United States Department of Energy

Energy Efficiency and Renewable Energy

STRATEGIC PROGRAM REVIEW

March 2002

MEMORANDUM FOR THE SECRETARY

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COPIES TO: DEPUTY SECRETARY BLAKE
UNDER SECRETARY CARD

SUBJECT: EERE STRATEGIC PROGRAM REVIEW

I am pleased to present the complete report of the *Strategic Program Review* (SPR). The SPR is the result of recommendations of the National Energy Policy Development Group as stated in the *National Energy Policy*.

The SPR concluded that EERE research, in the aggregate, generates significant public benefits and often exhibits scientific excellence. This finding is validated by external reviews by the National Academy of Sciences/National Research Council, and reinforced by the fact that EERE research is a top recipient of coveted "R&D 100" awards.

However, the SPR also concluded that there were significant areas needing improvement:

- Twenty projects should be terminated because they provide insufficient public benefits or have been successfully advanced to the point that no further public support is necessary. Among the projects identified were Natural Gas Vehicle Engines, Concentrating Solar Power Troughs and Residential Refrigerator Research.
- Six initiatives and processes need significant redirection, including the Partnership for a New Generation of Vehicles (PGNV) initiative.
- A variety of programs and projects have been placed on the "watch list," meaning that they will require close monitoring to advance effectively. Congressional earmarks, microturbine research, the biomass program, deployment programs in the Office of Building Technologies, and analytical underpinnings of the Federal Energy Management Program are examples of "Watch List" programs/projects.
- The application of "best program practices" is uneven across EERE sectors. Program management and evaluation, use of competitive solicitation, and sound business execution are not uniform.

The SPR also reports that there are program areas that could generate increased benefits with greater funding and emphasis. These program areas include the hydrogen program, fuel cell vehicles, building equipment R&D, and low speed wind turbines.

Thank you for the opportunity to undertake this review of EERE's programs, projects and processes.

Strategic Program Review
of the
Office of Energy Efficiency and Renewable Energy

March 2002

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Executive Summary and Recommendations

The National Energy Policy (NEP) recommended a review of the "historic performance" of the Office of Energy Efficiency and Renewable Energy (EERE) programs. Based on this review, the NEP recommended that the Secretary of Energy propose "appropriate funding" of those research and development programs that are "performance-based" and are modeled as "public-private partnerships".[1] Immediately after release of the NEP, Secretary Abraham directed EERE to perform such a review.

To determine the historic performance of EERE programs,[2] this Strategic Program Review (SPR)[3] examined EERE technical accomplishments, external recognition, and the benefits generated for taxpayers. To determine which programs were performance-based, the review examined how programs have changed over time, the use of competitive solicitations in research awards, the use of external program peer reviews, and whether non-performing projects were terminated. To determine which programs were modeled as public-private partnerships, the review examined the breadth and depth of partnering across the EERE programs. Finally, the alignment of the EERE programs with the direction of the President's National Energy Policy was evaluated. Based on these and other results, recommendations are presented immediately below for the purpose of improving program planning, budgeting, partnering, and performance. A summary of the findings of the SPR then follows.

RECOMMENDATIONS

Although EERE's record of historic performance, public-private partnerships, and performance-based management shows significant improvements in performance over time, the SPR found a number of areas where improvements can and should be made. EERE's historic performance includes being among the top recipients worldwide of R&D100 awards and, according to the National Academy of Sciences' National Research Council (NRC)[4], earning returns of 20 to 1 on the research investment the NRC reviewed.[5] EERE's partnership activities have involved more than two thousand individuals in

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[1] See: Report of the National Energy Policy Development Group, "National Energy Policy," (Washington, DC: U.S. Government Printing Office, May 2001), page 4-3, 6-4. See also this report: Chapter 1, Box 1-1,

[2] EERE has historically used the term "program" to cover a range of activities and has not adequately defined or differentiated the terminology of programs, projects, etc. This shortcoming was identified by the National Academy of Public Administration review of EERE in 2000, "A Review of Management in the Office of Energy Efficiency and Renewable Energy", as discussed under program redirections below. This shortcoming is, to some degree, unavoidable in the terminology used in this Strategic Program Review due to this legacy, but is an area that EERE is working to correct. For the purposes of this Strategic Program Review, the term "program" will generally refer to the EERE programs as defined in response to the NAPA review and their ancestors; "projects" will refer to those so defined in response to the NAPA review. Contributing to the imprecision here is that measures of historic performance, partnering, and other factors identified for review by the National Energy Policy are most often done at a project level rather than at the program level.

[3] The SPR was conducted by the Assistant Secretary, senior staff within the Office of the Assistant Secretary, and the Office of Planning, Budget and Management working with EERE's Deputy Assistant Secretaries, program managers, and staff.

[4] The National Research Council was created under the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine; for simplicity and brevity, this will be abbreviated here as the NRC.

[5] The R&D investment criteria developed as part of the President's Management Agenda are intended to further improve this record by helping EERE redirect resources from poorly performing programs to more promising ones.

technology roadmapping alone in the past five years and EERE has nearly three thousand current contracts with industry, universities, national labs, and others.[6] Indicators of EERE's performance-based management include roughly two-thirds of its R&D funding currently going through competitive solicitations, more than 60 terminations and graduations of activities,[7] and more than 20 external peer reviews by the NRC alone. Each of these is detailed in the Findings Section below and in the main report. These accomplishments have been achieved in spite of limitations in DOE-wide business management systems, which have spurred EERE to develop its own tools to manage its exceptionally large portfolio and range of research, development, demonstration, and deployment (RD^3) activities.
Areas the SPR identified for improvement are discussed here in terms of the following:

- Closures—activities that should be closed because the work (1) has been successfully completed and no significant further government role is needed (graduations), or (2) does not provide sufficient public benefit (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 that are not currently receiving adequate support in comparison to the benefits they can provide.
- Best Practices—actions that can be taken to improve overall program performance.

Criteria for these judgments include:

- Projected benefits (economic, environmental, security, options, knowledge) vs. total investment;
- Projected potential for commercialization by industry;
- Whether industry could or would do the RD^3 by itself; and,
- Program effectiveness as evidenced by the technical performance and business management measures used in this evaluation.

CLOSURES

The SPR identified 20 activities that should be terminated because the public benefits are expected to be achieved without further public support or because they do not provide sufficient public benefit (Table ES-1).[8] These include activities that would likely be terminated or graduated under standard EERE business practices, as well as activities for which the technical, market, or other bases for the work have passed but that continue because of ongoing stakeholder or other external support. Separately, Chapter 4 details more than 60 past graduations or terminations of activities, demonstrating EERE's business practices.

REDIRECTIONS

This SPR found several activities that can potentially provide appropriate public benefits but need redirection and redefinition to increase the probability of success. These fall into the categories of project (i.e., what work is done) and process (i.e., how the work is done) redirections, as follows.

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[6] EERE also provides financial assistance to states, communities, and others through grants and other mechanisms.
[7] Various new activities have been launched as these were graduated/terminated. See the footnote to Table 4-A2.
[8] It is difficult to prejudge R&D, so it is possible that subsequent work might modify this determination.

TABLE ES-1: RECOMMENDED CLOSURES*

ACTIVITY	REASON FOR CLOSURE
Wettable Ceramic-Based Drained Cathode Technology	Alcoa has acquired the intellectual property rights and can continue without DOE support.
Committee on Energy Efficiency Commerce and Trade (COEECT)	COEECT's role of coordinating Federal export assistance to U.S. energy efficiency industries should be ended. The Clean Energy Technology Exports initiative, currently in development under the NEP, should consider which COEECT activities may be worthy of future support.
SIDI—Hybrid Direct Injection R&D	SIDI technology is now believed sufficiently close to commercial feasibility that auto companies should conduct remaining R&D without public support.
Glass-Fiber-Reinforced Polymer Matrix Composites	Successful R&D of glass-fiber-reinforced polymer-matrix composites allows this activity to now end and funding used to ramp up work on carbon fibers.
Lighting technology development projects.	Solid-state ceramic lighting project, others, will be completed during 2002 and be transferred to industry for further development and commercialization.
Light Source Basic Research Projects	Materials development on coatings for incandescent filaments and new phosphors for fluorescent fixtures is being completed during 2002.
Advanced Gas Water Heaters	Research on condensing heat exchangers and absorption heat pumps for gas water heating is being completed during 2002 and results transferred to industry.
Dehumidification Characterization Research	R&D on the energy performance implications of various dehumidification processes is being completed during 2002 and results transferred to industry, others.
Develop an Integrated Window/Wall system	R&D, evaluation of specific combinations of advanced windows and wall materials for residential construction being completed in 2002 and transferred to industry.
Sensor for Verification of Gas Fill Integrity of Windows	Development work is being completed in 2002 and results transferred to industry and to market deployment efforts.
Whole Building Diagnostician	Research project is being completed in 2002 following successful demonstrations and will be made available for commercialization by private sector.
Natural Gas Vehicle Engine R&D	Limited technical opportunities for further performance improvements and significant market constraints indicate termination of R&D and redirection of resources toward barriers that prevent engines, vehicles from reaching customers.
Concentrating Solar Power (CSP) Program Troughs	A recent NRC report concluded that CSP troughs were not likely to be cost competitive in the U.S. in the foreseeable future. Based on this, trough activity should be closed.
Resource Energy Managers (REMs)	FEMP provided seed funding that resulted in successful REM programs in Washington and California. Since a number of Federal agencies are embracing this concept and will support this function directly, FEMP funding can be phased out.
FRESA, WATERGY and Integrated Screening Software	FEMP will phase out support of these tools as they did not rise high enough relative to other priorities to warrant further support.
Continuous Fiber Ceramic Composites	Several applications commercialized, and materials codes and standards will be completed and adopted. Applications limited by relative costs of these materials compared to most metal applications. Program should be closed.
Methane de-NOx Reburning for Wastewood, Sludge, and Biomass Fired Stoker Boilers	Demonstrations of methane de-NOx technology in three paper mill biomass boilers have successfully proven that the technology will increase thermal efficiency and the use of biomass fuel while reducing emissions and natural gas consumption.
Direct Production of Silicones from Sand	Fundamental understanding of making silicone was significantly advanced and several inexpensive materials that appeared to be suitable were identified, but closer study revealed that the direct synthetic route was not chemically feasible.
Residential Refrigerator Research	Past efforts reduced energy use of new residential refrigerators by nearly a factor of four since 1975 and non-residential refrigerator applications now offer higher returns, allowing research specifically on residential refrigerators to end.
Automotive Aluminum Casting	Developed technology that should be able to produce aluminum components that perform as well or better, cost the same or less, but weigh 40% less than steel components. Activities can be successfully concluded at the end of FY2002.

*Additional information concerning these recommended closures can be found in Chapter 7.

Recommended program and project redirections include:

- **PNGV Initiative**. As noted in the NRC Seventh Annual Review of the PNGV initiative, redefinition of the "PNGV charter and goals" is needed to "better reflect societal needs and the ability of a cooperative, pre-competitive R&D program to address these needs successfully." This initiative is nearing the end of its ten-year charter. The Administration is in discussion with its partners and is identifying potential new partners to determine how to best collaborate on energy-saving vehicle technologies. A more aggressive long-term orientation toward hydrogen and fuel cell technologies should be a central element of this new direction.[9]

- **Batteries**. EERE's Office of Transportation Technologies (OTT) has two sets of research efforts on batteries, one under the Electric Vehicle Program and one under the Hybrid Vehicle program. EERE *should* combine them into a single program that covers the full spectrum of battery-related research for transportation applications. Although dedicated electric vehicle markets remain small and their prospects highly uncertain, hybrid vehicles and plug-in hybrids are gaining increased attention and further work to lower the costs and improve the performance of batteries can assist their market acceptance.[10]

- **Regional Resource Centers for Innovation**. Close on-the-ground interaction with industry counterparts is essential for successful partnerships. It is also important, however, to minimize duplication of effort in such activities. There is a risk that some of EERE's Office of Industrial Technologies (OIT) Regional Resource Centers for Innovation overlap with or duplicate activities that could be undertaken through the EERE Regional Offices. EERE *should* examine closely and minimize potential overlaps to ensure best use of its resources.

Recommended process redirections include:

- **Program Structure**. The 1999 review by the National Academy of Public Administration recommended that EERE define what "constitutes a program and what constitutes a project" and to "clarify the roles and responsibilities of program and project managers." While EERE has made significant progress in identifying and developing such program structure, further work is needed. It is important to note, however, that there is no single logical structure that fits all the various EERE activities perfectly. Perhaps more important is building an organization that is inherently more flexible and can adjust to shifts in RD^3 priorities over time while still ensuring logical lines of authority and accountability. EERE *should* further examine and logically align its structure while also developing greater flexibility.

- **National Laboratories**. National laboratories have consistently provided critical technology advances, served as important bridges between basic and applied research, provided technological breadth and depth for increasingly diverse research challenges, and maintained a technological institutional memory.[11] However, the cost of doing business at the National Labs is high, with overheads substantially greater than those of private firms.[12]

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[9] The Administration launched the FreedomCAR initiative focused on fuel cell vehicles in January, 2002.

[10] See, for example: http://www.epri.com "Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options."

[11] These contributions help counterbalance industry reductions in R&D, shortened time horizons, and shifts from central research to independent profit centers where research becomes increasingly fragmented and narrow. The review of R&D100 awards found National Laboratories involved in roughly 90+% of EERE's winning research.

[12] National Labs maintain core technical competencies and provide support not provided by private firms, however.

- EERE *should* conduct detailed analysis of cost at the national laboratories to determine the key cost drivers and to reduce them to more competitive levels where possible. This might include, for example, greater consideration of the differences between the weapons labs and civilian facilities such as the National Renewable Energy Laboratory.
- National lab costs are significant for non-research programs such as the Federal Energy Management Program (FEMP), but which still use national labs as a primary source of support. EERE *should* examine how to reduce lab costs in providing support to FEMP; further, EERE *should* consider more extensive use of private sector alternatives.

WATCH-LIST

This SPR identified several activities that need close monitoring to ensure they advance effectively and expeditiously.

- **Congressional Earmarks**. Chapter 4, Tables 4-A8 and 4-A9, list Congressional earmarks in the Renewable Energy Resources portion of the Energy and Water Development appropriations for FY01 and FY02, respectively. In FY02, Congress earmarked 50 projects worth $86 million, or almost one fourth of the appropriation for renewables. In some areas (e.g., biomass and superconductivity), earmarked projects accounted for about 40 percent of the respective budgets. While the SPR found that a number of these Congressionally designated projects have merit, many are not optimally aligned with overall program objectives and/or priorities. At times, some earmarks may have no relationship at all to the technology research or program to which it is attached. Moreover, because earmarks bypass the competitive peer-reviewed selection process used by EERE to select projects, earmarked projects bring into question the overall integrity of merit-based selection, and interfere with overall program management and the development of a coherent program. EERE has not yet determined whether it will request reprogramming of FY 2002 appropriations that were earmarked. However, these and future projects will receive the same close scrutiny that EERE is applying to all of its work to ensure that statutory cost-sharing requirements, progress performance, and sound business practices are carefully followed, and associated risks fully considered. EERE's FY 2003 budget does not request funding for previously earmarked projects.

- **EERE's Office of Building Technologies, State and Community Programs (BTS) demonstration and deployment programs**. BTS combines technology development activities with demonstration, and deployment efforts such as Building America, Rebuild America, Energy Star, and the Community Energy Program, as well as the weatherization program. Such integration is necessary and important. The SPR did not, however, identify a strong analytical base in place or under development to determine how much demonstration was necessary and/or sufficient, including what was needed to achieve a critical mass of activity to cause market transformation in target areas. This is not only a concern but also an opportunity to develop such an analytic foundation, as discussed further under Best Practices, below, and in Chapter 4.

- **Biomass**. The overall direction of the biomass programs toward the development of integrated biorefineries producing chemicals, fuels, and power is appropriate and important. Although efforts to improve integration and joint planning continue, much work remains for the EERE biomass-related programs to be adequately integrated and sufficiently strategic, and to ensure that there is a critical mass of focused activity in key areas.
  - The biopower program effort on cofiring biomass with coal in conventional power plants does not directly contribute to the longer-term goal of developing integrated biorefineries. Indirectly, however, cofiring can potentially contribute by offering a market for biomass

feedstocks and encouraging the development of production, harvesting, and transport equipment to drive down the cost of biomass delivered to the biorefinery. The fossil energy program at DOE *should* be approached as a significant partner in and supporter of these cofiring demonstrations. Support for feedstock infrastructure activities is not adequately built into the current R&D program. Plant science and crop development are areas that the biomass program *should* strongly encourage USDA and others to undertake while ensuring a smooth transfer of current activities to USDA, so that important research is not disrupted.

- o The biofuels program supports R&D to convert lignin to liquid fuels and chemicals. However, some fraction of the input biomass feedstock will also be needed for producing power to operate an integrated biorefinery. Because of the difficulty of converting it to liquid fuels, lignin is perhaps the best near- to mid-term candidate to fire power generation. Research specifically on converting lignin to liquid fuels *should* be reduced and the resources concentrated on producing liquid fuels from celluloses or on producing high-value products, possibly including from lignin.

- **Federal Energy Management Program (FEMP)**. While FEMP has made progress in tracking the energy and cost savings produced by its direct project assistance under its Energy Saving Performance Contracts (ESPCs), technical assistance, and audit programs, further work is needed to develop adequate methods of measurement and evaluation linking project activities to the achievement of its programmatic goals. EERE and FEMP *should* develop these essential analytical underpinnings and a stronger analytic capability, and should also expand this analysis to the indirect program support it provides, particularly in the areas of training and outreach.

- **Microturbine Research in the Distributed Energy Resources (DER) program**. Although more efficient microturbines promise superior environmental performance compared to conventional reciprocating natural gas engines, cost and maintenance issues may limit their mass deployment in the marketplace. New activities in this area *should not* be undertaken unless careful analysis indicates significant future market opportunities for microturbines, and existing activities are successful in achieving their efficiency and emissions performance goals.

- **Concentrating Solar Power (CSP) Towers**. CSP integrated with molten salt storage provides a baseload capability that other solar technologies do not, by themselves, provide. However, an NRC Report released in FY 2000 concluded that CSP towers were not likely to be cost competitive in the United States in the foreseeable future,[13] and PCAST recommended exploring development of higher temperature receivers appropriate for use with gas turbine cycles to lower costs.[14] CSP towers may, however, have near-term opportunities in other parts of the world, which industry is currently exploring. Building on recent studies launched by the CSP program, EERE *should* conduct detailed analysis to determine if advanced technologies can provide a path for towers to become competitive in the mid to longer term in the United States. Further research in this area would depend on these findings.

[13] The report differentiated these technologies from solar dishes, which it concluded showed promise in distributed markets and which have been earmarked for funding by Congress the past two years. NRC, "Renewable Power Pathways: A Review of the U.S. Department of Energy's Renewable Energy Programs," 2000.
[14] President's Committee of Advisors on Science and Technology, "Federal Energy Research and Development for the Challenges of the Twenty-First Century", Executive Office of the President, November, 1997.

EXPANSIONS

Within EERE's portfolio, there were several programs that could achieve significantly increased benefit with additional funding.

- **Hydrogen**. The promise of hydrogen as an energy carrier that can provide pollution-free, carbon-free power and fuels for buildings, industry, and transport makes it a potentially critical player in our energy future. The acceleration of hydrogen technology development is appropriate and necessary. However, work is needed to more effectively structure the existing Hydrogen program in EERE's Office of Power Technologies (OPT) to meet this challenge. In particular, this includes ensuring that RD^3 activities are appropriately balanced so that near term projects that contribute to creating a hydrogen infrastructure also fit within the longer term plan for hydrogen providing energy security to the United States, and that there is a clear analytical basis for the value-added of each additional demonstration activity (see Best Practices, below).

- **Fuel cell vehicles**. Advanced vehicle technologies are essential elements of any effort to reduce our dependence on foreign oil. A critical step is the development of advanced fuel cell vehicles, building on current hybrid and fuel cell activities, to reverse the growing use of petroleum for highway transportation and to ultimately break the link between highway transportation and petroleum. The development of fuel cell vehicles is an important goal of the Administration, as reflected by the launch of the FreedomCAR program in January 2002. A key complementary activity is developing the necessary hydrogen infrastructure.

- **Building Equipment R&D**. The largest returns found by the NRC analysis of EERE benefits came from this program, which develops energy efficient heating, cooling, lighting, windows, and other building equipment and components. This equipment typically has lifetimes of 20 years or less, so that improvements can enter the market relatively quickly and have a broad impact on energy use throughout the United States. Some technologies, such as residential refrigerators, are approaching practical limits of improvement with current technologies, prompting reductions in funding. At the same time, advances in materials science, information technologies, and sensors/controls offer huge new opportunities. Integrating these technologies with distributed energy resources to develop zero net-energy and essential energy buildings is also important. The key new focus for this program should be next generation lighting.

- **Low-Wind Speed Turbines**. The cost of electricity generation by wind turbines has been reduced by a factor of 10+ over the past twenty years and wind energy is becoming the fastest growing energy supply source in the United States and worldwide. The current generation of wind turbines, however, is limited to areas with high (class 5&6) wind speeds to be economic, which sharply restricts their use. The development of turbines that can operate cost competitively in areas with moderate (class 3&4) wind speeds will increase the wind resource that can be tapped by a factor of twenty and greatly broaden the areas of application.

- **Peak load reduction**. EERE technologies have the potential to significantly reduce peak loading on energy systems through building and industrial energy efficiency that lowers both peak loads and load growth, by supplying distributed generation and storage, and by providing real time price and other information supported by communications and control technologies. The NEP has called upon EERE to exploit opportunities to reduce peak loading. Although current activities have often considered peak load issues, they do not give adequate attention to this opportunity relative to other ongoing work. Areas for increased research include: (1) building and industrial sector energy efficiency opportunities that reduce peak loads and load growth; (2)

distributed generation and storage systems that provide electricity to consumers without adding to the loads on transmission systems; (3) use of superconducting materials to enhance the capacity of key components of transmission systems; and, (4) grid control technologies, including responses to real time prices or other market signals, and interconnection standards that allow the grid to operate more efficiently. Careful analysis is needed to identify, evaluate, and prioritize peak load reduction opportunities for consideration in future funding requests.

- **Biobased Products.** An important opportunity for expansion in the biomass area is research on biobased products. Such R&D can create high value products that will support development of other components of an integrated biomass industry—from biomass harvesting to production of fuels and power. To date, bioproducts have received relatively little funding in comparison to other biomass activities, while potentially offering the highest value-added.

- **International**. International energy efficiency and renewable energy development can be extremely important as an outlet for U.S. exports of goods and services, to help drive down costs for these systems at home, to address global oil security and environment issues, and to help meet existing U.S. commitments under the U.N. Framework Convention on Climate Change. Current investments in this area are extremely modest. R&D support is needed to develop energy supply and service applications appropriate to developing countries—applications for use in buildings, industry, power, transport, agriculture, education, health, and, in particular, that can generate income for the user—building on U.S. renewable energy and energy efficiency technologies.[15]

In each of these areas, EERE *should* examine closely the potential and build the case for appropriate expansions of efforts and funding, where appropriate, for consideration by the Congress.

BEST PROGRAM PRACTICES[16]

This SPR identified a variety of actions that can be taken to improve overall EERE performance. These include a number of cases where particular EERE programs have developed internal "best practice" capabilities that could be replicated usefully in other EERE programs. The following discussion addresses best practices in program RD^3 and in business practices. They include:

- **Technology roadmapping**. Technology roadmapping has proven to be a valuable tool in developing public-private partnerships, identifying appropriate research opportunities, and defining appropriate public roles. Although experience shows that no single approach is likely to serve all needs, more systematic approaches to roadmap development and quality control, and to match roadmap approaches with user needs would be useful. EERE *should* examine closely roadmapping activities as practiced by the different sectors and develop recommendations on best practice approaches and mechanisms for quality control.

- **Project selection, planning, and execution**. EERE is working to implement multiyear planning, development of critical path milestones and metrics, and improved program execution. Although much progress has been made, EERE *should* strengthen its efforts to:
  - establish evaluation plans at the start of each project—including appropriate criteria and protocols for decision-making such as redirecting, graduating, or terminating projects;
  - incorporate market analysis activities in the project plan to help ensure that projects are appropriately targeted and to provide independent assessment (separate from the partnering companies) of the market opportunity and potential public benefit;

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[15] Note that this recommendation is in support of technology development activities, not of trade activities more appropriately done by the Department of Commerce and others.

[16] Additional detail on many of these is provided in Chapter 7.

  - develop reasonably standard protocols for planning and budget execution; and,
  - evaluate projects, including their overall portfolio balance and completeness—from research through development, demonstration, and deployment, including system integration, technical assistance, analytical tools, information outreach, technology ratings, codes and standards, and facilitating work on training.

- **Competitive Solicitations**. Much EERE work is now conducted through competitive solicitations, followed by successive down-selects, project redirections, and then further competitive solicitations—all on firm timelines. This approach requires strong discipline and astute technical and political management, especially when dealing with numerous external stakeholders. EERE *should* identify best practice approaches for competitive solicitations, down-selects, and project redirections, including establishing clear criteria for the selection of projects, specification of timelines, and project evaluation.

- **Program management**. During the SPR, several programs within OTT and OPT demonstrated strong program and project management practices. EERE *should* adapt these practices to the needs of the other sectors, incorporating the best practices of all the sectors. Further, in FY2001, EERE developed a Program Management Guide; this *should* now be implemented.

- **Role of technology demonstration and deployment**. To turn public investment into real public benefits requires moving laboratory research to commercial success. Historically, programs have sharply limited their roles in technology demonstration and deployment (D^2) out of concern that they might impinge on the private sector or be perceived as providing "corporate welfare." Today, there is growing recognition of the strategic role public facilitation of D^2 can serve, while recognizing these are primarily private sector activities and that they should not come at the expense of core R&D efforts. EERE *should* establish a strategy, a reasonably uniform process, evaluation criteria, and supporting analytical capability for D^2 in order to carefully evaluate and build on its current portfolio of activities, where appropriate. These efforts should also strengthen strategies for linking R&D, voluntary programs, and codes/standards.

- **Portfolio management**. Portfolio approaches are essential to program success. Portfolios must be defined to accommodate risk mitigation, provide multiple success strategies and pathways, and adapt to changing markets and policies. Additionally, the OIT practice of identifying "direct" and "relevant" portfolios appears to be a useful tool for portraying programmatic interrelationships and for defining strategies to meet larger programmatic objectives and *should* be considered by the other offices as well.

- **Program evaluation**. Systematic peer review is very important for strengthening/redirecting program activities. The SPR found that some form of peer review is frequently and widely used, though often on an ad hoc basis and not necessarily following best practices nor with sufficient regularity. EERE *should*:
  - examine all EERE peer reviews over the next 6-12 months to identify best practices;
  - identify the most important outcomes from the peer review process—such as improved DOE program management and decision-making, improved project quality, and increased public accountability—and determine means of achieving these;
  - benchmark EERE best practices against external models;
  - identify other EERE reviews that are less productive and can be subsumed in a regular peer review in order to minimize staff workloads;
  - develop model approaches for establishing systematic peer review for EERE; and,
  - implement consistent and systematic peer reviews across all EERE programs.

Benefits analysis is useful for determining the potential value of the research portfolio as well as the value of benefits achieved. EERE has done extensive benefits analysis, particularly through the formal, externally reviewed process for establishing appliance standards and the annual analysis conducted for the GPRA. Broader analysis of project costs and benefits would be useful, however. EERE *should* also further develop benefits analysis methodologies and begin a multiyear effort to implement a sophisticated benefits analysis capability. Benefits estimation is expensive, however, and needs consistent funding to build data sets and time series data. This will necessarily be balanced against other program needs, particularly core RD^3 work.

- **Institutional memory**. The SPR frequently found it difficult to retrieve information about past programs, particularly programs that were conducted ten or more years ago, due primarily to staff turnover and culling of old files. EERE *should* develop mechanisms to build and maintain program institutional memory.

- **Partners**. EERE technology is commercially introduced by private companies who often are R&D partners. One model for such partnerships involves forming groups of competing companies to work collaboratively on issues of common interest and to share the intellectual property that results. This model works well where there is an established industry. Another model involves working with individual companies where the company gains much (or all) of the intellectual property created. This works well for an emerging technology where a strong intellectual property position is necessary to attract the capital needed to build a new business—either from venture capitalists or in the equity market. Both models can provide good leverage for federal funds and should be benchmarked for best practices in order to be more effectively applied. In addition, there are also useful models for more general information and technology dissemination efforts. OIT has employed a practice of naming “Allied Partners” who will use information developed by OIT to reach out to people within their organization or industry. This practice appears to be highly effective, provides good leverage of federal funds, and is readily transferable to other sectors. Other partnering includes work with other Federal or state agencies, universities, and non-profits. EERE *should* launch an effort to benchmark best practices for these various approaches and to replicate these best practices across programs.

- **Business Execution.** In March 2000, the National Academy of Public Administration (NAPA) published *A Review of Management in the Office of Energy Efficiency and Renewable Energy.* This comprehensive review provided a benchmark on EERE management practices and a template against which progress can be evaluated since the issuance of the report. In response, the Strategic Management System (SMS) and the Program Management Initiative (PMI) have been launched, but are not yet fully implemented. The NAPA review found that each of the EERE organizations had a somewhat different business strategy, from predominant national laboratory activity to predominant public/private activity—in part reflecting the particular characteristics of the energy sector being worked with. While business strategies differ, EERE needs a common corporate “systems approach” for business execution. The intent of the SMS is to provide such a centralized management system. This is critical to furthering the goal of management excellence. Similarly, the PMI addresses the need to train staff for effective program and project management. EERE *should* continue to implement the SMS and PMI and move to common systems and practices including the use of common databases such as the “Budget Hut” for supporting planning, budget formulation, budget execution, and program analysis.

FINDINGS

PUBLIC REVIEW AND FINDINGS

As part of this Strategic Program Review, public comments on EERE programs were solicited in a series of EERE town meetings in Atlanta, Boston, Chicago, Denver, Philadelphia, Seattle, and Washington, D.C. These meetings, along with e-mail and postal mail responses, resulted in 4,279 public comments,[17] of which more than 99 percent expressed strong support for EERE programs.[18]

Many of the supportive comments were based on the rationale that EERE's programs would enable the nation to meet its energy needs through clean power technologies. The broad topic area that received the most attention in the public comments was the environment, followed by economic, budget, and energy security issues. Of the recommendations directed at EERE in the public comments, the most prevalent by an overwhelming margin, identified in more than 90 percent of the comments, was the recommendation to increase EERE's funding level. EERE completed a report summarizing these comments on August 31, 2001. That report is attached as Appendix A to the main report of the SPR.

HISTORIC PERFORMANCE

To determine the historic performance of EERE's programs, this SPR examined EERE technical accomplishments, external recognition, and benefits to taxpayers.

Technical Accomplishments

Specific technical innovations, performance gains, reductions in cost, design tools, standards, and other accomplishments were examined and a subset of EERE results (more than 150 examples) is detailed in Chapter 4. As brief examples, in the buildings sector, EERE contributed significantly to cutting refrigerator electricity use by nearly three-fourths over the past 25 years even as more features were added. In the industry sector, EERE developed with industry lost foam metal casting with an average 27% savings in energy, a 46% increase in productivity, and a 7% reduction in materials use. In the transport sector, EERE, the national labs, and industry reduced platinum content, a key cost factor, of PEM fuel cells by a factor of 10 over the past eight years.[19] In renewable energy, independent external reviews found cost reductions for specific technologies closely followed aggressive EERE projections, with technologies such as photovoltaics and wind turbines dropping in cost by as much as ten times over

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[17] Of the 4,279 comments, 457 were provided during the 7 public meetings, of which 456 were favorable to EERE programs and 1 was unfavorable. The 3,822 written comments included 1556 individual messages and 2,266 in 11 different form letters. Of these written messages, 3745 were favorable, 7 were unfavorable, and 70 did not provide enough information to determine the commenter's overall opinion. Details are provided in Appendix A.

[18] These results are generally in-line with statistically-rigorous public opinion polls. Specific examples of recent public opinion polls can be found at: http://www.publicagenda.org/issues/pcc.cfm?issue_type=environment and a review of more than 700 polls from 1973-1996 is at http://www.crest.org/repp_pubs/articles/issuebr3/issuebr3.html A published review of this issue is in: "Barbara C. Farhar, "Trends in US Public Perceptions and Preferences on Energy and Environmental Policy", *Annual Review of Energy and the Environment*, eds. Robert H. Socolow, Dennis Anderson, and John Harte, Vol. 19, pp.211-239, 1994.

[19] Some estimate that overall PEM fuel cell costs have also been reduced by a factor of ten, assuming mass production (see Chapter 4).

the past two decades.[20] The NRC noted that EERE was "dominant" or "influential" in half of what they identified as the most important technological innovations in energy efficiency since 1978.[21]

External Recognition

Awards were identified by the SPR as an important measure of external peer recognition of program performance. Although EERE programs received numerous awards of many types, most were too narrow in scope to provide adequate comparison of EERE programs to R&D programs of other institutions. Consequently, the R&D100 award was selected as a single measure of performance because: it provides broad technology coverage—not just energy; it provides broad participation—across companies, universities, public agencies, and countries; it is externally awarded and independently peer reviewed; and, it is widely recognized and highly regarded. The R&D100 awards have been characterized as the "Oscars of Invention." Across all EERE supported research, some 105 R&D 100 awards were received for the period 1978-2001. In comparison, EERE's 105 awards placed it: above all other government agencies except NASA, with 125 R&D100 awards; above all companies except GE, with 163; above all other countries except Japan, with 157, and; above all universities (MIT was first with 30).[22] Additionally, the number of R&D100 awards received by EERE increased over time, with 80% of the total received in the past ten years, and over half of the total from 1995 on.

Benefits

Economic, environmental, and security benefits resulting from EERE's RD^3 activities were also examined. In July 2001, the NRC published a review of the benefits from EERE programs.[23] This study examined, in detail, about $1.6 billion worth of the total $7.2 billion (constant 1999$) R&D investment by EERE in energy efficiency[24] from 1978-2000 and found a net realized economic benefit on this $1.6 billion of $30 billion—a return of roughly 20 to 1 (see Box ES-1).[25] In addition, the NRC estimated that the United States realized between $3 and $20 billion in environmental benefits from EERE programs. The NRC noted that if a constant technology baseline was assumed, estimated economic benefits would be $78 billion, but their "very conservative" methodology reduced these benefits to $30 billion.[26]

The SPR identified a number of additional technologies with potentially large benefits. Further development of the NRC methodology is in progress so that it can be applied to these and other cases. The NRC methodology did not consider potential future benefits of R&D that is still underway, which account for most EERE activities. External peer-reviewed estimates of these future benefits are developed annually under the Government Performance Requirements Act (GPRA) and were examined under this Strategic Program Review. Applying a NRC-like back-of-the-envelope methodology to these GPRA estimates placed the return at 15 to 1, which is similar to, but slightly more conservative than, the NRC results for past EERE work (see Chapter 5).

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[20] James McVeigh, Dallas Burtraw, Joel Darmstadter, and Karen Palmer, "Winner, Loser, or Innocent Victim? Has Renewable Energy Performed As Expected?" Resources for the Future, Washington, DC, Discussion Paper 99-28, March 1999; June 1999.
[21] NRC, "Energy Research at DOE: Was It Worth It?," July 2001.
[22] DOE, of which EERE is part, has won by far the most R&D100 awards of all institutions, with about 574. Details of the R&D100 analysis and uncertainties within it are described in Chapter 4.
[23] NRC, "Energy Research at DOE: Was It Worth It?," July 2001.
[24] The NRC only examined energy efficiency in the study; other studies have examined renewables.
[25] Within the $1.6 billion portfolio reviewed by the NRC were several other research activities which the NRC identified as having large benefits, but which they did not quantify (see Chapter 5).
[26] NRC, "Energy Research at DOE: Was It Worth It?" op cit., page 65: "... the committee adopted a 5-year rule to be very conservative about the effect of DOE R&D." See Chapter 5 for a detailed analysis of this methodology.

PERFORMANCE-BASED

To determine which programs were performance-based, the review examined how programs have changed over time, the use of competitive solicitations in research awards, the use of external program peer reviews, and whether non-performing projects were terminated.

Programmatic Changes

The Strategic Program Review found that EERE programs have been substantially reinvented over the past decade, from "technology push," based primarily on laboratory-identified R&D, to "market pull," built on technology roadmapping with industry partners. In addition, where the previous programs relied primarily on cost-plus contracts, the current programs extensively use competitive solicitations with cost sharing (see below). There was also a notable shift from individual component R&D to integrated systems R&D. The shift from technology push to market pull can be seen by the development of more than 40 technology roadmaps with industry partners in the past five years. The shift to integrated systems can be seen in the buildings sector's focus on "Whole Buildings" approaches; the transport sector's focus on integrated vehicle systems; the industry sector's focus on a "Whole Industries" approach under the Industries of the Future program; and the development of the integrated Biomass and Distributed Energy Resources programs.

Box ES-1: Estimating Benefits

It is sometimes difficult to understand how modest public R&D investments can be associated with such large benefits as described by the NRC. A simple example can illustrate how this is possible. Consider windows. Special "low-E" coatings were developed to reflect long-wavelength infrared radiation. These low emissivity window coatings help keep more heat in a house during the winter, and reflect some of the hot sun during the summer, reducing air conditioning loads. The EERE investment in low-E windows R&D was about $4 million, with some additional expenditure to develop window design tools, conduct information outreach, and do other activities. Low-E windows began penetrating the market in 1983 and by 1999 accounted for 40% of the window market, or 260 million square feet per year of low-E windows sold with lifetimes averaging 30 years. On average, each square foot of low-E glass saves a little more than $0.25 in energy costs per year compared to a conventional double-glazed window baseline. Individually, this is not much, but multiplied across 260 million square feet, this gives a lifetime savings of more than $2 billion for the windows sold in 1999. Summing these savings over the period since the technology began market penetration through 2005 then generates roughly $37 billion in net economic savings using the NRC methodology with a constant technology baseline of a conventional double-glazed window; or $8 billion using the conservative "5-year" rule of the NRC methodology.[27] Details of this calculation and a discussion of the NRC methodology and results are provided in Chapter 5.

Competitive Solicitations

Approximately two-thirds of the EERE solicitations that reside in the DOE Procurement Acquisition Data System (PADS) are competitive instruments, up from the 25 percent rate in 1996, as identified by the NAPA review.[28] This improvement was driven, in part, by a Congressional review in 1996 that criticized

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[27] The NRC describes this result in footnote 8, page 37, of their report "Energy Research at DOE: Was It Worth It?" op. cit. The NRC note that EE estimated $32 billion in the electronic ballast case is in reference to EE developing cost estimates at the direction of the NRC for the constant technology baseline case versus using the 5-year rule. The methodology used throughout was that of the NRC.

[28] A review of FY2001 non-grant obligations found 63% were classified as competitive, 19% non-competitive, and 18% were not classified but could be either competitive or non-competitive. Future work should strengthen the ability to determine whether an obligation is competitive or non-competitive, as discussed in Chapter 6.

EERE's reliance on non-competitive financial assistance actions for executing so much of its work. Since that time, EERE has continued to improve its competitiveness through a policy that promotes maximum competition. During this same period, DOE re-competed most of its Management and Operating (M&O) contracts, which changed the complexion of much of the work being performed with the national laboratories. Together, these factors have substantially increased EERE's use of competitive instruments.

Cost Share

EERE estimates that its financial assistance activities leverage approximately a forty percent non-federal cost share. However, the estimated cost share value is tentative due to the SPR identification of a number of problems in the DOE-wide PADS information database. Additionally, EERE is unable to evaluate the cost share of laboratory subcontracts awarded through the national laboratories, as this information is not tracked with current DOE-wide systems. These factors significantly impact EERE's overall estimated cost share.

Cost sharing in the Department will continue to be guided by statute and Administration policy. The Energy Policy Act of 1992 requires 20 percent cost share for applied research and 50 percent cost share for demonstration projects. The cost sharing guidelines developed with the R&D investment criteria as part of the President's Management Agenda are even more explicit, as shown below, and are what the Department will strive to achieve.

TABLE ES-2: COST SHARES BY TYPE OF RESEARCH

Activity	Industry Cost Share
Basic research	0- 30%
Applied research	25- 50%
Technology Development	50- 75%
Demonstration or commercialization	60-100%

Goals, Metrics, Milestones

The 1993 Government Performance and Results Act (GPRA) mandates that each Federal agency's fiscal year budget submission to Congress include a performance plan that describes the agency's mission, goals, key upcoming performance measures, and reports on previous progress. Such efforts have increased since the NAPA review, with every program developing overall goals, metrics, and milestones for its activities—with varying degrees of success—that are tracked by program managers, office directors, Deputy Assistant Secretaries, and the Assistant Secretary.

External Peer Reviews

Numerous external peer reviews were identified and examined, including peer reviews by the National Academy of Sciences, National Academy of Public Administration, President's Committee of Advisors on Science and Technology, General Accounting Office, Congressional Office of Technology Assessment, and A.D. Little. More than 20 external peer reviews have been conducted by the National Academy of Sciences alone since 1990, 19 of them since 1995.

Terminations and Graduations

This SPR identified more than 60 research activities that have been terminated or graduated. Terminations included such technologies as automotive Stirling engines, automotive gas turbines, ocean thermal energy conversion, vertical axis wind turbines, geopressured geothermal energy, municipal energy management, and others as detailed in Chapter 4. Aggregate statistics for OIT for the period FY98 to FY00 include 298 projects, for which public-private R&D was continued on 180, was completed on 96, and was terminated on 22. Of the 96 completed research projects, 44 were continued by industry, 34 were commercialized, and 18 contributed to the industry knowledge base. Thus, for the period FY98 to FY00, 40% of the OIT research projects were graduated or terminated. In other sectors, numerous terminations were also found within specific areas of research. For example, the thin film photovoltaics research program examined and subsequently terminated R&D on more than six materials. Work has continued primarily on three materials, for which energy conversion efficiencies in the laboratory have been increased by factors of two to four in the past 20 years. Because Congressional Budget line item titles generally remain the same from year to year, the extent of program restructuring and redirection is often not recognized externally.

Equally important have been the numerous graduations of technologies that have become fully commercial and for which further technical development offers relatively less return to the public than do other opportunities. Examples include low-emissivity windows, high-efficiency furnaces, electronic ballasts, ozone-safe refrigerants, ceramics for engines, spark-ignition direct-injection engines, and many others. It is important to note, however, that in many cases there may remain significant opportunities for further technical advance in a particular area so that work should continue on the technology—research on computer chips did not end with the invention of the first integrated circuit in 1959—but the specific focus shifts over time to new generations of the technology as particular technical barriers are overcome and new opportunities arise. EERE examples include several generations of work on windows (low-E, spectrally selective, electrochromic coatings), refrigerators (compressors, motors, refrigerants, cases, controls), photovoltaics (single-crystal silicon, amorphous silicon, cadmium telluride, etc.), and wind turbines (blade design, variable speed drives, high-strength flexible materials).

PUBLIC-PRIVATE PARTNERSHIPS

To determine which programs were modeled as public-private partnerships, the review examined the breadth and depth of partnering across the EERE programs. In some cases, these partnerships are developed with individual companies; in other cases, these partnerships may take the form of multi-agency, multi-industry cooperatives. Specific quantifiable measures include technology roadmapping, contracting, and cost sharing.

Roadmapping

As noted above, the shift to technology roadmapping with industry has further strengthened partnering, with over 40 roadmaps and over two thousand participants in that activity alone in the past five years.

Contracting and Cost-Sharing

EERE engaged in approximately 2900 procurement actions in FY 2000. These actions included work with M&O contractors, private industry, nonprofit organizations, state and local governments, tribes and native corporations, universities, and small businesses. (Note that substantial subcontracting was also performed through the National Laboratories, but is not reflected in the overall level of procurement activity since the DOE-wide PADS system does not capture laboratory subcontract activities.) Although not every procurement represents a partnership, this diversity of awardees indicates the breadth of EERE interactions with the private sector; within this, EERE's programs have an extensive set of partnerships such as FreedomCAR, 21st Century Truck, the Vision Industries, Biomass, Build America, Advanced Reciprocating Engine Systems, and others. In addition, as noted above, EERE estimates that its activities leverage approximately a forty percent non-federal cost share.

ALIGNMENT

This SPR evaluated the degree of alignment between EERE's RD^3 portfolio and the President's National Energy Policy. Key issues identified by the NEP include:

- Reducing the impacts of high energy prices on families, communities, and businesses;
- Protecting the environment and public health;
- Enhancing national energy security and international relationships;
- Strengthening America's energy infrastructure;
- Using energy wisely through increasing energy conservation and efficiency; and,
- Increasing use of renewable and alternative energy.

Multiple benefits are thus provided by EERE technologies—economic; local, regional, and global environmental; national security; and more. As determined by the NRC study, the portfolio they reviewed provided net realized economic returns of 20 to 1; in addition, net realized environmental benefits ranged from an estimated 2 to 1 up to more than 10 to 1.

Economics

EERE programs contribute to reducing the impact of high energy prices on families and businesses in several ways, strengthening the U.S. economy. First, improvements in energy efficiency directly reduce expenditures on energy, which currently cost U.S. consumers about $600 billion per year. The national benefit of energy efficiency was recognized in the NEP:

> "Had energy use kept pace with economic growth, the nation would have consumed 171 quadrillion British thermal units (Btus) last year instead of 99 quadrillion Btus. About a third to a half of these savings resulted from shifts in the economy, such as the growth of the service sector. The other half to two-thirds resulted from greater energy efficiency."[29]

These energy efficiency savings (one-half to two-thirds of the 72 quads in reduced energy consumption, or 36-48 quads) are greater than the 26 quad increase in energy supply since 1972. Assuming the current average energy price of $6 billion per quad remained the same,[30] these energy savings correspond to roughly $200-300 billion per year.[31] Energy efficiency improvements are similar to economic productivity enhancements in other factors of production (e.g. capital, labor) and contribute to overall economic productivity; they should really be called "energy productivity" improvements.

By reducing energy demand, energy efficiency improvements reduce pressure on energy supplies and correspondingly reduce upward price pressures. As renewable and alternative energy resources are developed and deployed, energy supplies will be increasingly diversified, price caps will be effectively established, and there could be further downward energy price pressure.

Finally, EERE's weatherization assistance program directly assists low-income families by retrofitting their homes and reducing their energy bills. Five million low-income homes have been weatherized to

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[29] Report of the National Energy Policy Development Group, "National Energy Policy," May 2001, page 1-4.

[30] Based on consumer expenditures for energy of $567 billion in 1997, divided by consumption of 94 Quads to give $6.0 B. See tables 1.1, 3.4 of: EIA, Annual Energy Review 2000, op. cit. Greater demand will often raise prices.

[31] This does not consider changes in capital costs of more efficient equipment, but that these investments were made by the economy indicates that they were cost-effective on a life-cycle basis.

date (out of an estimated 29 million currently eligible households) with federal and leveraged funds from states and utilities, and from fuel assistance program funds. The average primary heating savings is 23% across all fuel sources. Analysis of 17 state-level evaluations found that improved practices as of 1996 produced 80% higher average energy savings per dwelling, at 31 million Btu/year, compared to measured savings in 1989 of 17 million Btu/year. The Bush Administration proposal to spend an additional $1.4 billion over ten years on weatherization should begin to help address the needs of the additional 24 million households currently eligible for assistance.

Environment

The use of energy is a primary contributor to local urban smog, regional acid rain, and anthropogenic greenhouse gas (GHG) emissions, typically accounting for 90% or more of NO_x, SO_2, and CO_2 emissions. Emissions of NO_x, SO_2, particulates, and other pollutants can significantly impact the local and regional environment and studies increasingly implicate these emissions in significant health impacts. EERE programs directly address these environmental and public health issues through efficiency improvements that offset the use of energy—largely fossil—or through the use of renewable energy technologies with near-zero emissions. Technologies under development, such as hydrogen energy, potentially offer further gains in the long term, generating little but water vapor when used.[32]

Security

U.S. national security is impacted by energy in several ways, particularly through the import of over half of the oil used in the United States and by the risk of supply disruptions in domestic energy systems such as electricity. The United States consumed about 19.5 million barrels of oil per day (MMBbl/day) in 2000, a little more than a quarter of global oil use (75 MMBbl/day in 1999). Net oil and refined product imports are projected to increase to about 16.5 MMBbl/day by 2020, out of total U.S. consumption of about 26 MMBbl/day.[33] Most of the world's remaining low-cost conventional oil supplies are located in the Middle East, typically estimated at two-thirds to three-quarters of proven reserves, raising concerns about the political volatility of the region and the extent to which the Organization of Petroleum Exporting Countries (OPEC) can control production and determine oil prices.[34] Oil price shocks in 1973-74 and 1979-1980 significantly impacted the U.S. economy, with mid-range costs estimated around $70 billion per year averaged over the period 1972-1991.[35]

EERE programs help address these security concerns by developing technologies which can reduce demand for oil through efficiency improvements in cars and trucks, by developing alternative transport fuels such as ethanol from agricultural wastes or hydrogen from a variety of energy resources, and by developing bio-based feedstocks for industrial processes. The advanced automobile and truck programs had goals of, and made considerable technical progress towards doubling and tripling fuel economy. Although fuel economy improvements can stretch domestic oil supplies and reduce pressures on global

[32] If hydrogen is produced from fossil resources such as natural gas or coal, considerable emissions can be generated that will need to be sequestered geologically to avoid release to the atmosphere. The advantage of hydrogen is that such emissions are generated at central conversion facilities and can be sequestered, with little or no further emissions at the point of end-use. This is in contrast to using petroleum-based fuels for transportation, where their use in the vehicle results in emissions to the atmosphere that cannot be sequestered.

[33] EIA, "Annual Energy Outlook 2001," DOE/EIA-0383 (2001), December 2001; and EIA, "International Energy Outlook 2000," DOE/EIA-0484 (2000), March 2000.

[34] David L. Greene, Donald W. Jones, and Paul N. Leiby, "The Outlook for U.S. Oil Dependence," Energy Policy, V.26, N.1, pp.55-69, 1998. Costs of discovering, producing, and transporting oil in the Middle East have been estimated at $1-3/Bbl; far lower than U.S. costs.

[35] There is extensive literature on this issue. For a review, see: David L. Greene, Donald W. Jones, and Paul N. Leiby, "The Outlook for U.S. Oil Dependence," Energy Policy V.26, N.1, pp55-69, 1998.

oil prices, they do not eliminate U.S. economic, political, and military vulnerability to the risk of disruption of global oil supplies.[36] Consequently, the FreedomCAR initiative, announced in January, 2002, is focused on developing fuel cell vehicles that can use domestically produced hydrogen and have the long-term potential of ending U.S. light duty vehicle use of oil.

EERE technologies respond to the risk of domestic energy supply disruptions: by developing buildings that can stay comfortable for extended periods through winter storms or summer heat waves despite gas or power disruptions; by developing distributed power systems that can potentially[37] supply electricity even when utility supplies are down; and, by diversifying energy supplies to reduce risk.

Infrastructure

Infrastructure within the United States is supported by EERE through the development of: distributed energy resources to enable power and thermal production at an individual building; high temperature superconductors to improve power transmission and distribution (T&D)—particularly in underground urban systems; other T&D system technologies; interconnect standards and protocols; diagnostic tools; and many others. Distributed generation and storage, in particular, provide customers with the choice of controlling to a greater degree their own power costs, reliability, and power quality, and are important to delivering the ultra-high power quality required by sensitive communication, computing and control loads in the digital economy. Renewable and alternative energy supplies, such as biomass, offer new and diversified infrastructure paths. Energy efficient technologies can also reduce the pressure on infrastructure. Building and equipment energy efficiency improvements, for example, can reduce summer peak loads on T&D lines, as can intelligent power control systems. EERE programs are thus assisting the transition of the electric power delivery infrastructure from the central station system of the 20th century to an intelligent network allowing broad commerce in electric energy produced by sources ranging from large centrally-located generators to small distributed systems.

MARKET CHALLENGES

In considering the economic, environmental, and security benefits to be derived from energy efficiency and renewable energy technologies, it is important to recognize that they face significant challenges in their development, demonstration, and deployment, including market failures and market friction. Key examples of what economists have identified as market failures include the following and are discussed in detail in Chapters 2 and 3 of the report: (1) that companies cannot capture all the benefits of their R&D (incomplete appropriability); (2) that many of the benefits of R&D are public goods (e.g., benefiting national security) or reduce externalities (e.g., environmental damages) which may not be included in the price of the energy service, reducing or eliminating any incentive for the private sector to invest in them; (3) that regulations may interfere with advanced energy technology development or deployment; (4) that information available to consumers may be incomplete or inaccurate; and, (5) that the purchaser of energy-using equipment may not be the purchaser of the energy to power it—for example, the building owner and renter—reducing the incentive of both to invest in efficiency.

Examples of market friction include: (1) the high first cost of energy efficient or renewable energy technologies, which may deter potential users even if their lower fuel use results in comparable or lower lifecycle costs; (2) high transaction costs associated with purchasing and installing small household or

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[36] Vulnerability to global oil supply disruptions will remain for as long as the United States and its allies use large quantities of oil. Oil is a fungible commodity in a global market; an oil price spike therefore impacts all oil prices, wherever the oil is produced. Lower oil imports, however, will reduce wealth transfer offshore, among other benefits.

[37] There remain issues of synchronization of the AC power with the grid when interconnection is re-established.

business high efficiency or renewable systems; (3) the chicken-and-egg problem of developing new infrastructure for new technologies and fuels; and, (4) the chicken-and-egg problem of developing sufficiently large markets for new technologies that their market price can eventually be driven down to competitive levels.

These factors require unique considerations in program design and strategy. The SPR found that EERE programs had developed a number of strategies to address these market challenges and that these strategies had been substantially improved over time as understanding of these technologies and markets has grown. These strategies are reflected above in such factors as: the shift from technology push to market pull; the development of technology roadmapping; the use of competitive solicitations and cost sharing; and many others, as detailed in Chapters 3 and 4 of the main report.

THE LONG-TERM CHALLENGE

Time horizons for all these activities are long. The time to build political consensus to act; conduct the technology research, development, and demonstration; penetrate the market; and turn over the existing capital stock to significantly impact energy and oil use or criteria pollutants/GHG emissions is typically measured in decades, as indicated in Table ES-3. Conversely, to substantially impact a particular sector by some future period, the time when R&D needs to be aggressively pursued can be roughly determined by working back from that date using the crude time estimates in the table. Rough estimates such as these indicate that to significantly change the U.S. energy trajectory and its economic, environmental, and national security impacts in the 2030-2050 time frame requires aggressive energy R&D in the near-term.

TABLE ES-3: TYPICAL TIMES FOR RD^3 AND CAPITAL STOCK TURNOVER

Activity	Typical Times Required
Political development	1-10+ years
Research, Development, Demonstration	5-25+
Market Penetration	10-25+
Capital Stock Turnover	
• Cars	• 15
• Appliances	• 15-20
• Power Plant Equipment	• 30-40+
• Commercial Buildings	• 40-60
• Residential Buildings	• 60-80
• Industrial Facilities	• 40-80
• Industrial Facility Equipment	• 10-30+
• Urban Form	• 100s

Notes: Market penetration refers to the length of time required for the technology to become a large fraction (e.g. a third to a half) of the total market. *Capital stock turnover* refers to the typical lifetime of existing capital equipment before it would normally be replaced, potentially with a more efficient or cleaner technology. Note that buildings, industrial facilities, and power plants may be renovated several times over their lifetime, providing significant opportunities for improving their efficiency and to employ renewable energy technologies.

Chapter 1

Introduction

Over the past quarter century, the Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE) and its predecessor organizations have supported extensive research, development, demonstration, and deployment activities on energy efficiency, renewable energy, alternative fuels, distributed energy, and energy management technologies. Recognizing both the magnitude of national energy-linked economic, environmental, and security challenges and the potential of energy efficiency and renewable energy technologies to help meet those challenges, the President released the *National Energy Policy* (NEP) on May 16, 2001(see Box 1-1), which directed the Secretary of Energy to:

- review current funding and the historic performance of energy efficiency, renewable energy, and alternative energy research and development (R&D) programs in light of the NEP's recommendations; and,

- propose appropriate funding for R&D programs that are performance-based and modeled as public-private partnerships (NEP, pp. 4-11, 6-17, see the full list of NEP recommendations in NEP Appendix B, Table B-1).

This Strategic Program Review (SPR) is EERE's response. It examines how well EERE's current R&D programs have performed historically, responded to the changing demands of the U.S. economy, and interacted with the private sector.

EERE's research, development, demonstration, and deployment (RD^3) portfolio addresses advanced energy efficiency and renewable energy technologies[1] as they apply to the buildings, transportation, industry, power generation, and government sectors. EERE's:

- ***Advanced energy-efficiency technologies*** reduce the energy needed to provide energy services, thereby reducing environmental and national security costs of using energy and potentially increasing its reliability. Efficiency improvements are possible throughout energy markets, from the wellhead or mine-mouth to the power plant or refinery, and to the home, factory, or vehicle. These productivity improvements in the use of our energy resources are similar to productivity gains in other factors of production such as labor and capital, and increase economic prosperity. Further, energy savings from efficiency improvements cannot be used up and do not reduce the savings available in the future.

- ***Advanced renewable-energy technologies*** allow the nation to increase domestic energy production and reduce reliance on imported energy sources. Renewable resources can dampen the impacts of energy price swings of conventional fossil fuels, diversify available energy sources, and reduce the risk of future energy shortages. Most renewable resources have

[1] EERE also addresses "alternative energy" technologies, which use traditional energy sources/fuels in alternative applications that are more efficient and/or environmentally sound (e.g., distributed energy resources, combined heat and power, natural gas).

substantially lower environmental impacts than conventional energy systems, and often have no associated emissions. Distributed energy technologies, located near the end-user, reduce the need for new, expensive and potentially more vulnerable infrastructure to deliver power from distant large-scale power plants.

The EERE RD^3 portfolio should help meet the challenges of our dynamic economy, helping develop technologies that can provide cost-effective, clean, and reliable energy services when and where they are needed. The public RD^3 portfolio should leverage private sector investments where possible and appropriate. In addition, this portfolio should help prepare the nation for a variety of possible future energy-related challenges, including reducing the risk of and vulnerability to possible energy supply disruptions.

This review provides the basis for helping ensure that EERE's portfolio is aligned with the goals of the NEP and has been executed as efficiently and effectively as possible. The findings of this SPR will help EERE reorient its RD^3 priorities based on performance, market conditions, and policy concerns. It will also assist the President and Secretary of Energy in making funding decisions regarding EERE's RD^3 programs.

Box 1-1: Recommendations of the National Energy Policy Development Group

"The NEPD Group recommends that the President direct the Secretary of Energy to conduct a review of current funding and historic performance of energy efficiency research and development programs in light of the recommendations of this report. Based on this review, the Secretary of Energy is then directed to propose appropriate funding of those research and development programs that are performance-based and are modeled as public-private partnerships." National Energy Policy, May 2001, page 4-3.

"The NEPD Group recommends that the President direct the Secretary of Energy to conduct a review of current funding and historic performance of the renewable energy and alternative energy research and development programs in light of the recommendations of this report. Based on this review, the Secretary of Energy is then directed to propose appropriate funding of those research and development programs that are performance-based and are modeled as public-private partnerships." National Energy Policy, May 2001, page 6-4.

EERE ORGANIZATION

In 1990, EERE adopted a sector-based organizational structure in order to improve its ability to align its projects with the varying needs and opportunities of the key market segments. The five EERE sectors are:

- Buildings (Office of Building Technology, State and Community Programs, BTS);
- Industry (Office of Industrial Technologies, OIT);
- Transportation (Office of Transportation Technologies, OTT);
- Power (Office of Power Technologies, OPT); and,
- Government (Federal Energy Management Program, FEMP).

The first four are headed by Deputy Assistant Secretaries (DASs) while a Director heads the latter.

In 1999, EERE reorganized to include an office of Planning, Budget, and Management (PBM), which helps to strategically integrate EERE functions to ensure coordinated progress toward the organization's mission and goals.

Each of the five sectors is responsible for managing a number of programs (31 in total currently, see Appendix B, Figure B-1 at the end of this report), each of which encompasses a portfolio of projects. In addition, most sectors also closely coordinate related crosscutting work. Further, subprograms often help define types of activities and areas of research within individual programs.

"If we knew what it was we were doing, it would not be called research, would it?"
-- *Albert Einstein*

THE STRATEGIC PROGRAM REVIEW – THE PROCESS

Carrying out the direction of the Secretary of Energy, in June 2001 the Assistant Secretary initiated this SPR that has both public comment and internal review components.

PUBLIC COMMENTS

A public comment period, including seven public meetings, was coordinated by EERE's Outreach office. As a part of the public comment process, the EERE Regional Offices hosted a series of EERE town meetings in Boston, Denver, Seattle, Philadelphia, Atlanta, Chicago, and Washington, D.C. These meetings, along with e-mail and postal mail responses, accounted for 4,279 public comments, of which more than 99 percent expressed strong support for EERE's programs. The public comment period closed on June 29, 2001.[2] EERE completed a report summarizing these comments on August 31, 2001, which is attached at the back of this report as Appendix A.

INTERNAL REVIEW

Under the direction of the Assistant Secretary, a Review Team made up of senior staff from the Office of the Assistant Secretary and PBM was established, which worked with EERE's DASs, office directors, program managers, and staff. This team coordinated the internal review. Four programmatic elements were selected for the internal review, the results of which comprise several chapters of this report:

- alignment with energy policy and markets (chapter 3);
- technical performance (chapter 4);
- resulting benefits (chapter 5); and,
- business performance (chapter 6).

Each of these areas of review has both corporate and programmatic aspects, though some choices are inherently more closely related to one organizational level than another. Alignment with national energy policy and markets largely occurs at the corporate and sector levels, while technical and business performance assessment largely occurs at the program level. Program benefits are usually measured at the program level; however, EERE's analysis also examines benefits at an integrated sector and corporate

[2] These results are generally in-line with statistically-rigorous public opinion polls. Specific examples of recent public opinion polls can be found at: http://www.publicagenda.org/issues/pcc.cfm?issue_type=environment and a review of more than 700 polls from 1973-1996 is at http://www.crest.org/repp_pubs/articles/issuebr3/issuebr3.html A published review of this issue is in: "Barbara C. Farhar, "Trends in US Public Perceptions and Preferences on Energy and Environmental Policy", *Annual Review of Energy and the Environment*, eds. Robert H. Socolow, Dennis Anderson, and John Harte, Vol. 19, pp.211-239, 1994.

level. The various chapters of this Strategic Program Review assess EERE at these different organizational levels.

Data and Information. The examination of the programs included reviews of information and data on such issues as:

- current legislative and regulatory requirements;
- existing external and peer reviews;
- specific barriers to developing EERE technologies;
- strategies used to address these barriers;
- descriptions of how such strategies have evolved over time;
- program activities and technical results—including successes and failures; and
- program benefits—including impacts on energy supply and use, economic costs and benefits, reductions in environmental emissions, and security benefits such as reducing oil use. .

Consideration of Peer Reviews. A number of peer reviews of EERE's activities have been conducted over the last several years, providing additional perspectives on the performance of EERE's programs. In reviewing its programs, EERE examined existing reports from such peer organizations as the National Academy of Sciences/National Research Council, the President's Committee of Advisors on Science and Technology, and the Secretary of Energy's Advisory Board. Many individual research programs also conduct external peer reviews and summary reports from these reviews were also used.

Interviews and Summary Presentations. EERE used the responses from the sectors in conjunction with the public input, the external reviews, and other information to evaluate the past and present program strategies and performance. The Review Team interviewed program personnel in order to clarify market factors, past strategies, and program performance, as well as to fill in gaps in historical program summaries.

Following the interview phase by the Review Team, the DASs for each end-use sector (buildings, industry, transportation, power, and federal) and their program personnel presented and explained a summary of their program performance information to the Assistant Secretary for Energy Efficiency and Renewable Energy, the Principal Deputy Assistant Secretary for Energy Efficiency and Renewable Energy, and the Deputy Assistant Secretary for Planning, Budget and Management.

THE STRATEGIC PROGRAM REVIEW – THE RESULTS

The following chapters summarize the results of this review, first presenting the energy context for the review; the alignment of EERE activities with national goals; the historic technical performance of EERE programs and performance-based management of EERE programs; the benefits derived from EERE programs; the business performance of EERE programs including public-private partnerships; and, finally, findings and recommendations regarding those programs and projects that should be terminated, redirected, placed on a "watch" list, or expanded, as well as some of the "best practices" that should be further developed and widely adopted to improve program performance.

Chapter 2

Energy Market Context

Energy resources are not used for their own sake, but for the services they provide. These energy services are fundamental to our modern economy; they heat, cool, and light our buildings; power our industrial processes; process our food; fuel our transport; and energize our communications and information technologies.

Fueling these services entails significant costs. Economically, U.S. consumers spent roughly $570 billion in 1997 on energy.[1] When our energy infrastructure is strained, energy costs can spike, and the reliability and security of energy delivery can be jeopardized, generating additional economic costs. Environmentally, the use of energy is a primary contributor to local urban smog, regional acid rain, and global greenhouse gas emissions. Finally, with the United States importing over half of its oil, energy use incurs national security costs as well.

The *National Energy Policy* (NEP), released in May 2001, broadly describes U.S. energy markets and the key policy issues they generate.[2] This chapter briefly describes the role of energy markets in the economy and focuses on those trends and market conditions that can inhibit the development and adoption of energy productivity improvements and renewable energy resources in energy markets. The interested reader who wishes a more complete discussion of energy use in the economy is referred to the Energy Information Administration's (EIA) *Annual Energy Outlook.*

HOW WE USE ENERGY

In broad terms, coal, oil, natural gas, biomass, hydropower, uranium, wind, and other energy resources are extracted, refined or converted into "energy carriers" such as gasoline, electricity, natural gas, etc., and then consumed by the end-user to provide energy services such as building heating and cooling, industrial motor drive, and passenger transport. About 36 percent of the energy consumed in the United States is used to heat, cool, and light buildings and power the equipment and appliances in those buildings. Similarly, 38 percent of U.S. energy consumption is used to operate factories, farms, mines, and other industrial activities. The remaining 26 percent is used to transport people and goods in cars, trucks, planes, trains, and boats.[3]

The power sector consumes about 39 percent of total primary energy as it generates electricity.[4] The remaining 61 percent of primary energy is refined into gasoline, diesel or other petroleum fuels, cleaned for transmission and use as natural gas, and burned in vehicles, boilers, furnaces, water heaters, and other combustion equipment.[5]

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[1] Annual Energy Review 2000 ("AER 2000"), Energy Information Agency (EIA), Table 1.5.
[2] "National Energy Policy," Report of the National Energy Policy Development Group, (Washington, DC: U.S. Government Printing Office, May 2001).
[3] AER 2000, Table 2.1a.
[4] *Ibid*. Unless otherwise noted, all energy figures are in terms of primary energy. "Primary energy consumption is the amount of site energy consumption, plus losses that occur in the generation, transmission, and distribution of energy." From EIA's Energy Efficiency Glossary, available at http://www.eia.doe.gov/.
[5] AER 2000, Table 2.1a.

The three end-use sectors use energy in very distinct ways, and present unique obstacles and opportunities for improving the nation's energy outlook. For example, while the transportation sector is almost entirely dependent on oil, the buildings sector accounts for about two-thirds of all U.S. electricity consumption.[6] In contrast, the industrial sector uses a broad range of energy strategies and exhibits flexibility in responding to changes in energy markets.

BUILDINGS

Energy is used in buildings in two basic ways. About 50 percent is used to heat and cool buildings and to provide hot water. The remaining 50 percent is used to light the building and power its many appliances and pieces of equipment, such as refrigerators, commercial freezers, televisions, washing machines, and stoves (see Figure 2-2).[7] Although a small fraction of the total, "plug loads" such as televisions, coffeemakers, and computers, are the fastest-growing components of building energy use.

About 55 percent of building energy is used in homes, with the remainder consumed in commercial buildings, such as offices, schools, and hospitals.[8] Homes and businesses spent $234 billion in 1999 for energy use, with the average household spending approximately $1,300.[9]

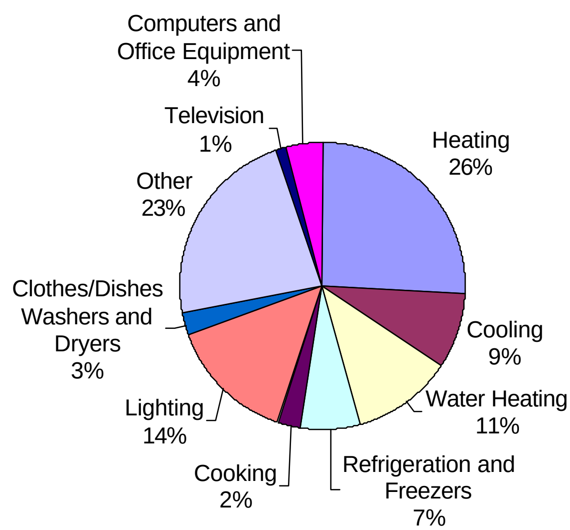

Figure 2-1: Energy consumption in residential and commercial buildings by end-use. Source: EIA, "Annual Energy Outlook, 2001", DOE/EIA-0383(2001) December 2001.

Providing these building energy services requires about two-thirds of the electricity and on-site consumption of one-third of the natural gas and one-twentieth of the oil used in the United States.[10] Building energy use accounts for one-fifth of NO_x, nearly half of SO_2, and about one-third of CO_2 emissions in the United States.[11]

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[6] 2001 BTS Core Databook, EERE, July 2001, Buildings Data Summary Sheet, p. 1.
[7] 2001 BTS Core Databook, EERE, July 2001, Buildings Data Summary Sheet, Table 1.7.
[8] AER 2000, Table 2.1a.
[9] 2001 BTS Core Databook, Tables 4.1.2, 4.2.2.
[10] 2001 BTS Core Databook, Table 1.2.
[11] 2001 BTS Core Databook, Tables 3.1.1; 3.3.1.

Buildings contribute disproportionately to the need for energy infrastructure because their demand for energy varies significantly by season and time of day. Natural gas and home heating oil are primarily used during the winter heating season, while electricity use peaks during the hottest and coldest months as it is used to provide air conditioning and space heating. Electricity use is also highest in the mid-afternoon and early evening, when equipment, appliances, and lighting in both homes and offices are used most extensively.

INDUSTRY

The industrial sector is the most diverse sector in terms of both the types of energy services required and the mix of energy sources used to provide those services. Several crosscutting types of energy services are particularly important in this sector:[12]

- motor drive equipment, which accounts for 64 percent of industrial electricity use;
- steam systems, both to heat products and to drive mechanical processes; and
- compressed air equipment.

Beyond these areas of similarity, however, industry energy use tends to be specific to the industrial process at hand. Whereas the chemical industry may use electricity primarily for processing materials, the aluminum industry uses it primarily for smelting.

Industrial energy use is heavily concentrated in a small number of "heavy" industries, which generally produce commodity materials that require substantial energy to move, process, and shape. As shown in Figure 2-2, nine industries account for three-fourths of total industrial energy use.

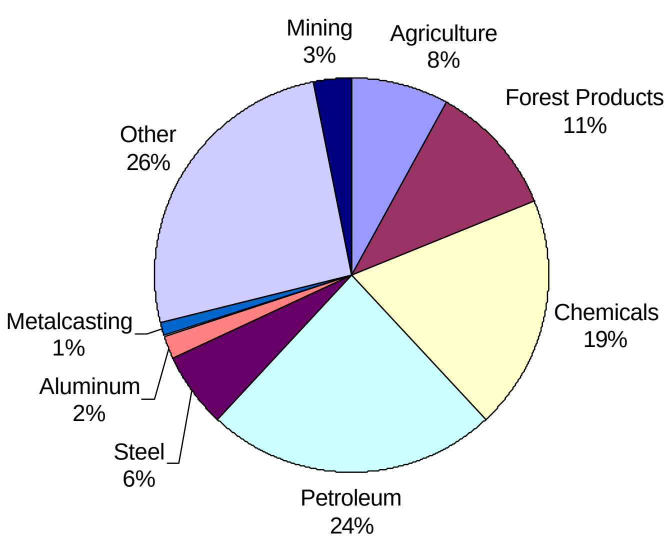

Figure 2-2: US energy consumption by industrial sector, 1998. Source: Manufacturing Energy Consumption Survey.

In the aggregate, the industrial sector also has the most diversified energy mix. About 37 percent of the sector's primary energy use is in the form of electricity, 28 percent natural gas, 24 percent oil products, 6 percent coal, and 5 percent biomass and other energy sources.

[12] OIT: *Profiles in Partnerships*, Jan. 2001, p. 116-117.

TRANSPORTATION

The transportation sector exhibits the least variation in energy sources and uses. The most striking feature about the sector is its nearly complete dependence on petroleum as its energy source; nationally, light-duty cars and trucks consume more oil than is produced in the United States. The transportation sector also uses comparatively small amounts of bioenergy, natural gas, and electricity.

Just over three-quarters of this energy is used on the nation's roadways by cars and trucks (see Figure 2-3). The 57 percent of transportation energy used by "light-duty vehicles" includes both cars and light trucks (generally sport utility vehicles or SUVs, minivans, and pickup trucks), with the latter now accounting for 47 percent of new vehicle sales.[13] This shift toward larger vehicles, along with growth in vehicle miles traveled, makes light-duty vehicles the largest component of transportation oil consumption. Alternative, non-oil transportation energy sources are increasingly used in urban areas, where vehicle fleets and population density provide some of the economies of scale needed to support an alternative energy infrastructure (e.g., natural gas fueling stations), and where transit systems are often electricity-based. Perhaps more important, the presence of non-attainment areas under the Clean Air Act Amendments (CAAA) has increased demand for vehicles with lower emissions of criteria (CAAA-regulated) pollutants and has increased interest in mass transit. Natural gas, hybrid electric, and even demonstration fuel cell buses are now running in many of these areas. Furthermore, non-oil fuels (e.g., MTBE, ethanol) are also used in blends for vehicle fuels.

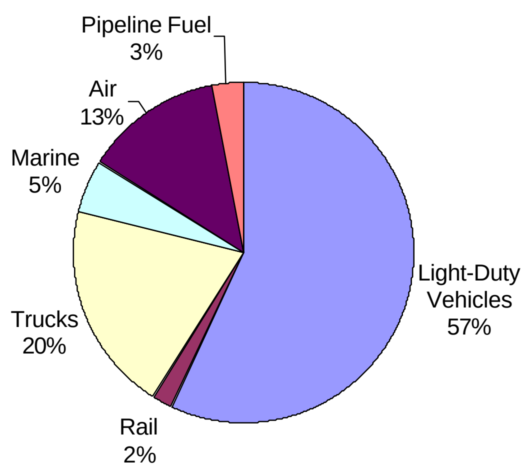

Figure 2-3: U.S. energy consumption in the transport sector by transport mode, 1999. Source: DOE/EIA, AEO 2001

[13] Transportation Energy Data Book, Ed. 21, ("TEDB") Office of Transportation Technology, 2001, Table 6.4.

POWER

Electricity's current 39 percent share of the U.S. energy picture is up sharply from its 24 percent share in 1970.[14] This electrification of the economy reflects both new manufacturing processes and new and growing energy services in buildings, such as office equipment. Nearly all of this electricity is produced at central power stations and delivered through a network of transmission and distribution lines. Although the electricity sector's importance to the economy has grown, its efficiency or productivity has seen little overall improvement; although that is changing as natural-gas-fired combined-cycle gas turbines penetrate the market. Currently in the United States, about two-thirds of the primary energy is lost in the process of generating the electricity (mostly as waste heat), with an additional 7 percent of gross generation (3 percent of primary energy) lost in transmitting it to consumers because of inefficiencies of the electric grid.[15]

Fossil fuels continue to dominate U.S. electricity production, accounting for about 71 percent of electricity produced.[16] Most new power plants, however, are natural gas-fired combined cycle turbines operating with thermal efficiencies of roughly 50-55% or more, compared to the typical 33% for a coal-fired power plant. These natural gas-fired combined cycle plants are typically about half the capacity in MW of the coal and nuclear plants built in the 1980s and can be put into place in two years, compared to five years for a coal plant and longer for a nuclear plant. Although no new nuclear power plants have been ordered since 1973, the plants currently on line are being operated more efficiently, and are thus producing more power. For example, nuclear power plant capacity factors have been raised from 78% in 1998 to 88% in 2000.[17]

Bioenergy—in pulp and paper plants, domestic woodburning, and waste to energy—comprises a large component of the U.S. renewable energy market, accounting for 50 percent of all renewables and 88 percent of non-hydropower renewables.[18] Hydropower is the second-largest contributor to renewable energy, comprising 44 percent of U.S. renewable energy production.[19] Wind power is one of the fastest-growing energy sources in the world, with rapid growth across both Europe and the United States. Other areas of renewable production include solar and geothermal power.

KEY ENERGY MARKET TRENDS

While U.S. energy markets have improved in a number of important ways since the 1970s, they also face several new (and, in some cases, revisited) challenges as we head into the first decades of the 21st century.

LARGE EFFICIENCY GAINS

Because energy services are fundamental to the economy, economic growth is associated with growth in energy use. From 1972 to 2000, however, U.S. energy use grew only one-fifth as fast as the economy.[20] As a result, the energy needed per dollar of GDP produced (referred to as "energy intensity") fell by about

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[14] AER 2000, Table 2.1a.
[15] *Ibid*, Diagram 5.
[16] *Ibid*, Table 8.2.
[17] *Ibid*, Table 9.2.
[18] *Ibid*.
[19] *Ibid*.
[20] AER 2000, Table 1.5.

40 percent during the same period.[21] The national benefit of energy efficiency was recognized in the NEP:

> "Although our economy has grown by 126 percent since 1973, our energy use has increased by only 30 percent. Had energy use kept pace with economic growth, the nation would have consumed 171 quadrillion British thermal units (Btus) last year instead of 99 quadrillion Btus. About a third to a half of these savings resulted from shifts in the economy, such as the growth of the service sector. The other half to two-thirds resulted from greater energy efficiency."[22]

These energy efficiency improvements decrease the amount of energy needed to operate factories, schools, homes, vehicles, and equipment.[23] In 2000, these savings (one-half to two-thirds of the 72 quads in reduced energy consumption, or 36-48 quads) were greater than the 26 quad increase in energy supply since 1972, and greater than the 22.6 quads of coal, 22.2 quads of natural gas, or 12.4 quads of oil produced in the United States in 2000.[24] Assuming the current average energy price of $6 billion per quad[25] remained the same, these savings of 36-48 quads correspond to roughly $200-300 billion[26] in direct reductions in energy bills in 2000; lower demand would likely have also reduced energy prices. Energy efficiency improvements are similar to economic productivity enhancements in other factors of production (e.g. capital, labor) and contribute to overall economic productivity; they should really be called "energy productivity" improvements.

GROWING DOMESTIC DEMAND, STAGNANT PRODUCTION

These strong efficiency gains, however, have not fully kept pace with the growth in the U.S. economy and population, and the resulting growth in demand for energy services. Between 1972 and 2000, domestic energy consumption grew by 35 percent, to 99 quads.[27] In EIA's "business as usual" case, demand is expected to continue to increase by 1.3 percent annually through 2020, with U.S. consumption in that year projected at more than 127 quads.[28] In EIA's "high economic growth" scenario, consumption in 2020 jumps to 136 quads.[29] These projections include 1.6 percent and 1.8 percent annual improvement in energy efficiency, respectively.

In contrast to the 35% growth in consumption since 1972, total U.S. energy production has grown by only 12% since 1980, although the primary energy sources have shifted somewhat. Although efficiency gains and shifts in the makeup of the economy have narrowed the production/consumption gap significantly, there is a substantial remaining shortfall between domestic energy supply and domestic energy consumption.

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[21] Monthly Energy Review ("MER"), EIA, August 2001, Table 1.4; Bureau of Economic Analysis, Current Dollar and "Real" Gross Domestic Product chart.
[22] Report of the National Energy Policy Development Group, "National Energy Policy," May 2001, page 1-4.
[23] Technically, energy efficiency improvements are reductions in the energy input to the production of energy services, holding constant the quantity and quality of the energy services produced and consumed. Unlike the broader term "energy conservation," the concept of energy efficiency does not entail any reduction in the level of energy services consumed, i.e., consumers do not change their behavior in such a way that they "do without" the heating, lighting, and other energy services they would otherwise consume.
[24] MER, Table 1.3.
[25] Based on consumer expenditures for energy at $567 billion in 1997 divided by consumption of 94.3 Quads to give $6.01B. See tables 1.1, 3.4 of: EIA, Annual Energy Review 2000, op. cit.
[26] This does not consider changes in capital costs of more efficient equipment, but that these investments were made by the economy indicates that they were cost-effective on a life-cycle basis.
[27] AER 2000, table 1.1, page 5.
[28] Annual Energy Outlook 2001, EIA, Table A2.
[29] Annual Energy Outlook 2001, EIA, Table B2.

INCREASING OIL DEPENDENCE

U.S. oil dependence is influenced by three factors: the amount of oil used per dollar of GDP produced (which is falling), the portion of this oil that is imported (which is rising), and the relative concentration of oil use within the economy (which is primarily an issue in the transportation sector as seen in Figure 2-4). U.S. dependence on imported oil as a share of total oil use is growing and is expected to continue to grow over the next 20 years.

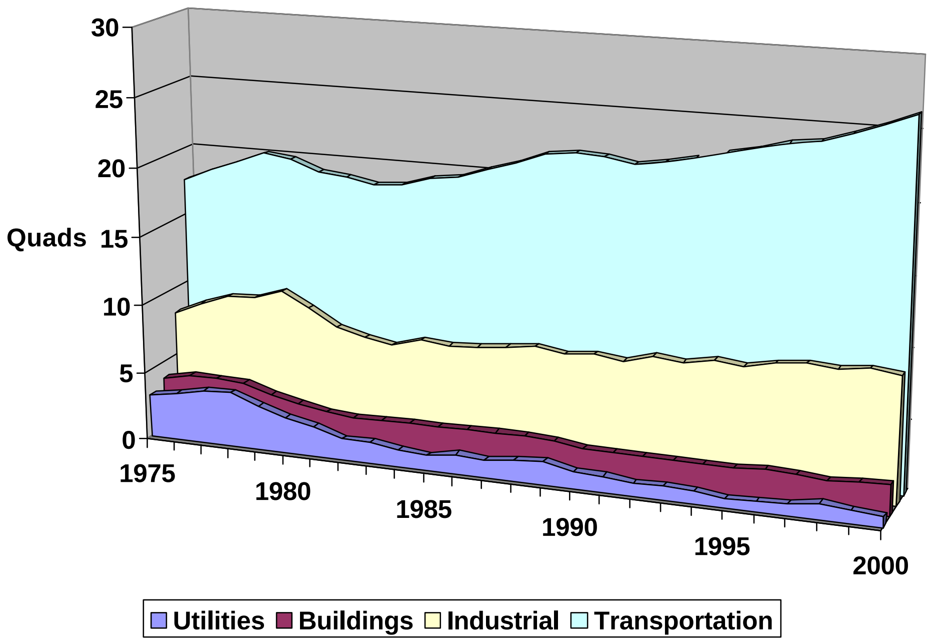

Figure 2-4: U.S. petroleum consumption by sector. Source: D. Gately & D. Greene, 2001

NEW ELECTRICITY RELIABILITY CONCERNS

Recent, highly publicized electricity shortages in California have brought electricity reliability into the national spotlight. Outages in New York City, Chicago, and elsewhere in recent years, often triggered by insufficient distribution and transmission capacity, are an indication of more generalized electricity reliability needs.

Generating Capacity

As demand for electricity grows, so does the need for new electricity generating capacity, or an equivalent reduction in overall loads and particularly peak loads. If new generating capacity is built in the traditional, centralized fashion, it will require new transmission and distribution capacity, as well. A report recently released by a leading Wall Street investment firm concluded that a large electricity capacity shortfall is on the horizon.[30] Although plant developers have announced a boom in electricity-generating plant construction, only a quarter of the announced additions are under construction, and only a little over half of the announced additions will actually be completed, according to the report.[31] Whether such shortfalls

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[30] "Wall Street Analysis Finds Nation Faces Big Electricity Shortage", The Energy Daily, Vol. 29, No. 176, Sept. 12, 2001, p. 1, citing CreditSuisse/First Boston report of Sept. 2001.
[31] *Ibid.*

will actually materialize is subject to considerable debate, given uncertain growth of the economy, the potential savings from more aggressive efficiency efforts—such as in California, and the relatively rapid development of new capacity that is possible with natural gas combined cycle systems.

Infrastructure

The nation's electricity transmission and distribution system has shown its age and limitations in the face of new challenges posed by increasingly competitive electricity markets, particularly at the wholesale level (see Figure 2-5). The electricity infrastructure is being stressed, in part, by growth in peak demand, largely attributable to the buildings sector. In addition, our nation's infrastructure, originally built to handle a limited number of bulk power transactions managed through vertically integrated utility companies, is today handling dramatically increasing volumes of electric power transactions involving myriad new market entrants, including independent power producers, electricity marketers and brokers, and an emerging class of distributed energy generators and combined heat and power producers.

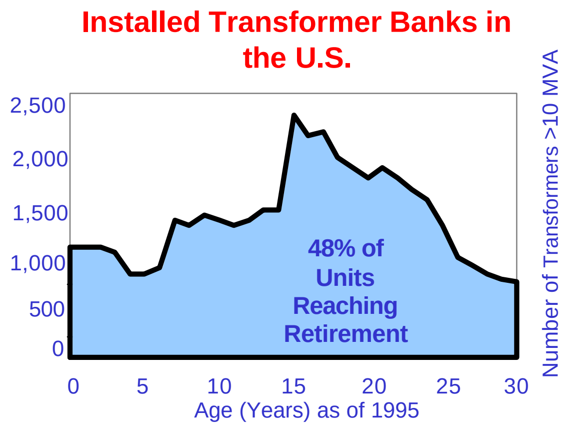

Figure 2-5. Age of U.S. electric power transformer infrastructure. Source: Waukesha Elec. Systems, 1997

Power Quality

The expanded use of information technologies and advanced telecommunications systems has resulted in productivity gains in the economy and has raised the required level of power quality and reliability needed by U.S. businesses. For example, sensitive electronic systems for automated manufacturing often have lower tolerances for voltage spikes and sags than traditional electromechanical equipment. Businesses lose labor hours and product each time production runs are disrupted, cumulatively costing the economy billions of dollars.

INCREASINGLY COMPLEX NATURAL GAS MARKETS

Over the last ten years, natural gas emerged as the primary fossil energy source of choice for new electricity generation plants, primarily because of its ability to meet environmental restraints, such as those required by the Clean Air Act. Newer natural gas technologies, including advanced natural gas turbines, combined heat-and-power systems, and combined-cycle natural gas (CCNG) plants, allow more efficient production of electricity. Natural gas consumption is increasingly year-round; natural gas is used to produce electricity in the summer and for heating purposes in the winter. However, high summer use can also discourage storage for winter needs. During the winter of 2000–2001, natural gas prices soared in some areas to previously unseen levels, jumping to $10/thousand cubic feet, compared to $2 to $3 per thousand cubic feet typical of the last decade, in part due to inadequate storage, transmission constraints, intermittent drilling activity in the past, and peaks in demand.

Natural gas markets are further complicated by their interactions with oil markets. Gas and oil can serve as substitutes in some markets, especially in portions of the industrial and power sectors, and gas prices generally move up and down with oil prices. Further use of natural gas for vehicles or stationary sources (buildings, factories) could tie oil and gas prices more closely (because of increased fuel substitutability) and create additional sources of seasonal variation in demand.

GROWING GLOBAL ENERGY DEMAND

Global energy consumption is projected to reach 607 quads per year in 2020, compared to 382 quads in 1999—a 59 percent increase.[32] Most of this growth in demand (75–90 percent) is expected to occur in developing countries.[33] The regions of developing Asia and Central and South America are expected to sustain energy demand growth of about 4 percent annually, accounting for more than half of the total projected increase in world energy consumption.[34] By 2020, energy consumption by developing nations is projected to roughly equal the projected consumption for the industrialized world.[35]

International Oil Markets

Because oil is a globally traded commodity, increases in demand anywhere in the world place upward pressure on the price of oil in the United States. Based on expected growth in population and income, Greene and Gatley (2001) estimate that the number of motor vehicles worldwide will rise from 673 million in 1997 to 1,667 million in 2030. Global demand for oil is expected to grow by 2.3 percent per year from 1999 to 2020, well above the 1.5 percent growth rate expected in the United States.[36] The result would be a 60 percent increase in oil demand, from 75 million barrels per day (mbd) to 120 mbd.[37]

International Electricity Markets

One-third of the world's population does not currently have access to electricity. As countries develop their electricity systems, the electricity choices they make will affect global capital markets and local and global environments, and may affect international fuels markets, as well. Where electricity transmission grids are weak or nonexistent, distributed electricity sources such as photovoltaic systems or small wind turbines, biomass power systems, and other renewable systems, may have a distinct cost advantage in bringing electricity to end users by avoiding the cost of long-distance transmission and distribution systems for relatively small amounts of power. Therefore, these factors have led many to believe that some of the most advanced U.S. energy technologies may find their first strong commercial markets abroad.

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32 International Energy Outlook 2001 ("IEO 2001"), EIA, Highlights, p. 1.
33 Citations are found in Clean Energy Futures.
34 *Ibid*.
35 IEO 2001, Highlights, p. 1.
36 IEO 2001; AEO 2001, Table A2.
37 IEO 2001, Highlights, p. 3.

ENERGY MARKET CHALLENGES

Economists and market analysts have long recognized that well-functioning competitive markets will maximize the goods and services a society can produce (technical efficiency) and allow consumers to trade their goods and services in ways that maximize the overall social welfare (allocative efficiency). However, markets that are not well functioning or competitive will result in the loss of output and welfare.[38] Within this framework, energy markets face a variety of challenges.

Of particular concern are large "market failures"[39] that can significantly distort market choices. Economists have identified three types of significant market failures that are frequently found in energy markets[40]:

- externalities and public goods—that is, benefits received or costs incurred that are not the result of voluntary transactions;[41]
- costly, imperfect, and asymmetric information; and,
- market power, in which economies of scale or other market features lead to some markets in which producers or consumers are not price takers (e.g., monopolists, cartels).

This section explores significant areas of market failure in energy markets, the specific subsectors that are most affected by the failure, and the impact of the failure on the levels of renewable energy, alternative fuels, and energy efficiency selected by the markets. First, because of their effect on EERE programs, four key types of externalities or public goods particularly relevant to energy markets are explored: national security costs, environmental costs, R&D benefits, and network externalities. These failures result in market prices that do not reflect the full costs and benefits of market energy choices. Second, information failures are explored as they relate to difficulties in realizing technical or allocative efficiency in these markets, again with a focus on the specific subsectors where the problems appear to be most acute. In addition, market power failures are those that occur, for example, due to the existence of a cartel like OPEC.

NATIONAL SECURITY EXTERNALITIES AND PUBLIC BENEFITS

Oil markets are a prime national security concern because, under relatively tight market conditions, the physical concentration of oil reserves in a relatively small number of countries generates the potential for physical and price-setting supply disruptions and imposition of extensive costs to the U.S. economy. These market conditions impose national security costs by reducing foreign policy flexibility and complicating military strategy, especially during periods of rising oil demand and tightening world markets. As examples, oil price spikes resulted from oil supply disruptions accompanying the Yom Kippur War (1973), the Iraq-Iran war (1979), and the Iraqi invasion of Kuwait (1990). At the same time, the ability to reliably provide energy for military and critical civilian applications enhances the provision of national security (a public good), regardless of whether the source of the threat is oil-related. Because the value of national security costs is not taken into account in the consumer price, consumers demand

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[38] See Bradley Schiller, Essentials of Economics, 4th edition, 2001, Chapters 6-9.

[39] Although a rather strong term, this is term used in the economics literature to refer to market conditions that do not satisfy the needs of fully competitive markets.

[40] See Schiller, *op. cit.*, Chapter 9. Also Cornes, Richard and Todd Sandler, "The Theory of Externalities, Public Goods and Club Goods", (NY: Cambridge University Press. 1986).

[41] Externalities are costs (or benefits) of a market activity borne by a third party; or, the difference between the social and private costs (benefits) of a market activity. A public good, on the other hand, is a good or service whose consumption by one person does not exclude consumption by others. Bradley Schiller, *op. cit.*, Chapter 9.

more oil than they otherwise would—and a significant portion of this oil comes from the Middle East due to its low cost of production there—and the market consequently under-invests in energy efficiency and alternative fuels. A recent report by the National Academy of Sciences estimates the uncaptured oil premium as $0.12/gal but the premium could range from $0.02/gal to $0.24/gal. [42]

Sources and Size of Externality

The extent to which OPEC (or any other group of countries) is able to exercise market power to curtail global oil supplies, and the resulting impact of the disruption (price spikes and possible physical losses) depends *both* on OPEC's share of global oil production and on the level of global demand for oil (see Figure 2-6).[43]

In 1979, when reductions in OPEC output produced a doubling of world oil prices, OPEC had a 49 percent world market share, and demand was running fairly close to world capacity.[44] OPEC's share bottomed out at 30 percent in 1985, due to both large global reductions in oil intensity and significant new sources of non-OPEC oil coming on line.[45] In 1979, OPEC oil accounted for 67 percent of U.S. oil imports; that figure dropped to 36 percent by 1985.[46] Today, imports from OPEC have risen to roughly 46 percent of our total oil imports.[47] Coordinating with Mexico and Norway, OPEC was able to temporarily increase oil prices with a supply cut in 2000. The current and expected growth in world oil demand described in the previous section is certainly an area of concern with regard to the potential for future oil market disruptions.

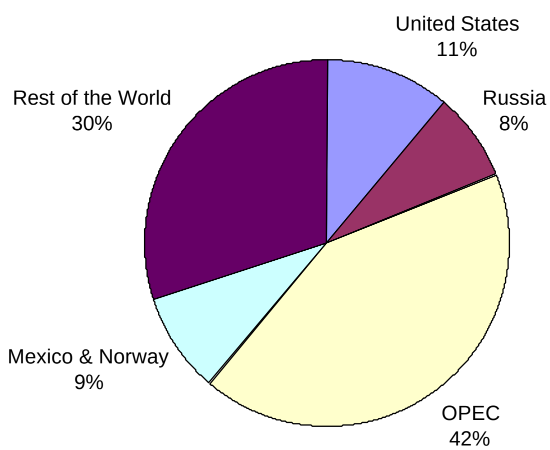

Figure 2-6: Sources of world petroleum, 1998. Source: D. Gately and D. Greene, 2001.

[42] Effectiveness and Impact of Corporate Average Fuel Economy (CAFÉ) Standards. Washington, DC: National Academy Press. 2001. Chapter 5.
[43] Analysts speculate, for instance, that one of the reasons that oil prices did not rise with the onset of the current conflict in Afghanistan is that the sharp downturn in travel in the month following the September 11 attacks significantly reduced demand for oil, with resulting decreases in oil prices. As demand rebounds, it may well be possible for one or more countries to effectively disrupt oil markets by withholding supply.
[44] AEO 2000, Table 11.4.
[45] *Ibid.*
[46] *Ibid.*
[47] AER 2000, Table 5.4.

National security concerns will remain as long as OPEC continues to control a significant portion of the world energy market. Over the near- to mid-term, OPEC's market power can be reduced by increasing supplies outside OPEC and reducing the global demand for oil. Over the longer term, however, national security concerns derive from the concentration of conventional oil *reserves* in a few countries, primarily in the Middle East. OPEC's current share of the world's conventional petroleum resources is about 50 percent. Because this is higher than its share of world output, its share of remaining reserves will grow as non-OPEC reserves are exhausted. This means that in the longer term (perhaps 20 to 30 years out), new technologies or fuels that could reduce key dependencies on oil (specifically, in the transportation sector and, to a lesser extent, the industrial sector) are a potential important national security hedge against future market disruptions, and thus, an important national security asset.

ENVIRONMENTAL IMPACTS

Energy production and consumption are associated with the vast majority of U.S. air emissions.

Sources and Size of Externality

The majority of the air emissions represented in Figure 2-7 are the result of the combustion of fossil fuels. The carbon dioxide emissions from vehicles are largely a function of the number of miles traveled and the efficiency (or miles per gallon) of the vehicles; emissions of NOx, carbon monoxide and particulates depend strongly on the age and level of maintenance of the vehicle, and the type of engine, among other factors. Emissions from fossil-fueled power plants depend on their type and vintage. For example, emissions of SO_2 and NOx can vary by factors of ten between a conventional coal plant and a natural gas-fired combined cycle plant. Nonfuel renewable (e.g., hydro, geothermal, wind) and nuclear power contribute very little to these environmental emissions during their operation, but indirectly generate small emissions in the production of steel, cement, and other materials used in their construction.

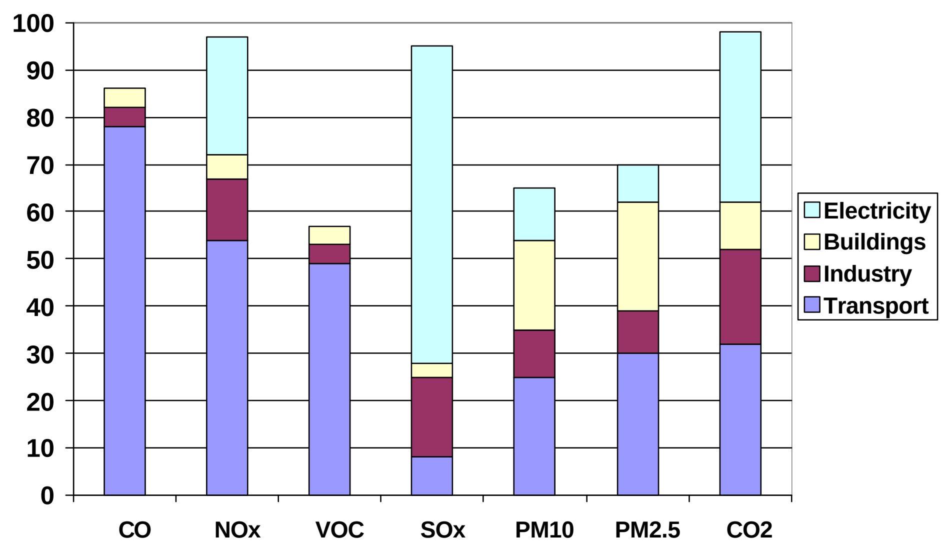

Figure 2-6: U.S. 1998 energy-linked emissions as a percentage of total U.S. emissions. Source: EPA, National Air Pollutant Emission Trends 1900-1998, EPA-454/R-00-002, Mar. 2000; EIA, Emissions of Greenhouse Gases in the U.S., 1999, DOE/EIA-0573(99), Oct. 2000.

Other types of energy-related environmental impacts, including water and ground contamination, relate to a broader range of energy sources. A number of sources of water discharge, including petroleum leaks from vessels and underground storage tanks, are being addressed through regulation and are on the decline.[48] MTBE,[49] an additive to reformulated gasoline, has contaminated drinking-water supplies in some areas. Nuclear power production generates fission by-products that require long-term storage. Sources of renewable energy present specific environmental concerns as well, such as fish kills from hydropower or avian mortality from wind power. In addition, biomass combustion can generate substantial amounts of particulate air pollution if not controlled.

Absent regulation that effectively internalizes the costs of environmental impacts, these costs are externalities much like those associated with national security. Environmental costs can include damage to: human health and welfare; agriculture and forestry crops; fish and wildlife; biodiversity; lands; structures; property values; and, economic sectors, such as tourism. When the market does not value these costs, energy services are met through overconsumption of higher-emission energy sources and underconsumption of lower-emission energy sources and efficiency improvements.

INCOMPLETE APPROPRIATION OF R&D

The level of R&D investments in any economy is a primary driver of future economic growth. The knowledge gained from R&D has its biggest economic growth benefit when it is broadly available to potential producers. Maintaining proprietary control over knowledge developments is very difficult. Generally, many other businesses that do not contribute to specific R&D are able to benefit from the R&D results. This spillover of benefits to “free riders” discourages optimum investment in R&D by the private sector; the investor cannot capture the full benefits of his investment. The result is a generally recognized less-than-optimum private-sector investment in R&D and a loss in overall social welfare.

Sources and Size of Externality

The extent to which the private sector can appropriate the benefits of its R&D varies substantially, depending on the type of R&D and the sector of the economy. Basic R&D provides the widest range of useful knowledge, and its benefits are the most difficult for the private sector to appropriate. As R&D moves toward commercialization, it is easier for private-sector firms to capture the benefits of their investments, although even at the latest stages of demonstration, the work inherently provides knowledge benefits to others.

The level of R&D investment, determined in part by the extent to which the R&D is appropriable by private firms, varies considerably by market segment and by the characteristics of each sector. Investment rates vary by several-fold within and among sectors. In the industrial sector, the average rate of investment for R&D in the manufacturing industry is about four percent of sales compared to approximately one percent in the metals, petroleum refining, and forest products industries. In contrast, some high-valued sectors, such as communications equipment and pharmaceuticals, have R&D investment rates of over ten percent.[50]

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[48] Greene & Gatley, 2001 on vessels.
[49] Methyl tertiary butyl ether.
[50] NSF., *R&D in Industry*, 1998. 1999. Table A-21.

To invest in R&D, firms need to believe that the resulting benefits, even though incomplete, will exceed their private costs of performing the R&D.[51] Market characteristics that help shape the extent to which firms can find it profitable to undertake R&D on their own include:

- **Market fragmentation**. In highly fragmented markets, individual companies may lack the scale of resources needed for advanced R&D investments, while increasing the number of potential external beneficiaries of the R&D results. Fragmentation can also make it difficult for firms to develop meaningful collaborations with other companies in order to develop necessary scale to encourage research investments.[52]

- **Product vs. process improvements**. R&D geared toward product differentiation can often enable the private firm to capture a higher share of the resulting benefits as they have a greater market share for the particular product. By definition, commodity materials (e.g., aluminum, glass, steel) offer relatively little opportunity for product differentiation (although there are specialty glasses, steel or aluminum alloys, etc.) and their industries are the least likely to be able to realize such product differentiation benefits. For these industries, R&D directed toward process improvements to reduce production costs is more relevant. However, because such process improvements are often applicable to plants of competing firms, the investing firm is likely to have great difficulty capturing all the benefits from any investment in R&D on process improvements for themselves alone. Such appropriability can also be very difficult in generic processes such as motor drive, steam generation, and air compression, where potential applications of efficiency improvements exist industry-wide.

- **Underlying financial health**. Industries that are declining as a share of the domestic and international economy or that have limited opportunity for product differentiation (commodities) may have limited resources to invest in R&D improvements.

NETWORK EXTERNALITIES

In most cases, an extensive network of infrastructure is required to move energy from its point of production to its point of use. Natural gas and oil pipelines and electricity transmission systems are some of the largest and most complex delivery networks in the world. Some of the inherent characteristics of delivery networks, however, can result in sub-optimum network design, capacity development, or reliability.

Sources and Size of Externality

Electricity transmission and distribution networks were originally built to facilitate unidirectional movement of power from central stations to a utility's own customers. Regulatory oversight attempted to ensure that distribution networks were neither over- nor under-built. In current electricity markets, however, extensive wholesale and (increasingly) retail sales now use the transmission network to facilitate an active market in buying and selling power from dispersed generators, often under different owners.

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[51] Including opportunity costs associated with its R&D investment, e.g., what it could have earned investing these funds elsewhere, and discounting for risk in R&D performance.

[52] Collaboratives help turn R&D benefits into a sort of "club good," a term economists use to define goods whose benefits are primarily shared by the members who contributed to their development. Public externalities can be internalized if a means is found to exclude non-payers or get most beneficiaries to contribute towards the costs of production.

The result of these new conditions is that buyers and sellers do not necessarily have to pay for the full costs to the system for their use of different components of the network, resulting in a negative external cost and insufficient market incentive to build sufficient capacity. At the same time, the overall reliability of the network is a shared output to which each owner of the network contributes. In this case, each user of the capacity shares with all of the other users any costs associated with degradation of performance from their activities. The result is a classic externality in which the reliability of the system's performance suffers as transmission capacity becomes congested and the incentive to maintain excess generating capacity for one's own customers is eroded and is known as a "congestion" externality. On the other hand, when additional users join a network, the network opportunities expand making the value of participating higher for everyone.

These external impacts of network usage on the quality of the system have contributed to the generation and transmission shortages occurring in California and elsewhere over the last several years, along with the apparent overall decline of surplus generating reserves in those markets.

INCOMPLETE/INACCURATE/ASYMMETRIC INFORMATION

Reliable information about product price and quality allows firms to identify the least costly means of production, and gives consumers the option of selecting goods and services that best suit their needs. In order to ensure that markets will equilibrate at optimum levels, it is important that relatively complete and inexpensive information be available to all parties. While competition among firms and arbitrage between buyers and sellers can help meet the information need of markets, a number of observers have demonstrated that costly, inaccurate, or asymmetrically held information in a market can result in inefficiencies in production or in consumers being unable to purchase the mix of goods and services they prefer.[53] Conversely, when one party to a transaction has substantially more product information, market opportunities will tilt toward the entity with the information advantage.

Sources and Size of Market Failure

The relative size and importance of information failures vary significantly across the goods and services produced and sold. Generally, when consumers or businesses frequently make large numbers of inexpensive purchases of products with directly observable qualities, they can rapidly identify the products they wish to buy with limited effort. However, it is substantially more difficult to learn about performance and costs associated with efficiency increases because they are often not directly observable.[54] Further, efficiency choices tend to be "bundled" with larger purchases, such as furnaces. Such purchases are not made very often, resulting in less opportunity for past decisions to inform future choices. For energy supply systems, performance is usually more readily observable, but the size of the investment required tends to be relatively large.

Information costs associated with newer products also tend to be higher, both because there is limited experience from others from which to learn, and because the attributes of products under development often change rapidly in their early years. Because energy efficiency and renewable energy technologies addressed by government research programs are, by their nature, new products, there is often limited

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[53] The 2001 Nobel Prize in economics was awarded to George Akerlof, Michael Spence, and Joseph Stiglitz for their groundbreaking work in the economics of information and the problems that asymmetric information can create in markets.

[54] The classic information problem is the "market for lemons," in which the purchase price obtainable for used cars falls as consumers discount their willing purchase price to reflect the fact that owners with "lemons" are more likely to resell their cars and consumers find they lack the performance information needed to determine which used cars are lemons. (Akerlof)

information about them, which is likely to reduce private market uptake of the products, compared to more traditional sources and uses of energy.

Finally, asymmetries in information abound in energy markets. Power, industry, or other companies wishing to generate their own electricity will find that they cannot, except at substantial expense, match the product and market information available to the traditional utilities with whom they must negotiate buy-back arrangements. Similarly, building owners do not have the same depth of information on building design characteristics or performance as do the builders, architects, or others they hire. As a result, they can find it difficult to ensure they are properly specifying or receiving the efficiency or renewable energy components they desire.

KEY MARKET CONDITIONS: SHAPING PROGRAM DESIGN

A variety of market conditions, while not market failures in their own right, can complicate the application of government policies and programs intended to achieve the public benefits obtainable from correcting or compensating for market failures. The line between market failures and other salient market features is not always clear. In fact, it is a substantial point of debate in both the economics and the energy policy literatures. Where relevant, the following discussion of market conditions may also point to underlying market failures, as well. As with market failures, a few conditions are found in one form or another in each sector:

- **Stock turnover**. The greatest opportunity for efficiency improvements or incorporation of new energy resources into markets is at the time when capital stock is added or replaced. Stock turnover rates vary by sector and application, and can range from a couple of years for a computer to the better part of a century for a home or a large industrial boiler. Turnover rates are also faster during periods of economic growth. In cases where original investments were made largely at the same time—e.g., during the economic expansion at the end of World War II—larger portions of capital stock will come due for replacement at about the same time. As a result, programs can target deployment information to firms expecting to make new purchases in the near term or can encourage firms to accelerate replacement decisions when life cycle costs for new equipment warrant early replacement. Stock turnover must be taken into account in assessing the potential market impacts of polices and programs.

- **High apparent rates of return**.[55] As with any other investment, energy investments are made with an expectation of future returns. Energy efficiency and renewable energy investments are often based on expectations of reduced future energy costs.[56] However, consumers frequently seem to require greater returns on investment than typical costs of capital would suggest—perhaps 40 percent or more, compared to up to 18 percent for a credit card purchase. Explanations for these higher rates vary, although the information problems discussed above undoubtedly contribute significantly. Consumers may also require higher rates of return to reflect technical uncertainty or undesirable product attributes (e.g., difficult to maintain). Regardless of the explanation, it is essential that these required returns be reflected in the R&D program design to ensure final market success.

- **Verification of performance**. Because the performance of efficiency technologies is difficult or impossible for consumers to observe directly, consumers often require that an unbiased source

[55] Typically referred to in economic literature as "high discount rates" for households.

[56] Individual consumers may have a range of other reasons for selecting these products, including a general preference for purchases associated with lower environmental externalities ("green purchasing"); some of these consumer preferences are considered below within the context of individual sectors.

has verified performance claims. The same is often true with attributes of alternative and renewable energy sources (e.g. effect of ethanol on car engines). Where this assurance is needed, it is important that it be addressed as part of the demonstration or deployment strategies for the product, perhaps through government certification. Energy labels, testing by certified laboratories, field verification, and rating procedures are all means of providing consumers with trusted sources of performance information. Lower-cost metering technologies could also help serve this role.

From the point of view of the supplier, a number of factors related to the product's development and life cycle are relevant to the design of energy efficiency and renewable energy programs:

- **Nascent industries**. Although many entirely new products are developed by larger, established industries, others emerge from smaller entrepreneurial firms located outside traditional industrial sectors. For instance, EERE-supported advances in electronic ballasts were made by several smaller firms. While the newness or smallness of the sector is not a basis for government funding per se, to help ensure a successful partnership, it is important for government R&D efforts to account for differences in underlying abilities and resources when the R&D is performed by a nascent industry. Small grants programs, inclusion of national laboratory capabilities in the partnership, and adjustment of cost-share expectations can all help make shared research in these markets more successful.

- **Economies of scale/learning by doing**. Niche markets can often support early product sales at higher prices than is possible in the mass market. Aggregating these niche markets can then allow production scale-up which helps drive down costs towards broadly cost-competitive levels. Demonstration programs can provide early learning-by-doing experience, while carefully targeted deployment efforts can help exploit niche markets in order to realize early economies of scale.

- **Embedded infrastructure.**[57] Current patterns of energy supply and demand are supported by well-developed markets that provide both the physical and market infrastructure needed to facilitate these patterns. This embedded infrastructure affords a relative advantage to the existing products and services it supports. New products often must develop new supply and distribution lines, and may need new types of physical infrastructure. The cost advantages of using existing systems compared to developing new systems must be taken into account in assessing the development and deployment of new resources.

Unique conditions affecting market performance are found in each sector, as well.

BUILDINGS AND EQUIPMENT SECTOR

- **Market fragmentation**. Market fragmentation is most serious in the residential sector, where new home construction and remodeling are dominated by very large numbers of small firms, and associated lower profit rates. This results in relatively slow adoption of new technologies and design and construction techniques. The top 400 homebuilders, for example, serve just 40% of the residential market. Although less pronounced, there is also considerable fragmentation of the commercial building market.

- **Regional variation**. The buildings industry uses regionally-varied construction materials and techniques to meet diverse climatic and stylistic demands. For example, the energy efficiency

[57] Often referred to as "technology lock-in."

needs of windows for northern and southern climates require different designs. As a result, energy efficiency and renewable energy building techniques and products often must be regionally customized before they will be widely adopted. .

- **No price tags**. The fact that it is difficult for consumers to determine the price they pay for the energy services they consume (e.g., because there is no submetering of electricity or gas for particular household uses) makes it difficult for them to respond effectively to price signals and changes in energy prices. It also makes it difficult for providers to warrant the performance of their energy efficiency products and services.

- **Limited consumer focus**. Except in periods of rapidly rising energy prices or shortages, consumer attention to energy in the home sector is limited, both because of the information limitations described above and because individual energy services constitute relatively small portions of the consumer household budget. Lighting, for example, constitutes about 6 percent of the average household energy budget.[58] As a result, in making lighting decisions, consumers often conclude that it is not worth the time and effort to figure out the energy cost impacts of each available lighting choice (e.g., halogen, incandescent, compact fluorescent).

- **Health and safety requirements**. Building code elements related to fire hazards, safety requirements for building components and equipment (e.g., UL ratings for lighting), and exposure limits (e.g., EPA radon guidelines, OSHA exposure limits) must be met by all renewable and efficiency technologies. When these technologies are relatively new to the buildings sector, the need to verify their safety can add to the time needed for their widespread commercialization.

INDUSTRY SECTOR

- **Energy and the company's mission**. Energy production or efficiency is not the primary business of manufacturers and, as such, therefore is often overlooked. Many companies, especially larger and more energy-intensive firms, have decided to incorporate energy management as a key corporate strategy. These companies have made impressive gains in efficiency improvements or in making energy production a profit center for the firm (e.g., through cogeneration). A means of sharing successful strategies and best practices can help improve overall industry performance and extend benefits to smaller, less profitable firms or others that cannot otherwise incorporate energy management as a corporate strategy.

- **Extremely varied/highly specialized applications**. Because industrial energy uses are so diverse, "one-size-fits-all" products rarely play a large role in this market. Achieving widespread use of technology breakthroughs can require dissemination of technical documentation and other forms of technical assistance to help firms tailor the technology to their particular production processes. A systems approach to energy production and savings can also provide general guidance on how combined heat and power, or other system techniques might be adapted by individual firms to their production needs.

- **High requirements for production reliability/limits to acceptable "downtime."** Energy reliability is often only one component of overall production reliability; companies are necessarily concerned with all the factors that affect reliability. Incorporation of energy production or savings opportunities into a production facility often requires downtime and learning time that can result in a significant disruption of earnings. This is especially true for

[58] BTS Core Databook 2001, Buildings Data Summary Sheet, p. 1.

newer technologies, where lack of field experience and immature product markets for the products can mean delays in deliveries of parts, inexperienced installation, and unexpected complications in tailoring the product to the particular plant at hand.

- **Short-term profit focus/cyclical markets**. Firms place varying degrees of emphasis on short-term (quarterly, annual) financial performance. Because many efficiency and renewable energy technologies have longer required timeframes for profitability, it may be necessary to include in deployment efforts means of providing products as services rather than purchases, or other ways of keeping the energy choices within the firm's timeframe.

- **Competing investment requirements**. Although, in theory, firms might be expected to borrow capital any time a profitable investment opportunity presents itself, in practice firms are often observed rationing capital—that is, imposing internal limits on capital investment. The result is that mandatory investments (e.g. required by environmental or health regulations) and those that are most central to the firms' product line often are made first.

TRANSPORTATION SECTOR

- **Consumer preferences and technology trade-offs**. Technological advances can often be incorporated into vehicles in differing ways, depending upon the desired mix of performance characteristics. When oil prices are low or moderate, consumers often prefer vehicles with relatively better speed and acceleration performance than energy efficiency performance. In the case of alternative-fuel vehicles, other performance characteristics, such as distance between refueling, can be important in the marketability of a car.

- **Safety requirements/harsh operating conditions**. The transportation sector is subject to important safety regulations that all new vehicle components and designs must meet. At the same time, vehicles operate under very harsh conditions, such as high engine temperatures and stress from vibration. As a result, products must be carefully evaluated for their ability to perform reliably and safely in this strenuous operating environment.

POWER SECTOR

- **Resource location**. Several of the renewable power generation sources are concentrated in specific regions of the country. For example, geothermal energy resources are mainly located in the West, wind energy has great potential in the Northern Plains states, and solar energy potential is particularly high in the Southwest. The development of these resources must acknowledge the geographic areas of high potential, and should focus on matching regional needs.

- **Interconnection standards**. The interconnection of distributed energy systems with the electricity grid is not covered by a single, uniform standard. Each utility has its own requirements and procedures, which makes it difficult for distributed energy developers to predict interconnection costs. This uncertainty has been a significant deterrent to construction of many small projects. Uniform national interconnection standards for distributed energy devices would help expand the potential market for distributed energy systems and make project economics more favorable in specific circumstances.

The next four chapters describe the implications of these challenges and conditions and how EERE programs respond to them.

Chapter 3

Aligning EERE's Program Activities with National Goals and Interests

SUMMARY

The National Energy Policy (NEP), published in May 2001, sets forth a comprehensive, long-term strategy that integrates energy, environmental, and economic policy. It identifies five national energy policy goals which, taken together, address the energy market trends and underlying market failures described in the previous chapter. These NEP goals include:

- **Modernize energy conservation.** Energy efficiency reduces the amount of energy needed to meet growing demands for energy services. In doing so, efficiency improvements reduce the environmental impacts associated with energy use and the potential economic impacts of energy price spikes. Oil conservation, in particular, helps reduce growing oil imports, lessen the potential economic impacts associated with oil supply disruptions or price spikes, and increase the Nation's diplomatic and military flexibility. Energy efficiency also reduces the underlying need for new infrastructure to deliver energy products.

- **Modernize our energy infrastructure**. Modernizing our energy infrastructure can improve reliability by providing additional network capacity, increasing the efficiency and effectiveness of that capacity, and reducing network loads. Network loads and the probability of network failures can be reduced both by development of distributed generation and demand side management.

- **Increase energy supplies**. Increasing domestic transport fuel supplies helps address national security externalities by reducing the need for oil imports and dampening the economic impacts of oil price spikes. Deriving these transport fuels from renewable resources can also potentially reduce environmental externalities.

- **Accelerate the protection and improvement of the environment**. Energy conservation and the development of cleaner domestic energy resources, such as renewables, can reduce environmental externalities.

- **Increase U.S. energy security**. Conservation, enhanced infrastructure, and increased domestic supplies all have the potential to increase energy security. This is particularly important when they reduce demand for oil or develop domestic supplies of oil for alternative fuels that could substitute for oil. In addition, fuel-flexible technologies, which can substitute biofuels for oil for example, may help mitigate the impacts of oil disruptions in some cases.

These five national energy policy goals will be met through a mix of complementary energy policies and programs across the Department of Energy and the Federal government. This chapter explores the roles that EERE's program portfolio currently plays in meeting each goal, and the general strategies they employ in doing so. As such, it provides a description of EERE's portfolio as a basis for considering the technical and business effectiveness of programs that comprise the building blocks of this portfolio. These are described in the following chapters.

Most of EERE's current portfolio contributes to more than one of the interrelated NEP goals. EERE attempts to maximize the effectiveness of these resources in meeting these goals by targeting the largest opportunities and taking into account specific market conditions.

The NEP includes 104 specific recommendations addressing an array of programmatic, analytic, and policy development contributions to its five broad goals. As one part of supporting these NEP goals, EERE is directly contributing to the implementation of 40% of these recommendations. EERE is the lead Federal office for 10 NEP recommendations; the lead DOE office for another 21 recommendations; and is supporting an additional 12. As part of an FY03 budget exercise directed by the DOE Chief Financial Officer (CFO), EERE ensured that all implementation requirements for the NEP recommendations were included in the FY03 budget submission to the Office of Management and Budget (OMB).

ALIGNMENT ISSUES

ADDRESSING MULTIPLE GOALS

Fig. 3-1 breaks out the EERE FY 2002 budget request by NEP goal. The relatively large representation of the environmental goal is due to the fact that nearly all of EERE's conservation and energy supply programs improve the environment along with contributing to these other goals. The security component of the EERE budget largely addresses domestic alternatives to oil consumption in the transportation sector, including efficiency improvements and new energy supplies. Direct support for energy infrastructure is a relatively new portfolio element for EERE, with a primary focus on the application of renewable and more efficient technologies to reducing the stress on the electricity transmission grid. Finally, EERE's energy supply programs address both the development of the Nation's renewable energy resources and the development of alternatives to oil.

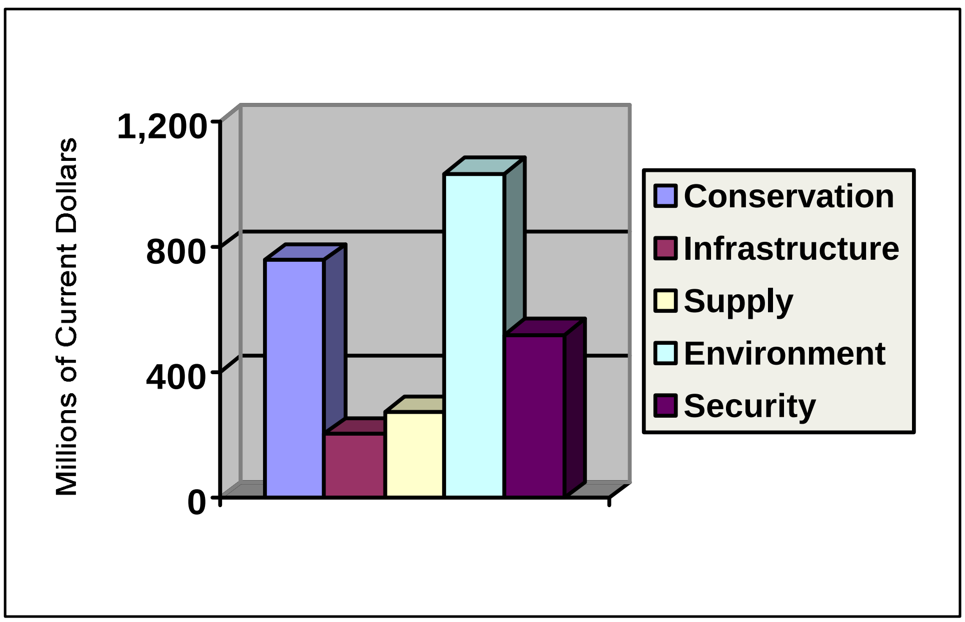

FIGURE 3-1: FY 2002 budget request by NEP goal. Sums to more than budget total because EERE programs support multiple NEP goals.

Because the energy characteristics differ significantly from sector to sector, the relative contributions to each NEP goal vary substantially by sector.

- The largest opportunities for improvements in energy security are in the transportation sector.
- The largest opportunities for new domestic energy sources related to EERE's mission are in the power sector.
- The largest opportunities for improved infrastructure are in the power and, potentially, in the buildings sector. In the longer term, there are large opportunities for improved infrastructure in the transport sector as well.

Figure B-1 in Appendix B illustrates the sector and program alignments with the NEP goals, illustrating the differences in relative contributions available from each sector and program type.

ADDRESSING R&D AND INFORMATION MARKET FAILURES

R&D represents about 84% of EERE's FY01 budget and 70% of EERE's FY02 budget, with the remainder comprising deployment programs that primarily address information market failures.

- **R&D programs** typically seek to improve the operating performance and cost-effectiveness of energy efficiency, renewable energy, and alternative energy technologies. Specific attention is placed on ensuring that the operating characteristics of resulting technologies are at least as attractive as those they are likely to replace in the market. For example, the advanced transportation program's efficiency goals specify the size, acceleration, and other features to be retained in achieving the desired levels of efficiency. In several cases, research is directed towards improving the environmental performance of an efficiency or renewable energy approach. Current work on efficient diesel engines, for instance, is addressing means of ensuring compliance with "Tier II" Clean Air Act Amendment NO_x regulations. All of the sector-level budgets, except FEMP, are predominantly research focused.

- **Deployment programs** typically seek to accelerate market introduction of advanced technologies to help meet specific policy objectives. These programs generally address technologies that have recently become cost-effective, or that are moving towards cost-effectiveness in new applications. The types of information provided can include product ratings and labeling, general information about cost-effective opportunities (efficiency, renewable, or alternative), and targeted technical assistance. Among the sectors, FEMP and BTS have the largest dissemination efforts, much of which is associated with two grant programs (the Weatherization Assistance Program and the State Energy Program within BTS). This is consistent with the more significant information programs needed by this highly dispersed sector with relatively non-technical customers.

ADDRESSING VARYING TIMEFRAMES

In addition to addressing different market failures, R&D and deployment programs address different policy timeframes. The benefits of deployment programs are generally realized sooner than those of R&D, and at any given time deployment programs constitute the bulk of the Federal government's ability to respond to near- or even mid-term energy needs. Deployment efforts have two basic timeframes:

- **Capacity**. These efforts help consumers and businesses lower energy costs over time by providing, among others, the basic, up-to-date information needed to make sound energy choices, and are designed to contribute to steady market penetration over a period of years. Appliance Standards setting, FEMP, Energy Star, Clean Cities, the Industrial Audit Centers (IAC), and

Geopowering the West are examples of such efforts. Although not information based, the Weatherization program provides similar steady, annual improvements in energy savings.

- **Emergency response**. These efforts are usually temporary extensions of existing capacity programs designed to assist consumers in responding to energy shortages or price spikes. Although these efforts vary in size and intensity as market conditions change, their effectiveness depends on the underlying technical expertise of the capacity programs. EERE provides emergency deployment services through a number of mechanisms, including the FEMP program, which can help the Federal government coordinate its own responses in times of energy need; the Regional Offices, which can tailor information to particular regional needs; and the State Energy Program, a grant program operated through BTS.

Research programs provide means of resolving energy needs over the longer term. Two types of EERE research efforts, with differing timeframes, can be roughly distinguished:

- **Incremental.** This research is targeted towards steady improvements in energy performance and tends to provide mid-term benefits in the form of relatively rapid (five to ten years from completion) improvements in performance and reductions in cost. These programs focus on less risky, more highly cost effective technology opportunities.

- **Breakthrough.** In the long run, fundamental breakthroughs in the way energy is produced, delivered, or used will be necessary to fully achieve our energy policy goals. For example, increases in domestic oil production and decreases in oil demand can contribute significantly to improved oil security over the short and mid terms, but they cannot break the near total dependency of the transportation sector on oil. That will require transport fuels from resources other than oil. Fuel cells and PV's are examples of potential break-through technologies applicable to important energy sectors. Because of the very long time frames typically involved, breakthrough or "leap-frog" research is often selected on a "contingency" or "options" basis to ensure the availability of key strategic energy resources and technologies as a means of being prepared for significant expected or possible future energy, environmental, or national security needs.

TARGETING AREAS OF OPPORTUNITY

Although EERE programs contribute to each of the five national energy policy goals, the portfolio does not attempt to address all aspects of energy use in all sectors, or all potential sources of new renewable energy supplies. Within each sector, EERE attempts to target resources towards those sub-sectors with the largest opportunities to contribute to the goals addressed. The size of the energy saving, supply, or infrastructure opportunity depends in part on the amount of energy used in the subsector. In the industrial sector, for instance, nine industries account for 75 percent of the energy used, making these industries a large potential source of energy savings.

The size of the opportunity also depends in part on the potential for programs to be able to change energy use in that subsector. In the buildings sector, for instance, while currently existing buildings constitutes the bulk of our future building energy use, it is generally more cost-effective and institutionally easier to facilitate energy savings as new buildings are constructed. The following sections identify targeted sub sectors related to each goal.

ACCOUNTING FOR PARTICULAR MARKET CHARACTERISTICS

Significant differences in market characteristics among sectors and sub-sectors require additional fine-tuning of program design and implementation. An important structural difference among programs is the choice of private sector partners and the relationship between the public and private components of the effort.

In the industrial sector, for instance, energy uses are highly tailored to the specific industrial process, and private-only collaboration among companies is difficult. In response to these market conditions, the Office of Industrial Technologies (OIT) developed a 'technology roadmapping' process, both helping to bring private sector partners together and tailoring the resulting research to the specific requirements of each manufacturing, mining, or agricultural subsector. In the transportation sector, by comparison, there are a small number of vehicle manufacturers, but a very large number of suppliers of components, each of which face differing underlying materials science, engineering, and other barriers to contributing the needed components of a more efficient vehicle, making it difficult for the industry as a whole to develop "leapfrog" improvements. In this case, the PNGV program and now the FreedomCAR program, developed out of extensive high-level discussion a public-private partnership in which the public role addresses more fundamental technical barriers to significant efficiency improvements, while manufacturers focus on engineering development.

ADDRESSING OPPORTUNITIES FOR BOTH PRODUCT- AND SYSTEMS-LEVEL SAVINGS

A growing portion of EERE research and deployment efforts address energy opportunities at the systems level, a significant change from early research that focused on the efficiency of specific products (e.g., windows) or the energy supply from specific products (e.g., wind turbines). Systems design can be realized at the building or factory site, the community, or the power system level. System design allows for greater energy savings, improved reliability, or increased energy supplies than are technically feasible by focusing on individual components alone. For example, Building America (within the Residential Buildings Integration program) is directed towards whole-house design that integrates the insulation, duct, and furnace components in ways that can improve the overall efficiency of the home by 30% to 50% compared to code.

Each EERE sector has added or expanded systems research in their portfolio over the last five years or so. For example, OPT addresses systems integration among generation, transmission, and demand in the electricity sector. This includes the integration of distributed generation into the electricity system; the integrated production of heat and electricity on site; and balancing of renewable electricity generation with demand loads. Similarly, whereas in the past OIT focused more on the development of component parts (e.g. efficient motors, pumps) for industry, the Vision Industries (VI) program currently works with individual industrial sectors on fundamental improvements in their overall production processes. The Bioenergy Initiative is another crosscutting integration effort intended to help develop technologies and infrastructure that can cost-effectively produce a range of biomass products, fuels, and power.

MODERNIZE ENERGY CONSERVATION

The NEP goal of *modernizing* conservation recognizes that the use of advanced technologies can improve the productivity of energy markets by improving energy efficiency. Energy efficiency improvements are possible throughout energy markets, from the wellhead to the power plant, home, office, factory, or automobile and are similar to productivity gains in labor and capital: they help the economy grow and increase economic prosperity. Recommendation 4-14 of the NEP makes this point clear by directing the

Secretary of Energy to "establish a national priority . . . to improve the energy intensity of the U.S. economy," therefore "improving energy efficiency."[1]

Productivity improvements in energy markets are realizable over time, as more efficient technologies for automobiles, appliances, and other energy-using products enter the market and capital stock turns over. Changes in market conditions—e.g., unexpected increases in natural gas prices, reduced reliability of centralized electricity supply—can spur the market adoption of technologies previously developed through R&D. As a result, it is important that EERE's efficiency-related programs reflect a fairly long time horizon in selecting areas of R&D opportunity, and explores the potential applications of new technologies to different potential future energy markets.

EERE's end use programs represent 68 percent of EERE's FY01 budget and 70 percent of EERE's FY02 budget (the remainder of the budget being in OPT). These programs help develop and deploy advanced technologies to improve the productivity with which energy is used in the economy. The buildings and transportation sectors receive the bulk of this funding, with more limited funding in the industrial and Federal sectors (see Table 3-1). In addition, several of EERE's power programs have efficiency components that contribute to the overall goal of modernizing conservation.

TABLE 3-1: FRACTION OF EERE BUDGET IN DIFFERENT SECTORS

	FY2001	**FY2002**
Buildings R&D	6.3%	5.7%
Buildings Grants	18.5	23.6
FEMP	2.2	1.8
Industry R&D	12.5	11.5
Transport R&D	21.5	19.5
Power R&D	35.3	34.6
Policy and Management	3.6	3.4

Notes: Numbers may not add to 100% due to rounding. Buildings R&D includes Energy Science and one-half of BTS Management costs. Buildings Grants includes Cooperative Programs with States and one-half of BTS Management costs. Power R&D includes Interior appropriations for Power Technologies.

BUILDINGS

The Office of Building Technology, State and Community Programs (BTS) addresses efficiency opportunities in residential and commercial buildings (e.g., schools, offices, hospitals, stores), both old and new. BTS also addresses energy use in activities associated with the Buildings sector, such as washing clothes or watching TV. About 19% of the BTS FY 2002 budget is for research, with the remaining 81% addressing deployment (72% is in the form of two grant programs: the Weatherization Assistance Program and the State Energy Program).

Appliances, equipment, materials and tools.

The Building Equipment and Materials program, funded at $38.5 M in the FY 2002 budget, conducts research on lighting, windows, insulating materials, water heaters and other household appliances, etc. It

[1] Assessment of the potential for improved energy intensity and the contributions of particular EERE programs to those reductions is coordinated at the EERE-wide level by the Office of Planning, Budget and Management (PBM), based on analysis undertaken by EERE sectors and programs.

also developed building design software for improving whole-building design efficiency and integrating renewable energy resources, and for use in basic buildings science and model codes. Ultimately this research area addresses essentially all buildings energy use, but it particularly addresses the 60% of energy use other than heating and cooling.[2]

Deployment efforts for more efficient technologies are assisted by product testing, rating, and labeling through the appliance standards and Energy Star programs. The appliance standards program also provides a relatively inexpensive means of moving the least efficient products from the markets based on technical and economic criteria.

Homes

More BTS R&D funding (the Residential Building Integration Program or "Building America") is directed at new construction than existing homes because of the lower costs and greater energy savings (30% to 50% of heating and cooling) achievable through the integrated use of energy efficiency technologies in new construction. Building America utilizes a field research approach in which public-private consortia construct test homes and document their energy savings. The consortia include some of the larger national homebuilders so that deployment opportunities are built into the structure of the program. Finally, the field-based consortium approach allows for research focused on energy needs under different climatic conditions and regional building styles.

With the notable exception of the Weatherization program, where improvements are purchased by the program based on a detailed house-by-house audit, previous program efforts to address energy savings in existing homes (such as Home Energy Rating Systems) proved extremely difficult to implement effectively and have since been scaled back or eliminated. The development of a simplified Energy Star rating for existing homes (pursuant to NEP recommendation 4.3) is a relatively new approach to realizing energy savings opportunities in existing homes. BTS also provides technical support to State building code officials and others in developing ceiling, wall, window, and other component efficiencies for new homes. The Weatherization Program addresses a specific market segment that cannot afford energy efficiency improvements at virtually any price. Households with incomes below 150 percent of the poverty level are eligible for free energy efficiency improvement. The program is structured to help target households with higher-than-average energy use.

Box 3-1: Acting on NEP Recommendations:

- NEP Recommendation 4.3 calls for extension of the Energy Star pro-gram to additional appliances.
- NEP recommendation 4.4 calls for identification of further opportunities for energy efficiency through appliance and equipment standards

Commercial buildings

BTS has recently developed a roadmap for commercial building integration research. This effort is relatively new, and totals $4.5 M in the FY2002 budget. BTS has substantially more experience with the development of integrated building design software for the commercial sector through work on "DOE 2", now completed, and its successor, "Energy Plus". The software has been deployed in two ways: both in working with the relatively larger architectural and engineering (A&E) firms often involved in the design

[2] 2000 BTS Core Databook, Summary Sheet, Table 7.

of new commercial buildings and in development of professional energy standards, which have served as the basis for state commercial building codes.

The Rebuild America program, part of the Community Energy Program, is the primary vehicle for delivering technical assistance regarding efficiency improvements in existing commercial buildings. The program involves partnerships with communities interested in overall assessments of, and improvements in, their existing building stock. The community approach is intended to engage building suppliers, local architects, and others in the field to help facilitate permanent changes in local building renovation practices, rather than just achieving building-by-building savings.

INDUSTRY

Because this sector is substantially more varied in its energy uses and efficiency potentials than are the other sectors of the economy, modernizing energy conservation requires a more disaggregated approach than is necessary in the other sectors. In addition, changes in energy use cannot be made in isolation of the industrial process itself. As a result, efficiency improvements often have to be developed in conjunction with overall improvements in manufacturing productivity.

System efficiency potentials can be quite large in this sector—any avoidance of heating, cooling, and reheating, for instance, can save substantial amounts of energy independent of the efficiency of the heating and cooling equipment. On a slightly larger scale, additional materials recycling, production of waste products into profitable products and other industry-wide changes can also reduce energy use in commodities industries.

OIT utilizes a two-part strategy for addressing these conservation potentials:

Intensive industries

Through the Vision Industries program, begun in 1994, approximately half of the OIT FY02 budget is directed towards pre-competitive research with eight of the most energy intensive industrial sectors, largely commodities-based industries. The Vision Industries include agriculture (primarily bio-based products industries), aluminum, chemicals, forest products, glass, metal casting, mining, petroleum refining,[3] and steel. These industries account for more than 75 percent of energy use and have up to four times the energy-intensity of most other manufacturing industries.

The VI strategy for working with these industries is to develop and implement vision and technology roadmaps in pursuit of medium- and long-term technology opportunities. Industry leaders collaboratively define a vision, develop industry-wide long-term goals, and create technology roadmaps that articulate specific technology and research strategies to achieve the vision. DOE issues competitive R&D solicitations in support of the roadmaps, requiring 20-50% cost share depending on the stage of research/development. OIT selects projects that help meet national energy goals and provide public benefits, have industry buy-in by addressing top industry needs, and require government support if they are to be done. Research is conducted through companies, in collaboration with national laboratories and universities. VI has established very effective partnerships with industry, in part, because public-private roles are well defined.

The research undertaken pursuant to VI roadmaps is developed to focus research on longer-term, strategic research. The roadmaps, some of which are entering their second edition, identify specific areas of

[3] The Petroleum Vision Industry technology roadmapping work was completed, no further DOE support was found to be warranted at this time, and no funding was requested for this activity in FY03.

research that would be of benefit to the sector as a whole. For example, the steel industry (in its 2001 updated draft of the "Steel Technology Roadmap") established a goal for developing an electric/oxygen furnace (EOF) by the year 2015. For the Chemical VI, OIT support to the industry has resulted in the development of a technology for electrodeionization of wastewater to recover water from chemicals manufacture and petroleum refining.

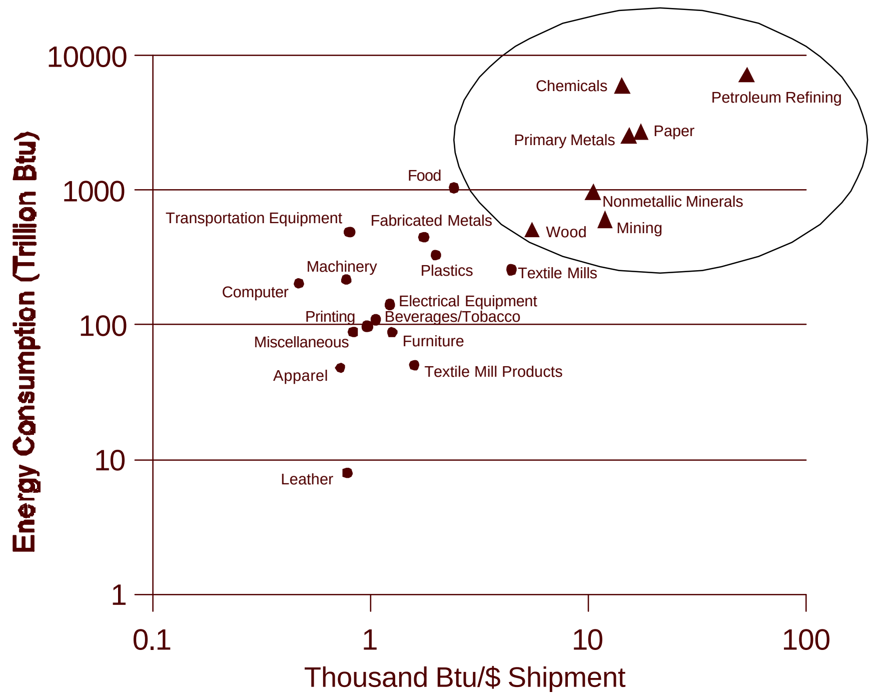

Figure 3-2: Energy intensity of various industries, with the Vision Industries circled.

Crosscutting applications

OIT's Enabling Technologies program focuses on developing cost-shared R&D that has broad application across the nine vision industries, with particular emphasis on developing clean combustion technologies, sensors and controls, and advanced industrial materials—all of which are geared toward increasing energy efficiency. Emerging from the Motor Challenge program, the Best Practices program is targeted towards the dissemination of information on means of improving efficiency of plant-wide systems, including motor, compressed air, steam, and process heat.

The type of information or technical assistance provided varies with the type of firm. Smaller firms can receive free energy audits through the Industrial Assessment Center (IAC) program. In operation since 1976, the program is administered through engineering schools as a means of improving industrial energy management education as well as helping individual firms save energy. For the larger firms, the technical assistance activities complement RD&D efforts. Technical assistance includes a continuum of services, from energy assessments and evaluations, through information on industrial equipment and systems, to tools and resources for measuring the effectiveness of new technologies. Larger firms can arrange for energy audits on a cost-shared basis.

Finally, the OIT Financial Assistance Program helps independent inventors, small businesses, and industry that lack the funds and/or know-how to move promising energy-savings and energy production technologies from the research bench to the marketplace. Program components include the Inventions &

Innovation Program and the National Industrial Competitiveness through Energy, Environment and Economics (NICE-3) Program that award grants and cost-shared grants, respectively, to inventors and industry-state technology innovation partnerships.

TRANSPORTATION

R&D represents approximately 90% of OTT's budget (FY02 budget), the great majority of which is used for vehicle efficiency improvements. Recent research on light duty vehicle systems has sought to develop technical improvements that will enable the production of family sedans with mileage of 80 mpg. However, since most light duty vehicle sales are not family sedans, a reorientation away from platform-specific technology is warranted. Representative activities include:

- **Engines**. A portion of engine research is targeted towards reducing the NO_x emissions associated with the diesel compression ignition, direct injection (CIDI) engine in order to help ensure that it can meet the TIER II emissions standards.

- **Materials.** The materials program seeks to increase efficiency further by developing materials that can reduce vehicle weight without reducing structural or other components of the vehicle.

- **Fuel Cells.** The fuel cells program focuses on developing cost effective fuel cell systems to power vehicles. The launch of FreedomCAR brings emphasizes the importance of this approach to allow use of domestically produced hydrogen in place of imported oil, and eliminating vehicle polluting and greenhouse gas emissions..

Research on heavy-duty vehicle systems includes reducing aerodynamic drag, more efficient engines, and auxiliary power systems for cab heating and cooling.

Deployment efforts related to vehicle efficiency are limited to publication of the Fuel Economy Guide, website information dissemination, and testing and validation of performance and emissions for advanced technology vehicles. The Clean Cities Program also supports public-private partnerships that deploy alternative fuel vehicles and builds supporting infrastructure.

POWER

EERE has a number of programs that address two large opportunities for efficiency improvements in the power sector. Approximately 5-7% of all electricity produced in the United States is lost in transmitting and distributing it to consumers. The Office of Power Technology's (OPT) High Temperature Superconductivity (HTS) program seeks to reduce the electricity losses associated with moving electricity within largely urban areas, as well as improving the efficiency of large motors and electric generators.

Although improvements in generation efficiencies are occurring, conventional electricity generation currently converts only about one-third of the fuel's potential energy into usable energy. The remaining two-thirds is lost in the form of waste heat. OPT's Office of Distributed Energy Resources (DER) develops advanced applications of combined heat and power (CHP) systems. These systems combine small advanced turbines, reciprocating engines, fuel cells, or other electricity generation devices located at the point of electricity use with technologies that utilize the waste heat for hot water, space heating, process heat, and other on-site uses.

MODERNIZE OUR ENERGY INFRASTRUCTURE

The reliable delivery of energy, including electricity, depends on increasingly complex infrastructures stretching from wellhead to pipeline to power generation, transmission, and distribution, to the equipment operated with that electricity. A fully modernized infrastructure can integrate each of these components into a more efficient and reliable energy service delivery network, capable of monitoring real-time supply and demand and adjusting usage activities accordingly at substantially lower over-all costs than the traditional hub-and-spoke approach.

EERE directly contributes to the modernization of our electricity infrastructure in a number of non-traditional, but potentially high-value added ways, which can contribute substantial savings to the overall costs of maintaining a reliable energy infrastructure (see also Box 3-2). In some cases, the least expensive option will be the development of additional traditional, centralized power plants and associated transmission upgrades. In other cases, the least expensive or most reliable option will be on-site generation, bypassing the need for new centralized transmission capacity. By addressing electricity and other energy markets as a system, EERE's portfolio is intended to help expand the range of reliable, lower-cost technology solutions available to the market (see Box 3-3). Although the primary EERE infrastructure emphasis is on electricity, some programs also help reduce the need for new fuels infrastructure to facilitate the possibility of transition to bioenergy, hydrogen or other domestic energy resources.

IMPROVED EFFECTIVE CAPACITY OF THE TRANSMISSION SYSTEM

The DER program is developing protocols to boost the operational efficiency of the existing transmission system in the short run. Over the longer run, the HTS program is developing applications of superconducting materials to electricity infrastructure. Superconducting materials have the ability to conduct electrical current with essentially no resistance, although energy is required to cool the cable to its operating temperature. HTS cables can carry three to five times more power than conventional utility cables for the same size cable. An HTS cable is currently being field demonstrated in Detroit.

LOWER COST AND MORE PRACTICAL STORAGE

Storage of fuels or electricity helps even out demand loads, reducing the peak capacity that the infrastructure must support. DER works on developing transportable storage systems through its Energy Storage Systems subprogram. Fuel Cell R&D under OPT is also developing reversible fuel cells for energy storage. OTT also contributes to energy storage issues through its Electric Vehicle R&D and Hybrid Systems R&D programs.

Box 3-2. Infrastructure areas with no, or limited, current EERE role.

- EERE does not address the issues related to the infrastructure for oil, oil products, or natural gas (e.g., pipeline safety, need for additional capacity), as they do not link directly to EERE's goals or mission.
- EERE explores on a limited basis the infrastructure issues related to the development of new energy resources and applications, including bioenergy (Biopower and Biofuels programs) and hydrogen (Hydrogen program), and alternative vehicle fuels (Fuels Utilization and Transportation Technology Assistance programs).
- OPT addresses issues of development of renewable electricity resources on Federal lands, but not the siting of transmission systems there.

DISTRIBUTED GENERATION (DG) RESOURCES

By producing electricity where it is used, distributed energy technologies can reduce the need for developing a costly new centralized infrastructure to deliver energy to distant customers that will suffer from some of the same weaknesses as the current system (e.g., transmission loss, vulnerability). Also, because distributed generators are located near the point of use, they allow for the capture of the waste heat produced by fuel combustion or fuel cells through combined heat and power (CHP) systems.

Box 3-3: Interactions with other NEP Goals.

EERE's end-use efficiency portfolio contributes to the overall reliability of our energy infrastructure by reducing the need for additional capacity and providing additional flexibility in the use of existing capacity.

- Across EERE, programs have focused increasingly on the role of IT technologies in providing opportunities for consumers to sell electricity back to the grid during peak demand periods, which can help to prevent outages and price spikes
- Because the buildings sector contributes the bulk of peak electricity demand, BTS programs help to significantly reduce the need for new power plants and transmission lines, while enhancing overall electricity reliability.
- OIT undertakes a number of research efforts, especially in the pulp and paper area, that contribute to the development of on-site electricity generating capacity in the industrial sector. OIT is also working to encourage industrial firms with the flexibility to schedule their production during off-peak electricity demand periods to reduce peak loads.
- OPT renewable energy programs both help to maintain existing generating capacity (e.g. hydropower) and to develop new opportunities for renewables to reliably meet growing electricity demands.

DG technologies often pose technological and regulatory challenges because of their need:

- for a relatively small footprint;
- for standardized interconnection protocols;
- for revised tax treatment to receive benefits given to other generators;
- to more carefully match local loads; and,
- to address environmental siting, permitting, and safety issues in zoned residential and commercial areas.

DG opportunities are being explored across OPT. The DER program currently conducts research and development in industrial gas turbines, CHP systems, fuel cells, microturbines, reciprocating engines, and thermally activated systems. The Solar program, in conjunction with BTS, undertakes research and development on rooftop PV and solar-thermal systems. As the Wind Energy program moves toward smaller-scale applications, this program will also increasingly provide DG opportunities. In several cases, technologies being developed for distributed application are also being developed by other DOE offices for traditional, centralized applications, including large advanced turbines and fuel cells.

Regulatory barriers to a modernized infrastructure

The Transmission and Distribution sub-program within the DER program addresses some of the barriers to a new electricity infrastructure by focusing on satellite synchronized measurements, high capacity transmission, and DER integration with the grid.

Emergency response

The DER, FEMP, and DEMP programs each contribute to electricity infrastructure emergencies. The FEMP and DEMP programs coordinate reduced peak demands at Federal facilities while the DER program provides assistance in locating available, clean sources of replacement power, usually in the form of DG units.[4]

REDUCED FUTURE DEMAND

All of the EERE end-use efficiency programs that help reduce peak electricity and natural gas demand also help reduce the need for new pipeline and transmission capacity, and reduce the current strain on existing electricity production and distribution systems. When EERE recently reorganized its portfolio to facilitate this systemic approach to infrastructure and reliability issues, it incorporated most components into OPT and created the DER program.

INCREASE ENERGY SUPPLIES

EERE R&D portfolio includes development of two types of domestic sources of energy: bio-based fuels and nonfuel renewable energy resources, such as wind and photovoltaic systems.[5] EERE's energy supply programs are focused on highly advanced applications of both types of these abundant domestic resources. Indeed, renewable resources are inexhaustible or non-depletable, which means that their use today will not limit the supplies available for future generations.

While some energy sources, such as solar radiation and wind, are non-depletable by their nature, others such as bioenergy resources can be developed in such a way that they are essentially inexhaustible. In addition, EERE is undertaking R&D related to the production and use of hydrogen as an energy source.

BIOFUELS

Through its Biofuels Initiative, EERE funds research, development, and deployment of technology to enable and support the expansion of an indigenous, integrated biomass-based industry that will provide for productive utilization of agricultural residues and municipal solid wastes. The bioenergy program is focused on development of cost-effective cellulosic ethanol additives with the potential to greatly expand the domestic availability of ethanol beyond that which can currently be produced from corn. Biodiesel represents an additional opportunity with U.S. production in 2000 of about 5 million gallons. Some research continues on electric and natural gas vehicles, albeit at lower levels than in the past. In the case of electric vehicles, the focus has shifted to electric-hybrid and, particularly, to fuel cell vehicles with the launch of FreedomCAR. In the case of natural gas, previous R&D successes have led to today's availability of natural gas engines in the marketplace. OTT's Fuels Utilization R&D program is completing development of cost-effective systems for class 3-8 trucks that can help make natural gas a preferred vehicle fuel option. Work on advanced diesel engines, while potentially providing more efficient consumption of a petroleum product, would also provide some additional market flexibility by facilitating a greater mix of refined petroleum products in vehicles.

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[4] In light of the energy crisis in California during early 2001, President Bush issued a Directive on May 3, 2001, ordering Federal agencies to conserve energy at their facilities.

[5] Load reductions through demand-side management can also be considered creation of new sources of electricity, so called "negawatts".

NON-FUEL RENEWABLE SUPPLIES

EERE's portfolio of non-fuel renewable energy sources includes wind, geothermal, hydropower, and solar (see also Box 3-4). These resources are at various stages of development, with each having both some commercial applications underway based on past R&D successes and additional opportunities possible for resource development.

- **Wind.** Advanced wind turbines are currently providing cost-competitive power in high wind (class 6) areas. As a result, the Wind Energy program is shifting its focus to new and different turbine advances that will allow for competitive wind development in the much more widely available class 4 wind areas.

- **Photovoltaics.** The cost of electricity from photovoltaic systems has fallen to roughly 20-30 cents per kWh today, depending on the application, in regions with good insolation. While still well above market prices for grid-connected electricity, PV is often the cheapest source of electricity in locations without a nearby connection to the grid.

- **Geothermal.** The Geothermal Energy program works in partnership with U.S. industry to establish geothermal energy as an economically competitive contributor to the U.S. energy supply, capable of meeting a large portion of the Nation's heat and power needs.

- **Hydropower.** In the case of hydropower, already an abundant and relatively inexpensive source of electricity, OPT focuses on making hydropower plants more compatible with aquatic life and other water resource users through "fish-friendly" turbines and the reduction of changes in the quality of dissolved gases in downstream water.

Box 3-4: Energy Supply areas with no, or limited, current EERE role.

EERE, by the nature of its goals and mission, contributes to the supply goal only through renewable and alternative energy resources. It therefore does not address development of new fossil or nuclear energy resources, these being addressed by the other two offices in the DOE Energy Resources Business Line.

Federal R&D on biobased products and bioenergy is undertaken jointly by DOE with EERE as lead, the Department of Agriculture, EPA, and seven other Departments and Agencies. Each performer leads efforts to support the development and commercialization of these technologies. DOE leads in the research and development of many of the process technologies, USDA in commercialization and technology transfer, and EPA in regulatory flexibility.

EERE's R&D strategy for some renewables differs somewhat from strategies being undertaken in Europe and Japan. For example, while Denmark is pursuing the development and use of very large and heavy wind turbines for off-shore applications, EERE's wind program is turning toward lighter weight turbines that can cost-effectively tap lower speed Class 4 wind resources, which are abundant throughout the United States.

HYDROGEN

OPT's Hydrogen program supports the research, development and validation of hydrogen technologies in production, storage, and utilization. The program works with industry to improve efficiency, lower emissions, and lower the cost of technologies that produce hydrogen from natural gas, as well as working with national laboratories to reduce the cost of technologies that produce hydrogen directly from sunlight and water. An abundant source of power, hydrogen can be used in stationary applications, such as residential fuel cells, as well as in fuel cell powered vehicles.

EERE attempts to promote renewable energy in ways other than through research and development (see Box 3-5). For instance, the Renewable Energy Production Incentive (REPI) was established by the Energy Policy Act of 1992 to provide an incentive payment to qualified electric power plants owned by state or local governments, or by nonprofit electrical cooperatives that produce electricity from solar, wind, geothermal, or biomass energy.

Box 3-5: Acting on NEP Recommended goals within EERE.

The NEP calls for integrating the R&D efforts of the Hydrogen, Fuel Cell R&D, and Distributed Energy Resources programs. Currently, the Hydrogen program is part of OPT, the Fuel Cell R&D program is within OTT, and Distributed Energy Resources is a crosscutting program housed within OPT. Although these programs already interact to a considerable degree because hydrogen and fuel cells are both key distributed energy technologies, in light of this specific NEP recommendation EERE is working to better integrate their activities and, therefore, promote the broad NEP goal of increasing the Nation's energy supplies

The NEP also calls for DOE to develop next-generation energy supply technologies through specific actions, such as developing an educational campaign that communicates the benefits of alternative energy sources. Implementing this recommendation will change both the priorities of the Office of Planning, Management, and Budget's outreach office, and the outreach efforts of several programs within OPT.

ACCELERATE THE PROTECTION AND IMPROVEMENT OF THE ENVIRONMENT

Although EERE's portfolio entails only very limited efforts directly related to improving the environmental performance of energy systems (see Box 3-6), virtually the entire portfolio contributes towards significant reductions in the environmental impacts of energy consumption by either decreasing the overall amount of energy required to supply energy services, or increasing the usage of no- or low-emission alternative and renewable energy resources. Since greater energy efficiency reduces the amount of energy used in a given activity, it benefits the environment by avoiding the amount of environmental emissions associated with the production, generation, or consumption of that particular type of energy. For instance, in the buildings sector, reduction in the amount of electricity used through the creation of advanced lighting systems will also eliminate the corresponding emissions of SO_x and NO_x that occur during electricity generation. Non-fuels renewable resources are often zero-emissions sources of power and/or heat.

Box 3-6: Acting on NEP Recommendations.

EERE is contributing to two of the major NEP recommendations regarding the environment.

-- The DER program is participating in the development of multi-pollutant legislation (SOx, NOx, & Hg).

-- DER is also developing technologies that minimize the obstacles to site permitting.

Under the Government Performance and Results Act (GPRA), EERE develops program-specific estimates of emissions reductions associated with its efficiency and renewable programs, allowing these contributions to the NEP to be weighed along with contributions to energy efficiency and energy supply goals in making portfolio choices. In addition to these overall direct contributions to the NEP goal of accelerating the protection and improvement of the environment, EERE's portfolio includes a number of projects that specifically target improved environmental performance of advanced renewable or efficient equipment (see also Box 3-7). A sample of these projects follows:

- One of the primary aims of the Hydropower Program is to minimize the environmental impact of an already prominent zero-emission energy source through the development of more "fish-friendly," low-impact turbines.

- The restructuring project in the DER Program addresses potential role for renewables and efficiency in meeting Clean Air Act requirements.

- The Clean Cities Program, while broadly addressing the use of alternative fuels in vehicles, has been a particularly popular partnership program in CAA non-attainment areas, with many of its 7,000 partnerships located in these metropolitan areas. In other areas of the country as well, participation in Clean Cities is a way to improve local air quality.

- The OTT program Advanced Combustion Engine R&D develops technologies that aim to improve the fuel efficiency of conventional piston engines while meeting emissions regulations. The program has already developed certain NO_x catalysts that have achieved greater than 90% NO_x conversion efficiency in laboratory bench tests.

- OPT's Wind Energy program is working to decrease avian mortalities and minimize turbine noise pollution, two issues that will not likely be mitigated by market forces.

- OIT's Vision Industries program works to cut emissions from industrial processes both by promoting less-polluting processes and reducing the amount of energy those processes demand.

Box 3-7: Environmental improvement areas with no, or limited, current EERE role.

Most of the energy efficiency improvements in the industrial sector result in process efficiency improvements as well, which can help firms reduce their non-energy-related environmental impacts; however EERE does not track or directly fund these sources of reduced environmental impacts.

EERE's work on indoor air quality is directly related to the interactions of building energy efficiency measures and air quality, and supports broader indoor air quality research funded by EPA.

INCREASE ENERGY SECURITY

EERE's programs address energy security in five distinct ways: First, EERE has a substantial focus, largely within the transportation sector, on reducing oil dependencies and related national security risks. Second, EERE is addressing means of making our domestic electricity infrastructure less vulnerable to disruptions from either natural or man-made events. Third, EERE helps coordinate Federal responses to the Nation's emergency power needs. Fourth, EERE works with basic commodities industries whose products have military and strategic importance and, as such, are advantageous to have available domestically. Fifth, a number of EERE technologies provide unique solutions to the military need for portable energy supplies and can significantly improve military transport efficiencies and logistics.

OIL SECURITY

EERE programs designed to reduce the oil intensity of the economy have evolved substantially since the late 1970s. Much of the early effort focused on oil reductions in the buildings and industrial sectors, small businesses, hospitals, and schools. One BTS effort helped bring flame retention burners for home oil heaters to the market, significantly reducing residential oil consumption.

The current EERE portfolio focuses on oil only in the transportation sector, with remaining oil consumption addressed in the other two sectors as part of more general energy efficiency programs. The two areas of transportation research described above—improved efficiency and development of domestic alternative fuels—jointly constitute one of the primary areas of current U.S. efforts to reduce oil dependencies and the potential for oil supply disruptions. These research efforts address both technologies applicable to current, relatively moderate-price oil markets and the development of "contingency" technologies that could facilitate a future transition to a highly efficient or non-oil transportation system if needed.

Reducing Oil Intensity

All else constant, the gains in vehicle fuel economy realized from 1974 to 1998 have reduced U.S. oil consumption by roughly 5.2 million barrels per day.[6] Combined with improvements in fuel economy worldwide, these technologies have been instrumental in achieving the lower oil prices we have enjoyed for much of the last decade and a half. In addition to R&D on improved efficiency, OTT publishes the annual "Fuel Economy Guide" to allow consumers to conveniently compare mileage.

Box 3-8: Interaction with other NEP goals

The development of biofuels also assists the NEP's environmental goal.

- Biofuels use products that would otherwise be treated as waste.
- Bioethanol is cleaner burning than petroleum and can serve as substitute for MTBE.
- There is a growing interest in using biodiesel where workers are exposed to diesel exhaust, in aircraft to control local pollution near airports, and in locomotives that face restricted use unless emissions can be reduced.

Alternative fuels

OTT pursues both an R&D and deployment strategy with regard to alternative vehicle fuels. Biofuels, natural gas, and electricity are the primary alternative fuels being explored by OTT. Fuel cells potentially expand transportation fuel options to hydrogen produced from fossil fuels or renewable energy. Biofuels and renewable generation of hydrogen or electricity offer non-depletable energy supplies for transportation (see also Box 3-8), while natural gas vehicles offer a more near-term trade-off between oil and an existing energy source with an extensive supply network. OTT's Clean Cities program is principally an alternative-fuel and advanced-vehicle deployment program designed to provide early market experience with emerging alternative fuels and vehicles, as well as helping to establish needed infrastructure.

International demand reduction

EERE's International Programs provide a gateway for accelerating dissemination of efficiency and alternative fuels technologies abroad. In addition, the international nature of the vehicle market indicates

[6] MER, Aug. 2001, Tables 1.8, 1.10.

that there are "spill-over" benefits to international markets from R&D efficiency improvements in vehicles. EERE does not currently attempt to estimate either of these impacts on energy prices or markets, but recognizes the importance of potential oil savings in international markets.

ELECTRICITY INFRASTRUCTURE VULNERABILITIES

The mix of EERE programs addressing electricity conservation and infrastructure reliability enhancements also help reduce the potential for severe disruptions of electricity services during emergencies. Distributed generation can be designed to help maintain electricity supplies in the event of loss of centralized power. Reductions in peak electricity use provide additional margin for transmission networks if particular power plants or transmission lines become unavailable. As an alternative to rolling blackouts, advanced load management technologies and markets can provide rapid, targeted reductions in electricity demand during temporary periods of shortage, helping to maintain electricity availability for the most essential services while selectively reducing consumption by less critical items.

EMERGENCY RESPONSE

FEMP and OPT work with DOD, FEMA, and other key Federal and state offices to provide technical support for development and use of mobile and distributed energy sources during and in preparation for energy emergencies. FEMP coordinates Federal participation in state and local demand reduction plans, and provides technical assistant to Federal agencies to identify load reduction opportunities. OPT provides consultation on options for local emergency power supplies.

COMPETITIVE COMMODITIES

Several of the OIT Vision Industries subprograms work with industries that produce basic commodities of strategic importance (e.g., aluminum, steel) and can help strengthen cost-effective domestic production of these commodities. The Secretary has noted that the Department of Energy and its forerunner organizations have had national security as a principal focus for fifty years.[7] By entering into cost-shared research and development projects that would not be done by the corporate sector alone in the absence of the program, these Vision Industries subprograms are strengthening our strategic materials production capabilities.

MILITARY APPLICATIONS

In some cases, renewable and efficiency technologies developed with EERE assistance have helped meet specific military needs. Photovoltaic cells, for instance, are used to help keep military vehicle batteries charged between uses. Solar power can also be used locally to produce clean water, refrigerate medicines, and operate communications equipment. Most importantly, these technologies do not rely on the availability of fuel supplies in order to continue to provide their services.

The potential impact of increased transportation fuel economy on military energy consumption is tremendous. The U.S. Department of Defense is the single largest user of energy in the United States.[8] In 2000, when total energy consumption in the United States was 98.5 quads, Federal energy use totaled 1.0 quad, with 80% of that energy consumed by the Department of Defense.[9] Of the top ten battlefield fuel consuming systems in the military, six are non-combat transport vehicles, such as truck tractors and cargo

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[7] Secretary of Energy Spencer Abraham, "The Mission and Priorities of the Department," 2001.
[8] AER 2000, Table 1.13.
[9] *Ibid*, Table 1.1, 1.13.

transports that could benefit from increased fuel efficiency.[10] Moreover, fuel comprises 70% of Army tonnage shipped to the battlefield.[11] Considering the "true cost" of transporting fuel to the front lines in a combat situation is as high as $25/gallon, fuel efficiency improvements can reap enormous economic and energy savings.[12] While the performance requirements for military vehicles vary considerably from those of commercial vehicles, there are many synergies whereby military vehicles can benefit from EERE research, especially through OTT's Heavy Vehicle Systems R&D program.

This brief survey indicates the alignment between EERE's portfolio and the National Energy Policy and identifies where this alignment can be strengthened.

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[10] Admiral Richard Truly, "Improving Fuel Efficiency of Weapons Platforms: An Analysis," National Renewable Energy Laboratory, August 2001.
[11] *Ibid.*
[12] *Ibid.*

Chapter 4

Program Technical Merit and Performance

SUMMARY

The National Energy Policy called for a review of the "historic performance" of the EERE programs and for the Secretary of Energy to propose appropriate funding of those programs that are "performance-based" and are modeled as "public-private partnerships".[1] In this chapter, the Strategic Program Review (SPR) examines these three factors from the perspective of EERE programs' technical performance.

Historic Performance

The SPR examined the historic performance of EERE on the basis of patents, awards, technical accomplishments, benefits (Chapter 5), and other factors.

- **Patents** were evaluated as a possible indicator of program performance; however, they were found by the SPR to offer no clear means at this time for benchmarking the relative value of their associated programs against either a baseline or the performance of programs of other institutions. The relative value of patents was not readily discernible, the numbers of patents were not necessarily correlated with the level of program innovation or impact, and, although some programs had tracked their patents, a number of EERE programs within EERE have not tracked their patents effectively and were not able to generate comprehensive listings of them. Consequently, patents were not considered further as an overall indicator of performance. It should be noted, however, that the limited tracking of patents identified over 70 in the Buildings sector, over 180 in Transport, and over 560 in Power. Patents pending and patent disclosures are further indicators of activity in patenting of technological developments emerging from the EERE programs. Future tracking of patents and other such measures of performance is needed together with citation analysis.

- **Awards** were identified by the SPR as an important measure of external peer recognition of program performance. Although EERE programs received numerous awards of many types, most were too narrow in scope to provide adequate comparison of EERE programs to R&D programs of other institutions. The R&D100 award, however, provides broad technology coverage—not just energy; it provides broad participation—across companies, universities, public agencies, and countries; it is externally awarded and independently peer reviewed; and it is widely recognized and highly regarded. The R&D100 awards have been characterized as the "Oscars of Invention". Consequently, the SPR selected the R&D100 award as an indicator of performance. Across all EERE supported research, some 105 R&D100 awards were received for the period 1978-2001 (Chapter 4 Appendix Table 4-A5). As Figure 4.1 indicates, EERE's 105 awards placed it above all other government agencies except NASA,[2] with 125 R&D100 awards; above all companies

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[1] "National Energy Policy," Report of the National Energy Policy Development Group, (Washington, DC: U.S. Government Printing Office, May 2001), page 4-3, 6-4.

[2] No comparison is made to DOE itself, which had more total awards than any other entity.

except GE, with 163; above all other countries except Japan, with 157; and above all universities (MIT was first with 30). Specifics of this tabulation, including associated uncertainties, are detailed later in this chapter. Overall R&D100 totals for these other organizations were generally evaluated from 1963 to 2001 while the EERE total was evaluated from 1978-2001. The number of R&D100 awards received by EERE was observed to increase over time, with about 80% of the total received in the past ten years, and over half of the total from 1995 on; predecessor agencies to EERE received a total of 6 awards through 1977 (Figure 4-1). EERE accounted for about 25% of the R&D100 awards received by DOE from 1996 to the present, using about 6% of DOE's budget during the same period.

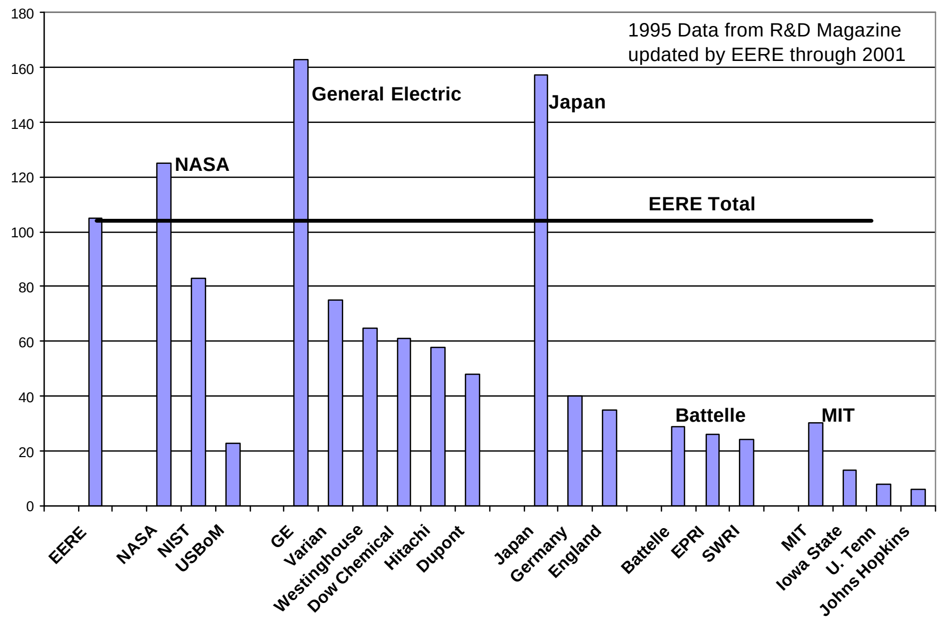

Figure 4-1: Total number of R&D100 awards received by EERE-supported research, 1978-2001, compared to the number of awards received by the top recipients among other Federal agencies, companies, countries, research institutes, and universities for 1963-2001. Source: R&D Magazine, September 1995, as updated by the SPR through 2001 by compiling individual award citations for 1996-2001.

- **Technical accomplishments**—including specific technical innovations, performance gains, reductions in cost, improved design tools, standards, and others—were examined and a subset of more than 150 EERE results is detailed in Table 4-A7 at the end of this chapter. Brief examples include:

  - *Buildings*. EERE work with the national labs, industry, and others cut refrigerator electricity use by nearly three-fourths from its level of 25 years ago even as significantly more features were added. Building energy use can now often be cut in half cost-effectively compared to current standard practice, and technologies to turn buildings into net energy producers with little or no emissions are available, if expensive.

  - *Industry*. EERE work on advanced combustion, combined heat and power, electronic motor drives, advanced materials, and improved sensors and controls have made possible dramatic reductions in industrial energy intensity. For example, EERE developed with industry Lost Foam Metalcasting with an average 27 percent savings in energy, a 46 percent increase in productivity, and a 7% reduction in materials use.

- *Transport*. EERE work with the national labs and industry cut the platinum content, a key cost of PEM fuel cells, by a factor of 10 over the past eight years; and some estimate that the overall cost of PEM fuel cells, assuming mass production, has been reduced by a factor of 10 as well.[3] Hybrid and fuel cell concept cars have been demonstrated with nearly three or more times the average efficiency of current cars, and the National Academy of Sciences noted "The most significant oil savings benefits from the energy efficiency program are embodied in the prospects for PNGV."[4] The FreedomCAR effort will accelerate fuel cell work.

- *Power*. In renewable energy, independent external reviews found cost reductions for specific technologies closely followed aggressive EERE projections, with technologies such as photovoltaics and wind turbines dropping in cost by as much as ten times over the past two decades.[5]

The National Academy of Sciences' National Research Council (NRC)[6] noted that EERE was "dominant" or "influential" in half of what the NRC identified as the most important technological innovations in energy efficiency since 1978.[7]

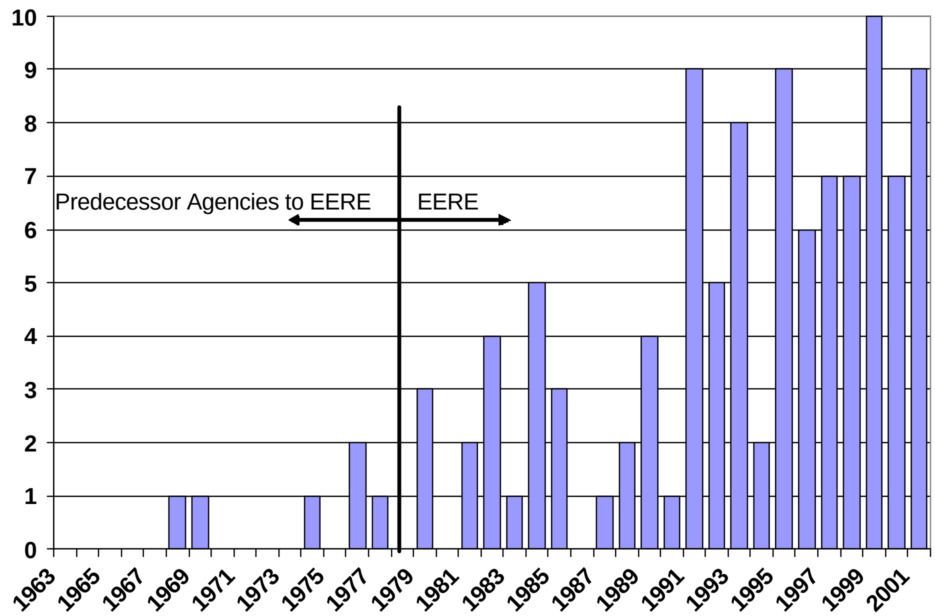

Figure 4-2: Number of R&D100 awards received by EERE-supported research by year, together with awards received by predecessor agencies to EERE before it was formed in 1978. Source: R&D Magazine, September 1995, as updated by the SPR through 2001 by compiling individual award citations for 1996-2001.

[3] A.D. Little, Inc., "Cost Analysis of Fuel Cell System for Transportation", March 2000. ref. 49739. This baseline cost analysis assumes a production rate of 500,000 systems per year and year 2000 technologies.
[4] National Academy of Sciences, National Research Council, "Energy Research at DOE: Was It Worth It?," July 2001, page 67.
[5] James McVeigh, Dallas Burtraw, Joel Darmstadter, and Karen Palmer, "Winner, Loser, or Innocent Victim? Has Renewable Energy Performed As Expected?" Resources for the Future, Washington, DC, Discussion Paper 99-28, March 1999; June 1999.
[6] The National Research Council was created under the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine; for simplicity and brevity, this will be abbreviated here as NRC.
[7] NRC, "Energy Research at DOE: Was It Worth It?," July 2001.

Performance-based

The SPR found that EERE programs had been substantially reinvented over the past decade, with a strong emphasis on performance. Key elements of this reinvention include:

- **Technology push to market pull**. EERE RD[3] activities transitioned from primarily "technology push", based largely on laboratory-identified R&D, to primarily "market pull" built on technology roadmapping with industry partners., EERE has developed more than 40 technology roadmaps with industry partners in the past 5 years (Table 4-A1).[8]

- **Competitive solicitations**. EERE efforts evolved from primarily cost-plus contracts to competitive solicitations with cost sharing, as described in Chapter 6. Overall, approximately two-thirds of EERE solicitations that reside in the DOE Procurement Acquisition Data System (PADS) database are competitive instruments, up from the 25 percent rate in 1996, as identified by the NAPA review. This improvement was driven in part by a 1996 Congressional review that criticized EERE's reliance on non-competitive financial assistance actions for executing so much of its work. Since that time, EERE has continued to improve its competitiveness through a policy that promotes competition. During this same period, DOE re-competed most of its M&O contracts, which changed the complexion of much of the work being performed with the national laboratories. Together, these factors have substantially increased EERE's use of competitive instruments, although it should be noted that competitive solicitations are not the only means of ensuring performance-based work.

  EERE estimates that EERE financial assistance activities leverage approximately a forty percent non-Federal cost share. However, the estimated cost share value is tentative due to the SPR identification of a number of problems in the DOE-wide PADS information database. Additionally, EERE is unable to evaluate the cost share of laboratory subcontracts awarded through the national laboratories, as this information is not tracked with current DOE-wide systems. This significantly impacts EERE's overall estimated cost share. These issues are detailed in Chapter 6.

- **Integrated Systems**. EERE moved from individual component R&D to primarily integrated systems R&D, as evidenced by the buildings sector reorganization to "Whole Buildings" approaches; the transport sector's reorganization to integrated vehicles under the Partnership for a New Generation of Vehicles and the 21st Century Truck programs; the industry sector reorganization to a "Whole Industries" approach under the Industries of the Future program; and the development of the integrated Bioenergy and Distributed Energy Resources programs.

- **Goals, Metrics, Milestones**. EERE transitioned from open-ended research to focused research with specific goals, metrics, and milestones. The 1993 Government Performance and Results Act mandates that with each fiscal year's budget submission, Federal agencies develop and communicate to Congress a performance plan that describes the agency's mission, goals, key upcoming performance measures, and report on previous progress. Such efforts have increased since the NAPA review, with every program developing overall goals, metrics, and milestones for its activities—with varying degrees of success—which are tracked by program managers, office directors, and Deputy Assistant Secretaries. Sectors/Programs such as the OTT Office of Advanced Automotive Technologies have developed innovative internal Internet platforms to track activities in detail.

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8 Note that the early use of technology push also reflected in part the emphasis on conducting basic R&D.

- **Peer Review**. EERE has increased its emphasis on external peer review. Numerous external peer reviews were identified, as tabulated in appendix table 4-A3, including reviews by the National Academy of Sciences, National Academy of Public Administration, President's Committee of Advisors on Science and Technology, General Accounting Office, Congressional Office of Technology Assessment, AD Little, and others. More than 20 external peer reviews were conducted by the National Academy of Sciences alone, 19 of them from 1995 on. In addition, peer reviews have also been performed at more basic programmatic levels to assist portfolio management decisions. Together, these reviews have often led to significant program redirection and refocusing.

- **Graduations and Terminations**. EERE has strengthened efforts to terminate research projects that are not performing or do not appear likely to lead to market success, and to graduate (from Federal support) research that has been successful but for which further work offers sharply diminishing returns on further Federal investment. Table 4-A2 lists more than 60 research activities that have been terminated or graduated, spread across all EERE sectors. Additionally, aggregate statistics for the Office of Industrial Technologies for the period FY98 to FY00 include 298 projects, for which public-private R&D was continued on 180, was completed on 96, and was terminated on 22. Of the 96 completed research projects, 44 were continued by industry, 34 were commercialized, and 18 contributed to the industry knowledge base. Thus, for the period FY98 to FY00, about 40% of the OIT research projects were completed or terminated. Because Congressional Budget line item titles generally remain the same from year to year, the extent of program restructuring and redirection is often not recognized externally.

Public-private partnerships

To determine the extent to which programs were modeled as public-private partnerships, the review examined the breadth and depth of partnering across the EERE programs. Specific quantifiable measures identified by the SPR include roadmapping, contracting, and cost sharing.

- **Partnering**. The shift to technology roadmapping in collaboration with industry has strengthened partnering, with over 40 roadmaps and over two thousand participants in that activity alone in the past five years. Roadmapping, which is guided by a shared vision, is just the first step in a long-term relationship forged with the private sector to pursue RD^3 opportunities in efficiency and renewables. Public-private partnership activities also include much of the RD^3 work that is done; establishing national codes and standards (ranging from building energy codes developed with ASHRAE to distributed energy system grid interconnection with the IEEE); voluntary deployment programs (such as green power or Energy Star labeling); and many others.

  Private companies, who often are R&D partners, commercially introduce EE technology. One model for such partnerships involves forming groups of competing companies to work collaboratively on issues of common interest and to share the intellectual property that results. This model works well where there is an established industry. Another model involves working with individual companies where the company gains much (or all) of the intellectual property created. This works well for an emerging technology where a strong intellectual property position is necessary to attract the capital needed to build a new business—either from venture capitalists or in the equity market. Both models can provide good leverage for Federal funds and help commercialize technology in the national interest. In addition, there are also useful models for more general information and technology dissemination efforts. OIT has employed a practice of naming "Allied Partners" who use information developed by OIT to reach out to people within their organization or industry. This practice appears to be highly effective, provides good leverage of Federal funds, and is readily transferable to other sectors. Other partnering includes work with other Federal or state agencies, universities, and non-profits.

Work undertaken is typically pre-competitive, higher-risk R&D that individual companies are unable or unwilling to undertake alone, which are then supported through these competitively developed cost-shared public-private partnerships. Activities are focused, wherever possible, to benefit a broad industry or sector rather than an individual company within that industry or sector. The large number of private participants involved at every level of roadmapping, research, development, demonstration, and deployment indicates the intensity with which public-private partnerships are pursued and nurtured. The broad use of competitive solicitations for the research undertaken coupled with the fact that much of it has a significant cost-share indicates the degree to which the work is strongly performance based and that it substantially leverages Federal tax dollars.

- **Contracting**. In contracting, there has been a strong shift to competitive solicitations with cost sharing, as noted above and described in Chapter 6. Currently, EERE maintains about 2,900 procurements spread across M&O contractors (National Labs) (27%)—of which many have industry subcontracts; educational institutions (11%); state, local, and tribes and Native American institutions (18%); private industry (15%); small business (12%); non-profits (10%); and others. Cost-sharing requirements are often an integral part of the solicitation request.

- **Cost-sharing**. As described in Chapter 6, approximately two-thirds of EERE solicitations that reside in the PADS database are competitive instruments, up from 25 percent in 1996, these competitive instruments include a cost-shared component in line with legal requirements where appropriate. EERE also does shared-in-savings contracting. An example is FEMP's Energy Savings Performance Contract (ESPC) program, in which energy service companies assume the capital costs of installing more efficient or renewable energy systems in Federal facilities and are paid directly from the cost savings generated by these technologies.

  Cost sharing in the Department will continue to be guided by statute and Administration policy. The Energy Policy Act of 1992 requires 20 percent cost share for applied research and 50 percent cost share for demonstration projects. The cost sharing guidelines developed with the R&D investment criteria as part of the President's Management Agenda are: 0-30% industry cost share for basic research; 25-50% industry cost share for applied research; 50-75% industry cost share for technology development; and 60-100% industry cost share for demonstration or commercialization.

Such public-private partnerships range over a broad array of efforts and are essential in overcoming the various barriers identified in Chapters 2 and 3.. These include cost-shared demonstrations verifying technology cost and performance, information outreach, developing testing standards, performance labeling, performance codes and standards, voluntary early adoption programs, training, technical assistance, cost buydown to help the technology move faster along its learning curve, and many others. Chapter 5 describes the benefits of these efforts.

Conclusions

Although these ongoing technical and program management changes are at times disruptive, they have substantially enhanced the performance of EERE programs. Further, these performance improvements have been achieved in cooperation and partnership with industry, national labs, and universities, in spite of the constraints and limitations of overall DOE business practices, as described in Chapter 6. Recent

EERE efforts to move past the constraints of DOE business practices with the Strategic Management System and other innovations are described in Chapter 6.

Because EERE programs vary significantly in their performance, further work is needed to spread "best practices" in technical program management throughout the organization. Raising every program to the level of the best performer in each particular area is a challenging but important goal. Benchmarking and matching the top performers in energy technology R&D and other R&D arenas more broadly across the United States and beyond, would naturally follow this. Processes for which best practices should be pursued include: roadmapping; establishing open and transparent project selection criteria; developing multiyear plans that include goals/milestones/metrics and critical path analysis; developing an appropriate balance and portfolio of activities—(ranging across time, stage of development, and other dimensions)—across specific programs, sectors, and EERE wide; strengthening peer review; building institutional memory; and others.

Although EERE-supported research has led to numerous advances, the well of energy efficiency and renewable energy technology RD^3 opportunities has not been emptied; it is replenished as understanding of these technologies and markets improves. Scientific and technological breakthroughs in materials sciences, genetic engineering, biotechnology, nanotechnology, sensors and controls, and information technology are opening up exciting opportunities for developing new energy efficiency and renewable energy technology improvements and creating more breakthroughs across every sector—buildings, industry, transport, and power. These range from advanced lighting, to improved boilers, fuel cells, aerodynamic trucks, high-efficiency photovoltaics, and many more. These technological advances also facilitate a host of ancillary benefits such as improved indoor air quality, improved productivity, improved end-user and electric grid reliability and power quality, and reduced infrastructure vulnerability.

INTRODUCTION

The use and performance of energy efficiency technologies have advanced sharply over the past two decades. In the 1970s there were significant concerns about whether energy efficient technologies could have a significant impact on the economy. Today the result is clear that these technologies have a significant and lasting impact. As noted in Chapter 2, from 1972 to 2000, the energy used per dollar of GDP produced fell by roughly 40 percent. (In comparison, from 1949 to 1972, energy used per dollar of GDP only fell by about 10%). One-half to two-thirds of this reduction in energy intensity was due to improvements in energy efficiency, with the remaining one-third to one-half related to changes in the structure of the economy. Had the energy intensity remained at 1972 levels, the United States would have used about 171 quads of energy in 2000, rather than 99 quads, with energy efficiency improvements accounting for about 36-48 quads of the savings. These savings are greater than the increase in energy supply since 1972, totaling about 26 quads,[9] including changes in domestic production of coal (+8.9 quads), natural gas (-2.5 quads), oil (-7.6 quads), nuclear (+7.4 quads), and renewables (+2.2 quads); and increased imports of natural gas (+2.6 quads) and oil (+11.8 quads). Assuming the current average energy price of $6 billion per quad remained the same,[10] these 36-48 quads correspond to savings of roughly $200-300 billion[11] per year. A recent National Academy of Sciences report notes that the EERE programs played a dominant or influential role in half of the technologies the NRC identified as the most important energy efficiency innovations since 1978.[12]

The performance of renewable energy technologies has similarly increased sharply, with the resulting cost of technologies such as wind and photovoltaics (PV) dropping as much as ten times over the past two decades. A review by Resources for the Future found that actual technology performance followed closely earlier EERE projections (see Figure 4-4). Market impacts were less than expected, however, due in part to generally low energy prices from the mid-1980s until the late 1990s.[13] This situation began to change several years ago as the cost of wind energy, for example, became increasingly competitive in the market—with assistance from production tax credits—and has posted 30-40% annual growth rates for several years.[14] Higher energy prices and continued cost reductions for renewable energy technologies are accelerating this market growth. Although some have commented that non-hydro renewables only contribute about 2% of national electricity needs, the value of this energy has grown to about $5 billion per year at present, and the contribution by these technologies, as noted, is increasing rapidly. For more than a decade, PV sales have grown at double-digit percentage rates, while worldwide sales totaled roughly 200 MW in 2000.

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[9] Energy Information Administration, "Annual Energy Review 2000", DOE/EIA-0384 (2000) August 2001, See Table 1.1, page 5.

[10] Based on consumer expenditures for energy at $567 billion in 1997 divided by consumption of 94.3 Quads to give $6.01B. See tables 1.1, 3.4 of: EIA, Annual Energy Review 2000, op. cit. Greater demand will often raise prices.

[11] This does not consider changes in capital costs of more efficient equipment, but that these investments were made by the economy indicates that they were cost-effective on a life-cycle basis.

[12] National Research Council, "Energy Research at DOE: Was It Worth It?," National Academy Press, July 17, 2001, See Table 2-1, page 22. Note also that the one technology in the Fossil Energy category for which DOE was identified as having a dominant role, Diamond Drill Bits, was made technically viable (companies had been trying to develop long-wearing diamond drill bits for many years, but had numerous technical problems) with funding from EERE's Geothermal program to Sandia National Laboratory, and for which Sandia received an Energy 100 award. These drill bits now constitute a more than $200 million per year industry. See: Sandia National Laboratory, "Energy 100 Awards", February 2000; and S. Falcone, "Technology Transfer Impact Profiles", School of Public Administration, University of New Mexico, Interim Report #1, Sandia National Laboratory, November 1995

[13] James McVeigh, Dallas Burtraw, Joel Darmstadter, and Karen Palmer, "Winner, Loser, or Innocent Victim? Has Renewable Energy Performed As Expected?" Resources for the Future, Washington, DC, Discussion Paper 99-28, March 1999; June 1999.

[14] The American Wind Energy Association at www.awea.org posts market data.

The Strategic Program Review identified numerous examples of advances in technical performance in EE technologies across every sector. In the transport sector, for example, the amount of platinum used in fuel cells has been cut by a factor of ten in the past 8 years. Concept vehicles using hybrid drives have been developed under the PNGV program that demonstrated the technical feasibility of 80 mpg for midsize cars, and concept fuel cell vehicles have been developed that achieve 108 mpg (e.g. GM Precept) gasoline equivalent. In addition, Ford, General Motors, and DaimlerChrysler have announced hybrid models of popular sport utility vehicles that will be available to consumers by the 2003 or 2004 time frames. Each of these vehicles will contain technologies enhanced or developed through partnership activities. These technologies, if fully implemented in personal transportation, would have a large impact on our Nation's energy security.

In the buildings sector, advances have been made in windows, lights, furnaces, and many others. Refrigerators, for example, have had their electricity consumption cost-effectively reduced by nearly a factor of four compared to the mid-1970s (Figure 4-3).[15] In each of these cases, EERE has worked closely with the national laboratories, industry, universities, and others to move the technologies forward.

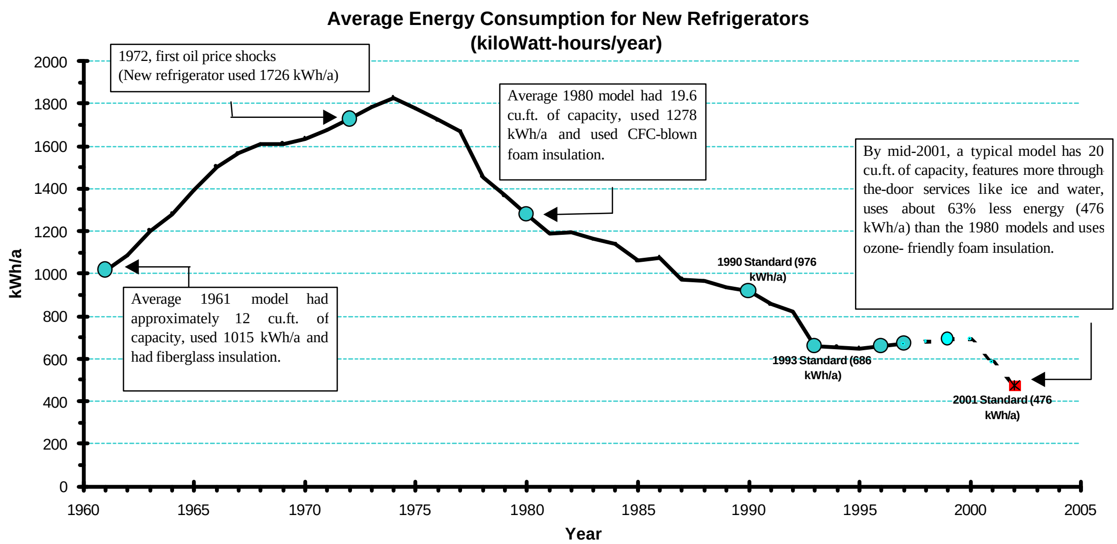

Figure 4-3: Change in annual electricity consumption for typical refrigerators over the past 4 decades, together with the typical size of the refrigerator. Electricity consumption increased sharply to about 1800 kWh per year in the mid-1970s. Since then, improvements in refrigerator technology followed by standards setting after the technology has been proven have cost-effectively reduced electricity consumption in a typical refrigerator to roughly 475 kWh/year. Meanwhile, the range of features and the size of refrigerators have increased significantly over this period. Source: National Research Council, "Energy Research at DOE: Was It Worth It?", National Academy Press, 2001 and Department of Energy.

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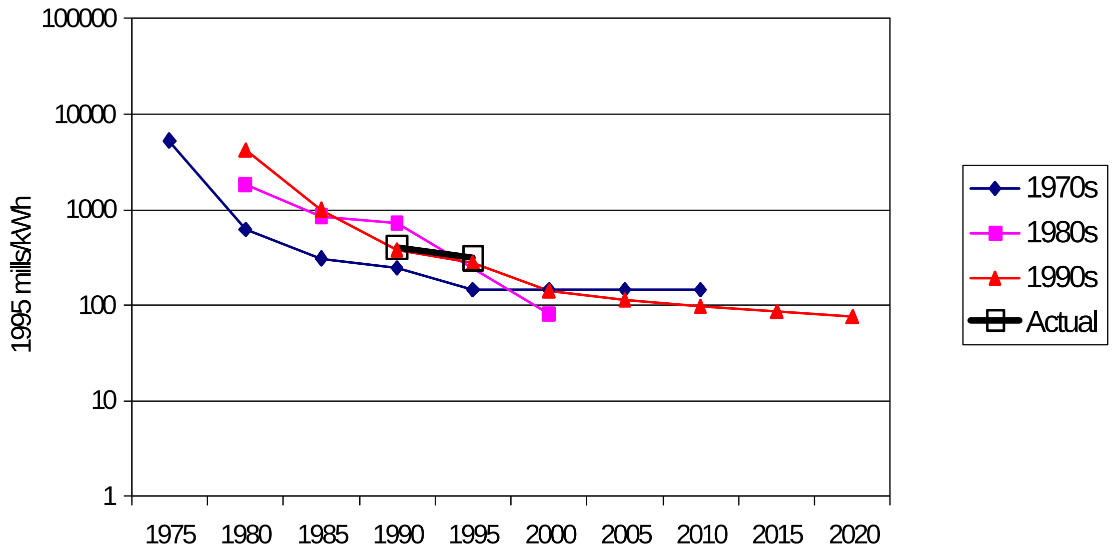
[15] National Research Council, "Energy Research at DOE: Was It Worth It?," National Academy Press, July 17, 2001.



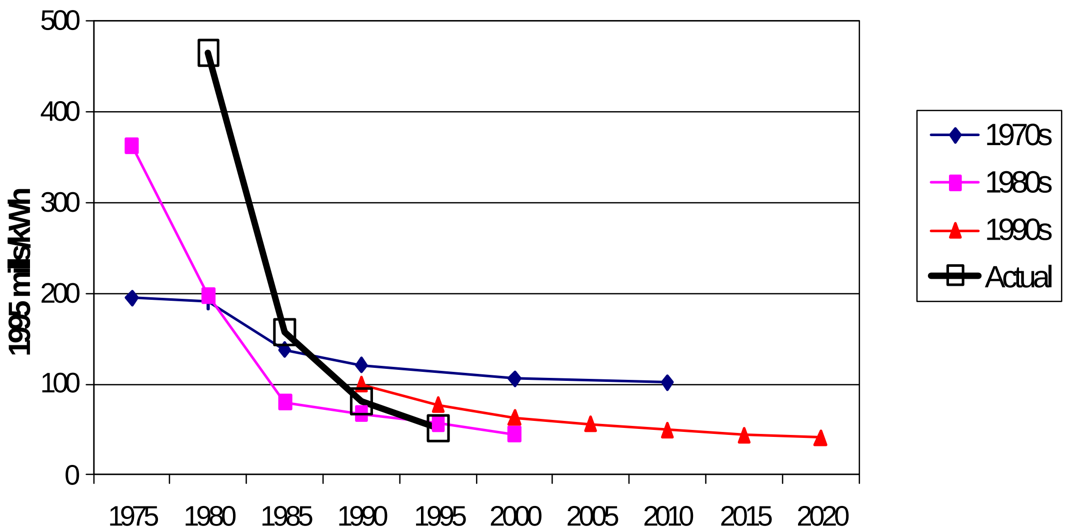


Figure 4-4: Resources for the Future (RFF) analysis of the reductions in the cost of electricity from solar photovoltaics (upper figure) and wind (lower figure), comparing EERE projections and the actual observed costs. Note that the scale for the photovoltaics case is logarithmic, with actuals ranging from roughly the 2000 mills/kWh range to near 200 mills/kWh. As noted in the review by RFF, actual costs closely followed EERE projections, and demonstrated reductions in cost of roughly a factor of 10 over the period examined. Source: Resources for the Future, McVeigh et al., op cit.

Describing EERE's large and complex set of activities in a simple manner is challenging. EERE manages nearly three thousand contracts (as discussed in Chapter 6) involving the full time equivalent of about ten thousand researchers from industry, national laboratories, and universities; and the research often involves highly technical efforts on energy-consuming equipment that underpin most of the U.S. economy. Therefore, the materials below are highly aggregated. More detail is available in specific program documents and other source materials.

The following analysis of EERE technical performance examines the changes in EERE's approaches to technology RD^3, the changes in EERE's programmatic approaches, and the resulting technical performance gains, including external recognition.

TECHNOLOGY APPROACHES

This Strategic Program Review found that over the past two decades EERE technical approaches have shifted from primarily focusing on individual technologies to being increasingly focused on integrated systems. R&D has been expanded to include not just individual technologies but also to consider the entire system for improving performance and reducing costs. This approach can create synergies that raise performance above what can be achieved by considering individual technologies in isolation.

BUILDINGS

Buildings research is now centered around "whole buildings" approaches, with the benefit, for example, that improvements in the building shell (exterior walls, windows, etc.) to reduce winter heat loss and summer heat gain can be translated into reductions in the size and cost of furnaces and air conditioners. There are similar benefits for appliances in buildings. Horizontal axis clothes washers, for example, both reduce the need for hot water from the water heater and, because they spin at higher speeds, reduce the amount of energy required for drying. Beyond lifecycle energy efficiency and economic costs and benefits, the integrated systems approach is also increasingly important in considering building construction, use, and demolition material wastes as well as other system lifecycle burdens on the economy and the environment. Analytical tools for whole building design have become increasingly important; some 15 companies, for example, market software that is built on the DOE-2 building design tools developed by EERE.[16]

INDUSTRY

The industrial process is already well integrated and focused on producing goods. The challenge for the industry programs is to identify and help implement the many technologies that can contribute to this integrated system, without risking a disruption of production. This has led to an industry-specific "Industries-of-the-Future" approach that develops new technology for specific industrial processes such as steel or aluminum production, metal casting, or chemical processing, and the development of cross-cutting enabling technologies such as sensors and controls, advanced materials, combustion and gasification, and other technologies and processes that can benefit numerous industries.

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[16] Companies selling DOE-2 with their own interfaces (program name in parentheses) as of August 2000, include: ADM Associates (ADM-DOE-2); RLW Analytics (Compare-IT); Item Systems (DOE-Plus); Gabel Dodd/EnergySoft (EnergyPro); Elite Software (EZDOE); Finite Technologies, Inc. (FTI/DOE2); Partnership for Resource Conservation (PRC-DOE-2); Charles Eley Associates (VisualDOE); J.J. Hirsch Associates (PowerDOE, eQuest); Gas Research Institute (DesiCalc); Florida Solar Energy Center (Energy Gauge USA); California Energy Commission (PERFORM 98); Olof Granlund Co. (RIUSKA); Natural Resources Canada (NECB Comply); GeoPraxis, Inc. (EMCOR Energy Edge). There are also two Lawrence Berkeley National Laboratory versions with specialized interfaces: Home Energy Saver (web version); RESFEN-3 (for windows energy-saving analysis).

TRANSPORTATION

Transportation research has evolved to encompass far more than engine research. All the elements of the complete vehicle, including the engine, drive train, tires, aerodynamics, and frame and body materials, are now studied to make it more energy efficient. The benefits can be complementary. For example, reducing aerodynamic losses allows the engine to be reduced in size and the frame to support the engine to be reduced in weight, further reducing the needed size of the engine and adding to the overall energy efficiency gains. Similarly, reducing heat gain in the passenger compartment also reduces the need for air conditioner capacity, which in turn reduces the load that it puts on the engine, the size of the engine, and the weight of the frame. Engine performance, catalyst behavior, and fuels formulation are also all interconnected, and to achieve the targeted fuel efficiency and cost performance, R&D must consider all of these elements together. This approach has resulted in revolutionary advances such as the hybrid electric and fuel cell power trains.

POWER

In the power sector, a key focus is now on distributed energy systems from an integrated system perspective. For example, the focus now is not only the turbine, but also how its waste heat can be coupled to other uses in the building, such as chillers. Distributed Energy Resources (DER) also examines how such systems can work with end-use equipment in the building and with the external utility grid to reduce total energy consumption and peak loads, and increase reliability of the electricity grid. The framework for DER is shown in Table 4-1 below.

Some renewable energy resources are intermittent—the sun does not always shine and the wind does not always blow.[17] In response, some solar and wind technologies are being developed as hybrids, combining them with other energy sources such as fossil fuels or energy storage to enable them to deliver power whenever needed. More generally, these technologies are integrated into larger utility grids. Power parks are also emerging as a system integration approach, combining natural gas and electricity grids, CHP, storage systems, and stationary and transportation end-use sectors.

BIOENERGY

Bioenergy--a crosscutting activity among the industry, transport, and power programs--is increasingly focusing on producing products, fuels, and power in integrated systems to maximize output value. While systems producing one of these three are currently competitive in niche markets, integrated biorefineries—producing the highest value combination of fuels, products, and power at any particular time—can potentially be more broadly competitive. Such technologies offer large potential job and income benefits for hard-pressed farmers or communities with biomass and/or residue feedstocks (waste wood or agricultural residue).

Activities have also been increasingly integrated along the innovation pipeline, from research to development, to demonstration, and to a few selected activities that facilitate market deployment. Such integration also provides important feedback of lessons learned in demonstration and deployment back into more fundamental research.

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[17] Note that no energy supply is 100% reliable and available, given inevitable maintenance needs and other problems.

DISTRIBUTED ENERGY RESOURCES

The Distributed Energy Resources (DER) program is an example of integration across both technologies and the innovation pipeline. Technology integration begins with power generation systems and continues through packaged systems and to interconnect and integration within the facility and with the utility grid, as indicated in the rows down Table 4-1. Integration along the innovation pipeline includes technology research, development, and demonstration in partnership with the private sector, codes and standards development for interconnection and control, and finally outreach and education. At each level of integration, broader and somewhat different sets of public and private actors are engaged. First is roadmapping with the private sector at the hardware level supported by the national labs. This is followed by gradually building outwards to the end-user hardware, facility, local fire official, and state/utility levels.

TABLE 4-1: DISTRIBUTED ENERGY RESOURCES (DER) PROGRAM ACTIVITIES

	Technology Development	***Demonstration and Field Testing***	***Private/Public Partnership Development***	***Codes and Standards***	***Education and Outreach***
Distributed systems	Advanced, "next generation" hardware	8,000 hours of operation in a real-world application site	Technology roadmapping with private sector producing these technologies; competitive solicitations, down-selects, etc.	Meeting industry protocols and safety standards	Program reviews and technology transfer among contractors with university and national lab support
Packaged Systems	Systems integration at hardware level to form packaged systems	See above, plus perform expanded testing of system components	See above, plus work with end-use equipment manufacturers that above will be integrated with	Protocols for interconnect of supply and end-use equipment at facility level	See above
Facility Integration	Integration into manufacturing plant, building, etc.—interconnect and local area networks and district energy systems	See above, plus regional test plans	See above, plus work with public officials on fire codes, building codes, etc.	Intra-building interconnect standards and communication protocols; fire codes, etc.	See above, plus technology transfer with facility managers and building owners
Utility Interconnect	Electricity, gas interconnect; development of improved transmission line cables, etc.	Case studies and documentation	See above, plus standards development with public/private institutions	Utility interconnect standards, e.g. with IEEE, public	Publications and workshops for DER developers and utility companies
Smart Systems	Info Tech; visualization tools (WAMs)	See above, plus expanded documentation and validation	See above, plus work with regional and national transmission owners and operators	Communication protocols and transmission reliability standards	Publications and workshops for transmission and distribution system owners and operators

Overall, the SPR found that EERE's shift towards integrated systems is positive and potentially provides more benefits than a component approach can provide. There remains in some cases, however, a continuing need to further break down technology "stovepipes" and to better integrate the activities towards a systems approach.

PROGRAM APPROACHES

The Strategic Program Review found that EERE programs have gone through dramatic changes over time in how they approach RD^3 activities. These changes respond to ongoing EERE-industry learning about how to most effectively structure activities.

TECHNOLOGY PUSH

In the late 1970s and early 1980s, program managers and laboratory researchers centered their efforts on technology push—identifying technologies that would be useful to develop, often with extensive industry and stakeholder input—and the technologies were developed under funding mechanisms such as cost-plus contracts, which were then widely used across government for long-term, high-risk research. The OIT program, among others, used broad Program Opportunity Notices to solicit ideas for energy-saving technologies, but also often funded unsolicited proposals. The Federal solar heating and cooling demonstration program had a tendency to contract with large, but inexperienced firms that ended up experimenting at the government's expense without meaningful cost sharing. Collaboration across industry or with other government agencies was often minimal.

The technology push approach, the general lack of experience with many of these technologies, and other factors—at times including the funding mechanism used—resulted in poor performance for a number of programs and projects.[18]

MARKET PULL

The lessons learned from the technology push experience together with many other factors have led EERE to substantially reinvent program management approaches over the last half-dozen years to increase program and project performance. The present focus is now on market pull, in which market considerations play a strong role in determining which technologies are developed. This approach is often balanced with some technology push work, particularly in infant industries. Although sector and program needs vary, several elements of these approaches have proven particularly valuable and have been widely adopted in recent years, including: technology roadmapping; the formation of public-private partnerships, in part through the technology roadmapping; competitive solicitations and cost sharing; the development of rigorous goals, metrics, milestones, and timelines; internal and external peer review; among others. Each of these is described below.

CONGRESSIONAL EARMARKS

Whether the approach is technology push or market pull, Congressional earmarks have recently grown and are becoming increasingly problematic for performance-based management. Tables 4-A8 and 4-A9 list Congressional earmarks for FY01 and FY02. In FY02, Congress earmarked 50 projects worth $86 million, or almost one-fourth of the appropriation for renewables. In some areas (e.g., biomass and superconductivity), earmarked projects accounted for about 40 percent of the respective budgets. While the SPR found that a number of these Congressionally designated projects have merit, many are not optimally aligned with overall program objectives and/or priorities. At times, some earmarks may have no relationship at all to the technology research or program to which they are attached. Moreover, because earmarks bypass the competitive peer-reviewed selection process used by EERE to select projects, earmarked projects tend to diminish the overall integrity of merit-based selection and interfere

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[18] There are some cases, however, where technology push approaches are appropriate and useful, particularly for significantly different technologies and industries without established markets to sell into, that lack infrastructural support, or that provide significant public benefits.

with overall program management and the development of a coherent program. EERE has not yet determined whether it will request reprogramming of FY 2002 appropriations that were earmarked. However, these and future projects will receive the same close scrutiny that EERE is applying to all of its work to ensure that statutory cost-sharing requirements, progress performance, and sound business practices are carefully followed, and associated risks fully considered. EERE's FY 2003 budget does not request funding for previously earmarked projects.

TECHNOLOGY ROADMAPPING

Technology roadmapping is a process used by EERE in which public and private participants are brought together to develop a long-term vision of what the particular industry sector should strive for in terms of technology cost and performance; overall energy use, economic and environmental performance; and other factors. They then develop industry-wide long-term goals and a specific description of the technology development needed, together with its various inter-relationships and timeframes, with priorities of the R&D required to achieve that vision. These roadmaps also serve as important tools for communicating across the public and private sectors. Although catalyzed and facilitated by EERE, the emphasis within this process is for industry to help lead the development of this vision and technology roadmap to ensure buy-in. The overall roadmapping process demonstrates the value and importance of the convening power of government.

Based on this work, EERE then identifies, with industry, a subset of activities having sufficient public, as well as private, interest to justify cost-shared R&D. These are typically pre-competitive, high-risk R&D activities that individual companies are unable or unwilling to undertake without government support. Figure 4-5 illustrates how the technology roadmapping process identifies RD^3 areas of interest to the private sector and to the public sector. Within these areas there is a smaller subset of activities of sufficient interest that both will provide support. This allows the public sector to gain increased public benefits by leveraging private dollars, without inappropriately supporting private activities. Similarly, this area of common interest provides industry the incentive to invest and bring the technology to market, helping realize the public benefit. Note, however, that there may be areas of much public importance that cannot attract private cost sharing.

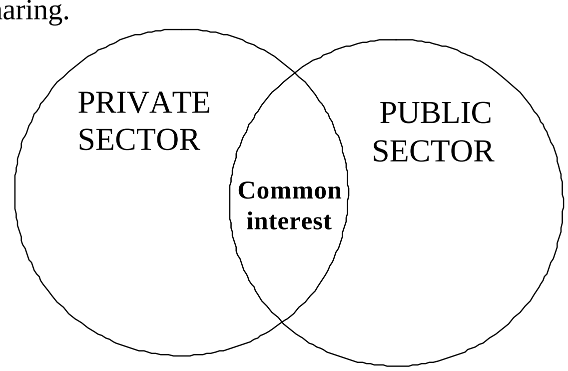

FIGURE 4-5: Technology Roadmapping and Areas of Common Interest**.** This figure illustrates how the technology roadmapping process identifies RD^3 areas of interest to the private sector and to the public sector. Within these areas, there is a smaller subset of activities of sufficient interest that both will provide support. This allows the public sector to assist private sector technology development activities and gain increased public benefits by leveraging private dollars, without inappropriately supporting private activities. Similarly this area of common interest provides industry the incentive to invest and bring the technology to market, helping realize the public benefit. Note, however, that there may be areas of public importance that cannot attract private cost sharing but that are still important to do.

Table 4-A1 lists more than 40 roadmaps that have been developed with more than two thousand industry, university, national laboratory, NGO, and other participants in the past five years. EERE sectors have established general criteria for R&D, recognizing the need for flexibility, to evaluate whether or not a particular project is likely to provide sufficient public benefits that public investment is warranted. Guidelines for the R&D investment criteria have also been developed as part of the President's Management Agenda:

- **Energy**. Projects must move technologies along the innovation (RD^3) pipeline that have the potential to provide significant energy savings or alternative supply, and that meet national energy goals.

- **Economic savings**. Potential energy-related and total economic savings are evaluated. Although energy-related savings are the primary focus, opportunities to improve industry productivity and competitiveness are also important. OIT, for example, works with energy-intensive industries that have been under severe competitive stress in recent years. Improved productivity can help them compete.

- **Environmental benefits**. Projects should provide significant environmental benefits for the public compared with conventional technologies.

- **Require public support**. Only projects that clearly will not be funded by the private sector alone in a timely manner are supported. This includes cases involving large companies where the direct savings to the firm are neither sufficient in size nor sufficiently near-term to warrant R&D investment, but collectively across the entire industry, the savings are sufficiently large to justify public involvement.

- **Industry needs**. For industry to be willing and able to invest, the work must also address top industry needs, as identified in the roadmap. Industry participation in the roadmapping process helps to ensure this.

By working with entire industries to develop these roadmaps, EERE maximizes the energy benefits of the technology investments across the industry and helps foster public-private partnerships. In many cases, however, actual technology development is conducted under a competitive solicitation that a consortium may win or perhaps just one or a few companies win. In other cases, individual companies—often small, innovative firms—may come forward with particularly promising technologies worthy of support, or an infant industry may need an initial technology push approach. Technology roadmapping has proven very valuable, but flexibility to meet changing market, industry, and technology needs is key. Roadmaps typically respond to a 20-year vision and are updated periodically to address changing conditions. This helps the roadmapping process explore more aggressive RD^3 activities in advance of industry's willingness to explore them.

These roadmaps vary significantly in terms of level of specificity and detail, timelines, and other factors. Recognizing that these roadmaps serve many uses for highly varying audiences and sectors, it would be useful to identify "best practices" in developing and using roadmaps and related materials and activities.

PUBLIC-PRIVATE PARTNERSHIPS

Private companies who often are R&D partners commercially introduce EE technology. One model for such partnerships involves forming groups of competing companies to work collaboratively on issues of common interest and to share the intellectual property that results. This model works well where there is an established industry. Another model involves working with individual companies where the company gains much (or all) of the intellectual property created. This works well for an emerging technology where a strong intellectual property position is necessary to attract the capital needed to build a new business – either from venture capitalists or in the equity market. Both models can provide good leverage for Federal funds. In addition, there are also useful models for more general information and technology dissemination efforts. Partnering also includes work with other Federal or state agencies, universities, and non-profits.

Although EERE has historically partnered with the private sector, efforts to develop and strengthen such partnerships have increased significantly, particularly through such mechanisms as technology roadmapping and by catalyzing and facilitating the formation of research consortia. Work undertaken is typically pre-competitive, higher-risk R&D that individual companies are unable or unwilling to undertake alone, which are then supported through these competitively-developed, cost-shared, public-private partnerships. Activities are focused, wherever possible, to benefit a broad industry or sector rather than an individual company within that industry or sector. The large number of private participants involved at every level of roadmapping, research, development, demonstration, and deployment indicates the intensity with which public-private partnerships are pursued and nurtured. The broad use of competitive solicitations for the research undertaken coupled with the fact that much of it has a significant cost-share indicates the degree to which the work is strongly performance-based and that it substantially leverages Federal tax dollars.

Most programs now conduct a large share of their business through such partnerships, as discussed in Chapter 6. As noted above, the technology roadmapping activity alone has involved over two thousand experts from across the industry, university, NGO, national laboratory, and other communities, indicating the high degree of involvement by the public and private sectors in forging these partnerships.

In addition to roadmapping, the Strategic Program Review found that public-private partnerships extended throughout EERE to include the principal activities of research, development, demonstration, and deployment, as well as facilitating activities such as codes and standards development. There are numerous examples of each of these. In codes and standards development, for example, partnership work includes developing building energy codes and standards with the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE), developing grid interconnect standards for distributed energy resources with the Institute of Electrical and Electronic Engineers (IEEE), revising with ASTM coal ash standards to allow sales of ash from co-fired boilers, and many others. There are also many partnership activities such as voluntary deployment programs—green power, Energy Star labeling, and others.

COMPETITIVE SOLICITATIONS AND COST SHARING

Two decades ago, EERE often conducted RD^3 work through cost-plus contracts, following the pattern set more broadly throughout DOE, by DOD, and by other Federal agencies. Today, most EERE work is done through cost-shared contracts or financial assistance established under competitive solicitations (see Chapter 6). The advantages of cost-shared contracts and financial assistance include the leveraging of public investment with private investment; a stronger commitment by the private sector to achieve success in the R&D effort, and a high private interest in developing a strong market for the technology—a market pull rather than a technology push strategy—and to quickly move the technology into commercial markets.

Flexibility in cost sharing is needed, however. A number of factors can influence the appropriate level of cost sharing that should be applied to a given activity. Among these are the estimated levels of risk (both technical risk and economic risk), compelling external reasons (short falls or significant changes needed to the infrastructure), or a compelling government interest such as the need for energy security. While longer-term fundamental science work is less able to attract private sector cost sharing, near-term applied research can often command relatively high cost shares. R&D in new areas without established markets or that face large infrastructure changes or other challenges are likely to attract less cost sharing than in well-established technical areas with large, well-developed market opportunities. Innovative small businesses and universities may have less capacity for cost sharing than conventional large-scale companies. There is necessarily a careful balance in all cost-shared activity in supporting R&D that has sufficient value to justify public investment and that is also of interest to the private sector. An emphasis on maximizing private sector cost sharing may reduce the public sector leverage in negotiations and shift RD[3] activities away from areas with the strongest public benefits into areas that are more closely aligned with near-term private interests. EERE program managers were found to be quite sensitive to these concerns.

Cost sharing in the Department will continue to be guided by statute and Administration policy. The Energy Policy Act of 1992 requires 20 percent cost share for applied research and 50 percent cost share for demonstration projects. The cost sharing guidelines developed with the R&D investment criteria as part of the President's Management Agenda are shown in Table 4-2 below. These are the same cost share levels used in the former OTT PNGV program.

TABLE 4-2. INDUSTRY COST SHARES

Activity	Industry Cost Share, percent
Basic research	0- 30
Applied research	25- 50
Technology Development	50- 75
Demonstration or commercialization	60-100

Direct cost sharing, as an explicit requirement for program participation, is not the only factor that should be considered. Harder to characterize, and often overlooked, is the investment in R&D by participating partners that is not part of a formal agreement. Sometimes government expenditures can stimulate participants to undertake R&D outside of the program that further leverages the government investment. An example of such "implicit" cost sharing has been the R&D investments by the domestic automotive manufacturers in response to the PNGV program, by some estimates totaling several times the DOE investment.[19]

GOALS/METRICS/MILESTONES/TIMELINES

Many EERE programs historically included some of each of the elements of goals, milestones, measurements of progress and timelines. The 1993 Government Performance and Results Act mandates that with each fiscal year's budget submission, Federal agencies develop and communicate to Congress a performance plan that describes the agency's mission, goals, key upcoming performance measures and report on previous progress. Since the NAPA review, these basic planning and execution components are now required of all EERE programs, with every program developing overall goals, metrics, and milestones for its activities—with varying degrees of success. EERE program management and Deputy

[19] National Research Council, Review of the Research Program of the Partnership for a New Generation of Vehicles, sixth report, pp. 75-76, 2000, estimated over $900 million in related R&D by the auto manufacturers outside of the formal agreement, or roughly eight times the DOE investment. This could well include a number of investments that are not very closely related to the PNGV program that the companies would have made regardless.

Assistant Secretaries track key milestones, and programs are evaluated against progress towards goals. Since the summer of 2001, EERE has been working to broaden its required GPRA metrics from energy, energy-related cost savings, and carbon, to include other benefits. For example, OPT is developing several metrics relating to power reliability and infrastructure robustness. EERE also is continuing to develop and align Performance Plan goals and GPRA metrics with lower level project milestones and activities to better determine program performance. While all of EERE participates in tracking milestones at least twice a year, some sectors and programs such as the advanced automobile technology programs within OTT have also set up innovative internal Internet platforms to track activities in more detail. This application could be usefully adapted to other programs, and is an internal "best practice".

Timelines pose a substantial challenge for research programs. When a program is not following its timeline, it is difficult to determine whether this shortcoming is because of a technical problem that can be solved with a modest amount of more time, or because the technology has hit a significant limit that is unlikely to be resolved. For example, the Lost Foam metal casting technology was invented in 1960, but individual industries were unsuccessful in solving the technical challenges until DOE got involved in 1989 and formed a research consortium to address them. Each year programs at the margin, in terms of performance or estimated impacts, are considered for termination. Peer review of such work serves an important role in guiding such decisions, and a more systematic peer review process would be useful.

GRADUATIONS/TERMINATIONS

As a technology is being commercialized, DOE involvement can be minimized or may shift to issues such as technology ratings, codes and standards, information outreach, voluntary market facilitation activities, and eventually to close out as the technology graduates to fully private sector activity. A number of DOE-assisted technologies have so graduated. In contrast, some technologies do not demonstrate sufficient progress within the desired timeframe or face technical, economic, or other problems, and decisions must be made about terminating (down-selecting) those. A number of examples of graduated and down-selected technologies are listed in Table 4-A2; additional examples can be found within the various program documents. As for holding research projects to strict timelines, as noted above, it is difficult to know when a program has reached a significant limit that is unlikely to be resolved versus when a breakthrough is just around the corner; decisions concerning the closeout of such research then require careful attention by scientists and engineers in an in-depth peer review process. A summary of the status of OIT projects is shown in Figure 4-6, indicating the number of projects completed, commercialized, terminated, and so forth.

PROGRAM REDIRECTIONS

In addition to these graduations/terminations, numerous program redirections were identified, ranging from the EERE-wide redirection from technology push to market pull activities and associated approaches described above down to individual cases within each sector and program. For example, the OTT fuel cell program has shifted its development strategy several times as it has completed successive phases involving the auto industry, engaging auto industry suppliers, developing reformer technology, and others, gradually shifting to more fundamental development of fuel cell materials and supporting technologies. The fuel cell case is described in Box 4-1. More broadly, given the typical contract duration of roughly 3 years, programs shift direction at least a little—and often substantially—with each new solicitation cycle.

PROGRAM AND PORTFOLIO BALANCE

Energy efficiency and renewable energy technologies vary widely in their RD^3 characteristics—the cost of the RD^3, the risk, the potential economic, environmental, and security returns, and so forth. To most

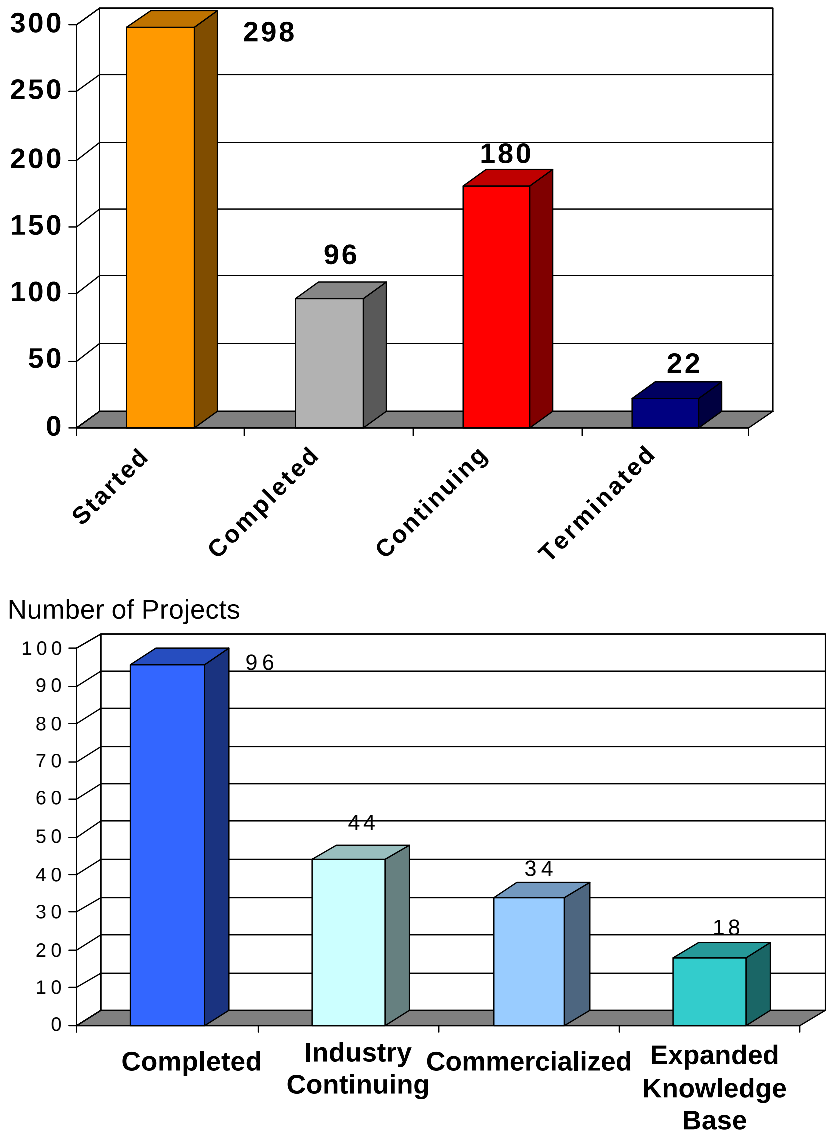

Figure 4-6: OIT project statistics FY98-FY00 (preliminary). Projects recently completed by OIT have been assessed in terms of the results, and are shown in the accompanying graphic. These include projects that ended in FY98 through FY00.

effectively develop and deliver energy efficiency and renewable energy technologies for the public benefit and to address future national energy needs and risks, the overall EERE portfolio as well as the sector and program portfolios needs to be balanced across these various dimensions. Such balance ranges across the sectors—buildings, industry, and transport efficiency and renewables and power; it varies within the sectors; and it varies within the individual programs, for example, balancing across parallel technology opportunities competing to achieve the same performance goal. This balance also extends along the innovation pipeline—from research, through development, demonstration, and deployment—as well as within each of these RD^3 areas, including across the entire energy technology system and across the various supporting activities such as test standards, technology codes and standards, tools for rating equipment, design tools, analysis and evaluation, information-outreach and training, technical assistance, financial assistance, and policy programs. Figure 4-7 attempts to illustrate these many dimensions.

The bottom line is how to optimize the balance across all of these dimensions so as to get the greatest return for the public investment while addressing public risk. EERE programs were found by the Strategic Program Review to have invested considerable effort in developing an appropriate program balance, with generally good results. This was done, however, on a somewhat ad hoc basis. Additional systematic analysis is needed to better understand the various tradeoffs in balancing programs and portfolios across these various dimensions. Complicating this is the necessity of working within periodic policy shifts, often driven by non-technical concerns.

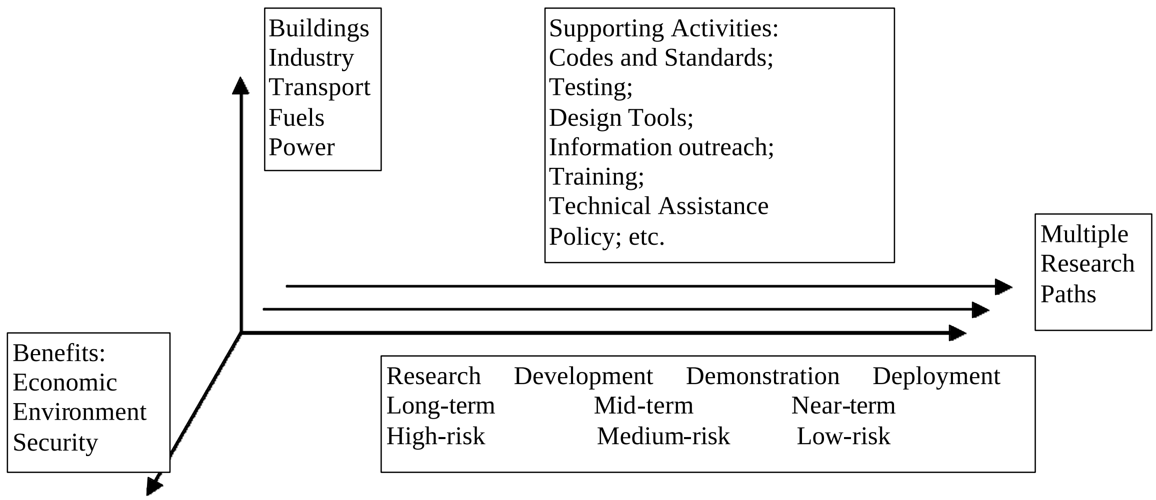

FIGURE 4-7: Balancing the overall portfolio**.** This figure illustrates the various dimensions that the R&D portfolio needs to be balanced across, with the optimal balance varying with the particular desired outcome. These dimensions include: (1) sectors—buildings, industry, transport, fuels, power; (2) innovation pipeline—research, development, demonstration, and deployment; (3) supporting activities—such as test standards, tools for rating equipment, design tools, analysis and evaluation, information outreach and training, technical assistance, market facilitation (e.g. labeling), policy, etc.; (4) time frames—near, mid, and long-term; (5) risks—low, medium, and high; and (5) benefits—economic, environmental, security; and others. Further, to mitigate risk, it is preferable to have several alternative research paths towards a common goal—alternative materials, alternative technologies, etc.—to increase the likelihood that at least one approach will be successful.

PROGRAM AND PEER REVIEW

Formal internal and external reviews can provide a very important feedback function and can help move programs in more productive directions. The SPR found that formal internal program reviews are done on an annual basis for many programs to ensure that policy is being effectively implemented and program funding is being responsibly utilized. Reviews also include annual or semi-annual laboratory performance self-assessments and technical division reviews, quarterly reviews of DOE-industry contracts, annual subcontractor reviews, advisory board reviews, and annual development of quality metrics under GPRA with internal and external peer review of the results.

External peer reviews necessarily vary significantly in how they are done and used. They can be retrospective, such as the recent NRC report,[20] or prospective, such as done annually under the Government Performance Results Act. They can cover entire programs or provide input to selection

[20] NRC, "Energy Research at DOE: Was It Worth It?" op. cit.

officials about specific competitive solicitations. Conducting basic scientific research is quite different from building a user facility; peer review will correspondingly differ. For basic, early applied, and some other scientific research, an annual peer review is sufficiently frequent in most cases; more frequent peer reviews often divert researchers from doing research and perhaps even skew the research from trying innovative approaches that help lead to fundamental understanding of the issues to a lower risk approach of standardizing test runs and meeting criteria through repetition.

In contrast, the other end of the spectrum of building a user facility would require a combination of perhaps an annual peer review to ensure that the scientific mission was being met, and a more frequent evaluation of progress in the actual construction. This Strategic Program Review found that external peer review is widely used across EERE, but with considerable variation in frequency and format—ranging from ad hoc internally organized reviews to broad annual external reviews by the National Academy of Sciences. Table 4-A3 summarizes this peer review data. This large variation in practice offers the opportunity to explore the advantages and disadvantages of alternative approaches, benchmark these practices against external models, identify other types of reviews that are less productive and can be subsumed in a regular peer review, and identify best practices and develop model approaches for regular systematic external peer review that minimize staff workloads while maximizing benefits.[21]

EVALUATION

Efforts to evaluate the impacts of EERE activities have increased significantly. OIT, for example, tracks all technologies with respect to their commercialization and extent of use by the private sector as part of an analytic effort to verify program performance and results. The tracking process involved collecting technical and market data on each commercially successful technology, including:

- Number of units sold, installed, and operating in the United States and abroad;
- Units decommissioned since the previous year;
- Energy savings by the technology;
- Environmental benefits from the technology;
- Improvements in quality and productivity achieved through use of the technology;
- Other impacts of the technology, such as employment, effects on health and safety, etc.; and
- Marketing issues and barriers.

When full-scale commercial units of a technology are operational in private industry, that technology is considered commercially successful and is placed on the active tracking list. When a commercially successful technology has been in operation for approximately ten years, that particular unit is then considered mature technology and is usually no longer actively tracked. A summary of this tracking analysis of more than 140 technologies, entitled "Impacts" is published biennially.[22] This report also describes over 120 emerging technologies and more than 30 past successes that are no longer tracked. Care is needed, however, in identifying causal relationships and relative roles of participants to the extent possible.

Such evaluation is also done to various degrees by the other programs. It is important to note, however, that such tracking—indeed, as with all of the activities discussed here—carries with it substantial costs,

[21] More detailed discussions of peer review issues can be found in: U.S. Department of Energy, Office of Inspector General, Office of Audit Services, "The Department of Energy's Peer Review Practices", April 1998; U.S. General Accounting Office, "Federal Research: DOE is Providing Independent Review of the Scientific Merit of Its Research", GAO/RCED-00-109, April 2000; Task Force on Alternative Futures for the Department of Energy National Laboratories (Galvin Report), "Alternative Futures for the Department of Energy National Laboratories, prepared by the Secretary of Energy Advisory Board, February 1995. See Volume 2, pages 33-47.

[22] "Impacts" can be found at http://www.pnl.gov/impacts

both financially and in terms of staff time. These costs limit EERE's ability to do thorough, systematic long-term tracking of each R&D project that results in commercialized technology. Because of the constraints of the Paperwork Reduction Act, managed by OMB, mandatory data collection is rarely used and EERE relies heavily on voluntary reporting or industry analyses, further limiting EERE's ability to track specific R&D project outcomes. In addition, many EERE research projects result in technical data, process improvements, and other advances available to the entire industry, which are significant, but can be very difficult to track. An appropriate level of tracking—sufficient to adequately determine the impacts of the work undertaken for policymakers decision-making purposes and to develop lessons learned to guide future program development, but not so much as to significantly reduce resources for RD^3 activities—is needed. There are many variations in these approaches across sectors and even among programs within sectors. The identification and transfer of best practices across sectors and programs, adapted as needed to particular program circumstances, and cross-fertilization among these various approaches will assist program development and performance.

ROLES IN DEMONSTRATION AND DEPLOYMENT

To turn public investment into real public benefits requires moving laboratory research to commercial success. Low public awareness, lack of education, low market availability and acceptance, infrastructure gaps and other factors have required program specific outreach efforts. Historically, programs have sharply limited their roles in technology demonstration and deployment (D^2) out of concern that they might impinge on the private sector or be perceived as giving "corporate welfare". Today, there is growing recognition of the strategic role public facilitation of D^2 can serve, while recognizing these are primarily private sector activities and that they should not come at the expense of core R&D efforts. There is often a critical need to conduct operational tests on new technologies to demonstrate factors such as availability and reliability that are key to successful commercialization and use of the technology. FEMP has made an impact by adopting energy managers early in the process, resulting in successful deployment of some EERE technologies in the Federal sector. Working with BTS, FEMP has used the significant purchasing power of the Federal government to create demand for compact fluorescent lamps and is working towards creating a market for highly efficient rooftop air conditioners.

In developing successful research programs, a key lesson has been the need to develop a commercialization plan and management commitment from the industrial participants at the earliest possible stages of a program. These ensure that requirements for technical performance, cost sharing, siting, permitting, and high volume manufacturing are well understood and accepted from the very beginning, leading to large-scale deployment. Further work is needed to develop better strategic processes to buy down the cost of technologies along their learning curve through highly leveraged public-private partnerships, and to better understand how to catalyze demonstration and deployment. For example: How much demonstration is necessary and sufficient—including what is needed to achieve a critical mass of activity to cause market transformation in target areas and lead to self-sustaining commercial deployment of particular improved technologies?

An effort is needed to develop a D^2 strategy, a reasonably consistent process (recognizing the many variations and needs that exist between sectors and applications), evaluation criteria, and supporting analytical capability in order to carefully build on EERE's current portfolio of activities. This should include approaching D^2 activities with a more systematic "design-of-experiment" statistical approach, where possible, in order to better determine the value-added of each additional activity and how to achieve critical mass levels of activity needed for market transformation. (Of course, such work must recognize resource constraints). Every activity should be specified as part of an overall plan, and the method of evaluation and criteria for success should be outlined in advance. These efforts should also strengthen strategies for linking R&D, voluntary programs, and codes/standards.

BOX 4-1: CASE STUDY OF FUEL CELL PROGRAM MANAGEMENT

In the late 1980s and early 1990s, EERE began work with the Department of Transportation on the demonstration of phosphoric acid fuel cell buses. Operating on reformed methanol, these buses had long start-up times and slow responses. EE identified PEM fuel cells as having more promise for light-duty vehicles as they had higher power density, their lower operating temperature enabled quicker start-up, and the solid polymer electrolyte is more practical and less corrosive than the liquid acid electrolyte used in phosphoric acid fuel cells.

EERE brought PEM fuel cells to the attention of industry and catalyzed industry activity in the early 1990s with competitive contracts to each of the domestic automakers, with fuel cell developers as subcontractors. These contracts were focused on direct hydrogen and methanol fuel cell systems because they are the simplest fuels for fuel cells. These projects initiated fuel cell vehicle programs within the U.S. auto companies, and ultimately led to the recent unveiling of concept cars by the domestic automakers. Once initiated, further direct contract work on fuel cells with the major automakers was not necessary and no further solicitations were conducted.

In 1997, the program began to focus on gasoline fuel cell systems to accelerate commercialization of automotive fuel cells by enabling use of the existing fuel infrastructure. Competitive contracts were awarded to fuel cell and fuel processor developers who would ultimately supply the automotive industry. This approach eliminated the overlap that occurred with the previous process—when the developers were subcontractors to the auto companies—and enabled the auto companies' greater access to a variety of fuel cell technologies. The result of this work was the demonstration of the first full functional automotive-scale gasoline fuel cell system in 2000.

In 1999, the program shifted emphasis from system development and integration to research and development of low-cost, high-performance fuel cell materials, components, manufacturing processes, and enabling technologies. System integration is now handled by the industrial supplier base (without government support), which the program helped to develop. This current phase of the DOE program is addressing the remaining cost and performance challenges that are keeping automotive fuel cells from being commercialized.

Technical targets for program activities were established in collaboration with the U.S. Council for Automotive Research (USCAR), and annual peer review processes are in place to assess progress toward targets. Roughly one-third of the work is done at the national laboratories, with no cost sharing, and two-thirds is done under competitive contracts with industry, with an overall cost share of about 35%. Since 1993, there have been six solicitations, with a total of 230 proposals and 73 awards with a public cost of $230 million and a private cost share of $89 million. In the last three years, important firms have initiated large R&D fuel cell efforts with no government cost share.

The EERE OTT Fuel Cell Program played an instrumental role in getting the auto industry interested in fuel cells, helped develop a PEM fuel cell industry in the United States[23], and has helped to pioneer the development of fuel cell and fuel processing technology.

Accomplishments of the OTT program working with national labs, industry, and universities included:

--Developed the first 50-kW ambient-pressure fuel cell system and demonstrated record efficiency (57% at ¼ power).

--Developed the first functional integrated gasoline fuel cell systems, with breakthroughs in CO clean-up and electrode CO tolerance

--Developed low-cost composite plates; demonstrated fabrication processes amenable to high-volume manufacturing;

--Reduced the platinum content of fuel cells from 10 grams/kW in 1994 to 1 g/kW in 2001;

--Reduced the volume and weight of 50-kW fuel cell stack systems by approximately 50% and 25% respectively between 1997 and 2001, and doubled the system durability to 2000 hours;

--By one estimate, reduced the estimated system cost from $3000/kW in 1994 to about $300 for a gasoline-based system (including reformer) or $200/kW for a hydrogen-based system in 2001, assuming a production rate of 500,000 systems per year and year 2000 technologies.[24]

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[23] This includes companies such as Plug Power, Energy Partners, and NUVERA, and the development of PEM fuel cell programs at companies such as 3M, International Fuel Cells, and Honeywell.

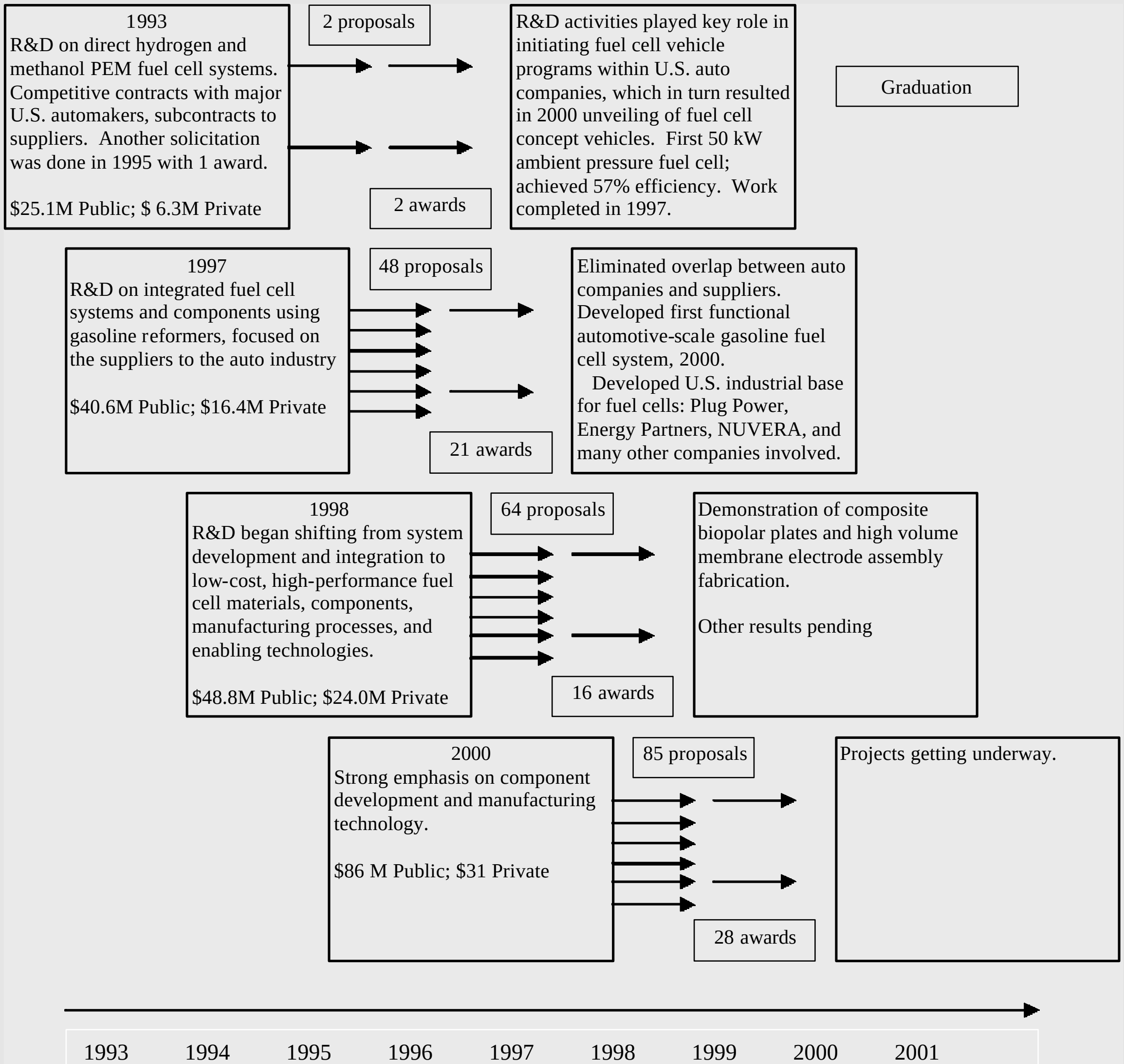

Figure 4-8: Redirections and competitions in the transport fuel cell program. This figure illustrates the sequence of: (1) initiating research with the major auto companies beginning in 1993 and ending that work when the auto companies had successfully launched and were committed to their fuel cell work; (2) initiating work with the auto supplier companies, with a focus on gasoline fuel cell systems in 1997; (3) shifting research in 1998 from system development and integration to low-cost, high-performance fuel cell materials, components, manufacturing technologies, and enabling technologies to drive costs down to competitive levels. In addition to these strategic shifts in program direction and support, the large number of proposals and strong cost sharing in this infant industry are notable, particularly given the long term high risk nature of this research.

[24] A.D. Little, Inc., "Cost Analysis of Fuel Cell System for Transportation", March 2000. ref. 49739.

PROGRAM ACCOMPLISHMENTS.

The SPR examined the technical performance of EERE on the basis of technical accomplishments, patents, and awards. Program benefits are discussed in Chapter 5.

TECHNICAL ACCOMPLISHMENTS

Technical accomplishments, including specific technical innovations, performance gains, reductions in cost, design tools, standards, and others were examined and a subset of more than 150 EERE results is detailed in Appendix Table 4-A7. Technologies as diverse as residential refrigerators (Figure 4-3), fuel cells, photovoltaics (Figure 4-4, see also Figure 4-9), and wind turbines had various aspects of their cost or performance improved by factors of roughly 4 to ten or more. Building energy use can now be cut in half cost-effectively compared to current standard practice, and technologies to turn buildings into net energy producers with little or no emissions are available, though expensive. Many of these technologies can also be applied to Federal and State buildings, reducing energy use in the public sector sharply; substantial gains have already been realized. Significant reductions in industrial energy intensity are possible, including in specific industrial processes as well as in cross-cutting areas through use of technologies such as advanced combustion, materials, combined heat and power, electronic motor drives, and improved sensors and controls.

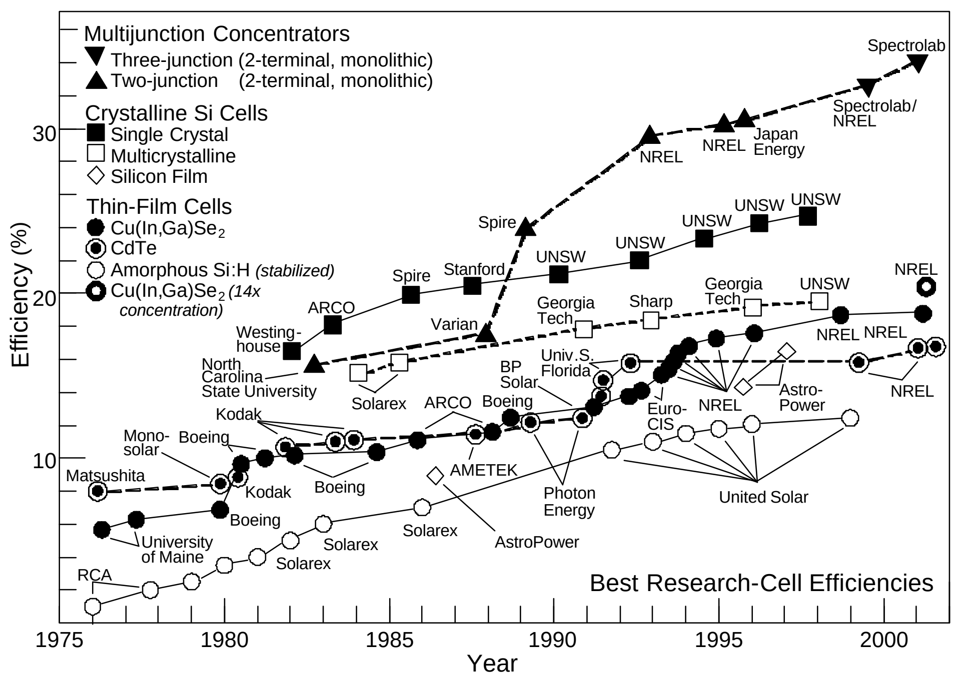

Figure 4-9: PV cell efficiency over time. This figure shows the progress that has been made in advancing the efficiency of small area PV cells. Translating these high efficiencies into large-area commercial cells requires substantial technical prowess and it takes a number of years to develop the capability after it has been demonstrated in a small-area cell in the laboratory. That such high small area performance has already been demonstrated indicates the likely technical feasibility of approaching such efficiencies in commercial products. Notes: Thin film photovoltaic technologies consist of very thin—one sixtieth of the diameter of a human hair—layers of active material to generate electricity from sunlight. Multijunction concentrator photovoltaic cells consist of multiple layers of material optimized to maximize efficiency. Since such cells are expensive, they are typically used with low-cost optical systems (mirrors, fresnel lenses, etc.) to concentrate the sunlight.

Hybrid and fuel cell concept vehicles have been demonstrated with nearly three times and more the equivalent miles per gallon of current average vehicles. Moreover, the cost reduction and performance gains from integration of power electronic components and the achievements of the high power battery that make hybrid and electric vehicles viable will benefit many other programs in EERE, including distributed power and back-up power systems. Similarly, advances in DER and others can potentially help transport technologies.

Power technologies such as wind energy are becoming cost competitive with conventional grid power, while other technologies such as photovoltaics are increasingly competitive in remote power applications. In these various areas, paths are reasonably well defined towards technologies that can eventually be cost-competitive, dramatically reduce pollution and carbon emissions, and greatly improve energy security by reducing our dependence on foreign oil. For example, the advances in the efficiency of photovoltaic cells in the laboratory, Figure 4-9, demonstrate a clear path forward for commercial products to achieve dramatic gains in cost and performance over the next 5-10 years, as technologies are developed to transfer these high efficiencies from small area laboratory cells to large area mass-produced commercial products.

Given the difficulties posed by DOE-wide business management systems identified in Chapter 6, it is clear that the scientists and engineers of EERE, with industry, national labs, and universities, succeeded in their work in spite of the constraints and limitations of overall DOE business practices. Recent EERE efforts to move past the constraints of overall DOE business practices with the Strategic Management System and other innovations are helping to further this success. Additional gains in improving technical management can be achieved through the transfer of the best internal practices by specific sectors and programs across all of EERE, and by further analysis and benchmarking of external best practices and their transfer to EERE.

PERFORMANCE INDICATORS

The SPR considered a variety of indicators for the performance of EERE programs. In addition to the direct indicators of technical accomplishments noted above, external peer reviews, and others already discussed, the SPR examined patents and awards.

PATENTS

Patents were evaluated as a possible indicator of program performance. Patents were found by the SPR to offer no clear means for benchmarking the relative value of their associated programs against either a baseline or the performance of programs of other institutions. The relative value of patents was not readily discernible, and the number of patents was not necessarily correlated with program innovation or impact. Further, a recent study of patent data in the energy sector found a marked shift in who the patent was assigned to. Analyses of patents found that the number of patents assigned to DOE overall dropped sharply, but the number of patents identified as related to DOE research increased sharply, with the overall number increasing modestly over the past decade. This shift in assignment reflects the increasingly successful efforts in technology transfer to the private sector, with the patent assignment going to the private sector rather than to DOE.[25] It also, however, makes it somewhat more difficult to track the program-specific patent record.

Whether assigned to DOE or related to DOE research, EERE programs should be able to track the patents associated with the research they fund. However, a number of programs within EERE were not able to

[25] Robert M. Margolis and Daniel M. Kammen, "Evidence of under-investment in energy R&D in the United States and the impact of Federal policy," Energy Policy V.27, 1999, pp.575-584.

generate comprehensive listings of patents; Table 4-A4 has a partial listing. Given that the aggregate patent data shows a modest increase in patent numbers over the past decade[26] but that program-specific data were not consistently available; and given that patents offered no clear means of benchmarking their relative value against either a baseline or the performance of other institutions, patents were not considered further as an overall indicator of performance.

Patent data can offer an important and powerful means of benchmarking relative value against either a baseline or the performance of other institutions. Patents, when tracked as part of a comprehensive patent citation analysis that includes appropriate indicators of patent activity (relative technological emphasis based on patenting growth rates), a current impact index (how influential an entity's patents are based on how frequently they are cited by, and used as a foundation for, other patents), technology strength (a quality-weighted measure of technological size), technology cycle time (the median age of patents in a portfolio), scientific citations (the number of papers cited in an entity's patent filings) and other indicators, can be a powerful tool to track relative value. Future tracking of patents and other such measures of performance is needed, including to the extent possible a comprehensive patent citation analysis with additional appropriate indicators of patent activity above and beyond the tabulation of number of patents. Of course, the resources this would require must be weighed against other priorities.

EXTERNAL RECOGNITION

Awards were identified as an important measure of external peer recognition of program performance. Programs were asked in this review to identify the awards they had received. In response, the programs identified numerous awards, far too many to identify in this synopsis. For example, one of the 31 programs reviewed, the High Temperature Superconductor program, identified some 30 awards over the past 8 years, including DOE 100 Awards, Federal Laboratory Consortium Awards, the Georgia Grand Award, the Georgia Engineering Excellence Award, LANL Laboratory Fellows Prize, Council for Chemical Research Collaboration Success Award, ORNL Technical Achievement Award, TR 100 Award, R&D100 Award, SBIR Technology of the Year Award, NOVA Award, National Science Foundation Presidential Young Investigator Award, Journal of Technology Transfer Gold Medal for Technology Transfer, and others. Most of these awards were too narrow in scope to provide adequate comparison of EERE programs to R&D programs of other institutions.

Consequently, the R&D100 award was selected as a single measure of performance because it provides broad technology coverage—not just energy; it provides broad participation—across companies, universities, public agencies, and countries; it is externally awarded and independently peer reviewed; and it is widely recognized and highly regarded. The R&D100 awards have been characterized as the "Oscars of Invention". Across all EERE supported research, some 105 R&D100 awards were received for the period 1978-2001. These are listed in Table 4-A5. Although these awards were received by research supported by EERE, other institutions sometimes also supported the research and may have played a significant role in initiating or managing the work.

To evaluate EERE's performance in R&D100 awards, two analyses were conducted. First, the change in the number of awards over time was evaluated; second, the number of awards was compared to other institutions.

The change in the number of awards over time can be pulled directly from Table 4-A2 and the results are shown in Figure 4-2, together with the six R&D100 awards identified by the SPR received by predecessor agencies to EERE before it was formed in 1978. Where several agencies jointly supported research, such as EERE and NIST or NASA, no attempt was made to parse credit between EERE and the other agency.

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[26] Margolis and Kammen, op. cit.

There may also be other R&D100 awards to predecessor agencies to EERE, but the SPR was not able to identify them. Although there is substantial year-to-year variability, the number of awards has generally increased, with 80% of EERE's total received from 1990 on, and over half of the total received from 1995 on. A significant increase in performance over time can be seen.

Second, to compare the number of awards received with other institutions, total awards for various agencies, companies, countries, and universities must be tallied. R&D Magazine provided such a tally in its September 1995 issue for awards through that year (Table 4-A6). The SPR updated those numbers by reviewing the 1996 through 2001 issues and adding those values to the official 1995 data. Considerable effort was made to avoid double counting (except as noted above) and appropriately assign awards to the appropriate entity, but issues such as how to assign awards for companies that merged, how to identify the DOE role for research conducted by private companies without any attribution in the award description, how to identify sponsors of R&D when they were not listed, and other such factors complicate this tabulation. Therefore, the estimated values may differ slightly from the R&D Magazine update of these statistics that recently began, but the SPR believes that these variations will be no more than a few awards. Titles listed in R&D Magazine for various awards may also differ somewhat from the title in the official award plaque. As seen in the figure below, the relative ranking of EERE is unlikely to change with any corrections because of the large differences between the various top performers and the next level of performers.

The 105 awards are about one-fifth of the DOE total of about 540. In comparison, EERE's 105 awards placed it above all other government agencies except NASA, with 125 R&D100 awards; above all companies except GE, with 163; above all other countries except Japan, with 157; and above all universities (MIT was first with 30). Figure 4-1 compares the top ranked organizations. Overall R&D100 totals for these other organizations were generally evaluated from 1963 to 2001 while the EERE total was evaluated from 1978-2001. EERE accounted for about 25% of the R&D100 awards received by DOE from 1996 onward, using about 6% of DOE's budget. Finally, to put this into perspective, it should be noted that the 7 to 10 awards that EERE-supported research has won in each of the past 5 years represents 7 to 10% of all the R&D100 awards given out globally for all technology research—from aircraft, to biotechnology, to computer technology, to nanotechnology, to telecommunications.

This summary of technical performance illustrates some of the dramatic shifts that have taken place within these programs over the past two decades and the resulting impacts on R&D activities and results.

APPENDIX 4-A: TECHNICAL MERIT ANALYSIS

TABLE 4-A1: RECENT TECHNOLOGY ROADMAPS

Sector/Roadmap	Participants[1]	Date	Source
BUILDINGS			
Appliances		*	
Building Envelope Technology	>75	2001	A
Heating Ventilation Air Conditioning, and Refrigeration (in cooperation with Air Conditioning and Refrigeration Institute)	>60	1997	C
High Performance Commercial Buildings	>20	2000	A
Residential Buildings (in cooperation with Multi-Agency Presidential Initiative “Partnership for Advancing Technology in Housing)	>75	2000	B
Vision 2020: Lighting Technology	~170	2000	A
Window Industry Technology	>25	2000	A
INDUSTRY			
Agriculture/Bioproducts Plant/Crop-Based Renewable Resources 2020	80+	1999	D
Aluminum Industry Technology Roadmap	30+	1997	D
Chemical Industry Roadmaps: --Biocatalysis Roadmap --Combinatorial Chemistry --Computational chemistry --Computational Fluid Dynamics --Materials of Construction --Materials Technology --New Process Chemistry --Reaction Engineering --Separations --Catalysis Technology Roadmap Workshop Report --Process Measurement and Control	 58 65 51 45 25 66 131 51 163 66 47	 2000 2001 1999 1998 2000 2000 2001 2001 2000 1997 1998	D
Coatings on glass technology roadmap workshop	60+	2001*	
Combustion, and update	39, 42	1999 2002	D
Forest Products: Agenda 2020, The Path Forward	80+	ongoing	
Glass Technology Roadmap workshop	68	2001*	
Metal Casting Industry Roadmap	750+	1998	
Mining Industry Roadmap for Crosscutting Technologies	33	1999	D
Mining: Mineral Processing Technology Roadmap	30	2000	D
Mining: Exploration and Mining Roadmap	30	2001*	
Petroleum: Technology Roadmap for the Petroleum Industry	50+	2000	D
Process Heating	50+	2000	D
Heat Treating	17+	1997	D
Forging	30+	1997	D
Welding	20+	2000	D
Powder Metallurgy and Particulate Materials	39	2001	D
Steel Industry Technology Roadmap and 2001 update	75+	1998/2001	D
Vision 2020: Reaction Engineering Roadmap	~50	2001	D
Carbon Products		*	
Advanced Ceramics		*	

TABLE 4-A1: RECENT TECHNOLOGY ROADMAPS, continued

Sector/Roadmap	Participants[1]	Date	Source
TRANSPORT			
Energy-Efficient Vehicles for a Cleaner Environment, Office of Advanced Automotive Technologies R&D Plan, 2001 update.		1998 2001*	
Technology Roadmap for the 21st Century Truck Program	16	2000	E
Aluminum Industry Roadmap for the Automotive Market	11	1999	F
A Roadmap for Recycling End-of-Life Vehicles of the Future	8	2001	G
Plastics in Automotive Markets: A Vision and technology Roadmap	28	2001	H
POWER			
DER: U.S. Combined Heat and Power Vision	50	1999	I
DER: Transmission Reliability MultiYear Program Plan	20	2001	J
HTS: Cryogenic Roadmap	80	2000	
Photovoltaic: Solar Electric Power. The U.S. PV Industry Roadmap	>100	2000	
Concentrating Solar Power Roadmap	40	2001	
Zero Energy Homes Roadmap	>50	*	
Biopower	35	2001	K
Wind: Small Wind Turbines	15	2001	L
National CHP Roadmap	70	2001	I
BCHP Technology Roadmap	200	2000	M
Strategic Plan for DER	50	2000	N
Advanced Microturbine System Program Plan	30	2000	O

[1]Participants include individuals from companies, associations, universities, nonprofits, and others.
*Draft, not available yet
A. http://www.eren.doe.gov/ buildings/technology_roadmaps/
B. http://www.pathnet.org
C. http://www.arti.org
D. http://www.eren.gov/ and look under Office of Industrial Technologies, Industries of the Future
E. http://www.osti.gov/hvt/21stcenturytruck.pdf
F. The Aluminum Association, Washington, D.C. www.aluminum.org.
G. Argonne National Laboratory, Argonne, IL
H. American Plastics Council, Arlington, VA. www.plastics.org
I. http://www.nemw.org/uschpa
J. http://www.eren.doe.gov/der/transmission
K. http://www.eren.doe.gov/biopower
L. Expected to be completed in late Fall 2001.
M. http://www.bchp.org
N. http://www.eren.doe.gov/der
O. http://www.eren.doe.gov/cpt

TABLE 4-A2: REPRESENTATIVE GRADUATIONS AND TERMINATIONS*

TECHNOLOGY	PERIOD	REASON FOR GRADUATION OR TERMINATION AND STATUS
BUILDINGS		
Low-E Windows	1976-1983	Low-E coatings successfully developed, reducing window heat loss by about one-third, with private sector annual sales of about 260 million square feet of low-E windows or 40% of the market (see Chapter 7).
Spectrally-Selective Windows	1980-1984	Spectrally selective coatings successfully developed, reducing Solar Heat Gain Coefficient by about 40% compared to conventional double glazed windows.
Superwindow Project	1982-1988	Successful demonstration of impact of various components integrated into very high performance windows, e.g., multiple layers of low-E coatings, krypton gas, baffles, etc. Thermal performance equivalent to a reasonably well insulated wall (R-10). Industry incorporated various components into new efficient window products.
High-Efficiency Furnaces	1979-1987	Corrosion resistant alloys successfully identified, enabling use of condensing-extraction furnaces with efficiencies increasing from the high 70% range to 92+%, with current annual sales of nearly 700,000/year, or a quarter of the market
Flame-retention head oil burners	1979-1981	Successfully provided a range of market facilitation supports to aid deployment of technology increasing efficiency roughly 20%, capturing 100% of market
Refrigerator Compressors	1978-1981	Completed multiple advances in refrigerator technology, with energy consumption dropping by nearly three-fourths, 1975-2001; standards now ensure 100% use
Electronic Ballasts	1977-1982	Electronic ballasts successfully developed, reducing energy use about 25%, with private sector annual sales of about 40% of the market.
DOE-2	1980-1998	A series of progressively more sophisticated building energy simulation DOE-2 models have been developed, with more than 18 private companies using them as core analytic engines for their commercial software tools.
Radon Mitigation	1988-1996	EE research showed the routes and mechanisms for radon infiltration and ways to effectively mitigate it; EPA has assumed outreach/implementation activities designed to reduce radon levels in new and existing homes. No further DOE work required.
National equipment performance standards	various	Refrigerators and freezers, residential furnaces, water heaters, clothes washers, central air conditioners and central air conditioning heat pumps, room air conditioners, dishwashers, clothes dryers, direct heating equipment, pool heaters, kitchen ranges and ovens, fluorescent lamp ballasts, commercial building heating and air conditioning equipment, certain incandescent and fluorescent lamps, and electric motors, have been developed and put into place, with large public benefits (Chap. 5).
Ozone-safe refrigerants	1980-1997	Beginning in 1970's EE supported research on advanced refrigerants exploring the fundamental science of two-phase flow. The objective was to increase understanding of the science and possibly develop refrigerants that improve energy efficiency. This work contributed to the selection of refrigerants to satisfy the global agreements for ozone depletion in the late 1980's. EE sponsored research to solve the lubrication and materials compatibility problems with the new refrigerants. Solutions provided to HVAC industry and no further EERE work was required.
Urban Heat Islands Highly Reflective Surfaces	1994-1999	EERE established the analytical basis for the Urban Heat Islands issue. Began some research and information dissemination on specific reflective surfaces and materials. Program incorporated in the buildings envelope research program beginning in 1999.
Home Energy Rating Systems	1993-1998	EERE facilitated the development of a reasonable rating basis for residential construction. Private sector is now providing this rating service for energy efficient mortgages and other purposes.
Municipal Energy Management Program	1988-1999	Provided grants to Chicago Regional Office to fund annual solicitation to communities to conduct energy efficiency and renewable energy projects. Program was completed in 1999.
Residential Energy Efficiency Program	1980-1994	EERE worked with an industry partner to develop a mechanism to introduce new or under represented energy technologies into the marketplace. Termination of program occurred as other mechanisms such as PATH came on line.

TABLE 4-A2: REPRESENTATIVE GRADUATIONS AND TERMINATIONS, continued

TECHNOLOGY	PERIOD	REASON FOR GRADUATION OR TERMINATION AND STATUS
Institutional Conservation Program	1978-1995	Congress authorized grants to States and to public and non-profit schools to identify and implement energy conservation measures. Additional funding for program provided from Petroleum Violation Escrow Settlements in 1980's. ICP was consolidated with the State Energy Conservation Program to form the State Energy Program in 1995.
Energy Extension Service	1977-1990	Congress authorized grants to States to establish outreach services to assist small energy users. Program was incorporated into the State Energy Conservation Program to streamline program administration.
Laser-welded vacuum glazing	1988-1994	Marginal benefits of NREL technology could not justify costs over krypton superwindow technologies, there was limited US industry interest, and Laser-weld technique had technical problems. U.S. DOE-supported development efforts were discontinued. Some renewed interest is starting to form. [International interest and new US industry interest, plus new lower cost, more durable technologies.]
Aerogel	1985-1989	Early versions of technology had some technical issues plus required very high cost production equipment. DOE ended work in 1989. [New versions of technology have lower production costs; and spin-off markets.]
Diamond-like clear protective coatings	1994-1996	This protect the coating strategy was abandoned in lieu of more durable coatings using new deposition and material capabilities.
Daylighting Systems	Deferred/ reduced effort in 1991	This research focused on advanced materials such as holographic films, fiber optics etc. Due to budget constraints and competition with lower tech solutions, i.e., dimmable electronic ballasts; daylighting controls, etc., the program abandoned it's pursuit of long term advanced solutions to focus on more practical opportunities.
Residential Furnace and Boiler Combustion R&D	1980-1997	With oil heating industry EERE research improved oil burning equipment for residential use. Successes included flame retention head burners. Program evolved into industry run program supported out of fees collected by the oil distribution co's.
INDUSTRY		
Novel Non-Consumeable Anode for Electorwinning Primary Aluminum,	FY99-FY2001	Demonstrate feasibility of a novel non-consumeable (gas) anode based on fuel cell technology as a retrofit replacement for the carbon anodes in production of primary aluminum. Proved not feasible because solubility of the proposed materials was too high for use in a cryolite melt. Task terminated. Project team is completing tasks on basic salt chemistry, sensor system for aluminum smelting.
Wettable Ceramic-Based Drained Cathode Technology	FY1997-FY2001	Final task of project, commercial scale demonstration of the wetted cathodes at Kaiser Aluminum, could not be performed in FY2001 because of the shut down in Kaiser smelting capacity in the Pacific Northwest. Alcoa has acquired the intellectual property rights and can continue without DOE support.
DeZincing Steel Scrap	--FY98	Terminated because of a lack of industry interest
Microstructure Engineering in Hot Strip Mill	--FY99	Hot strip mill model developed that quantitatively links mechanical properties of hot rolled steel to operational characteristics of its mill, reducing energy use by not having to rework product that does not meet specifications. In commercial use.
Hot Blast Stove Process Model and Controller	--FY99	Completed in FY99. Technology is available and in commercial use.
Low-NOx Oxy-fuel burner for Steel Reheating	--FY99	Oscillating combustion industrial burner for steel reheating furnace, designed to suppress formation of Nox and increase heat transfer to the steel, improving energy efficiency up to 5%
Optical Sensors and Controls for BOF	--FY99	Completed FY99, technical progress recognized and industrial partner continuing work.
Auto Glass Process Control	--FY00	High temperature glass property database designed to improve modeling and thus improve process control, reduce wastes, reduce emissions. One technology going into commercialization; other two research activities considered for continuation by industry

TABLE 4-A2: REPRESENTATIVE GRADUATIONS AND TERMINATIONS, continued

TECHNOLOGY	PERIOD	REASON FOR GRADUATION OR TERMINATION AND STATUS
Integrated Batch and Cullet Preheater System	--FY00	Project completed and commercialization expected
Other	FY98-FY00	118 project graduations/terminations documented by OIT (see Figure 4-6).
TRANSPORT		
Ceramics for heat engines	1984-1996?	Developed toughened zirconia ceramics for diesel engine and other applications, with production now exceeding 300 tons/year. Further development not likely to provide sufficient reliability or low-cost for PNGV applications; development continues for heavy truck engines and for stationary distributed power systems. Ceramic coatings for diesel engine piston rings--330,000 sold in 2000. Ceramic fuel injector components with millions of sales. Camshaft-roller followers with millions of sales. Applications in gas turbines. Improved cutting tools with sales of $30M/year. Used as forming dies for beverage containers.
Automotive Stirling Engines	1981-1990 1993-1998	Cost-shared work with General Motors, 1993-1998, unable to overcome low thermal efficiency, high heat rejection requirements, poor specific power, and excess hydrogen leakage in time frame needed for PNGV. Private sector is developing technology for distributed power
Automotive Gas Turbine	1978-1997	Performance not competitive with conventional engines and diesel engine judged more likely to meet efficiency, emissions, reliability, durability needs in time frame of PNGV. Allison, Allied Signal continuing development for other applications.
Ultra-capacitor energy storage	1990-1997	Cost of materials (ruthenium oxide) not potentially competitive for auto market Private sector continuing development for power electronics, stationary energy storage and other applications
Flywheel energy storage	1993-1996	Concerns about safety of high-speed rotors and stage of development incompatible with PNGV time frame. Private sector commercializing them for stationary power.
Series hybrids	1993-1997	Lack of maturity along with inability to meet system performance requirements when coupled with other selected technologies led to the decision to pursue parallel hybrids and not series hybrids
Lead-acid batteries for hybrid vehicles/ Pneumatic/hydraulic storage	1997	While not part of the development program these technologies were considered alongside other candidate technologies for program selection. It was decided that these energy technologies could not, at the time, provide the needed technical performance to contribute to the program goals of efficiency, emissions, and cost.
Glass-Fiber-Reinforced-Polymer-Matrix Composites	1995-2001	Development of glass-fiber-reinforced-polymer-matrix was successfully completed with initial introduction into automotive products. Program effort has turned to carbon-fiber composites because of the potential weight savings of 2 times greater than glass-fiber composites.
Fuels Utilization	1993-1995	Methanol and ethanol engines developed, certified, and tested. Because of the higher cost of these fuels attention turned to advanced petroleum based and gaseous fuel.
Diesel Bottoming Cycle	-1985	Too complex and unlikely to be cost competitive. Private sector subsequently terminated efforts as well.
Electric Vehicle Program	1977-1990	R&D shifted toward more promising hybrid vehicle development; battery development continued. Some drivetrain work adapted by Ford, others for California.
Phosphoric Acid Fuel Cells for transport	1990-1994	PEM fuel cells were determined to have greater potential for transport applications due to their high power density, low operating temperature and relatively fast start-up times. PAFC work is continuing outside of EE for stationary power applications
Twin Screw, Toroidal Vane, Piston, and Scroll Compressors	1996-2001	Of the five compressor technologies for automotive fuel cell systems that EE initially supported, peer review identified turbocompressors as the most viable and terminated work on other four. Longer-term turbocompressor/scroll hybrids and Toroidal Intersecting Vane machines are also being pursued.
Spark ignition direct injection engines	1999-2001	R&D to reduce NOx and hydrocarbon emissions, broaden efficient operating regime, and increase efficiency. R&D terminated as technology has entered commercial use, fuel efficiency benefit is less than potential of diesel engines and fuel cells.

TABLE 4-A2: REPRESENTATIVE GRADUATIONS AND TERMINATIONS, continued

TECHNOLOGY	PERIOD	REASON FOR GRADUATION OR TERMINATION AND STATUS
POWER		
Ocean Thermal Energy Conversion (OTEC)	1975-1994	The feasibility of OTEC systems to generate electricity from the temperature difference between warm surface water and deep cold water was verified, but system costs were prohibitive and there was minimal potential for widespread U.S. use
District Heating and Cooling	1979-1992	Various technology applications developed and demonstrated at 40+ locations in U.S.; no significant further Federal R&D was required at time of program closure. Progress on power park concepts and DER may make it appropriate to reconsider this technology in terms of systems integrated with CHP.
Integrated Resource Planning	1988-1996	Analysis/information dissemination to utility regulators and staff on "best practices" for integrated supply/demand planning. Electricity restructuring led to elimination of IRP at many PUCs and utilities, and IRP mandates no longer a PUC priority
Solar One and Solar Two Power Towers	1977-1998	Technical feasibility of solar power towers validated during Solar One; integration of molten salt thermal storage validated during Solar Two. U.S. industry actively developing commercial power towers in Spain and Morocco today, with hope for possible U.S. deployment in the future as costs become more competitive.
Vertical Axis Wind Turbines	1977-1997	While VAWT technology offers some design and maintenance advantages over conventional horizontal axis system, inherent technical and economic difficulties led to a configuration that was not cost competitive.
Magma Energy Extraction	1984-1989	Established baseline technological parameters and assessed cost effectiveness potential, but limited U.S. applicability and likely high cost led to closeout.
Hot Dry Rock	1978-1995	Technology did not demonstrate sufficient progress and potential benefits.
Geothermal Test Facility	1976-1990	Insufficient activity to justify costs of facility
Heat Cycle Research Facility	1979-1994	Successful demo of metastable turbine expansions and working fluid supercritical heating/condensing; work graduated to cooperative research with industry to reduce costs and transfer technology.
Geopressured Geothermal R&D	1975-1992	Demonstration projects successfully completed. Technology not expected to become viable under market conditions.
Geothermal Heat Pumps	1992-1999	Successfully completed utility-led partnership with more than 500,000 GHPs in use. Industry continues to grow at more than 10% per year in both residential and commercial building markets.
EMF Health Effects	1994-1999	Successfully answered Congressional Energy Policy Act of 1992 question of whether power frequency fields cause adverse health effects, finding no significant impact, and transferred a reduced program to NIEHS
Advanced Turbine Systems	1992-2000	Developed 4.2 MWe advanced turbine system with 37.5% efficiency—exceeding program goal of 33%—and ultra-low emissions. Technology successfully demonstrated, currently in beta testing, commercial units expected within 1-2 years.
PQ 2000 Energy Storage		Work on PQ2000 system completed successfully and 40 MW are now in use.
Country Studies Program	1993-2000	Initiated at 1992 UN Framework Convention. Assessed 56 countries—energy needs, resources, and potential use of GHG-reducing technologies; demonstration of feasible technologies in representative geographic regions achieved.
Hydrogen Storage: Magnesium hydride	1994-1998	Terminated magnesium hydrides due to excessively high temperatures of desorption.
Hydrogen Storage: Glass Microspheres	1996-1998	Terminated glass microspheres due to the energy requirements for storage.
Hydrogen production	1996-2001	Reforming diesel fuel to produce hydrogen terminated as not likely to meet efficiency goals
Solar hemispherical bowl concentrators	1977-1982	Efficiency too low relative to other solar tracking options.

TABLE 4-A2: REPRESENTATIVE GRADUATIONS AND TERMINATIONS, continued

TECHNOLOGY	PERIOD	REASON FOR GRADUATION OR TERMINATION AND STATUS
Solar dish Rankine engines	1975-1986	Systems did not tolerate continuous solar cycling.
Solar dish Brayton engines	1975-1987	Systems did not tolerate continuous solar cycling
Solar industrial process heat	1981-1995	Found to be too costly relative to natural gas and a lower value product than electricity
Solar photocatalysis for Detoxification	1990-1995	Found that it could be done at lower cost with fossil fuels
Central Receivers with rock/oil thermal storage	1978-1989	Efficiency too low relative to other options due to the relatively low storage temperatures; molten salt storage proved superior.
Thin-film Photovoltaics	Various from 1974-1988	Cu_2S; Cu_2Se; Zn_3P_2; $ZnSiAs_2$; InP; CdSe; InSb, and other thin film materials were investigated and efforts terminated due to efficiency, stability, other problems. Work continues on higher performance thin film materials
Hydropower Improved Turbine Design	1994-2001	Voith design for dissolved oxygen turbine currently being installed at several TVA sites; project has been successful and no further testing planned.
Minnesota Agripower Project	1994-1999	Terminated Minnesota Agripower Project due to regulatory and financial issues
Hawaiian Biomass Gasification Commercialization	1991-1999	Major technical issues were encountered and project partners were not willing to increase their cost-share to finance the necessary technical modifications.
Superconductivity	1996-1999	General Atomics successfully completed demonstrations of pre-commercial superconducting fault current limiter at Southern California Edison substation. Didn't proceed to commercialization because of high costs and need for more reliable cooling system design.

* Various new activities have been launched as these were graduated/terminated. In some areas this formed a progressive sequence. For example, in windows, low-emissivity (low-E) coatings were developed and the work graduated, then (perhaps with some overlap) spectrally-selective coatings were developed and the work graduated, and currently the focus is on electrochromic coatings. In other areas, entire areas of research were terminated/graduated, such as OTEC, and new, unrelated activities launched. The overall impact of these terminations/graduations and new launches can be seen by the budget totals shown in Appendix C at the back of this report.

TABLE 4-A3: EXTERNAL PEER REVIEWS, 1990-2001

Reviewer	SECTOR REVIEWED/DOCUMENT TITLE	Date
	EERE	
NRC	Review of the Strategic Plan of the U.S. Department of Energy Office of Conservation and Renewable Energy	1992
OTA	Energy Efficiency: Challenges and Opportunities for Electric Utilities	1993
SEAB	Energy R&D: Shaping Our Nation's Future in a Competitive World	1995
PCAST	Federal Energy Research and Development for the Challenges of the Twenty-First Century	1997
AD Little	Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs, Annual Peer Reviewed analysis of EERE projected benefits	1997-present
DOE I.G.	The Department of Energy's Peer Review Practices[27]	1998
PCAST	Powerful Partnerships: The Federal Role in International Cooperation on Energy Innovation	1999
NAPA	A Review of Management in the Office of Energy Efficiency and Renewable Energy [28]	2000
NRC	Energy Research at DOE: Was It Worth It? [29]	2001
	BUILDINGS--BTS	
OTA	Building Energy Efficiency	1992
External Panel	Electrochromic Windows Project – Peer Review	1990
ACEEE, ASE	Achieving Greater Energy Efficiency in Buildings: The Role of DOE's Office of Building Technologies; Report of the Building Energy Efficiency Program Review Group, Alliance to Save Energy	1992
Office of Energy Research	Summary Results of an Assessment of Research Projects in the Lighting Research Program	1997
Office of Energy Research	An Assessment of Research Projects in the Building Technology Program; 18 Panels reviewing 114 R&D projects	2000
	FEMP	
OTA	Energy Efficiency in the Federal Government: Government by Good Example?	1991
OTA	Energy Efficiency in Federal Facilities: Update on Funding and Potential Savings	1994
GAO	Energy Savings Performance Contracting in Federal Civilian Agencies	1996
ASE	Leading by Example: Improving Energy Productivity in Federal Facilities	1999
DOE I.G.	Audit Report- Department of Energy's Super Energy Savings Performance Contracts	2001
	INDUSTRY—OIT	
OTA	Industrial Energy Efficiency	1993
NRC	Intermetallic Alloy Development: A Program Evaluation[30]	1997
NRC	Separation Technologies for Industries of the Future	1998
NRC	Manufacturing Process Controls for the Industries of the Future	1998
Various	Critical Program Review—Inventions and Innovations Program	1998
NRC	Industrial Technology Assessments: An Evaluation of the Research Program of the Office of Industrial Technologies[31]	1999
ORNL	Industrial Assessment Center Program Impact Evaluation[32]	1999
NRC	Materials Technologies for the Process Industries of the Future	2000
NRC	Catalytic Process Technology	2000
NRC	Evolutionary and Revolutionary Technologies for Mining	2001

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[27] USDOE Office of I.G., "The Department of Energy's Peer Review Practices," DOE/IG-0419, April 1998

[28] National Academy of Public Administration, "A Review of Management in the Office of Energy Efficiency and Renewable Energy", Washington, DC, March 2000. www.napawash.org

[29] NRC, "Energy Research at DOE: Was It Worth It?," National Academy Press, Washington, 2001.

[30] NRC, "Intermetallic Alloy Development: A Program Evaluation", National Academy Press, 1997

[31] NRC, "Industrial Technology Assessments: An Evaluation of the research Program of the Office of Industrial Technologies", National Academy Press, Washington, DC, 1999

[32] Oak Ridge National Laboratory, "Industrial Assessment Center Program Impact Evaluation," Oak Ridge National Laboratory, Oak Ridge, TN, ORNL/CON-473, December 1999.

TABLE 4-A3: EXTERNAL PEER REVIEWS, 1990-2001, continued

Reviewer	SECTOR REVIEWED/DOCUMENT TITLE	Date
	TRANSPORT—OTT	
OTA	Saving Energy in US Transportation	1993
NRC	Review of the Research Program of the Partnership for a New Generation of Vehicles: 1	1995
NRC	Review of the Research Program of the Partnership for a New Generation of Vehicles: 2	1996
NRC	Review of the Research Program of the Partnership for a New Generation of Vehicles: 3	1997
Auto Industry	Comprehensive Peer Review of the DOE/PNGV Auto. Lightweight Materials Program	1997
NRC	Review of the Research Program of the Partnership for a New Generation of Vehicles: 4	1998
NRC	Review of the Research Program of the Partnership for a New Generation of Vehicles: 5	1999
NRC	Review of the Research Program of the Partnership for a New Generation of Vehicles: 6	2000
NRC	Review of the Research Program of the Partnership for a New Generation of Vehicles: 7[33]	2001
NRC	Review of the Research Strategy for Biomass-Derived Transportation Fuels	2000
NRC	Review of the U.S. Department of Energy's Heavy Vehicle Technologies Program	2000
Selected Experts	DOE Automotive Lightweight Materials Advisory Panel	2001
	POWER AND RENEWABLES—OPT	
NRC	Assessment of Research Needs for Wind Turbine Rotor Materials Technology	1991
Independent Panel	Superconductivity Annual Peer Review 2000 Meeting Proceedings, Superconductivity Program for Electric Systems[34] (Public meetings are held annually. Most recent had 180 participants, 7 national laboratories, and 25 partners—including industry and universities.	1990-present
American Wind Energy Assn.	R&D Committee has conducted annual reviews	1990-present
Office of Energy Research	An Assessment of Research Projects in the Federal Wind Energy Research Program. Internal Use Only	1991
Office of Pgm. Analysis	Power-Geothermal Energy Program/"Peer Review of Geothermal Energy Program	1992
Independent Panel	Hydrogen Program Annual Peer Review	1994-2001
HTAP	Hydrogen Technical Advisory Panel: Review of the Hydrogen Program; Report to Congress	1998
IndpndtPanel	Summary Results of an Assessment of Research Projects in the National PV Program[35]	1995
OTA	Renewing Our Energy Future	1995
IndpndtPanel	Final Report of Peer Review on Solar Thermal Electric (STE) Program, USDOE [36]	1997
NRC	Renewable Power Pathways	2000
NRC	Review of the Hydrogen Program	2000
IndpndtPanel	Peer Review of DOE's Photovoltaics Program	2001
IndpndtPanel	Concentrating Solar Power Program Peer Review	2001
IndpndtPanel	Solar Buildings Program Peer Review	2001
IndpndtPanel	Power-Geothermal Energy Program/Geothermal Program and Peer Review XVII	1999
IndpndtPanel	Power-Geothermal Energy Program/TBD	2001
IndpndtPanel	July 2001Geothermal Annual Review, edited by Sentech, Inc., currently in preparation.	

Key: NRC—National Academy of Sciences' National Research Council; OTA—Congressional Office of Technology Assessment; SEAB—Secretary of Energy Advisory Board; PCAST—President's Committee of Advisors on Science and Technology; ACEEE—American Council for an Energy Efficient Economy; ASE—Alliance to Save Energy; DOE Office of Energy Research; DOE Inspector General.

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[33] NRC, "Review of the Research Program of the Partnership for a New Generation of Vehicles: Seventh Report," National Academy Press, Washington, DC, August 2001

[34] Annual Peer Review 2000 Meeting Proceedings, July 17-19, 2000, available on CD-ROM from Energetics, Inc., 7164 Gateway Drive, Columbia, MD 21046, (410) 290-0370, order number DE00759424

[35] USDOE, Office of Energy Research, Summary Results of an Assessment of Research Projects in the National Photovoltaics Program", DOE/ER-0663, July 1995.

[36] Robert Reid, et. al., "Final Report of Peer Review on Solar Thermal Electric (STE) Program, U.S. Department of Energy," SUNLAB, Sandia National Laboratory and National Renewable Energy Laboratory, January 1997.

TABLE 4-A4: PATENTS, 1978-2001

Sector/Program	Granted	Pending	Invention Disclosures
BUILDINGS—BTS*	76	19	108
Residential Buildings Integration			
Commercial Buildings Integration			
Building Equipment and Materials			
Energy Star	Does not do R&D		
Weatherization Assistance	Does not do R&D		
State Energy Program	Does not do R&D		
Community Energy Program	Does not do R&D		
FEMP/DEMP	Does not do R&D		
INDUSTRY—OIT			
Vision Industries			
• Metals Initiative	18		
Enabling Technologies			
Industrial Technology Assistance			
Financial Assistance			
TRANSPORT—OTT			
Hybrid Systems R&D	85 with GM, Ford, DCX, NREL	NA	7
Fuel Cell R&D	56 (1991-)	26	
Advanced Combustion Engines	8 in FY99 and FY2000		
Electric Vehicle R&D	30 private; 42 at national labs		79 pvt; 49 labs
Heavy Vehicle Systems R&D			
Fuels Utilization			
Transportation Materials	5	10	
Transport. Technology Assistance			
Biofuels			
POWER—OPT			
DER	5		
Superconductivity, 1991-2001	209 total (108 at national labs)	239 total (54 at labs)	574 total (272 at labs)
Hydrogen	32 patents since 1978	16 pending	1
Wind	10 patents since 1985 (includes 3 for SNL)		
Solar	>235 patents		
Geothermal	7	10	35
Hydropower	1	1	
Biopower	75 since 1980		
International	Does not do R&D		

*Data is through 1996.

TABLE 4-A5: EERE R&D100 AWARDS, 1978-2001

ACTIVITY[1]	**RECIPIENT**	**YEAR**
BTS--BUILDINGS		
Compact Vacuum Insulation	NREL	1991
Flame Quality Indicator	ORNL	1992
CFC/HCFC Ratiometer	ORNL	1992
Transpired Solar Collector (counted under OPT)	*NREL, Conserval Engineering*	*1994*
Sulfur Lamp	Fusion Lighting, LBNL	1995
Constricted Plasma Source Thin Films	LBNL	1997
Life-Cycle Advantage™	PNNL	1998
Frostless Heat Pump	ORNL	1999
Microheater	PNNL	1999
Drop-In Residential Heat Pump Water Heater	ORNL, ADL, ECR International	2001
Gas-filled Panels/Airliner	LBNL	2001
OIT—INDUSTRY		
Anaerobic Upflow Packed Bed Bioreactor	*ORNL: By Predecessor agency to EERE*	*1976*
Tapered Fluidized Bed BioReactor	ORNL	1979
Oxygen High Pressure Gasifier	NREL	1982
Nickel-Iron Aluminide	ORNL	1983
Sludge to Oil Reactor System	PNL, Battelle	1988
Binder-Enhanced Densified Refuse-Derived Fuel Pellets	ANL	1989
Biomass Energy System	PNL, TEES	1989
Gasless Atomizing Nozzle	ORNL	1989
Inexpensive Phenol Replacements from Biomass	SERI	1990
Petroleum Sludge Treatment Process	PNNL, OnSite*Offsite, Inc.	1991
X-Ray Tomographic Microscope	LLNL, SNL, Georgia Institute of Technology, and Material Data, Inc.	1991
Planar Waveguide Spectrometer	PNNL	1991
Bipolar Li/FeS2 Battery	ANL	1991
Solar Detoxification of Hazardous Materials in Wastewater	NREL, SNL	1992
Data Gator Flowmeter	Yellowstone Environmental Science, NIST	1993
Waste Tire Utilization	Composite Particles, Inc.	1995
Exo-Melt Process	ORNL	1995
Polymer Filtration System	LANL, Boeing Defense & Aerospace	1995
New Method for Making Silicon Carbide Powders	NREL, Golden Technologies Corp	1995
Gel Casting (shared with OTT)	ORNL	1995
Oxygen Enriched Air Staging	Institute of Gas Technology	1996
Biologically-derived Succinic Acid	ORNL, NREL, ANL, PNNL, & Applied Carbochemicals	1997
Plastics, Fibers, and Solvents from biosynthetically Derived Organic Acids	PNNL, ORNL, Applied CarboChemicals, U of Illinois-Urbana, Engelhardt, New Horizon Eng.	1997
New Recovery for Sulfide Reduction	LATA Group	1997
Metal Compression Forming (counted under OTT)	*ORNL & Thomson Aluminum Casting Co.*	*1997*
Life-Cycle Advantage Software	PNNL	1998
Rapid Solidification Process Tooling	INEEL	1998
MACLEAN/MACER Solvent Cleaning System	PNNL, Micell	1998
Galvanneal Temperature Measurement System	ORNL, American Iron & Steel Institute, Bailey Engineers, National Steel Technical Center	1999
Submergible Robotic System	INEEL, Solex	1999

TABLE 4-A5: EERE R&D100 AWARDS, 1978-2001, continued

ACTIVITY	RECIPIENT	YEAR
Mechanical Fluidized Vacuum Reactor for Bulk Powders	Kemp Development Corp., Action Materials, Inc., Inventions & Innovation Program	1999
Recovering Plastics from Auto Shredder Residue	ANL	2000
Real Time Biomass Analysis	NREL	2000
TRANSPORT—OTT		
Lightweight Rechargeable Power Cells	*ANL: Supported by predecessor agency to EERE*	*1968*
High-Capacity LiAl/FeS Rechargeable Battery Cells	*ANL: Supported by predecessor agency to EERE*	*1974*
Electric Vehicle Battery Charging System	ANL	1981
Multifunctional Sensor Electrode	ANL	1982
Deep-Cycle Sealed Lead-Acid Battery	ANL with Gould Battery	1982
Biaxial High-Temperature Fatigue Extensometer	ORNL	1985
Micromembrane-Electrode Sensor	ANL	1987
Self-Replenishing Boric Acid Films	ANL	1991
Alkaline Fluoride-Carbonate Electrolyte for Zinc-Nickel Oxide Cells	LBL	1992
Sulfide Ceramic Materials	ANL	1993
Ethanol from Corn Fiber	NREL, New Energy Company of Indiana	1993
Single Fermenter Cellulosic Biocatalyst	NREL	1995
Gel Casting (shared with but counted under OIT)	*ORNL*	*1995*
CARES/LIFE Integrated Design Software	ORNL, NASA/Lewis, Phillips	1995
Thin Film Rechargeable Batteries	ORNL	1996
Variable Conductance Insulation Catalytic Converter	NREL & Benteler Industries	1996
Metal Compression Forming – shared with OIT	ORNL & Thomson Aluminum Casting Co.	1997
Near Frictionless Carbon Coating	ANL	1998
Clean Diesel Technology	ANL	1999
Compact Microchannel Fuel Processing	PNNL	1999
High Thermal-Conductivity Low-Density Graphite Foam	ORNL and POCO Graphite	2000
Autothermal Reforming Catalyst for Fuel Processors	ANL	2001
Current Interrupt Charging Algorithm for Lead-Acid Batteries	NREL, Recombination Technologies, Optima Batteries, Inc.	2001
Catalyst Materials for Plasma-Catalysis Engine Exhaust Treatment	PNNL, Delphi Research Laboratories and Ford Research Laboratory	2001
POWER—OPT		
Concrete Polymer Materials	*BNL: Supported by predecessor agency to EERE*	*1969*
Dielectric Compound Parabolic Concentrator	*ANL: Supported by predecessor agency to EERE*	*1976*
Non-imaging Solar Collector	*ANL: Supported by predecessor agency to EERE*	*1977*
Redox Energy Storing System	DOE; NASA-Lewis	1979
Cu2S/CdS thin film solar cell	Institute for Energy Conversion	1979
Large Propeller Type Wind Energy System	DOE; NASA-Lewis	1981
High Pressure Oxygen Biomass Furnace System	NREL	1982
Superconducting Magnetic Energy Storage System	LANL	1984
Copper Indium Selenide/Cadmium Zinc Sulfide Soar Cell	SERI, Boeing	1984
Automated Seismic Processor	LBL	1984
Flash Evaporation Method and Apparatus	NREL	1984
Automated Seismic Processing System	LBNL	1984
Volume-Indexed Secondary Ion Mass Spectrometry	SERI	1985
Zinc Oxide Varistors	ORNL	1985

TABLE 4-A5: EERE R&D100 AWARDS, 1978-2001, continued

ACTIVITY	RECIPIENT	YEAR
Zinc Phosphate Conversion Coating System	BNL	1988
Spectroscopic Scanning Tunneling Microscope	SERI	1989
Gallium Indium Phosphide/Gallium Arsenide Tandem Solar Cell	SERI	1991
Cadmium Telluride Photovoltaic Modules	SERI; Photon Energy	1991
Advanced Wind Turbine Blades	SERI	1991
Atomic Processing Microscopy	NREL	1992
Dish/Stirling Concentrating Solar Power System	SNL	1993
Scanning Defect Mapping System	NREL	1993
Aqueous Chelating Etch	SNL	1993
Solar Detoxification of Hazardous Materials in Groundwater	NREL/SNL	1993
New and Efficient Process to Produce Pure HTS with Superior Properties	ANL	1993
Transpired Solar Collectors (shared with BTS)	NREL, Conserval Engineering	1994
High Performance Silicon Photovoltaic Cell	SNL, EPRI, Amonix, Inc., Sunpower Corp.	1994
Photovoltaic Solar Cell AP-225	NREL; Astropower	1995
Cryosaver Superconducting Current Leads	American Superconductor Corporation	1996
Superconducting Magnetic Flux Imaging System	Phase Metrics Co., ANL, and Institute of Solid State Physics of the Russian Academy of Sciences, Chernogolovka	1996
High Strength, High Temperature Superconductor Fabrication Technology	American Superconductor Corporation	1996
PV Optics Software Light-trapping Model	NREL	1997
PQ 2000 Power Quality System	Sandia, EPRI, Oglethorpe Power Corp., PG&E, AC Battery Corp.	1997
UNI-SOLAR Triple Junction Amorphous-Silicon Solar-Electric Modules	United Solar Systems Corporation, NREL	1998
Underground Radio with Superconducting Detector	LANL, Raton Technology, Inc.	1998
High Throughput Biomass Gasifier	FERCO, Battelle Columbus Labs; Burlington Electric Department, NREL	2000
Rolling-Assisted Biaxially-Textured Substrates (RABITS)	ORNL	1999
Advanced Direct-Contact Condenser	NREL, Alstom Energy Systems, Inc.	1999
High Efficiency CIS PV Modules	Siemens Solar Industries, NREL	1999
Geothermal Silica	BNL, Caithness Operation Company	2001
Electro-exploded Metal Nanopowders	NREL, Argonide Corp., Republican Engineering Tech Center, LANL	2000
Northern Power Systems Cold Weather Turbine	Northern Power Systems, NREL, NASA, NSF	2000
ThermaLock Cement	BNL, Unocal Corporation, and Halliburton Company	2000
Triple-Junction Terrestrial Concentrator Solar Cells	NREL, SpectroLab	2001
DRWiN ™ Electronically Scanning Antenna	NREL, Paratek Microwave, Micron Technology, Inc., St. Petersburg State Electrotechnical University	2001
EBC Coating for Ceramic Composite Combustor Liners	NASA, Pratt and Whitney, Solar Turbines, General Electric	2001

[1]Activity titles may vary between R&D100 Magazine and the award statement.

ANL: Argonne National Laboratory; BNL: Brookhaven National Laboratory; INEEL: Idaho National Environmental Engineering Laboratory; LBNL: Lawrence Berkeley National Laboratory; LLNL: Lawrence Livermore National Laboratory; NREL: National Renewable Energy Laboratory; ORNL: Oak Ridge National Laboratory; PNNL: Pacific Northwest National Laboratory; SERI: Solar Energy Research Institute (its name was changed to NREL in 1991); SNL: Sandia National Laboratory

TABLE 4-A6: TOP R&D100 WINNERS, 1963-2001

Category/Winner	R&D Magazine 1963-1995*	SPR Estimate 1996-2001	Total
Government Agencies			
U.S. DOE	386	181	567
U.S. DOE/EERE	6 (‘63-‘78), 59 (‘78-‘95)	46	111
NASA	101	24	125
NIST	76	7	83
U.S. Bureau of Mines	23	0	23
Industry			
General Electric	160	3	163
Varian Associates	72	3	75
Westinghouse	63	2	65
Dow Chemical	56	5	61
Hitachi	44	14	58
Dupont	45	3	48
Hewlett Packard	40	1	41
Countries other than U.S.			
Japan	116	41	157
Germany	28	12	40
England	25	10	35
Private Research Institutions			
Battelle	18	11	29
EPRI	18	8	26
Southwest Research Institute	15	9	24
IIT Research Institute	7	0	7
Universities			
MIT	15	15	30
Iowa State	3	10	13
University of Tennessee	5	3	8
Johns Hopkins	6	0	6

*Robert Cassidy, “R&D100s: Technology for a Better World”, R&D Magazine, September 1995.

TABLE 4-A7: SELECTED PROGRAM ACCOMPLISHMENTS*

PROGRAM/ ACTIVITY	ACCOMPLISHMENTS—IN COOPERATION WITH INDUSTRY, NATIONAL LABORATORIES, AND UNIVERSITY PARTNERS
	BUILDINGS—Building Technology, State, and Community Programs
Heating, Cooling, Ventilation	• Energy Efficient Furnaces. Developed/Identified corrosion-resistant alloys for use in high-efficiency condensing-extraction furnaces, raising efficiencies from the high 70% level to 92-95%. These furnaces now account for a quarter of the market with annual sales of 700K. • Developed Low-E Windows that reflect far infrared radiation to reduce heat loss (or heat gain) through a window by a third compared to conventional double glazed windows. Currently account for about 40% of the window market or 260 million square feet per year • Developed Spectrally-Selective Windows that reflect near infrared radiation to reduce summer heat gain from sunlight, reducing the Solar Heat Gain Coefficient by over 40% compared to conventional double glazed windows, and reducing typical residential electricity costs for heating and cooling an estimated 10-20%.[37] • Developed techniques to reduce duct air leaks and heat conduction losses, reducing heating/ cooling energy use by up to 30% for systems where ducts pass through unconditioned spaces • Developed absorption gas heat pumps that are up to 40% more efficient than the best available condensing gas furnaces; now moving towards commercialization. • Superwindow project demonstrated impact of various components integrated into very high performance windows, e.g., multiple layers of low-E coatings, krypton gas, baffles, etc., to achieve thermal performance equivalent to a reasonably well insulated wall at R-10. Project completed. Industry incorporating various components into new efficient window products.
Equipment and Materials	• Developed baseline work on ozone-safe refrigerants while increasing energy efficiency, assisting early phase-out of CFCs. • Developed electronic ballasts for fluorescent lights, reducing energy consumption per lumen of light output by 25% compared to magnetic ballasts, and now accounting for about 40% of the market. Lighting systems also account for 40% of commercial building cooling loads, so improving lighting efficiency can sharply reduce building air conditioning loads. • Developed refrigerators using 340 kWh/year compared to current standards of about 475 kWh/year and mid-1970 models that used over 1800 kWh/year, while allowing size to increase and incorporating additional features, and using ozone-friendly refrigerants.
Codes and Standards	• DOE has promulgated minimum efficiency standards for 19 energy consuming products resulting in estimated 3.8 Quads of energy savings cumulative through July 2000. Refrigerators & freezers, residential furnaces, water heaters, clothes washers, central air conditioners and central air conditioning heat pumps, room air conditioners, dishwashers, clothes dryers, direct heating equipment, pool heaters, kitchen ranges and ovens, fluorescent lamp ballasts, commercial building heating and air conditioning equipment, certain incandescent and fluorescent lamps, and electric motors codes/stds developed and in place. • Developed technologies and standards to gradually increase performance and reduce energy use in typical refrigerators by nearly three-fourths for products sold in July 2001, compared to the mid 1970s. The latest standard, established in 1997, effective July 1, 2001, is projected to save 6.67 quads through 2030. Developed Central A/C rule in 1992, which will save estimated 0.12 quads through 2002.

[37] Bill Prindle and Dariush Arasteh, "Energy Savings and Pollution Prevention Benefits of Solar Heat Gain Standards in the International Energy Conservation Code."

TABLE 4-A7: SELECTED PROGRAM ACCOMPLISHMENTS*, continued

PROGRAM/ ACTIVITY	ACCOMPLISHMENTS—IN COOPERATION WITH INDUSTRY, NATIONAL LABORATORIES, AND UNIVERSITY PARTNERS
Residential Building Integration	• Demonstrated performance of buildings designed as integrated systems, with savings averaging over 50% for Building America homes in the Chicago area; 40-45% for homes under the Building America program near Las Vegas.[38] • Pulte Homes, Inc. committed to converting entire product line to Building America homes for new communities in Las Vegas, Tucson, and Phoenix. • Developed Blower Door technology for measuring and diagnosing air leakage in residential buildings. [39] • Simplified, improved usability, and expanded scope of residential energy codes; demonstrated that current model and consensus codes could be increased in stringency from 10-20% and be cost effective with current construction practice.
Commercial Building Integration	• Developed design software such as DOE-2, used widely to develop building codes and standards, and the foundation on which some 18 companies have built energy design tools. DOE-2 used to evaluate more than 2 billion ft^2 of new construction and 12 billion ft^2 of renovations. DOE-2 used to develop commercial building energy codes including ASHRAE 90.75, 90.1, 90.2, California Title 24, and in at least 9 other countries. • Research findings contributed to the technical bases of numerous consensus standards, for example: Ventilation standards of American Society Heating Refrigerating, and Air-Conditioning Engineers (ASHRAE), and measurement standards of (American Society of Testing and Materials ASTM). • Developed EnergyPlus software for building energy simulation allowing private sector to develop improvements and expansions. • Simplified, improved usability, and expanded scope of commercial energy codes; demonstrated that current model and consensus codes could be increased in stringency from 10-20% and be cost effective with current construction practice. • Developed Energy Code for Federal Commercial Buildings.
Energy Star	• Voluntary program working with over 100 utilities and state administrators, 2,500 residential builders, and 1,200 product manufacturer and retailers, representing over 7,000 retail outlets to label energy efficient equipment meeting Energy Star performance levels, typically set at 10-20% more efficient than minimum mandated standards or guidelines, with some, such as clothes washers, using less than half as much energy as conventional models. • Extending Energy Star to windows, skylights, etc. Introducing a new generation of compact fluorescent light bulbs
Low-income Weatherization	• Weatherized 5 million low-income homes to date with Federal and leveraged funds, state and utility monies, and fuel assistance program funds. Average primary heating savings in low-income homes of 23% for all fuel sources. • Analysis of 17 state-level evaluations found that improved practices as of 1996 produced 80% higher average energy savings per dwelling, at 31 million Btu/year, compared to measured savings in 1989, at 17 million Btu/year.
Community Energy Program	• Through Rebuild America program's 375 partnerships, energy efficiency measures implemented in 340 million square feet of space and for another 375 million square feet committed for construction, with average 30-50% reduction in energy use as recorded by 75% of partnerships, states, and building owners during a program-wide data request in May 2001.

[38] See: www.eren.doe.gov/buildings/building_america/
[39] See: www.epb1.lbl.gov/Blowerdoor

TABLE 4-A7: SELECTED PROGRAM ACCOMPLISHMENTS*, continued

PROGRAM/ ACTIVITY	ACCOMPLISHMENTS—IN COOPERATION WITH INDUSTRY, NATIONAL LABORATORIES, AND UNIVERSITY PARTNERS
State Energy Program	• Have helped modernize more than 69,000 schools, hospitals, and government buildings (through Institutional Conservation Program, consolidated with SECP to form SEP) to make them more energy efficient, leveraging $4 of investment in energy projects for every $1 of DOE funding.[40] States also fund energy efficiency and renewable energy in industrial, transportation, utility and emergency planning. Mahjor additional source of funding from 1980-1990 was Petroleum violation Escrow funds. State goals to reduce overall projected energy use by 10-20%.
	FEDERAL ENERGY MANAGEMENT PROGRAM
FEMP	• Technical assistance: Since FY97, >473 projects, including design assistance and CHP/DER projects; FY00 energy savings per project of 3,680 MMBtu/year and annual average cost savings of $47,000/year; in FY01, FEMP Assessment of Load and Energy Reduction Techniques (ALERT) Teams reduced energy demand by 10.8% at 25 Federal sites • Financing: Since 1998, the Super Energy Savings Performance Contract (ESPC) program has grown from $6 million to $120 million in annual private sector investment. To date, the program helped agencies enter into 71 DOE Super ESPCs valued at $229 million; an average delivery order produces more than $$350,000 in guaranteed annual cost savings and approximately 24,000 MM Btu in estimated annual energy savings; FEMP's technology specific ESPCs are instrumental in commercializing EERE technologies—delivery orders awarded through FEMP's Geothermal Heat Pump ESPCs total $27 million in private investment. Federal agencies have also entered into 507 Utility Energy Service Contracts (UESCs) valued at $622 million. • Outreach/Training: Since FY97, trained 17,300 students; published 47 technical information guides; produced more than 3 dozen product procurement guides; responds to 18,000 inquiries annually through the FEMP Help Desk. • Program Evaluation: Annual analyses identify opportunities for increasing energy and cost savings in the Federal sector. In FY01, completed program-wide survey of 413 customers and 398 prospective customers; survey noted high satisfaction ratings among current customers. • Cross-Cutting Initiatives: OIT: Industrial Assessment Centers for Federal sites and publicizes Inventions and Innovations Program in the Federal sector; OPT: collaboration on DER/CHP projects and developing strategy with Wind Powering America; BTS: collaboration with DOE Energy Star Program and new technology procurement; FEMP also coordinates EERE's involvement in the Green Energy Parks Program.
DEMP	• DOE has reduced energy consumption per square foot by over 43% since 1985 under predecessors to DEMP; funded cumulative investment of $350 million in energy retrofit projects with return on investment of greater than 25%. The over 1000 completed energy retrofit projects reduced energy consumption by $100 million per year and 3 trillion Btu
	INDUSTRY—Office of Industrial Technologies
OIT-wide	• OIT has helped commercialize over 140 technologies as of 1999, with energy savings of about 1.6 Quads
Glass	• Developed Oxygen-Fired Glass Furnace with industry using vacuum-pressure swing adsorption (VPSA) oxygen separation process to provide point-of-use oxygen with 90-95% purity at reduced cost for furnaces. By Sept. 2000, 114 glass furnaces converted to VPSA, 28% of U.S. total glass production with reductions in energy use and emissions, and increases in productivity.
Steel Industry of the Future	• Demonstrated pilot smelting process and catalyzed development of American Iron and Steel Institute direct steelmaking process, with potential benefits of saving as much as 0.2 Quads per year of energy, increasing productivity by 5% to 8%, reducing CO emissions by up to 40%, and other benefits. Licensing negotiations are underway. • Developed hot blast stove process model, reducing natural gas consumption by 7% • Developed nickel aluminide transfer rolls, heat trays, and fixtures, with net cumulative energy savings by 2005 estimated at 12 trillion Btu

[40] See: www.eren.doe.gov/buildings/state_energy/history.html

TABLE 4-A7: SELECTED PROGRAM ACCOMPLISHMENTS*, continued

PROGRAM/ ACTIVITY	ACCOMPLISHMENTS—IN COOPERATION WITH INDUSTRY, NATIONAL LABORATORIES, AND UNIVERSITY PARTNERS
Steel Industry of the Future, continued	• Developed low-NOx oxy-fuel steel reheat burners, cumulatively saving 2 TBtu by 2005 • Developed dilute oxygen combustion system, cumulatively saving 3.4 TBtu by 2005 • Developed energy-efficient process for hot-dip galvanizing with up to 30% energy savings • Developed atmosphere recovery/regeneration reducing energy use in heat treating by 40% • Plus more than 30 other projects.
Metal Casting	• Developed lost foam casting technology with industry (after industry had failed to solve the technical barriers by itself for 29 years), with an average 27% reduction in energy consumption, a 46% increase in productivity, and a 7% reduction in material use. Shipments of lost foam castings were estimated by the private sector to be 90,000 tons in 1997 and projected to be 167,000 tons in 2000. (See chapter 5).
Forest Products Industry	• Developed XTREME Cleaner™ to reduce contaminants from wastepaper pulp slurries, operating in 3 plants as of 1997, with savings of $3,500-$11,000 per day per mill. • Developed kraft recovery boiler technology with industry, increasing furnace throughput and increasing industry-wide production capacity by 10%; increased black liquor solids firing from 63% to 68% solids liquor, saving 0.032 quads per year and reducing tube fouling; improved boiler safety; and reduced boiler emissions. • Developed and demonstrating with industry PulseEnhanced™ Steam Reformer to gasify biomass and related materials for increased energy production with lower emissions.
Intermetallic Alloy Development	• Developed innovative alloys and alloying techniques, casting processes, and materials and processes for making structural welds and weld repairs. Materials now being used in transfer rolls in steel manufacture and heat-treating fixtures. The nickel aluminide heat treating fixtures have greater carburization and oxidation resistance, greater strength at high temperatures, and last twice as long as conventional trays, and have enabled 50% increases in furnace capacity at GM Delphi Saginaw Steering Systems, for example. • Developing various intermetallic alloys for use in composite tubes for ethylene cracking as they show essentially no carburization or ethylene cracking, thus improving heat and mass transfer and eliminating shutdowns for de-coking or tube replacement. Evaluation underway. • Forging dies made from intermetallics have demonstrated lifetimes 30 times that of steel and are under development and commercialization. • Developing iron aluminide, titanium aluminide, and various silicides.
NICE3	• Scrap Decoater for aluminum developed • Lightweight steel containers –a system for manufacturing steel dispensing containers that use less raw material than conventional processes commercialized. • Powder paint coating system—that virtually eliminates VOC emissions and solid waste while greatly reducing energy usage commercialized. • Waste-minimizing plating barrel reduce energy use and waste products commercialized for the metal finishing industry
Bioproducts	• Ten technology platforms identified and under development, including fermentation, gasification, pyrolysis, lipids/oils, lignin derivatives, anaerobic digestion, and others. • Emerging technologies include: polylactic acid (PLA); succinic acid; propylene glycol; ethylene glycol; levulinic acid; polyols; ethyl-lactate; phenol replacements; and others • Biocatalysis and bioprocessing—fluidized bed reactors and pressure cycle reactors developed using immobilized cell systems.

TABLE 4-A7: SELECTED PROGRAM ACCOMPLISHMENTS*, continued

PROGRAM/ ACTIVITY	ACCOMPLISHMENTS—IN COOPERATION WITH INDUSTRY, NATIONAL LABORATORIES, AND UNIVERSITY PARTNERS
	TRANSPORT—Office of Transportation Technologies
Fuel Cells 1990-present	• Developed first 50-kW ambient pressure fuel cell system • Demonstrated high efficiency fuel cell system, 57% at ¼ power • Developed first functional 50-kW integrated gasoline fuel cell system • Reduced platinum loading from 10 grams/kW to 1 g/kW • Reduced the volume and weight of fuel cells by 50% and 25% respectively • Cut estimated system cost from $3000/kW (1994) to $200/kW in 2001--CONFIRM • Doubled estimated fuel cell system lifetime to 2000 hours.
Hybrid Systems 1994-present	• Developed world's first production feasible mid-size car hybrid propulsion system. • Demonstrated 50+ mpg hybrid vehicles, leading to 70-80 mpg concept vehicles developed by the auto companies • Developed analytical tools/test facilities for hybrid vehicles, used extensively by auto firms. • Developed award winning catalytic converter • Pioneered high power energy storage batteries, and reduced volume and mass of battery management system by 75%. • Reduced cost of power electronics from $25/kW to $10/kW and doubled the power output per unit weight. • Demonstrated 50% reduction in vehicle air-conditioning loads • Developed breakthrough technology for simulating human thermal comfort • Vehicles recently announced that would use hybrid technologies include Dodge Durango (2003), Ford Escape (2003), Chevrolet Silverado (2004). • Reduced cost of high power battery systems from $4000 to $1300 (units) and increased life from 1 year to 7 years, and transferred the enabling technologies—low cost polymer fabrication, carbon foam processing, and high power density thin film technologies to industry.
Electric Vehicle R&D 1991-present	• Developed world standard test procedures for measuring key battery characteristics • Developed Nickel metal hydride batteries, doubling EV range over lead-acid batteries • For Lithium-based batteries, increased power density from 250 W/liter to 500+; specific power from 100 W/kg to 300+; Energy density from 110 Wh/liter to 180; cycle life from 130 to 500+
Transportation Materials	• Developed toughened zirconia ceramics, increasing operating temperatures from 1800 ^{o}F to 2500 ^{o}F and toughness by 5X; now produced at more than 300 tons per year, used in fuel injectors (millions sold), camshaft roller-followers (millions). • Developed ceramic coatings for diesel engine piston rings to reduce energy use and emissions, lengthen life, with production of 330,000 rings per year in 2000. • Developed silicon carbide reinforced alumina ceramics for machine tool industry • Developed material design property databases, tooling technologies, forming technologies • Optimized superplastic forming for aluminum auto sheet, commercialized • Reduced the potential cost of carbon fiber from $8.00 per pound to near $6.00 per pound. • Reduced costs of lightweight aluminum castings for autos and trucks by 50%; reduced potential costs of aluminum sheet structures for autos by 38%. • Proved cost-effectiveness of fiber-reinforced polymer matrix composites for autos; commercialized.
Advanced Combustion Engines	• Diesel engine out emissions reduced up to 50% for NOx and PM through cleaner combustion • NOx emission control devices improved from under 30 percent to over 90 percent conversion rate (required to meet Federal Tier 2 standards) in short-term laboratory vehicle tests • Developed and demonstrated integrated emission control systems with NOx, particulate matter, and fuel sulfur control stages while minimizing engine efficiency impact.

TABLE 4-A7: SELECTED PROGRAM ACCOMPLISHMENTS*, continued

PROGRAM/ ACTIVITY	ACCOMPLISHMENTS—IN COOPERATION WITH INDUSTRY, NATIONAL LABORATORIES, AND UNIVERSITY PARTNERS
Fuels Utilization Program	• R&D on impact of sulfur on emission controls; Data used in EPA rulemaking • R&D on health impacts of transport emissions; to be used in state/local rulemaking • Developed LNG tank with 25% more capacity and costing 42% less than standard. • Developed conformable tanks storing 40% more fuel • Increased natural gas engine power ratings from 250 hp to 400 hp. • Increased energy efficiency of heavy-duty natural gas engines from 19% to 25%
Heavy Vehicle Systems	• Identified aerodynamic drag as the dominant engine energy loss for line haul trucks, conducted extensive computational fluid dynamics analyses of truck aerodynamics; identified innovative approach to reduce drag through the use of active air control, and began wind tunnel tests to verify performance.
Biofuels	• Feedstock development: see materials under Biopower. • Developed three recombinant organisms for ethanol production • Reduced projected cost of cellulose to ethanol production from $1.70-$2.60 in late 1980s to $1.10-$1.40 today; completed integrated process at bench scale and at pilot scale with 2 industry partners; began work with corn fiber with third industry partner • Increased switchgrass yields from 4 dry tons per acre in 1985-1990 to 7 dry tons/acre in 1995
Clean Cities	• Participation by approximately 80 designated Clean Cities, over 5,000 stakeholders, and covers almost 50% of all U.S. alternative fueled vehicles. • Awarded over 150 State grants valued at over $10 million (Federal funding) that attracted $40 million in non-Federal funding during the past three years. • Natural gas refueling stations grew from 500 in 1992 to over 1,250 in 2001. • Alternative fueled vehicles on the road almost doubled (250,000 to 450,000) from 1992 to 2001. • In 2000, Clean Cities coalitions increased the number of alternative fuel vehicles by the 17 percent necessary to reach its 10-year goals.
	POWER—Office of Power Technologies
Distributed Energy Resources	• Developed 4.2 MWe advanced gas turbine with efficiency of 37.5% (nearly 1/3 higher than previous 29% efficiency) and ultralow NOx (<10 ppm compared to 25 ppm previously), substantially exceeding performance goal of 33.5% efficiency. Now in final test. • Developed PQ2000 energy storage system, with a total of 40 MW capacity online • Developed triple-effect absorption refrigeration system; field-testing beginning with expected efficiencies to be 30-40% higher than commercially available double-effect systems. • Developed Wide Area Measurement System for transmission reliability. • Developed draft national interconnection standard for DER through the IEEE.
High Temperature Super-conductors	• Developed HTS wire carrying 100 times as much current as the same cross-section copper wire; and in a cable form with cooling lines, HTS cable that carries 3+ times as much current as the same size copper cable. • Demonstrated world's first industrial field-test of HTS cables (20-MVA, 3-phase, 12.5-kV) in powering Southwire Company manufacturing facility for over 10,000 hours (01/10/01). • Completed successful year of use of a 25 MW cable supplying three Atlanta-area manufacturers • Demonstrated 1 MVA transformer, 1000 horsepower motor; and generator feasibility • Tested 15-kV HTS current controller at utility substation. Carried 9,000 A during fault. • Demonstrated 3-kW flywheel electricity system using HTS bearings & scalable to a 100-kW/10-kWh system • Demonstrated near single-crystal-like performance of superconducting coating on buffered, metal template; licensed to five U.S. companies. • Demonstrated HTS cables in powering Southwire manufacturing facility

TABLE 4-A7: SELECTED PROGRAM ACCOMPLISHMENTS*, continued

PROGRAM/ ACTIVITY	ACCOMPLISHMENTS—IN COOPERATION WITH INDUSTRY, NATIONAL LABORATORIES, AND UNIVERSITY PARTNERS
Hydrogen	• Demonstrated fuel reformer/separation membrane system producing 700 cc/minute of pure H2. • Ran 24,000 standard cubic feet per day Process Development Unit of a ceramic membrane reactor for converting natural gas to hydrogen. • An electrolyzer for producing hydrogen for buses passed the 1000-hour time mark for operation. • Demonstrated significantly increased hydrogen production from a pyrolysis and fluidized bed reforming system over a fixed bed system. • Demonstrated 5000 psi storage tank containing 7.5% by weight hydrogen in vehicle • Developed and testing 10,000 psi tank • Developed/transferred to industry storage tank technology that will achieve a 350-mile range at a weight 16 percent less than the target set by the PNGV Technical Advisory Committee. • Developing cryogenic, pressurized, hydrides, and carbon nanostructure storage • Demonstrated reversible 5.2% by weight hydride storage system. The system was also shown to release hydrogen rapidly enough to meet the demands of an onboard fuel cell. • Showed that CVD production of nanotubes will cost about $1/kg • Demonstrated record 12.7% efficiency from solar photoelectrochemical cell • Demonstrated record hydrogen production from algal system • Developed a mutant alga with chlorophyll receptor antenna half the size of the wild type. Small antennae are critical to solar efficiency for producing hydrogen from water via photobiology. • Demonstrated a hydrogen sensor with response times of less than half a second and sensitivity down to 200 ppm hydrogen
Solar Buildings	• Developed award winning transpired solar collector for ventilation air preheat • Developed the technical base for development of passive heating/cooling and active solar heating applications in the U.S. • Developed Solar Rating and Certification Corp with its solar hot water heating system rating and certification program.
Solar Concentrators	• Demonstrated viability of power tower using Solar One, with three years of performance testing and three years of power generation; • Demonstrated integrated molten salt storage and 24 h/d operation in Solar Two; achieved receiver efficiency of 88% • Reduced heliostat costs from $2000/m2 to $120/m2; reduced receiver losses by 60%; increased peak fluxes by factor of 4. • Demonstrated dish systems and achieved record 29.4% system conversion efficiency • Demonstrated first trough system at SNL; industry developed and installed 354 MW of troughs in Southern California; • Identified O&M improvements that can lead to cost reductions to $0.015/kWh, saving
Solar Photovoltaics	• From 1975-present, reduced the cost of crystalline silicon modules by more than 20-fold, to <$4/W; doubled module efficiencies (to 10-13%), increased lifetime by 10X (to more than 20 years), and assisted in a 100-fold increase in US module production (to >74 MW in 2000) • Achieved multiple record thin-film PV efficiencies, exceeding 17% in two cases, proving thin-film PVs could provide cost-competitive power; developed initial large area modules using potentially scalable production processes; developed modules with >10% efficiency over 1 m^2 and began initial production. • Developed high-reliability trackers and high efficiency concentrators. • Demonstrated gallium arsenide-based cell with efficiency under concentrated sunlight exceeding 32%; this greatly increases the low cost feasibility of terrestrial concentrator systems • Developed national standards with industry to test, characterize, certify modules

TABLE 4-A7: SELECTED PROGRAM ACCOMPLISHMENTS*, continued

PROGRAM/ ACTIVITY	ACCOMPLISHMENTS—IN COOPERATION WITH INDUSTRY, NATIONAL LABORATORIES, AND UNIVERSITY PARTNERS
Solar Photovoltaics, continued	• Crystalline silicon ingot/etc. size has been increased by 120%, cell sizes by 50%, cell thickness has been reduced by 30%, relative efficiency has been increased by 15%, and production yields have increased by 190% since 1992, contributing to an overall 30% decrease in manufacturing costs and a 7X increase in production capacity • Obtained commitments from partnerships for one million roof top systems by 2010.
Wind	• Reduced the cost of wind-generated electricity from ~$0.40-0.80/kWh in 1980 to $0.04/kWh in 2001 at high wind sites with favorable financing. • Developed blade designs that increased energy capture by 8-30%. • Developed advanced computer codes for modeling airfoil aerodynamics in 3D including turbulence and inflow, structural, control and fatigue modeling, etc. • Developed advanced wind mapping technology and mapped U.S. wind resources • Assisted development of 1.5 MW wind turbine 17% more cost effective than original baseline machine, with sales of >300 units expected in 2001, worth >$400 million. • WindPowering America. Developed, sponsored or co-sponsored state-level outreach efforts and partnerships in a number of states; co-leading examination of DOE-wide renewable energy credit pilot program. • Established role of three dimensional, unsteady flow on wind turbine blade aerodynamics through field experiments, recently confirmed by flying experiment in controlled turbulence of NASA wind tunnel • Developed computer tools for fatigue estimation, turbulence simulation, systems dynamics, and blade design and then transferred to industry. Now used by 10 or more U.S. firms. • Demonstrated feasibility of wind/diesel hybrid systems on large scale at Kotzebue AK, and smaller scale at Wales AK to allow villages to save significant quantities of diesel fuel. • Developed high cycle material database for wind turbine blade fatigue at Montana State University that covers major variants of materials commonly used in blades and allows industry to predict fatigue failure and to optimize design.
Geothermal	• Developed durable polycrystalline diamond compact drill bits, doubling bit lifetime and now drilling 30% of well footage internationally and >$200M in annual sales in PDC bits and reducing drilling costs from $500/ft to $300/ft. • Developed pH-modification and reactor-clarifier technology enabling 240 MW of geothermal to operate at Salton Sea, California • Developed flash and binary generation technologies for low temperature geothermal resources, cutting cost of power from these resources roughly in half. • U.S. companies have installed 1,500 MW, worth about $3 billion, overseas. • Geothermal developments return over $40 million per year to the U.S. Treasury • Developed reservoir engineering models for injection of waste water at the Geysers, restoring 68 MW of output • Verified slim-hole drilling for reservoir confirmation, cut exploratory drilling costs by 50% • Developed CO_2-resistant cement, extending well life from 1 yr to 20 yrs in acidic formations • Developed Advanced Direct Contact Condenser, which increased potential generating capacity by nearly 17 percent, improved electricity efficiency by 5 percent, and cut in half the cost of emissions treatment at a geothermal power plant at The Geysers. • Demonstrated new process for identifying and plugging loss zones in geothermal wells at ¼ cost, reducing overall cost of geothermal wells by 10%. • Demonstrated technical feasibility of Hot Dry Rock and geopressured geothermal • Supported deployment of geothermal heat pumps, >500,000 units installed by private sector. • Developed thermally conductive grout for use with geothermal heat pumps that has three times higher conductivity and 35 % lower borehole resistance than conventional grouts.

TABLE 4-A7: SELECTED PROGRAM ACCOMPLISHMENTS*, continued

PROGRAM/ ACTIVITY	ACCOMPLISHMENTS—IN COOPERATION WITH INDUSTRY, NATIONAL LABORATORIES, AND UNIVERSITY PARTNERS
Hydropower	• Fish-friendly turbine designed and scheduled to begin pilot-scale testing in 2001. Initial test of Voith design modifications show fish survival rates of 94-97% compared to as low as 70% for some older turbine designs. • Biological performance criteria for shear stress and pressure/bas supersaturation developed • Voith design for dissolved oxygen turbine currently being installed at several TVA sites.
Biopower	• Feedstock development: screened more than 30 species as energy crops; developed, among others, fast growing hybrid poplar clones with the potential to yield up to 10 tons per acre per year. Roughly 120,000 acres of short rotation woody crops have now been planted for commercial fiber and power production with a value of $58 million per year. • Successfully demonstrated 200 ton/day indirect gasification process at Burlington, VT • Developed 3 cofiring projects with EPRI, utilities, and independent power producers, demonstrating that boiler performance could increase and emissions significantly decrease. • From more than two dozen gasifier approaches, four selected for larger-scale testing. Developed understanding of mechanisms/kinetics of biomass thermochemical conversion; developed gasifiers with high carbon conversion efficiencies, that can produce medium-energy fuel gases; that can vary hydrogen to CO ratio; and that produce particulate loadings of less than 5 ppm. • Developed rapid pyrolysis technologies yielding liquid fuels at up to 65% conversion effic. • Demonstrated modular power systems using gasifiers with IC engines, microturbines
Outreach	• Green Power Analysis and Outreach (www.eren.doe.gov/greenpower) • Database of State Incentives for Renewable Energy (www.dsireusa.org) • Renewable Electric Plant Information System (www.eren.doe.gov/repis) • Technology Characterizations (www.eren.doe.gov/power/techchar.html)
International	• CORECT, identified at least 175 project opportunities, valued at $1.5 billion and 16 of those projects secured outside funding valued at $200 million. • America's 21st Century: identified and developed projects in Brazil, Argentina, Chile • USIJI accepted 40 projects in 19 countries on 4 continents that when fully financed and implemented, will offset or sequester more than 300 million metric tons of CO2. • Provide support for 39 Memoranda of Cooperation and 127 S&T agreements • TCAPP/TCIP activities have engaged some 20 countries and facilitated over $120 million in increased investment in clean energy technologies • COEECT is a 15 member interagency group that has facilitated $9 million in international energy efficiency projects with $13 million more in the pipeline

*Note that most work is done in partnership with industry, national laboratories, universities, non-profits, or others. No effort was made to identify the particular contributions of any of these participants in the examples given in the table.

TABLE 4-A8: FY2001 CONGRESSIONAL EARMARKS

Program	Activity	$thousands
Biopower	MEAD - Tillamook Bay, OR (Methane Energy and Ag Development) Cow manure methane/IC engine electricity generator - ~350kw capacity	$1,000
Biopower	Thermo-Depolymerization (TDP) – NV Producing Power and Specialty Chemicals from Turkey Offal and Litter Using the Thermo-Depolymerization (TDP) and Chemical Reformer Process.	4,000
Biopower	Michigan Biotechnical Institute (MBI) Bio Chem and Fuels related research *[earmark is $1,000 K each in Biofuels and BioPower]*	1,000
Biopower	Mount Wachusett College (MA) Wood-fired boiler (hot water) for campus heat production	1,000
Biopower	EERF - Mich St Univ/Environmental Research and Education Foundation Bioreactor landfill project -	500
Biopower	Vermont Agriculture Methane Project Foster Brothers Farm Cow manure methane/IC engine electricity generator - for onsite use	395
Biopower	Iowa switch grass project - (request was $2000k) Co-Firing system using "closed-loop" switchgrass as a substitute for up to 15% of the coal (heat value)	2,000
Biopower	VT Gasifier (FERCO) McNeill Power Station, Burlington, VT Utility-scale gasifier (50MW) using wood	4,000
Biofuels	Energy and Environmental Research Center Integration of biomass with fossil fuels for adv. power transportation fuels	1,000
Biofuels	University of Louisville Design of bioreactors for producing fuels, chemicals	600
Biofuels	Regional Biomass Ethanol Manufacturing in Southeast Alaska for ethanol from softwood residues in conjunction with Sealaska Corporation	2,000
Biofuels	Michigan Biotechnical Institute (MBI); Demonstrate technology for co-products in conjunction with Heartland Grain Fuels (SD), develop innovative pretreatment processes, and demonstrate effectiveness of new polymers.	1,000
Geothermal	Lake County (CA) Basin 2000 Project	2,000
Hydrogen	Montana Trade Port Authority, Billings, MT	350
Hydrogen	Iowa Switch Grass Gasification	250
Hydrogen	ITM Syngas Project	800
Hydrogen	Underground Mining Locomotive and Earth Loader in Nevada	2,000
Solar	Planning for 1 MW Dish Engine Field Validation Power Project at U. NV Las Vegas	1,000
Wind	Kotzebue, Alaska Wind Project	1,000
Wind	Wind Turbine and Educational, Purposes at Turtle Mountain Community College, ND	100
Systems and Storage	Completion of Distributed Power Demonstration at DOE Nevada Test Site	500
Systems and Storage	Continue work with electric utilities to facilitate voluntary, cost-effective emissions reductions	100
Renewable Support	Office of Arctic Energy	1,000
Renewable Support	International Utility Efficiency Partnership Inc (IUEP) to promote carbon dioxide emission reduction	1,000
Renew Support	Indoor Air Quality and Energy, Conservation Research Planning Grant	1,000
Renew Support	Renewable Indian energy resources	6,600
DER	Power Technologies: -Cooling, refrigeration and thermal energy management equipment capable of using natural gas or hydrogen fuels	300
	TOTAL EERE	$37,795

TABLE 4-A9: FY2002 CONGRESSIONAL EARMARKS, ENERGY AND WATER DEVELOPMENT APPROPRIATIONS

Account	Description	$thousands
Biomass	Agricultural Waste Methane Power Generation Facility in California	$2,500
Biomass	Cost-shared Agricultural mixed waste biorefinery in Alabama	2,000
Biomass	Black belt bioenergy demonstration project in Alabama using thermal depolymerization technology	1,500
Biomass	McNeil Biomass Plant in Burlington, Vermont	3,000
Biomass	Methane Energy & Agriculture Development Program in Tillaook Bay, Oregon	750
Biomass	Biorenewable Resource Consortium	2,000
Biomass	Micro combustion at ORNL	1,000
Biomass	Oxygenated diesel fuel demo in Clark County, Nevada, and cities in CA	1,000
Biomass	Michigan Biotechnology Initiative	2,000
Biomass	Prime LLC of South Dakota integrated ethanol complex	3,000
Biomass	Biomass Energy Resource Center Project in Vermont	300
Biomass	Continue the Sealaska ethanol project	2,000
Biomass	Biomass Gasification Research Center in Burlington, Alabama	3,000
Biomass	Winona, Mississippi biomass project	3,000
Biomass	Iroquois Bio-Energy Cooperative project in Indiana	3,000
Biomass	Gridley Rice Straw Project in California	3,000
Biomass	Great Plains Institute for Sustainable Development, Minn. switchgrass project	1,000
Biomass	Consortium for Plant Biotechnology Research	1,000
Geothermal	for Lake County Basin project in California	2,000
Geothermal	Santa Rosa geysers project in California	2,000
Geothermal	for the UNR Geothermal Energy Center's demo project	1,000
Hydrogen	Fuel Cell Technology Assessment/Demonstration, U. Alabama, Birmingham	1,000
Hydrogen	Big Sky Economic Development Authority Demonstration fuel cell tech.	350
Hydrogen	Montana Trade Port Authority in Billings Montana	
Hydrogen	for gasification of Iowa Switchgrass	500
Hydrogen	for the ITM Syngas project	1,500
Hydrogen	for the fuel cell installation project at Gallatin County, Montana	1,500
Hydrogen	for continued demonstration of hydrogen locomotive, front-end loader projects	1,000
Hydropower	To plan hydroelectric facility at Gustavus, Alaska	400
Hydropower	Completion of Power Creek hydroelectric project in Alaska	1,900
Solar Energy	Navajo electrification project	3,000
Solar Energy	Resource opportunities and electric power needs of southwestern US	4,000
Wind	Pilot project at the Toledo Harbor Lighthouse	500
Wind	Washington Electric Cooperative in Vermont	1000
Wind	for Kotzebue (Alaska) wind project	1,000
Wind	Wind turbine education, Turtle Mountain Community College, North Dakota	500
Wind	Wind Technology Center feasibility study for St. Paul and Unalaska, Alaska	250
Wind	Small wind project developed by the Vermont Dept. of Public Service	500

TABLE 4-A9: FY2002 CONGRESSIONAL EARMARKS, ENERGY AND WATER DEVELOPMENT APPROPRIATIONS, continued

Account	Description	$thousands
EESS	Electric energy systems and storage (EESS) Field testing of aluminum ceramic fiber composite conductors	4,000
EESS	Smart Energy Management Control System in Alabama	1,000
EESS	UADispatch Outage Management System in Alabama	2,000
EESS	Distributed generation demonstration project in Indiana	3,000
EESS	Development of bipolar wafer-cell nickel metal hydride battery	1,000
EESS	Glenallen power generation upgrades	2,000
EESS	Kachemak Bay Power System	2,000
EESS	Swan Lake-Lake Tyee	3,000
EESS	Complete Prince of Wales Island	3,000
EESS	NREL RD&D	3,000
EESS	Joint effort between New Mexico Tech. and Natural Energy Lab of Hawaii	500
International	International Utility Efficiency Partnerships, Inc	1,000
Renew. support	National Alliance for Clean Energy Incubators	1,500
TOTAL		**$85,950**

Chapter 5

Program Benefits

SUMMARY

Have EERE R&D programs provided greater public benefits than the expenditures on them? That was the question recently examined by the National Academy of Sciences' National Research Council (NRC).[1] Their answer contributes directly to this Strategic Program Review analysis of the "historic performance" of EERE programs.

The NRC used a conservative methodology[2] to examine in depth about $1.6 billion or one-fifth of EERE's energy efficiency programs and found a net realized economic benefit —after all the public and private expenditures on R&D and purchasing equipment—of roughly $30 billion; a return of roughly $20 associated with every $1 invested in those programs by EERE. In addition, they found significant net realized environmental and security benefits, which they quantified as providing a value of roughly $3-20 billion, on top of the $30 billion in economic benefits. The NRC identified significant options and knowledge benefits as well, but did not quantify them.[3] These estimates did not include potential future benefits from further market penetration (after 2005) for commercialized technologies or for technologies under development, which account for the bulk of EERE work.

This chapter explores that same question more broadly. It begins by examining the relationship between technology development programs and public benefits. Then, it reviews the NRC benefits analysis framework and identifies and begins to implement important extensions to it. The review continues with a synopsis of the results from several other analyses, including those written by OIT on industrial technologies, BTS on technology codes and standards, and all of EERE under the Government

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[1] The National Research Council is created under the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine; for simplicity and brevity, this will be abbreviated here as NRC. NRC, "Energy Research at DOE: Was It Worth It?," July 2001. This study looked only at selected programs funded under Interior Committee Appropriations. Programs funded under Energy and Water Development Committee Appropriations, such as EERE's Renewable Energy Technologies, were not included in this review.

[2] National Academy of Sciences, National Research Council, "Energy Research at DOE: Was It Worth It?," July 2001. Statements by the NRC include: "Where it has used quantified benefits to support its findings and recommendations, the committee considers it has been conservative in establishing upper and lower bounds for its benefits estimates. In general, the Committee believes it is more likely than not that a more thorough analysis would increase the value of the benefits that the Committee has assigned to DOE's programs."(p.19) "The committee adopted a 5-year rule to be very conservative about the effect of DOE R&D."(p.37) "Applying this rule reduced the net realized economic benefits of electronic ballasts from about $32 billion estimated by EE to $15 billion, for example. For the refrigerator/freezer compressor the benefits decreased from about $9 billion to $7 billion. For low-e windows the benefits were decreased from $37 billion to $8 billion 1999 dollars."(p.37, footnote 8) "For some technologies, the 5 years (NRC5-year rule methodology) may be much too conservative, and this is indeed reflected in some of the case studies. For example, the building sector is fragmented and supports only limited R&D activities, so government R&D might speed change by much more than 5 years" (p.37). Note also, that an inconsistency in the NRC analysis resulted in the estimated benefits for low-E windows being reduced from a value of about $15 billion when tracking actual penetration as measured by units sold under the 5-year rule to $8 billion, as discussed below.

[3] Options and knowledge benefits are discussed in Appendix 5A.

Performance Results Act (GPRA). GPRA is an externally peer reviewed analysis of the entire EERE portfolio that looks into the future, in contrast to the NRC methodology which examines actual measured impacts retrospectively. The analysis of this chapter also addresses in part the issues of "performance-based" research and development and "public-private partnerships".

The SPR analysis reached the following conclusions:

- As a retrospective analysis of program impacts, the NRC methodology is a useful complement to the work currently implemented under the Government Performance Results Act (GPRA), which projects future benefits. Using a common benefit analysis framework across all EERE programs that builds on the NRC and GPRA frameworks would be useful and would contribute to ongoing analysis of EERE's historic performance. The NRC methodology is not, however, sufficiently sophisticated to substitute for EERE's analysis of codes and standards, which go through extensive public review.

- The NRC methodology breaks new ground in identifying environmental, security, as well as options and knowledge benefits, in addition to the realized economic benefits normally considered. This methodology, however, has several weaknesses, such as ignoring the potential benefits of technologies under development. Some of these shortcomings can be readily overcome, but others will require substantial further analytical development, particularly for evaluating options and knowledge costs and benefits.

- The development of a coherent and balanced program to help realize public benefits is important; there are, in fact, few realized benefits unless the technology developed significantly penetrates the market. This may require a variety of facilitating actions, from information outreach, to the development of standards, to policy incentives. Chapter 4 discussed some aspects of such a balanced and comprehensive program. The EERE programs have begun to develop such activities, but remain primarily focused on core technology development. Further development of mechanisms to facilitate market use of advanced energy efficiency and renewable energy technologies is needed, however, to complement core technology development work, both to realize potential benefits and also because lessons learned from demonstration and deployment activities can provide important input into the direction of future basic and applied research.

- Work to facilitate market use of technologies should include the development of methodologies to determine the necessary and sufficient critical mass of activity needed to catalyze market use, to concentrate that critical mass to effect market transformation, and to develop capable analytical tools to plan, execute, and evaluate the work. The emphasis of the NEP on "performance-based" programs indicates both the need to further pursue such market facilitation and analytical methodologies. It must be noted, however, that such program evaluation and analysis can require significant staff and other resources and must be balanced against other priorities, particularly conducting the needed RD^3 to advance energy efficiency and renewable energy technologies.

- The NRC analysis and this SPR both demonstrate that a portfolio of RD^3 activities is essential. The fundamental nature of research is that one cannot know in advance if a particular research path will be successful. Developing a range of technologies in parallel, and multiple pathways to achieve particular technological goals, are therefore fundamental to success. This is similar to the importance of stabilizing income and moderating risk by investing in a portfolio of stocks, rather than betting everything on a single stock. Just as high-performing funds have portfolios, performance-based R&D programs must build diversified and strategic portfolios. The SPR found that EERE has done this fairly effectively.

- The innovation pipeline, including research, development, demonstration, and deployment (RD^3) has numerous feedback loops between each of its elements. The facilitation of deployment and understanding market responses can play a significant role in guiding early technological development. Additional attention needs to be given to strengthening these interactions.

- The NRC analysis, noted above, was reviewed and generally confirmed by the SPR.[4] This SPR identified a number of additional technologies—beyond those examined by the NRC—where an updated NRC methodology should be applied to determine benefits. Preliminary estimates for a few of these technologies identified benefits of a similar magnitude as found in the NRC analysis. Work is needed to further develop and peer review these methodologies and case studies. Significant options and knowledge benefits were also found but, as for the NRC study, were not quantified. As most of the EERE technologies are under development, estimated future benefits are even larger when these technologies are able to significantly penetrate the market. Peer reviewed GPRA estimates, for example, project returns of roughly $60 billion per year by 2020. Conducting a back-of-the-envelope NRC-type analysis on these externally peer-reviewed GPRA results indicates a return of roughly 15 to 1 associated with the public investment, which is roughly similar to the 20 to 1 return found by the NRC study of benefits already realized from EERE R&D.

The SPR begins, but does not complete, the extension of the NRC benefits analysis framework and its application to the full range of EERE activities. Work to further develop this framework has been initiated, including the planning of workshops, external reviews, and other activities for early 2002, and will be followed by application of the resulting methodology to a range of EERE activities, some of which are described below. An important aspect of this work is to develop a methodology that effectively melds the prospective GPRA analyses with the retrospective NRC methodology, potentially enabling quantitative improvement of GPRA projections over time as they are compared to NRC-type retrospectives. This builds on the NEP call for a review of the historic performance of EERE programs by enabling such analysis to be provided on an ongoing basis.

TECHNOLOGY DEVELOPMENT PROGRAMS AND PUBLIC BENEFITS

Technology R&D programs only deliver public benefits if the technology enters the market. This research, development, demonstration, and deployment (RD^3) process is long and complex. This larger process has been historically characterized as an innovation pipeline, sequentially moving from basic science, to applied science, to technology research, development, and demonstration, to deployment in the market. In recent years, researchers have become increasingly aware of the shortcomings of this simple pipeline model due to the numerous interactions and feedback loops between all of these stages, including from demonstration and market deployment activities back to basic and applied science and engineering.

Consider solar water heaters. Solar hot water heaters made of copper and glasswork well, but are expensive and thus are cost-effective only in areas with high insolation and high energy prices. To become more broadly competitive, lower cost materials are necessary. Most promising are various polymers, but for them to have a sufficiently long lifetime, their degradation due to ultraviolet (UV) light from the sun must be greatly reduced. This, in turn, requires basic research into UV-induced polymer degradation mechanisms and related polymer chemistry and structure. In this case, market requirements feed back to stimulate more fundamental scientific research.

[4] The exception was the estimated net realized benefits for low-E glass, as detailed *infra* in note 9.

Box 5-1: Estimating Benefits

It is sometimes difficult to understand how modest public R&D investments can be associated with such large benefits as described by the NRC. A simple example can illustrate how this is possible. Consider windows. Special "low-E" coatings were developed to reflect long-wavelength infrared radiation. These low emissivity coatings help keep the heat in a house during the winter, and reflects some of the hot sun during the summer.[5] The investment in low-E windows R&D was about $4 million, with additional expenditures to develop window design tools, information outreach, and other activities. Low-E windows began penetrating the market in 1983 and by 1999 accounted for 40% of the window market, or 260 million square feet per year of low-e windows sold with lifetimes averaging 30 years. On average, each square foot of low-E glass saves more than $0.25 in energy costs per year compared to a conventional double-glazed window baseline.[6] Individually, this is not much, but multiplied across 260 million square feet, this gives a lifetime savings of more than $2 billion for the windows sold in 1999. Adding up such savings since the technology began penetration of the market then generates roughly $37 billion in net economic savings using the NRC methodology[7] with a constant technology baseline of a conventional double-glazed window, or $8 billion using the conservative NRC 5-year rule methodology.[8] This also highlights the sensitivity of the reported benefits to the underlying assumptions and methodologies. Assuming a constant no-change baseline for comparison, as has been typically done by EERE, leads to higher estimates of benefits than the conservative NRC framework, which assumes—contrary to empirical evidence in a number of cases—that the baseline follows the same trajectory as the case where EERE provides assistance, with just a five year delay. These two approaches effectively bracket the range of likely benefits.

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[5] Note that low-E windows are designed to reflect long-wavelength infrared appropriate for keeping heat in a building during the winter, but are not very effective at reflecting the near infrared radiation of the hot summer sun. To reduce summer heat gain, other coatings have been developed, called spectrally selective coatings, which are designed to reflect near infrared radiation.

[6] Each square foot saves about 33 kBtu/year with a weighted average value of about $0.01/kBtu, or $0.33/square foot of window. The incremental cost for low-E windows is about $1.25 per square foot or averaged over their lifetime, about $0.04/square foot. Thus, there is a net annual savings per square foot of window of about $0.29. Multiply the 260 million square feet by $0.29 per square foot per year and by a lifetime of 30 years, and the windows installed in 1999 save roughly $2.3 billion over their lifetime. Note that the NRC methodology uses a baseline that assumes—beyond the next best alternative, which in this case is a conventional uncoated double glazed window—that the private sector would similarly develop and begin market penetration of a low-E window within five years of the public effort, as discussed below

[7] The NRC note (page 37, footnote 8) that EE estimated $32 billion in the electronic ballast case is in reference to EE developing cost estimates at the direction of the NRC for the constant technology baseline case versus using the 5-year rule. The methodology used throughout was that of the NRC.

[8] NRC, op. cit, Page 37, footnote 8. The $37 billion estimate is drawn from the NRC calculation, which tracks actual market penetration from 1983 through the present and then projects penetration through 2005, at which point no further penetration is assumed. Low-E window sales went from 0 in 1982, to 200 million square feet in 1993, to 263 million square feet in 1999—the last year for actual data, and were projected to 360 million square feet in 2005, with the accelerated penetration to 2005 based on recent manufacturer plant conversions. Assuming average sales of about 220 million square feet per year, generating a benefit of $1.7 billion over the lifetimes of the windows sold in a year, over those 22 years gives about $37 billion. Under the NRC framework, this $37 billion is then reduced by assuming that anything the public sector does, the private sector would have done anyway within 5 years, which changes the constant baseline assumption to a baseline that tracks actual penetration with just a 5-year delay. Using this 5-year rule, as described later in this chapter, results in the NRC reported benefit of $8 billion (page 29) rather than the $37 billion assuming a constant baseline. Discussions with NRC Panel members and subsequent calculations found that the $37 billion figure is correct, but that the NRC used in this case a percentage penetration rate for their 5-year offset rather than the actual number of units sold, as was done in their other cases. With a rapidly growing market, this led to significantly higher unit sales for their 5-year offset case than for the observed penetration rate—in contrast with their other analyses, which kept unit sales at the observed penetration rates but offset by 5 years. Correcting the 5-year rule offset for the actual observed unit sales gives a net benefit of $15 billion and pulls the ratio between baseline and NRC 5-year cases in line with the other case studies cited in the NRC report. This inconsistent analytical approach also illustrates the sensitivity of this methodology to the starting assumptions. Personal communication with William Fulkerson, July, 2001.

These many interactions among the various stages of RD^3 have become ever more important with increasingly sophisticated technology, increasing global competition, and ever shorter product cycles. Researchers have characterized this innovation process as more of a tapestry than a pipeline, with all of the RD^3 activities “strongly entangled and inseparable”.[9]

Within this complex innovation process, there are numerous technical, institutional, and market challenges, as described in Chapter 2. For example, technologies face significant challenges in building market share. They generally begin with low production levels and high costs per unit, limiting their use to niche markets. As experience with the technology accumulates and markets grow, manufacturing can be scaled up and costs driven down to more broadly competitive levels. This transition from low-volume/high-cost to high-volume/low-cost production can be very slow. Companies face the so-called “Mountain-of-Death” in getting high initial costs down to competitive levels. Companies also face the so-called “Valley-of-Death” in covering technology development and marketing costs until sales are sufficient to provide net positive cash-flow both annually and over the technology development lifecycle, including the early development costs. For these reasons, to move a technology into large-scale market use can require various forms of assistance or facilitation—from information outreach, to standards development, to financial incentives such as tax credits to initiate market sales and thereby enable manufacturing scale-up and cost reductions—all while maintaining the discipline of the marketplace.[10]

EERE programs have developed several strategies designed around appropriate public roles for these stages in the innovation process. These begin with the development of the technology itself through a variety of public-private partnerships; and continue with facilitating market penetration by the private sector through information outreach, technical assistance, design tool development, technology ratings, performance codes and standards, and other approaches. Chapter 4 summarized the impact of the EERE efforts on technical performance and described the overall program balance across these various technology development and market facilitation activities.

EERE programs are primarily targeted towards meeting the technical challenges, as described in Chapter 4; their role in facilitating market penetration—and the overall benefits against which they will be judged—is much more limited and considered only where there is clearly an appropriate public role, as described in Chapter 2. Thus, Chapter 4 focuses on technology performance, which the EERE programs can directly influence, whereas this Chapter focuses on program benefits, which require complex market responses, which EERE can only modestly and indirectly influence in most cases.

More broadly, various public policies, such as tax incentives, assist market penetration of new technologies in some cases. In all cases, however, the time to build political consensus; conduct the technology research, development, and demonstration; penetrate the market; and turn over the existing capital stock to significantly impact energy use or environmental emissions is typically measured in decades, as indicated in Table 5-1. Conversely, to substantially impact a particular sector by some future period, the time when R&D needs to be aggressively pursued can be roughly determined by working back from that date using the crude time estimates in the table.

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[9] President’s Committee of Advisors on Science and Technology, “Federal Energy Research and Development for the Challenges of the Twenty-First Century”, Executive Office of the President, Office of Science and Technology Policy, November 1997. See pages 7-14 to 7-20

[10] President’s Committee of Advisors on Science and Technology, “Powerful Partnerships: The Federal Role in International Cooperation on Energy Innovation”, Executive Office of the President, Office of Science and Technology Policy, June 1999, See Chapter 3.

Of course, market penetration also depends significantly on market conditions. As described by Resources for the Future, although the technical performance of renewable technologies generally matched projections and showed significant cost reductions over the past two decades, market impacts were less than expected due to changing market conditions such as the collapse of oil prices in the mid-1980s, low natural gas prices, and the development of natural gas combined cycle gas turbines, among others (see Chapter 4).[11]

TABLE 5-1: TYPICAL TIMES FOR RD^3 AND CAPITAL STOCK TURNOVER

Activity	Typical Times Required
Political development	1-10+ years
Research, Development, Demonstration	5-25+
Market Penetration	10-25+
Capital Stock Turnover	
• Cars	• 14
• Appliances	• 15-20
• Power Plants	• 30-40+
• Commercial Buildings	• 40-60
• Residential Buildings	• 60-80
• Industrial Facilities	• 40-80
• Industrial Facility Equipment	• 10-30+
• Urban Form	• 100s

Note: Market penetration refers to the length of time required for the technology to become a large fraction (e.g. a third to a half) of the total market. Capital stock turnover refers to the typical lifetime of existing capital equipment before it would normally be replaced, potentially with a more efficient technology. Note that buildings, industrial facilities, and power plants may be renovated several times over their lifetime, providing significant opportunities for improving their efficiency and to employ renewable energy technologies.

BENEFITS AND THE SECTORAL CONTEXT

The energy sectors vary significantly in how technologies penetrate the market and what benefits are generated.[12] Each sector is examined below in turn.

The buildings sector suffers substantial market fragmentation and very low rates of R&D investment (see Chapter 2). As a consequence, the buildings sector has had and continues to have numerous opportunities where relatively small R&D investments can generate significant technological improvements. Further, because the buildings sector is so large and similar technologies are used so widely, a technological advance can generate huge benefits if it is successfully and widely commercialized. Examples include low-E windows, electronic ballasts, improved refrigerators, and many others. Successful innovations have tended to be in the equipment arena because of the limited number of manufacturers to work with. In contrast, the extensive fragmentation of the construction industry, among other factors, has blunted the

[11] James McVeigh, Dallas Burtraw, Joel Darmstadter, and Karen Palmer, "Winner, Loser, or Innocent Victim? Has Renewable Energy Performed As Expected?" Resources for the Future, Washington, DC, Discussion Paper 99-28, March 1999, June 1999.

[12] The public sector is the largest "single" consumer of energy in the United States, with the Federal government spending $4 billion on energy for its half-million buildings in FY2000 and more than $3 billion on energy for its vehicles and equipment. The public sector will be variously treated as related to the buildings and transport sector in this chapter when referring to technical issues, and will be treated as the separate Federal Energy Management Program when examining programmatic issues or savings potentials.

impact of innovations compared to the case for equipment; however, this area also has particularly high energy savings potential for further development. Potential energy savings in the buildings sector come primarily from electricity[13] or natural gas.

The industrial sector presents different challenges. The industries that consume the most energy are limited to a handful of energy-intensive industries such as steel, chemicals, petroleum refining, forest products, and a few others. These tend to be more mature industries producing large volume, low margin commodity materials, facing considerable offshore competition, and having low levels of R&D investment. For these industries, although there remain numerous energy technology innovation opportunities, many of the relatively easy innovations have already been developed due to the pressure of energy costs on their bottom lines. Introducing energy technology innovations poses substantial challenges due to the risks of disrupting entire process lines at high cost for relatively small potential energy and cost savings. Potential productivity improvements associated with the energy technology innovation then become particularly important to encourage adoption. Further, energy technology innovations tend to have a somewhat limited area of application, often confined to one segment of the particular industry. These factors tend to reduce the potential scale of impact of energy technology innovations in the industrial sector for any particular project and require the development of numerous relatively small projects. Despite all this, the industrial sector is the largest U.S. energy-consuming sector, at 37% of total U.S. energy, and cannot be ignored.

The transportation sector poses yet another set of challenges. The transport sector consumed more than 26 quads of petroleum-derived fuels in 1999, more than two-thirds of all U.S. oil consumption.[14] There are only a few major companies[15] involved in the light vehicle sector and the market is large and relatively homogeneous; therefore, relatively few companies need to be involved and any innovation has the potential to impact a large part of the market. However, the industry has a century's worth of experience experimenting with and improving engine and system design, making the identification and development of innovative energy technologies particularly difficult. Indeed, technologies that have been pursued jointly with industry and subsequently terminated include Stirling engines, gas turbines, diesel bottoming cycles, ultracapacitor and flywheel energy storage, and others (see Chapter 4). Only with recent advances in power electronics have various hybrid technologies become possible, with potentially very large impacts on U.S. oil imports, urban air quality, and greenhouse gas emissions. Advances in fuel cells have the potential to further amplify these benefits, but a transition to hydrogen faces substantial barriers to the extent that infrastructural changes are required. Compared to the light vehicle sector, the heavy-duty vehicle sector involves a greater number of companies, is less homogeneous and has a smaller market. This structure poses additional challenges in developing and commercializing innovative energy technologies. Addressing U.S. oil dependence then requires focused attention on transportation energy efficiency and alternative fuels and supplies. The NRC found that the most significant oil savings benefits from energy efficiency programs are embodied in the prospects for PNGV, and that the 21st Century Truck Partnership holds the same promise.[16] FreedomCAR has the potential to extend these benefits through the development of fuel cell vehicles.

In the power sector, the introduction of high-efficiency combined cycle gas turbines using low priced natural gas has forced coal prices lower and heightened competition in general. Competing against low-cost fossil energy resources and low-cost commodity electricity has left relatively little opportunity for renewable energy, with its important but under-valued environmental and security benefits. This has

[13] Note that upstream electricity generation, transmission, and distribution losses mean that saving a unit of electricity at the building can save three units of primary energy going into the power plant.
[14] AER 2000, Tables 1.3, 2.1e.
[15] This refers to the systems integrators—the major auto makers; there are many component manufacturers.
[16] National Research Council, "Energy Research At DOE: Was It Worth It?" op. cit., Page 67.

reduced the rate of expected market penetration of renewable energy technologies even as their performance has dramatically improved and the costs for many of them have fallen sharply, in line with original EERE projections (see Chapter 4).[17] More recently, uncertainty about electricity restructuring and environmental regulations has in some cases also hindered market adoption of promising EERE technologies.

As a result of these developments, strategies and market opportunities for renewable power technologies have evolved considerably. Industry and EERE now emphasize the identification and development of niche markets; their aggregation to obtain sufficient production volume to achieve economies of scale in order to lower costs; and the exploitation of newly identified market segments such as distributed energy resources. As a consequence of these and other factors, some notable advances are occurring in solar, wind, biopower and other renewable power. Wind energy, for example, is currently the fastest growing electricity supply in the United States.

In each of these sectors, the challenges of developing technologies and significantly impacting the market have proven substantially more formidable than was expected two decades ago. Significant benefits, however, some 20 times the total cost of the public R&D investment examined, were identified by the NRC as already realized, with the promise to grow significantly in the years ahead.[18] These benefits are examined in detail below and indicate the historic benefits of the EERE programs.

BENEFITS FRAMEWORKS

A number of frameworks have been used to estimate past benefits or project future benefits resulting from the work of EERE. These include the annual development of future benefits estimates under the GPRA[19] and analysis of appliance codes and standards development.[20] Both of these methodologies are subject to external peer review, with codes and standards work undergoing extremely detailed formal review. Past benefits are also estimated by the Office of Industrial Technologies,[21] and other offices, and by the NRC in their recently released report noted above. Each of these analyses uses somewhat different methodological frameworks. These alternative approaches are briefly summarized below and their benefits identified and compared in a few cases.

The retrospective look of this SPR at successful technologies should not be interpreted to suggest that other technology areas should be cut back for being less productive. In the field of scientific research and development, it is easy to pick winners in hindsight. Retrospectively one knows what worked; prospectively one <u>cannot</u> know what will work. It is therefore essential that a balanced portfolio of R&D be pursued, including multiple pathways to increase the likelihood that technical challenges can be overcome.

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[17] James McVeigh, Dallas Burtraw, Joel Darmstadter, and Karen Palmer "Winner, Loser, or Innocent Victim? Has Renewable Energy Performed As Expected?" Resources for the Future, Washington, DC, Discussion Paper 99-28; March 1999; June 1999.

[18] National Research Council, "Energy Research At DOE: Was It Worth It?" op. cit. The NRC found net realized economic returns of about $30 billion for an energy efficiency portfolio of $1.6 billion that they examined.

[19] National Renewable Energy Laboratory, "Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs," USDOE, Office of Energy Efficiency and Renewable Energy, July 2000.

[20] See, for example: http://www.eren.doe.gov/buildings/codes_standards/

[21] USDOE, Office of Energy Efficiency and Renewable Energy, Office of Industrial Technologies: Summary of Program Results, "Impacts", DOE/EE-0240, January 2001.

METHODOLOGY

The primary methodology used in the analysis presented here is based on the NRC study and is described in detail in Appendix 5-A, following this chapter.[22] In brief, the methodology tracks the observed market sales of a technology both up to the present and as projected through 2005, together with measured per unit energy savings or supply compared to the next best alternative. Unit sales (per unit energy savings or supply) and unit lifetimes are then multiplied together to determine the overall energy savings, from which the economic value and the corresponding changes in environmental emissions and oil consumption can be determined, with appropriate multipliers to convert these into approximate dollar values for the particular fuel mix.

A similar calculation is done assuming that market penetration would have been realized by the private sector anyway within 5 years (known as the 5-year rule), and this is subtracted from the first case where there was a public role. As noted by the NRC Panel and as can be seen in the tables below comparing the constant baseline to the 5-year rule, the 5-year rule is a very conservative assumption.[23] Though perhaps reasonable in some cases, there are other cases that indicate substantially longer periods than 5 years would have been required for the technology to be developed and penetrate the market if the public sector had not gotten involved.

Examples include Lost Foam Metal Casting where the private sector unsuccessfully pursued the technology over a 29-year period. Consequently, given empirical evidence in a number of cases that the private sector did not successfully develop and deploy such technologies independently over a five-year period, and given that there are often long gestation times for technologies supported by public R&D efforts and that market penetration by an individual company is slower than that by an industry-wide response in many publicly-supported cases, this has also been extended to a 10-year rule at half the penetration rate, as described below and in Appendix 5-A.

One innovative approach in the NRC study is the acknowledgement and inclusion of options and knowledge benefits, as described in Appendix 5-A. This SPR followed the NRC lead and only examined these benefits qualitatively. Future analytical work should begin examining how to quantify some aspects of these benefits measures.

The NRC methodology did not include any post-2005 consideration for technologies already being commercialized or likely to be commercialized. Since EERE is focused on developing new technologies, the NRC methodology thus gives little or no credit for the current portfolio of research. To address this, an additional column was added to the NRC framework (as discussed in appendix 5-A) and potential expected economic, environmental, and security benefits—post 2005—based on GPRA analysis were included. This will be an important consideration in future benefits analyses.

There are a number of other methodological difficulties with the NRC approach. In addition to the challenge of defining the counterfactual baseline (e.g., what would have happened in the absence of EERE activities) noted above for the constant, 5-year, and 10-year baselines, these difficulties include: discounting of past and future benefits and costs; amortizing capital costs appropriately; and using marginal costs, efficiencies, emissions, and other factors rather than average costs. These will need to be addressed in future work on benefits analysis.

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[22] National Research Council, "Energy Research At DOE: Was It Worth It?" op. cit. See Chapter 2 and Appendix D of the NRC report for their description of the methodology.

[23] *See* note 2, *supra*.

An interesting aspect of the cases analyzed below is the remarkably large return that is observed. Because of the large amount of energy—roughly $600 billion per year—that our $9 trillion economy uses, even small improvements in a widely used technology can provide very large returns. Further, because of the small, modular nature of many of these energy efficient and renewable energy technologies, the RD&D costs tend to be low compared to the size of the respective sector and the cost of its energy use (the entire EERE portfolio, for example, is only about 0.2 percent of what is spent on energy in the United States per year). This allows one to build a diversified portfolio of RD&D, increasing the likelihood that there will be some successful projects, any one of which could provide very large returns when replicated across the country.

PRECISION AND SCALE

It is important to recognize that the estimates below are approximate and high levels of precision are neither possible nor particularly useful. Precision is not possible because the baseline is counterfactual: what would have happened in the absence of EERE actions is unknowable and a conservative baseline is assumed under the NRC framework—that the private sector would have accomplished exactly the same level of unit sales within five years on its own. Precision is not particularly useful because the estimated returns on successful projects are several orders of magnitude greater than the investment and virtually any change in assumptions will still leave the benefit much larger than the cost. The advantage of these considerations of precision and scale is that a relatively robust analysis can be conducted in a reasonably straightforward manner using overall average or marginal values, without spending a lot of time and effort adjusting parameters to specific locales or conditions. Of course, the user of such analyses can not expect much more than single digit accuracy, if that much.

CAUSALITY AND APPORTIONING CREDIT

The relative roles of the public and private sectors in causing these benefits and how credit should be apportioned between them are also frequently voiced concerns. The NRC Panel grappled with this issue but was not able to resolve it. How much credit should be given to the inventor of a breakthrough technology; how much credit should be given to the company that turns the technology into a commercial product and successfully markets it? Neither the inventor nor the company generates value without the contribution of the other. The NRC 5-year rule can sidestep this question as it reduces the calculated benefits for EERE by typically one-half to two-thirds (see Table 5-2) and can serve as a proxy for apportioning credit.[24]

BENEFITS OBSERVED

The results of the NRC analysis are summarized in Table 5-2. This is not a complete listing of their work, as there were several technologies which they identified as having very large impacts, but which they were not able to quantify in the time available, including DOE-2 building design software and Indoor Air Quality. Nor does this capture the extensive case studies that they developed.

The results below indicate a few cases where there are huge associated savings, with benefits 1000 times or more greater than the public investment that helped create them. This should not be interpreted to mean that other activities did not also make meaningful and important contributions. In many cases, benefits associated with publicly supported R&D have been several times greater than the public investment to date, with much larger benefits expected to accrue in the future as the technology further

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[24] This should not be interpreted as suggesting that the private sector would have a substantial propensity to invest in technology improvements that have greater public benefits than appropriable profits.

penetrates the market. Further, many of the examples given below do not begin to cover even the related advances in that specific area. For example, only improved refrigerator compressor benefits were specifically quantified by the NRC (see Table 5-2), whereas advances have also been made in insulants, controls, cases, ozone-safe refrigerants, and others, reducing refrigerator energy consumption by nearly three-fourths over the past 25 years (Chapter 4). Similarly, only low-E windows were examined by the NRC, whereas benefits are also being generated as spectrally selective coatings penetrate the market. This brief summary demonstrates, however, that even under the conservative analytical methodology used by the National Academy of Sciences,[25] the benefits already realized from just this subset of activities—one-fifth of the total EERE portfolio—are many-fold larger than the total public investment for all of EERE.

Table 5-2 indicates the impact of the NRC methodology on the reported net realized economic benefits for several of the technologies reviewed by the NRC. This table shows three cases: a constant baseline, the NRC "5-year rule", and a "10-year, half penetration rate rule", as described in Appendix 5-A. There is a difference between the reported benefits in these three methodologies of a factor of two, three, or more. Thus, assumptions about what the market would have accomplished in the absence of EERE activity—an inherently unknowable factor—can change the reported benefits significantly. As discussed in Appendix 5-A, there is no empirical basis for the NRC 5-year rule, and case studies show in some cases much longer periods where industry was unsuccessful in developing a technology before EERE provided technical assistance. For example, industry was unsuccessful in solving some of the technical problems of the Lost Foam metal casting technology for 29 years, before EERE formed a research consortium that successfully solved the research challenges. In other cases, technologies depend on more fundamental work done in publicly supported labs over a decade or more before the applied technology development can even begin.

Specific technologies listed in the NRC benefits Table 5-2 include the following:

- **Advanced Refrigerator Compressors**. The NRC analysis examined the benefits resulting from compressor improvements developed between 1978-1981. In cost shared work under a competitive solicitation with industry, some 13 modifications were incorporated into a laboratory prototype compressor. These included (1) improvements in motor efficiency through better materials and design, and (2) reduced pressure losses in the refrigerant circuits due to improved port and valve design. These resulted in a 44% improvement in compressor efficiency over the technology commonly used in the late 1970s. A number of additional improvements have subsequently been made to refrigerator technology that is not included in the NRC analysis.

- **Electronic Ballasts for Fluorescent Lamps.** Traditionally, magnetic ballasts constructed from inductors, transformers, and capacitors were used to provide the high voltage needed to start fluorescent lamps and then control the current at the correct operating level. Electronic ballasts can do all these tasks more efficiently than magnetic ballasts, and are also able to operate at higher frequencies to further improve efficiency of the light generation process itself. These improvements reduce energy consumption per lumen of light output by typically 25 percent. The technology was developed through R&D at Lawrence Berkeley National Laboratory and industry subcontracts. One of the major firms in the industry tried to block introduction of the electronic ballast by acquiring intellectual property rights, requiring six years of litigation to overcome.

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[25] National Academy of Sciences, National Research Council, "Energy Research at DOE: Was It Worth It?," July 2001, op cit.

TABLE 5-2: NET REALIZED BENEFITS ESTIMATED FOR SELECTED TECHNOLOGIES RELATED TO ENERGY EFFICIENCY RD&D CASE STUDIES[26]

Technology	**Economic Benefits (Cumulative Net Energy Savings and Consumer Cost Savings)**				**Environmental Benefits (Cumulative Pollution Reduction)**				**Security Benefits (Oil Use or Outage Reduction)**		
	Cost of DOE and Private RD&D (billion $)[a]	Fuel (Q)[b]	Electricity (Q of primary energy)[c]	Net Cost Savings (billion $)[d]	SO_2 (millions of metric tonnes)	NO_x (millions of metric tonnes)	Carbon (millions of metric tonnes)	Damage Reduction (billion $)[e]	Oil and LPG (Q)[f]	Electricity Reliability	Value (billion $)[g]
Advanced refrigerator/freezer compressors	~0.002[h]		1	7[i]	0.4	0.2	20	1-5	0.04		0.02-0.1
Electronic ballast for fluorescent lamps	>0.006[j]		2.5	15	0.7	0.4	40	1-10	0.1		0.05-0.3
Low-e glass	>0.004[k]	0.7	0.5	8[l] see also note[z]	0.3	0.2	20	0.5	0.2		0.1-0.7
Advanced lost foam casting	0.008		0.03	0.1[m]	0.01	0.006	0.5	0.02-0.1			
Oxygen-fueled glass furnace	0.002	0.06		0.3		0.02	1	0.05-0.2			
Advanced turbine systems	~0.356	0.09		~0 by 2005[n]		0.02	1	0.05-0.2		Yes	
Total	~0.4			~30				~3-20			0.2-1

NOTE: The EE benefits are total (EE plus other sponsors, including industry).

[26] Source: NRC.

Notes a-n below are directly reproduced from the NRC report, "Energy Research at DOE: Was It Worth It?", op. cit.

[a] DOE R&D investment plus all private sector R&D cost share in billions of 1999 dollars.

[b] Cumulative fuel savings in quadrillion Btu (quads, or Q).

[c] Cumulative electricity savings in quadrillion Btu of primary energy.

[d] Cumulative energy cost savings net of R&D costs, extra capital, and labor costs compared to the next best alternative all in 1999 dollars. The DOE investment is assumed to have led to the innovation coming on the market 5 years earlier than it otherwise would have.

[e] Avoided emissions of SO_2 and NO_x are assumed to be valued in the ranges of $100 to $7,500 and $2,300 to $11,000 per metric tonne, respectively, in avoided damages, and avoided carbon emissions are assumed to be worth $6 to $11 per metric tonne. These ranges are for the lower end of damage values estimated in the literature. The open market value of mitigating a tonne of SO_2 is $100-300, and $100 was used to peg the lower end of the range for SO_2. SOURCE: Stirling, 1997; Ottinger at al., 1990; ORNL, 1994; EC, 1996-2001; OTA, 1994; Pearce at al., 1996; Tol, 1999.

[f] Fuel oil saving from saving electricity is equal to the primary energy used to make electricity times 1/30.

[g] Reducing oil use by one barrel is judged to be worth $3 to $20 in reducing the cost of an oil price shock. The value of $3 assumes cartel pricing and oil price shocks have cost the U.S. economy $25 billion per year. This derives from Paul N. Leiby, Donald W. Jones, T. Randall Curlee, and Russell Lee, "Oil Imports: An Assessment of Benefits and Costs," ORNL-6851, Nov. 1, 1997. That report also examined (Table 5.9) the range of oil import premiums and found them to be from $0.21 to $9.91/bbl. The value of $20/bbl comes from taking the total cost of cartel pricing and oil price shocks over the past 28 years and dividing by the total cumulative use of oil by the United States during that time. The cost is estimated to be $3.7 trillion divided by 153 billion barrels, or $22/barrel. The total cost is from Greene and Tishchishyna, 2000.

[h] Private sector cost share was $0.28 million.

[i] As a result of DOE R&D investment with a compressor manufacturer, a series of much more efficient compressors for refrigerator/freezers came on the market beginning in 1981. These were assumed to have resulted in half the energy savings of the sales weighted average refrigerator/freezers sold between 1981 and 1990 compared to 1979 as a base from which to calculate the savings. The net life-cycle cost savings of units sold through 1990 were reduced by assuming an improved compressor would have appeared on the market by 1986 without the DOE investment, and that it would have followed the same penetration path displaced by 5 years. No energy or cost savings beyond the 1990-year were assumed, but the full life-cycle savings over the assumed 20-year life of the units was counted. Beyond 1990, improvements in efficiency were due to DOE standards and R&D on HCFC substitutes without performance degradation, and these are estimated to save 2.6 Q of primary energy for electricity generation and $15 billion in net consumer life-cycle savings through 2005.

[j] Private sector cost share unknown.

[k] Private sector cost share unknown.

[l] The net energy cost savings was $37 billion (due to use in residential buildings and heating load reductions only). The committee applied the 5-year rule and the savings dropped from 6 to 1.2 Q and the energy cost savings dropped to $8 billion. These benefits ignore those deriving from cooling load reductions and commercial buildings applications.

[m] EE estimates the benefit from substituting the lost foam casting technology for sand casting at 46 percent in labor productivity and 7 percent reduction in material cost. These cost savings are much larger than the net energy cost savings, but they are not reflected in the realized economic benefits number.

[n] For this case, the net life-cycle energy cost savings over the 10 years of turbine lifetime for turbines installation estimated by 2005 pays for the R&D invested by DOE and private sector partners.

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[z] $15 billion is the corrected value per footnote 8 *supra*.

TABLE 5-3: NET REALIZED ECONOMIC BENEFITS ASSOCIATED WITH PUBLIC RD^3*

Case	Year **	Observed Unit Sales per year **	Unit Lifetime, years	Net Energy Savings per Unit per year, MMBtu	Net Economic Savings per Unit per year	Period	Total Benefit ***	Benefit under "5-year" rule to "10-year" rule****
Low-E Glass	1999	263 million square feet	30	0.0333	$0.29	to 2005	$38 B	$15[27]-32 B
Electronic Ballasts	1999	41.6 million units	15	0.64	$4.26	to 2005	$32 B	$15-

*Note that these economic benefits are associated with work that DOE has done, but any precise partitioning of credit between the DOE and private sector roles is not possible. Instead, the reported economic benefit is reduced according to the 5-year and 10-year rules to indirectly account for what would have happened without DOE's participation; this also, in effect, partitions the DOE and private sector contributions.
**Most recent year for which actual sales data are available, or are projected by industry analysts.
***Total benefit is calculated by multiplying the observed or projected unit sales each year, by the cost savings per unit compared to the next best available technology at the beginning of the period, and by the number of years of service of the unit, and summing over the years considered.
Note that values in this table are likely to change following workshops currently being developed and the resolution of issues such as the treatment of discounting, amortization, marginal pricing, uncertainty ranges, and other factors.
****Using the modified NRC methodology, as discussed in Appendix 5A.

- **Low-E Glass**. Low-E glass has a special coating that is transparent to visible light, but reflects long wavelength infrared radiation. As noted above, this helps keep the heat in a house during the winter, reducing window heat loss by about one-third, and reflects some of the hot sun during the summer. Low-E R&D was done at LBNL and several small research firms between 1976-1983. Subsequent advances have been made in spectrally selective coatings that reflect the near infrared to block summer solar heating, and others.

- **Advanced Lost Foam Metal Casting**. Lost Foam Casting enables metal casters to produce complex parts often not possible using other methods; it allows designers to reduce the number of parts, reduce machining and minimize assembly operations; and it allows foundries to reduce solid waste and emissions. Program results indicate an average energy savings of about 27%, coupled with a 46% increase in labor productivity and the use of about 7% by weight fewer materials in lost foam casting compared to green sand or resin bonded sand molding, the next best alternatives. [28]

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[27] As discussed in note 9 *supra*, the estimated net realized benefits under the NRC methodology are actually $15 billion when the methodology is applied consistently.
[28] Lost foam castings grew to 90,000 tons in 1997 and industry projected shipments at 167,000 tons in 2000. At $1 per pound for iron castings and $2.25 per pound for aluminum castings, with 50,000 and 60,000 tons of iron and aluminum lost foam castings produced in 1997, assuming an average 30% cost savings from productivity improvements gives an overall economic benefit of roughly $110 million in 1997 alone. These productivity savings would then be summed over the lifetime of the plant and equipment installed up to 2005. These productivity savings are not included in the NRC analysis of benefits, which considers only energy savings.

- **Oxy-fuel Glass Furnace.** The U.S. glass industry uses large amounts of energy to produce glass containers, windows for buildings and automobiles, fiberglass insulation, and other specialty products, such as TV tubes, fiber optic cables and light bulbs. EERE worked with industry to develop low-cost, large-volume oxygen production systems. These oxy-fuel furnaces substitute oxygen for air in the combustion process, which significantly reduces NO_x and other gas emissions and the amount of energy required per ton of glass produced. As of September 2000, 114 glass furnaces (28% of U.S. commercial scale glass furnaces) had been converted to oxy-fuel firing in the U.S., resulting in up to a 45% reduction in energy consumption in smaller furnaces and roughly 15% in large furnaces, based on measurements at individual facilities.

- **Advanced Turbine Systems.** EERE—in partnership with gas turbine manufacturers, universities, and national laboratories—initiated the Advanced Turbine System (ATS) Program in 1992 to produce the "next generation" of gas turbine systems for electric power generation. Turbine efficiencies of 37.5% have been achieved for the "Mercury 50" 4.2 MW_e turbine, nearly double the efficiency increase goal of raising performance from the best available (29% to 33%), while reducing NOx from the best available at 25 ppm to less than 9 ppm. This work has also developed and demonstrated the viability of ceramic liners and shrouds on industrial gas turbines, with efficiency gains of 1.5% per unit.

These examples capture only a small portion of the benefits stemming from EERE's RD^3 activities, but as determined by the NRC and as shown in Table 5-3, even under the conservative NRC methodology, the net benefits on just this subset of R&D activities are several times the total public RD^3 investment on all of EERE investments to date. Further work is needed to develop a reasonably complete analysis of the benefits resulting from EERE activities.

The SPR identified a number of additional successes that would be useful to further analyze when an improved NRC-like methodology is fully developed. This work has begun, with some preliminary estimates noted below and workshops being planned to address key methodological issues. Some of the technologies that would be useful to examine further are indicated in Table 5-4. More complete and detailed discussions can be found in program materials.

The OIT program has specifically tracked over 140 technologies, identifying 1.6 quads of energy savings through 1999, with a net return of about $3.4 billion (Figure 5-1).[29] These savings are not directly comparable to the NRC methodology, as (1) the NRC extends the analysis for expected market sales through 2005 whereas the OIT analysis more conservatively cuts off savings in 1999; and (2) the NRC assumes that the private sector would have accomplished the same result as with public assistance in five years whereas the OIT analysis assumes a constant baseline, among other differences. As one comparison, the NRC methodology estimates cumulative net energy savings from Oxy-Fuel gas furnaces at 60-128 trillion Btu, whereas the OIT methodology estimated savings of 21 trillion Btu, or one-third to one-sixth as much as the NRC.[30] A reasonable subset of the 140 technologies tracked by OIT should be analyzed using an improved NRC methodology in order to put them all on a common basis.

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[29] Office of Industrial Technologies, "Impacts: Summary of Program Results", Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, January 2001.

[30] NRC, "Energy Research at DOE: Was It Worth It?," op. cit., page 29 lists energy savings for Oxy-fueled glass furnaces at 0.06 quads; page 139 lists the savings as 128 trillion Btu.

TABLE 5-4: EXAMPLE TECHNOLOGIES NEEDING FURTHER QUANTITATIVE BENEFITS ANALYSIS WITHIN AN IMPROVED NRC METHODOLOGICAL FRAMEWORK

Technology	**Description**
	BUILDINGS—BTS
Advanced Refrigerators/Freezers	EERE has developed numerous advances in refrigerators, including improved motors and compressors noted in the NRC analysis, insulation, controls, and cases; and ozone-safe refrigerants. These technologies were developed through cost-shared competitive solicitations with industry and, after the technology was proven, were ultimately followed by energy-efficiency standards. As a consequence, under the new 2001 standards, refrigerators use just a third to a fourth as much electricity as typical models used in 1972 (Figure 4-3). As residential refrigerators currently use about $14 billion worth of electricity per year, these improvements are generating very large economic benefits.
Spectrally-Selective Windows	In addition to Low-E glass examined by the NRC Panel, EERE has developed spectrally selective windows that use special coatings to block near-infrared radiation and thus reduce summer heat gain and air conditioning loads. These coatings reduce the solar heat gain coefficient by over 40% compared to clear double-glazed windows.
Condensing Gas Furnaces	Conventional gas furnace efficiency is limited to 78% and is usually lower than that in practice; by capturing the energy in the water vapor produced by combustion (e.g. condensing the escaping moisture), furnace efficiencies can be raised to 92% or more. However, this condensed moisture corrodes conventional steels used in furnaces, even many stainless steels. Industry had been unable to prevent corrosion in furnaces due to this problem for over 50 years[31] and this prevented widespread use of higher efficiency technology—which became a significant problem with the push for higher efficiencies during the 1970s. EERE identified specialty alloys that prevented corrosion and allowed widespread use of condensing gas furnaces. As of 1998, these high efficiency furnaces accounted for about a quarter of the market, 688,000 high efficiency units per year sold, with unit net savings of $45/year.[32] Using the modified NRC methodology (Appendix 5A), preliminary estimates of savings under the 5-year rule were $11 billion; under the 10-year rule were $16 billion; and with a constant baseline $19 billion.
Flame Retention Head Oil Burner.	The flame retention head oil burner was a privately developed and commercially available technology that had not achieved market penetration over a period of nine years, even as oil prices tripled. EERE supported field testing of safety, reliability, and performance—and validated the utility of this technology; conducted consumer outreach; and supported service technician training to address key market barriers to the technology. Subsequently, the technology achieved 80% market penetration within three years, reaching 100% after seven years. Sales in 1994 were 496,000 units with net savings per unit of $130/year. Preliminary estimates using the modified NRC methodology (Appendix 5A) of the net realized economic benefits under the NRC 5-year rule were $7.5 billion, under the 10-year rule were $25 billion, and for a constant baseline were $35 billion.
DOE-2	DOE-2 is a computer program that simulates the energy performance and associated operating costs of buildings. DOE-2 has been used to help design energy-efficient buildings; guide research of and evaluate the performance of new technologies; develop voluntary national standards for energy efficiency such as ASRAE 90.1 and 90.2, California Title 24, and international building codes and standards in at least nine countries; and some 18 companies market building energy design tools based on DOE-2. Such information helps architects and developers to design and construct energy-efficient buildings in a cost-effective manner. Typical energy savings from using DOE-2 are 20% or more.[33]

[31] The first use of alloys to control efficiency in condensing gas furnaces occurred in 1928, but the chrome-nickel alloys used was inadequate in controlling corrosion and the furnace was withdrawn from the market. See James R. Brodrick and Alex Moore, “Conquering Corrosion”, ASHRAE Journal. April 2000, pp.29-33.
[32] James R. Brodrick and Alex Moore, “Conquering Corrosion”, ASHRAE Journal. April 2000, pp.29-33.
[33] Robert Sullivan and Frederick Winkelmann, “Validation Studies of the DOE-2 Building Energy Simulation Program” June 1998, LBNL-42241; reference on Pacific Northwest Case.

TABLE 5-4: EXAMPLE TECHNOLOGIES NEEDING FURTHER QUANTITATIVE BENEFITS ANALYSIS WITHIN AN IMPROVED NRC METHODOLOGICAL FRAMEWORK, continued.

Technology	Description
Indoor Air Quality	EERE created an indoor air quality research and technology transfer program to quantify the relationships among infiltration, ventilation rate, building characteristics, indoor pollutant sources, and acceptable indoor environments. The program developed ways to harvest the large energy savings potential of reducing the energy penalties associated with air infiltration and ventilation without degrading the resulting indoor environment. An important outcome of the program has been establishing the technical underpinnings of many industry consensus standards and guidelines. In addition, a hardware technology improved through the program, the blower door, is now used extensively by energy efficiency practitioners in detecting and correcting sources of building leaks. This program also helped facilitate the development of the radon mitigation industry.
Codes and Standards	Appliance energy codes for refrigerators, freezers, room air conditioners, central air conditioners, clothes washers, electric clothes dryers, gas clothes dryers, dishwashers, electric water heaters, gas water heaters, gas furnaces, and electronic ballasts have been developed, with energy savings under the peer reviewed and published analysis of the impact of these codes and standards estimated at about 80 quads of savings for units installed through 2030 over their lifetime. This is a different and much more sophisticated and more extensively peer reviewed methodology than that used by the NRC.[34] It would be useful to adapt the NRC methodology to the case of codes and standards in order to make a comparison across all technologies on a common basis.
Energy Star	The U.S. EPA initially developed the Energy Star label, and EERE became involved in 1996. The two agencies have developed performance criteria in 31 product categories, including lighting, appliances, windows, heating/cooling equipment, electronics, exit signs, transformers, and building materials. Energy Star has been adopted as the platform for energy efficiency activities by more than 100 utilities and state administrators, representing 47% of the U.S. population. There are now more than 1,200 participating manufacturers and retailers offering Energy Star products in 50 states. All Energy Star qualified appliances exceed existing Federal efficiency standards by approximately 13-20%, while Energy Star windows are 40% more efficient than required under common building codes.
Low-Income Weatherization.	The mission of the Weatherization Assistance Program is to reduce the heating and cooling costs for low-income families by improving the energy efficiency of their homes while ensuring their health and safety. An average of 33% of natural gas space heating consumption is saved in weatherized homes, and nearly 5 million out of 29 million currently eligible households, or 18% of the total, have been weatherized to date.
	FEMP
FEMP.	The Federal Energy Management Program is the central government office responsible for providing leadership, technical guidance, assistance and reporting on energy management activities and progress. With FEMP's assistance, agency actions, and mission changes, the Federal government lowered its energy intensity at Federal facilities by 20.5% in 1999 compared to 1985 levels, achieving the 20% reduction goal set by Congress in the Energy Policy Act of 1992 a year ahead of schedule.[35] Since 1985, the Federal government has saved $1 billion as a result of energy improvements in its facilities. According to preliminary data from 2000, the Federal government further reduced its energy intensity by 23.1% compared to 1985 levels. Further analysis is needed, however, of the specific roles of various factors in reducing this energy use.

[34] http://www.eren.doe.gov/buildings/codes_standards/

[35] This is based on 1985 energy use of 470.4 trillion BTUs in 3.4 billion square feet of Federal facility space, or 138,300 BTUs per square foot, declining to 1999 use of 336.9 trillion BTUs in 3.1 billion square feet of space, or about 109,700 BTUs per square foot. The reduction of 0.3 billion square feet in facility space was due to a DOD reduction of 0.6 billion square feet and a civilian agency facility increase of 0.3 billion square feet.

TABLE 5-4: EXAMPLE TECHNOLOGIES NEEDING FURTHER QUANTITATIVE BENEFITS ANALYSIS WITHIN AN IMPROVED NRC METHODOLOGICAL FRAMEWORK, continued.

Technology	Description
	INDUSTRY—OIT
OIT	As discussed elsewhere, the OIT program has specifically tracked over 140 technologies, identifying 1.6 quads of energy savings through 1999, with a net return of about $3.4 billion. These cases should be analyzed using an improved NRC methodology in order to put them all on a common basis.
Direct Steelmaking	The goal of the Direct Steelmaking project was to develop an in-bath, coal-charged smelting process coupled to continuous refining. This continuous process would be energy efficient and economically competitive, deriving at least part of its advantages from the avoidance of coke and its associated capital requirements and environmental problems. The benefits of post-combustion include: energy savings of 20-60 kilowatt hours per ton (less 5 to 8 kilowatt hours per ton to manufacture oxygen), a 5- 8% increase in productivity, energy cost reduction of $0.50-1.00 per ton, total cost savings of $2.50-$4.00 per ton, and CO emission reductions of up to 40%. The American Iron and Steel Institute for-profit unit, Steel Technology Corporation, has a strong patent position and is in licensing negotiations.
Intermetallic Alloys.	Oxidation resistance and high temperature strength of intermetallic alloys, such as iron and nickel aluminides, make these materials strong candidates for energy-saving, emissions-reducing, and productivity-increasing use in certain industries, including steel, chemicals, and petroleum, and in supporting industries including heat treating and forging. Sample benefits include savings and increased productivity from reduced downtime using nickel aluminide heat treating fixtures, and savings and improved productivity through fewer and shorter decoking operations using iron aluminide and other advanced material tubes for ethylene cracking.
Black Liquor Gasification.	Black liquor gasification has been investigated as an alternative to Tomlinson recovery boilers, in which black liquor—a byproduct of paper manufacturing—is currently burned, with several technologies having emerged as possibilities for commercial application. These technologies have been demonstrated with up to 10% higher thermal efficiency, two to three times greater electric power generation, 5% greater chemical reduction efficiency, lower capital and operating costs, and significant environmental benefits compared to the Tomlinson boilers.
	TRANSPORT—OTT
Catalytic Conversion for Cleaner Vehicles.	Compression-ignition direct-injection (CIDI) engines have the highest thermal efficiency of any proven automotive power plant, are excellent candidates for use in conventional or hybrid vehicle propulsion systems and are expected to deliver fuel economy in mid-sized vehicles. But to be competitive with future gasoline vehicle emissions and allay concerns about toxic and particulate emissions, it is necessary to develop catalytic emission control devices for CIDI engines. Significant economic, environmental and security benefits are anticipated from CIDI. For instance, for diesels with catalyzed emission controls, the fuel saved per vehicle over a 150,000 mile lifetime would save the consumer nearly $1,500 in life cycle costs and avoid CO_2 emissions of 17 tons per lifetime for light-duty trucks and 9 tons per lifetime for passenger cars.
Heavy Diesels.	The Heavy Vehicles Systems R&D program seeks to develop, in collaboration with truck manufacturers and suppliers, technologies that will reduce parasitic energy losses from aerodynamic drag, rolling resistance, and accessory loads, while ensuring powertrain and truck system integration to increase overall vehicle system energy efficiency. Using pneumatic devices attached to the rear of the trailer has demonstrated tractor-trailer aero drag reduction of 15%, with possible future drag reductions of 35-50% based on anticipated technological improvements.

TABLE 5-4: EXAMPLE TECHNOLOGIES NEEDING FURTHER QUANTITATIVE BENEFITS ANALYSIS WITHIN AN IMPROVED NRC METHODOLOGICAL FRAMEWORK

Technology	Description
Transportation Materials Technologies.	R&D on structural ceramics, metals and polymeric-matrix composites (PMCs) has been pursued to increase vehicle fuel economies. This program developed toughened silicon nitride ceramics, increasing operating temperatures from 1800 °F to 2500 °F and toughness by 5X; now produced at more than 300 tons per year, used in fuel injectors (millions sold), camshaft roller-followers (millions). Developed ceramic coatings for diesel engine piston rings to reduce energy use and emissions, lengthen life, with production of 330,000 rings per year in 2000. Developed silicon carbide reinforced alumina ceramics for machine tool industry. The current focus is now on metals and PMCs. In metals work, it is anticipated that design and product optimization will lead to mass savings of 25% relative to current light alloy designs, resulting in 13-18% total part cost reduction, in addition to significant energy savings for the die and metal casting industry. PMC work is reducing the cost of carbon fiber while increasing its strength and durability.
Advanced Batteries	Current work on advanced battery technology for electric vehicles was begun under a joint program with the United States Advanced Battery Consortium (USABC) in 1991; one goal is production of advanced batteries that would allow for fully competitive electric vehicles.
	RENEWABLES AND POWER—OPT
Geothermal.	Geothermal Energy provides about 2100 MW of base load electrical capacity for the United States, at capacity factors that typically exceed 95%. Direct use (thermal) applications account for another 600 MW. Research on polycrystalline diamond compact drill (PDC) bits led to the development of durable bonding between the tungsten head and the diamond, making these bits widely applicable for well drilling. A study found that PDC bits accounted for about one-third of oil wells drilled in the world, they reduced costs per well by an average of $65,000 (1987$) due to increases in productivity and reductions in lost time accidents, and they generated some $262 million per year in worldwide sales in 1995. With some 25,000 oil and gas wells drilled in the United States in 1998, assuming a very conservative $20,000 savings per well, and that 30% of the wells use PDC bits, this corresponds to an annual savings in well-drilling costs of $150 million.[36] High-temperature CaP cements, developed by EERE and industry partners, will be used at an estimated 50 geothermal wells over the next 20 years, saving more than $150 million in future well remediation costs.
Photovoltaics.	EERE assisted research on photovoltaics (PVs) has doubled efficiencies and reduced module costs by ten times over the past two decades (Chapter 6). As a result, U.S. based production has increased from 15 MW in 1990 to 78.5 MW megawatts (MW) in 2000. Module manufacturing costs have declined from over $25 per watt in 1980 to the present $2.70 per watt, and projections through 2006, with continuing R&D, indicate module costs will decline to an average cost of $1.75 per peak watt with roughly 240 MW of U.S. production capacity. Worldwide, there are now a cumulative total of 1 GW of PV installed, and sales have grown over 30% per year in the last four years.
Wind.	The cost of wind-generated electricity has declined by ten times since 1980, with current unsubsidized costs for new wind turbines in good wind resources at $0.04 to 0.05 per kWh. As of 2000, the U.S. had 2554 MW of wind generating capacity, and 1700 MW were installed in 2001, a more than 60% increase. The program is currently focused on reducing the cost of energy from utility-scale turbines by developing turbines capable of cost-effective operation in widespread areas with lower speed winds, and improving technology for small wind systems. The wind program also helped U.S. manufacturers supply wind turbines for several large domestic projects that would have otherwise used foreign-manufactured machines. 2001 GPRA metrics estimate that by 2020, the wind program will displace 1.23 quads of energy and supply $2.8 billion in energy annually, in addition to displacing over 22 MMTCE annually

[36] S. Falcone, "Technology Transfer Impact Profiles," School of Public Administration, University of New Mexico, November 1995. These are the values and assumptions used by Falcone, op. cit

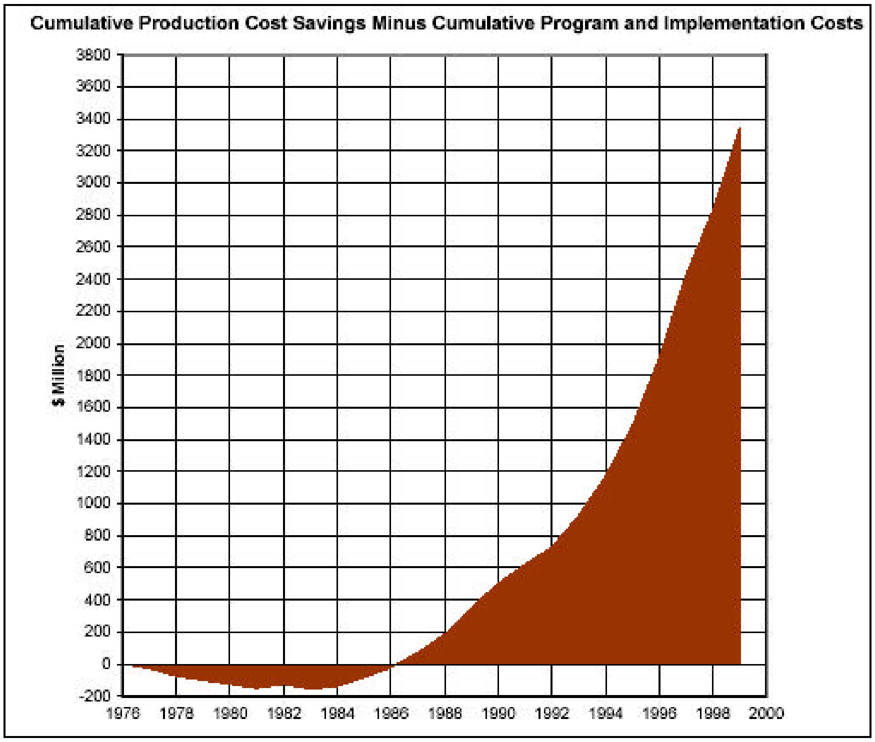

Figure 5-1: OIT estimates of net cumulative production cost savings from its research programs.

POTENTIAL ECONOMIC BENEFITS

The potential future economic benefits from EERE RD[3] activities have been estimated through a peer-reviewed process managed by AD Little, Inc., under the Government Performance Results Act of 1993. This analysis is developed through a process of surveys, external reviews, and integrated analysis using the Energy Information Administration National Energy Modeling System (NEMS) model. From 1997 to 2001, the revisions in estimates due to external review have narrowed by a factor of six, as shown in Figure 5-2.

The integrated analysis eliminates possible double counting that could result from summing the benefits of different technologies under development which impact the same final energy use; integrated analysis reduces estimated savings by about one-fourth in 2020. The results of the most recent full GPRA analysis available are shown in Table 5-5. If these estimates are reduced by the NRC 5-year rule—that is, that anything the public sector does would have been done by the private sector within five years—then the benefits are reduced to roughly $18 billion per year for a public investment of roughly $1.2 billion per year or a ratio of about 15 to 1 (Table 5-6).[37] This is in line with, but somewhat less than the NRC study

[37] This is estimated by analogy to the NRC methodology by assuming that benefits grow linearly till 2025—similar to the NRC approach which evaluated current benefits through 2005—giving a total benefit of 0.5*(5/4)*65*25=$1015 billion where this is the area of the triangle formed by the years 2000 to 2025 on the x-axis and (5/4)*65 is the magnitude of the benefits that would be reached in 2025, for benefits of $65 billion—the midpoint of the range—reached in 2020 (see Table 5-F). A similar estimate for the private sector curve with a five year delay gives 0.5*65*20=$650 billion. Subtracting these gives a net benefit of $365 billion, which is then divided by 20 years multiplied by $1.2 billion R&D investment per year at constant 2001 expenditures, or $24 billion, giving a ratio of about 15 to 1. These estimates obviously have large uncertainties in them, but are indicative of the rough magnitude of potential benefits.

which found cumulative benefits of $30 billion associated with public R&D investments totaling $1.6 billion, a ratio of roughly 20 to 1, using a methodology that, as noted previously, they considered to be conservative. Regardless, this indicates the potential for these programs to be associated with benefits that are more than ten times greater than the public investment over the next twenty years.

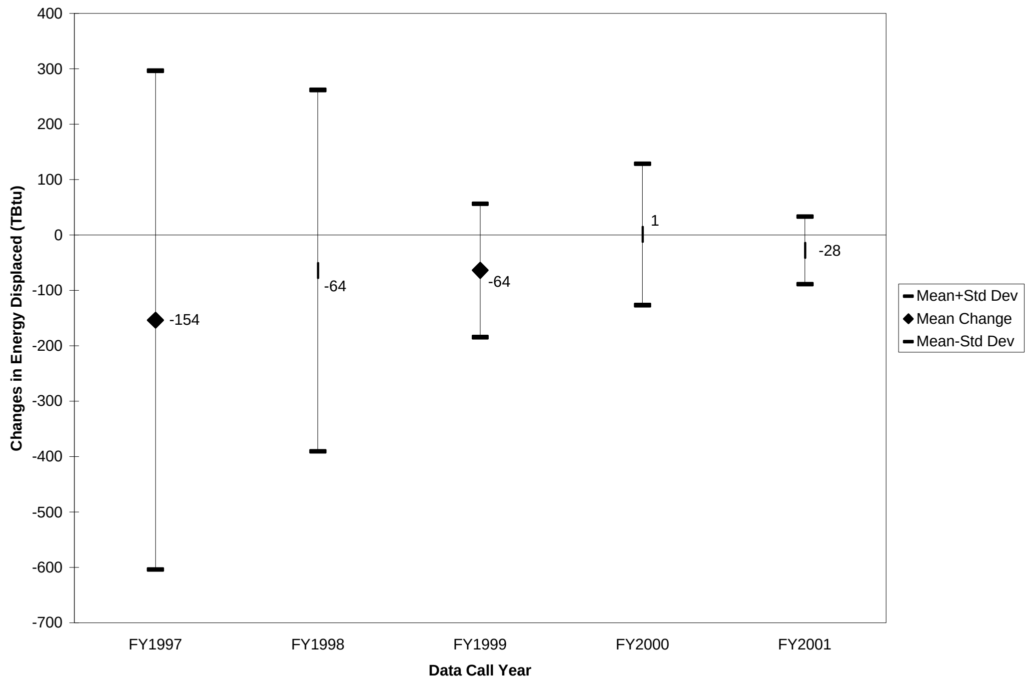

Figure 5-2: Changes in energy displacement after external reviews, FY1997-2001. Source: GPRA FY01, op. cit.

OPTIONS BENEFITS

Options benefits were only considered qualitatively by the NRC panel, and similarly were only examined qualitatively by the Strategic Program Review. Perhaps most significant of these options is the potential of EERE's advanced transportation technologies to increase vehicle efficiency and reduce our dependence on insecure supplies of oil. This is an increasingly urgent need. If the goals of these programs were realized, this would have a significant impact when these vehicles are fully phased into the market over the next several decades.

Extensive research into options analysis has been done over the past decade[38], and quantitative tools to address options analysis in the EERE context need to be developed and applied.

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[38] See, for example: Avinash K. Dixit and Robert S. Pindyck, "Investment Under Uncertainty", Princeton University Press, 1994. For their retrospective analysis, the NRC used the term "options" to refer to a technology that has been developed but does not penetrate the market. For example, the technology might be more expensive than current technologies and would only be competitive if the price of oil rose above $40 per barrel for an extended period. In this case, even though it is not necessarily made use of, the technology provides an insurance value against unexpected long-term oil price increases. More broadly, "options analysis" is a branch of economic science developed to quantify the value of future uncertain financial options in markets, and is now being extended to analyze uncertain future costs/benefits for a variety of investments.

TABLE 5-5: GPRA ESTIMATES, FY01:
EERE PROGRAMS PROJECTED BENEFITS BY SECTOR THROUGH THE YEAR 2020

	Total Primary Energy Displaced (Quadrillion BTUs)			**Energy Cost Savings* ($ billions)**			**Carbon Reductions (million metric Tonnes)**		
	2005	2010	2020	2005	2010	2020	2005	2010	2020
Transportation Sector *(oil savings in quads)*	0.2-0.3 *(0.5-0.6)*	0.9-1.0 *(1.4-1.5)*	2.5-3.5 *(2.8-3.2)*	1.7-3.3	8.4-9.9	20.1-22.6	3.8-4.6	17.9-19.5	46.0-50.1
Industry Sector	0.6	1.4-1.5	3.8-4.8	2.1-2.2	5.5-6.8	17.3-19.3	10.3-11.9	26.0-26.7	65.3-99.8
Building Technology, State & Community Sector	0.5-0.6	1.0-1.3	1.9-2.7	3.8	8.4-10.3	15.0-21.7	9.2-11.2	17.1-23.0	34.4-47.4
Federal Energy Management Program	.05	.07	.07	0.3	0.4	0.3	1.0	1.2	1.2
Power Sector	0.2-0.6	0.7-1.6	1.9-3.7	1.2-2.2	3.2-5.0	6.4-7.4	2.0-11.6	12.1-32.1	35.0-75.5

Note: The program benefit ranges are developed through an impact analysis process undertaken annually by the Office of Energy Efficiency and Renewable Energy (EERE). EERE's sectors analyze the impacts their programs will have on energy savings, cost savings, and carbon reductions if all program goals are met. These estimates are externally reviewed by Arthur D. Little. An integrated analysis model run by an external contractor controls for interaction effects. The integrated analysis model accounts for inter- and intra-sector double counting as well as market trends, including reductions in new electricity generation created by reduced demand. Totals for Transportation include impacts from the Biofuels program funded under Energy and Water appropriations.

TABLE 5-6: GPRA FY01 ANALYSIS*

	2000	2005	2010	2020
Energy Savings, Quads	~0**	1.5-2.1	4.0-5.4	10-14
Carbon Savings, Million Metric Tonnes	~0**	26-40	74-100	180-270
Energy Cost Savings per year, $billions	~0**	9.1-12	26-32	59-71

*Only the results of the integrated analysis are shown.
**Note that GPRA estimates for EERE have been renormalized to zero each year.

KNOWLEDGE BENEFITS

The NRC only considered knowledge benefits in the most general way, and in contrast to options analysis, there is little quantitative methodology to value knowledge benefits. Brief indicators of the knowledge benefits resulting from EERE's work include the more than 800 patents that have been generated and the tens of thousands of technical articles written.[39] A number of the technologies developed by EERE or, in some cases terminated because they could not meet the performance or development time constraints, can be identified as generating knowledge benefits as well. This includes

[39] See: www.eren.doe.gov as a gateway to some of this literature.

ultracapacitors and flywheels for energy storage, automotive gas turbines, stirling engines, oxy-fuel furnaces (for applications other than glass), and others.

EERE should identify and partner with researchers developing methodologies for quantifying knowledge benefits, and begin applying these methodologies in test cases where appropriate.

CONCLUSIONS

The Strategic Program Review confirmed and extended the findings of the NRC study, which found that the net realized economic benefits from the EERE programs were greater than $30 billion—a return of 20 to 1 for the programs examined, with further environmental, security, options, and knowledge benefits. These results demonstrate the historic performance of the EERE programs. In addition to those technologies with benefits quantified by the NRC, more than 20 additional technologies developed with EERE support over the past two decades were identified that appear likely to have resulted in large net realized benefits, but which have not yet been analyzed in detail.

This Program Review also identified several important gaps:

- **Improved Benefits Analysis**. Weaknesses identified in the NRC benefits analysis such as uncertainties around the 5-year rule, the lack of discounting, and other factors indicate a need to develop a stronger benefits analysis methodology that can be applied on a reasonably consistent basis across EERE.

- **Unified Benefits Analysis.** EERE has conducted extensive analysis of potential future benefits of its RD^3 activities under the Government Performance Results Act for the past half-dozen years, using external peer review with increasing agreement in the estimates. EERE has not, however, done as much work on retrospective benefits analysis, as was necessary in response to the NRC study. A methodology is needed that can meld both past and prospective GPRA benefits analyses within a single common framework that is applied consistently across EERE to the extent possible and appropriate.

- **Options and Knowledge Benefits.** Methodologies need to be developed and applied to EERE's portfolio to determine quantitatively, to the extent possible, the options and knowledge benefits resulting from EERE's work.

- **Tracking**. The actual impacts of EERE's work were often not readily available but would be useful to track, recognizing that this is difficult to do and must be done within some reasonable constraints on staff time and cost.

- **Portfolios**. EERE programs have clearly demonstrated some very big winners—generating benefits thousands of times greater than the program costs; modest winners—generating benefits of up to tens or hundreds of times greater than the program costs; and some losers—which were terminated before completion or for which no market developed. Most of EERE's portfolio, of course, is still under development and it is too soon to know how these technologies will fare. The key word, however, is portfolio. As it is impossible to know the outcome of research before it begins, a portfolio of projects is needed to help ensure that there will be some successes.

APPENDIX 5-A: BENEFITS ANALYSIS

In this appendix, the NRC methodology is described, its key weaknesses are identified, and the modifications used to develop the analysis presented in this report are explained.[40] The discussion presented here builds on the NRC framework, but was sharply constrained by the limited time between the release of the NRC report in mid-July and the completion of the Strategic Program Review; the possible modifications to the NRC framework identified below are an initial effort to examine methodological sensitivities and options. The issue of benefits analysis specifically and metrics broadly is very important to EERE, however, and further development of the benefits estimation methodology is planned for 2002. The discussion of extensions to the methodology presented here are preliminary.

THE NRC METHODOLOGY, AS IMPLEMENTED

The NRC benefits/costs methodology uses a framework consisting of 9 cells in a 3x3 matrix, as shown in Table 5-A1. The rows show Economic, Environmental, and Security Benefits/Costs. The columns show degrees of uncertainty about the benefits obtained, ranging from Realized, to Options, to Knowledge Benefits/Costs. This methodology is described in depth elsewhere and will be only briefly summarized here.[41]

TABLE 5-A1: NRC BENEFITS ANALYSIS METHODOLOGY

	Realized Benefits/Costs	**Options Benefits/Costs**	**Knowledge Benefits/Costs**
Economic Benefits/Costs			
Environmental Benefits/Costs			
Security Benefits/Costs			

Benefits Analysis: Rows

The rows of the NRC methodology consist of economic, environmental, and security net benefits with the following considerations.

- **Economic Net Benefits/Costs** are:
  - Based on changes in total market value of goods/services produced by the United States for normal conditions—i.e. with no significant energy disruptions or energy price shocks—due to the presence of the technology/regulatory change/etc. This considers changes in energy use (net of all costs, e.g., energy savings less capital costs), labor productivity, increased exports, benefits of derived energy standards, etc.
  - Measured net of all costs, including public/private R&D, lifecycle purchase costs, etc. (Note that private R&D costs will be necessarily covered by the cost of the technology charged end-users; and end-user costs are subtracted from energy savings, etc.)
  - Calculated on the basis of comparison with next best alternative. The development of a counterfactual baseline—what would have happened if EERE had not acted—poses significant problems for any estimate of the benefits resulting from EERE activities. This has been implemented using what the NRC terms the "**5-year rule**", which assumes that anything the public sector does the private sector would have done anyway within 5 years. There are several problems with this implementation, as discussed below.

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[40] This appendix examines the report: National Academy of Sciences, National Research Council (NRC), "Energy Research at DOE: Was It Worth It?," July 2001.
[41] NRC, op. cit., See Appendix D of their report.

  - Calculated for the entire lifetime of installations completed through a cutoff year, set by the NRC to **2005.** As discussed below, this cutoff and its implementation raises several problems because of EERE's GPRA-mandated requirement to look at future impacts.
  - Calculated without considering macroeconomic jobs or economic impacts; rebound effects; etc.

- **Environmental Net Benefits/Costs** are:
  - Based on the impact of the technology, or the regulations/standards that the technology enables, on the quality of the environment.
  - Calculated per the technical and/or regulatory changes that impact emissions or other environmental burdens. The NRC assigns a range of monetary values for these impacts, as drawn from the literature, and are in the neighborhood of: \$100-\$7,500/tonne for SO_x; \$2300-\$11,000/tonne for NO_x; and \$6-\$11/tonne for CO_2.[42]
  - Calculated per the 5-year rule and 2005 cut-off, as above.

- **Security Net Benefits/Costs** are:
  - Based on the probability and potential impact of oil disruptions and price shocks or other energy system disruptions (such as blackouts versus improved reliability) that would damage or disrupt the economy, environment, or national security of the United States. The probabilities and impacts for oil disruptions, for example, might be compared to the cost of reducing oil dependence.
  - Calculated on the basis of security costs that dependence on foreign oil carries. The NRC assigns a range of monetary values drawn from the literature that is in the range of \$3-20 per barrel of imported oil. A separate NRC study recently estimated the value as roughly \$0.02 to \$0.24 per gallon, or \$0.84 to \$10.08 per barrel.[43] No set of values is available for reliability.
  - Calculated per the 5-year rule and the 2005 cut-off, as above.

Benefits Analysis: Columns

The columns of the NRC methodology consist of realized, options, and knowledge benefits and costs, reflecting increasing uncertainty—technical, economic, market, political, etc.—about the benefits obtained, with the following considerations.

- **Realized Net Benefits/Costs** are:
  - Based on the benefits of technologies that are developed or in final development and demonstration, for which the current economic and policy (e.g. regulatory, tax, etc.) conditions are favorable for deployment, and for which the technology is penetrating or is expected to penetrate the market within the 2005 cut-off time set by the NRC.
  - Calculated using the considerations above for economic, environmental, and security lifecycle benefits for technology installed through 2005 compared to the NRC counterfactual 5-year rule baseline.

- **Options Net Benefits/Costs** are:
  - Based on technologies that have been successfully developed but for which economic and policy conditions are not currently favorable for their market penetration but which could become favorable under reasonable scenarios in the future.
  - Not calculated within the NRC methodology, but are presented qualitatively. In the future, a quantitative options analysis framework would be useful here.

- **Knowledge Net Benefits/Costs** are:
  - Based, within the NRC framework, on scientific and technical knowledge gained for technologies for which R&D is not yet completed, for technologies which will not be commercialized, and for technologies for which development was unsuccessful but which nevertheless generated useful

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[42] Note that these costs appear to mix damage costs and mitigation costs.
[43] NRC, "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards", 2001.

knowledge potentially applicable elsewhere. As implemented, this has several weaknesses, as discussed below.
- Not calculated within the NRC methodology, but are presented qualitatively.

The framework used by the NRC for classifying the benefits of technologies at various stages of development is shown in Table 5-A2.

TABLE 5-A2: CLASSIFICATION OF BENEFITS BY STATE OF TECHNOLOGY DEVELOPMENT

Technology Development & Economic/Policy Conditions	**Technology Developed**	**Technology Development in Progress**	**Technology Development Failed**
Favorable for Commercialization	Realized Benefits	Knowledge Benefits	Knowledge Benefits
Might become favorable for commercialization	Options Benefits	Knowledge Benefits	Knowledge Benefits
Will not become favorable for commercialization	Knowledge Benefits	Knowledge Benefits	Knowledge Benefits

WEAKNESSES OF THE NRC METHODOLOGY

> "*For some technologies, the 5 years (*NRC 5-year rule methodology*) may be much too conservative, and this is indeed reflected in some of the case studies. For example, the building sector is fragmented and supports only limited R&D activities, so government R&D might speed change by much more than 5 years*".[44] (NRC, p.37)

A brief review of the NRC methodology identifies several weaknesses, as listed below.

- **"5-year" rule**. The NRC methodology presumes that anything DOE does would be done by the private sector within five years and at the same rate of market penetration. Weaknesses with this approach include the following.
    - **Gestation**. The NRC 5-year rule ignores the long gestation time for many technological developments and assumes that the private sector can bring them forth in five years, irrespective of whether a foundation for them has been developed, often through long-term public supported research.
    - **History**. The NRC 5-year rule is contradicted by some of their case studies, such as the lost-foam technology that industry developed in 1960, but which no company—including large auto companies—had successfully developed until EERE got involved in 1989. In the case of electronic ballasts, industry leaders were actively trying to prevent development and use of the technology. Indeed, in most cases, DOE would not want to be involved if the private sector could and would do the research within five years anyway.

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[44] National Academy of Sciences, National Research Council, "Energy Research at DOE: Was It Worth It?," July 2001. Other statements by the NRC concerning how conservative its methodology is include the following: "Where it has used quantified benefits to support its findings and recommendations, the committee considers it has been conservative in establishing upper and lower bounds for its benefits estimates. In general, the Committee believes it is more likely than not that a more thorough analysis would increase the values of the benefits that the Committee has assigned to DOE's programs."(p.19) "The committee adopted a 5-year rule to be very conservative about the effect of DOE R&D."(p.37) "Applying this rule reduced the net realized economic benefits of electronic ballasts from about $32 billion estimated by EE to $15 billion, for example. For the refrigerator/freezer compressor the benefits decreased from about $9 billion to $7 billion. For low-e windows the benefits were decreased from $37 billion to $8 billion in 1999 dollars."(p.37, footnote 8).

  - **Penetration rate**. The NRC 5-year rule assumes that the private sector will achieve the same rate of market penetration as EERE efforts. However, EERE activities often span the entire industry, and EERE provides a variety of supports such as testing standards, rating standards, software design tools, information outreach, etc.; these activities and supports are likely to significantly accelerate market penetration.
  - **Modifications.** Modifications to the NRC framework described below include analysis of alternative baselines and alternative penetration rates. In addition to the NRC framework which uses a "5-year-rule" with the same rate of penetration as observed for DOE-assisted technologies, a "10-year-rule" is added with a penetration rate one-half the rate observed for DOE.

- **The 2005 cut-off**. The NRC study does not count benefits for technologies deployed after 2005, neither for technologies that are already being deployed nor for technologies just approaching deployment. Weaknesses of this approach include the following:
  - **Benefits Excluded**: Most technologies that are penetrating the market follow an S-type diffusion curve, as indicated in the figure below. The NRC methodology, as implemented, does not include potential benefits for technologies deployed after 2005 in the "Realized Benefits" column, nor does it include these potential benefits anywhere else in their matrix. Thus, the majority of the most likely benefits of DOE's RD^3 efforts—those benefits realized after 2005 for technologies being or likely to be deployed under current economic and policy conditions—are not included anywhere in the matrix. This also risks tilting apparent benefits towards the options column, which are those technologies under development or not commercially viable under current conditions.
  - **Benefits Included**: By using a 2005 cut-off, the NRC methodology, as implemented, tilts the reported benefits towards those technologies that have been on the market the longest, distorting the basis for comparing the value of different technologies, and misleading the casual reader to implicitly or explicitly infer that the older technologies have more value than recent R&D activities.
  - **R&D Risk and Return**. The NRC methodology also risks turning the long-term fairly high-risk EERE program upside-down, implicitly demanding near-term benefits for the work rather than recognizing the long-term potential.
  - **Modifications**. To describe the potential benefits of future market penetration of technologies under development or deployment as "Realized" under the NRC framework is not accurate; to ignore them altogether, as the NRC framework does, is also not correct, as it effectively sets to zero most of the benefits of RD^3 on innovative energy technologies. Consequently, in the framework described below, a fourth column for "Potential" (between "Realized" and "Options") Benefits/Costs is added and methods for estimating the value of this column are discussed. This corresponds to requirements placed on DOE under the Government Performance Requirements Act in which DOE is required to look forward at the potential performance of its technologies.

- **Methodological Sensitivities.** Because the methodology cuts off market penetration in 2005, it is highly sensitive to when technologies begin deployment. A simple model spreadsheet (generating Figure 5-A1) demonstrates that the 5-year rule and 2005 cut-off can lead to variations in "realized benefits" of 2-5 times or more.
  - **Modifications.** The above modifications adding a "Potential" column and generating a range of values using an upper bound of a 10-year-rule at half the penetration rate reduce the modeling sensitivity and may help provide a more realistic portrayal of the uncertainties inherent in this type of calculation.

- **Options Column**. As formulated, the NRC framework includes under "Options" only those technologies for which technology development is complete and for which market penetration is not significant under current market conditions and policies, but for which a change in policy or market conditions could lead to significant market penetration. This approach ignores a broad range of technologies under development where there is good likelihood of success and for which there would be significant market opportunity under current market and policy conditions. More broadly, it ignores the portfolio basis for technology development in EERE; it also ignores a large literature on options valuation and how options analysis is approached. Finally and most importantly, it ignores the Government Performance Results Act, which requires Federal research programs look forward at potential benefits and to benchmark activities, whereas the NRC framework only looks retrospectively.

- **Modifications**. The NRC approach was modified by including discussion of technologies under development within a new "potential" column.

- **Other**. Other weaknesses of the NRC methodology include that it does not discount past or future costs; it uses average costs, efficiencies, emissions factors, site to source conversion factors, etc. rather than marginal values; and it does not generally consider shifts in fuel shares over time for different regions.

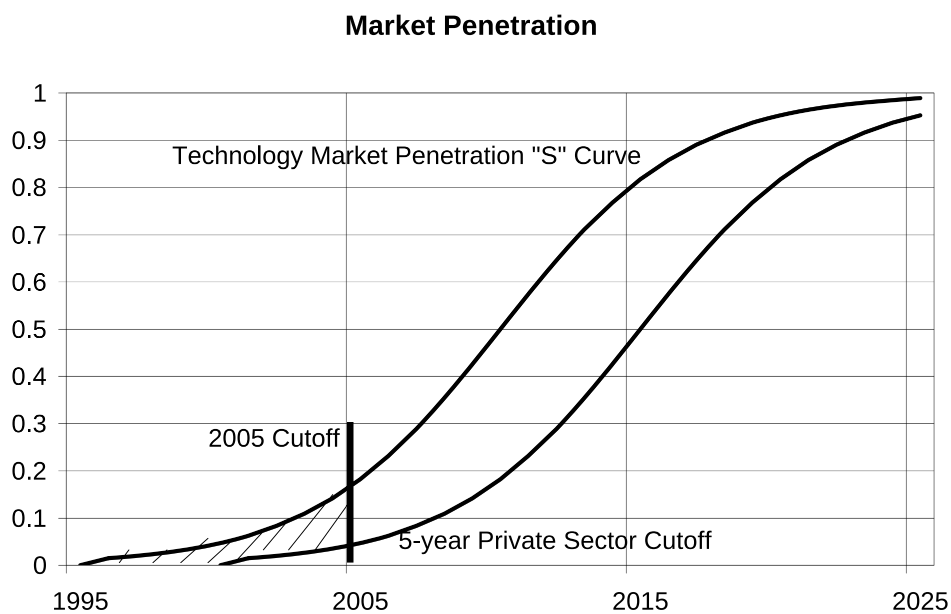

Figure 5-A1: Market penetration. This figure illustrates the impact, for typical S-curves of market penetration, of the NRC methodology of cutting benefits off after 2005 and of using the "5-year rule" private sector cutoff as a counterfactual baseline. In cases examined by the NRC, the "5-year rule" reduced estimated benefits compared to the next best alternative baseline by roughly 20-60%; the impact of cutting off potential future benefits was not quantified, but is suggested by this figure. See NRC, op. cit., Page 61, footnote 8. Also see footnote 8, *supra* on the adjustment of the NRC $8 billion estimate for low-E windows to the methodologically consistent $15 billion.

STRATEGIC PROGRAM REVIEW BENEFITS ANALYSIS METHODOLOGY

The Strategic Program Review has begun the initial development of a benefits analysis methodology similar to that of the NRC, but with the modifications described below. A few preliminary analyses have been done and are briefly mentioned in the chapter text above (Tables 5-3 and 5-4 Condensing Gas Furnace; Flame Retention Head Oil Burner); further development is under way.

- **"5-year Rule"**. In contrast to the rigid "5-year rule" counterfactual baseline used by the NRC, the SPR varies the counterfactual baseline across:
  - **Multiple time periods**—5-year and 10-year; and
  - **Multiple penetration rates**—100% of DOE-assisted technology penetration rate on a unit basis and 50% of DOE rate. (Note that penetration rates are calculated on a unit basis rather than as a market penetration percentage. For a growing market, a percentage penetration rate would result

in private sector penetration rates 5-years later growing on a faster per unit basis than for the DOE case, with correspondingly higher requirements for investment, manufacturing scaleup, training, development of retail outlets, etc. This is contrary to the desire to build a counterfactual baseline corresponding to that observed in actual markets.)

- o **Ranges**—together, the multiple time periods and multiple penetration rates are simply presented as a range, with the lower bound representing the NRC framework with a 5-year cutoff and a 100% (of the public sector rate) penetration rate; the upper bound representing a 10-year cutoff with a 50% (of the public sector rate) penetration rate. Appropriate ranges and other factors will be considered in followup to the March 2002 benefits workshop.

- **“2005 Cut-off”**. The SPR adds a column for “Potential Benefits/Costs” to examine the benefits/costs for technologies deployed after 2005—for both technologies already being deployed as well as technologies under development—in response to requirements under the Government Performance Results Act. As it is the most recent year in which fully developed peer reviewed estimates are available and because it uses a relatively mature and well-developed methodology, GPRA FY01 analysis is used to estimate these future benefits/costs. The modified framework is shown in Table 5-A3. Case studies of this feature have not yet been tested.

- “**Potential Benefits**”. Potential benefits and costs include discussion of particularly promising technologies under development. A resulting change in the from “knowledge benefits” to “Options Benefits” in the cells indicated below in bold.

- **Knowledge benefits** include knowledge generated across all technologies, not just those that failed.

Other elements of the NRC methodology remain the same for this Program Review, pending the results of the work planned for the Spring of 2002.

TABLE 5-A3: MODIFIED NRC BENEFITS ANALYSIS METHODOLOGY

	Realized Benefits/Costs	Potential Expected Benefits/Costs	Options Benefits/Costs	Knowledge Benefits/Costs
Economic Benefits/Costs				
Environmental Benefits/Costs				
Security Benefits/Costs				

TABLE 5-A4: CLASSIFICATION OF BENEFITS BY STATE OF TECHNOLOGY DEVELOPMENT

Technology Development & Economic/Policy Conditions	Technology Developed	Technology Development in Progress	Technology Development Failed
Favorable for Commercialization	Realized Benefits, Potential Benefits after 2005, Knowledge Benefits	**Potential Benefits,** Knowledge Benefits	Knowledge Benefits
Might become favorable for commercialization	Options Benefits, Knowledge Benefits	**Options Benefits,** Knowledge Benefits	Knowledge Benefits
Will not become favorable for commercialization	Knowledge Benefits	Knowledge Benefits	Knowledge Benefits

- **Net Benefits/Costs**. Incremental lifecycle capital, operating, and other costs/savings for the technology, the cost of RD^3, and other cost for the entire life of all installations are included, compared to the next best alternative, not the average, technology. This "next best alternative" applies primarily to the interval before the 5-year or 10-year rule launches the private sector introduction of the equivalent technology.

- **Deflators**. All costs are in constant year 2000 dollars, using average GDP deflators.

- **Discounting**. No discounting is done in the preliminary cases mentioned in the Chapter text above (Tables 5-3, 5-4, Condensing Gas Furnace; Flame Retention Head Oil Burner), following the NRC methodology, but the lack of discounting in the NRC methodology is a problem that will need to be addressed by EERE in future development of the benefits analysis methodology.

- **Rebound Effect**. The "rebound effect"—in which lower prices for energy services induce consumers to use more of those services—is not considered in the NRC methodology nor here, as the "consumer who chooses to buy more of the energy service as a result of a reduction in its price obtains a benefit from the additional services and faces a cost from the additional expenditures. For the rational consumer, the additional cost and benefit should be roughly equal and the net additional benefits from the rebound effect should therefore be very small or zero."[45] However, "rebound" demand does change the impact of a policy/technology on energy use and emissions levels in ways that do affect the net social value of the policy/technology when externalities related to energy use are important.

- **Worker Productivity**. Increases or decreases in worker productivity are considered within the economic benefits.

- **Macroeconomic Effects.** Job creation is not considered as a benefit. The Macroeconomic impacts of energy disruptions are considered, in a most approximate way, under security benefits.

- **Options Benefits**. A detailed options analysis is not done by the NRC nor here, given the time constraints.

- **Environment**. Proxy values for the mitigation/damage costs of various environmental burdens are included, using the values identified by the NRC.

- **Security**. Proxy values for the mitigation/damage costs of various security burdens are included, particularly for oil and energy reliability, using the values identified by the NRC values.

- **Partitioning credit**: NRC was not able to develop a satisfactory approach for partitioning credit between the public and private roles, nor was it done here.

[45] NRC, "Energy Research at DOE: Was It Worth It?", op. cit.

APPENDIX 5-B: GPRA FY01 RESULTS

TABLE 5-B1: GPRA FY01 SUMMARY RESULTS

	Primary Energy Displaced (TBtu)			Energy Cost Savings ($ Billion)			Carbon Reductions (MMTCE)		
Planning Unit	2005	2010	2020	2005	2010	2020	2005	2010	2020
BTS									
Commercial Buildings Integration	8	42	159	$0.06	$0.32	$1.22	0.15	0.75	2.81
Community Energy Program	113	293	575	$0.80	$2.21	$4.54	2.02	5.05	9.86
Energy Star Program	92	219	279	$0.77	$1.93	$2.39	1.78	3.99	4.90
Equipment, Materials & Tools	177	532	1,236	$1.33	$4.20	$10.16	3.28	9.43	22.07
Residential Buildings Integration	3	20	110	$0.02	$0.15	$0.81	0.05	0.33	1.78
State Energy Program	27	51	97	$0.19	$0.37	$0.70	0.48	0.88	1.64
Technology Roadmaps and Competitive R&D	47	88	162	$0.36	$0.69	$1.28	0.87	1.56	2.82
Weatherization Assistance Program	32	63	92	$0.23	$0.44	$0.63	0.54	1.03	1.50
BTS TOTAL (non-integrated)	498	1,307	2,709	$3.76	$10.31	$21.74	9.17	23.02	47.38
BTS TOTAL (integrated)	570	1,020	1,870	$3.80	$8.40	$15.00	11.20	17.10	34.40
OIT									
Agriculture Vision	1	4	45	$0.00	$0.01	$0.06	0.00	0.03	0.30
Advanced Industrial Materials (AIM)	7	22	86	$0.01	$0.04	$0.19	0.06	0.20	0.89
Aluminum Vision	16	40	148	$0.08	$0.21	$0.73	0.41	1.13	4.47
Best Practices	79	163	336	$0.28	$0.63	$1.26	1.26	2.50	5.26
CFCCs/Engineered Ceramics	21	58	153	$0.06	$0.18	$0.43	0.33	0.93	2.56
Chemicals Vision	81	196	876	$0.18	$0.48	$2.35	1.08	2.49	9.95
Distributed Generation	86	163	541	$0.49	$1.14	$3.17	2.48	6.41	21.44
Forest & Paper Products Vision	111	259	1,510	$0.52	$1.29	$7.37	2.17	5.97	37.20
Glass Vision	24	43	77	$0.08	$0.15	$0.27	0.36	0.66	1.20
Industrial Assessment Centers (IAC)	20	39	54	$0.11	$0.20	$0.28	0.34	0.61	0.88
Inventions & Innovations	3	43	108	$0.01	$0.18	$0.47	0.05	0.78	1.92
Metal Casting Vision	10	25	96	$0.03	$0.08	$0.32	0.20	0.55	2.15
Mining Vision	3	9	39	$0.01	$0.04	$0.16	0.07	0.20	0.92
NICE-3	1	16	98	$0.00	$0.06	$0.38	0.02	0.25	1.55
Petroleum Refining Vision	74	206	417	$0.20	$0.59	$1.20	1.00	2.80	5.59
Sensors and Controls	2	2	5	$0.01	$0.01	$0.02	0.04	0.05	0.09
Steel Vision	27	79	238	$0.07	$0.21	$0.61	0.39	1.19	3.42
OIT TOTAL (non-integrated)	568	1,367	4,827	$2.15	$5.50	$19.27	10.26	26.74	99.79
OIT TOTAL (integrated)	600	1,490	3,760	$2.20	$6.80	$17.30	11.90	26.00	65.30

TABLE 5-B1: GPRA FY01 SUMMARY RESULTS, continued

	Primary Energy Displaced (TBtu)			**Energy Cost Savings ($ Billion)**			**Carbon Reductions (MMTCE)**		
	2005	2010	2020	2005	2010	2020	2005	2010	2020
OTT									
Biofuels	23	182	683	-$0.01	$0.01	$0.13	0.44	3.43	12.86
Fuel Utilization (1)	0	0	0	$0.00	$0.00	$0.00	0.00	0.00	0.00
Materials Technologies	1	9	43	$0.02	$0.11	$0.49	0.03	0.18	0.85
Technology Deployment (2)	0	0	0	$0.39	$0.78	$0.96	1.20	1.83	2.25
Vehicle Technologies	154	742	1,768	$1.30	$7.52	$18.56	2.91	14.09	34.18
OTT TOTAL (non-integrated)	179	933	2,495	$1.70	$8.42	$20.14	4.58	19.53	50.14
OTT TOTAL (integrated)	280	1,010	2,490	$3.30	$9.90	$22.60	3.80	17.90	46.00
OPT									
Biomass Power R&D	186	503	826	$0.08	$0.18	$0.32	4.42	11.70	17.43
Competitive Solicitation	3	3	3	$0.00	$0.00	$0.01	0.06	0.06	0.05
Concentrating Solar Power	3	12	43	$0.01	$0.04	$0.14	0.06	0.22	0.77
Energy Storage	0	1	4	$0.00	$0.00	$0.01	0.01	0.02	0.07
Geothermal Energy R&D	23	94	307	$0.05	$0.24	$0.70	0.45	1.73	5.54
High Temperature Superconductivity	5	85	343	$0.01	$0.21	$0.78	0.10	1.58	6.20
Hydrogen	1	43	303	$0.00	$0.00	$0.00	0.02	1.87	13.45
Photovoltaic Systems R&D	6	21	98	$0.01	$0.05	$0.22	0.12	0.40	1.76
Solar Buildings	34	64	164	$0.22	$0.39	$1.00	0.50	0.93	2.46
Transmission Reliability	65	164	339	$0.30	$0.65	$1.43	1.07	2.78	5.50
Transmission Reliability	*24*	*74*	*132*	*$0.00*	*$0.00*	*$0.00*	*0.52*	*1.62*	*2.82*
Distributed Power	*41*	*89*	*207*	*$0.30*	*$0.65*	*$1.43*	*0.55*	*1.17*	*2.68*
Wind Energy R&D	246	585	1,231	$0.55	$1.47	$2.80	4.81	10.79	22.24
OPT TOTAL (non-integrated)	573	1,576	3,662	$1.23	$3.24	$7.41	11.63	32.08	75.48
OPT TOTAL (integrated)	220	740	1,930	$2.20	$5.00	$6.40	2.00	12.10	35.00
FEMP	52	67	66	$0.27	$0.37	$0.30	0.99	1.22	1.20
FEMP TOTAL	52	67	66	$0.27	$0.37	$0.30	0.99	1.22	1.20
TOTAL (non-integrated)	1,870	5,250	13,758	$9.10	$27.84	$68.85	36.63	102.59	273.99
TOTAL (integrated + FEMP)	1,722	4,327	10,116	$11.77	$30.47	$61.60	29.89	74.32	181.90
Bold = ADL Reviewed Planning Unit									

(1) Benefits for Fuels Utilization are included in the benefits for Vehicle Technologies

(2) Primary energy benefits for deployment of fuel efficient vehicles are included in the benefits for Vehicle Technologies; primary energy benefits for alternative fuel vehicle programs are assumed to be zero because petroleum based fuels are being replaced by alternative fuels. However, since the alternative fuels are often less costly and produce less carbon, there are benefits due to energy cost savings, carbon reduction, and oil displacement.

Chapter 6

Business Performance Review

SUMMARY

The *National Energy Policy* calls for a review of the "historic performance" of the Office of Energy Efficiency and Renewable Energy (EERE) programs and for the Secretary of Energy to propose appropriate funding of those programs that are "performance-based" and are modeled as "public-private partnerships".[1] In this chapter, the Strategic Program Review (SPR) examines these three factors from the perspective of EERE programs' business performance.

While examining the historic business performance of the EERE programs, it became apparent that the changes suggested by the National Academy of Public Administration (NAPA) in their 1999 review were on target. EERE has begun implementation of a comprehensive management framework (EERE's Strategic Management System), has developed standards, tools and learning materials to improve the program management skills of the EERE staff, and has devised a method using the performance management system to promote accountability among the senior EERE managers. EERE is confident that it can fully implement these three changes – thereby establishing itself as one of the best performing organizations in the Federal Government. However, delays in implementation have persisted longer than anticipated. It is also important to note that the three changes initiated by EERE apply directly to the "Budget and Performance Integration" goals articulated in the recently published *President's Management Agenda*.[2]

One of the positive findings of this review was the fact that despite all of the fragmentation, lack of central management and leadership, and lack of data systems, EERE has implemented effective public-private partnerships, obtained extensive cost share on R&D projects, and achieved many of the organization's scientific objectives.

BACKGROUND

As previously discussed, the National Academy of Public Administration (NAPA) published "A Review of Management in the Office of Energy Efficiency and Renewable Energy," in March 2000. That review identified deficiencies in EERE business management practices and suggested future improvements. NAPA provided 38 recommendations for improving overall EERE business performance. In addition, several fundamental changes recently initiated by EERE to improve effectiveness and efficiency were affirmed by NAPA. Lastly, the NAPA review and the associated recommendations continue to provide the template by which EERE can implement "best in class" R&D business management practices. This chapter follows the NAPA template to examine EERE's business performance.

The NAPA review noted that EERE suffered from the consequences of a period of ineffective central management and leadership. The primary consequence was fragmentation in program implementation, which has both good and bad points. The silver lining from program fragmentation was that each sector developed their own approach to plan, implement, and evaluate their programs. As a result, the latitude

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[1] "National Energy Policy," Report of the National Energy Policy Development Group, (Washington, DC: U.S. Government Printing Office, May 2001), page 4-3, 6-4.
[2] "The President's Management Agenda: FY 2002," U.S. Office of Management and Budget, 2001.

for innovation led to best practices in different areas of program management among the sectors. Some of these best practices are addressed in the Executive Summary and described in detail in Chapters 4 and 5. Currently, EERE promotes effective central leadership and management through several key initiatives described below.

The three fundamental changes affirmed by the NAPA review formed the basis of the Implementation Plan developed by EERE to respond to the 38 recommendations in the NAPA report. These changes were:

- Fully implement a comprehensive management framework – the Strategic Management System (SMS) – for the business management functions of planning, budget formulation, budget execution, and evaluation. Ensure a strong program analysis and evaluation capability to support all phases of the system. [EERE began SMS implementation in Fall 1999.]
- Strengthen program management by setting high standards for program managers; clearly defining their roles and responsibilities; providing the tools necessary to manage efficiently; and providing the training necessary to use those tools effectively. [EERE began developing the Program Management Initiative (PMI) in the Fall of 2000; implementation will begin in earnest in Winter 2002.]
- Hold all levels of EERE management and employees accountable for accomplishing the goals and objectives of the organization, including management reforms and the implementation of this plan. [EERE included program-specific accountability measures in SES performance standards in 2001. Accountability measures will cascade to all levels of EERE in 2002.]

The rest of this chapter describes the status of EERE business performance in the context of:

- a description of the three changes noted above;
- the means by which the three changes support the goals of the "Budget and Performance Integration" chapter of the President's Management Agenda;
- the improvements still needed in EERE to fully implement the changes; and,
- recommendations for EERE to continue to improve its business performance.

CHANGE 1: THE STRATEGIC MANAGEMENT SYSTEM (SMS)

EERE developed the Strategic Management System (SMS) in 1999 as the business model for increasing the efficiency and effectiveness of its planning, budget formulation, budget execution, and program analysis and evaluation. The SMS links these activities in an orderly, systematic fashion while improving timeliness, transparency, and increasing the responsiveness of EERE programs. The implementation of this system helps to ensure the alignment of programmatic and business management activities and is intended to provide critical information at the right time for key decision-making.

Most of the elements described in the SMS existed in the past, but were carried out in a piecemeal fashion. The SMS integrates those elements into a cohesive whole based on common terms and definitions and applies them using a consistent set of principles, procedures, and information management systems. In so doing, the SMS becomes the vehicle to integrate the various performance demands that EERE faces, both internally and externally. In addition, the SMS complies with the Government Performance and Results Act of 1993 (GPRA), the Government Management Reform Act of 1994, the Federal Managers Financial Integrity Act, Office of Management and Budget (OMB) directives, Executive Orders on customer service and performance management, and Congressional guidance.

The key processes – planning, budget formulation, budget execution, and program analysis and evaluation – are highly interdependent and designed for effective program implementation and delivery of EERE's products and services to the Nation. Planning identifies the goals and priorities of the organization and determines the methods to achieve those goals. Budget formulation allocates resources including the utilization of staff. Budget execution delivers goods and services to customers. Program analysis and evaluation assesses how well EERE has implemented its programs and is progressing toward achieving its goals; and is integral to the next planning cycle.

The annually updated SMS Guidance Letter describes all of the SMS activities in the chronological order for a single fiscal-year cycle. For example, the FY 2004 cycle starts with planning in Fall 2001 and ends with the issuing of the DOE FY 2004 Annual Accountability Report in Spring 2005. However, EERE does not work on only one fiscal year at a time. During the 42 months it will take to complete the full FY 2004 cycle, parts of the cycles for FYs 2001, 2002, 2003, and 2005 will also be underway. At any given time, EERE conducts planning, budgeting, execution, or evaluation activities for four distinct fiscal years.

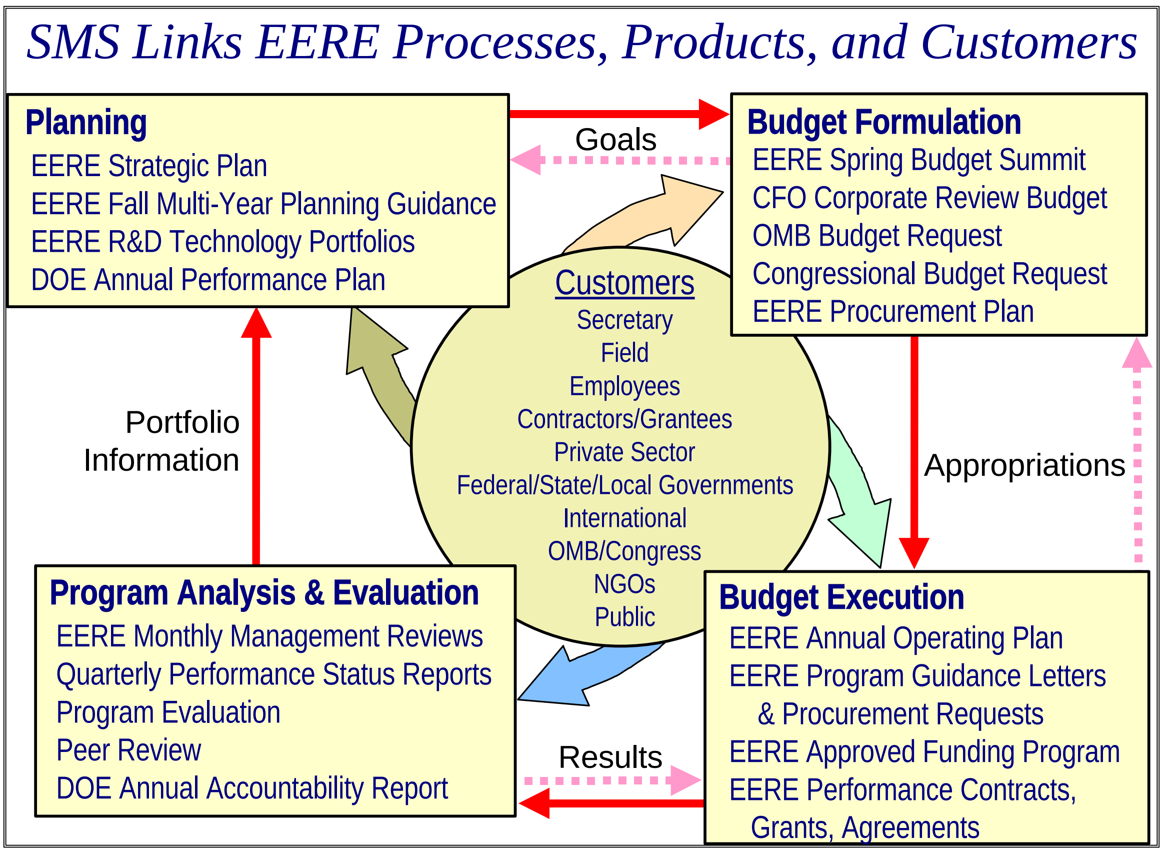

Figure 6-1: The Strategic Management System (SMS)

This Strategic Program Review identified five key activities that are recommended to improve operations. They are:

- Fully implement the centralized management system (SMS);
- Replicate best practices throughout the EERE organization;
- Address the need for training people for effective program and project management (PMI Initiative);
- Develop a consistent acquisition strategy for EERE and its associated implementation plan; and,
- Hold people accountable for their performance.

PLANNING

Planning is conducted at four organizational levels: EERE corporate, EERE Sectors, Field Organizations, and Contractors. Planning is also conducted for three time horizons; namely, strategic (5 to 20 years), multi-year programmatic (2-5 years), and annual/operational (1 year).

Between July 2001 and May 2002, EERE will focus much of its long-term planning on completing several major analysis efforts that:

- Evaluate EERE's current R&D portfolio and assess alignment with the *National Energy Policy*;
- Evaluate input from stakeholders and the public from the seven public meetings held throughout the United States during June 2001; and,
- Incorporate the results of EERE's Strategic Program Reviews, held in July and August 2001, to evaluate the past and potential future performance of EERE's 31 programs.

While planning is essential at the aforementioned organizational levels and time frames, the SMS requires only a minimal number of plans be published. Wherever possible, plans should be consolidated and redundancies eliminated. Plans should clearly identify their purpose and their relationship to the SMS.

As SMS implementation progresses, it will be essential to define the relationship between corporate planning and program planning, and establish the proper linkage between these processes.

BUDGET FORMULATION

The SMS budget formulation process provides early budget guidance to make major issues and concerns highly visible, to enable EERE management to make decisions in an efficient and timely manner, and to deliver a performance-based budget to the CFO on schedule. Budget formulation relies heavily on information derived from the planning process activities, especially the EERE Strategic Plan and the Fall Multi-Year Planning Guidance.

BUDGET EXECUTION

Through budget execution, EERE uses appropriated funds to implement the programs, projects, and activities directed by the Congress. The funds permit EERE, its Regional Offices, Field organizations, contractors, and other performers to deliver goods and services in support of the programs. Due to the breadth of program activities and work performers involved, it is critical that the performance commitments made in EERE's planning and budget formulation process be clearly communicated, understood, and agreed to by the Regional Offices, Field organizations, contractors, and other performers.

This Strategic Program Review examined the issue of uncosted balances and found that the NAPA report did not fully characterize this problem. Specifically, NAPA recommended that EERE "[d]iscontinue the practice of including uncosted balances as a factor in fee awards or giving personnel awards solely on reducing uncosted balances." This review found that the level of uncosted balances varied across the sectors because of (1) the different procurement strategies employed by each sector (i.e., predominant use of national laboratories in lieu of the private/public sector), (2) the long lead times associated with completing the procurement process, and (3) the level of project management capabilities demonstrated by the program office in administering RD^3. This SPR concluded EERE must achieve a balance that recognizes external business factors (e.g., implementing state energy efficiency grants) while establishing challenging uncosted balance targets to ensure that EERE programmatic work is implemented in a timely fashion.

In considering uncosted balances, EERE should exempt or develop a unique baseline to evaluate important partnership efforts with States through activities such as the formula grant programs, the State Energy Program special projects solicitation, Cooperative Programs with States, and NICE-3. Because of different budget cycles, the level of uncosted obligations for those programs will normally be above thirty-five percent (35%). The level of uncosted obligations for each of these programs needs to take into account the timing of the awards (late in the FY for SEP special projects, sometimes into the next FY for Cooperative Programs with States) and the fiscal year cycles of the states, which affect the formula grant programs.

PROGRAM ANALYSIS AND EVALUATION

Program analysis and evaluation, as defined for the SMS, includes tracking, reporting, and analyzing performance measurement data, conducting in-depth analyses (evaluations) of EERE programs, and providing results of the analyses and evaluations for use in planning. Performance measurement data includes performance measures in the DOE Annual Performance Plan, the Secretary's Performance Agreement with the President, performance measures in the Budget, and performance data related to EERE's financial operations, human resources, and customers. Analysis of performance data includes documentation of goal achievement, verification and validation of performance levels, and external factors that may have influenced performance. Performance information is tracked and reported throughout the year, with year-end results being reported in DOE's Annual Accountability Report.

CHANGE 2: THE PROGRAM MANAGEMENT INITIATIVE (PMI)

The Program Management Initiative (PMI) addresses the challenge of managing a complex, multi-performer RD^3 program using Federal leadership and non-Federal implementers (states, national laboratories, universities, non-profit organizations, and private R&D firms).

The PMI, in concert with the SMS, envisions a near-term future in which EERE becomes a program management model that will be sought out by other Federal entities interested in improving their program management performance.

The PMI includes program management tools and training aides such as a Program Management Guide, training targeted specifically for program management, a "virtual university" to assist in identifying additional training opportunities, and a program for "certifying" program managers as a means to recognize and reward the skills and professionalism required of excellent program managers.

CHANGE 3: INCORPORATING THE SMS AND PMI IN PERSONNEL REVIEWS

In 2001, EERE included organizational performance criteria in the performance standards for each of the EERE Senior Executives. These criteria will be cascaded to all EERE Program personnel and key management personnel in the EERE Field organizations in 2002. The performance criteria generally focus on the consistent maintenance and use of the principles and tools of the SMS and the PMI. Although such principles and tools do not assure attaining results in the context of “outcomes” or “outputs” – such assurances are difficult in the world of planning and managing large complex R&D programs – the insistence on their maintenance and use of the principles and tools establishes the management processes that are most likely to attain those results.

LINKAGE TO BUDGET AND PERFORMANCE INTEGRATION

The three changes (SMS, PMI, and Accountability) support several of the major goals of the “Budget and Performance Integration” chapter of the *President’s Management Agenda*. These goals include:

- Linking budgets to results;
- Linking organization performance to management and staff rewards (holding program managers responsible for organizational performance);
- Aligning authority and accountability; and,
- Empowering managers with timely and complete information to monitor and improve results.

LINKING BUDGETS TO RESULTS

The SMS provides the overall principles, including the system tool for linking budgets to results in planning, budget formulation, budget execution, as well as a method of evaluation of results relative to budgets. These practices are already underway in the context of the Spend Plan, Milestones, and Project Description spreadsheets referred to together in the SMS as the Annual Operating Plan (AOP), although implementation remains incomplete. Whether in the context of an “outyear” (in the case of planning or budget formulation) or in the current “execution year,” the three spreadsheets link the allocation and distribution of funds to program goals expressed as “outcomes” and “outputs,” as well as to shorter-term performance measures and milestones.

LINKING ORGANIZATION PERFORMANCE TO MANAGEMENT AND STAFF REWARDS

As noted previously, EERE included organizational performance criteria in the standards for evaluating the performance of the Senior Executives in 2001, and will cascade these criteria to the performance criteria for the Program personnel and key management personnel in the EERE Field organizations in 2002.

EERE described the linkage of organization performance to personnel accountability in a recently distributed internal brochure summarizing key components of the PMI.

EERE PROGRAM MANAGER AND PROJECT MANAGER POSITIONS

EERE is developing new position descriptions (PD’s) for EERE program managers and project managers based on clarified roles and responsibilities. EERE intends to have these positions carry high esteem and be sought after by individuals aspiring to a challenging and meaningful career of significant achievement and contribution in the public sector. Following the preparation of the program and project manager PD's, EERE will review and adjust, as necessary, other PD's within the EERE community to ensure and maintain appropriate and consistent relationships of all EERE employees to the select cadre of EERE program and project managers.

PERFORMANCE PLANS

Once the position descriptions are developed and installed, EERE will annually prepare a set of objectives for inclusion in all EERE employees' individual performance plans (IPP's). These objectives will link the responsibilities of the position descriptions to the performance requirements (objectives, measures and standards) of the organization.

ALIGNING AUTHORITY AND ACCOUNTABILITY

The SMS and the PMI both feature alignment of accountability for program management with the authorities necessary to execute the required duties. Such authorities include:

- The ability to get timely access to accurate data regarding the status of:
  - total funds availability;
  - obligations and costs;
  - goals, measures and milestones; and,
  - procurements, including major subcontracts;
- Appropriate training and documentation regarding the program management skills and duties for which the Program Manager will be held accountable – including the use of the systems and procedures needed to manage work;
- A variety of procurement and financial assistance options for funding programs and projects; and,
- Access to skilled project and procurement managers to assist in the planning and implementation of programs.

RECENT EERE BUSINESS PERFORMANCE

SMS BUDGET HUT

FY 2001 served as EERE's first year for SMS Budget Hut implementation, a data warehouse that is central to implementation of the SMS. The year saw several accomplishments and identified several areas for improvement. For example, the organization:

- Improved business performance through implementing improved delegations of authority to all sector Deputy Assistant Secretaries (DAS's) and Assistant Deputy Assistant Secretaries (ADAS's) for source selections;
- Provided limited source selection authority to the Regional Office Directors;
- Created new tools with fixed grant obligation awards and omnibus state grants, and established operating delegations of authority for project management activities;
- Reviewed several of its operational processes and created EERE organizational procurement guidance, and developed an EERE-wide electronic procurement system (pilot);
- Initiated inclusive processes to evaluate and refine the SMS Budget Hut requirements;

- Implemented SMS Budget Hut training for all EERE employees; and,
- Conducted FY 2003 EERE Spring Budget Summit and created and refined EERE Performance metrics while completing the FY 2002 Congressional Budget.

Despite these accomplishments, the monthly updates of the financial information from the Budget Hut Spend Plans, Project Descriptions, and Milestone Spreadsheets have remained inconsistent and unreliable through FY 2001. These problems can be attributed to system initiation difficulties, transition issues, lack of defined terms, lack of system knowledge, and lack of sector support resources (a legacy of the years of fragmentation identified by NAPA). The dearth of accurate and consistent data has weakened the organization's ability to conduct the analysis necessary to determine the efficiency and effectiveness of the EERE programs.

INFORMATION TECHNOLOGY ENVIRONMENT

DOE's Program Acquisition Data System (PADS) and Management and Reporting System (MARS) data downloads are important elements of the EERE Budget Hut. However, this Strategic Program Review found several problems in making effective use of these databases. For example, during the review of EERE's data entries into PADS, a large number of fields were identified that were either incorrectly coded, not coded, or did not accommodate laboratory subcontractor data that affects EERE's performance. These coding problems exist for a variety of reasons including:

- Failure to reflect changes in DOE's competition policies relative to Management and Operating (M&O) contracts;
- Failure to properly capture cost share;
- Inability of the system to capture cost share for laboratory subcontractors. This issue is important because approximately one-third of all funds sent to the national laboratories are sent to laboratory subcontractors such as universities, states, small business, and the private sector. The lack of subcontractor information impacts EERE's ability to measure its program performance; and,
- Lack of standard reports from national laboratories containing other important business information such as the allocation of laboratory personnel at the organizational level (i.e. administrative, scientific) and staff allocations to specific program/project activities.

This SPR also acknowledged the inherent differences between the PADS system (designed to track the status of procurement actions, whether or not funds are actually obligated) and the MARS system (designed for accounting and funds tracking purposes). It is important for program managers to recognize the value and limitations of the existing Departmental information systems.

EERE ACQUISITION STRATEGY

This Strategic Program Review found a wide variety of procurement and acquisition practices among the EERE sectors. The identification and replication of best practices (incorporated into a "corporate" acquisition strategy) will make an important contribution to achieving EERE's mission.

Effective public-private partnership efforts are well suited to financial assistance as the primary procurement mechanism. In some parts of EERE, there is extensive use of national laboratories as procurement vehicles. The downsides of this practice are:

- National laboratories both select the awards and perform project management;
- EERE pays a premium for the procurement and project management services; and,
- The laboratories (who have a vested interest in intellectual property rights) currently negotiate intellectual property rights with their subcontractors.

Benefits of such an arrangement include that EERE can implement work quickly and as a result can be recognized as having an effective program with lower uncosted obligations, and that the labs can bring a high level of technical acumen to these processes.

An effective acquisition strategy must promote a balanced procurement portfolio including the appropriate use of the national laboratories and the private sector. For example, the Federal Acquisition Regulations clearly state that the labs are not intended to compete with the private sector, and their use is intended for work that the private sector does not provide or perform. The proper use of the national laboratories is touched upon in the Executive Summary and Chapter 7. EERE will address various acquisition options when creating the EERE Acquisition Strategy. Alternatives to be considered include increased priority in the use of the Department's existing field acquisition and project management resources, obtaining the approval of the Procurement Executive to use the acquisition and project management resources of another agency, establishment of a Project Management Office capability, or the creation of new “tools” requiring regulatory and/or legislative approval.

RESOURCE ISSUES

Project implementation is crucial to EERE’s success, yet EERE lacks sufficient field project management capability to directly control its programs. For example, approximately fifty percent of EERE’s program funds, and the staff resources to execute that work, are direct reports to other DOE organizations. The result is that EERE’s work is not always a priority for field offices managed by other DOE programs. The lack of dedicated staff for acquisition and project management for much of EERE’s program is an impediment to the timely implementation of work for programs that use competitive financial assistance as their primary acquisition mechanism, as well as national laboratory projects. It is not a coincidence that EERE’s direct oversight of the National Renewable Energy Laboratory results in its most effective and efficient program and budget execution metrics.

EERE’s systemic problems require strategic solutions involving the establishment of a focused project management organization, standard policies on project planning and execution, and the establishment of an EERE corporate procurement system that serves to standardize procurement operations throughout EERE. By improving project management oversight capability, EERE can better achieve its business performance objectives.

THE STATUS OF THE THREE CHANGES
(THE SMS, PMI, AND PERSONNEL ACCOUNTABILITY)

The implementation of the SMS and the PMI, including the increased access to key program and project data, has allowed EERE to understand the organizations strengths and weaknesses. The gaps in implementation cause a reduction in effectiveness, efficiency, and value to the American people.

STATUS OF IMPLEMENTATION

The following examples demonstrate the accomplishments to date:

- In October 2001, EERE issued the SMS Annual Guidance Letter for the third straight year – reflecting the continued focus on the need to identify and describe key business management products, events, and other requirements as part of an overall integrated process.
- EERE has conducted two annual Spring Budget Summits in which all EERE Headquarters and Field managers corporately determine the portfolio of programs and their funding requirements as the first step in the Departmental budget formulation process.
- EERE completed the Program Management Guide – a 200-page, step-by-step instruction on the roles and responsibilities of the Program Manager.
- The Budget Hut continues to include monthly updates to key financial, procurement, and budget reports from data in Departmental systems. EERE has trained almost 200 Headquarters and Field personnel in the use of the Budget Hut. As a result, EERE personnel have better access to current data for obligations, costs, and procurement status.
- EERE has started to incorporate organizational goals into the annual personnel review criteria for managers.
- The SMS Budget Hut Working Group has begun to standardize data definitions and formats as part of an overall process to increase the value of budget and performance data maintained throughout EERE.
- OIT received a "Hammer Award" in conjunction with DOE's Idaho Operations Office for streamlining the solicitation process; using consistent, streamlined solicitations for its entire program; and implementing the PMO concept.[3]
- OTT created an exceptionally successful project management model, including the development of standards.

These examples reflect an EERE organization much better managed than the organization NAPA reviewed almost two years ago, but much remains to be done.

WHAT NEEDS TO BE DONE – THE GAPS

The most significant gaps in improving EERE effectiveness and efficiency relate to implementing SMS – inculcating standard practices and procedures throughout EERE, in general – and the consistent maintenance of standard data. Key examples of these gaps include the following:

- EERE sector organizations still resist developing, maintaining, and using the standard data and formats required of the Spend Plan, Milestones, and Project Description spreadsheets. This data is fundamental to numerous important management objectives, including:
  - Linking budgets to work and program performance;
  - Linking lower-level milestones to higher-level goals and measures;
  - Optimizing the process by which EERE funds work; and,
  - Providing a standard data repository for reporting funding, work status and project history.
- Some Program Managers and other EERE personnel still do not use effectively, if at all, the Departmental and external financial, procurement, and budget information in the Budget Hut as the primary means to understand the status of funding availability, obligations, costs, procurement status, and the location of funds.

[3] "Hammer Awards" were issued by former Vice President Gore for exemplary actions in "reinventing government."

- Program Managers and other EERE personnel still do not understand (or use well) important parts of the procurement and acquisition process, thereby causing otherwise unnecessary delays in starting and managing work.
- "Downloads" of data from the national laboratories, although helpful, differ significantly by laboratory, thereby limiting their utility.
- Without a dedicated project management organization, EERE must use a variety of implementers between itself and the performers of the work to deliver funds and manage projects. These implementers include Departmental operations offices, the Golden (Colorado) Field Office, and EERE's regional offices. The result is a maze of funding paths and reporting relationships that severely hinder effective and efficient project planning and execution.

In addition to EERE having problems implementing its own business process improvements, important Departmental business processes and systems do not provide the support they should for effectively and efficiently managing business. Routine Departmental budget execution and procurement processes, for example, are unnecessarily confusing and cumbersome, thereby impairing the flexibility and timeliness by which Program Managers can fund work. Some of the most significant problems with Departmental processes and systems include:

- Data from the procurement system is inadequate for confidently evaluating the relative costs and benefits of various procurement and financial assistance vehicles. EERE cannot use this data, for example, for determining the value per dollar of funding work through a prime contract versus funding it through a grant.
- DOE does not have a complex-wide automated corporate system for processing contracts, financial assistance, or work authorizations. The lack of such a system causes delays in funding projects and starting new awards.
- Neither the procurement system nor the financial system tracks the execution of funds or work beyond the primary recipient of the funds. As a result, EERE has to establish its own means for tracking such data – including the $400 million sent annually to the Department's national laboratories.
- No Departmental system tracks subcontracting, so it is difficult for EERE to answer routine questions related to, among others:
  - The value of cost sharing by EERE partners – much of that cost sharing occurs between the direct recipient of the funds and their partners or subcontractors.
  - The ultimate destination of EERE funding – direct recipients of EERE funds often subcontract those funds widely among companies, universities, and associations located across the country.
  - Funding for small businesses, 8(a) contractors, historically black colleges and universities, and other entities working as subcontractors to the prime recipient of EERE funds.
- No Departmental system relates budgets or funding to work performance.
- No Departmental system tracks work milestones, objectives, or goals consistent with GPRA.

The result of these gaps is that EERE has difficulty understanding, evaluating, and improving its performance over the long term as well as month-to-month. The SMS, PMI, and the Budget Hut, when fully implemented, should resolve these gaps.

WHAT ARE THE IMPACTS OF THESE GAPS?

The impacts of these gaps range from inconvenience to fundamental mission inhibition. For example, EERE continues to perform poorly when measured against key business efficiency criteria such as unobligated and uncosted balances. The latest financial reports show that as of the end of August 2001, the level of unobligated appropriations as a percent of total funding was only slightly better than at the same time in the previous year (18% in 2000 compared to 15% in 2001). Uncosted obligations – the funds obligated by EERE for which the goods or services have not been provided – also continue to trend higher. The level of uncosted balances measured at the end of the year has increased over the last two years ($447 million in 1999; $480 million in 2000) and will probably be higher for 2001 (the data will be available in winter 2002). The significance of the uncosted balances lies in the fact that uncosted funds have not been put to work.

A fundamental impact of these gaps is that EERE loses credibility with Congress, the Administration, customers, stakeholders, and internally when (as has traditionally been the case in EERE):

- EERE cannot readily answer seemingly routine questions regarding, project status, major subcontractors, the types of entities with which EERE does business, cost share, and the number of competitive awards as compared to non-competitive;
- EERE cannot direct funds to a new project in a timely manner;
- EERE Field organizations must support multiple (uncoordinated) EERE Headquarters business management systems requiring the same type of data;
- EERE Sector organizations maintain funding and work performance data in diverse systems and formats such that only with great difficulty can they be incorporated into an "EERE system."

RECOMMENDATIONS

EERE understands its business performance problems and is on a path to correct these problems. The obstacles to change include reluctance within EERE, if not outright resistance, and the lack of adequate support processes and systems outside of EERE. This SPR offers the following recommendations:

- EERE should work with the Departmental CFO to establish a standard format for the national laboratories to transmit monthly data on the status of subcontracts, funding, in-house work, and cost share.
- Work with the Departmental CFO to improve the timeliness of the funding process.
- Establish a plan to replace disparate business systems throughout EERE with a single corporate system.
- Develop an EERE-wide business management responsibility matrix that specifies key points of contact and key responsibilities for implementing major SMS milestone activities (planning, budget formulation, budget execution, evaluation, and program reporting requirements).
- Support current Departmental efforts to replace the major procurement and financial systems with one that integrates and supports all DOE corporate operations.
- Restate the policy for the sectors to complete FY 02 Spend Plans and distribute eighty percent of their appropriation for receipt by the field organizations not later than November 15, 2001.

- Establish an EERE-wide policy that (1) recognizes the individual acquisition strategy used by each program, (2) establishes prudent levels of uncosted obligations for that program, and (3) does not exceed an overall EERE goal of thirty percent (30%) uncosted obligations balance at the end of each fiscal year.
- Review individual program business implementation approaches to determine if they are using the most effective and efficient methods to accomplish programmatic goals and objectives.
- Promote an EERE Acquisition Strategy that promotes advance planning, a balanced use of national laboratories and public/private sectors, full and open competition, and efficient and effective solicitation processes.
- Work with the DOE Procurement Executive and the CFO to establish simplified financial management mechanisms that allow for awards within 120 days of issuance of a solicitation and establishes expedited simplified methods for financial assistance awards less than $100,000.
- Seek alternative procurement authorities or mechanisms that allow EERE to develop collaborative partnerships with national associations, utilize outside service organizations to support procurement and project management needs, and establish more timely awards to private industry, states, and universities.

Chapter 7

Findings and Recommendations

This Strategic Program Review has examined the "historic performance" of the Office of Energy Efficiency and Renewable Energy (EERE) programs and the extent to which they are "performance-based" and are modeled as "public-private partnerships".[1]

To determine the historic performance of the EERE programs,[2] this Strategic Program Review (SPR)[3] examined EERE technical accomplishments, external recognition, and the benefits generated for taxpayers. To determine which programs were performance-based, the review examined how programs have changed over time, the use of competitive solicitations in research awards, the use of external program peer reviews, and whether non-performing projects were terminated. To determine which programs were modeled as public-private partnerships, the review examined the breadth and depth of partnering across the EERE programs. Finally, the alignment of the EERE programs with the direction of the President's National Energy Policy was evaluated.

EERE's historic performance includes being among the top recipients worldwide of R&D100 awards and, as determined by the National Academy of Sciences' (NAS) National Research Council (NRC), [4] earning returns of 20 to 1 on the research investment the NRC reviewed. [5] In the past five years, EERE's partnership activities have involved more than two thousand individuals in technology roadmapping alone and EERE has nearly three thousand current contracts with industry, universities, national labs, and others.[6] Indicators of EERE's performance-based management include roughly two-thirds of its R&D funding currently going through competitive solicitations, more than 60 activity terminations and graduations,[7] and more than 20 external peer reviews by the NRC alone. Each of these is detailed below. These accomplishments have been achieved in spite of limitations in DOE-wide business management systems, which have spurred EERE to develop its own tools to manage its exceptionally large portfolio and range of research, development, demonstration, and deployment (RD^3) activities.

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[1] "National Energy Policy," Report of the National Energy Policy Development Group, (Washington, DC: U.S. Government Printing Office, May 2001), page 4-3, 6-4. See Chapter 1, Box 1-1.

[2] EERE has historically used the term "program" to cover a range of activities and has not adequately defined or differentiated the terminology of programs, projects, etc. This shortcoming was identified by the National Academy of Public Administrators review of EERE in 2000, "A Review of Management in the Office of Energy Efficiency and Renewable Energy", as discussed under program redirections below. This shortcoming is, to some degree, unavoidable in the terminology used in this Strategic Program Review due to this legacy, but is an area that EERE is working to correct. For the purposes of this Strategic Program Review, the term "program" will generally refer to the EERE programs as defined in response to the NAPA review and their ancestors; "projects" will refer to those so defined in response to the NAPA review. Contributing to the imprecision here is that measures of historic performance, partnering, and other factors identified for review by the National Energy Policy are most often done at a project level rather than at the program level.

[3] The SPR was conducted by the Assistant Secretary, senior staff within the Office of the Assistant Secretary, and the Office of Planning, Budget and Management working with EERE's Deputy Assistant Secretaries, program managers, and staff.

[4] The National Research Council was created under the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine; for simplicity and brevity, this will be abbreviated here as the NRC.

[5] The R&D investment criteria developed as part of the President's Management Agenda are intended to further improve this record by helping EERE redirect resources from poorly performing programs to more promising ones.

[6] EERE also provides financial assistance to states, communities, and others through grants and other mechanisms.

[7] Various new activities have been launched as these were graduated/terminated. See the footnote to Table 4-A2.

Building on these findings and other results, the SPR makes a number of recommendations for activity closeout, redirection, close monitoring and evaluation (the watch list), or expansion. The SPR has also identified a number of "best practices" that should be adapted and adopted throughout EERE programs. Twenty projects are identified for closeout, including activities in every sector—buildings, industry, power, transport, and government. Activities identified for redirection included consolidating programs such as the Regional Assistance Centers and battery research, clarifying overall EERE program structure, and reducing high national lab costs. Activities requiring close monitoring to ensure they are advanced effectively and expeditiously include Congressional earmarks, BTS demonstration and deployment programs, bioenergy, and Federal Energy Management Program (FEMP) analytical work. Areas of research that could generate significantly increased benefit with additional funding include building equipment R&D, fuel-cell vehicles, and low-wind speed turbines. Finally, the SPR recommends that "best practice" capabilities of leading programs in each area be transferred across all EERE programs, including technology roadmapping; project selection, planning, and execution; competitive solicitations; program management; demonstration and deployment; program evaluation; partnering; and business execution. Each of these is discussed below.

FINDINGS

PUBLIC REVIEW AND FINDINGS

As part of this Strategic Program Review, public comments on EERE programs were solicited through a series of EERE town meetings in Atlanta, Boston, Chicago, Denver, Philadelphia, Seattle, and Washington, D.C. These meetings, along with e-mail and postal mail responses, resulted in 4,279 public comments,[8] of which more than 99 percent expressed strong support for EERE programs.[9]

Many of the supportive comments were based on the rationale that EERE's programs would enable the nation to meet its energy needs through clean power technologies. The broad topic area that received the most attention in the public comments was the environment, followed by economic, budget, and energy security issues. Of the recommendations directed at EERE in the public comments, the most prevalent by an overwhelming margin, identified in more than 90 percent of the comments, was the recommendation to increase EERE's funding level. EERE completed a report summarizing these comments on August 31, 2001. That report is attached as Appendix A to the main report.

HISTORIC PERFORMANCE

To determine the historic performance of EERE's programs, this SPR examined EERE technical accomplishments, external recognition, and benefits to taxpayers.

[8] Of the 4,279 comments, 457 were provided during the 7 public meetings, of which 456 were favorable to EERE programs and 1 was unfavorable. The 3,822 written comments included 1556 individual messages and 2,266 in 11 different form letters. Of these written messages, 3745 were favorable, 7 were unfavorable, and 70 did not provide enough information to determine the commenter's overall opinion. Details are provided in Appendix A.

[9] These results are generally in-line with statistically-rigorous public opinion polls. Specific examples of recent public opinion polls can be found at: http://www.publicagenda.org/issues/pcc.cfm?issue_type=environment and a review of more than 700 polls from 1973-1996 is at http://www.crest.org/repp_pubs/articles/issuebr3/issuebr3.html A published review of this issue is in: "Barbara C. Farhar, "Trends in US Public Perceptions and Preferences on Energy and Environmental Policy", *Annual Review of Energy and the Environment*, eds. Robert H. Socolow, Dennis Anderson, and John Harte, Vol. 19, pp.211-239, 1994.

Technical Accomplishments

Specific technical innovations, performance gains, reductions in cost, design tools, standards, and other accomplishments were examined and a subset of more than 150 examples are detailed in Chapter 4. As brief examples, in the buildings sector, EERE contributed significantly to cutting refrigerator electricity use by nearly three-fourths over the past 25 years, even as more features were added. In the industry sector, EERE developed with industry lost foam metal casting with an average 27% savings in energy, a 46% increase in productivity, and a 7% reduction in materials use. In the transport sector, EERE, the national labs, and industry cut the platinum content, a key cost factor, of PEM fuel cells by a factor of 10 over the past eight years; and some estimate that the overall cost of PEM fuel cells, assuming mass production, has been reduced by a factor of 10 as well.[10] In renewable energy, independent external reviews found cost reductions for specific technologies closely followed aggressive EERE projections, with technologies such as photovoltaics and wind turbines dropping in cost by as much as ten times over the past two decades.[11] The National Academy of Sciences' National Research Council (NRC)[12] noted that EERE was "dominant" or "influential" in half of what they identified as the most important technological innovations in energy efficiency since 1978.[13]

External Recognition

Awards were identified by the SPR as an important measure of external peer recognition of program performance. Programs were asked in this review to identify the awards they had received. In response, the programs identified numerous awards, far too many to identify in this synopsis. For example, one of the 31 programs reviewed, the High Temperature Superconductor program, identified some 30 awards over the past 8 years, including DOE 100 Awards, Federal Laboratory Consortium Awards, the Georgia Grand Award, the Georgia Engineering Excellence Award, LANL Laboratory Fellows Prize, Council for Chemical Research Collaboration Success Award, ORNL Technical Achievement Award, TR 100 Award, R&D 100 Award, SBIR Technology of the Year Award, NOVA Award, National Science Foundation Presidential Young Investigator Award, Journal of Technology Transfer Gold Medal for Technology Transfer, and others. Further, most of these awards were too narrow in scope to provide adequate comparison of EERE programs to R&D programs of other institutions.

Consequently, the R&D100 award was selected as a single measure of performance because it provides broad technology coverage—not just energy; it provides broad participation—across companies, universities, public agencies, and countries; it is externally awarded and independently peer reviewed; and it is widely recognized and highly regarded. The R&D100 awards have been characterized as the "Oscars of Invention." Across all EERE supported research, some 105 R&D 100 awards were received for the period 1978-2001. In comparison, EERE's 105 awards placed it above all other government agencies[14] except NASA, with 125 R&D100 awards; above all companies except GE, with 163 awards; above all other countries except Japan, with 157 awards; and above all universities (MIT was first with 30 awards). Figure 7-1 compares the top ranked organizations. The number of R&D100 awards received by EERE increased over time, with about 80% of the total received in the past ten years, and over half of the total

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[10] A.D. Little, Inc., "Cost Analysis of Fuel Cell System for Transportation," March 2000. ref. 49739. This baseline cost analysis assumes a production rate of 500,000 systems per year and year 2000 technologies.

[11] James McVeigh, Dallas Burtraw, Joel Darmstadter, and Karen Palmer, "Winner, Loser, or Innocent Victim? Has Renewable Energy Performed As Expected?" Resources for the Future, Washington, DC, Discussion Paper 99-28, March 1999; June 1999.

[12] The National Research Council was created under the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine; for simplicity and brevity, this will be abbreviated here as NRC.

[13] National Research Council, "Energy Research at DOE: Was It Worth It?," July 2001.

[14] DOE, of which EERE is part, has won by far the most R&D100 awards of all institutions, with about 574.

from 1995 on, as shown in Figure 7-2. Details of this analysis and associated uncertainties are described in Chapter 4.

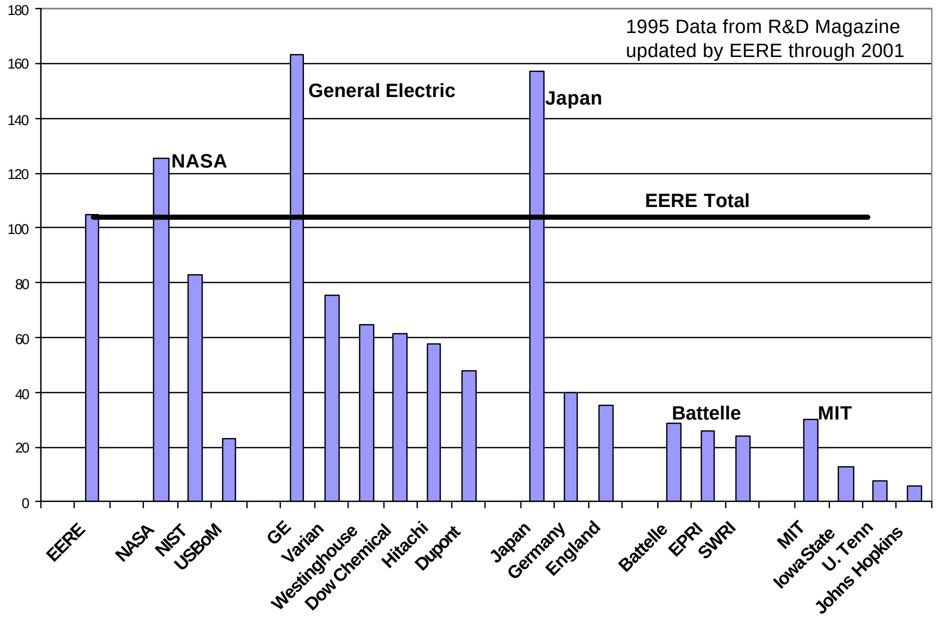

Figure 7-1: Total number of R&D100 awards received by EERE-supported research, 1978-2001, compared to the number of awards received by the top recipients among other Federal agencies, companies, countries, research institutes, and universities for 1963-2001. Source: R&D Magazine, September 1995, as updated by the SPR through 2001 by compiling individual award citations for 1996-2001 (see Chapter 4)

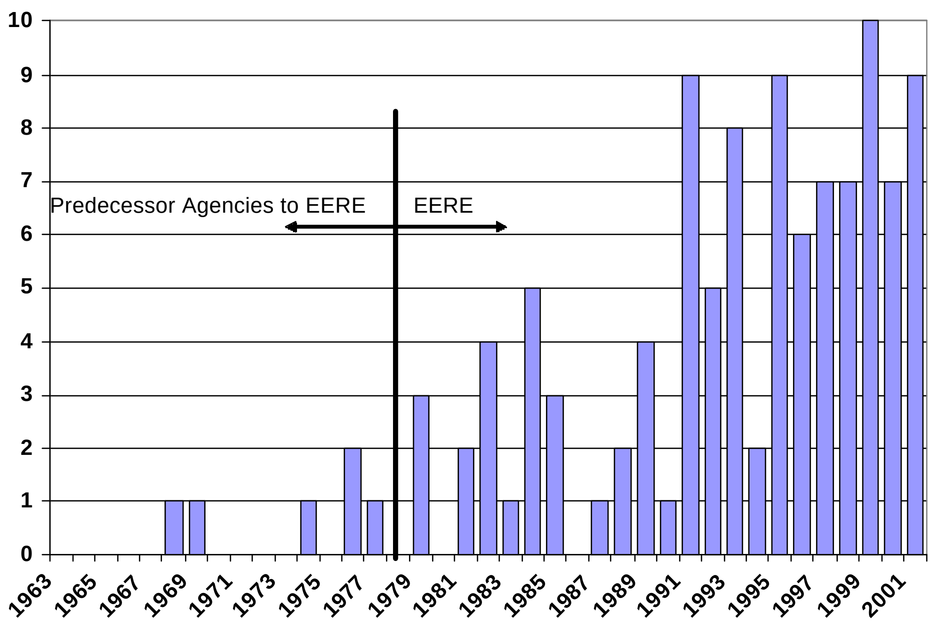

Figure 7-2: Number of R&D100 awards received by EERE-supported research by year, together with awards received by predecessor agencies to EERE before it was formed in 1978. Source: R&D Magazine, September 1995, as updated by the SPR through 2001 by compiling individual award citations for 1996-2001 (see Chapter 4).

Benefits

Economic, environmental, and security benefits resulting from EERE's RD^3 activities were also examined. The NRC published a review of the benefits from EERE programs in July 2001.[15] This study examined, in detail, about $1.6 billion worth of the total $7.2 billion (constant 1999$) R&D investment by EERE in energy efficiency[16] from 1978-2000 and found a net realized economic benefit on this $1.6 billion of $30 billion—a return of roughly 20 to 1 (see Box 7-1). Within this $1.6 billion portfolio reviewed by the NRC were several other research activities which the NRC identified as having large benefits, but which they did not quantify, including the DOE-2 building design tool and indoor air quality. In addition, the NRC estimated that the United States realized between $3 and $20 billion in environmental benefits from EERE programs. The NRC noted that if a constant technology baseline was assumed, estimated economic benefits were $78 billion, but their "very conservative" methodology reduced these benefits to $30 billion.[17] The SPR identified more than twenty additional technologies with potentially large benefits. Further development of this benefits analysis methodology is currently underway and, when developed, will be applied to these or other cases.

The NRC methodology did not consider potential future benefits of R&D that is still underway, which account for most of EERE activities. External peer-reviewed estimates of these future benefits are developed annually under the Government Performance Requirements Act (GPRA) and were examined under this Strategic Program Review. Applying a NRC-like back-of-the-envelope methodology on these GPRA estimates placed the return at 15 to 1, which is similar to, but slightly more conservative than, the NRC results for past EERE work (see Chapter 5).

Patents

Patents were evaluated as a possible indicator of program performance. Patents were found by the SPR to offer no clear means for benchmarking the relative value of their associated programs against either a baseline or the performance of programs of other institutions. The relative value of patents was not readily discernible and the numbers of patents were not necessarily correlated with program innovation or impact. Further, a recent study of patent data in the energy sector found a marked shift in who the patent was assigned to. Analyses of patents found that the number of patents assigned to DOE dropped sharply, but the number of patents identified as related to DOE research increased sharply, with the overall number increasing modestly over the past decade. This shift in assignment reflects the increasingly successful efforts in technology transfer to the private sector, with the patent assignment going to the private sector rather than to DOE.[18] It also, however, makes it somewhat more difficult to track the program-specific patent record.

Whether assigned to DOE or related to DOE research, EERE programs should be able to track the patents associated with the research they fund. However, a number of programs within EERE were not able to generate comprehensive listings of them; Table 4-A4 has a partial listing. It should be noted that the limited tracking of patents identified over 70 in the Buildings sector, over 180 in Transport, and over 560

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[15] NRC, "Energy Research at DOE: Was It Worth It?," July 2001.
[16] The NRC only examined energy efficiency in the study; other NRC studies have examined renewables.
[17] NRC, "Energy Research at DOE: Was It Worth It?" op cit., page 37 : "... the committee adopted a 5-year rule to be very conservative about the effect of DOE R&D." A detailed analysis of this methodology is presented in Chapter 5. Note, as discussed in Chapter 5, that the when the NRC methodology is applied consistently, the total is actually $37 billion.
[18] Robert M. Margolis and Daniel M. Kammen, "Evidence of under-investment in energy R&D in the United States and the impact of Federal policy," Energy Policy V.27, 1999, pp.575-584.

in Power. Patents pending and patent disclosures are further indicators of activity in patenting of technologies emerging from the EERE programs. Given that the aggregate patent data shows a modest increase in patent numbers over the past decade[19] but that program specific data was not consistently available; and given that patents offered no clear means of benchmarking their relative value against either a baseline or the performance of other institutions, patents were not considered further as an overall indicator of performance. Future tracking of patents and other such measures of performance is needed together with citation analysis, as discussed in Chapter 4.

Box 7-1: Estimating Benefits

It is sometimes difficult to understand how modest public R&D investments can be associated with such large benefits as described by the NRC. A simple example can illustrate how this is possible. Consider windows. Special "low-E" coatings were developed to reflect long-wavelength infrared radiation. These low emissivity window coatings help keep more heat in a house during the winter, and reflect some of the hot sun during the summer, reducing air conditioning loads. The EERE investment in low-E windows R&D was about $4 million, with some additional expenditure to develop window design tools, conduct information outreach, and do other activities. Low-E windows began penetrating the market in 1983 and by 1999 accounted for 40% of the window market, or 260 million square feet per year of low-E windows sold with lifetimes averaging 30 years. On average, each square foot of low-E glass saves a little more than $0.25 in energy costs per year compared to a conventional double-glazed window baseline. Individually, this is not much, but multiplied across 260 million square feet, this gives a lifetime savings of more than $2 billion for the windows sold in 1999. Summing these savings over the period since the technology began market penetration through 2005 then generates roughly $37 billion in net economic savings using the NRC methodology with a constant technology baseline of a conventional double-glazed window; or $8 billion using the conservative "5-year" rule of the NRC methodology.[20] Details of this calculation and a discussion of the NRC methodology and results are provided in Chapter 5.

PERFORMANCE-BASED

To determine which programs were performance-based, the review examined how programs have changed over time, the use of competitive solicitations in research awards, the use of external program peer reviews, and whether non-performing projects were terminated.

Programmatic Changes

The Strategic Program Review found that EERE programs have been substantially reinvented over the past decade, from "technology push" based primarily on laboratory-identified R&D to "market pull" built on technology roadmapping with industry partners. In addition, where the previous programs relied primarily on cost-plus contracts, the current programs extensively use competitive solicitations with cost sharing (see below). There was also a notable shift from individual component R&D to integrated systems R&D. The shift from technology push to market pull can be seen by the development of more than 40 technology roadmaps with industry partners in the past five years. The shift to integrated systems can be seen in the buildings sector's focus on "Whole Buildings" approaches; the transport sector's focus on integrated vehicle systems; the industry sector's focus on a "Whole Industries" approach under the Industries of the Future program; and the development of the integrated bioenergy and Distributed Energy Resources programs.

[19] Margolis and Kammen, op. cit.

[20] The NRC describes this result in footnote 8, page 37, of their report "Energy Research at DOE: Was It Worth It?" op. cit. The NRC note that EE estimated $32 billion in the electronic ballast case is in reference to EE developing cost estimates at the direction of the NRC for the constant technology baseline case versus using the 5-year rule. The methodology used throughout was that of the NRC.

Competitive Solicitations

Approximately two-thirds of the EERE solicitations that reside in the DOE Procurement Acquisition Data System (PADS) are competitive instruments, up from the 25 percent rate in 1996, as identified by the National Academy of Public Administration (NAPA) review.[21] This improvement was driven, in part, by a Congressional review in 1996 that criticized EERE's reliance on non-competitive financial assistance actions for executing so much of its work. Since that time, EERE has continued to improve its competitiveness through policies that promote maximum competition. During this same period, DOE re-competed most of its M&O contracts, which changed the complexion of much of the work being performed with the national laboratories. Together, these factors have substantially increased EERE's use of competitive instruments.

Cost Sharing

EERE estimates that EERE financial assistance activities leverage approximately a forty percent non-Federal cost share. However, the estimated cost share value is tentative due to the SPR identification of a number of problems in the DOE-wide PADS information database. Additionally, EERE is unable to evaluate the cost share rate of laboratory subcontracts awarded through the national laboratories, as this information is not tracked within current DOE-wide systems. This significantly impacts EERE's overall estimated cost share.

Cost sharing in the Department will continue to be guided by statute and Administration policy. The Energy Policy Act of 1992 requires 20 percent cost share for applied research and 50 percent cost share for demonstration projects. The cost sharing guidelines developed with the R&D investment criteria as part of the President's Management Agenda are even more explicit, as shown below, and are what the Department will strive to achieve.

TABLE 7-1: INDUSTRY COST SHARES

Activity	Industry Cost Share, percent
Basic research	0- 30
Applied research	25- 50
Technology Development	50- 75
Demonstration or commercialization	60-100

Goals, Metrics, Milestones

The 1993 GPRA mandates that with each fiscal year's budget submission, Federal agencies develop and communicate to Congress a performance plan that describes the agency's mission, goals, key upcoming performance measures, and a report on previous progress. Such efforts have increased since the NAPA review, with every program developing overall goals, metrics, and milestones for its activities—with varying degrees of success—which are tracked by program managers, office directors, Deputy Assistant Secretaries, and the Assistant Secretary.

[21] A review of FY2001 non-grant obligations found 63% were classified as competitive, 19% non-competitive, and 18% were not classified but could be either competitive or non-competitive. Future work should strengthen the ability to determine whether an obligation is competitive or non-competitive, as discussed in Chapter 6.

External Peer Reviews

Numerous external peer reviews were identified and examined, including peer reviews by the NAS, NAPA, President's Committee of Advisors on Science and Technology, General Accounting Office, Congressional Office of Technology Assessment, and A.D. Little. More than 20 external peer reviews have been conducted by the National Academy of Sciences alone since 1990, 19 of them since 1995.

Terminations and Graduations

This SPR identified more than 60 research activities that have been terminated or graduated.[22] Terminations included such technologies as automotive Stirling engines, automotive gas turbines, ocean thermal energy conversion, vertical axis wind turbines, geopressured geothermal energy, municipal energy management, and others as detailed in chapter 4. Aggregate statistics for the Office of Industrial Technologies (OIT) for the period of FY 1998 to FY 2000 include 298 projects, of which public-private R&D was continued on 180, completed on 96, and terminated on 22. Of the 96 completed research projects, 44 were continued by industry, 34 were commercialized, and 18 contributed to the industry knowledge base. Thus, for the period of FY 1998 to FY 2000, 40% of the OIT research projects were graduated or terminated. In other sectors, numerous terminations were also found within specific areas of research. For example, the thin film photovoltaics research program examined and subsequently terminated R&D on more than half-a-dozen materials. Work has continued primarily on three materials, for which energy conversion efficiencies in the laboratory have been increased by factors of two to four in the past 20 years. Because Congressional Budget line item titles generally remain the same from year to year, the extent of program restructuring and redirection is often not recognized externally.

Equally important have been the numerous graduations of technologies which have become fully commercial and for which further technical development offers relatively less return to the public than do other opportunities. Examples include low-emissivity windows, high-efficiency furnaces, electronic ballasts, ozone-safe refrigerants, ceramics for engines, spark-ignition direct-injection engines, and many others. It is important to note, however, that in many cases there may remain significant opportunities for further technical advance in a particular area so that work continues on the technology—research on computer chips did not end with the invention of the first integrated circuit in 1959—but the specific focus shifts over time to new generations of the technology as particular technical barriers are overcome and new opportunities arise. EERE examples include several generations of work on windows (low-E, spectrally selective, electrochromic coatings), refrigerators (compressors, motors, refrigerants, cases, controls), photovoltaics (single-crystal silicon, amorphous silicon, cadmium telluride, etc.), and wind turbines (blade design, variable speed drives, flexible materials).

PUBLIC-PRIVATE PARTNERSHIPS

To determine which programs were modeled as public-private partnerships, the review examined the breadth and depth of partnering across the EERE programs. In some cases, these partnerships are developed with individual companies; in other cases, these partnerships may take the form of multi-agency, multi-industry cooperatives. Specific quantifiable measures include technology roadmapping, contracting, and cost sharing.

Roadmapping

As noted above, the shift to technology roadmapping with industry has further strengthened partnering, with over 40 roadmaps and over two thousand participants in that activity alone in the past five years.

[22] Various new activities have been launched as these were graduated/terminated. See the footnote to Table 4-A2.

Contracting and Cost Sharing

EERE engaged in approximately 2900 procurement actions in FY 2000. These actions included work with management and operating contractors, private industry, nonprofit organizations, State and local governments, and tribes and native corporations, universities, and small business. (Note that substantial subcontracting was also performed through the National Laboratories, but is not reflected in the overall level of procurement activity since DOE's PADS system does not capture laboratory subcontract activities.) Although not every procurement represents a partnership, this diversity of awardees indicates the breadth of EERE interactions with the private sector. Within this, EERE's programs have an extensive set of partnerships such as FreedomCAR, 21st Century Truck, the Vision Industries, Biomass, Build America, Advanced Reciprocating Engine Systems, and others. In addition, as noted above, EERE estimates that its activities leverage approximately a forty percent non-federal cost share.

Together, the above measures indicate the historic performance of the EERE programs, their performance-based focus, and their strong partnerships with the private sector.

ALIGNMENT

This SPR evaluated the degree of alignment between EERE's RD^3 portfolio and the National Energy Policy (NEP) of May 2001. Key issues identified by the NEP include:

- Reducing the impacts of high energy prices on families, communities, and businesses;
- Protecting the environment and public health;
- Enhancing national energy security and international relationships;
- Strengthening America's energy infrastructure;
- Using energy wisely through increasing energy conservation and efficiency; and,
- Increasing use of renewable and alternative energy.

Multiple benefits are thus provided by EERE technologies—economic; local, regional, and global environmental; national security; and more. As determined by the NRC study, the portfolio they reviewed provided net realized economic returns of 20 to 1; in addition, net realized environmental benefits ranged from an estimated 2 to 1 up to more than 10 to 1.

Economics

EERE programs contribute to reducing the impacts of high energy prices on families and businesses in several ways, thus strengthening the U.S. economy. First, improvements in energy efficiency directly reduce expenditures on energy, which currently cost U.S. consumers about $600 billion per year. The national benefit of energy efficiency was recognized in the NEP:

> "Had energy use kept pace with economic growth, the nation would have consumed 171 quadrillion British thermal units (Btus) last year instead of 99 quadrillion Btus. About a third to a half of these savings resulted from shifts in the economy, such as the growth of the service sector. The other half to two-thirds resulted from greater energy efficiency."[23]

[23] Report of the National Energy Policy Development Group, "National Energy Policy," May 2001, page 1-4.

First, these energy efficiency savings of one-half to two-thirds of the 72 quads in reduced energy consumption, or 36-48 quads, are greater than the increase of 26 quads in energy supply since 1972. The increase in energy supply included changes in domestic production of coal (+8.9 quads), natural gas (-2.5 quads), oil (-7.6 quads), nuclear (+7.4 quads), and renewables (+2.2 quads); and increased imports of natural gas (+2.6 quads) and oil (+11.8 quads). Assuming that the current average energy price of $6 billion per quad remains the same,[24] these energy savings correspond to roughly $200-300 billion per year.[25] Energy efficiency improvements are similar to economic productivity enhancements in other factors of production (e.g. labor, capital) and contribute to overall economic productivity; they should really be called "energy productivity" improvements.

Second, by reducing energy demand, energy efficiency improvements reduce pressure on energy supplies and correspondingly reduce upward price pressures. As renewable and alternative energy resources are developed and deployed, energy supplies will be increasingly diversified, price caps will be effectively established, and there could be further downward energy price pressure.

Third, EERE's weatherization program directly assists low-income families by retrofitting their homes and reducing their energy bills. Nearly 5 million low-income homes have been weatherized to date (out of an estimated 29 million currently eligible households) with Federal and leveraged funds from states and utilities, and from fuel assistance program funds. The average primary heating savings is 23% across all fuel sources. Analysis of 17 state-level evaluations found that improved practices as of 1996 produced 80% higher average energy savings per dwelling, at 31 million Btu/year, compared to measured savings in 1989 of 17 million Btu/year. The Bush Administration proposal to spend an additional $1.4 billion over ten years should begin to help address the need of the additional 24 million households currently eligible for assistance.

Fourth, technologies such as biomass and wind energy offer the potential to significantly benefit the rural economy, providing income and jobs to hard-pressed rural areas. By providing net economic benefits, biomass and wind energy technologies may offset some of the need for other Federal supports to these rural areas.

Environment

The use of energy is a primary contributor to local urban smog, regional acid rain, and anthropogenic greenhouse gas emissions, typically accounting for 90% or more of NO_x, SO_2, and CO_2 emissions. Emissions of NO_x, SO_2, particulates, and other pollutants can significantly impact the local and regional environment and studies increasingly implicate these emissions in significant health impacts (Chapter 2).

EERE programs directly address these environment and public health issues through efficiency improvements which offset the use of energy—usually fossil—or through the use of renewable energy technologies with near-zero emissions. Ultra-clean technologies under development, such as hydrogen-fueled power systems, offer further gains in the longer term.[26]

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[24] Greater demand will often raise prices.

[25] This does not consider changes in capital costs of more efficient equipment, but that these investments were made by the economy indicates that they were cost-effective on a life-cycle basis.

[26] If hydrogen is produced from fossil resources such as natural gas or coal, considerable emissions can be generated that will need to be sequestered geologically to avoid release to the atmosphere. The advantage of hydrogen is that such emissions are generated at central conversion facilities and can be sequestered, with little or no further emissions at the point of end-use. This is in contrast to using petroleum-based fuels for transportation, where their use in the vehicle results in emissions to the atmosphere that cannot be sequestered. The combustion of pure hydrogen in such settings creates essentially only heat and water as by-products.

Security

U.S. national security is impacted by energy in several ways, particularly through the import of over half of the oil we use and by the risk of supply disruptions in domestic energy systems such as electricity. The United States consumed about 19.5 million barrels of oil per day (MMBbl/day) in 2000, a little more than a quarter of global oil use (75 MMBbl/day in 1999). Net oil and refined product imports are projected to increase to about 16.5 MMBbl/day by 2020, out of total consumption of about 26 MMBbl/day.[27] Most of the world's remaining low-cost conventional oil supplies are located in the Middle East, typically estimated at two-thirds to three-quarters of proven reserves, raising concerns about the political volatility of the region and the extent to which the Organization of Petroleum Exporting Countries (OPEC) can control production and determine oil prices.[28] Oil price shocks in 1973-74 and 1979-1980 significantly impacted the U.S. economy, with costs variously estimated as 1-5% of GNP, as $1.2 trillion[29] cumulative during the 1970s, as $73 billion per year averaged over the period 1972-1991, and so forth.[30] The reason for these large costs is that markets cannot respond quickly to short term price changes; long-term oil market elasticities are typically on-the-order of ten times larger than short-term elasticities.[31] Because of this, production cutbacks can generate sharp price increases and large returns for oil producers, but in turn reduce market share and monopoly power over the longer term.

EERE programs help address these security concerns by developing technologies which can reduce demand for oil through efficiency improvements in cars and trucks, by developing alternative transport fuels such as ethanol from agricultural wastes or hydrogen from a variety of energy resources, and by developing bio-based feedstocks for industrial processes. The advanced automobile and truck programs had goals of, and made considerable technical progress towards doubling and tripling fuel economy. Although fuel economy improvements can stretch domestic oil supplies and reduce pressures on global oil prices, they do not eliminate U.S. economic, political, and military vulnerability to the risk of disruption to global oil supplies.[32] Consequently, the FreedomCAR initiative, announced in January, 2002, is focused on developing fuel cell vehicles that can use domestically produced hydrogen and have the long-term potential of ending U.S. light duty vehicle use of oil altogether.

EERE technologies respond to the risk of domestic energy supply disruptions by developing buildings that can stay comfortable for extended periods through winter storms or summer heat waves despite gas

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[27] EIA, "Annual Energy Outlook 2001", DOE/EIA-0383(2001), December 2001; and EIA, "International Energy Outlook 2000", DOE/EIA-0484(2000), March 2000.

[28] David L. Greene, Donald W. Jones, and Paul N. Leiby, "The Outlook for U.S. Oil Dependence," Energy Policy, V.26, N.1, pp.55-69, 1998. Costs of discovering, producing, and transporting oil in the Middle East have been estimated at $1-3/Bbl; far lower than U.S. costs.

[29] Note that unless specifically indicated, dollar estimates are given as reported in the literature and have not been converted to consistent year 2000$.

[30] There is extensive literature on this issue. For a review, see: Donald W. Jones and Paul N. Leiby, "The MacroEconomic Impacts of Oil Price Shocks: A Review of Literature and Issues," DRAFT, Jan. 5, 1996, Oak Ridge National Laboratory; GAO, op. cit., citing Department of Energy and others; David L. Greene, Donald W. Jones, and Paul N. Leiby, "The Outlook for U.S. Oil Dependence," Energy Policy V.26, N.1, pp55-69, 1998; and USDOE/NES "Report of the NES Oil Externality Subgroup," DRAFT, October 12, 1990.

[31] David L. Greene, Donald W. Jones, and Paul N. Leiby, "The Outlook for U.S. Oil Dependence," Energy Policy, V.26, N.1, pp.55-69, 1998.

[32] U.S. vulnerability to global oil supply disruptions will remain for as long as the United States and our allies use a significant quantity of oil. Oil is a fungible commodity in a global market; an oil price spike therefore impacts all oil prices, wherever it is produced. Lower oil imports will reduce wealth transfer offshore, among other benefits.

or power disruptions, developing distributed power systems that can potentially[33] supply electricity even when utility supplies are down, and diversifying energy supplies to reduce risk.

Infrastructure

Infrastructure within the United States is supported by EERE through the development of distributed energy resources that enable power and thermal production at an individual building site, high temperature superconductors that improve power transmission and distribution (T&D)—particularly in underground urban systems, other T&D system technologies, interconnect standards and protocols, diagnostic tools, and many others. Distributed generation and storage, in particular, provide customers with the choice of controlling to a greater degree their own power costs, reliability, and power quality, and are important to delivering the ultra-high power quality required by sensitive communication, computing, and control loads in the digital economy. Renewable and alternative energy supplies, such as bioenergy, offer new and diversified infrastructure paths. Energy efficient technologies can also reduce the pressure on infrastructure. Building and equipment energy efficiency improvements, for example, can reduce summer peak loads on T&D lines, as can intelligent power control systems. EERE programs are thus supporting the transition of the electric power delivery infrastructure from the central station system of the 20th century to an intelligent network allowing broad commerce in electric energy produced by sources ranging from large generators to small, distributed systems.

RECOMMENDATIONS

Although EERE's record of historic performance, public-private partnerships, and performance-based management shows significant improvements in performance over time, the SPR found a number of areas where improvements can and should be made. Areas the SPR identified for improvement are discussed here in terms of the following:

- Closures—activities that should be terminated because the work has been successfully completed and no significant further government role is needed (graduations), or that do not provide sufficient public benefit (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 that are not currently receiving adequate support in comparison to the benefits they can provide; and,
- Best Practices—actions that can be taken to improve overall program performance.

Criteria for these judgments include:

- Projected benefits (economic, environmental, security, options, knowledge) vs. total investment;
- Projected potential for commercialization by industry;
- Whether industry could or would do the RD^3 by itself; and,
- Program effectiveness as evidenced by the technical performance and business management measures used in this evaluation.

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[33] There remain issues of synchronization of the AC power with the grid when interconnection is re-established. Further technical development is needed.

CLOSURES

The SPR identified twenty activities that should be terminated either because the associated public benefits are expected to be achieved without further public support or because they do not provide sufficient public benefit.[34] These include activities that would likely be terminated or graduated under standard EERE business practices, as well as activities for which the technical, market, or other bases for the program have passed but that continue because of ongoing stakeholder or other external support. Separately, Chapter 4 details more than 60 past graduations or terminations of R&D activities, demonstrating EERE's business practices.

Recommended closures are the following:

1. **Wettable Ceramic-Based Drained Cathode Technology.** Commercial scale demonstration of wetted cathodes at Reynolds/Kaiser Aluminum could not be performed in FY2001 because of the shut down of Kaiser smelting capacity in the Pacific Northwest. Alcoa has acquired the intellectual property rights and can continue without DOE support. Alcoa will integrate the technology advances for the cathode with EERE-supported work on the advanced anode to significantly reduce the energy intensity of the electrolytic cell, which is used for the smelting process.

2. **Committee on Energy Efficiency Commerce and Trade.** The Committee on Energy Efficiency Commerce and Trade (COEECT) is a 15 member Federal working group established in 1993 whose function is to coordinate Federal export assistance to the U.S. energy efficiency industries. The Department had contracted with the Export Council for Energy Efficiency (ECEE) to provide industry input and identify market needs on behalf of COEECT. COEECT should now be closed and the Clean Energy Technology Exports initiative, currently in development under the NEP, should consider which COEECT activities may be worthy of future support.

3. **Hybrid Direct Injection R&D.** The Hybrid Direct Injection Engine R&D program focused on developing technology for direct injection gasoline engines (i.e. Spark Ignition Direct Injection (SIDI)). This engine technology has the potential to improve the fuel economy of conventional passenger cars by 10 to 15 percent. Most of the obstacles to commercialization of this technology are related to meeting future tailpipe emission standards and reducing the cost of the high-pressure fuel injection systems. Considerable progress was made on both fronts during the term (1999-2001) of the program. The technology is now believed to be close enough to commercial feasibility that the auto companies should undertake the remaining development work without Government support. The Program should be discontinued and all activities funded through this budget line cease. This will make more funds available for exploring the longer term, higher efficiency engine technologies in the Office of Advanced Automotive Technology portfolio.

   Direct injection gasoline engines have been commercially available for several years in Japan and Europe. In addition to improved fuel economy, the engines have higher power output and offer engine developers another very precise variable to control in optimizing engines for the competing demands of low emissions, high efficiency, and performance. The technology has not reached the U.S. because: (1) the fuel economy improvement in typical U.S. driving conditions would be very modest, (2) the incremental cost of the engines is not justified in view of lower U.S. fuel costs, and (3) the higher sulfur level in U.S. gasoline is incompatible with the emission

[34] It is difficult to prejudge R&D, so it is possible that subsequent work might modify this determination.

control devices used in gasoline direct injection engines. Discontinuation of this program allows more emphasis to be placed on the remaining engine technologies in the OAAT portfolio (advanced diesel, homogeneous charge compression ignition, and variable compression ratio), all of which promise higher potential engine efficiency and compatibility with our larger vehicles and higher driving speeds.

4. **Glass-Fiber-Reinforced Polymer Matrix Composites.** Glass-fiber-reinforced polymer-matrix composites (PMCs) activities of the Automotive Lightweight Materials program demonstrated that large automotive structures probably could be manufactured out of fiber-reinforced PMCs in minutes at costs typical of the high-volume automotive industry, instead of the days and weeks typical of the aerospace, small-boat, and sporting goods industries. This activity should now end and funding be used to ramp up longer term, higher risk work on PMCs reinforced with carbon fibers.

   A major focus of the Automotive Lightweight Materials (ALM) program has been and is the development and validation of technologies to enable cost-effective manufacturing of the structures of automobiles out of fiber-reinforced polymer-matrix composites (PMCs), to replace the carbon steels now used. Established aerospace, small-boat and sporting goods uses (of most note among many uses) show that fiber-reinforced PMCs can do the same structural job as steel at 25 to 60 percent less weight, but typically at costs two to three times higher. In order to realize the inherent weight savings and thus full economy improvements, the costs of making the vehicles out of the PMCs must be about the same or less than those using the steels.

   From FY 1995 to the end of FY 2001, the ALM and the Automotive Composites Consortium of the US Council for Automotive Research of the three traditionally US-based automakers (Chrysler Group of the DaimlerChrysler Corporation, the Ford Motor Company and General Motors Corporation (GM)), cofunded an effort termed "Focal Project 2." The main aim was to show that large automotive structures probably could be manufactured out of fiber-reinforced PMCs in minutes (and therefore likely at costs) typical of the high-volume automotive industry, instead of the days and weeks typical of the aerospace, small-boat, sporting goods etc. industries. While it was recognized from the beginning that glass-fiber-reinforced PMCs could only achieve about 25% weight reduction with respect to steel, the initial efforts used glass fiber in order to prove out the likelihood of the cost-effective manufacturing. This was indeed shown using a pickup truck bed as the example structure. The results were so encouraging that GM adapted the technology using its own funds to produce a truck bed that has first appeared as an option on its 2002 Chevrolet Silverado truck. In FY 2002, a new effort dubbed "Focal Project 3" was ramped up to develop and prove technologies for cost-effectively manufacturing automotive structures out of **carbon-**fiber-reinforced PMCs which can achieve 60% weight reduction.

5. **Lighting technology development projects.** Developed under cost-shared competitive solicitations, the development of solid-state ceramic lighting for "signage" will be completed during 2002 and be transferred to industry for further development and commercialization.

6. **Light Source Basic Research Projects.** Basic materials development on coatings for incandescent filaments and new phosphors for fluorescent fixtures is being completed during 2002 and the next phase of work is subject to private sector interest.

7. **Advanced Gas Water Heaters.** Research on condensing heat exchangers and absorption heat pumps to demonstrate the next discrete efficiency jumps available for gas water heating is being completed during 2002 and results transferred to industry for further development and

commercialization. Continued low gas prices reduce likelihood of immediate development activity in private sector.

8. **Dehumidification Characterization Research.** Research to develop more accurate understanding of the energy performance implications of various dehumidification processes is being completed during 2002 and results transferred to industry, DOE and standards organizations for R&D planning and standards development purposes.

9. **Integrated Window/Wall Systems Development.** Through competitive solicitation, this heavily cost-shared project focuses on the development and evaluation of specific combinations of advanced windows and wall materials that could lead to energy efficient product offerings in residential construction. Work is being completed in 2002 and transferred to industry for further development and commercialization.

10. **Sensor for Verification of Gas Fill Integrity in Insulated Windows.** Development work is being completed in 2002 and results transferred to industry and to market deployment efforts. Research on further improvements in technology is not viewed as critical to success.

11. **Whole Building Diagnostician.** A research project for a building operations optimization system is being completed in 2002 and has successfully demonstrated value in several research studies of buildings. Results will be made available for commercialization by private sector.

12. **Natural Gas Vehicle Engine R&D.** DOE and industry cost-shared partnerships over the last 8 years have resulted in over 20 certified heavy-duty engines that set new standards for low emissions and high performance using natural gas. There has not been, however, much success in the marketplace due to barriers to adoption of natural gas engine technologies and lack of refueling infrastructure. Given the limited technical opportunities for further performance improvements and significant market constraints, technology R&D should be terminated and resources redirected toward short term technical barriers that may prevent engines and vehicles from reaching customers. This should involve coordinated efforts with State and local authorities that have established policies to promote the use of alternative fuel vehicles.

    Near-term technical barriers that would be useful to address include:

    - Engine emissions testing and certification, establishment of natural gas specific engine deterioration factors, and durability issues;
    - Adaptation of CNG engines to LNG operations to allow for extended range vehicles;
    - Platform engineering, i.e., engine/chassis integration to ensure that advanced natural gas engines are utilized in platforms that customers need;
    - Advanced infrastructure technology to reduce cost, increase reliability, and improve functionality, such as standardized nozzles, card-readers systems, slow and fast-fill compressor systems;
    - Coordination of Federal, State, and local technical specifications, such as emissions levels required to earn incentives or meet regulatory requirements; and,
    - Market research on the types of platforms that will be in demand can provide significant oil reduction, and significant environmental benefits.

13. **Concentrating Solar Power (CSP) Program.** CSP troughs were commercialized in the late 1980s in California and 354 MW of installed capacity have been operating since that time with

ongoing technical assistance on issues such as improved O&M techniques. A recent NRC Report concluded that CSP troughs were not likely to be cost competitive in the United States in the foreseeable future. Based on this, the specific trough activity should be closed. This should be distinguished from solar dish R&D, for which the NRC report concluded there was promise in distributed markets. Troughs should also be distinguished from solar power towers, for which advanced high temperature receivers and Brayton cycles or other technologies may provide a technical path forward to become competitive in the mid to longer term. The CSP Program has recently sanctioned several external program, technology, and market reviews, which will shed additional light on the technical potential of various options and on future program direction.

14. **Resource Energy Managers (REMs).** FEMP provided seed funding that resulted in successful REM programs in Washington and California. Since a number of Federal agencies are embracing this concept and will support this function directly, FEMP funding can be phased out.

15. **FRESA, WATERGY and Integrated Screening Software Tools.** FEMP will phase out support of these tools, as they did not rise high enough relative to other priorities to warrant further support.

16. **Continuous Fiber Ceramic Composites.** This program has been ongoing for ten years. Several applications have been commercialized, and materials codes and standards will be completed and adopted. Applications are limited by the relative costs of these materials compared to most metal applications, however. The program should be closed out with the remaining funds.

17. **Methane de-NOx Reburning Process for Wastewood, Sludge, and Biomass Fired Stoker Boilers.** Demonstrations of methane de-NOx technology in three paper mill biomass boilers have successfully proven that the technology will increase thermal efficiency and the use of biomass fuel while reducing emissions and natural gas consumption. This work can now be closed out.

18. **Direct Production of Silicones from Sand.** The direct conversion of silicon dioxide (sand or quartz) into silicone polymers would eliminate the energy-intensive silicon manufacturing step required in the conventional process. A team of researchers (including GE, Molecular Simulation, Inc., and OM Group Inc.) used advanced combinatorial chemistry technology to survey hundreds of catalysts that might enable direct or one-step conversion. Although the team did identify several inexpensive materials that appear to be suitable, closer study revealed that the direct synthetic route was not chemically feasible. Thus, this work can be closed out. Nonetheless, the fundamental understanding of making silicone was significantly advanced. Several patents will be filed.

19. **Residential Refrigerator Research.** Past research and regulatory efforts have reduced the energy use of new refrigerators by nearly a factor of four since 1975. Continuing research in areas such as improved insulation, more efficient motors, and general refrigerator cycle efficiency research is important for non-residential applications, but research specifically focused on conventional vapor-cycle residential refrigerators now has lower potential returns than work in other areas and should be discontinued. Recent development of potentially low cost giant magnetocaloric effect materials may make magnetic refrigeration systems cost effective for residential use, replacing the current technology of conventional vapor-cycle refrigeration. If these materials continue to show technical progress, then it may be worthwhile to reconsider R&D in residential refrigerators.[35]

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[35] The recent advances in giant magnetocaloric effect materials can be found in: O. Tegus, E. Bruck, K.M.J. Buschow, and F.R. de Boer, "Transition-metal-based magnetic refrigerants for room-temperature applications",

20. **Automotive Aluminum Casting.** Aluminum casting activities of the Automotive Materials Technologies program have developed technology that, if implemented by industry, should be able to produce aluminum components that perform as well or better, cost the same or less, but weigh 40% less than steel components. These activities are drawing to a successful conclusion and can be stopped at the end of FY2002.

    An early focus of the ALM sub-program was development and validation of technologies to enable cost-effective casting of aluminum structures for automobiles. Major ALM aluminum-casting projects "Design and Product Optimization for Cast Light Metals," "Die Casting Die Life Extension" and "Rapid Prototyping of Casting Dies" concluded on or before FY 2001, as did major projects "Metal-Compression Forming" and "Ultra-Large Caster" funded by the Office of Heavy Vehicle Technology's High Strength Weight Reduction program. The program is shifting to support longer term, higher risk work on issues of casting magnesium and metal-matrix composites. Major projects on casting of magnesium and of aluminum-matrix composites reinforced with ceramics were begun during or before FY 2001 and have now been increased in FY 2002.

REDIRECTIONS

This SPR found several activities that can potentially provide appropriate public benefits but need redirection and redefinition to increase the probability of success. These fall into the categories of project (i.e., what work is done) and process (i.e., how the work is done) redirections, as follows.

Selected Recommended Program and Project Redirections

- **PNGV Initiative.** As noted in the seventh annual NRC review of the PNGV initiative, "The PNGV program has overcome many challenges and has forged a useful and productive partnership of industry and government participants" and has "addressed formidable technical issues and made significant progress on many of them despite the complexity of managing an interdisciplinary program involving three competing companies, several government agencies, and significant government budget constraints."[36] Another NRC study notes, "PNGV … could save a huge amount of petroleum consumption if overall success is achieved" and "this is a very significant energy security option benefit."[37] However, as noted in the NRC Seventh Annual Review of the PNGV initiative, redefinition of the "PNGV charter and goals" is needed to "better reflect societal needs and the ability of a cooperative, pre-competitive R&D program to address these needs successfully." This initiative is nearing the end of its ten-year charter. The Administration is in discussion with its partners and is identifying potential new partners to determine how to best collaborate on energy-saving vehicle technologies. A more aggressive long-term orientation toward hydrogen/fuel cell technologies should be a central element of this new direction.[38]

Nature, Vol 415, 10 January 2002, pages 150-152. For a background on near-room temperature magnetic refrigeration see C. Zimm, et al., "Description and Performance of a Near-Room Temperature Magnetic Refrigerator", Advances in Cryogenic Engineering, Vol.43, pp.1759-1766.

[36] National Research Council, "Review of the Research Program of the Partnership for a New Generation of Vehicles," Seventh Report, National Academy Press, 2001, see page 2.

[37] National Research Council, "Energy Research at DOE: Was It Worth It?" National Academy Press, 2001.

[38] The Administration launched the FreedomCAR initiative focused on fuel cell vehicles in January, 2002.

- **Batteries.** Battery research is very important, not just for vehicles, but also increasingly for the entire suite of mobile applications, such as computer and communications technologies. More extensive work, both fundamental and applied, on battery technology is needed. As companies invest, the DOE portfolio has been and can continue to be adjusted. For example, the recent Texaco investment of $150 million in nickel-metal hydride batteries, may allow DOE work to progress to new opportunities. Although dedicated electric vehicle markets remain small and their prospects highly uncertain, hybrid vehicles and plug-in hybrids are gaining increased attention and further work to lower the costs and improve the performance of batteries can assist their market acceptance.[39] OTT has two sets of research efforts on batteries, one under the Electric Vehicle Program and one under the Hybrid Vehicle program. EERE *should* combine them into a single program that covers the full spectrum of battery-related research for transportation applications.

- **Regional Resource Centers for Innovation.** Close on-the-ground interaction with industry counterparts is essential for successful partnerships. It is also important, however, to minimize duplication of effort in such activities. There is a risk that some of EERE's Office of Industrial Technologies (OIT) Regional Resource Centers for Innovation overlap with or duplicate activities that could be undertaken through the EERE Regional Offices. EERE *should* examine this closely and minimize potential program mission overlaps to ensure the best use of its resources.

Selected Process Redirections

- **Program Structure.** The 1999 review by NAPA recommended that EERE define what "constitutes a program and what constitutes a project" and to "clarify the roles and responsibilities of program and project managers." While EERE has made significant progress in identifying and developing such program structures, further work is needed. Crosscutting research is often particularly problematic. Key areas include such crosscutting technologies as biopower, biofuels, and bioproducts; sensors and controls; power electronics; information technologies; distributed energy systems; and others. Over time, many programs are likely to shift direction or not line up with the budget line items; there is no single logical structure that will fit all the various EERE activities perfectly over time. It is essential that the programs develop mechanisms to work effectively across the grain of the EERE structure. Perhaps more important is building an organization that is inherently more flexible and can adjust to shifts in program priorities over time while still ensuring logical lines of authority and accountability. EERE *should* further examine and logically align its structure while also developing greater flexibility.

- **National Laboratories.** National laboratories have consistently provided critical technology advances, served as important bridges between basic and applied research, provided technological breadth and depth for increasingly diverse research challenges, and maintained a technological institutional memory.[40] However, the cost of doing business at the national laboratories is high, with overheads substantially greater than those of private firms.[41]
    - EERE *should* conduct detailed analysis of cost at the national laboratories to determine the key cost drivers and to reduce them to more competitive levels where possible. This might

[39] See, for example: http://www.epri.com "Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options."

[40] These contributions help counterbalance industry reductions in R&D, shortened time horizons, and shifts from central research to independent profit centers where research becomes increasingly fragmented and narrow. The review of R&D100 awards found national laboratories involved in roughly 90+% of the winning research.

[41] National laboratories do maintain core technical competencies and provide support not provided by private firms.

include, for example, greater consideration of the differences between the weapons labs and civilian facilities such as the National Renewable Energy Laboratory. As this could include changes in such factors as health and safety controls, infrastructure costs, small business contracting, and others, policymakers may need to choose between relaxing these requirements, where appropriate, or allowing by default a gradual diminution of the role of the national laboratories in working with the private sector on key technological innovations.

- National lab costs are significant for programs such as FEMP, which does not conduct research, but which still uses national laboratories as a primary source of support. EERE *should* examine how to reduce lab costs in providing support to FEMP; further, EERE *should* consider more extensive use of private sector alternatives.

WATCH-LIST

This SPR identified several activities that need close monitoring to ensure they advance effectively and expeditiously.

- **Congressional Earmarks.** Chapter 4, Tables 4-A8 and 4-A9, list Congressional earmarks in the Renewable Energy Resources portion of the Energy and Water Development appropriations for FY01 and FY02, respectively. In FY02, Congress earmarked 50 projects worth $86 million, or almost one fourth of the appropriation for renewables. In some areas (e.g., biomass and superconductivity), earmarked projects accounted for about 40 percent of the respective budgets. While the SPR found that a number of these Congressionally designated projects have merit, many are not optimally aligned with overall program objectives and/or priorities. At times, some earmarks may have no relationship at all to the technology research or program to which it is attached. Moreover, because earmarks bypass the competitive peer-reviewed selection process used by EERE to select projects, earmarked projects tend to bring into question the overall integrity of merit-based selection, and interfere with overall program management and the development of a coherent program. EERE has not yet determined whether it will request reprogramming of FY 2002 appropriations that were earmarked. However, these and future projects will receive the same close scrutiny that EERE is applying to all of its work to ensure that statutory cost-sharing requirements, progress performance, and sound business practices are carefully followed, and associated risks fully considered. EERE’s FY 2003 budget does not request funding for previously earmarked projects.

- **Office of Building Technologies, State and Community Programs (BTS) Demonstration and Deployment programs.** BTS combines technology development activities with demonstration, and deployment efforts such as Building America, Rebuild America, Energy Star, and the Community Energy Program, as well as the Weatherization Assistance Program. Such integration is necessary and important. The SPR did not, however, identify a strong analytical base in place or under development to determine how much demonstration was necessary and/or sufficient, including what is needed to achieve a critical mass of activity that causes market transformation in target areas. This is both a concern and an opportunity to develop such an analytic foundation, as discussed further under Best Practices and in Chapter 4.

- **Bioenergy.** The overall direction of the bioenergy program towards the development of integrated biorefineries producing chemicals, fuels, and power is appropriate and important. Although efforts to improve integration and joint planning continue, much work remains for the EERE bioenergy-related programs to be adequately integrated and sufficiently strategic in their approach/work, and to ensure that there is a critical mass of focused activity in key areas.

- The biopower program effort on cofiring biomass with coal in conventional power plants does not directly contribute to the longer-term goal of developing integrated biorefineries. Indirectly, however, cofiring can potentially contribute by offering a market for biomass feedstocks and encouraging the development of production, harvesting, and transport equipment to drive down the cost of biomass delivered to the biorefinery. The fossil energy program at DOE *should* be approached as a significant partner in and supporter of these cofiring demonstrations. Support for feedstock infrastructure activities is not adequately built into the current R&D program. Plant science and crop development are areas that the biomass program *should* strongly encourage USDA and others to undertake while ensuring a smooth transfer of current activities to USDA, so that important research is not disrupted.
- The Biofuels program supports R&D to convert lignin to liquid fuels and chemicals. However, some fraction of the input biomass feedstock will also be needed for producing power to operate an integrated system. Because of the difficulty of converting it to fuels or chemicals, lignin is perhaps the best near- to mid-term candidate to fuel power generation. Research specifically on converting lignin to liquid fuels should be reduced and the resources concentrated on producing liquid fuels from celluloses, or on producing high-value products, possibly including from lignin.

- **Federal Energy Management Program (FEMP).** While FEMP has made progress in tracking the energy and cost savings produced by its direct project assistance under its Energy Saving Performance Contracts (ESPC's), technical assistance, and audit programs, further work is needed to develop adequate methods of measurement and evaluation linking project activities to the achievement of its programmatic goals. FEMP should also expand this analysis to the indirect program support it provides, particularly in the areas of training and outreach. This insufficient analytical underpinning raises questions about the impact of FEMP activities on the overall reductions in energy consumption that have been achieved government-wide to date. These missing linkages hinder the allocation of resources to achieve specific objectives. For example, ESPC's are generally accepted as a valid means of financing investments in energy saving technologies in Federal facilities without significant initial capital outlay by the Federal government. FEMP should follow up on its study of this government-wide ESPC potential to identify the remaining ESPC opportunities at individual agencies, the amount of energy that could be saved, and the role of FEMP in the implementation of these potential projects. EERE and FEMP *should* develop these essential analytical underpinnings and a stronger analytic capability, and should also expand this analysis to cover the indirect program support it provides, particularly in the areas of training and outreach.

- **Microturbine Research in the Distributed Energy Resources (DER) program.** Although more efficient microturbines promise superior environmental performance compared to conventional reciprocating natural gas engines, cost and maintenance issues may limit their mass deployment in the marketplace. New activities in this area *should not* be undertaken unless careful analysis indicates significant future market opportunities for microturbines, and existing activities are successful in achieving their efficiency and emissions performance goals.

- **Concentrating Solar Power (CSP) Towers.** CSP integrated with molten salt storage provides a baseload capability that other solar technologies do not, by themselves, provide. However, an NRC Report released in FY 2000 concluded that CSP towers were not likely to be cost competitive in the United States in the foreseeable future[42] and PCAST recommended exploring development of higher temperature receivers appropriate for use with gas turbine cycles to lower

[42] The report differentiated these technologies from solar dishes, which it concluded showed promise in distributed markets and which have been earmarked for funding by Congress the past two years.

costs.[43] CSP towers may, however, have near-term opportunities in other parts of the world, which industry is currently exploring. High temperature receivers and Brayton cycles, or perhaps other configurations, may provide a path for CSP to become competitive in the mid- to longer term in the United States. Building on recent studies launched by the CSP program, EERE *should* conduct detailed analysis to determine if there is a technical path forward for these technologies. Further research in this area would depend on these findings.

EXPANSIONS

Within EERE's portfolio, there were several programs that could achieve significantly increased benefit with additional funding.

- **Hydrogen.** The promise of hydrogen as an energy carrier that can provide pollution-free, carbon-free power and fuels for buildings, industry, and transport makes it a potentially critical player in our energy future. The acceleration of hydrogen technology development is appropriate and necessary. However, work is needed to more effectively structure the existing Hydrogen program within EERE's Office of Power Technology (OPT) to meet this challenge. In particular, this includes ensuring that RD^3 activities are appropriately balanced so that near term projects that contribute to creating a hydrogen infrastructure[44] also fit within the longer term plan for hydrogen providing energy security to the United States. There must also be a clear analytical basis for the value-added of each additional demonstration activity (see Best Practices, below). Efforts should continue to be coordinated with the Fossil Energy program where appropriate.

- **Fuel Cell Vehicles.** Advanced vehicle technologies are essential elements of any effort to reduce our dependence on foreign oil. The next critical step is the development of more advanced fuel cell vehicles, building on the current hybrid and fuel cell activities, to reverse the growing consumption of petroleum for highway transportation and to ultimately break the link between highway transportation and petroleum.[45] A key complementary activity is developing a hydrogen infrastructure, as noted above. Efforts should continue to be coordinated with OPT, the Fossil Energy program, and others where appropriate to develop an integrated strategy, particularly for driving costs down.

- **Building Equipment R&D.** This program develops energy efficient heating, cooling, lighting, windows, and other building equipment and components. The largest returns found by the NRC analysis of EERE benefits came from this program. This equipment is also of interest because it typically has lifetimes of twenty years or less, so that improvements can enter the market relatively quickly and have a broad impact on energy use throughout the United States. Advances in materials science (including materials for LED lighting), information technologies, and sensors and controls offer huge new opportunities for this program. Integration of these technologies with distributed energy resources to develop zero net-energy and essential energy buildings is also important.

- **Low-Wind Speed Turbines.** The cost of electricity generation by wind turbines has been reduced by a factor of 10+ over the past twenty years and wind energy is becoming the fastest growing energy supply source in the United States and worldwide. The current generation of

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[43] President's Committee of Advisors on Science and Technology, "Federal Energy Research and Development for the Challenges of the Twenty-First Century", Executive Office of the President, November, 1997.

[44] This could include on-site reformers and hydrogen storage as one strategy to developing an infrastructure, particularly as a mid-term option.

[45] As noted above, the Administration launched the FreedomCAR initiative in January 2002.

wind turbines, however, is limited to areas with high (class 5&6) wind speeds to be economic, which sharply restricts their use. The development of turbines that can operate cost competitively in areas with moderate (class 3&4) wind speeds will increase the wind resource that can be tapped by a factor of twenty and greatly broaden the areas of application by reducing the transmission distance to consumers. Tapping these wind resources can also provide an additional source of income to rural communities.

- **Peak Load Reduction.** Peak load reduction can also make a significant contribution to energy security and strengthening the energy infrastructure, because the resiliency of the supply infrastructure is most limited under peak load conditions. Building on NEP Recommendations 7.1 (grid reliability) and 7.4 (removal of grid constraints), EERE will increase its research on peak load reduction and management technologies. Efforts will include research on (1) building and industrial sector energy efficiency opportunities that reduce peak loads and load growth thereby reducing the need for additional power plants and infrastructure capacity; (2) distributed generation and storage systems that provide electricity to consumers without adding to the loads on transmission systems and emergency power in the event of losses of centralized facilities; (3) use of superconducting materials to enhance the capacity of key components of the transmission and distribution systems; and, (4) grid control technologies, including responses to real time prices or other market signals, and interconnection standards that allow the grid to operate more efficiently. Careful analysis is needed to identify, evaluate, and prioritize peak load reduction opportunities for consideration in future funding requests.

- **Biobased Products.** An important opportunity for expansion in the biomass area is research on biobased products. Such R&D can create high value products that will support development of other components of an integrated biomass industry, from biomass harvesting to production of fuels and power. To date, bioproducts have received relatively little funding in comparison to other biomass activities, while potentially offering the highest value-added.

- **International.** International energy efficiency and renewable energy development can be extremely important as an outlet for U.S. exports of goods and services. This can help to drive down costs for these systems at home, to address global oil security and environment issues, and to help meet existing U.S. commitments under the U.N. Framework Convention on Climate Change. Current investments in this area are extremely modest. R&D support is needed to develop energy supply and service applications appropriate to developing countries—buildings, industry, power, transport, agriculture, education, health, and in particular those that can generate income for the user—building on core U.S. renewable energy and energy efficiency technologies.[46]

EERE *should* examine closely the potential in each of these areas and build the case for appropriate expansions of efforts and funding, where appropriate, for consideration by Congress.

BEST PROGRAM PRACTICES

This SPR identified a variety of actions that can be taken to improve overall EERE program performance. The NAPA report focused on the consequences of a period of minimal central management in EERE. The primary consequence was fragmentation, which forced each program sector to develop its own approaches to effectively plan, implement, and evaluate their programs, and led to best practices in different areas of program management in different sectors. Following the NAPA report, effective central

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[46] Note that this recommendation is in support of technology development activities, not of trade activities more appropriately done by the Department of Commerce and others.

leadership and management began being instilled in EERE through the Strategic Management System (SMS), the Program Management Initiative (PMI), and efforts to develop a consistent acquisition strategy for EERE and its associated implementation plan. The SPR has identified a number of other internal "best practice" capabilities that could be replicated usefully across EERE programs, in addition to continuing effective implementation of centralized systems such as the SMS and PMI. The following discussion addresses best practices in program RD^3 and in business practices.

- **Technology Roadmapping.** Technology roadmapping has proven to be a valuable tool in developing public-private partnerships, identifying appropriate research opportunities, and defining appropriate public roles. Although experience shows that no single approach is likely to serve all needs, more systematic approaches to roadmap development and quality control, as well as matching roadmap approaches with user needs would be useful. EERE *should* examine closely roadmapping activities as practiced by the different sectors and develop recommendations on best practice approaches and mechanisms for quality control.

  Technology roadmaps are important for guiding research activities and for identifying and encouraging research in areas of joint concern. However, several cases were identified by the SPR in which industry expressed no initial interest in particular research, only to later become strong proponents when public investments showed significant opportunities. For example, industry members showed little interest in improving truck aerodynamics (i.e., reducing wind resistance), but have become strong supporters as the research has demonstrated opportunity. In other cases, established industry actively worked to prevent innovation in order to protect its market control and capital investment; one example is the electronic ballast.[47] That industry is not interested in pursuing particular new research opportunities, even relatively near-term opportunities, should not necessarily constrain public exploration of such opportunities.

- **Project Selection, Planning, and Execution.** EERE is working to implement multiyear planning, development of critical path milestones and metrics, and improved program execution. Although much progress has been made, EERE *should* strengthen its efforts to:
  - establish evaluation plans at the start of each project—including appropriate criteria and protocols for decision-making such as redirecting, graduating, or terminating projects—in order to fully realize the benefits of the public investment;
  - incorporate market analysis activities in the project plan to help ensure that projects are appropriately targeted and to provide independent assessment (separate from the partnering companies) of the market opportunity and potential public benefit;
  - develop reasonably standard protocols for planning and budget execution; and,
  - evaluate projects (including their overall portfolio balance and completeness) from research through development, demonstration, and deployment, including system integration, technical assistance, analytical tools, information outreach, technology ratings, codes and standards, and facilitating work on training.

- **Competitive Solicitations.** Much EERE work is now conducted through competitive solicitations, followed by successive down-selects, project redirections, and then further competitive solicitations—all on firm timelines. This approach requires strong discipline and astute technical and political management, especially when dealing with numerous external

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[47] The NRC report, "Energy Research at DOE: Was It Worth It?" found that a major magnetic ballast producer bought intellectual property rights to the electronic ballast technology and then held them from the market, resulting in six years of litigation before the small innovating company was able to recapture rights and move the technology forward. This technology has provided a net realized economic benefit of $15 billion to U.S. consumers under the NRC methodology (see Chapter 5).

stakeholders. EERE *should* identify best practice approaches for competitive solicitations, down-selects, and project redirections, including establishing clear criteria for the selection of projects, specification of timelines, and project evaluation.

- **Program Management.** During the SPR, several programs within OTT and OPT demonstrated the strongest program and project management practices. EERE *should* adapt these program and project management practices to the needs of the other sectors, incorporating the best practices of all the sectors. Further, in FY2001, EERE developed a Program Management Guide; this *should* now be implemented.

  As an example, OTT has developed a set of integrated program and project management tools that provide a performance based system for planning, execution, evaluation, and reporting. Planning includes developing a multi-year R&D plan, budget formulation, and an overall program execution plan. Program execution includes the detailed execution of the budget, procurement, and project planning. Evaluation includes monthly program progress reviews, annual external peer reviews, and quarterly industry and laboratory reviews. Finally, reporting includes annual progress reports, monthly cost reporting, and annual peer review reports. Within this, there are additional levels of detail that telescope down to specific elements of each research activity. For example, multi-year R&D program plans, the first element identified above, includes the development of program goals and objectives, identification of technical barriers, development of detailed technical tasks and corresponding technical targets, identification of Go/No Go decision points, and detailed schedules. Similar breakouts are developed for each of the other elements within the overall tool, and all of them are tightly interlinked to strengthen management capabilities.[48]

- **Role of Technology Demonstration and Deployment.** To turn public investment into real public benefits requires moving laboratory research to commercial success. Historically, programs have sharply limited their roles in technology demonstration and deployment (D^2) out of concern that they might impinge on the private sector or be perceived as providing "corporate welfare." Today, there is growing recognition of the strategic role that public facilitation of D^2 can serve, while recognizing these are primarily private sector activities and that they should not come at the expense of core R&D efforts. All demonstration and deployment activities should carefully determine what the value-added for each additional demonstration is, identify to the extent possible what critical mass levels of activity are, and design these demonstration and deployment activities to assist market transformation, all with the recognition that these activities should facilitate, not displace, private sector activities. EERE *should* establish a strategy, a reasonably uniform process, evaluation criteria, and supporting analytical capability for D^2 in order to carefully evaluate and build on its current portfolio of activities, where appropriate. These efforts should also strengthen strategies for linking R&D, voluntary programs, and codes/standards.

- **Portfolio Management.** Portfolio approaches are essential to program success. Portfolios must be defined to accommodate risk mitigation, provide multiple success strategies and pathways, and adapt to changing markets and policies. Additionally, the OIT practice of identifying "direct" and "relevant" portfolios, appears to be a useful tool for portraying programmatic interrelationships and for defining strategies to meet larger programmatic objectives and *should* be considered by the other offices as well. This is a networking and tracking effort that identifies research activities at other agencies that are related to the OIT research portfolio.

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[48] The technology roadmap developed for the 21st Century Truck program indicates the kind of detail that is developed overall (see: http://www.osti.gov/hvt/21stcenturytruck.pdf).

Overall program balance or completeness must consider the entire innovation pipeline—from research through development, demonstration, and deployment, effective system integration, and supporting or facilitating work on training, technical assistance, analytical tools, information outreach, technology ratings/codes/standards, and others. The appropriate mix of these activities varies during the development of a technology. The balance must also address the risks of insufficient resources to conduct adequate research on multiple parallel paths to reduce risk appropriately, or for which there are insufficient resources to adequately prove the technology or to begin the cost buydown process. Figure 7-3 illustrates the many dimensions across which there must be balance.

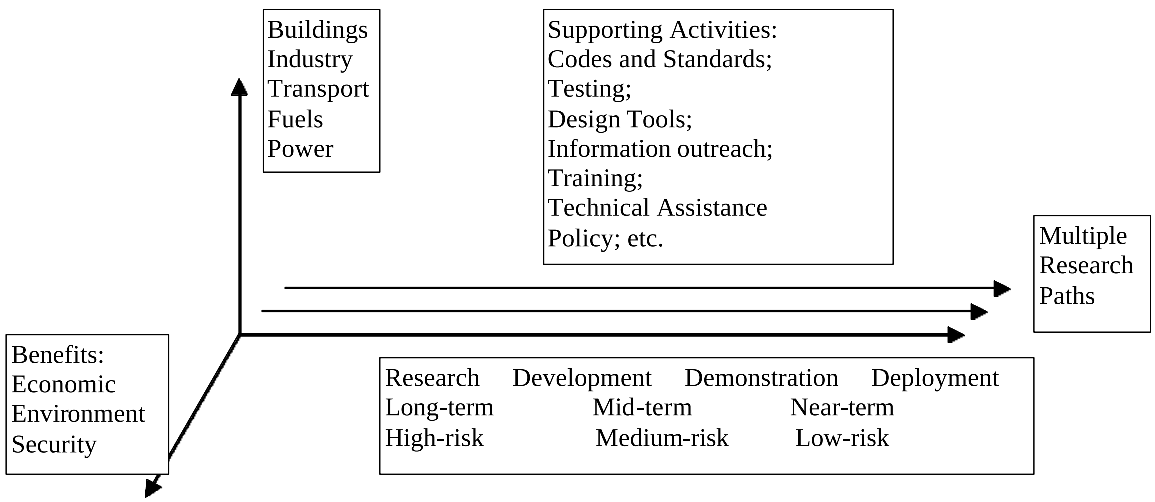

FIGURE 7-3: Balancing the overall portfolio**.** This figure illustrates the various dimensions that the R&D portfolio needs to be balanced across, with the optimal balance varying with the particular desired outcome. These dimensions include: (1) sectors—buildings, industry, transport, fuels, power; (2) innovation pipeline—research, development, demonstration, and deployment; (3) supporting activities—such as test standards, tools for rating equipment, design tools, analysis and evaluation, information outreach and training, technical assistance, market facilitation (e.g. labeling), policy, etc.; (4) time frames—near, mid, and long-term; (5) risks—low, medium, and high; and (5) benefits—economic, environmental, security; and others. Further, to mitigate risk, it is preferable to have several alternative research paths towards a common goal—alternative materials, alternative technologies, etc.—to increase the likelihood that at least one approach will be successful.

- **Program Evaluation.** Program evaluation includes peer review, benefits analysis, and other approaches. Systematic peer review is very important for strengthening/redirecting program activities. The SPR found that some form of peer review is frequently and widely used, though often on an ad hoc basis and not necessarily following best practices nor with sufficient regularity. EERE *should*:
  - o examine all EERE peer reviews over the next 6-12 months to identify best practices;

- identify, and determine means of achieving, the most important outcomes from the peer review process, such as improved DOE program management and decision-making, improved project quality, providing public accountability;
- benchmark EERE best practices against external models;
- identify other EERE reviews that are less productive and can be subsumed in a regular peer review in order to minimize staff workloads;
- develop model approaches for establishing systematic peer review for EERE; and,
- implement consistent and systematic peer reviews across all EERE programs.

Benefits analysis is useful for determining the potential value of the research portfolio as well as the value of benefits achieved. EERE has done extensive benefits analysis, particularly through the formal, externally reviewed process for establishing appliance standards and the annual analysis conducted for the GPRA. Broader analysis of project costs and benefits would be useful, however. The NRC study provided a useful starting point for this analysis and identified the need for more consistency across the EERE programs in benefits analysis. The NAS methodology has many useful characteristics and is a significant step forward, but also has a number of methodological problems, as noted in Chapter 5 and Appendix 5A. These include the so-called "5-year rule", discounting, marginal costs, marginal emissions, and others. This methodology cannot be applied to technology standards without significant modification. Further development of benefits analysis in the NAS framework is also needed in terms of quantitative evaluation of options benefits, quantification of knowledge benefits, pricing of environmental impacts, and pricing of security impacts. Statistical analysis is needed in many cases to provide greater rigor in evaluating program impacts. At the same time, efforts to quantify these benefits should not attempt greater precision than is appropriate, given the inherent uncertainties in evaluating such benefits.

EERE *should* further develop benefits analysis methodologies and begin a multiyear effort to implement a sophisticated benefits analysis capability. Benefits estimation is expensive, however, and needs consistent funding to build data sets and time series data. This will necessarily be balanced against other program needs, particularly core RD^3 work.

- **Institutional Memory.** The SPR frequently found it difficult to retrieve information about past programs, particularly programs that were conducted ten or more years ago, due primarily to staff turnover and culling of old files. EERE *should* develop mechanisms to build and maintain program institutional memory. The analytical effort should also include development of a programmatic and technology development institutional memory through case studies and by other means, with supporting annual data calls. In some cases this may, however, require resources that will need to be carefully weighed against other priorities.

- **Partners.** EERE technology is commercially introduced by private companies, who often are R&D partners. One model for such partnerships involves forming groups of competing companies to work collaboratively on issues of common interest and to share the intellectual property that results. This model works well where there is an established industry. Another model involves working with individual companies where the company gains much (or all) of the intellectual property created. This works well for an emerging technology where a strong intellectual property position is necessary to attract the capital needed to build a new business – either from venture capitalists or in the equity market. Both models can provide good leverage for Federal funds and should be benchmarked for best practices in order to be applied more effectively. In addition, there are also useful models for more general information and technology dissemination efforts. OIT has employed a practice of naming "Allied Partners" who will use information developed by OIT to reach out to people within their organization or industry. This practice appears to be highly effective, provides good leverage of Federal funds, and is readily transferable to other sectors. Other partnering includes work with other Federal or State agencies, universities, and non-profits. EERE *should* launch an effort to benchmark best practices for these various approaches and to replicate these best practices across programs.

Perspectives of appropriate public roles in working with the private sector in research, development, demonstration, and deployment have changed over time. As awareness has grown of the numerous linkages across all of the stages of innovation, including from deployment back to basic research, nuanced and pragmatic perspectives have developed that recognize the importance of the public role as a catalyst and facilitator. The important role of EERE as a convener and facilitator is often the principal attraction that brings multi-billion dollar companies to participate in technology roadmapping activities, as it can coalesce activities across the entire industry from which all can benefit. There has been a similar growth in understanding of the strategic linkages between R&D, programs for the facilitation of voluntary adoption of advanced technologies, and the valuable role of codes and standards to remove poorly performing equipment from the market to protect consumers and benefit the public. The bottom line is identifying what works to generate the greatest public benefit at the least public cost.

Some argue that regulatory approaches should be sufficient to stimulate private activity and that public R&D would then be irrelevant. However, the record shows declining private sector R&D in the energy sector—at a time when energy-linked challenges are increasing and there is a spin-out of central corporate R&D to their independent profit centers—which has tended to make the R&D more near-term and product focused. Energy sector deregulation has also resulted in sharp declines in longer-term R&D as companies search for ways to improve near-term financial performance. Public investment thus plays a key role in pre-competitive and longer term R&D, as well as in supporting and facilitating near-term demonstration and deployment activities. A regulatory approach is insufficient given corporate time horizons and financial pressures.

- **Business Execution.** In March 2000, NAPA published *A Review of Management in the Office of Energy Efficiency and Renewable Energy*. This comprehensive review provided a benchmark on EERE management practices and a template against which to evaluate progress since the issuance of the report. In response, the SMS and PMI were launched, but are not yet fully implemented. The NAPA review found that each of the EERE organizations had a somewhat different business strategy, from predominant national laboratory activity to predominant public/private activity—in part reflecting the particular characteristics of the individual energy sector with whom EERE was working. While business strategies differ, EERE needs a common corporate "systems approach" for business execution. The intent of the SMS is to provide such a centralized management system. This is critical to furthering the goal of management excellence. Similarly, the PMI addresses the need for training staff for effective program and project management. EERE *should* continue to implement the SMS and PMI and *should* move to common systems and practices, including the use of common databases (such as the "Budget Hut") for supporting planning, budget formulation, budget execution, and program analysis requirements.

MARKET CHALLENGES

In considering the economic, environmental, and security benefits to be derived from energy efficiency and renewable energy technologies, it is important to recognize that they face significant challenges in their development, demonstration, and deployment, including market failures and market friction. Key examples of what economists have identified as market failures include the following and are discussed in Chapters 2 and 3 of the report:

- that companies cannot capture all the benefits of their R&D (incomplete appropriability);
- that many of the benefits of R&D are public goods (e.g. benefiting national security) or reduce externalities (e.g. environmental damages) which may not be included in the price of the energy service, reducing or eliminating any incentive for the private sector to invest in them;
- that regulations may interfere with advanced energy technology development or deployment;
- that information available to consumers may be incomplete or inaccurate; and
- that the purchaser of energy-using equipment may not be the purchaser of the energy to power it—for example, the building owner and renter—reducing the incentive of both to invest in efficiency.

Examples of market friction include:

- the high first cost of energy efficient or renewable energy technologies which may deter potential users even if their lower fuel use results in comparable or lower lifecycle costs;
- high transaction costs associated with purchasing and installing small household or business high efficiency or renewable systems;
- the chicken-and-egg problem of developing new infrastructure for new technologies and fuels;
- the chicken-and-egg problem of developing sufficiently large markets for new technologies that their market price can eventually be driven down to competitive levels; and more.

These factors require unique considerations in program design and strategy. The SPR found that EERE programs had developed a number of strategies to address these market challenges and that these strategies had been substantially improved over time as understanding of these technologies and markets has grown. These strategies are reflected above in such factors as the shift from technology push to market pull, the development of technology roadmapping, the use of competitive solicitations and cost sharing, and many others as detailed in previous Chapters.

THE LONG-TERM CHALLENGE

Time horizons are long for all these activities. The time to build the political consensus to act; conduct the technology research, development, and demonstration; penetrate the market; and turn over the existing capital stock to significantly impact energy use or criteria pollutants/GHG emissions is typically measured in decades, as indicated in Table 7-1. Conversely, to substantially impact a particular sector by some future time period, the timetable for action by which R&D needs to be aggressively pursued can be roughly determined by working back from that date using the crude time estimates in Table 7-2.

TABLE 7-2: TYPICAL TIMES FOR RD^3 AND CAPITAL STOCK TURNOVER

Activity	Typical Times Required
Political development	1-10+ years
Research, Development, Demonstration	5-25+
Market Penetration	10-25+
Capital Stock Turnover	
• Cars	• 14
• Appliances	• 15-20
• Power Plants	• 30-40+
• Commercial Buildings	• 40-60
• Residential Buildings	• 60-80
• Industrial Facilities	• 40-80
• Industrial Facility Equipment	• 10-30+
• Urban Form	• 100s

Note: Market penetration refers to the length of time required for the technology to become a large fraction (e.g. a third to a half) of the total market. Capital stock turnover refers to the typical lifetime of existing capital equipment before it would normally be replaced, potentially with a more efficient technology. Note that buildings, industrial facilities, and power plants may be renovated several times over their lifetime, providing significant opportunities for improving their efficiency and to employ renewable energy technologies.

Appendix A

Public Comments on the Office of Energy Efficiency and Renewable Energy

Summary Report

Office of Energy Efficiency and Renewable Energy
Office of Planning, Budget, and Management

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Public Comments at a Glance

The purpose of this report is to present a summary of the findings from 4,279 public comments on the Office of Energy Efficiency and Renewable Energy's (EERE's) programs. This page presents the report's highlights.

The public comments were overwhelmingly in support of EERE's programs.

Overall Opinion of EERE Programs	
Opinion	**Public Comments**
Favorable	4,201
Unfavorable	8
No Opinion Provided	70

In many of the public comments, specific EERE programs were discussed. In total, 22 of EERE's 31 programs were addressed in the comments. The programs that received 500 or more comments are listed below.

EERE Programs Identified	
Program	**Number of Times**
Solar Technology	1,486
Wind	1,251
Geothermal	796
Energy Star	767
Advanced Vehicle R&D	689
Residential Building Integration	577
Hydrogen	551
Hydropower	545
Buildings Materials & Equipment	536

The majority of public comments contained one or more issues that were of concern to the commenters. In total, 70 issues were identified in the public comments reviewed. The top 5 issues identified in the public comments were:

Issues Identified in Public Comments	
Name	**Number of Times**
EERE Programs Funding Level	3,337
Climate Change	2,031
Impacts of Nuclear Waste	1,705
Environmental Issues in General	1,639
America's Reliance on a Fossil-Based Economy	1,174

The majority of the public comments submitted on EERE's programs also made one or more recommendations to the Department. In total, 51 Departmental recommendations were identified in the public comments. The top 5 recommendations were:

Recommendations Identified in Public Comments	
Recommendations	**Number of Times**
Increase EERE Funding Level	3,891
Reduce or eliminate funding for non-EERE programs	1,372
Reduce Air Pollutants	1,242
Increase CAFE standards	1,161
Reduce Climate Change (in general)	931

Introduction

The Bush Administration’s National Energy Policy (NEP) recommended a review of current funding and historic performance of the Department of Energy:s (DOE) Office of Energy Efficiency and Renewable Energy (EERE) programs. To facilitate this review, DOE senior officials solicited public comments on EERE’s programs in seven regional meetings and through postal mail and e-mail in June 2001 (see the Federal Register notice in Appendix I).

The public meetings were held from 9:00 a.m. to 9:00 p.m. at the following locations:

June 12	**Atlanta, Georgia** - Location: Main Auditorium (Lower Level), Richard B. Russell Federal Building and Courthouse, 75 Spring Street SW, Atlanta, GA 30303
June 12	**Chicago, Illinois** - Location: James Benton Parson Memorial Court Room Dirksen Federal Building, Room 2525, 219 South Dearborn Street, Chicago, IL 60604
June 19	**Boston, Massachusetts** - Location: John A. Volpe National Transportation Systems Center, 55 Broadway, Kendall Square, Cambridge, MA 02142-1093
June 19	**Seattle, Washington** - Location: Bell Harbor International Conference Center International Promenade Room, Pier 66, 2211 Alaskan Way, Seattle, WA 98121-1604
June 21	**Denver, Colorado** - Location: Adam's Mark Hotel Denver, 1550 Court Place Denver, CO 80202
June 21	**Philadelphia, Pennsylvania** - Location: Myerson Auditorium, 210 South 34th Street, Philadelphia, PA 19104
June 26	**Washington, D.C**.- Location: Washington Hilton and Towers, 1919 Connecticut Avenue, Washington, DC

The purpose of this report is to present a summary of the findings from 4,279 public comments on EERE’s programs.

Overall Opinion of EERE Programs

The public comments were overwhelmingly in support of EERE’s programs, with 98 percent of the total comments expressing an overall favorable opinion of EERE’s programs (see Appendix II for details on the Methodology). Of the 4,279 comments reviewed, 8 comments had an unfavorable view of EERE’s programs, and 70 did not provide enough information to determine the commenter’s overall opinion. All but one of the 457 public comments provided at the seven public meetings expressed an overall favorable opinion of EERE’s programs.

Many of the public comments expressed support for EERE's programs because they will enable the country to meet its energy needs through clean technologies. For example, Vaughn Brandt wrote:

> I am writing to support alternative energy research and proposals. I firmly believe in the importance of funding green energy research and sources to reconcile our nations growing energy crisis.

A large number of comments also expressed strong support for the energy efficiency programs of EERE. For example, Patrick Quinlan noted:

> Energy efficiency and conservation represent the nation's best short-term energy options and DOE's overall energy-efficiency program should be significantly expanded.

Others, such as a comment by Linda Davis Peairs highlighted the vital role the Department plays in supporting energy efficiency and renewable energy R&D:

> DOE is a cornerstone in U.S. research, development, and demonstration activities in the energy field. Their programs provide alternatives to polluting energy sources and are vital for the commercialization of renewable energy and energy efficient technologies.

In other cases, the comments emphasized the key role EERE technologies can play in the development of a diverse "energy mix" that will mitigate the impacts of future energy crises. For instance, Bernard A. Stewart wrote:

> By purely basing the economy on fossil fuels, the U.S. is establishing an unstable short-term "band aid" quick fix. The longer-term effect will be a greater reliance on imported fuels and ultimately an unstable economy at risk of foreign meddling. The time is now right to invest in alternative energies to ensure that an "energy mix" is in place to offset future crisis.

Several of the public comments that expressed an unfavorable opinion of EERE's programs were in agreement with EERE's vision; however, they had concerns that the program goals and objectives were inadequate to actually achieve the vision. For example, Thomas Bearden remarked:

> [The] objectives of the current energy efficiency and renewable energy research, development, demonstration and deployment programs [are] inadequate to do the job that is required if the escalating electricity demands are to be met, at anywhere near an economical price and in time to prevent severe repercussions on both the national economy and the global economy.

Thomas Miller also had an unfavorable view of EERE's programs because he felt they were insufficient to realize EERE's vision.

> I feel the majority of the efforts directed towards the building industry are failures, or at least a small fraction of what they could be. The future direction should be augmented by continuing education, and developing online tools to enable architects and engineers to make intelligent decisions regarding building orientation, fenestration placement and type, and materials. A life cycle approach must be instituted where design decisions can be evaluated and first costs

tempered by energy costs. Technology has reached critical penetration that give the Department of Energy an opportunity to leverage and mine the information produced in a project's lifecycle.

Programmatic Focus of Comments

EERE's mission is to lead the nation in the research, development, and deployment (RD&D) of both energy efficiency and renewable energy technologies. In the public comments, 70 percent of the commenters addressed both EERE's energy efficiency and renewable energy programs. Twenty-three percent focused exclusively on the renewable energy programs, while seven percent commented only on the energy efficiency programs.

Programmatic Focus		
	Comments	**Percentage**
RE & EE Programs	2,938	70%
Efficiency Programs Only	273	7%
Renewables Programs Only	950	23%

Programs and Subprograms Identified in Comments

In many of the public comments, specific EERE programs and/or subprograms were discussed. In all, 22 of EERE's 31 programs were addressed in the comments (see the complete list in the Program Table below). EERE's Solar Technology Program received the most public comments, with a total of 1,486 comments. The Wind Program was mentioned in the public comments the 2nd most often with 1,251 comments, while the Geothermal Program was mentioned the 3rd most often with 796 comments. Nine EERE programs were addressed in 500 or more public comments.

EERE Programs Identified			
Programs	**Number of Times**	**Programs**	**Number of Times**
Solar Technology	1,486	Distributed Energy Resources	123
Wind	1,251	Weatherization Assistance	116
Geothermal	796	FEMP	79
Energy Star	767	Industries of the Future	69
Advanced Vehicle R&D	689	Commercial Building Integration	69
Residential Building Integration	577	Biofuels	49
Hydrogen	551	Community Energy	17
Hydropower	545	HTS	10
Building Equipment & Materials	536	Advanced Automotive Techs.	7
Biomass	147	Materials Technologies (OTT)	6
State Energy Program	135	Heavy Vehicles	5

Two EERE subprograms were mentioned in 500 or more public comments (see the complete list in the Subprogram Table below). The Photovoltaics Subprogram, which is part of EERE's Solar Technologies Program, was mentioned the most often in the public comments. The Lighting Subprogram, which is part of EERE's Buildings Equipment and Materials Program, received the second largest number of comments. Three EERE subprograms were mentioned in about 150 public comments.

EERE Subprograms Identified

Subprogram	Number of Times	Subprogram	Number of Times
Photovoltaics	741	LIHEAP	14
Lighting	522	Energy Smart Schools	9
Concentrating Solar Power	147	NICE [3]	9
Solar Buildings	138	Brightfields	7
Fuel Cells	132	Industrial Assessment Centers	6
MSW	73	REPI	5
Building Codes and Standards	66	Metal Casting Vision	4
Rebuilding America	60	PVMAT	4
Best Practices	34	Motor Program	4
Inventions and Innovations	32	Agriculture Vision	3
Million Solar Roofs	20	Chemical Visions	1

Issues Discussed in Comments

The majority of public comments identified one or more issues that were of concern to them. In total, 70 issues were identified in the public comments reviewed. The 70 issues were classified into categories relevant to EERE and its strategic mission to the nation. For instance, one issue frequently identified in the public comments is the link between fossil fuels and air pollution. This issue was categorized under "Environment" because providing Americans with a cleaner environment is a key component of EERE's mission. The strategic categories used to classify the issues are as follows:

- Budget
- Economy
- Education
- Energy Security
- Environment
- Health
- Infrastructure
- Policy
- Program Management
- Reliability

EERE Strategic Issues	
Strategic Issues	**Number of Times**
Environment	8,273
Economy	3,809
Budget	3,410
Energy Security	2,308
Health	1,566
Policy	1,051
Program Management	756
Education	352
Infrastructure	162
Reliability	148

As shown in the accompanying table, the strategic category that received the most attention in the public comments was the environment.[1] (The complete list of Issues by Strategic Area can be seen on pages 10-11.) Within the Environmental Issues category, the issue of climate change was addressed most often with 2,031 public comments (47 percent), followed by the impact of nuclear waste on the environment with 1,705 public comments (40 percent) and the environment in general with 1,639 public comments (38 percent).

Issues related to the Economy received the second most attention in the public comments. Within the Economic Issues category, the two issues that received the most attention were America's reliance of a fossil fuel based economy, which was discussed by 1,174 public comments (27 percent), and the cost of energy, which was addressed in 1,079 public comments (25 percent).

Issues related to the Budget received the third most attention in the public comments. Within the Budget Issues category, the funding level of EERE programs was the issue addressed most often, with 78 percent of the comments discussing this issue (see the complete list of Issues ranked by order on pages 12-13.) .

Recommendations Provided in Comments

The majority of the public comments submitted on EERE's programs also made one or more recommendations to the Department. In total, 51 such recommendations were identified in the public comments. The 51 recommendations were classified into three areas of relevance to EERE:

- Budget Related
- Policy Related
- Program Management Related

Recommendation Areas	
Area	**Number of Times**
Policy Related	6,456
Budget Related	5,446
Program Management Related	782

(See the complete list of Recommendations by Area on pages 14-15.)

Ninety-one percent of the public comments supported increasing the funding level for EERE (see the complete list of recommendations ranked by order on pages 16-17). The recommendation suggested the next most often in the public comments also dealt with program funding issues , however, this recommendation called for reducing or eliminating funding for non-EERE

[1] The number is larger than the 4,279 comments reviewed in this report because some comments discussed more than one issue in a strategic category. For example, a lot of the comments that addressed the environmental issue *climate change* also addressed the environmental issue *air pollution*.

Programs (32 percent). The third, fourth, and fifth most commonly made recommendations dealt with policy issues and called for reducing air pollution, increasing CAFÉ standards, and reducing climate change, respectively (see the complete list of Recommendations rank ordered on pages 15-16).

Issues Grouped by Strategic Area	
Issues	**Number of Times Identified**
Budget - EERE Programs Funding Level	3,337
Budget - Consistency in Funding	53
Budget - Other Program Funding Level	20
Economy - America's Reliance on a Fossil-Based Economy	1,174
Economy - Cost of energy	1,079
Economy - Contribute to economic growth	622
Economy - America's reliance on nuclear power	464
Economy - Contribute to development of domestic clean energy industry	231
Economy (General)	157
Economy - International market opportunities	82
Education - EERE Information for the General Public	133
Education - EERE Information for Energy Professionals	90
Education (General)	49
Education - EERE Information and Schools	40
Education - EERE Information for Decision-Makers	24
Education - Federal Support for Advanced Studies of EERE Technologies	16
Energy Security - Dependence on Foreign Oil	735
Energy Security - Finite Supply of Fossil Fuels	624
Energy Security - Concerns About Nuclear Proliferation	509
Energy Security - Overpopulation	266
Energy Security (General)	170
Energy Secuirty - Vulnerability of Central Grid to Attack	4
Environment - Climate Change/CO2/Greenhouse Gases & Fossil Fuels	2,031
Environment - Impacts of Nuclear Waste	1,705
Environment (General)	1,639
Environment - Forests and Fossil Fuel	980
Environment - Water Pollution & Fossil Fuels	868
Environment - Air pollution & Fossil Fuels	606
Environment - Oil spills	347
Environment - Wildlife and Fossil Fuel	47
Environment - Fish and Dams/Hydropower	39
Environment - Athestics of Power Gen-Trans-Distri Equipment	6
Environment - Bird Fatalities and Wind Turbines	5

Issues Grouped by Strategic Area (cont'd)	
Issues	**Number of Times Identified**
Health (General)	946
Health - Pollution and Asthma	508
Health - Burning of Fossil Fuels is Hazardous to Health (general concern)	45
Health - Impacts of Nuclear Energy	33
Health - Pollution and Lung Cancer	14
Health - Nuclear Waste and Cancer	11
Health - Pollution and Brain Damage	5
Health - Pollution and Heart Attacks	4
Infrastructure (General)	42
Infrastructure - Inadequate of AFV Infrastructure	37
Infrastructure - Inadequate Electric Power Infrastructure	31
Infrastructure - Inadequate Natural Gas Infrastructure	29
Infrastructure - Difficulty Connecting New Energy Options to Grid	20
Infrastructure - Inadequate Oil Refining Capacity	3
Policy - Uneven Subsidies (fossil more subsidized than RE)	656
Policy - Big Oil/Big Money/Conventional Suppliers Driving Energy Policy	161
Policy - Businesses not large enough to conduct R&D on their own	82
Policy - Energy Efficiency Standards (General)	64
Policy (General)	48
Policy - Regulatory Burdens of Installing EE and RE Technologies	26
Policy - Electricity Industry Restructuring	11
Policy - Regulatory Burdens of Installing Power Plants & Transmission Lines	3
Prog. Mgmt. - Public-Private Partnerships	275
Prog. Mgmt. - Plan Energy Programs for the Long Term	151
Prog. Mgmt. - State/Local Programs	119
Prog. Mgmt. - Regional Collaboration	58
Prog. Mgmt. - EERE Programs Scope	55
Prog. Mgmt. - Challenge to Have Performance-Based R&D Programs	32
Prog. Mgmt. - (General)	18
Prog. Mgmt. - EERE Programs Not Performance Based	17
Prog. Mgmt. - Joint Agency Programs	16
Prog. Mgmt. - Challenge of Allocating Existing Resources	10
Prog. Mgmt. - Scope of EERE Programs to Narrow Scope	5
Reliability - (General)	82
Reliability - Power Outages	52
Reliability - Quality of Electricity	14

Issues Identified in Public Comments		
Name	**Number of Times Identified**	**Percentage**
Budget - EERE Programs Funding Level	3,337	77.99%
Environment - Climate Change/CO2/Greenhouse Gases & Fossil Fuels	2,031	47.46%
Environment - Impacts of Nuclear Waste	1,705	39.85%
Environment (General)	1,639	38.30%
Economy - America's Reliance on a Fossil-Based Economy	1,174	27.44%
Economy - Cost of energy	1,079	25.22%
Environment - Forests and Fossil Fuel	980	22.90%
Health (General)	946	22.11%
Environment - Water Pollution & Fossil Fuels	868	20.29%
Energy Security - Dependence on Foreign Oil	735	17.18%
Policy - Uneven Subsidies (fossil more subsidized than RE)	656	15.33%
Energy Security - Finite Supply of Fossil Fuels	624	14.58%
Economy - Contribute to economic growth	622	14.54%
Environment - Air pollution & Fossil Fuels	606	14.16%
Other	540	12.62%
Energy Security - Concerns About Nuclear Proliferation	509	11.90%
Health - Pollution and Asthma	508	11.87%
Economy - America's reliance on nuclear power	464	10.84%
Environment - Oil spills	347	8.11%
Prog. Mgmt. - Public-Private Partnerships	275	6.43%
Energy Security - Overpopulation	266	6.22%
Economy - Contribute to development of domestic clean energy industry	231	5.40%
Energy Security (General)	170	3.97%
Policy - Big Oil/Big Money/Conventional Suppliers Driving Energy Policy	161	3.76%
Economy (General)	157	3.67%
Prog. Mgmt. - Plan Energy Programs for the Long Term	151	3.53%
Education - EERE Information for the General Public	133	3.11%
Prog. Mgmt. - State/Local Programs	119	2.78%
Education - EERE Information for Energy Professionals	90	2.10%
Economy - International market opportunities	82	1.92%
Policy - Businesses not large enough to conduct R&D on their own	82	1.92%
Reliability (General)	82	1.92%
Policy - Energy Efficiency Standards (General)	64	1.50%
Prog. Mgmt. - Regional Collaboration	58	1.36%
Prog. Mgmt. - EERE Programs Scope	55	1.29%

Issues Identified in Public Comments (cont'd)		
Name	**Number of Times Identified**	**Percentage**
Budget - Consistency in Funding	53	1.24%
Reliability - Power Outages	52	1.22%
Education (General)	49	1.15%
Policy (General)	48	1.12%
Environment - Wildlife and Fossil Fuel	47	1.10%
Health - Burning of Fossil Fuels is Hazardous to Health (general concern)	45	1.05%
Infrastructure (General)	42	0.98%
Education - EERE Information and Schools	40	0.93%
Environment - Fish and Dams/Hydropower	39	0.91%
Infrastructure - Inadequate of AFV Infrastructure	37	0.86%
Health - Impacts of Nuclear Energy	33	0.77%
Prog. Mgmt. - Challenge to Have Performance-Based R&D Programs	32	0.75%
Infrastructure - Inadequate Electric Power Infrastructure	31	0.72%
Infrastructure - Inadequate Natural Gas Infrastructure	29	0.68%
Policy - Regulatory Burdens of Installing EE and RE Technologies	26	0.61%
Education - EERE Information for Decision-Makers	24	0.56%
Budget - Other Program Funding Level	20	0.47%
Infrastructure - Difficulty Connecting New Energy Options to Grid	20	0.47%
Prog. Mgmt. (General)	18	0.42%
Prog. Mgmt. - EERE Programs Not Performance Based	17	0.40%
Education - Federal Support for Advanced Studies of EERE Technologies	16	0.37%
Prog. Mgmt. - Joint Agency Programs	16	0.37%
Health - Pollution and Lung Cancer	14	0.33%
Reliability - Quality of Electricity	14	0.33%
Health - Nuclear Waste and Cancer	11	0.26%
Policy - Electricity Industry Restructuring	11	0.26%
Program Management - Challenge of Allocating Existing Resources	10	0.23%
Environment - Athestics of Power Gen-Trans-Distri Equipment	6	0.14%
Environment - Bird Fatalities and Wind Turbines	5	0.12%
Health - Pollution and Brain Damage	5	0.12%
Prog. Mgmt. - Scope of EERE Programs to Narrow Scope	5	0.12%
Energy Secuirty - Vulnerability of Central Grid to Attack	4	0.09%
Health - Pollution and Heart Attacks	4	0.09%
Infrastructure - Inadequate Oil Refining Capacity	3	0.07%
Policy - Regulatory Burdens of Installing New Power Plants and Transmission Lines	3	0.07%

Recommendations Organized by Areas		
Recommendation	**Number of Times**	**Percentage**
Budget - Increase EERE Funding Level	3,891	90.93%
Budget - Reduce or eliminate funding for non-EERE programs	1,372	32.06%
Budget (General)	69	1.61%
Budget - Multiyear Funding	47	1.10%
Budget - Support National Labs (non-defense)	39	0.91%
Budget - Allocate budget based on performance	28	0.65%
Prog. Mgmt. - Promote Public/Private Partnerships	251	5.87%
Prog. Mgmt. - Promote Federal/State/Local Partnerships	143	3.34%
Prog. Mgmt. - Expand outreach and educational programs	122	2.85%
Prog. Mgmt. - Expand Scope of EERE Program Research	74	1.73%
Prog. Mgmt. - Increase support of regional efforts	67	1.57%
Prog. Mgmt. - Perform Cost/Benefit Analysis of Existing Programs	44	1.03%
Prog. Mgmt. (General)	29	0.68%
Prog. Mgmt. - Pursue Joint Agency Programs	26	0.61%
Prog. Mgmt. - Review Decision-Making Processes	19	0.44%
Prog. Mgmt. - Draw Clear Distinction Between Research and Product Development	6	0.14%
Prog. Mgmt. - Implement Multi-year Programs	1	0.02%

Recommendations Organized by Areas (cont'd)		
Recommendation	**Number of Times**	**Percentage**
Policy - Reduce Air Pollutants	1,242	29.03%
Policy - Increase CAFE standards	1,161	27.13%
Policy - Reduce Climate Change (General)	931	21.76%
Policy - Increase Energy Efficiency Standards (General)	911	21.29%
Policy - Don't Drill in ANWR	624	14.58%
Policy - Tax Credits/Incentives/Subsidies for EERE technologies	344	8.04%
Policy - Expand EERE Deployment/Commercialization Activities	210	4.91%
Policy - Diversify Fuel Supply	168	3.93%
Policy - Renewable Portfolio Standard	127	2.97%
Policy - Expand AFV Infrastructure	93	2.17%
Policy - Reduce Climate Change by Advancing Clean Technologies	91	2.13%
Policy - Increase Building/Applliance Efficiency Standards	83	1.94%
Policy - Eliminate Tax Credits/Incentives/Subsidies for Coal, Oil and Nuclear R&D	79	1.85%
Policy (General)	61	1.43%
Policy - Give consumers choice for renewable power generation/Green Power	50	1.17%
Policy - Greater Use of Regulations to Advance EERE	49	1.15%
Policy - Support activities to advance DER	44	1.03%
Policy - Increase Building Efficiency Standards	33	0.77%
Policy - Adopt Interconnection Standards	26	0.61%
Policy - Establish public benefits fund for efficiency and renewables	20	0.47%
Policy - Comply with International Energy Standards	16	0.37%
Policy - Include Externalities in Price of Energy	15	0.35%
Policy - Streamline Regulatory Aspects	13	0.30%
Policy - Improve Transmission and Distribution Regulations	11	0.26%
Policy - Reduce Climate Change through Cap and Trade Initiatives	11	0.26%
Policy - Repeal Price-Andersen Act	10	0.23%
Policy - Allow marketplace to find solutions	8	0.19%
Policy - Support husbandry (Greening of America)	7	0.16%
Policy - Modify labeling laws	6	0.14%
Policy - Support Development of Clean Coal	6	0.14%
Policy - Excess Profit Legislative Bills for Electric Utilities	3	0.07%
Policy - Reduce Climate Change through Voluntary Programs	3	0.07%

Recommendations Identified in Public Comments		
Recommendations	**Number of Times**	**Percentage**
Budget - Increase EERE Funding Level	3,891	90.93%
Budget - Reduce or eliminate funding for non-EERE programs	1,372	32.06%
Policy - Reduce Air Pollutants	1,242	29.03%
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Policy - Increase Energy Efficiency Standards (General)	911	21.29%
Policy - Don't Drill in ANWR	624	14.58%
Policy - Tax Credits/Incentives/Subsidies for EERE technologies	344	8.04%
Prog. Mgmt. - Promote Public/Private Partnerships Cost and/or Information Sharing	251	5.87%
Policy - Expand EERE Deployment/Commercialization Activities	210	4.91%
Policy - Diversify Fuel Supply	168	3.93%
Prog. Mgmt. - Promote Federal/State/Local Partnerships	143	3.34%
Policy - Renewable Portfolio Standard	127	2.97%
Prog. Mgmt. - Expand outreach and educational programs	122	2.85%
Policy - Expand AFV Infrastructure	93	2.17%
Policy - Reduce Climate Change by Advancing Clean Technologies	91	2.13%
Policy - Increase Building/Applliance Efficiency Standards	83	1.94%
Policy - Eliminate Tax Credits/Incentives/Subsidies for Coal, Oil and Nuclear R&D	79	1.85%
Prog. Mgmt. - Expand Scope of EERE Program Research	74	1.73%
Budget (General)	69	1.61%
Prog. Mgmt. - Increase support of regional efforts	67	1.57%
Other	66	1.54%
Policy (General)	61	1.43%
Policy - Give consumers choice for renewable power generation/Green Power	50	1.17%
Policy - Greater Use of Regulations to Advance EERE	49	1.15%
Budget - Multiyear Funding	47	1.10%
Prog. Mgmt. - Perform Cost/Benefit Analysis of Existing Programs	44	1.03%
Policy - Support activities to advance DER	44	1.03%
Budget - Support National Labs (non-defense)	39	0.91%

Recommendations Identified in Public Comments (cont'd)		
Recommendations	**Number of Times**	**Percentage**
Policy - Increase Building Efficiency Standards	33	0.77%
Prog. Mgmt. (General)	29	0.68%
Budget - Allocate budget based on performance	28	0.65%
Prog. Mgmt. - Pursue Joint Agency Programs	26	0.61%
Policy - Adopt Interconnection Standards	26	0.61%
Policy - Establish public benefits fund for efficiency and renewables	20	0.47%
Prog. Mgmt. - Review Decision-Making Processes	19	0.44%
Policy - Comply with International Energy Standards	16	0.37%
Policy - Include Externalities in Price of Energy	15	0.35%
Policy - Streamline Regulatory Aspects	13	0.30%
Policy - Reduce Climate Change through Cap and Trade Initiatives	11	0.26%
Policy - Improve Transmission and Distribution Regulations	11	0.26%
Policy - Repeal Price-Andersen Act	10	0.23%
Policy - Allow marketplace to find solutions	8	0.19%
Policy - Support husbandry (Greening of America)	7	0.16%
Policy - Support Development of Clean Coal	6	0.14%
Prog. Mgmt. - Draw Clear Distinction Between Research and Product Development	6	0.14%
Policy - Modify labeling laws	6	0.14%
Policy - Reduce Climate Change through Voluntary Programs	3	0.07%
Policy - Excess Profit Legislative Bills for Electric Utilities	3	0.07%
Prog. Mgmt. - Implement Multi-year Programs	1	0.02%

Appendix I: Federal Register Notice

[Federal Register: June 11, 2001 (Volume 66, Number 112)]
[Notices]
[Page 31224-31226]
From the Federal Register Online via GPO Access [wais.access.gpo.gov]
[DOCID:fr11jn01-47]

DEPARTMENT OF ENERGY

Office of Energy Efficiency and Renewable Energy

National Energy Policy; Announcement of Public Meetings

AGENCY: Office of Energy Efficiency and Renewable Energy, DOE.

ACTION: Notice of public meetings and request for comments.

SUMMARY: The recently-released National Energy Policy (NEP) recommended a review of current funding and historic performance of the Department of Energy's Office of Energy Efficiency and Renewable Energy programs. To facilitate this review, Department of Energy senior officials will receive public comments on the programs in seven regional meetings during the month of June. Comments should address: (1) The objectives of the current energy efficiency and renewable energy research, development, demonstration and deployment programs, (2) suggested potential objectives for future programs, (3) implementation of current and future programs, and (4) whether these Federal programs are achieving intended objectives.

DATES: Written comments will be accepted and must be submitted to the Department of Energy no later than 5:00 p.m. EDT, June 29, 2001. See SUPPLEMENTARY INFORMATION section for meeting dates.

ADDRESSES: Comments may be sent to: Ms. Bonny Overton, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, EE 3.1, 1000 Independence Avenue, SW., Washington, DC 20585, or e-mail to EERENEP.comments@ee.doe.gov. To accommodate as many individuals as possible, each speaker will be limited to five minutes. In the event that time does not permit all individuals who would like to comment, several other options are available to receive public input. Forms will be available at each location to provide hand-written comments. Written comments will be accepted and must be submitted to the Department of Energy no later than 5 p.m. EDT, June 29, 2001. Written comments should be no more than four single spaced pages, using 12 pitch font and 1 inch margins. All written comments will be included in the proceedings of the seven public meetings. The Department of Energy also invites their federal partners to submit written comments. Copies of the National Energy Plan can be found on the web at www.**energy**.gov. For further information about EERE programs, please visit www.EREN.doe.gov.

FOR FURTHER INFORMATION CONTACT: Nancy Jeffery, 202-586-9373.

SUPPLEMENTARY INFORMATION: The following public meetings will be held from 9 a.m. to 9 p.m. From 9 a.m.-10 a.m., the Department will receive comments from public officials only.

June 12--Atlanta, Georgia--Location: Main Auditorium (Lower Level), Richard B. Russell Federal Building and Courthouse, 75 Spring Street SW, Atlanta, GA 30303
June 12--Chicago, Illinois--Location: James Benton Parson Memorial Court Room Dirksen Federal Building, Room 2525, 219 South Dearborn Street, Chicago, Illinois 60604
June 19--Boston, Massachusetts--Location: John A. Volpe National Transportation Systems Center, 55 Broadway, Kendall Square, Cambridge, MA 02142-1093
June 19--Seattle, Washington--Location: Bell Harbor International Conference Center International Promenade room, Pier 66, 2211 Alaskan Way, Seattle, WA 98121-1604
June 21--Denver, Colorado--Location: Adam's Mark Hotel Denver, 1550 Court Place Denver, Colorado 80202
June 21--Philadelphia, Pennsylvania--Location: Myerson Auditorium, 210 South 34th Street, Philadelphia, PA 19104
June 26--Washington, D.C.--Location: Washington Hilton and Towers, 1919 Connecticut Avenue, Washington, DC

Office of Energy Efficiency and Renewable Energy--List of programs

Building Equipment and Materials

The mission of the Buildings Equipment and Materials Program is to advance affordable energy efficiency improvements in building equipment and materials through a targeted program of industry cost-shared research and regulatory options.

Commercial Buildings Integration

The mission of the Commercial Buildings Integration Program is to develop new whole-building technologies and building design and operation strategies that will reduce overall energy needs and improve the quality of building energy services, including voluntary consensus building energy codes and mandatory codes for Federal buildings.

Community Energy Program

The Community Energy Program provides technical assistance, demonstrations, training, and education to communities to accelerate the use of innovative and cost-effective energy technologies, strategies, and methods. The program helps communities, towns, and cities save energy, create jobs, promote economic growth, and protect the environment through improved energy efficiency and less energy intensive building design and operation.

Energy Star Program

Using the ENERGY STAR symbol as the primary tool, identify and promote high efficiency consumer products and buildings; in partnership with EPA, manufacturers, retailers, utilities, and builders.

Residential Buildings Integration

In partnership with homebuilders, industry, States, and communities, the Residential Buildings Integration Program improves the energy efficiency in new and existing homes through R&D, demonstrations, and regulatory strategies.

State Energy Program

The State Energy Program (SEP) mission is to support States' effective, flexible capacity to promote the use of energy efficiency and renewable energy strategies for meeting energy needs in both the near and long-term future.

Weatherization Assistance Program

The Weatherization Assistance Program works to maximize the number of low-income households receiving cost-effective, energy efficient improvements while ensuring the health and safety of people served.

DUET

The Departmental Energy Management Program is administered by the Federal Energy Management Program's (FEMP) Departmental Utility and Energy Team (DUET). DUET targets FEMP services at DOE facilities to improve energy and water efficiency, promote renewable energy use, and manage utility costs in DOE's facilities and operations.

FEMP

The Office of Federal Energy Management Programs (FEMP) reduces the cost and environmental impact of the Federal government by advancing energy efficiency and water conservation, promoting the use of renewable energy, and assisting federal facilities in managing utility costs and operations, including those of the Department of Energy.

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Enabling Technologies

The Industries of the Future (Crosscutting) Initiative works with IOF industry partners and suppliers to conduct cost-shared R&D on technologies that have potential applications across the nine vision industries as well as provide the immediate tools and technical assistance industry needs to expedite the implementation of energy-efficient, clean manufacturing technologies.

Financial Assistance

The OIT Financial Assistance Program helps independent inventors, small businesses, and industry who may lack the funds and/or know-how to move promising energy-saving and energy production technologies from the research bench to the marketplace.

Industrial Technology Assistance

The Industries of the Future (Crosscutting) Initiative works with IOF industry partners and suppliers to conduct cost-shared R&D on technologies that have potential applications across the nine vision industries as well as provide the immediate tools and technical assistance industry needs to expedite the implementation of energy-efficient, clean manufacturing technologies.

Vision Industries

The Industries of the Future (IOF) program develops and delivers advanced technologies and best practices to improve the energy efficiency and environmental performance of America's most energy-and waste-intensive industries. To provide the best value and optimum use of public investments, the IOF program focuses on nine major U.S. industries that account for roughly 75 percent of industrial energy use and over 75 percent of manufacturing wastes (aluminum, agriculture, chemicals, forest products, glass, metal casting, mining, steel, and petroleum).

BioPower

In partnership with industry, the Biopower Program will assist the development and utilization of biopower technologies that are clean and reliable, and competitive with conventional power systems

Distributed Energy Resources

The Distributed Energy Resources (DER) Program leads a national effort to develop and integrate the ``next generation'' of clean, efficient, reliable, and affordable distributed energy technologies; document the energy, economic, and environmental benefits of the expanded use of distributed energy resources and widely disseminate the findings; and implement deployment strategies, including national and international standards, that address infrastructure, energy delivery, institutional, and regulatory needs.

Geothermal Energy

The Geothermal Technology Development Program works in partnership with U.S. industry to establish geothermal energy as an economically competitive contributor to the U.S. energy supply, capable of meeting a large portion of the Nation's heat and power needs.

High Temperature Superconductivity

The High Temperature Superconductivity (HTS) R&D program investigates the properties of crystalline materials that become free of electrical resistance at the temperature of liquid nitrogen. The lack of electrical resistance makes possible electrical power systems, super-efficient generators, transformers, and transmission cables, that reduce energy losses by half and allow equipment to be half the size of present electrical systems.

Hydrogen

The mission of the Hydrogen Program is to support the research, development and validation of hydrogen technologies in production, storage and utilization. These technologies will facilitate the use of renewable energy resources, improve electrical reliability using distributed fuel cell power systems, and reduce the Nation's dependence on imported fossil fuels in the electric power generation and transportation sectors.

Hydropower

The Hydropower Program improves the technical, economic, and environmental performance of the Nation's abundant, in-place hydropower resources through collaborative research and development with industry and other Federal agencies.

International Programs

Provide diplomatic support to catalyze markets, provide technical assistance, and support U.S. Native American Tribal community on a ``government to government'' basis.

Solar Technologies

The Office of Solar Energy Technologies sponsors research and development (R&D) that improves the performance and reliability while reducing the cost of solar technologies that can harness the sun's energy.

Wind Energy

The Program focuses on completing the research, testing, and field verification needed by U.S. industry to fully develop advanced wind energy technologies, and on coordinating with partners and stakeholders to overcome barriers to wind energy use.

Advanced Combustion Engine R&D

The Advanced Combustion Engine R& D program develops technologies that will significantly improve the fuel efficiency of conventional piston engines while cost-effectively meeting projected emissions regulations.

Biofuels

The Biofuels Program funds research, development, and demonstration of technology to enable and support the expansion of an indigenous, integrated biomass-based industry that will reduce reliance on imported fuels; promote rural economic development; and provide for productive utilization of agricultural residues and municipal solid wastes.

Electric Vehicles R&D

The Electric Vehicles R& D program develops and validates advanced electric vehicle battery technologies that will enable full-range electric vehicles and facilitate their commercial viability.

Fuel Cell R&D

The Fuel Cell R& D Program develops highly-efficient, low and zero emission, cost-competitive vehicle fuel cell power system technologies that operate on conventional and alternative fuels.

Fuels Utilization R&D

The Fuels Utilization R&D Program, along with partners in the energy and transportation industries, pursues R&D that will provide transportation vehicles with fuel options that are cost competitive, achieve high fuel economy, and deliver low emissions.

Heavy Vehicle Systems R&D

The Heavy Vehicle Systems R&D Program sets performance targets for components and subsystems in the context of the heavy vehicle as an integrated system, and validates achievements of vehicle-level OTT objectives.

Hybrid Systems R&D

The Hybrid Systems R&D program develops advanced propulsion and ancillary system components and tests and validates them in a vehicle context.

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Materials Technologies

The Materials Technologies Program supports the development of the cost-effective materials and materials manufacturing processes necessary to successfully commercialize the next generation of fuel-efficient, low-emission transportation vehicles.

Transportation Technology Assistance

The Transportation Technology Assistance Program accelerates the adoption and use of alternative-fuel and advanced-technology vehicles to help meet national energy and environmental goals.

Issued in Washington, DC on June 5, 2001.
John Sullivan,
Acting Deputy Assistant Secretary, Office of Planning, Budget and Management, Office of Energy Efficiency and Renewable Energy.
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BILLING CODE 6450-01-P

Appendix II - Methodology

The findings are based on a review of 4,279 public comments submitted to the Department of Energy. EERE received 457 of these comments at the seven public meetings that were held across the country in the month of June. The remaining 3,822 comments were submitted to EERE through either e-mail or postal mail. The Department received 11 form letters, each written by a different organization and signed by the participants of the form letter. In total, the form letters accounted for 53 percent of the public comments (2,266) reviewed in this summary report. The information from each comment was extracted into the following categories:

1. Commenter name
2. Organization name (if any)
3. Type of organization
    - Public
    - Private
    - NGO
    - Citizen
    - Other
4. City of public meeting
    - Atlanta
    - Boston
    - Chicago
    - Denver
    - Philadelphia
    - Seattle
    - Washington
5. Overall impression of EERE Programs
    - Favorable
    - Unfavorable
    - No Opinion Provided
6. Program Area Focus
    - Efficiency & renewables programs
    - Efficiency programs
    - Renewables programs
7. Name(s) of specific EERE programs/subprograms discussed
8. Issue(s) addressed in comment
9. Recommendation(s) presented in comment

After each comment was reviewed, information presented in the comment was entered into a database that contained the 9 categories mentioned above. The data for this preliminary report were compiled by summing the information in the public comments database.

In some cases, a public comment did not present information for a particular category so the database field for this category was left blank. For instance, if the public comment did not provide enough information to determine if the commenter's overall attitude toward EERE's programs was favorable or unfavorable, this category was left blank. As such, even though 4,279 public comments were reviewed, some categories in the database have data for fewer than this number. For example, 70 public comments did not provide enough information to determine the respondent's overall attitude toward EERE's programs, and therefore there are data on 4,209 comments for this category, not 4,279.

After the data were summed, 111 comments were randomly selected for a second review to assess the reliability of the content analysis for the following categories: overall impression of EERE program, program area focus, names of specific EERE programs/subprograms discussed, issues addressed in comment, and recommendations presented in comment. The level of agreement between the two reviews of the 111 randomly selected comments was:

- 100% - Overall impression of EERE programs[2]
- 92% - Program area focus
- 95% - Name(s) of specific EERE programs/subprograms discussed
- 88% - Issue(s) addressed in comment
- 89% - Recommendation(s) presented in comment

In other words, if someone else were to review all 4,279 public comments they may arrive at slightly different totals than were found in this review. Using the percentages from the sample above, the S*olar Technologies* program might be identified with between 1,412 and 1,560 comments (i.e., plus or minus 5 percent of the 1,486 found in this review). Likewise, a second review might find that between 1,105 and 1,379 comments recommended reducing air pollutants (plus or minus 11 percent of the 1,242 found in this review).

[2] The finding that the level of agreement in this category was 100 percent is a byproduct of the fact that a large percentage of commenters (98 percent) had an overall favorable impression of EERE programs and less than 5 percent of the public comments were reviewed for the reliability assessment. We assume that if a large percentage of the public comments were reviewed a second time, the level of agreement would be slightly less than 100 percent.

APPENDIX B

EERE ALIGNMENT WITH THE NATIONAL ENERGY POLICY

The Tables below indicate the alignment between EERE programs and EERE-relevant National Energy Policy Recommendations. A discussion of these issues is provided in Chapter 3.

Figure B-1: EERE Programs v. EERE-Relevant National Energy Policy (2001) Recommendations

PROGRAM	1.1	1.2	1.3	2.1	2.3	2.4	2.5	2.6a	2.6b	3.1a	3.1b	3.1c	3.1d	3.3	4.1	4.2	4.3a	4.3b	4.3c	4.4a	4.4b	4.5	4.6	4.7	4.8
POWER																									
DER	X	X	X				X	X	X	X	X			X	X								X	X	X
Superconductivity	X	X	X																						
Hydrogen	X	X	X							X	X	X	X	X										X	
Wind	X	X	X	X			X			X	X	X	X	X										X	
Solar	X	X	X							X	X	X	X	X										X	
Geothermal	X	X	X	X			X			X	X	X	X	X										X	
Hydropower	X	X	X							X	X	X	X											X	
International	X	X	X																						
Biopower	X	X	X				X			X	X	X	X											X	
BUILDINGS																									
Residential Buildings Integration	X	X	X	X			X								X		X		X						
Commercial Buildings Integration	X	X	X	X											X		X		X						
Building Equipment and Materials	X	X	X												X					X	X				
Weatherization Assistance		X	X	X	X	X	X								X				X						
State Energy Program		X	X	X		X	X	X							X				X					X	
Community Energy Program		X	X	X			X								X				X					X	
Energy Star Program		X	X	X											X		X	X	X						
FEMP																									
FEMP	X	X	X	X					X						X				X			X			
DEMP	X	X	X												X				X			X			
INDUSTRY																									
Vision Industries	X	X	X							X	X	X	X	X	X										
Enabling Technologies	X	X	X												X										
Industrial Technology Assistance	X	X	X	X						X	X	X	X		X								X		
Financial Assistance	X	X	X												X										
TRANSPORTATION																									
Hybrid Systems R&D	X	X	X												X										
Fuel Cell R&D	X	X	X												X										
Advanced Combustion Engine R&D	X	X	X												X										
Electric Vehicle R&D	X	X	X												X										
Heavy Vehicle Systems R&D	X	X	X												X										
Fuels Utilization	X	X	X												X										
Materials Technologies	X	X	X												X										
Transport. Technology Assistance	X	X	X	X											X										
Biofuels	X	X	X												X										
PLANNING BUDGET MGMT																									
Planning	X	X	X							X	X	X	X	X	X	X				X	X				
Outreach	X	X	X					X	X	X	X	X	X		X				X						
Regional Offices	X	X	X	X			X		X					X	X									X	X

PROGRAM	4.9a	4.9b	4.9c	4.10	4.11	4.12a	4.12b	4.12c	4.13	4.14	4.15	5.5	5.10	5.11	5.17a	5.17b	5.17c	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.10	6.11a
POWER																										
DER									■				■	■								■				■
Superconductivity													■	■				■				■				■
Hydrogen													■					■				■				■
Wind												■	■	■								■	■			■
Solar													■	■								■		■		■
Geothermal												■	■								■	■				■
Hydropower													■		■	■	■	■				■				
International																						■				
Biopower													■					■		■		■	■		■	■
BUILDINGS																										
Residential Buildings Integration											■															
Commercial Buildings Integration																										
Building Equipment and Materials											■															
Weatherization Assistance											■															
State Energy Program											■											■				
Community Energy Program											■											■				
Energy Star Program											■															
FEMP																										
FEMP																										
DEMP																										
INDUSTRY																										
Vision Industries																										
Enabling Technologies																										
Industrial Technology Assistance																										
Financial Assistance																										
TRANSPORTATION																										
Hybrid Systems R&D					■																					
Fuel Cell R&D					■		■																			
Advanced Combustion Engine R&D					■				■																	
Electric Vehicle R&D					■																					
Heavy Vehicle Systems R&D					■			■	■																	
Fuels Utilization	■	■	■		■		■	■	■																	
Materials Technologies					■																					
Transport. Technology Assistance	■	■	■	■	■	■	■	■	■																	
Biofuels			■		■																				■	■
PLANNING BUDGET MGMT																										
Planning										■		■			■	■	■	■	■	■	■	■	■	■	■	■
Outreach											■	■			■	■	■									
Regional Offices											■															

PROGRAM	6.11b	6.11c	6.12	6.13	7.1	7.2	7.4a	7.4b	7.4c	7.9	7.11	7.12	7.13	8.1	8.3	8.4	8.5	8.7	8.10	8.11	8.12	8.24	8.25	8.26	8.28
POWER																									
DER	■			■	■	■	■	■	■		■	■										■	■		
Superconductivity					■	■	■																■		
Hydrogen	■	■																					■		
Wind																						■	■		
Solar						■	■															■	■		
Geothermal																		■				■	■		
Hydropower																							■		
International														■	■	■	■	■	■	■	■	■	■		
Biopower											■	■							■	■		■	■		
BUILDINGS																									
Residential Buildings Integration							■		■														■		
Commercial Buildings Integration							■		■														■		
Building Equipment and Materials							■		■														■		
Weatherization Assistance																							■		
State Energy Program													■										■		
Community Energy Program													■										■		
Energy Star Program																							■		
FEMP																									
FEMP																							■		
DEMP																							■		
INDUSTRY																									
Vision Industries											■	■											■		
Enabling Technologies							■																■		
Industrial Technology Assistance																						■	■		
Financial Assistance																							■		
TRANSPORTATION																									
Hybrid Systems R&D	■		■																			■	■	■	
Fuel Cell R&D	■		■																				■	■	
Advanced Combustion Engine R&D			■																				■	■	
Electric Vehicle R&D	■																						■	■	
Heavy Vehicle Systems R&D																							■	■	
Fuels Utilization	■		■							■								■				■	■	■	
Materials Technologies																		■				■	■	■	
Transport. Technology Assistance			■							■								■				■	■	■	
Biofuels	■									■													■	■	
PLANNING BUDGET MGMT																									
Planning	■	■	■	■			■	■	■					■	■	■	■	■	■	■	■	■	■	■	■
Outreach											■	■	■										■		
Regional Offices										■			■										■		

Appendix C

Historic Budgets

The following graphs depict the historic budgets of the EERE programs. The programs themselves are discussed in the chapters of the report.

Figure C-1: Office of Energy Efficiency and Renewable Energy
Historic Budget Breakout: FY 1980 - 2002
(Millions of 1999 Dollars)

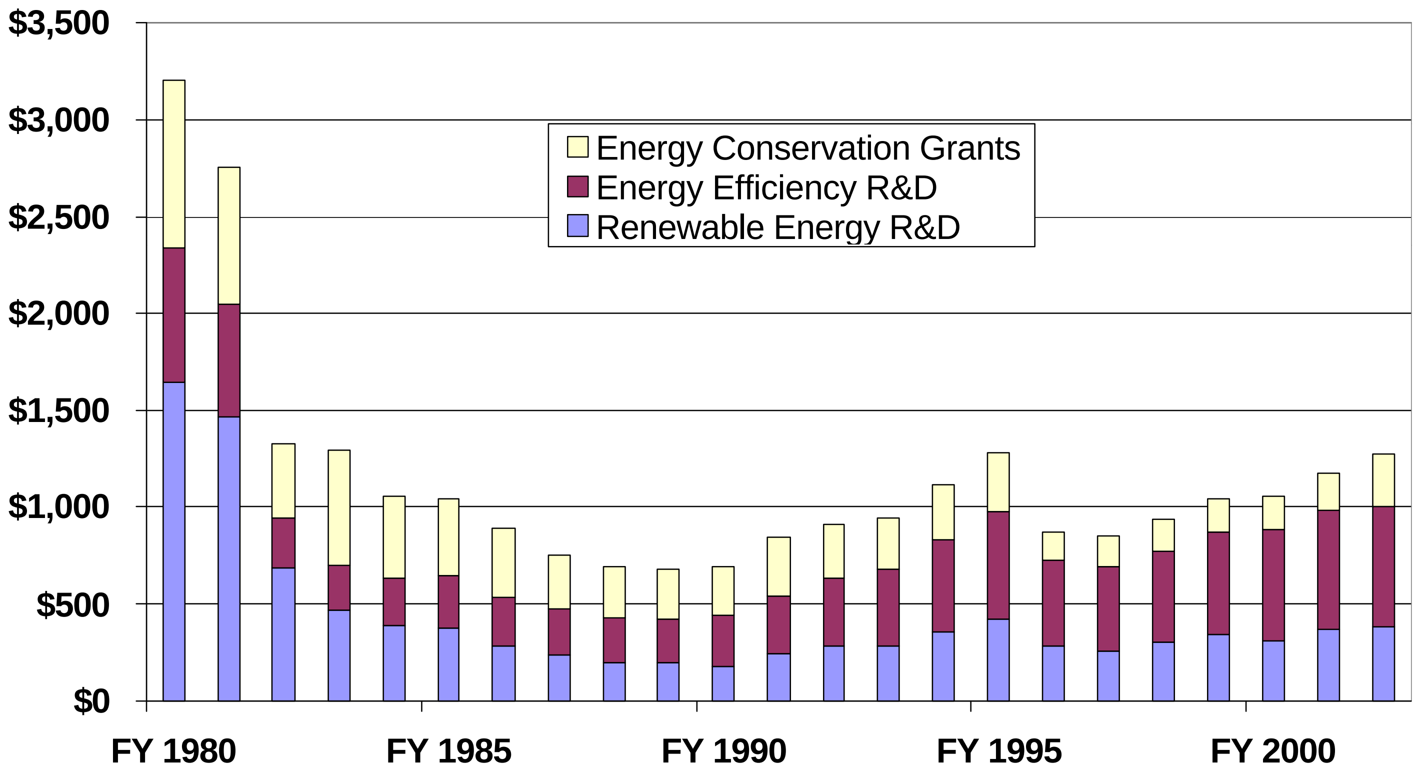


Figure C-2: Office of Energy Efficiency and Renewable Energy Budget
FY 1980 - FY 2002
(Millions of Current Dollars)

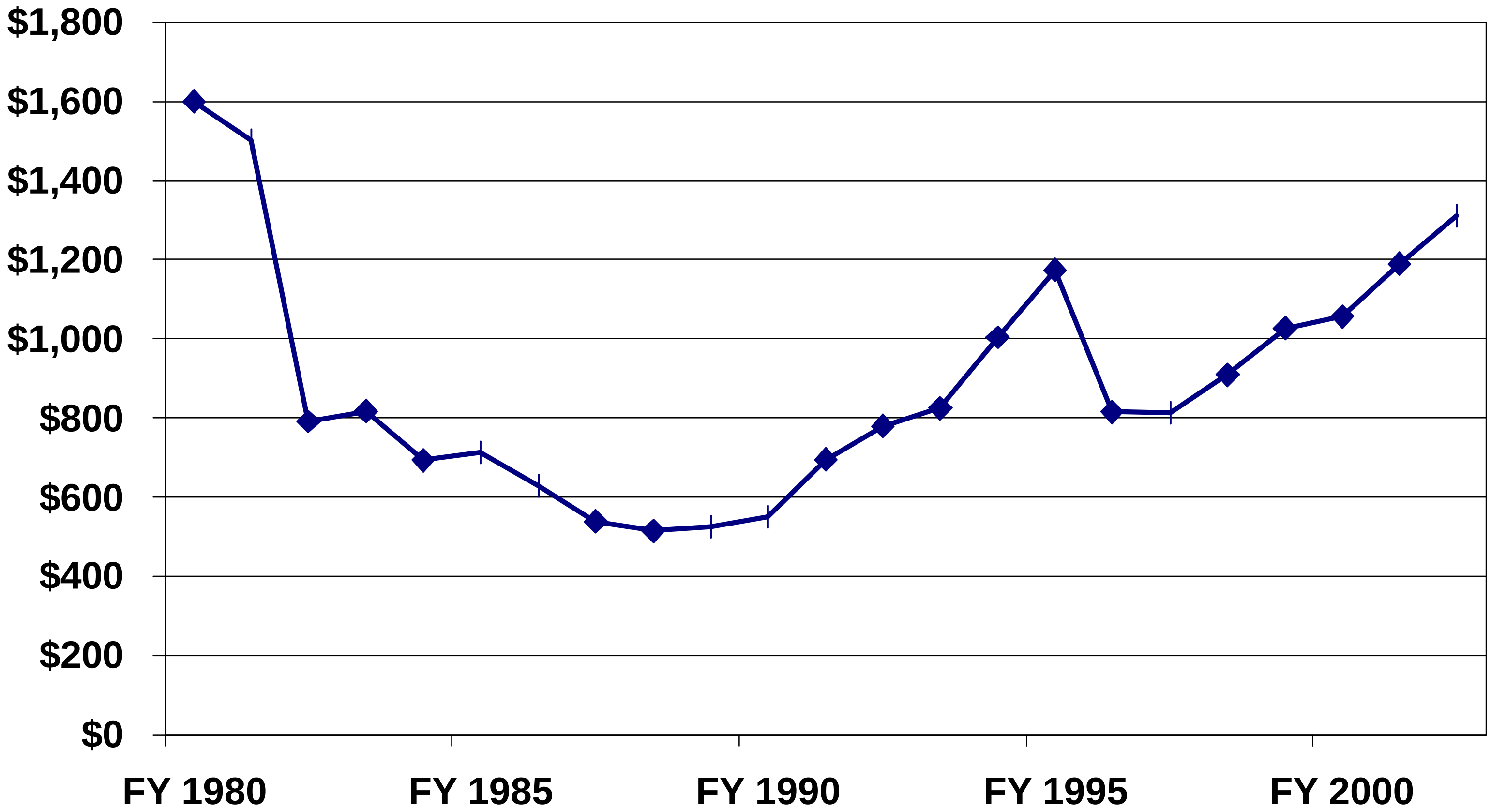


**Figure C-3: Office of Energy Efficiency and Renewable Energy Budget
FY 1980 - FY 2002
(Millions of 1999 Dollars)**

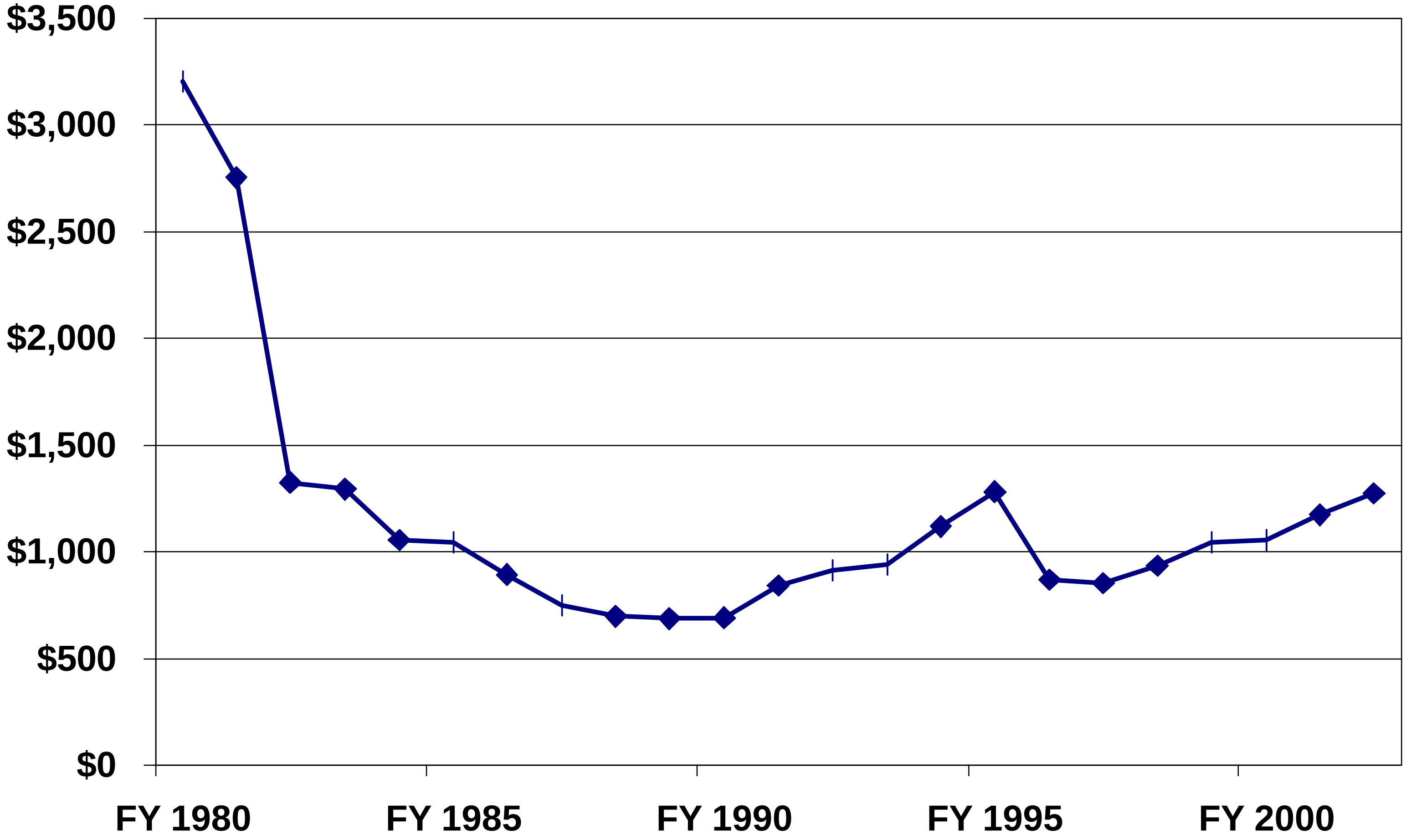


Figure C-4: Office of Energy Efficiency and Renewable Energy R&D Budget (excludes Grants): FY 1980 - FY 2002 (Millions of Current Dollars)

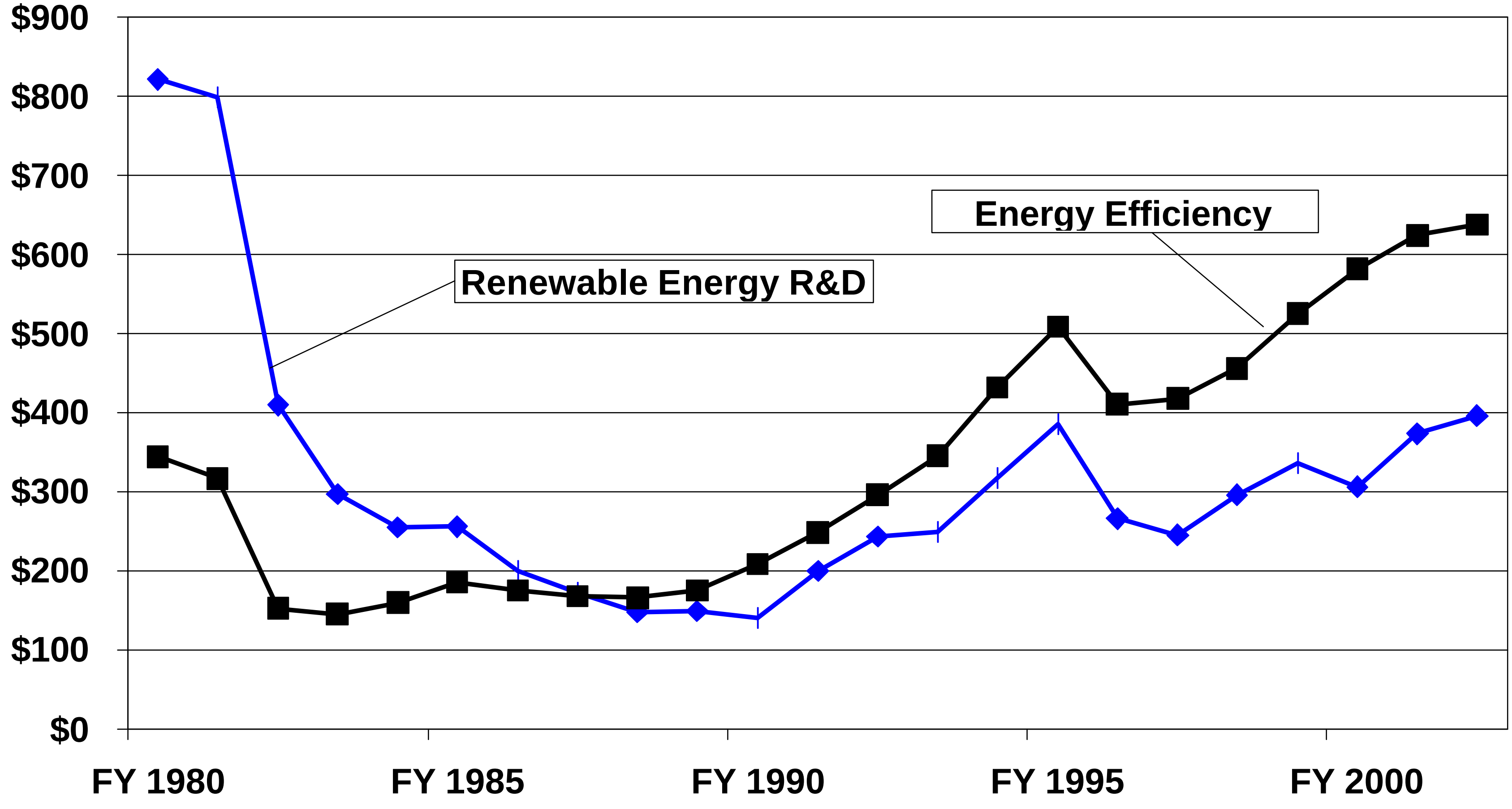


Figure C-5: Office of Energy Efficiency and Renewable Energy R&D Budget (excludes Grants): FY 1980 - FY 2002 (Millions of 1999 Dollars)

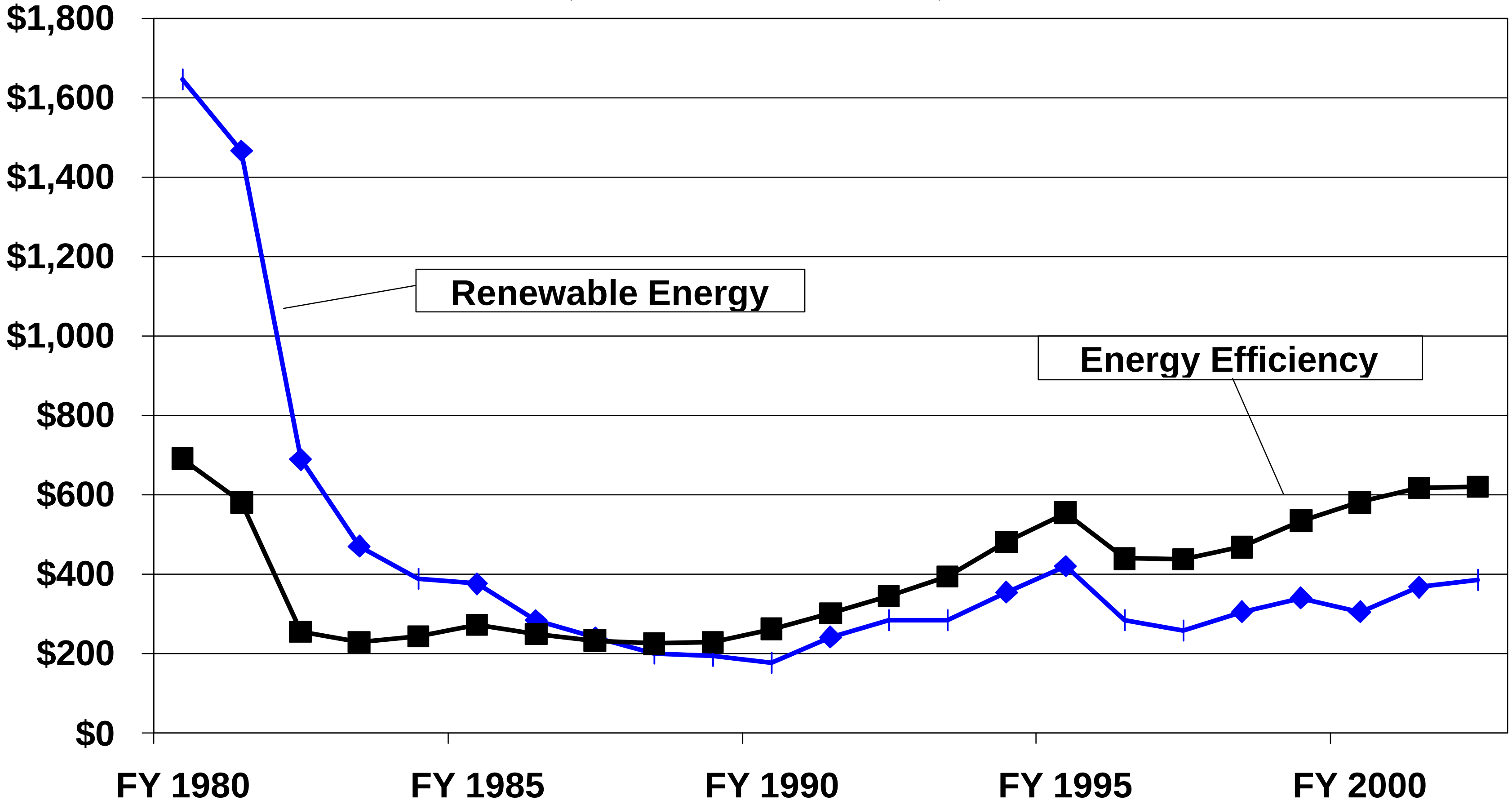


Figure C-6: Office of Energy Efficiency and Renewable Energy R&D and Grants Budget: FY 1980 - FY 2002 (Millions of Current Dollars)

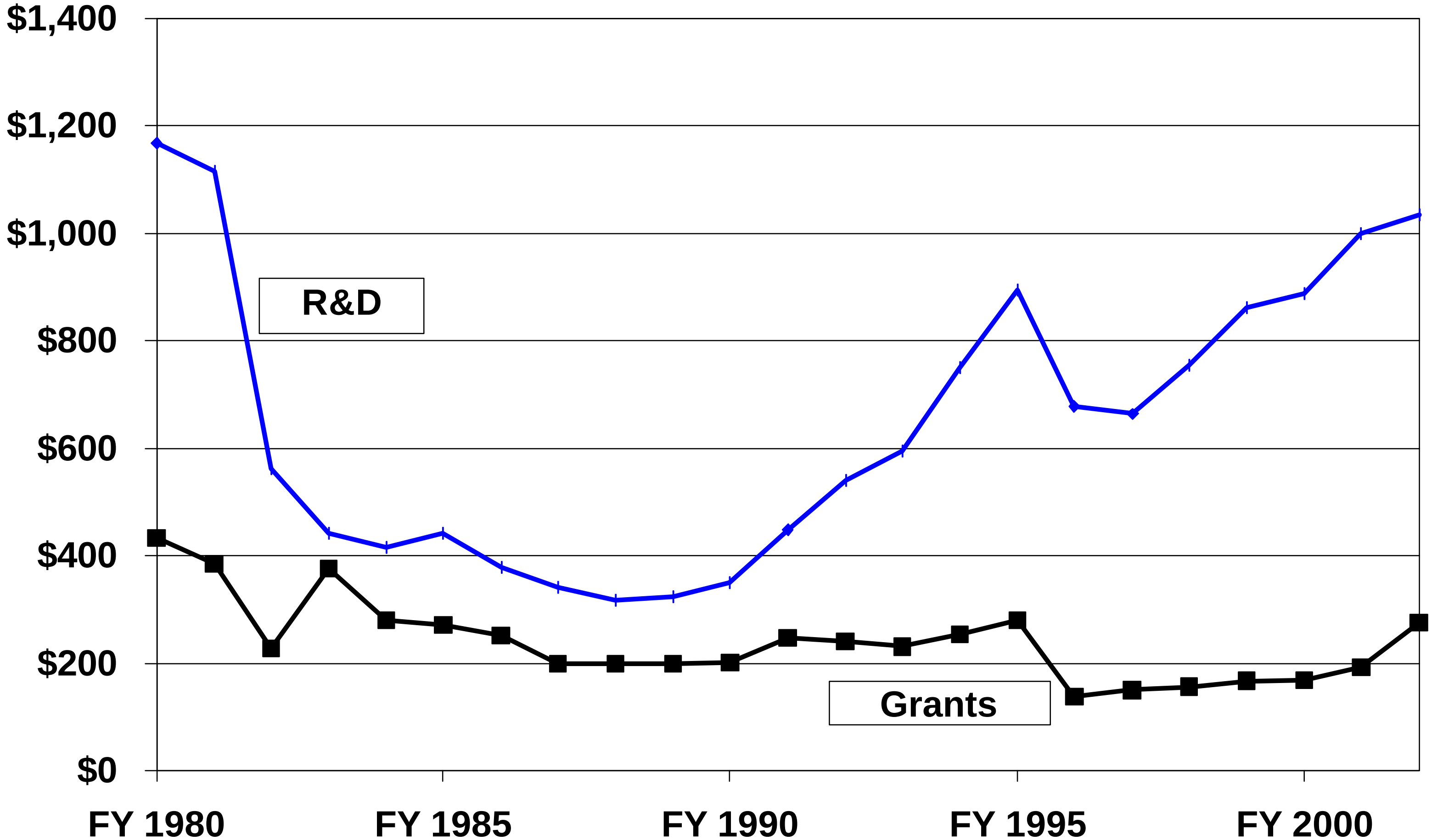
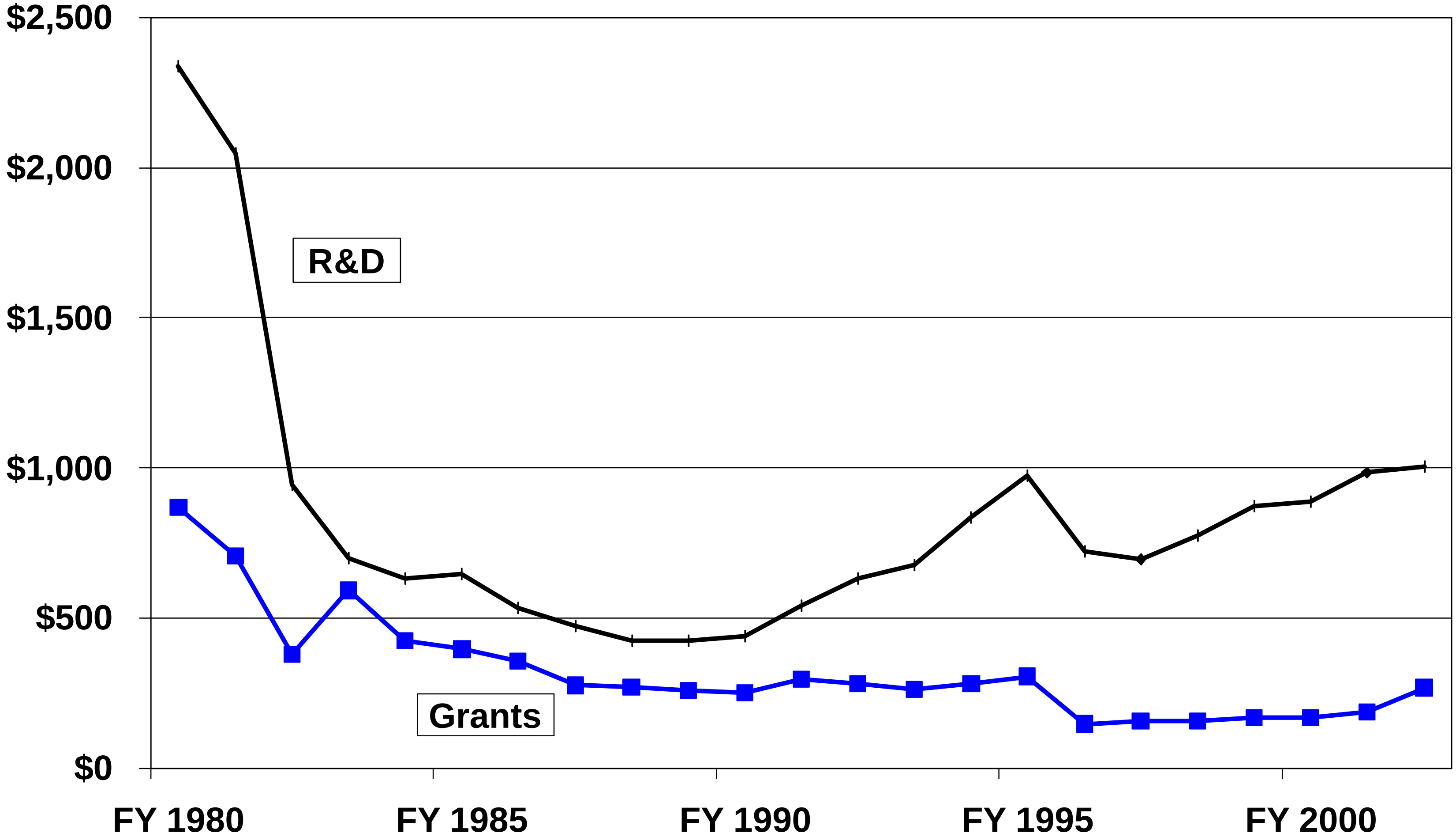


Figure C-7: Office of Energy Efficiency and Renewable Energy R&D and Grants Budget: FY 1980 - FY 2002 (Millions of 1999 Dollars)



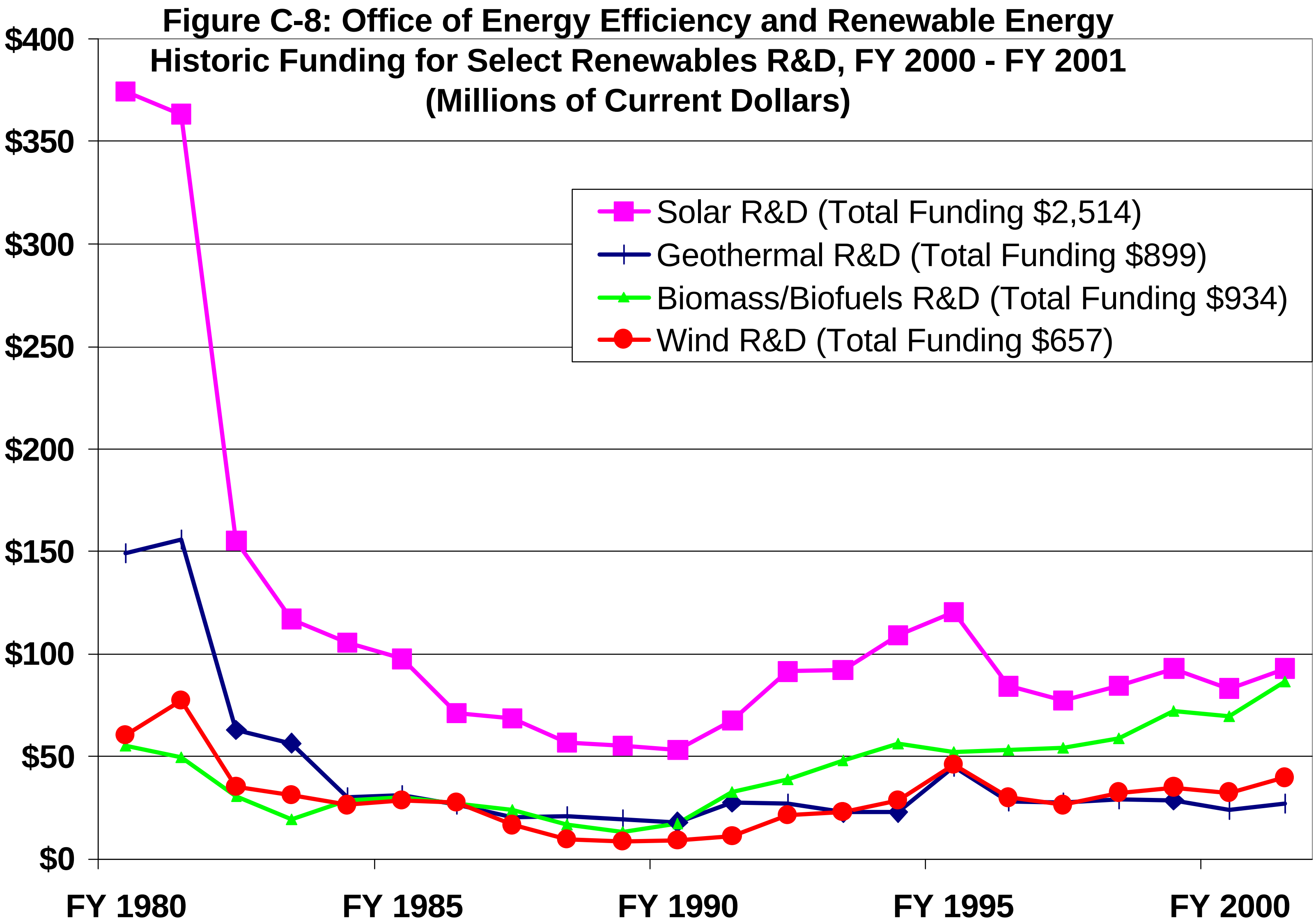


Figure C-8: Office of Energy Efficiency and Renewable Energy
Historic Funding for Select Renewables R&D, FY 2000 - FY 2001
(Millions of Current Dollars)
$400
$350
$300
$250
$200
$150
$100
$50
$0
Solar R&D (Total Funding $2,514)
Geothermal R&D (Total Funding $899)
Biomass/Biofuels R&D (Total Funding $934)
Wind R&D (Total Funding $657)
FY 1980
FY 1985
FY 1990
FY 1995
FY 2000

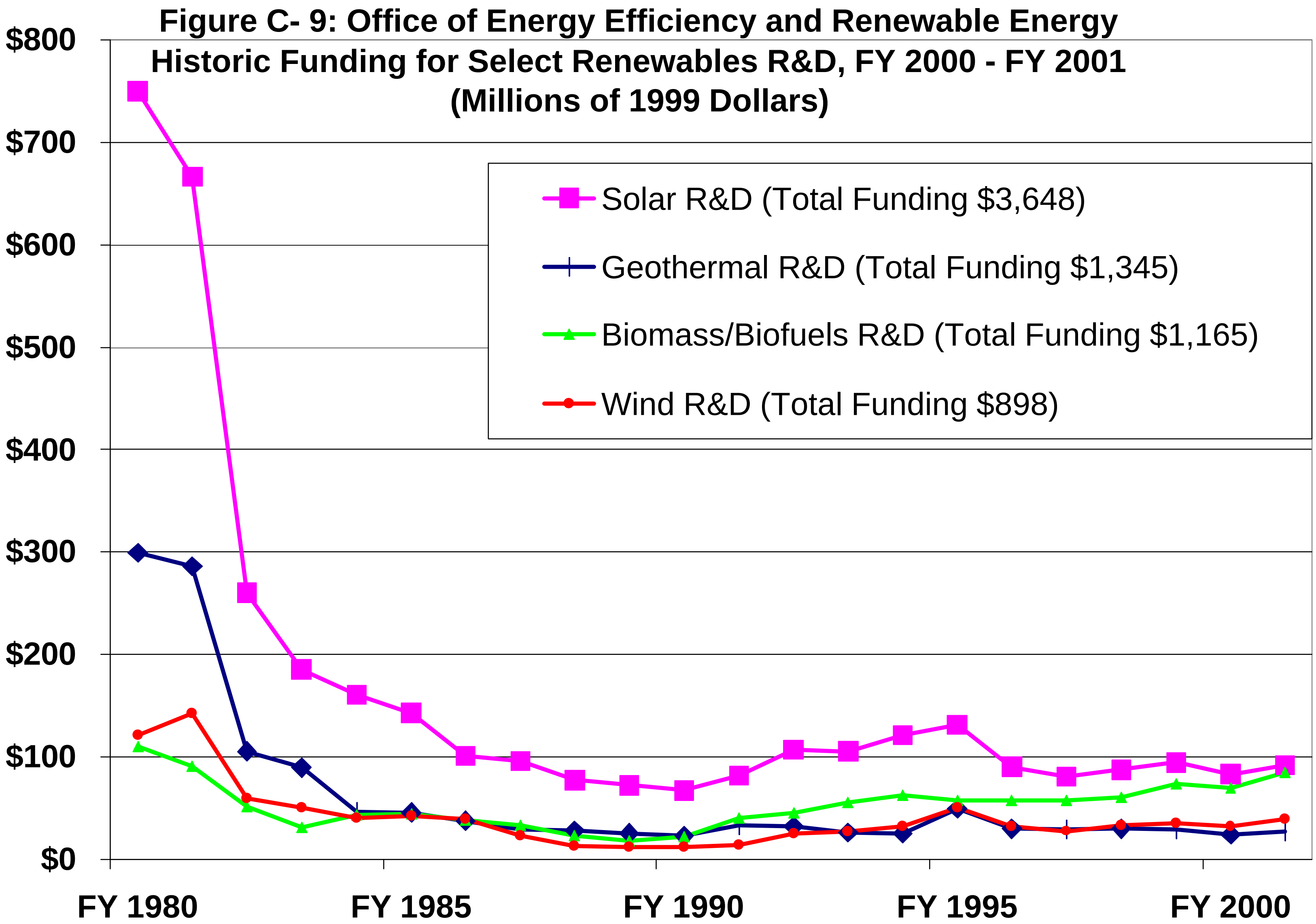


Figure C- 9: Office of Energy Efficiency and Renewable Energy
Historic Funding for Select Renewables R&D, FY 2000 - FY 2001
(Millions of 1999 Dollars)
$800
$700
$600
$500
$400
$300
$200
$100
$0
Solar R&D (Total Funding $3,648)
Geothermal R&D (Total Funding $1,345)
Biomass/Biofuels R&D (Total Funding $1,165)
Wind R&D (Total Funding $898)
FY 1980
FY 1985
FY 1990
FY 1995
FY 2000