R&D Issues in the Office of Energy Efficiency and Renewable Energy

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Background

The Office of Energy Efficiency and Renewable Energy (EERE) leads the federal government's research, development, and deployment (RD&D) efforts to provide reliable, affordable, and environmentally sound energy for America's future. EERE's role is to invest in high-risk, high-value research and development that is critical to the Nation's energy future and would not be sufficiently conducted by the private sector acting on its own. EERE also works with stakeholders to develop programs and policies to facilitate the deployment of advanced clean energy technologies and practices.

The vision of EERE is a prosperous future where energy is clean, abundant, reliable, and affordable. Its mission is to strengthen America's energy security, environmental quality, and economic vitality through public-private partnerships that:

- Promote energy efficiency and productivity;
- Bring clean, reliable, and affordable energy technologies to the marketplace; and
- Make a difference in the everyday lives of Americans by enhancing their energy choices and their quality of life.

The strategic goals of EERE are to:

- Dramatically reduce, or even end, dependence on foreign oil;
- Reduce the burden of energy prices on the disadvantaged;
- Increase the viability and deployment of renewable energy technologies;
- Increase the reliability and efficiency of electricity generation, delivery, and use;
- Increase the energy efficiency of buildings and appliances;
- Increase the energy efficiency of industry;
- Spur the creation of a domestic bioindustry;
- Lead by example through government's own actions; and
- Change the way EERE does business.

The 11 programs reside in EERE's Office of Technology Development and consist of the following:

- Solar Energy Technology
- Wind and Hydropower Technologies
- Geothermal Technologies
- Distributed Energy, Electricity Infrastructure and Reliability
- Biomass
- Industrial Technologies
- FreedomCAR and Vehicle Technologies

- Hydrogen, Fuel Cells and Infrastructure Technologies
- Building Technologies
- Weatherization and Intergovernmental Grants
- Federal Energy Management (FEMP)

EERE's programs work closely with the National Renewable Energy Laboratory, which is the only national laboratory dedicated completely to EERE's mission. EERE's programs also collaborate with other national laboratories, other federal agencies, state energy offices, industry, universities, non-government organizations, and other stakeholders to develop programs and policies to facilitate the deployment of advanced clean energy technologies and practices.

Energy Consumption by End-Use Sector and Source

Buildings

Energy use by residential and commercial buildings accounts for over one third of the Nation's total energy consumption, including two-thirds of the electricity generated in the U.S. This electricity costs the Nation about $240 billion annually, with lighting alone accounting for 7% of all energy usage. Improving the energy efficiency of buildings and equipment reduces energy consumption, especially during critical peak demand periods. This, in turn, reduces America's vulnerability to energy supply disruptions, energy price spikes, and constraints on the country's electricity transmission and distribution infrastructure. In addition, since energy for buildings also contributes one-third of urban air pollution and roughly a third of our carbon emissions, new energy efficiency technologies can have significant economic and environmental benefits.

With a growing population and increased amenities that require more energy, building energy consumption is projected to grow from 34 to over 40 quadrillion Btu (Quads) by 2020. Therefore, through its Building Technologies Program, EERE is working to make residential and commercial buildings more energy efficient, productive, and affordable. Research is being conducted to improve the energy efficiency of building components and equipment as well as developing highly-efficient, whole-building, system-design techniques. The program also supports the development of building energy efficiency codes and national energy efficiency standards for appliances and building equipment; integrates renewable energy systems into building design and operation; and conducts technology transfer, education and information exchange. Work is also directed at forging consensus on research directions and priorities, and industry-wide codes and standards for such technologies as:

- Advanced refrigeration and air conditioning;
- Advanced lighting;
- Windows (spectrally selective coatings and electrochromics);
- Power electronics, sensors, controls; and
- Water heaters

Industry

The competitiveness of our most energy-intensive industries is particularly sensitive to energy prices. Advanced energy efficiency technologies can help mitigate the impacts of price swings on industry, thereby increasing their economic competitiveness in global markets. At the same time, industry provides unique opportunities to co-generate heat and electricity, thus reducing the need for new electric power plants. The Industrial Technologies Program is helping American industry reduce its energy-related expenditures by facilitating broader market adoption of energy efficiency technologies and practices, by conducting energy assessments of various industrial sectors, by developing software to analyze and optimize plant systems, and by demonstrating energy-saving technologies. The Industrial Technologies Program is also supporting leading-edge research and development in crosscutting technologies, such as advanced materials and intelligent sensors and controls, that can enable efficiency improvement in multiple industries. In addition, the program is directing much effort at research designed to improve the following industries and technologies:

- Efficient, high temperature separations, including high temperature membranes, filters, and separations in multicomponent systems;
- Improved process control, including high temperature sensors;
- Chemical, petroleum refining operations (heterogeneous catalysis/surface chemistry; homogeneous catalysis/metalorganic chemistry; separation science; materials properties/synthesis; diagnostics);
- Boilers, furnaces, and gasifiers;
- Industrial process flows, heat transfer, etc.; and
- Metal casting, including alloy chemistry and processing; and rapid, non-destructive evaluation of alloy chemistry/properties.

Transportation

The transportation sector is almost entirely dependent on oil, the majority of which is imported. Currently the U.S. imports about 55 percent of its oil from foreign sources, a percentage that is expected to increase to 68 percent by 2025. The current gap between total U.S. consumption and net production of oil is roughly 11 million barrels per day. Although promoting efficiency in the use of oil and finding new domestic sources of oil are important short-term undertakings, over the long-term a petroleum-free option is eventually required. EERE is taking the lead in sponsoring research into advanced transportation technologies. This includes programs such as the FreedomCAR Partnership and Hydrogen Fuel Initiative, which are designed to develop the technologies necessary for hydrogen fuel cell vehicles and the infrastructure to support them. It also includes the 21st Century Truck Partnership which seeks to increase the efficiency of heavy-duty vehicles through improved aerodynamics and advanced combustion engine technologies. EERE-sponsored research in the transportation sector covers the following areas:

- Advanced fuels, including petroleum-based and biomass-based fuels;

- High performance engines, including:
    - Real-time, high sensitivity multispecies measurements
    - Chemistry of soot formation and evolution
    - Lean NOx catalysts with high conversion rate over a wider exhaust temperature range
    - Low speed flows; turbulence; multiphase flows
- Hydrogen production and storage
    - Fossil fuels; biomass; nuclear; solar; solar thermochemical
    - Carbon nanostructures, chemical hydrides
- Fuel Cells (cost; platinum loading; fuel processing/reformers, water/air management
    - Electrocatalysis; ionic transport in polymer electrolytes; fuel processing catalysis
- Aerodynamic drag (low-speed flow and turbulence)
- Frames (composite materials and materials science)
- High power energy storage
    - Abuse tolerance, electrochemistry
- Advanced motors and power electronics
    - Cost ($4/kW, $7/kW) and reliability (15 years)

Bioenergy

America possesses vast agricultural and forest resources that offer the Nation a tremendous opportunity to use domestic, sustainable resources to provide fuel, power, and chemical needs from plants and plant-derived materials. The integrated industrial biorefineries of the future have the potential to be an integral part of America's energy economy. The strategy behind the EERE Bioenergy Program includes developing advanced technologies for converting biomass to fuels, power, and products; and conditioning markets for significant penetration of biomass-based technologies. EERE-sponsored biomass research focuses on improving both feedstock production and conversion processes:

- Feedstock production
    - Plant growth and response to stress
    - Higher productivity at lower input
    - Production of certain components and/or new components
- Biochemical pathways
    - Biocatalysis (enzyme function and regulation; enzyme engineering)
    - Catalyst reaction rates and specificity
- Thermochemical pathways (thermal cracking)
- Bioproducts
    - Novel monomers and polymers
    - Biomass composites and adhesion/surface science
- Combustion
    - NOx chemistry

Renewable Power Technologies

Renewable energy technologies currently account for about 10 percent of the Nation's energy production. Domestic renewable energy resources such as solar, wind, and geothermal are vast and provide a significant opportunity for the United States to enhance and diversify its energy supplies. Research in these areas is described below:

- Photovoltaics
  - Materials, growth, characterization;
  - Multi-junction thin films, including interface chemistry, physics, defects, materials compatibility, quantum dot cells, multiple quantum well devices;
- Geothermal
  - Geoscience, including formation/flow of fluids through fractured media; characterizing geology; geochemistry; remote sensing;
- Wind
  - Computational fluid dynamics to model turbulent flow for turbine design;
  - Modeling meso-scale atmospheric phenomena for wind forecasting for utilities;
  - Composite materials (strength and fatigue properties);
- Remote sensing
  - Algorithms for determining atmospheric and surface properties (aerosol optical depth, surface insolation, surface winds, bioenergy resources).

What Has EERE Accomplished?

The National Academy of Sciences/National Research Council (NAS/NRC) framework assumes that the effect of public support of research and development accelerates development and penetration by 5 years. The NRC characterized their methodology as "very conservative." The NRC review of $1.6 billion worth of EERE R&D activities (one-fifth of the total) over the past twenty years found $30 billion in realized net economic savings, and $3-20 billion in environmental benefits. The Strategic Program Review of EERE identified numerous other technologies with likely large economic and environmental benefits. In addition, the Strategic Program Review produced the following list of recommendations for the existing programs:

- Closures: activities that should be closed because the work has been successfully completed and no significant further government role is needed (graduations), or does not provide sufficient public benefits (terminations).
- Redirections: activities that potentially provide appropriate public benefits but need redirection and/or redefinition to increase the probability of success.
- Watch List: activities that need close monitoring to ensure that they advance effectively and expeditiously.
- Expansions: activities not currently receiving adequate support in comparison to the benefits they can provide.
- Best Practices: actions to improve overall program performance.

The criteria for judging ongoing projects are:

- Projected benefits (economic, environmental, security, options) vs. investment;
- Projected potential for commercialization by industry;
- Whether industry would do the research, development, demonstration, and deployment by itself; and
- Program effectiveness (technical performance, business management, etc.)

Challenges in R&D Management

- Diverse portfolios: The current research sponsored by EERE addresses the national economic, environmental, security, and infrastructure goals. It also addresses multiple markets, including buildings, industry, transport, electricity, and fuels. EERE currently has 11 programs with about 3000 projects.
- Very long timeframes are the norm, with 20+ years devoted to R&D, followed by an undefined period of market penetration.
- Multiple performance criteria for the technology and multiple advances are often needed (performance, cost, lifetime, size, density).
- Discontinuous changes in markets (hydrogen vehicles and infrastructure)
- Different measures needed for program results and portfolio benefits (technology performance versus emissions reductions, oil savings, etc.)

References

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