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The New Center For Advanced Energy Studies (CAES)

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The INL is a
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Abstract

A secure and affordable energy supply is essential for achieving U.S. national security, in continuing U.S. prosperity and in laying the foundation to enable future economic growth. The next generation energy workforce in the U.S. is a critical element in meeting both national and global energy needs. The Center for Advanced Energy Studies (CAES) was established in 2005 in response to U.S. Department of Energy (DOE) requirements. CAES, located at the new Idaho National Laboratory (INL), will address critical energy education, research, policy study and training needs. CAES is a unique joint partnership between the Battelle Energy Alliance (BEA), the State of Idaho, an Idaho University Consortium (IUC), and a National University Consortium (NUC). CAES will be based in a new facility that will foster collaborative academic and research efforts among participating institutions.

Introduction

The world is not running out of energy, but it is starting to run out of some of those sources of energy which have been most commonly used. To meet global energy demand over the next century new technologies will be needed. This will require a highly skilled and inventive workforce. However, it is projected that 40% of the U.S. skilled workforce can retire within about four years, and within the U.S. Department of Energy (DOE) complex 75% of those workers with nuclear and related technology expertise could retire by 2010[1]. The U.S. has for a long time supplemented its native U.S. science and technology labor force by attracting foreign born and trained persons. Increasing global competition and slower entry for both foreign students and professionals is impacting this past shortcut to meeting U.S. trained workforce needs. A secure and affordable energy supply is essential for achieving U.S. national security, in continuing U.S. prosperity, and in laying the foundation to enable future economic growth. The next generation workforce is a critical element in meeting both national and global energy demand.

It is recognized with the 2005 Energy Policy Act[2] that it is critical for the U.S. to address energy supply issues, including workforce education and training. Part of the U.S. energy strategy includes the formation of the new Idaho National Laboratory (INL). The INL, which has a key nuclear energy mission, was officially established February 1, 2005. The Battelle Energy Alliance (BEA), in responding to the request for proposals[3] for the new INL, developed a partnership with the State of Idaho, an Idaho University Consortium (IUC), a National University Consortium (NUC) and various industrial organizations to establish a joint institute, the Center for Advanced Energy Studies (CAES).

CAES is defined by the U.S. Department of Energy[3] as being:

> "… an independent entity, in which the INL and Idaho, regional, and other universities cooperate to conduct on-site research, classroom instruction, technical conferences, and other events for a world-class academic and research institution".

The Secretary of Energy, Samuel Bodman, formally inaugurated the programmatic activities for CAES on June 1, 2005. The need for CAES, in association with the INL and its academic partners, to address key energy challenge issues is evident given the current U.S. and global energy situation, U.S. science and engineering educational challenges, and the combination of current energy industry workforce demographics and future workforce projections.

This paper provides a summary of education and training challenges faced by the energy community, introduces the Center, and outlines a 5-year plan during which time CAES will progress from its current status as an "*Initiative"* of the INL to that of an independent, nonprofit joint institute. This institute will be a partnership which integrates government, industry and university resources and it will engage a wide network of other national and international organizations.

The Energy Challenge

World energy demands are at an all time high. The world's population- currently over 6 billion people - uses almost 400 quadrillion BTU of energy annually. This is roughly equivalent to 180 million barrels of crude oil per day. These energy demands are expected to triple by 2050 as a result of several factors and could increase by a factor of seven by the end of the century.

First, as the population of the world continues to increase, the energy demands are projected to further rise. Global population is expected to increase to over 9 billion people during the current century, and some projections go significantly higher. Economic industrialization occurring throughout the third world further adds to the global energy demands. Globally, about one fourth of the land surface is devoted to agriculture and one fourth is forested. At present, as population grows in general terms, land is converted from forest to food production, and productive agricultural land is being lost to urban growth. Additionally, meeting these energy demands is further compounded by resource depletion and environmental concerns, such as climate change, land use change, water resource availability, and global sustainable development efforts.

The U.S. accounts for approximately 5% of the global population and approximately 25% of the world's energy consumption, or approximately 100 quadrillion BTU each year. The U.S. requires secure, sustainable, and affordable energy supplies that can be achieved with limited environmental impact. In 1997, a report to the President reviewed federal energy research and development challenges[4]. This report identified that the U.S. faces major energy-related challenges as it enters the twenty-first century.

The global energy resources currently used are finite. Achieving a sustainable energy system is essential to meeting both U.S. national needs in terms of energy security and economic stability, as well as meeting global energy demands in ways that avoid wars and economic instability[5].

Numerous publications present future energy scenarios. Some reports state that global production of sweet light crude oil will peak in 2005-2006 and that global oil production could be down by 75% within 30 years. Other reports are more optimistic and assume that alternative hydrocarbon resources, including tar sands and gas hydrates combined with bio-based synthetic fuel production, will be utilized and that no problems will be encountered for many decades. One example of estimates for future global energy reserves based on one of many global energy use scenarios is shown in Figure 1. This scenario assumes the rapid development and deployment of advanced nuclear energy technologies used together with a closed nuclear fuel cycle.

Although the world may not be running out of energy, it can be argued that it is running out of the types of hydrocarbon-based energy that are currently the basis for global energy delivery. Two critical challenges are (a) developing an integrated and coordinated approach – at the global level – that enables an orderly transition to an advanced energy future that is sustainable, affordable, and has limited environmental impact and that can meet growing global energy demands, and (b) providing the critical technologies to meet the global energy future, whether it be the hydrogen economy that some envision, advanced nuclear energy, and/or new synthetic hydrocarbons together with clean coal and renewable energy technologies. It is this second challenge which will require a highly skilled and innovative science and engineering community.

In the long-term, one vision is of a world transportation system powered by hydrogen and nuclear systems providing electricity via fission and fusion and integrated closed fuel cycles. A closed fuel cycle with recycling of spent nuclear fuel offers an energy system with significantly reduced environmental impact, reduced residual waste volume and isotope life, and zero-greenhouse gas emissions. Full implementation of such energy systems is several generations in the future. Generation IV and advanced nuclear energy sources are not expected to be commercially available before mid-century[6].

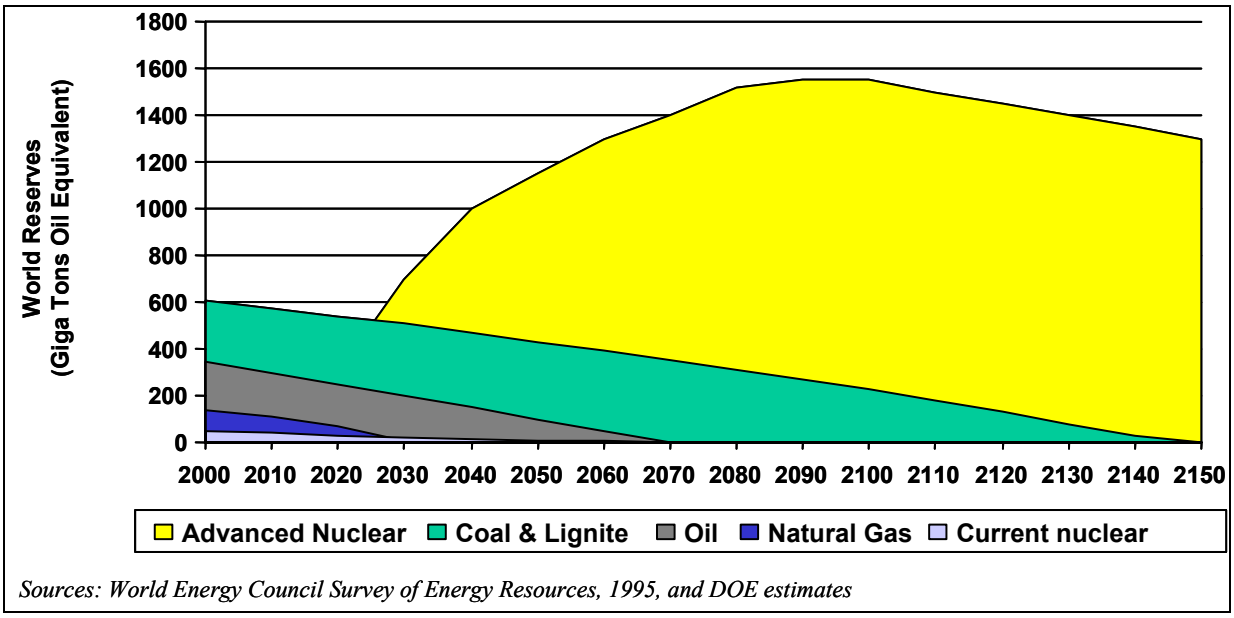

Figure 1. Projection of World Energy Reserves.

Over the next fifty years, the U.S. and the global population will need all current types of energy resources (Figure 2) and envisioned energy technology systems if global energy demand is to be met. CAES will play a vital role by facilitating integration of the necessary science, engineering, and policy to create a world-class center of *thought leadership* and science and technology delivery, recognized for addressing some of these critical science and energy policy issues through its established and distinctive signatures.

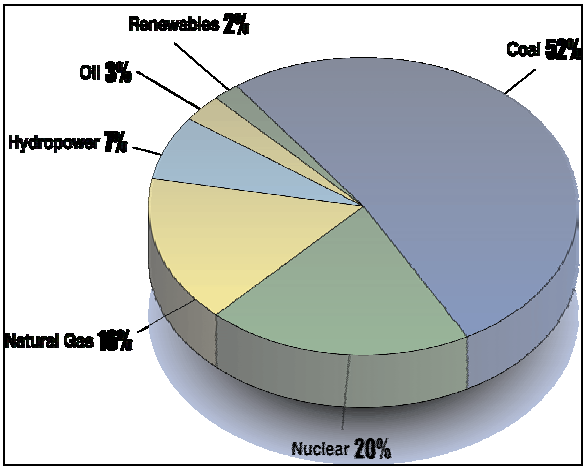

Figure 2. Current U.S. electricity generation.

The Education Challenge

A series of recent studies discuss the science and engineering labor force and in particular the nuclear education and staffing challenge that is facing the U.S. and other nations. The National Science Board[7] with the report "Science and Engineering Indicators, 2004" and the companion

document, "An emerging and critical Problem of the Science and Engineering Labor Force"[8]; "**highlight trends that threaten the economic welfare and security of our country**." Within the U.S., there is a lack of talent entering the general science and technology workforce pipeline[9,10]. The BEST Report also noted that 25% of U.S. scientists and engineers would reach retirement age by 2010.

Recent reports also indicate that only 26% of U.S. high school graduates were considered to be qualified for entry into science or engineering programs in further and higher education. The numbers of students entering science and engineering as a percentage of students is a much smaller fraction than those in countries with which the U.S. has to compete, and actual numbers are small when set in a global context. The U.S. currently graduates about 60,000 BS engineers per year, and whereas in China and India combined the total is about 1 Million per year. A further issue is the reduction in numbers of trained science and engineering graduates entering and remaining in the U.S. and at least in some critical areas reductions in numbers of foreign students in U.S. programs. The ability to provide adequate numbers of educated and trained staff to meet U.S. energy industry needs can be expected to be a major and growing issue over the next decade.

This situation is considered particularly significant within the nuclear energy industry. Over recent years a series of studies and papers have reported and discussed the nuclear education and staffing challenge that is faced in rebuilding critical skills to meet the needs of the nuclear research and industry personnel pipeline[1,11]. For example, a report states that "Over the past decade the number of nuclear engineering programs in the U.S. has declined by half (from 80 to 40), the number of university research and training reactors by two-thirds (from 76 to 28), and total enrollments have dropped by almost 60% (from 3,440 to 1,520)"[12].

Several studies report B.S. and M.S. graduates in nuclear engineering numbers at about 200 per year[12,13]. Magwood cites a Nuclear Engineering Department Heads Organization (NEDHO) report[14] that states demand is for ~600 graduates annually and rising. Further, Magwood reported that total national undergraduate enrollment in nuclear engineering was just under 1,000 in 2001, down from a level of ~1,500 that persisted through the 1980s and until 1995.

Recent data regarding nuclear engineering degrees is available from the Oak Ridge Institute for Science and Education (ORISE)[15]. This information shows:
B.S. level – 219 graduates in 2004, as compared with 222 in 1998 and a low of 120 in 2001.
M.S. level – 154 graduates in 2004, as compared with 160 in 1998 and a low of 130 in 2002.
Ph.D. level – 75 graduates in 2004, as compared with 98 in 1998 and a low of 67 in 2002.

While enrollment in nuclear engineering programs appears to be increasing slightly from the low seen in ~2002, it has returned only to the level of the late 1990's. The demand for nuclear engineers still exceeds the supply. Enrollments are very much lower than will be needed to support a nuclear energy resurgence. As with other areas of science the U.S. is only one part of a global picture, and in this case there is international concern regarding the supply of the nuclear educated and trained workforce[16]. There are also significant challenges in the areas of health physics, actinide chemistry, and related engineering and science disciplines needed to replace projected retirements throughout the advanced energy research and production sectors.

The Advanced Energy Research Challenge

In 1997, a report to the President reviewed federal energy research and development challenges of the twenty-first century[17]. This report identified that the U.S. faces major energy related challenges as it enters the twenty-first century. Since this time, there have been numerous reports and reviews that address various aspects of the energy research arena: reports have considered basic research needs to assure a secure energy future (Basic Energy Sciences-Advisory Committee (2003)[18], moving forward with nuclear power: issues and key factors (Secretary of Energy Advisory Board (2005)[19], a series of Generation IV nuclear energy system documents [6,20], Climate Change Technology Program Strategic Plan (2005)[21], etc.

In addition to government led activities, there are also non-government efforts under development. Groups such as Electric Power Research Institute (EPRI) have developed the "Electricity Technology Roadmap"[22], the U.S. Energy Association has developed the "National Energy Security, Post 9/11" [23] document, the Massachusetts Institute of Technology (MIT) has developed the Inter-disciplinary study – The Future of Nuclear Power[24] and the International Atomic Energy Agency (IAEA) has developed "Innovative Nuclear Reactor Development"[25] documentation.

The Center for Advanced Energy Studies

In addressing these energy-related challenges, CAES is being structured as an academic and research institution in which the INL; the DOE; Idaho, regional, and other national universities; and the international community cooperate to conduct energy-related research, classroom instruction, technical training, policy conceptualization, public dialogue, and other events.

Although ultimately planned to be operating as an independent, nonprofit company, as governed by section 501(c)(3) of the Internal Revenue Code, CAES is initially operating as an internal INL organization staffed with representatives from the INL, universities, and industry.

Collaborative and collocated centers, established in association with CAES, will serve as implementation partners to focus resources in critical energy areas and partner with CAES researchers and staff. As such, CAES will serve as the hub for a wider network of Idaho, regional and national universities; private industry; and other associated institutions that will form collaborative arrangements to share CAES resources, equipment, and technical staff.

CAES Vision

By 2015, CAES will become a world-class, advanced-energy organization with an emphasis on nuclear energy and recognized for contributions to energy research, policy studies, and the revitalization of nuclear education. CAES will also train a diverse science and engineering workforce.

As a central element of the INL transformation strategy, CAES will engage in workforce reinvigoration, development of a workforce pipeline enabling strategic hiring, workforce

diversification, and culture change. CAES will develop research partnerships that provide its university network with enhanced access to INL facilities.

CAES Mission

The CAES mission is to address critical science and engineering issues that will help resolve the grand challenges associated with providing an appropriate mix of energy technologies needed to address critical U.S. and global energy needs. Although CAES will have an emphasis on nuclear energy, it will also address other energy areas that are critical to ensuring U.S. energy security, including affordability, limited environmental impacts, and leadership in the global energy arena. Energy technologies to be addressed include those for nuclear, hydrogen, and fossil fuels (coal, oil, and gas) and the full spectrum of renewable energy sources.

The Center will develop its research agenda to advance the education of the next generation of scientists and engineers and provide them with skills and experience needed to address critical workforce needs. CAES will engage in long-term, university-based research activities and host a range of national and international events. Activities are being designed to facilitate an informed debate, which will address the questions and issues concerning the best energy technology mix necessary to meet U.S. and global needs, non-proliferation challenges and provision of technologies which minimize environmental impact. In addressing these issues the dialogue will present the facts about the benefits and risks of nuclear energy in the world energy and environmental debate, and conduct a wide range of academic and public education activities.

The Center will advance academic capabilities by fostering collaborations and interdisciplinary studies and by making its research and development facilities and those of the INL available to a network of universities.

Idaho University Consortium

An important core of CAES is its university partners. The Idaho University Consortium (IUC), consists of the three Idaho research universities: Boise State University (BSU), Idaho State University (ISU), and the University of Idaho (UI). Through this team, the IUC is able to better integrate the current education and research assets of the Idaho universities. IUC provide a core of vital resources and expertise to CAES researchers and students. These resources include capabilities in engineering, biology, chemistry, mathematics, health physics, physics, geology, hydrology, public policy, and information science.

In partnership with the State of Idaho, the IUC and BEA are developing the detailed plans for constructing a 50-60,000 square foot academic research and development (R&D) laboratory to be built at University Place in Idaho Falls. This CAES facility will be a key element in enabling the larger CAES programmatic vision. The new facility will be occupied jointly by CAES, BEA, and other tenants such as INL co-located research centers. Resources are already being mobilized across the IUC, the INL, BEA partners, and CAES to construct this facility for opening during 2008. It is being constructed as a project under the Idaho State Board of Education and through the Idaho Public Works Department.

National University Consortium

The National University Consortium (NUC) consists of academic representation of five national universities. This partnership was formed as a part of the BEA Proposal Team for the Idaho National Laboratory. These five NUC universities are Massachusetts Institute of Technology (MIT), North Carolina State University, Ohio State University, Oregon State University, and the University of New Mexico.

These NUC organizations are of critical importance to the future of the nation's nuclear industry and will assist CAES in accessing academic expertise via the establishment of university-based Academic Centers of Excellence (ACE). ACE will channel academic expertise to CAES programs, collocated Centers and affiliate researchers. MIT will provide ACE expertise for Advanced Energy Systems; Oregon State University will provide ACE expertise for Thermal Fluids and Reactor Safety; North Carolina State University will provide ACE expertise for Modeling and Simulation; Ohio State University will provide ACE expertise for Instrumentation and Control (I&C) and Safety of Advanced Energy Systems; and the University of New Mexico will provide ACE expertise in the area of Space Nuclear Power. An Idaho ACE is also being developed in the area of fuel cycle and this will be a key element of CAES.

Academic and Research Agenda

To achieve its vision of being a recognized world-class organization, CAES will meet the following programmatic goals and objectives.

1. CAES will advance energy-related research, education, training, and policy. CAES will facilitate research that is critical to DOE by resolving the technical challenges associated with achieving a mix of advanced energy sources. CAES will advance academic expertise and capabilities in energy science, technology, and policy and do so in Idaho, nationally, and internationally. CAES will facilitate the training of the next generation of nuclear scientists, engineers, and technicians. CAES will advance sound energy policy leading the U.S. towards improved energy security and address nonproliferation challenges.

2. CAES will develop a fully functional, nuclear education and research user-facility by 2008. Along these lines, CAES will facilitate the collocation and collaboration of Government-University-Industry energy-related interests. CAES will have collocated and collaborating Centers.

3. CAES will enhance Idaho nuclear educational opportunities. CAES will create a bridge between Idaho, national, and international universities and the INL. CAES and INL research and development capabilities and facilities will be available to a network of universities. CAES will aid the Idaho Universities in becoming world-class centers for nuclear research and education.

4. CAES will be a self-sustaining and internationally recognized advanced energy organization by 2015. CAES will develop distinctive technical signatures in energy-

related research, education, training, and policy. CAES will be a joint institute of Idaho State University (ISU), Boise State University (BSU), University of Idaho (UI) and INL. CAES will serve as the hub of a network of INL-affiliated universities initially involving Massachusetts Institute of Technology, North Carolina State University, the Ohio State University, Oregon State University, and the University of New Mexico. CAES will continue to engage a wider network of partnering organizations (e.g. Dalton Nuclear Institute, University of Manchester, UK) and will support the international Generation IV network.

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