Energy, Climate, and Infrastructure Security (ECIS)

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Introduction

Access to reliable, affordable, and sustainable sources of energy is essential for all modern economies. The global demand for energy will increase from 145 petawatt-hours (PWh) in the year 2007 to 216 PWh by the year 2035. U.S. demand will also increase during this period though not nearly as great—from 30 PWh in 2007 to 33 PWh. Meeting this need will have a profound impact on energy production and consumption patterns, on the environment, on the global economy, and ultimately on global political stability. Since the late 1950s, we Americans have not been energy self-sufficient. Our addiction to foreign oil and fossil fuels puts our economy, our environment, and ultimately our national security at risk. The future security of our nation will rely on our ability to address energy security and intertwined climate, and infrastructure challenges facing the U.S. and the world.

Sandia has a long history addressing the nation's energy challenges. Our contributions have been based upon capabilities derived from our nuclear deterrence heritage and associated core competencies in engineering, materials science, geosciences, chemistry, microelectronics, and nuclear safety/security. In FY10, our programs total approximately $300M and include national and international activities supported by three federal agencies and industry.

The Energy, Climate, and Infrastructure Security (ECIS) Strategic Management Unit (SMU) leads and manages this mission area. Our heritage as a national security laboratory brings a unique perspective to addressing the new challenges and opportunities outlined by President Obama and the current administration. "Each of us has a part to play in a new future that will benefit all of us. As we recover from this recession, the transition to clean energy has the potential to grow our economy and create millions of jobs—but only if we accelerate that transition. Only if we seize the moment. And only if we rally together and act as one nation—workers and entrepreneurs; scientists and citizens; the public and private sectors."

-President Obama, June 15, 2010

We have developed a strategy that provides a roadmap for Sandia's research and development priorities: to accelerate development of reliable, affordable, and sustainable sources of energy; to be prepared for and understand potential consequences of climate change; and to assure a safe, secure, and reliable energy delivery infrastructure. Combined together, these address the three main national challenges recently highlighted by the President's Council of Advisors on Science and Technology (PCAST) e.g., economic competitiveness, the environment, and energy security.

"American economic competitiveness, environmental stewardship, and enhanced security depend on picking up the pace of energy technology innovation in this decade. Many other countries are quickening their step, and we must do so as well if we are to retain our leadership position." [1]

Our Strategy

Our strategy is based on a vision and set of objectives congruent with our competencies, current programs, and role as a national security laboratory to support the nation. Consistent with these objectives, we have identified a set of relevant broad

[1] The President's Council of Advisors on Science and Technology (November, 2010).***Report to the President on Accelerating the Pace of Change in Energy Technologies Throughan Integrated Federal Energy Policy*** [Online] Retrieved November 29, 2010 from http://www.whitehouse.gov/administration/eop/ostp/pcast/docsreports

national challenges across the energy, climate, and infrastructure mission sectors that define Sandia's priorities. From each of these challenges we have created a set of five-year, outcome-focused goals.

Ultimately, our goal is to make the nation successful. A successful national strategy in turn is dependent on the success of the private sector, on sound government policy, on a successful positioning of the U.S. in the global market, and on the sustainment of certain federal technical competencies. These were important factors in our strategy development process and form the basis of our objectives.

SMU Vision & Objectives

ECIS Vision

To enhance the nation's security and prosperity through sustainable, transformative approaches to our most challenging energy, climate, and infrastructure problems.

Ten-Year Objectives

In fulfillment of our vision the ECIS SMU has identified four, ten-year objectives:

- Accelerate U.S. industries' innovation, development, and successful deployment of energy solutions to the nation's most challenging problems.
- Create and steward enduring science, systems, and security competencies to support inherently government functions and services.
- Support U.S. leadership in global energy challenges through strategic international engagement.
- Enable sound government energy policy decisions by providing timely and objective technology assessments and systems analyses.

National Challenges

From the President's priorities and emerging national issues, nine key national challenges have been selected that define Sandia's contributions and priorities. These are:

- Reduce our dependence on foreign oil
- Increase use of low carbon power generation
- Provide the scientific foundation that anticipates the needs of a global climate treaty
- Advance credible carbon management strategies
- Assure water safety, security, and sustainability
- Assure energy security for critical installations
- Strengthen the nation's S&T base to accelerate industry for energy and climate security
- Advance energy storage technologies
- Increase security and resiliency of the electrical grid and energy infrastructure

Program Area Five-Year Goals

ECIS has four principal program areas each led by a director: Energy Security, Climate Security, Infrastructure Security, and Enabling Capabilities. Each program area has a set of five-year goals, aligned with the SMU objectives and national challenges that drive our internal investments. Program development resources are directly tied and tracked to these goals. Our program area goals are not intended to be fully comprehensive for the entire set of SMU activities but instead form the principal roadmap for priority investments. They align with federal program priorities, our current activities and competencies, and our focus for future impact. Each goal below ties back to our identified national challenges.

Energy Security

1. Advance solar technologies and systems to enable a domestic solar industry to deliver at less than 10 cents perKW/hr.
2. Demonstrate, in a working prototype, 12.5% sunlight to syngas (or other intermediate) and analysis for a system design to achieve >6% end-to-end sunlight to fuel and a roadmap to >10% lifecycle sunlight to fuel.
3. Develop reactor designs and support systems to demonstrate the application of small modular reactors (SMRs) to fulfill DoD mission goals for energy security.
4. Complete a deep borehole disposal system demonstration project with industry that will transform nuclear waste management.

5. Provide for the science-based design tools necessary for industry to reduce carbon dioxide and petroleum footprint of the transportation fleet by 25%.

Climate Security

1. Assess U.S. prosperity and security impact risks by modeling climate and human response at the regional level with quantified uncertainty.
2. Design data-gathering and analysis systems that would be needed if the U.S. were to sign a global climate treaty.
3. Develop a credible technical path for achieving DOE's 2015 goal of an industrial-scale demonstration of carbon capture and sequestration (10MT/yr).
4. Deploy technology solutions that make government and private sector success in water safety, security, and sustainability, both domestically and globally.
5. Enable a viable transition from fossil fuels to environmentally sustainable energy sources.

Infrastructure Security

1. Establish and grow critical cyber security capabilities within DHS with Sandia as the enduring advanced development partner.
2. Increase resilience of U.S. critical infrastructure system by providing government, regulatory, and industry stakeholders with increased understanding of interdependencies and risk.
3. Reduce the risk of energy supply disruptions from globally strategic sources to the U.S. and to key overseas installations.
4. Design and demonstrate 30% renewable energy penetration into the energy surety microgrid (ESM) within five years.
5. Develop and utilize energy security systems analysis/assessment tools to meet DoD/DOE/DHS defined energy security objectives.

Enabling Capabilities

1. Deepen fundamental science and engineering competencies in key strategic areas to enable ECIS mission objectives and goals.
   - Light-matter interactions (PV, SSL, …)
   - Energy storage – nanoscale scale engineered materials systems and novel diagnostics
   - Interfacial electrochemistry – in-situ diagnostics for (batteries, fuel cells,…)
   - Exascale computing for e.g., climate modeling, reliable grid simulation/operation, carbon management
   - Next-generation reactors – materials and defect effects, fuel cycle aspect
   - Engineering science – thermal & fluid flows—climate, combustion, geothermal, sequestration and recycling, wind, …) (modeling and validation)
   - Science of systems analysis for ECIS
2. Nurture discovery science for fundamental breakthroughs in:
   - Interfacial science
   - Quantum phenomena
   - Materials physics
   - Bioscience
   - Gas-phase chemistry
   - Nanomaterials systems & architecture
   - Math algorithms
3. Determine capability needs for the SMU and support capability development through targeted Laboratory Directed Research and Development (LDRD) project awards.
4. Accelerate industry development of transformational energy technologies through ARPA-E.

SMU Operations

An efficient and effective ECIS operations office is a key component for success. Through central coordination of all financial, communications, business development support functions, and LDRD program management, the SMU operations office will provide the support to achieve greater effectiveness and efficiency for all ECIS activities. For example, the SMU office will coordinate and support a SMU-wide industry partnership strategy. A SMU wide communications strategy is now in place and being implemented. Centrally coordinated business development support for proposal development will

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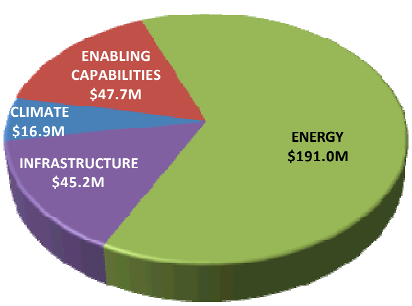
be deployed to ensure the quality and consistency of ECIS proposals. The final operations plan will be completed in FY11.

Challenges

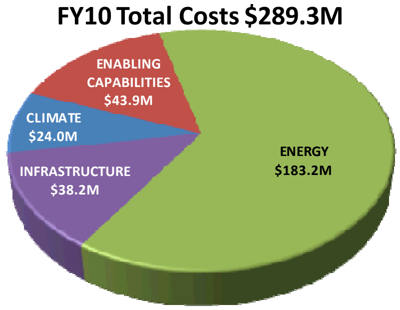
To achieve success, the ECIS SMU must confront a number of important challenges. Enhancing our industry partnerships is central to our strategy. ECIS must forge new types of relationships between Sandia and industry to increase the impact our programs will have to the broader energy and climate enterprise. As our federal leadership considers and debates new policy options, sound technical information will be a necessity to making effective decisions. Developing the credibility and trusted relationships with our national leadership will be important. While our federal government continues to develop a broader and concrete energy policy, individual states have moved out much more aggressively. Building partnerships with and supporting state governments will be important to furthering our national goals.

Financial & FTE Information

FY10 Total Revenue $300.7M



FY10 Total Costs $289.3M



In FY10, the total number of ECIS SMU full time equivalents (FTE) was 504. The ECIS SMU FY11 projected revenue is $317M with a projected FTE workforce of 513.

SMU Highlights

Consortium for Advanced Simulation of Light Water Reactors (CASL)

Sandia computational scientists will lead and support key technical areas in a DOE effort to create a “virtual” nuclear reactor, to be headquartered at Oak Ridge National Laboratory (Oak Ridge). The advanced simulator will use capabilities of the world’s most powerful computers to attempt significant leaps forward in nuclear reactor design, engineering, and operation. Information gleaned from a virtual model of a currently operating reactor could help improve nuclear reactor safety, increase reactor power production, and extend reactor life and licenses over the near, mid, and long term. The work, funded by a DOE award of up to $122 million over five years, will be coordinated by the Nuclear Energy Modeling and Simulation Energy Innovation Hub at Oak Ridge. DOE recently announced that the new hub will be funded at up to $22 million in FY10 and then at an estimated $25 million per year for the next 4 years, subject to congressional appropriations. Named the Consortium for Advanced Simulation of Light Water Reactors, the hub includes partners from universities, industry, and other national laboratories. Sandia scientists and engineers will pro-vide leadership and technical expertise to the verification, validation, and uncertainty quantification program, provide technical expertise and management to the virtual reactor integration program, and participate in the Consortium board of directors.

LNG Test Yields High-Quality Data

After 9/11, several studies evaluated possible consequences of a terrorist attack on a liquefied natural gas (LNG) ship. As large as a modern aircraft carrier, an LNG ship can transport up to 6 billion cubic feet of natural gas. A spill from a ship of this size could have severe consequences on people and property. That is why the widely varying consequence estimates from the studies conducted were of broad public concern. Subsequently, Sandia responded to a Department of Energy (DOE) request to conduct an independent, third-party assessment of the hazards of an LNG spill over water. Sandia’s report identified some knowledge gaps in large-scale LNG fire data and is currently used worldwide as the primary guidance for assessing the risks and hazards of large NG spills.

In February and December 2009, two tests were conducted for LNG spills with diameters of approximately 25 m and 85 m, respectively. The second LNG test was the largest ever.

State-of-the-art cameras, spectroscopic diagnostics, and extensive heat-flux sensors were used to obtain heat flux data from the two fires. Additionally, the LNG spreading and the pool fire dynamics were photographed with gyroscopically stabilized cameras mounted in U.S. Air Force helicopters. The high-quality data obtained is being used to validate high-fidelity pool fire models to more accurately calculate hazards from LNG pool fires of 300 to 500 m in diameter.

Successful Close-Out of the Deepwater Horizon Tri-Lab Response Effort

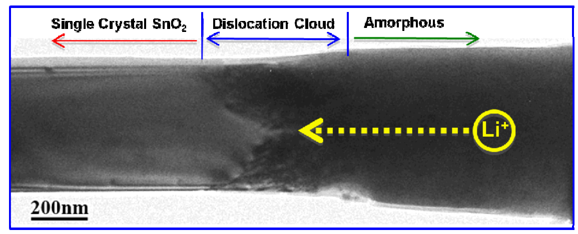
In May of 2010, Energy Secretary Steven Chu assembled a tri-lab team from Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), and Sandia National Laboratories (SNL) to assist BP's Incident Management Team (IMT) in responding to the Deepwater Horizon disaster in the Gulf of Mexico. Several Sandians, including former Laboratories Director Tom Hunter played key roles in bringing together unique DOE technical capabilities to support the analytical needs of the IMT.

The DOE tri-labs contingent made significant contributions during the 137 day engagement which included: estimating maximum well shut-in pressures, examining annular or central flow indicators, reviewing the mechanical design/integrity of "first of a kind" hardware (e.g, the capping stack), and calculating the structural integrity of the riser kink.

September 14th, 2010, ended Sandia's engagement with the BP IMT effort, but we continue to explore solutions in order to prevent another massive oil spill and environmental disaster from happening.

The Nanoscale Science of Batteries

Sandia scientist Jianyu Huang led a team of scientists that reported in the December 10th, 2010, issue of *Science* about the creation of the world's



first nanocale battery inside a transmission electron microscope.

It is widely recognized that the next generations of lithium-ion batteries will use nanostructured electrodes to help increase the power and energy density for electric vehicles and mobile devices. These nanostructured electrodes are typically constructed of mats of hundreds of millions of nanofibers woven together, where each nanofiber is 1000× smaller than a human hair. These tiny fibers are too small to study with conventional methods and require new, more powerful techniques. Jianyu Huang *et al.* have accomplished this task by creating a battery inside an electron microscope using a single nanowire electrode as the battery's anode, metaphorically "isolating a tree, from the forest." The team demonstrated this new technique by imaging the charging characteristics of a single tin oxide nanowire electrode, a potential new high-energy-density battery material, during charging. Dynamic changes in the wire's structure due to the lithium inserting into the nanowire could be studied. The team plans to continue their research into other new high-impact nanostructured battery materials such as silicon to help lead in the science-based development of these materials.

This work allowed for the first time the direct real-time observation of the change in a battery's atomic structure during charging and discharging, and lays the foundation for *in situ* studies that will have far reaching impact in energy storage, corrosion, and the general chemical research field.