Fellows' Report on Strategy for Energy Research

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Introduction

Energy could become America's overwhelming security issue in this century. New threats are emerging that are outside the nation's traditional response structure. Two of these are the inability to meet our energy requirements without massive importation of oil and the destructive effects of climate change. As the nation's premier national security science laboratory, Los Alamos can work better to help solve many energy problems. If we are to contribute to national energy security, we must do so in areas where we have unique strengths. The national needs are clear and compelling. The scientific and engineering problems are national-laboratory scale. The tasks we have emphasized are well aligned with LANL missions and grand challenges, and we have the people and the infrastructure ready to work. We describe here the four main areas where LANL can become a leader. For such an effort to succeed, support for it must begin immediately and must engage management, program offices, the research library to provide coordinated information access, scientists, and partners. Funding cycles at LANL, the DOE and elsewhere are too long; other routes must be found. For example, LANS, a private entity, should use that status by supporting research from corporate profits with the expectation of a return on investment from licensing fees.

Nuclear Energy

With growing public acceptance of nuclear energy, there are now substantial opportunities for LANL to provide the science and engineering required for the next generation of nuclear-powered electrical generators. With the likely decline of support for nuclear weapons, building a strong nuclear power program would redirect to energy our excellent weapons core competencies in nuclear physics, engineering, actinide chemistry, and materials science. Along with the growing widespread realization that nuclear energy is a source of energy that can reduce carbon emissions and enhance energy security, there also remain challenges in nuclear reactor safety and disposal of nuclear waste that LANL has the expertise to tackle.

Reactor fuel processing, waste processing, and safe innovative reactor designs are intertwined. LANL has studied reactor designs using thorium (a non-fissile but more abundant element than uranium) that must be run in a U- or Pu-seeded breeder mode or can be run inherently safely using accelerator-supplied neutrons where excess neutrons can also transmute transuranic waste. India has already built a thorium breeder prototype, but recent LANL advances in highly-reliable superconducting linac technology make the accelerator-driven reactor worth pursuing. LANL, partnering with ORNL and INL, is ideally positioned to take the lead in this approach. LANL has also studied a small, inherently safe reactor using uranium hydride that could be used as a distributed or mobile power source. There are many more examples of LANL innovation for nuclear generation of power, and these should be nurtured and strengthened.

Nuclear fusion remains a long-term hope for true energy independence, but national and LANL efforts in this area have decreased over the years. Ongoing LANL work with the National Ignition Facility (NIF) at Livermore and (Z-, theta-) pinch fusion should be expanded. LANL collaborates with Savannah River to supply DT fuel for the ITER magnetic fusion device and leads in the development of a pulsed high-energy-density physics approach to fusion--Magnetized Target Fusion--in collaboration with AFRL. These areas call upon our capabilities in materials science as well as plasma theory and simulation and diagnostic development and should expand.

Energy Storage and Capture

Energy storage is an area that is wide open for development, weakest in present technology, and must be a theme for future fundamental and applied research at LANL. A major advance in energy storage by whatever means would be a disruptive technology, enabling full use of renewable energy resources, maximally-efficient use of fossil-fuel energy, and of course, a place to store harvested solar photons. From the DOE Basic Energy Sciences 2 April 2007 report Basic Research Needs For Electrical Energy Storage they write "Revolutionary breakthroughs in EES have been singled out as perhaps the most crucial need for this nation's secure energy future". For example, Public Service Company of New Mexico occasionally produces more than half our state's electricity from wind and boasts the highest fraction of wind power of any state. If more cheap storage were available, more wind energy could be used. Batteries, though one of the most important storage sources, are not a LANL strength; however supercapacitors that use an electric field in an electrolyte as the storage mechanism are. New chemical processes studied at LANL promise to increase the energy density in nano-science-based supercapacitors to levels useful for transportation, while nano-science and new high-dielectric-constant solids point the way toward coordinated, multidisciplinary basic research into dielectric-capacitor-based energy storage at densities at or above that of batteries. Hydrogen and the fuel cells that oxidize it are another important energy storage system in which most emphasis in research today is on the energy recovery process. This, and the LANSCE probes of fundamental interactions of hydrogen in matter are LANL strengths, as is the reverse process where energy capture via solar photocatalysts provide for high efficiency water splitting that converts sunlight to hydrogen; later, that hydrogen can be used to generate electricity or stored. The fuel cell, its conceptually-reversed version, and photo catalysts are some areas that LANL should pursue.

Energy Information Science

Electric vehicles may not only reduce global warming and reduce our foreign-oil dependence but may also provide massive amounts of distributed energy storage. The management on a national scale of the increased complexity of a utility grid with new demands, the potential for massive distributed storage, and the statistical fluctuations in the availability of increasing renewable energy capacity will be a national-laboratory-scale computational and modeling challenge. The management of peak shaving and siting of renewable energy collectors is also an immense problem. "Intelligent grid management" with development of nodes (points on the grid where energy is used or stored), the communication from nodes to the control codes, and the optimization of usage is a tremendous opportunity for LANL computational capabilities and a route to expanding our ongoing partnership with regional public utilities. Although intelligent grid management is under intense study by many public utilities, none possess the ability to construct the management codes. This could be a LANL win and must be pursued. This, together with the complexities of carbon sequestration and climate-change modeling, remote sensing and data analysis of climate-relevant variables, and the validation of the ensuing models are obvious and urgent targets for LANL information science and technology efforts.

Fuels and Fuel Cycles

Biofuels have the potential to make a huge impact on future energy needs, acting as a very efficient means for storing solar energy and as a carbon-neutral replacement for fossil-derived gasoline and diesel. Even using present production methods, biofuels such as ethanol have a superior energy life-cycle inventory compared to gasoline. Moreover, the infrastructure to distribute and use such biofuels is in place. LANL is poised to make several outstanding contributions in this area as a partner supplying missing expertise and technology to a commercial or government initiative. First, an internationally regarded LANL effort has produced substantial (up to four-fold) increases in crop yield using transgenic plants; the work extends to algae (yields doubled) tailored to be directly harvested as a fuel. Second, LANL studies of organism- and enzyme-based processes leading to efficient cellulose-to-fuel conversion are underpinned by the diagnostic expertise at LANSCE and the stable isotopes effort; eventually, it will be possible to convert a wide range of organic matter (e.g. bamboo, grass crops, paper, wood waste) directly into fuel. Third, state-of-the-art conventional catalysis is being exploited at LANL to mine every last Joule of energy from biofuel sources.

Enhanced exploitation of conventional fuels is another LANL strength, exemplified by the joint Chevron Corporation/LANL research project to recover hydrocarbons trapped in oil shales and slow-flowing oil formations. This collaboration, which focuses on the Piceance Basin in Colorado, builds on the extensive geological expertise at LANL developed for implementation and analysis of underground nuclear tests and is directed at development of an environmentally responsible, commercially viable process to recover crude oil and natural gas from western US oil shales. The study includes reservoir simulation and modeling, as well as experimental validation of new recovery techniques, including a form of in-situ production that has the potential to mitigate greenhouse gas emissions via the capture and re-use of combustion gases.

Commercial electricity generation is presently inefficient, as it depends on various forms of heat engines (steam turbines etc.) that are Carnot-limited to of order 35% in efficiency. LANL is studying alternative fuel cycles that, by avoiding heat engines, are not Carnot limited. Instead, relying on power-station-scale air/hydrogen fuel cells, an energy-balanced chemical reaction of coal, involving gasification, carbonization, and calcination, can double present coal-fueled power-station efficiency, and halve the carbon dioxide output. The waste is pure carbon dioxide (not mixed with nitrogen or air) so that it is easy to sequester, for example by pumping into currently non-viable oil fields to displace inaccessible fuel reserves. Such technologies are robust against future changes in fuel reserves because they are applicable to any carbon-based fuel, including biomass. Only a national laboratory has the resources to bring such technology to the stage of readiness required to breach the barriers of a necessarily conservative electric-power-generation industry.

Path Forward

Considering the urgency of the energy problem, the magnitude of the needed scientific breakthroughs and the historic rate of scientific discovery, current energy research efforts will likely be too little too late. Accordingly, BESAC (Basic Energy Sciences Advisory Committee) supports the view that a new national energy research program is essential and must be initiated with the intensity and commitment of the Manhattan Project, but, unlike the Manhattan project, this program will likely continue for the foreseeable future. Additionally, the American

Competitiveness Initiative doubles, over 10 years, funding for innovation-enabling research at key Federal Agencies that support high-leverage fields of physical science and engineering (e.g., NSF, SC, NIST) All of these elements argue for development of a bold research initiative for a secure energy future. We therefore recommend that you take steps to move LANL more strongly into supporting or in some areas leading national energy research efforts. Steps we recommend include:

1. **Coordinate** efforts of the energy council to select overall strategy and reject directions not well suited to LANL, and of the Fellows to identify specific science targets and people, and of the the energy program office to interface with funding agencies and their targets.

2. **Identify** new science targets, industrial partners and matching funding agencies in the areas of nuclear energy, energy storage, fuels and fuel cycles and energy information science with a goal of a dozen or so new, well-targeted proposals submitted within the next few months to DOE BES (Basic Energy Sciences), DOE EDRE (Electricity Delivery and Energy Reliability), DOE EERE,(Energy Efficiency and Renewable Energy), DOE NE (Nuclear Energy), DOE FE (Fossil Energy), DOD/Navy, EPRI (Electric Power Research Institute). Each proposal should exploit a unique LANL strength, a unique industrial collaboration, or a new science approach.

3. **Assess** the current state of the art in nuclear energy, energy storage, fuels and fuel cycles and energy information science. This is crucial in the identification of research directions. A key minefield is the incredible collection of recent patents and information in the hands of private companies that are closely guarded. We will need to be very careful not to either reinvent something already patented, nor to follow blind alleys already explored. To do this well will take careful study, dedication and "retraining" via conference attendance, workshops, seminars, tutorials and the like, the collaboration of the LANL library team, the Technology Transfer team, and will require engaged LANL scientists and engineers.

4. **Partner** closely with industry. Public Service Company of New Mexico and others are studying intelligent grid management, and may use nuclear energy, energy storage, and new fuels and fuel cycles in the future. The complexity of the grid management problem is perfect for LANL advanced computation. Can we use our sensor communication efforts to help read the grid? Can we change the way power is generated and used in New Mexico as a paradigm for the nation as a whole. We should actively pursue collaborations with industry in the areas identified above, and take some risks. We must take the initiative with industry as soon as possible.

5. **Generate funding** vehicles, including an LDRD ER and DR component separate from the current processes, and a weapons funding component (s) specifically targeted at national security funds aimed at new initiatives directly related to energy security. Fund new peer-reviewed proposals in areas we wish to engage. This will require investment by LANL and LANS now, with the expectation of a substantial return on that investment later.