



## ENERGY AND ENGINEERING TECHNOLOGY

### Mission Statement

The Energy and Engineering Technology (E&ET) Division delivers science-based research and development and engineered solutions. We

- Develop new and efficient energy sources
- Enhance human performance, systems performance, and decision-making
- Deliver engineered solutions for disposition of waste and nuclear materials
- Deliver environmental stewardship technologies.

### *Energy & Engineering Engineered Solutions*



### Description

The Energy and Engineering Technology Division's FY-04 program is structured to position INEEL as a leading alternative-energy and engineering research and development organization. This fiscal year's Annual Work Plan is best characterized as being a multiprogram research and development portfolio executed by three directorates: Sustainable and Intelligent Systems, Environmental Technology and Engineering, and Energy Efficiency and Technology. The division will develop and use technologies to enhance the performance of complex systems and to provide solutions in the fields of alternative energy, environmental management and remediation, waste and nuclear materials, legacy management, and the associated challenges in ecological and cultural resources. The division's clients include the secretarial offices of the Department of Energy; the Idaho Completion Project; other sites within the Department of Energy complex; other federal agencies, such as the Department of Defense, U.S. Nuclear Regulatory Commission, NASA, and the Environmental Protection Agency; national interest organizations; private business; and international partners in Australia, Belgium, Canada, Japan, Korea, and the United Kingdom.

The Division is comprised of three directorates and 13 departments. Individual departments, based upon a division-wide business plan, capture our business. What follows is a summary and description of the work performed and the client base organized by directorate and department.

## **Sustainable and Intelligent Systems**

The directorate's FY-04 work focuses on three technical areas: systems and decision sciences, ecological and cultural resource issues, and human factors-remote-robotic systems. The directorate provides decision support, systems engineering, analysis, integration, and systems science solutions and support to government- and commercial-sector customers. It also develops decision-aiding tools designed to support intelligent, sustainable management of natural and cultural resources at and around the INEEL, enabling customers to comply with federal and state regulations pertaining to stewardship of land, water, and biotic resources in economically and socially responsible ways. These tools will be used wherever possible to address and resolve technical challenges that are relevant across the Northwest region. Directorate scientists and engineers will continue research that resolves issues related to human reliability and risk assessment, artificial intelligence and learning, human-performance measurement, and human-machine/human-robot interactions.

**Systems and Decision Science.** The Systems and Decision Science Department provides the decision support, systems engineering, systems analysis, systems integration, and systems science products and expertise necessary to help government and private industry customers develop solutions to complex challenges. Decision support focuses on developing and facilitating logical, traceable, and defensible decisions by integrating people and methods with decision-making principles. Systems engineering, integration, and systems science will be developing systems tools and methodologies, such as road-mapping sciences, complex system modeling, simulation, and analyses, organizational performance and maturity modeling, social sciences, applications of chaos, constraint, and complexity theories, and intransitive relationship tool sets.

Current and future business thrusts:

- Systems Support to INEEL and ICP
  - INEEL: Explosive Detection System, Systems-Based Management System
  - ICP: Glovebox Excavator Method project, Waste Area Groups 3 and 7, Idaho Nuclear Technology and Engineering Center (INTEC) remediation
- Decision Support to INEEL and ICP
  - INEEL: SIINET, Module Monitoring and Accountability System, Specific Manufacturing Capability modeling
  - ICP: Value engineering, facilitation, and life-cycle costing support to INTEC, Radioactive Waste Management Complex and Test Area North; facility deactivation, decontamination, and decommissioning modeling support
- New Business Development in National and Homeland Security
  - Future combat systems for U.S. Army
  - D&T Project for Savannah River Site
  - Risk-Based Prioritization Program for Homeland Security

- New Business Development in Energy and Environmental Security
  - Yucca Mountain Systems Design for Bechtel SAIC
  - Chalk River Infrastructure Review for Atomic Energy of Canada
  - Generation IV: Next Generation Nuclear Plant, Advanced Fuel Cycle Initiative
- New Business Development in System Sciences
- Simulation-Based Acquisition for DMSO and Defense Advance Research Projects Agency.

**Ecological and Cultural Resources.** The Ecological and Cultural Resources group develops and deploys decision-making tools for managing natural and cultural resources. Technologies developed will enable customers to comply with federal and state regulations pertaining to stewardship of land, water, and biotic resources in a way that recognizes the economic and social components of these systems. The department will continue its technical outreach to regional entities. This focuses INEEL capabilities jointly with those of collaborating partners to resolve technical challenges important to the greater Northwest. The outreach and collaboration program, known as Western Connections, will facilitate technical collaborations (among INEEL divisions and between INEEL and other agencies or organizations) that will help resolve important regional energy and environmental challenges. This initiative will build the INEEL's capacity to solve intractable problems, beyond the capability of the private sector alone. Mine-waste issues will be a key thrust element during FY-04, and tasks related to watershed science and management will be explored.

Current and future business thrusts:

- *Ecological applications* will concentrate on the development of tools to manage watersheds, terrestrial ecology, environmental decision support, soil science and engineering, environmental toxicology, and ecological risk assessment.
- *Cultural resource management and tribal liaison* will provide services in areas of sensitivity analysis, predictive modeling, and inventory tools for the protection and evaluation of archaeological and historical resources.
- *Stewardship technologies* will be provided to integrate socioeconomic, sustainability, and optimization technologies for long-range stewardship success.
- *Western Connections mine waste work* will continue to support the Department of Environmental Quality (DEQ) in managing information from area-wide and site-specific studies on selenium contamination near phosphate mines. A prototype Geographic Information System (GIS) Internet Map Service (IMS) has been developed in conjunction with the DEQ, Bureau of Land Management, U.S. Forest Service and Idaho Mining Association and Idaho State University. We anticipate that FY-04 will see development of a fully functional GIS IMS that incorporates stakeholder requirements and includes additional data sets. We will continue developing relationships with the DEQ, U.S. Environmental Protection Agency (EPA) and others in the Coeur d'Alene River Basin to identify tasks where INEEL resources can be applied to improve efficiency or reduce costs of remedial actions related to cleanup of historical mining-related contamination. Support will continue for regional mine waste (and other) problems through the EPA technical assistance program. Emerging relationships with the Bureau of Reclamation and the Bear River Water Quality Task Force may allow recently developed systems dynamic modeling tools to be applied to watershed-management issues.

**Human Factors, Robotic and Remote Systems.** In FY-04, the department's projects will touch on a broad variety of products and services including human reliability and risk assessment, artificial intelligence and learning systems, human performance measurement, technology design and assessment, and human-machine and human-robot interaction research. The department will continue to research and develop automated systems that enhance operator safety and performance and reduce hazards. The department will continue its division-level Intelligent Systems Initiative, enabling high-performance "human machine" teams to do what was once considered impossible. The initiative will research and develop powerful hybrid human machine technology to accomplish tasks that human or mechanical capability cannot do alone.

Current and future business thrusts:

- Applied Remote Operations
  - Remote material handling
  - Remote inspection
  - Remote monitoring
  - RAMS/RATV
- Unmanned Vehicle Systems
  - UAV/UGV operations
  - Air/ground collaboration
  - Mixed autonomy control
  - Robot/human teaming
- Control Room Design and Operator Performance
  - Human Reliability Analysis
  - Simulator Studies
  - Control Room Design
  - Emergency Management
- Other (INEEL/Classified)
  - Time-critical operations modeling
  - Vulnerability consequence modeling
  - Human performance analysis
  - Spatial cognition.



**Environmental Technology and Engineering**

In FY-04, the directorate will continue to address human and natural environmental challenges with engineering resources. It will apply engineered solutions and technologies to waste and nuclear materials management, environmental restoration, decontamination and decommissioning of facilities and

sites at INEEL and other DOE sites, and legacy-management issues with a focus on the interface between the DOE Offices of Nuclear Energy (NE) and Environmental Management for the long-term NE “mortgage” at the INEEL.

**Waste Management Technologies.** The Waste Management Technologies Department will provide expert technical support in management, processing, and disposition of the nation’s most challenging waste streams and materials. Two major objectives for FY-04 are to be the preferred provider of technical support and leadership to the ICP in management and disposition of legacy wastes and materials and to use unique expertise, as well as ICP successes, to develop a business base in waste management, processing, and disposition with non-ICP customers, including DOE and non-DOE entities.

Current and future business thrusts:

- Waste Process Technologies
  - Providing expert technical investigation, evaluation, and development of waste process technologies for DOE and non-DOE customers
  - Developing improved thermal treatment waste processing options, including advanced off-gas technologies
  - Developing improved waste stabilization options
  - Identifying beneficial uses for “waste” materials
- Waste Management and Disposition Services
  - Investing in new business base for Transuranic Certification—national and local
  - Developing predictive capability for the performance of materials in shipping/storage containers and final waste forms
  - Providing technical support and project leadership for ICP and non-ICP customers
  - Developing information-based technologies and tools to support cost-effective management and control of waste and material inventories for the DOE complex, as well as non-DOE customers.
- Nuclear Materials Management and Disposition Services
  - Providing expert technical support and networking to disposition excess nuclear materials for the DOE complex
  - Expanding role in Radiological Security and Disposition program.

**Environmental Systems.** The Environmental Systems Department will protect human health and safeguard the environment by promoting risk-reduction actions through the implementation of reliable environmental systems. The challenges associated with environmental remediation, infrastructure decommissioning, and legacy waste management require an integrated approach that couples the strengths of the natural system with that of engineered solutions and institutional controls. This program will continue to develop and implement advanced environmental systems, technologies, and strategies to assist our customers in cost-effectively complying with applicable regulations by establishing strategic partnerships with private industry, universities, and other federal agencies.

Current and future business thrusts:

- Remedial Engineering
  - Environmental remediation
  - Infrastructure deactivation, decontamination, and decommissioning
  - Surveillance and monitoring
  - Technical assistance
- Information Management
  - Data acquisition
  - Data storage
  - Data mining
- Performance and Risk Communications
  - Systems modeling
  - Life-cycle assessment
  - Risk communications.



**Environmental R&D Laboratory.** The Environmental Research and Development Laboratory Department will use its extensive expertise in flow-sheet development, separation techniques, off-gas technology, waste treatment and disposal forms, waste minimization, decontamination, material science and corrosion in support of ICP and non-ICP projects. Laboratory facilities, including traditional wet chemistry capabilities, materials science equipment, and pilot-plant facilities, will continue to be made available in supporting treatment process studies to address technical issues relating to ICP challenges in projects such as sodium-bearing waste. These facilities will also be available to serve customers from areas outside the ICP.

Current and future business thrusts:

- Waste Treatment Technology
  - Process Modeling—computer modeling of chemical systems to provide fast, cost-effective data for process design and optimization
  - Waste Treatment—development of new and unproven technologies to treat hazardous and radioactive wastes
  - Off-Gas Treatment—testing of off-gas cleanup and instrumentation technologies
- Advanced Separations Technology
  - Filtration—development of emerging filtration technologies such as the cross-flow filtration unit and the Spin-Tek filtration unit
  - Solvent Extraction—liquid/liquid extraction treatment technologies for removal of radioactive components of waste solutions

- Ion Exchange—solid/liquid extraction treatment for removal of radioactive and hazardous species
- Process Intensification—methods of process control that allow higher throughput at lower cost
- INTEC Process and Materials Technology
  - INTEC Plant Support—technical support for the waste processing facilities at INTEC
  - Decontamination—Development, testing, and evaluation of novel radioactive treatment technologies for INTEC
  - Materials testing and inspection—on-site support for materials testing of waste processing and spent fuel materials, corrosion examination, and early warning of corrosion problems
  - Waste Minimization—pollution prevention evaluations for INTEC waste processing facilities.

## **Energy Efficiency and Technology**

The Energy Efficiency and Technology Directorate is the focal point for all non-nuclear energy research and development at the INEEL. The directorate will continue to offer applied expertise in the areas of fossil energy (oil and gas technologies, carbon management), renewable energy (geothermal, hydropower, wind, and bioenergy), sustainable building and energy management, transportation technologies (advanced battery development and testing, energy storage, vehicle technologies, transportation infrastructure), and hydrogen (production, storage, and utilization). The INEEL, through the Energy Efficiency and Technology Directorate, is the lead laboratory for advanced high-power energy storage testing and evaluation for both the Partnership for New Generation Vehicles and the Hybrid Vehicle Propulsion Programs of the U.S. Advanced Battery Consortium. The directorate will continue to be the lead lab for the Advanced Vehicle Testing Activity, light-duty vehicle testing, the National Geothermal Program, and the lead laboratory for engineering support in the National Hydropower Program. Strategic objectives of the directorate are:

- Build the INEEL portfolio of R&D projects funded by DOE's Offices of Energy Efficiency and Renewable Energy and Fossil Energy, and related work for others (WFO), to support DOE's multiprogram energy needs, as well as contribute to laboratory leadership in Technology Transfer.
- Apply INEEL technical expertise and capabilities to the development and demonstration of clean energy technologies, with the focus on becoming a significant contributor to the DOE Biomass and Hydrogen Programs.
- Enhance the scientific excellence and recognition of the INEEL through publications, awards, professional and technical leadership, and academic partnerships.

**Fossil Energy Technologies.** Fossil Energy Technologies Department will continue to provide innovative research and development to reduce U.S. petroleum imports, increase use of cleaner-burning natural gas, solve environmental problems, reduce industry operating costs, commercialize quality products and services, develop exploration and production technologies, develop gas and oil processing technologies, develop and test natural gas vehicles, and develop technologies for environmental projects, such as hydrogen, Clean Coal, and ultra clean fuels. Carbon management (including CO<sub>2</sub> capture and sequestration) will be given increased emphasis in FY-04 as the U.S. government places more emphasis on carbon management.

Current and future business thrusts:

- In partnership with industry, develop new and improved oil and gas (including methane hydrates and coal bed methane) exploration, drilling, production, and transport technologies.
  - INEEL is the lead laboratory for Drilling Completion, and Stimulation Technology Forum in the Natural Gas and Oil Technology Partnership Program
  - Exploration (down hole seismic sources and sensors, numerical methods for Basin and Range exploration, exploration strategy development)
  - Reservoir characterization (assessment of gas capacity in CBM reservoirs and CO<sub>2</sub> sequestration potential)
  - Pipeline data management and monitoring technologies.
- In partnership with industry, develop new and improved technologies to accelerate the use of natural gas.
  - Small-scale natural gas liquefaction cooperative research and development agreement (CRADA) with PG&E/SoCal (R&D 100 application submitted)
  - Natural Gas Fueling Station (easily migrated to hydrogen)
  - Migrate the liquefier to 100% liquefaction for stranded gas applications, to compressor-based front-end systems, and to CO<sub>2</sub> gas cleanup
- In partnership with industry, develop new and improved technologies to process and use oil, gas, and coal and to deal with their environmental use consequences.
  - Attempt to transfer the coal plant to industry to serve as a site to produce electricity and hydrogen, and serve as a large engineering test bed
  - Supercritical catalyst regeneration (R&D 100 application submitted)
  - Work for others has included Clean Coal Technology Assessment for Bechtel, a mini-ammonia plant design for Bechtel, and the auto-thermal diesel reformer
  - Base business hydrogen technologies including diesel reformer, fuel cells, and gas processing activity
  - Support carbon management activities and the Carbon Capture Geologic CO<sub>2</sub> Sequestration Project Risk Assessment.

**Renewable Energy/Power Technologies.** Renewable Energy/Power Technologies Department will perform engineering in support of the research and development and deployment of renewable energy technologies (geothermal energy, hydropower, wind, and solar photovoltaic technologies) and power systems (power system reliability and control, hybrid power applications, distributed power, and sensors). Key product areas will continue to be geothermal energy, hydropower, wind power, and power systems.

Current and future business thrusts:

- Geothermal Energy (DOE-EE)—in partnership with industry, establish geothermal energy as an economically competitive contributor to the U.S. energy supply (lower costs and increased utilization through technology development) with a developing emphasis on increasing geothermal resources through Enhanced Geothermal Systems R&D.

- INEEL is the lead laboratory for geoscience in the DOE Geothermal Program (reservoir confirmation, characterization, and management; Enhanced Geothermal Resources)
- Exploration (numerical methods for Basin and Range exploration, exploration strategy development)
- Energy conversion (coupled reservoir/power plant management, performance enhancement, process monitors, GeoPowering the West)
- Hydropower (DOE-EE)—maintain the viability of existing hydropower resources by working with industry to develop hydropower technology with improved environmental performance (98%+ survival rate, dissolved oxygen, enhanced downstream habitat), and conduct work for the use of low-head/low-power resources.
  - INEEL is the lead laboratory for engineering support to the DOE Hydropower Program
  - Advanced Hydropower Turbine System Research and Development (design, field testing, environmental analysis)
  - Basic/Applied R&D (computational fluid dynamics modeling, sensor fish, biological criteria)
- Other Hydropower (DOE-EE, DOE-EIA)
  - Low Head/Low Power Resource Assessment
  - Hydropower Cost/Economics—development of cost modeling tools
  - Alaska Projects—technical oversight for Native American hydropower projects in Alaska
  - Wind-Hydropower Initiative—couple wind energy and hydropower generation
- Wind Energy (DOE-EE)—in partnership with industry, establish wind energy as an economically competitive contributor to the U.S. energy supply (lower costs) for both large wind systems and small wind turbine systems
  - INEEL supports the DOE program through technology outreach under Wind Powering America
  - Interconnect standard development
- Power Technologies (DOD-AF, National Aeronautical and Space Administration)—provide, using both renewable and conventional energy technologies, electrical power systems, upgrades, and system integration to meet challenging needs (cost, availability, reliability, power quality, etc.)
  - Ascension Island power systems
  - Lajes AFB 60 Hz to 50 Hz conversion
  - Essential utilities
  - Wind energy assessment.

***Sustainable Buildings and Applied Mechanics.*** The Sustainable Buildings and Applied Mechanics Department provides research, development, and consulting in sustainable building topics such as energy efficiency, water conservation, alternative energy application, recycled materials, and indoor environment. The department provides applied mechanics research, development, and application of structural performance, heat transfer, fluid dynamics, and computational modeling and optimization.

Primary activities will include development of standards, static and dynamic testing, and computational modeling of high-consequence structures and processes, such as hazardous material storage, critical infrastructure, and power production processes.

Current and future business thrusts:

- Sustainable design best practices for DOE facilities
- Sustainable design of Housing and Urban Development residential and manufactured housing
- In-house energy management and water conservation at INEEL and Argonne-West
- National Spent Nuclear Fuel Program standardized canister design and testing
- High-level waste canister design and testing
- American Society of Mechanical Engineers Code interpretation and acceptance for the Very High Temperature Reactor and Hydrogen initiatives
- Structural analysis for Advance Fuel Cycle experiments.

**Transportation Technologies/Infrastructure.** Transportation Technologies and Infrastructure department develops and tests advanced systems and component technologies for the transportation industry, focusing on energy storage, energy conversion, alternative fuels, and infrastructure and vehicle systems.

Current and future business thrusts:

- High Power Energy Storage (DOE-EE)
  - Support to battery suppliers and original equipment manufacturers
  - Advanced vehicle test and evaluation (DOE-EE)
  - Life and performance modeling Freedom CAR national technical teams
  - Lead DOE ATD test lab
- Heavy vehicle (DOE-EE).

**Industrial and Material Technologies.** Industrial and Material Technologies Department continues to invent, develop, and demonstrate significant enhancements to, or replacements of, existing industrial processes, using advanced material, processing, and control technologies to enhance U.S. competitiveness, productivity, energy efficiency, and environmental quality. Key technology areas are advanced materials, biotechnology, chemical processing, metals joining, plasma processing, robotics, sensors and advanced process control, separations, simulation and modeling, and spray forming.

Current and future business thrusts:

- Industrial Technologies (DOE-EE and associated WFO)—in partnership with industry and the DOE Industries of the Future Program, apply INEEL expertise and technology to enhance the competitiveness, productivity, and energy efficiency of domestic industry.
  - Developing and applying laser-assisted arc welding to steel
  - Spray rolling aluminum strip

- Controlled thermo-mechanical processing of tubes and pipes for enhanced manufacturing CRADA
- Integration of RSP tooling with rapid prototyping for die casting applications
- Development and demonstration of advanced tooling alloys for molds and dies
- Improved recovery boiler performance through control of combustion, sulfur, and alkali chemistry
- Alternative anode reaction for copper electrowinning CRADA.
- Biomass (DOE-EE and associated WFO)—in partnership with industry, academia, and the Northwest Bioproducts Research Institute, apply INEEL expertise and technology to develop methods to overcome key barriers to cost-effective utilization of agricultural biomass for energy, fuels, chemicals, and durable goods.
  - Biomass feedstock harvesting and collection
  - Development of precision farming technologies CRADA
  - Fractal separation system CRADA
  - Multi-component harvesting CRADA
  - Value-added products from hemicellulose utilization in dry mill ethanol plants CRADA
- INEEL Test Highway (U.S. Department of Transportation, Federal Highway Administration) —in partnership with the Idaho Transportation Department and the National Institute for Advanced Transportation Technology at the University of Idaho, apply INEEL expertise in materials and intelligent control to establishing a materials test highway at the INEEL.
- Bioenergy/Bioproducts—DOE and the U.S. Department of Agriculture have begun a national effort to develop a range of renewable energy sources with bioenergy as the centerpiece to reduce our dependence on fossil fuels. The INEEL, in partnership with the Northwest Bioproducts Research Institute, academia, and industry, continues to investigate and develop methods for overcoming key barriers to cost-effective use of crop residuals and forestry wastes for energy, fuels, and chemicals production.

Current and future business thrusts:

- Feedstock Harvesting and Collection
  - Distributed physical and molecular separations for selective harvest
  - Multi-component harvesting equipment
  - CNH global CRADA
  - Characterization and modeling of biomass separations
  - Biomechanics of straw stems
  - Development of analytical decision-making tools



- Transportation and Storage
  - Acidophilic bioprocessing
  - Production of value-added biopolymers
  - Removal of minerals from crop residues
- Pretreatment/Hydrolysis and Separations
  - Fractal based chromatography
  - Pretreatment technologies for cellulosic biomass
  - Stable enzymes for hemicellulose hydrolysis
  - Computational fluid dynamics-based real-time separations control.

**Hydrogen Initiative.** Hydrogen is becoming widely recognized as an important clean energy carrier of the future. As stated by Energy Secretary Spencer Abraham, “Hydrogen offers the long-term potential for a highly efficient energy system that produces near-zero emissions and is based on domestically available resources. Hydrogen can be produced from fossil, nuclear, and renewable resources, thus encouraging diversity in the nation’s energy supplies.” Before the potential benefits of the hydrogen economy can be realized, however, numerous technical and scientific issues must be addressed. INEEL already has a number of projects, both LDRD and direct-funded, addressing many of these issues. Hydrogen as a division initiative began in early FY-03; a laboratory-wide Hydrogen Initiative will begin in FY-04. It is envisioned that the future INEEL hydrogen program will capitalize on our strengths in engineering demonstration accompanied by an increasing scientific element.



The current INEEL hydrogen program has support from industry, DOE-EE, DOE-FE, and DOE-NE. With the wide variety of technical areas to be addressed and the rapidly increasing competitiveness of hydrogen research, development, and demonstration, it is necessary for INEEL to focus its hydrogen program. A high priority for FY-04 will be the development of a Hydrogen Business Plan. There may be some adjustments in the direction of the hydrogen initiative with the development of that plan.

Current and future business thrusts:

- Distributed hydrogen production (diesel reformer)
- Nuclear energy for hydrogen production
  - High-temperature electrolysis using solid oxide fuel cell (SOFC) technology
  - Thermochemical cycles
  - System integration issues
- Hydrogen separation
- Storage (impermeable composite tank liner, chemical hydrides emphasizing borohydride regeneration)
- Hydrogen infrastructure (pressurization, liquefaction)

- Utilization
  - Fuel cell fabrication (SOFC)
  - Fuel cell testing using the diesel reformer facility
  - Hydrogen vehicle testing (Advanced Vehicle Testing Activity in Phoenix, initiation of activity at INEEL).

### **Projected Business Volume**

Major Business Area	FY-04 (\$M)
Sustainable and Intelligent Systems	4.7
Environmental Technology and Engineering	19.7
Energy Efficiency and Technology	22.8
<b>Total</b>	<b>\$47.2</b>