250K	$250K		
A, B / 1, 5	Pyrometallurgical furnaces & associated thermal analysis equipment (2)				$575K	$575K		
A, B / 1, 5	Sample Prep equipment; microbalances, cutting/polishing/drilling				$100K			
A, B / 1, 5	General Lab Equipment (non-capital)				$100K			
A, B / 1, 5	Hot Fuel Dissolution Apparatus (2)				$300K		$300K	
A, B / 1, 5	Thin Film Optical Microscope						$200K	
A, B / 1, 5	TGA with Quadrapole Mass Spec						$300K	
	Actinide-Integrated Pilot-Scale Unit Ops (FCF Wash Station)							
A / 1, 3	D&D/Room Prep, (Utilities, HVAC, Infrastructure)				$500K			
A / 1, 3	Argon Atmosphere glove boxes & associated equipment (4)					$500K	$500K	
A / 1	Pyrometallurgical furnaces & associated thermal analysis equipment (4)					$875K	$875K	
A / 1	Sample Prep equipment; microbalances,					$100K	$100K	

Obj/Gap	Activity – (Electrochemical) ($K)	FY11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17
	cutting/polishing/drilling- (2)							
A / 1	General Lab Equipment (non-capital)					$100K	$100K	
A / 1	Product and Waste form Inserts/Adaptors to use Hot Eng.-Scale Equipment							$1400K
	Product Processing/UCl3 Relocation to Hallway in FCF (Wash Station Extended)							
A / 2, 3	D&D/Room Prep, (Utilities, HVAC, Infrastructure)- (2)					$1,000K		
A / 2, 3	Argon Atmosphere glove boxes & associated equipment (2)						$500K	
A / 2	Pyrometallurgical furnaces & associated thermal analysis equipment (2)						$700K	
A / 2	Sample Prep equipment; microbalances, cutting/polishing/drilling							$200K
A / 2	General Lab Equipment (non-capital)							$200K
	Hot Cell-Feasibility/Small-Scale Integrated Process Testing Capability (HFEF windows 9M & 11M)							
A / 1,3,5	Design, fabricate, & Unit Op cold testing	$850K	$1,000K	$500K	$350K			
A / 1,3,5	Modifications, integration, & installation in Hot Cell		$600K	$1,550K	$2,200K	$250K	$250K	$250K
A / 1,3,5	Integrated process testing				$2,500K	$2,500K	$2,500K	$2,500K
	Staff Augmentation(* Dollars shown for year of hire and will need to continue)							
C / 6	Technician (3)		$200K		$200K		$200K	
C / 6	Metallurgical Engineer/Scientist- (3)	$300K		$300K[b]			$300K	
C / 6	Mechanical Scientist/Engineer- (2)		$300K			$300K		
C / 4, 6	Computer/Modeling Expert				$300K			
C / 6	Chemical Engineer/Scientist- (3)		$300K	$300K			$300K	
Totals by Fiscal Year for Electrochemical- ($K)		**FY11**	**FY 12**	**FY 13**	**FY 14**	**FY 15**	**FY 16**	**FY 17**
		$2,323K	$3,725K	$4,300K	$7,725K	$6,750K	$7,125K	$4,550K

[b] LDRD funding requirements are identified in a red font in table three and show the fiscal year where the initial funding is needed to add the necessary expertise to expand INL's electrochemical separations capabilities.

3.4 Waste Forms

Today waste forms expertise is split between two INL organizations, Energy and Environment and Nuclear Science and Technology. This provides an opportunity to leverage the synergy, expertise, and capabilities existing between both organizations. The collaborative, unified, and coordinated efforts of these capabilities and expertise will result in a larger suite of shared/combined capabilities, more efficient and cost effective use of existing resources, unified/centralized departmental coordination and customer interfaces, and much greater ability and flexibility to attract new funding and personnel at INL. This more efficient use of existing resources and capabilities would be beneficial to both NE and EM missions, along with being a critical enabler to the DOE-NE and INL objective to develop and optimize sustainable nuclear fuel cycles going forward. Key objectives, enablers, and activities for waste forms identified in the strategic plan are as follows:

A. Establish and develop warm/transuranics and hot capabilities for aqueous separations and waste forms bench, pilot and engineering-scale R&D

B. Organize waste forms expertise into a unified, collaborative activity that will attract new funding from DOE-NE, other DOE offices, and other agencies.

C. Transfer and construct planned RD&D facilities, such as the RAL at INTEC) the REL in Idaho Falls, the FDP hot cells at INTEC, and the FPF at INTEC/CPP-691.

D. Develop integrated and enhanced engineering-scale R&D capabilities for waste forms

E. Develop critical expertise through professional development and hiring of researchers/scientists who have specialized skills in separations and waste forms science and engineering.

Table 5 shows the developmental capability gaps for waste forms at INL.

Table 5. Developmental Capability Gaps for Waste Forms

Current	Future	Gaps
Baseline – Warm/TRU & hot R&D and processabilty capabilities at HFEF. Metal waste form equipment and some ceramic waste form equipment for treatment of used sodium-bonded fuel at MFC. HIP and CCIM	Develop integrated modeling and simulation expertise Establish hot engineering- and pilot-scale R&D capabilities at INL Unified/consolidated capabilities, techniques and expertise in waste forms that can be leveraged for multiple programs Maintain HIP capabilities	1. Modeling and simulation expertise. 2. Facility space, equipment, and expertise dedicated to Waste Form R&D. 3. INL waste form capabilities currently not unified to leverage maximum potential between two organizations. 4 Additional personnel required for advancing INL's waste forms capabilities.

Table 6 shows the detailed breakdown (by fiscal year) of the capital equipment, people, facilities and investments required to close the identified gaps over the next five to seven years. These are specific activities that support milestones identified in the strategic plan.

Table 6. Preliminary Cost Estimates for Advanced Waste Form Capabilities ($K)

Obj/Gap	Activity- (Waste Forms)- ($K)	FY11	FY 12	FY 13	FY 14	FY 15
	Add Waste Form Processabilty Equipment					
A / 2	General Lab Equipment (non-capital)				50 K	
A / 2	Large 2000’c Furnace			$200K		
A / 2	Vacuum Arc Melter				$200K	
A / 2	Small Melter/Furnace ~10to20 Lbs. with off gas system					$500K
A / 2	Process monitoring equipment (high accuracy flow meters, thermo resistors, fiber optic capability for high frequency applications)				$150K	
A / 2	Waste form dissolution apparatus for TCLP/PCT/VHT testing					$100K
A / 2	XRD/SEM/FT/etc. analytical equipment use (leverage equipment/capabilities identified for other areas)					$500K
A / 2	Duplicate specific melter equipment (TBD) for installation in a hot cell at MFC				$200K	
	Staff Augmentation- (* Dollars shown for year of hire and will need to continue)					
E / 4	Waste Form Qualification Specialist			$300K[c]		
E / 4	Geo-Chemist				$150K	
E / 4	Mechanical Engineer/Designer					$200K
E / 1	Computer/Modeling Expert			$225K		
E / 4	Chemical engineer/off gas specialist					$200K
E / 4	Analytical chemists (use those identified in other areas)					$150K
E / 4	Glass chemist/ceramicist/materials scientist (2)		$400K			$250K
	Totals by Fiscal Year for Waste Forms- ($K)	**FY11**	**FY 12**	**FY 13**	**FY 14**	**FY 15**
			$400K	**$725K**	**$750K**	**$1,900K**

4. FUNDING SOURCES and SCHEDULE

Existing funding sources include programmatic funding, infrastructure funding, LDRD funding, and Battelle Energy Alliance, LLC (BEA) institutional investments. These funding/budget allocations need to be firmed up in FY 2011 and should go out through FY 2016 at a minimum in support of Phase I development activities.

- **Programmatic Funding** – For most of the equipment and staff development needed for various programs, programmatic funding will be used for acquisition and installment. Careful planning will identify the synergistic needs among programs to optimize equipment purchases and maximize capability. This includes leveraging opportunities with NE, EM. National Nuclear Security Administration (NA), and other governmental, industrial, and educational entities.

[c] LDRD funding requirements are identified in a red font in table three and show the fiscal year where the initial funding is needed to add the necessary expertise to expand INL’s waste form capabilities.

- **Infrastructure Funding** – It is anticipated that infrastructure funding will be used for facility upgrades and new facilities that cost less than $10M. Infrastructure funding may include institutional investments, such as IGPP and programmatic capital investments. In addition, equipment maintenance and repair costs may be covered by infrastructure funding as new equipment becomes operational. Infrastructure funding may also be used as a strategic investment for items that are not directly needed by the existing programs but are deemed necessary to support future missions.

- **Institutional Investments** – For facilities, equipment, or expertise development, internal BEA funds may be available for targeted strategic investments.

- **Capital Line Items** – For major procurements and facilities that cost more than $10M, a line item capital appropriation will be requested from DOE on a timely basis. A Line Item Building (LIB) request will be initiated in FY 2011, if applicable. As capital line items are identified, discussions will be held with DOE as early as possible to support pre-planning and pursuit of funding sources.

- **LDRD Funding** – LDRD funding would be used in R&D of innovative equipment, innovative use of existing equipment, and improved analytical processes. A fraction of the LDRD funds will be dedicated to cover early development needs until a successful implementation path is defined (at which point programmatic funds are expected to take over the additional development and implementation). The expectation is that the LDRD funding requirements will be three-year commitments.

- **IGPCE Funding –** Institutional general purpose capital equipment (IGPCE) funding provides a means to procure equipment and instrumentation in support of the overall INL mission. This equipment is specifically intended to be beneficial to multiple programs across the Laboratory. There are two pools of funding available to procure capital equipment: Landlord General Purpose Capital Equipment and IGPCE. It may also be possible to leverage opportunities with other governmental, educational, and industrial opportunities for this funding.

Table 7 shows funding sources anticipated for each of the activities in this implementation plan.

Table 7. Proposed Activity Funding Sources

	Proposed Funding Source					
	Programmatic	**Infrastructure**	**Institutional**	**Line Item**	**LDRD**	**IGPCE**
	$K	**$K**	**$K**	**$K**	**$K**	**$K**
Aqueous Separations						
RAL Operational Readiness						
Procedure Development/Pedigree Update		240				
Readiness Training		80				
Administrative Requirements		80				
FDP/FPF						
Transition FDP/INTEC from EM to NE for Engineering-Scale Demonstration & Materials Dispositioning	500	500	500			

	Proposed Funding Source					
	Programmatic	Infrastructure	Institutional	Line Item	LDRD	IGPCE
	$K	$K	$K	$K	$K	$K
RCL Instrumentation/Facility enhancements						
Hot NMR Instrument						600
Nano Calorimeter						100
FTIR instrument						100
FT-Raman instrument						125
Laser induced Fluorescence Spectroscopy with IR detection capability						300
Additional gamma irradiator						300
Bench top fluorimeter. (Electrophoresis equipment)						75
General Lab equipment (non-capital)	120					
Glove boxes (3)			180			
Redo drain lines			250			
Continuous emission monitoring stack			250			
HPLC-MS-MS						600
Lab/Bench Scale Hot Separations Capability (RAL)						
Centrifugal contactor upgrade						300
Support Equipment for Contactors	100					
Fuel Dissolution Apparatus	200					
ICP MS						200
Ion Chromatograph						150
General lab equipment (non-capital)	125					
Gamma counter						140
Liquid scintillation counter						125
Alpha spectrometer						40
Low energy gamma spectroscopy						50
Warm Engineering Scale Separations Capability (REL)						
5-cm Centrifugal Contactor Pilot Plant (40 stage)	800					
Individual Engineering Scale Contactors (centrifugal, mixer-settler, columns)	250					
Laboratory support equipment (centrifuges, balances, titrators, mixers…)(non-capital)	150					
Glove boxes /enclosures						1,000
liquid scintillation counter						125
Alpha/Beta gas proportional counter						80
Alpha spectrometer						40
Low energy gamma spectroscopy						50

	Proposed Funding Source					
	Programmatic	Infrastructure	Institutional	Line Item	LDRD	IGPCE
	$K	$K	$K	$K	$K	$K
ICP-MS						200
Staff Augmentation (Dollars shown for year of hire and will need to continue)						
Radiochemical Separation Scientist					300	
Chemical Engineers	600				300	
Modeling/Simulation Specialist	300					
Mass Spectroscopist	300					
Chemist	300					
Radiation Chemist	300					
Technician	400					
ICP-MS	200					
Totals for Aqueous	**4,645**	**900**	**1,180**	**0**	**600**	**4,700**
Electrochemical Separations						
Non-Rad Glove Box Capability (EDL- 789 & Water Chem Lab)						
Argon Atmosphere glove boxes & associated equipment (2)			250			
Pyrometallurgical furnaces & associated thermal analysis equipment (4)	100	400			50	600
Particle size analyzer						100
Sample Prep equipment; microbalances, cutting/polishing/drilling (non-capital)	50					
General Lab Equipment (non-capital)	100					
Hot Fuel Dissolution Apparatus-Mock-Up						150
ICP-MS						200
Actinide-Low Rad Glove Box Capability (FCF Room 20)						
D&D/Room Prep, (Utilities, HVAC, Infrastructure)		500				
Argon Atmosphere glove boxes & associated equipment (1)		250				
Pyrometallurgical furnaces & associated thermal analysis equipment (1)	100					600
Sample Prep equipment; microbalances, cutting/polishing/drilling	100					
General Lab Equipment (non capital)	50				50	
X-Ray Diffractmeter			150			
SEM with EDAX Capability						200
X-Ray Fluorescence						150
Atomic Microprobe						150
Actinide-Low Rad Glove Box Capability (REL/FCF Room 26)						
D&D/Room Prep, (Utilities, HVAC, Infrastructure)		500				
Argon Atmosphere glove boxes & associated equipment (2)		500				

	Proposed Funding Source					
	Programmatic	Infrastructure	Institutional	Line Item	LDRD	IGPCE
	$K	$K	$K	$K	$K	$K
Pyrometallurgical furnaces & associated thermal analysis equipment (2)	250		250		150	500
Sample Prep equipment; microbalances, cutting/polishing/drilling			100			
General Lab Equipment (non-capital)	100					
Hot Fuel Dissolution Apparatus (2)	300					300
Thin Film Optical Microscope						200
TGA with Quadrapole Mass Spec						300
Actinide-Integrated Pilot-Scale Unit Ops (FCF Wash Station)						
D&D/Room Prep, (Utilities, HVAC, Infrastructure)			500			
Argon Atmosphere glove boxes & associated equipment (4)		250	250			500
Pyrometallurgical furnaces & associated thermal analysis equipment (4)	100	500	500		100	550
Sample Prep equipment; microbalances, cutting/polishing/drilling- (2)	200					
General Lab Equipment (non-capital)	200					
Product and Waste form Inserts/Adaptors to use Hot Eng.-Scale Equipment	200	250	250		200	500
Product Processing/UCl3 Relocation to Hallway in FCF (Wash Station Extended)						
D&D/Room Prep, (Utilities, HVAC, Infrastructure)- (2)		1,000				
Argon Atmosphere glove boxes & associated equipment (2)		500				
Pyrometallurgical furnaces & associated thermal analysis equipment (2)		350	350			
Sample Prep equipment; microbalances, cutting/polishing/drilling		200				
General Lab Equipment (non-capital)	200					
Hot Cell-Feasibility/Small-Scale Integrated Process Testing Capability (HFEF windows 9M & 11M)						
Design, fabricate, & Unit Op cold testing	2,700					
Modifications, integration, & installation in Hot Cell	5,100					
Integrated process testing	10,000					
Staff Augmentation(* Dollars shown for year of hire and will need to continue)						
Technician (3)	600					
Metallurgical Engineer/Scientist- (3)	600				300	
Mechanical Scientist/Engineer- (2)	600					
Computer/Modeling Expert					300	
Chemical Engineer/Scientist- (3)	600				300	
Totals for Electrochemical	**22,250**	**5,200**	**2,600**	**0**	**1,450**	**5,000**

	Proposed Funding Source					
	Programmatic	Infrastructure	Institutional	Line Item	LDRD	IGPCE
	$K	$K	$K	$K	$K	$K
Waste Forms						
Add Waste Form Processabilty Equipment						
General Lab Equipment (non-capital)	50					
Large 2000'c Furnace						200
Vacuum Arc Melter						200
Small Melter/Furnace ~10to20 Lbs. with off gas system			500			
Process monitoring equipment (high accuracy flow meters, thermo resistors, fiber optic capability for high frequency applications)						150
Waste form dissolution apparatus for TCLP/PCT/VHT testing						100
XRD/SEM/FT/etc. analytical equipment use (leverage equipment/capabilities identified for other areas)						500
Duplicate specific melter equipment (TBD) for installation in a hot cell at MFC			200			
Staff Augmentation- (Dollars shown for year of hire and will need to continue)						
Waste Form Qualification Specialist					300	
Geo-Chemist	150					
Mechanical Engineer/Designer	200					
Computer/Modeling Expert					225	
Chemical engineer/off gas specialist	200					
Analytical chemists (use those identified in other areas)	150					
Glass chemist/ceramicist/materials scientist (2)	250				400	
Totals for Waste Forms	**1,000**	**0**	**700**	**0**	**925**	**1,150**
TOTAL	**27,895**	**6,100**	**4,480**	**0**	**2,975**	**10,850**

4.1 Investment Strategy

The execution of the proposed plan requires a phased approach to increasing separations capabilities and waste form development. Consequently, a mixture of funding strategies/sources will be needed. The following steps and strategy will be utilized to facilitate the execution of this implementation plan. This investment strategic covers only the near-term activities in Phase I of the strategic plan, (FY 2011 to FY 2015). Tables 2, 4 and 6 contain the detailed breakdown (by fiscal year) of the Phase I activities being executed in this implementation plan. The overall investment strategy is summarized as follows:

- INL will move to develop cold/low radiological level electrochemical testing capabilities. The primary funding need is for initial equipment/instrumentation – FY 2014 to FY 2015.

- Early Phase I aqueous programs in RAL will be supported by program-specific funding or institutional investments (as applicable) for minor upgrades and modifications – FY 2011 to FY 2012.
- LDRD, Programmatic, and IGPCE funding will be pursued to design and install the inert glove boxes needed to establish INL's cold, warm/TRU and hot R&D capabilities in electrochemical separations – FY 2012 to FY 2015.
- Idaho Facilities Management (IFM) Programmatic or Institutional General Plant Project (IGPP) funding, as appropriate, will be pursued to support development of modifications to operating facilities for uranium recycle to commercial market and modifications to increase process throughput/efficiency and accelerate EBR-II treatment.
- Aqueous and electrochemical processing technologies have the opportunity to leverage funding from other (non-NE) sources, and this will be the key to successfully moving forward with engineering-scale R&D.
- Limited DOE-NE budget will require partnering with other DOE offices to bring engineering-scale operations on line in a timely manner for demonstration of solutions to fuel cycle and nuclear materials challenges (i.e., recover material for fabricating lead test assemblies [LTA] and demonstrate fuel cycle closure for future candidate fuels).
- Possible funding opportunities will be investigated for developing capabilities into a research hub and user facility.

5. NEAR-TERM CUSTOMERS and PROGRAMS

This advanced suite of capabilities supports the specific missions of DOE-NE and DOE-EM. Further, the capabilities resident in these advanced tools and instruments also support nuclear attribution, fuel cycle development work, U.S. governmental agencies, U.S. industry, and research collaborations, and make INL the "*GO-TO*" place for domestic and international nuclear material disposition challenges. These capabilities will also help revitalize U.S. leadership in nuclear energy R&D and the underlying domestic nuclear science and technology infrastructure. With continuing investments to revitalize the existing infrastructure and fill mission-related capability gaps, INL will continue to provide a national nuclear energy capability for decades to come. This capability will provide industry, universities, national laboratories, and other federal agencies with the tools required to ensure sustainable use of nuclear energy.

6. RISK

The completion of the overall strategy requires serious investments by programmatic and IFM funding as identified in this plan. A major risk is the allocation of resources (as needed) on a yearly basis. Because of funding uncertainties, there is a risk that the major milestones may not be met as scheduled. Delays in implementing this plan would impact INL's ability to realize DOE-NE's vision for extended and possibly increased deployment of advanced nuclear energy systems in the United States.

Other identified risks to the strategic plan are as follows:

- Attrition and retirement of highly trained personnel and knowledge base (> 40% of skilled workforce retiring within 15 years). **This is a major concern for aqueous, electrochemical, and waste forms and must be carefully managed.**

- Funding approvals and shortfalls
- Possible negative impacts to other INL programs
- INL approval of the Strategic Plan
- Allocation of resources on a yearly basis
- Possible conflicts and priority challenges between the concentrated set of activities and resources needed to support the myriad of day-to-day operations and ongoing programmatic activities scheduled at MFC in FY 2011 and beyond.

To mitigate the risks, the following measures will be taken:

1. The *Integrated World-Leading, Advanced Separations and Waste Forms Capabilities Strategy* and major milestones will be incorporated into the appropriate INL strategic documents.
2. Advanced separations and waste forms R&D capability-related activities will be incorporated into the operational schedules of MFC, INTEC, CFA, and the Idaho Falls research, test, and demonstration facilities.
3. The needs and resources of multiple programs will be reviewed on a quarterly basis to alleviate the funding fluctuations that occur in a single program.
4. The aqueous, electrochemical, and waste forms department managers will proactively recruit the critical expertise needed to maintain and expand the specialized knowledge base to advance INL's R&D capabilities to world-leading, as described in this plan.
5. The execution of this implementation plan will be implemented using a three-phase approach, broken down into 5-year increments,out through 2025.

7. SUMMARY

This implementation plan has outlined the near-term tactical activities that will establish the RD&D capabilities that will be the foundation and building blocks for advancing INL's expertise in separations and waste forms based on internal investments and customer development. The key objectives, enablers, and activities to becoming world-leading in separations and waste forms are as follows:

- Establish and develop warm/TRU and hot R&D capabilities for bench-, pilot-, and engineering-scales, as appropriate, for aqueous separations and waste forms
- Establish and develop cold, warm/TRU, and hot bench-scale R&D capabilities for electrochemical separations
- Organize waste form expertise at INL into a single, unified, collaborative organization with sufficient capability and expertise as a whole to attract new funding from NE, EM, and other agencies.
- Transfer and operate future planned RD&D facilities—such as RAL at INTEC, REL in Idaho Falls, the FDP hot cells at INTEC, and FPF at INTEC/CPP-691, as defined in this strategic plan

- Develop integrated and enhanced engineering-scale R&D capabilities for separations and waste forms
- Develop critical expertise through the hiring of recognized researchers/scientists in separations and waste form science and engineering.

The success of this implementation plan greatly depends on adequate annual funding along with the close coordination between INL, DOE-Idaho Operations Office (ID), and DOE-Headquarters to ensure timely information exchange, budget planning, and contingency management. Table 8 summarizes the expenses by fiscal year.

Table 8. Preliminary Cost Estimates by Fiscal year ($K)

	FY 11	FY 12	FY 13	FY 14	FY 15
Aqueous Separations	$90K	$2,435K	$2,235K	$2,755K	$2,305
Electrochemical Separations	$2,325K	$3,725K	$4,300K	$7,725K	$6,750K
Waste Forms	$0	$400K	$725K	$750K	$1,900K
Total	**$2,415K**	**$6,560K**	**$7,260K**	**$11,230K**	**$10,955K**

8. REFERENCES

1. DOE, *Nuclear Energy Research and Development Roadmap*, Report to Congress, U. S. Department of Energy, April 2010.
2. INL, *Ten-Year Site Plan* (TYSP), June, 2010
3. INL, *Advanced Separations and Waste Forms RD&D Capabilities Strategic Plan*, March, 2011