A Systems Approach to Energy and the Environment

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1. Introduction

Many aspects of energy and the environment contain interacting elements that are best viewed as a system, albeit a complex one. This paper addresses energy and the environment from a broad perspective and frames the solution space via a systems approach. It recommends advances in technology that will be critical for our future and presents a strategy that involves supply, demand and culture change with respect to energy and the environment. Examples of development and implementation of energy strategies include: the Department of Defense technology investment plan for energy and power technologies from 2001 to 2005; the U.S. Air Force comprehensive energy strategy actions and organizational approach from 2005 to 2007; a recent national energy plan released by the U.S. Chamber of Commerce's Institute for 21st Century Energy; and the Colorado State University's current efforts to address energy and environment from perspectives of education, research, and operations on its approximately 100,000 acre campus.

2. Key Features

A strong technical foundation for developing new, more efficient operational energy systems was recognized as important in the U.S. Department of Defense (DoD), and from FY01 to FY05, the DoD's Science and Technology (S&T) investment in Energy and Power Technologies more than doubled, representing the largest percentage increase of any S&T area. In the Office of the Director of Defense Research and Engineering, the focus was on power generation, energy storage, and energy conversion and management. Goals were set within the DoD in areas such as hybrid electric technology and technology for greater efficiencies in propulsion and energy conversion systems, supported alternative fuels efforts, and enhanced partnerships with industry and universities.

The Energy and Power Technologies initiative pursued the goal to advance the electric components of DoD systems and improve military logistics. An example included improvements for primary and auxiliary power; as electric power density for air, ground and sea platforms was increasing, the demands for thermal management increased in turn, which was also addressed in the initiative. Megawatt-size superconducting motors and generators were tested that take a fraction of the space of conventional machines. Rechargeable Lithium-ion batteries and state-of-charge battery life indicators for soldier system power also entered production. In addition, an investment was made in a new hybrid fuel cell/battery power system for the individual soldier that weighed less than half of our current systems.

Efforts were enhanced to address the workforce situation and develop critical skills, especially in math, science and engineering that would be needed to meet tomorrow's science and technology challenges. A scholarship program was implemented for promising students who would enter the two-year program with an employment payback component – part of a new National Defense Education Program to develop, recruit, and retain individuals who will be critical in fulfilling the Department's national security mission.

In 2005, the U.S. Air Force created a new energy strategy, starting with a vision to "Make Energy a Consideration in All We Do." This comprehensive strategy addressed demand-side energy efficiencies, supply-side energy assurance options, and the establishment of a culture of conservation. An Energy Senior Focus Group oversaw this strategy and its implementation, and coordinated and developed various programs to improve supply and demand aspects of energy, such as improving efficiency in aviation and infrastructure operations, investing in more energy efficient future systems, and establishing goals and metrics to manage progress. Thus, an energy vision and a strategy to implement that vision were established. A goal was to source the energy needed, while at the same time achieving cost savings through energy conservation while using renewable energy sources wherever feasible.

The Air Force energy strategy included instilling an energy conservation culture throughout the organization, the adoption of a variety of renewable energy sources to provide energy to our bases and other installations, and the research and development of lighter and more efficient airframes, engines and synthetic fuels. Encouraging a culture of energy conservation throughout an organization is actually critically important to producing significant energy cost savings and cost avoidance. People must routinely turn off lights and computer monitors and adjust office air conditioning and heating units when they are not in use. All individuals have a role to play in ensuring energy cost savings individually and through key functions such as the procurement of new systems. New systems considerations should include the specific system requirements as well as life cycle cost analysis. For example, many Air Force bases and installations around the world have low mandatory speed limits (e.g. 25 mph), and thus, procuring low speed/low energy vehicles was a good approach.

When considering energy supply options, the Air Force pursued various renewable energy sources such as wind, solar, geothermal, and biomass. Various renewable energy sources were being used to provide for the energy needs of a number of Air Force installations around the world, and others were being explored. For example, four Air Force bases were using renewable energy sources that were providing the majority of their everyday energy needs. F.E. Warren Air Force Base in Wyoming and an Air Force installation on Ascension Island in the South Atlantic Ocean have wind farms that provide a significant amount of their energy needs. Both Whiteman AFB in Missouri, and Offutt AFB in Nebraska, were installing geothermal pumps in dormitories for Air Force personnel. A large photovoltaic solar farm at Nellis AFB in Nevada was commissioned in December, 2007, producing up to 14 megawatts of energy. Lastly, Hill AFB in Utah was operating a landfill gas project, where the gasses of decomposing landfill waste produced approximately 1.3 megawatts of usable energy. The Air Force was the nation’s largest single purchaser of renewable energy in FY05 (approximately one million megawatt-hours in FY05 and FY06).

The Air Force also continued to pursue research in energy efficient airframes and engines for its aircrafts, both those operating today and enabling new systems options for the future. Today, most of our aircrafts use aluminum and titanium airframes that are relatively light metals, but the trend is towards new and evolving composite airframe structures. The lighter the airframe, the less fuel required to power the aircraft in flight, and so energy cost savings are realized. The Air Force also continues to sponsor research into even more fuel efficient aircraft engines, in partnership with the aerospace industry. In a parallel effort, the Air Force increased its research on the use of synthetic fuels that could eventually supplement traditional, oil-derived aviation fuel. In 2006, the Air Force began a test program to certify its aircraft for a fuel made up of a 50/50 mix of JP-8 – the standard kerosene-based aviation fuel used by the Air Force – and a synthetic fuel (initially from a Fischer-Tropsch process) that began flight testing in September 2006 on a B-52 aircraft, leading to certification of the aircraft in August 2007. Certification efforts and research and development continue through partnerships with industry, universities, technical societies, and other government organizations.

The Air Force actions in energy and the environment were recognized by several prestigious awards from 2005-2007. These awards included the Green Power Partner of the Year Award by the Department of Energy and Environmental Protection Agency (EPA); the Climate Protection Award, given by the EPA; the Stratospheric Ozone Protection Award, presented by the United Nations Environmental Program and the EPA; and the overall Presidential Award for Leadership in Federal Energy Management, for such achievements as saving 3.3 trillion BTUs in FY06 (enough for 100,000 households).

3. Conclusions

Recently, the U.S. Chamber of Commerce’s Institute for 21st Century Energy released its “Blueprint for Securing America's Energy Future”, which presented recommendations for a comprehensive approach to energy. The Institute stated that “we are at a turning point when it comes to energy. We must find new, viable and clean sources of energy to meet this surge in demand. From aggressively promoting energy efficiency and reducing the environmental impacts of our energy consumption and production, to addressing critical shortages of qualified energy professionals and transforming our transportation sector, there is plenty of work to be done and we must continue to work together to engage our political leadership on the elements of a balanced and comprehensive strategy.”

As the Institute’s “Blueprint for Securing America's Energy Future” suggests, several approaches should be pursued with a view toward integrated solutions. For example, at Colorado State University, approximately 100 faculty members are engaged in energy-related research, in a focused manner, with a goal of taking ideas to the market place as rapidly as possible. Active research and development is occurring in areas such as: solar, wind, smart grid, and algae to transportation fuel production. The Colorado State University Research Foundation is also playing an important role to assist the University in working with government and industry partners. A new customer-driven degree program, a Master of Engineering in Systems Engineering, began this Fall, primarily serving a working professional population that is engaged in complex systems development. The Systems Engineering disciple, evolved within the aerospace community, is being extended and applied to applications within energy and the environment.

Finally, a systems approach to the energy and environment challenges is critical. This approach will also require the collaborative efforts of industry, government, and the university community to be successful.

4. References and Bibliography

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Speaker's Biography

Dr. Ronald M. Sega holds a B.S. in math and physics from the U.S. Air Force Academy in Colorado Springs, an M.S. in physics from Ohio State University and a Ph.D. in electrical engineering from the University of Colorado. Dr. Sega is the Woodward professor of systems engineering at Colorado State University and is the special advisor to the Colorado State University president for energy and the environment. He also serves as vice president for energy, environment and applied research with the Colorado State University Research Foundation (CSURF).

Dr. Sega was a faculty member in the College of Engineering and Applied Science at CU-Colorado Springs, also serving as dean from 1996-2001. He also served as technical director of the Laser and Aerospace Mechanics Directorate at the F.J. Seiler Research Laboratory at the U.S. Air Force Academy, and as assistant director of the Space Vacuum Epitaxy Center at the University of Houston. Dr. Sega was director, defense research and engineering, and the chief technology officer for the Department of Defense from 2001-2005. He retired from the Air Force Reserve in 2005 after 31 years in the Air Force, having served at Air Force Space Command as a command pilot and as reserve assistant to the chairman of the joint chiefs of staff. He most recently was the under secretary of the Air Force from 2005-2007. Dr. Sega has authored or co-authored more than 100 technical publications, has served on numerous local, regional and national advisory and governance boards, and is a Fellow of the American Institute of Aeronautics and Astronautics (AIAA) and the Institute of Electrical and Electronics Engineers (IEEE). A former astronaut, Dr. Sega flew aboard Space Shuttles Discovery (1994) and Atlantis (1996). Dr. Sega also led the Air Force team that won the overall Presidential Award for Leadership in Federal Energy Management in 2007.