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Resources, Community, and
Economic Development Division

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April 15, 1996

The Honorable John R. Kasich
Chairman, Committee on the Budget
House of Representatives

Dear Mr. Chairman:

You asked us to review the Department of Energy's (DOE) report Success Stories: The Energy Mission in the Market Place. Specifically, you asked us to determine whether (1) the claims DOE makes in the report are valid and (2) Success Stories can be used to assess the value of DOE's applied research and development (R&D) programs. As you know, DOE's applied R&D programs are designed to support the development of technologies that accomplish the nation's energy objectives, such as securing future energy supplies. In fiscal year 1995, DOE received appropriations of about $1.65 billion, or about 9.5 percent of its total budget, to fund its applied energy R&D programs. Some Members of Congress and the Congressional Budget Office (CBO) have questioned whether the federal government's investment in these programs is cost-effective.

DOE published Success Stories in May 1995 to respond to these concerns. The report briefly describes 61 technologies developed or supported by DOE's applied R&D programs. Each case study highlights how a technology resulted in measurable benefits, such as securing future energy supplies. To address your questions about the report, we evaluated the support for the benefits claimed for 15 of the cases. We selected our sample to include (1) cases representing a cross section of DOE's applied research programs and (2) cases that cited large quantified benefits.

In summary, we found the following:

-- Although Success Stories makes some valid claims about the benefits of DOE's applied research, we found problems with the analyses DOE used to support the benefits cited in 11 out of the 15 cases we reviewed. These

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problems include basic math errors, problems in the supporting economic analyses, and unsupported links between the benefits cited and DOE's role or the technology. These problems make DOE's estimates of the benefits for these cases questionable.

-- While Success Stories shows that DOE's applied R&D programs do produce some benefits, it cannot be used to assess the effectiveness of DOE's applied research programs overall because it only describes the "successes" of a very small percentage of the projects DOE has funded. In addition, Success Stories does not report how much DOE spent to support any of the technologies we evaluated. Without a comparison of costs and benefits, the success of DOE's applied energy R&D programs cannot be determined.

BACKGROUND

For many years, DOE has devoted significant resources to energy R&D. From fiscal year 1978 through fiscal year 1993--the last year for which actual spending data are available--DOE spent $45.5 billion on R&D.[1] DOE's spending constituted over 48 percent of all domestic spending on energy research in fiscal year 1993. DOE received appropriations of about $2.37 billion in fiscal year 1995 for its research programs. Since the mid-1980s, DOE has dedicated about 70 percent of its total spending in energy R&D to applied research, which develops scientific knowledge that has specific commercial applications.[2] DOE has also invested significant amounts in basic research. Basic research is directed at increasing the understanding of energy phenomena without regard for immediate commercial objectives. In fiscal year 1995, DOE received appropriations of $726 million for basic research in such areas as materials and chemical sciences.

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[1]Figures are in 1994 dollars.

[2]To estimate DOE's spending, we obtained DOE's historical budget data, then applied the budget categories for basic and applied research developed by the Secretary of Energy Advisory Board's Task Force on Strategic Energy Research and Development.

Critics have maintained that applied research should be performed by the private sector, not the government. Also, in a March 1994 report,[3] CBO contended that few successful technologies have emerged as a result of DOE's applied R&D programs.

To prepare Success Stories, DOE's Office of Science Policy first asked its applied research program offices to provide examples of technologies they had developed that produced quantifiable benefits. Officials from this office then chose what they considered the best examples to include in the report on the basis of the significance of the R&D in terms of DOE's mission, quantifiable measures of its impact, and other factors. They also selected cases that illustrate the range of DOE's applied research programs.

The resulting Success Stories report provides brief case studies of 61 technologies that were developed or otherwise supported by DOE's applied R&D programs. The cases presented in the report vary greatly according to the size and type of the research project, the types of benefits attributed to the project, the time at which the benefits occur, and the sophistication of the methods DOE used to estimate the benefits. For example, some describe relatively small DOE R&D projects that were completed years ago, while others discuss multimillion dollar efforts still under way, such as DOE's photovoltaic program, which has been directed at developing ways to convert solar energy into electricity since the 1970s.

In describing the different types of economic benefits attributable to the technologies, some case studies cite how a technology has conserved energy, cut production costs, or increased energy supplies, while others attribute increased exports or environmental benefits to the new technology. Similarly, the cases differ in the time frames in which the estimated benefits are achieved. Some cases estimate benefits that have accrued for one year, some estimate benefits throughout the 1980s and early 1990s, and others project benefits for recent or ongoing R&D efforts that will not occur before 2000. More importantly, DOE used different approaches or methodologies to estimate the benefits. In some cases, the analyses supporting the examples

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[3]Reducing the Deficit: Spending and Revenue Options, Congressional Budget Office, Mar. 1994. CBO's February 1995 report on the same subject no longer specifically states that few successful technologies have emerged from DOE's applied R&D programs. However, the report states that many lawmakers have questioned the value to the economy of those R&D programs.

use market models or other sophisticated techniques, while in other cases the analyses rely on other approaches, such as available sales data or an expert's best judgment about future markets.

The 15 case studies we selected for detailed review (1) covered all major program areas and fuel sources and (2) accounted for most of the large economic benefits identified by the report.[4]

REPORT CITES SUPPORTABLE BENEFITS BUT CONTAINS MANY WEAKNESSES

Success Stories contains supportable claims for some of the benefits of DOE's research. For example, the atmospheric fluidized-bed coal combustor developed by DOE allows utilities to efficiently produce electricity from low-grade coal. DOE also documented its claim that DOE-2, a computer software program that helps reduce energy use in buildings, saved almost $2 billion in energy costs for buildings constructed through 1993.

However, we found problems with the analyses supporting the benefits cited for 11 of the 15 cases we reviewed. Although these problems cause us to question the amount of benefits claimed for these cases, substantial benefits may still be attributable to some of these cases. The enclosure to this report summarizes the problems we found with the analyses supporting the 15 cases we reviewed.

As the enclosure shows, the problems we identified in the 15 cases fell into the following four general categories:

-- Math Errors. Two of the case studies were based on analyses containing basic math errors that greatly affected the estimates of benefits. For example, the supporting analysis for the benefits of the carbon dioxide (CO_2) sand fracture production technology--a new process that is expected to increase production from some gas wells--improperly applied the price of natural gas to an incorrect amount of expected increased production. This error resulted in an unrealistic estimate of the increased revenues that could be expected from each well using the new technology. Applying the price of gas to the correct amount of expected increased

[4]Because the case studies were not consistently prepared and because we did not select a random sample, we cannot quantitatively generalize from our sample of 15 to the 46 other technologies described in Success Stories.

production from the test wells over their first 7 years of production leads to an estimate of increased revenues of between $216,000 and $294,000 per well--not the $20 million per well cited in Success Stories.[5]

-- Problems with the supporting economic analysis. Nine of the 15 cases contain estimates of benefits that are based on analyses containing weak economic reasoning, poor assumptions, or other errors. For example, when DOE projected the domestic sales of its integrated gasification combined cycle (a clean coal technology) from 1998 to 2030, it did not discount the sales figures to reflect the time value of money. Using a conservative interest rate, discounting would reduce DOE's claimed benefit from $150 billion to $44 billion. In another example, the supporting analysis for the mud-pulse telemetry project--a well-drilling technology developed by DOE that saves time and money--assumes that the total amount of money the well-drilling industry has spent on this technology equals the amount saved by the industry. This assumption incorrectly implies that every dollar spent on the technology is a savings attributable to the technology. The value of this technology to the industry is the amount of money the industry has saved by using it, rather than the amount of money the industry has spent on it.

-- Weak or indirect link between the stated benefits and DOE's R&D activities. Although DOE claims in Success Stories that it developed the sand fracture technology, the supporting documents provided to us state that the process was developed and patented in Canada and that DOE is currently demonstrating its effectiveness on a number of U.S. wells. In another case, DOE cites energy savings of $5 billion attributable to the use of the flame retention head oil burner technology over the past 15 years, although DOE's contribution was limited to testing and publicizing the technology. Although Success Stories clearly identifies DOE's limited role, the reader could easily be led to believe that the value of DOE's contribution is the estimate of total energy savings from the technology. We do not believe that the total savings resulting from consumers' use of this technology should be linked directly to DOE's activities.

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[5]In this case, DOE also incorrectly assumed the technology would increase production throughout the productive life of each well. However, the supporting documents provided to us by DOE indicate that the scientists and engineers conducting the project are not willing to assume that the wells will continue to produce at increased rates past the first 7 years of the project.

-- Benefits did not result from the technology. In its discussion of the benefits of the AC electric drive train, Success Stories cites a California mandate for electric vehicles that is expected to create a $350 million market in 2003. However, according to an official with the California Air Resources Board, the mandate was developed independently of the AC electric drive train. Although the drive train may help automakers meet the mandate by improving the performance of electric vehicles, it did not result in the mandate. Thus, the potential market created by the mandate cannot be considered a result of the drive train.

REPORT CANNOT BE USED TO ASSESS THE VALUE OF DOE'S APPLIED R&D PROGRAMS

In our opinion, Success Stories cannot be used to assess the effectiveness of DOE's applied R&D programs for two reasons. First, none of the case studies we evaluated discuss how much DOE spent on its R&D efforts supporting the technology. Such information is necessary to determine whether DOE's investment in applied R&D programs is cost-effective. For example, in describing the environmental advantages of the nuclear light-water reactor technology and the savings that will result if the operating licenses of current plants are extended, DOE does not mention that it has spent about $1 billion over the past 10 years on efforts to improve and advance the use of nuclear light-water reactor technology. DOE also does not discuss the environmental downside of nuclear power--the unresolved problem of long-term disposal of the high-level radioactive waste created by the reactors.

Secondly, we believe that the report cannot be used to evaluate DOE's applied R&D programs because it highlights only a small percentage of the projects funded by these programs and describes only what DOE considers to be the most successful of the technologies the Department has supported. The cases summarized in Success Stories are not a representative sample that can be used to evaluate DOE's applied R&D programs overall.

AGENCY COMMENTS

We provided a draft of this report to DOE for its review. In commenting on the draft, DOE officials, including the Acting Assistant Secretary for Policy, acknowledged that our review revealed several errors in the analyses supporting the benefits cited in Success Stories and said DOE would improve the "quality control" over similar reports in the future.

These officials expressed concern that some readers of our report would see our criticism of Success Stories as a general condemnation of DOE's R&D programs. They believe such criticism to be inappropriate given the limited scope of our review. Similarly, they believe that the enclosure to our draft report summarizing the types of problems we found in the analyses supporting the 15 success stories conveys the misleading message that the 11 cases for which we identified problems are "failures," with no benefits. They pointed out that these projects may still have benefits and may still be "successes," although DOE made some errors in analyzing the benefits.

We agree that in several of these cases, the benefits may be substantial. We have added clarifying language to the report to underline that our chart is simply a summary of the problems we identified and that our review was limited to the Success Stories report. We are drawing no conclusions about DOE's R&D programs and, in fact, conclude that the report cannot be used to evaluate the programs overall.

DOE also disagreed with our conclusion that Success Stories is of limited use in evaluating the effectiveness of its applied R&D programs. In this regard, the Acting Assistant Secretary for Policy compared the Department's investment in applied R&D projects to a "high-risk" investment portfolio. According to this official, an investor managing a high-risk portfolio accepts a large percentage of failures in exchange for a few successes with very large returns. Similarly, DOE believes it is entirely appropriate to focus on a few successful projects with large benefits to justify its R&D programs overall.

We continue to believe that any evaluation of DOE's applied R&D programs must consider both the costs and benefits of each project. DOE's applied R&D programs include many high-risk efforts that could lead to a high rate of failure. However, we believe that without comparing costs and benefits, it is impossible to determine whether projects are successes or failures. Moreover, without cost information, it is impossible to determine the rate of return on the federal government's total investment in the programs.

To accomplish our objectives, we interviewed officials within DOE's Office of Science Policy and reviewed documentation they provided. To test the claims of economic impact made in Success Stories, we selected 15 cases that provided a cross section of DOE's applied R&D programs and allowed us to assess the analyses for many of the largest claims of benefits for detailed

review. We contacted the officials in the appropriate DOE research program offices who were responsible for the individual projects and obtained and evaluated the supporting documentation provided for each case. We conducted our work from October 1995 through March 1996 in accordance with generally accepted government auditing standards.

We are sending copies of this report to other congressional committees; the Secretary of Energy; and the Director, Office of Management and Budget. We will also make copies available to others upon request. If you have any questions about this report, please call me at (202) 512-3841. Major contributors to this report were Robin Nazzaro, Ronald Stouffer, and Daren Sweeney.

Sincerely yours,

Victor S. Rezendes
Director, Energy, Resources,
and Science Issues

SUMMARY OF GAO'S ANALYSES OF SELECTED TECHNOLOGIES FEATURED IN DOE'S SUCCESS STORIES REPORT

Note: Although these problems cause us to question the amount of benefits claimed for these cases, each may still have substantial benefits.

Technology	Description	Benefits claimed	GAO's analysis				
			Adequate support for all benefits claimed	Inadequate support for benefits claimed[1]			
				Math error	Economic analysis problem	Benefits not directly linked to DOE's role	Technology not directly linked to benefits
Fluorescent lamp electronic ballasts	DOE developed the electronic fluorescent lighting ballast at its Lawrence Berkeley Laboratory in the mid-1970s. The ballast eliminates the flicker and hum of traditional magnetic ballasts and saves energy.	Ballast has improved lighting quality and saved consumers $750 million in energy bills.			■		
Software for building design	DOE developed a software tool, DOE-2, that estimates, on the basis of a building's characteristics, its energy use and cost.	Use of this software accounts for $1.9 billion in energy savings for buildings constructed through 1993.	■				
Nickel metal hydride batteries	DOE is supporting the development of a low-cost, high-performance battery for electric vehicles through the United States Advanced Battery Consortium. This battery would double an electric vehicle's driving range between recharges and significantly increase power.	The mandates for electric vehicles in California and the Northeastern states will create a $350 million market for this battery in 2003.			■		■

ENCLOSURE

Technology	Description	Benefits claimed	GAO's analysis				
			Adequate support for all benefits claimed	Inadequate support for benefits claimed[1]			
				Math error	Economic analysis problem	Benefits not directly linked to DOE's role	Technology not directly linked to benefits
AC electric drive train	Under a cost-shared contract with DOE, Ford Motor Company and General Electric developed a new electric drive train for electric vehicles that run on AC current.	New design will reduce consumers' costs and allow electric vehicles to enter the market sooner. California laws mandating zero-emission vehicles will result in approximately $70 million in electric vehicle sales in 1998, growing to $350 million by the year 2003.		■		■	■
Electrochemical dezincing of steel scrap	DOE has developed an electrochemical method that removes the zinc from steel scrap so that the scrap can be used in steelmaking operations.	Electrochemical method will (1) increase production yields and quality and (2) by the year 2000, will save 50 trillion Btus and reduce raw material imports by at least 75,000 tons of zinc per year, thereby saving $77 million annually.			■		
Integrated gasification combined cycle (IGCC)	IGCC is an advanced coal-burning system that DOE believes will be the power plant of the 21st century.	IGCC technology will (1) reduce sulfur dioxide and nitrous oxide emissions to less than 10 percent of new source performance standards, (2) reduce carbon dioxide emissions by 35 percent to 45 percent, (3) reduce solid wastes by 40 percent to 50 percent, and (4) be less costly to build.			■		

ENCLOSURE

Technology	Description	Benefits claimed	GAO's analysis				
			Adequate support for all benefits claimed	Inadequate support for benefits claimed[1]			
				Math error	Economic analysis problem	Benefits not directly linked to DOE's role	Technology not directly linked to benefits
Photovoltaics	Photovoltaics are devices that convert light into electricity. DOE's photovoltaic program has succeeded in reducing the cost of such electricity from 90 cents per kilowatt hour to 20 cents per kilowatt hour.	$100 million in photovoltaic sales supports or creates 3,800 U.S. jobs.	■				
Mudpulse telemetry	In the 1970s, DOE helped a private company develop an instrument for measuring while drilling that significantly cut the cost and time of drilling oil and gas wells.	Mudpulse telemetry has gained wide acceptance in the drilling industry, and DOE estimates that it has saved the natural gas and oil industry at least $1 billion over the past 20 years.			■		
Carbon dioxide sand fracture production technology	DOE developed, tested, and helped commercialize this technology for stimulating production from natural gas wells. It has been shown to increase production by 200 to 500 percent.	This technology could generate $20 million more revenue over the productive life of some wells.		■	■	■	
Atmospheric fluidized bed coal combustor	DOE helped develop a coal combustor that uses low-polluting coal to produce electricity. According to DOE, every U.S. boiler manufacturer now sells a fluidized bed coal combustor.	Over the last 8 to 10 years, more than $6 billion in domestic sales and $2 billion in foreign sales have been reported. Domestic sales alone translate into more than 250,000 jobs.			■		

ENCLOSURE

Technology	Description	Benefits claimed	GAO's analysis				
			Adequate support for all benefits claimed	Inadequate support for benefits claimed[1]			
				Math error	Economic analysis problem	Benefits not directly linked to DOE's role	Technology not directly linked to benefits
Light-water reactors	DOE has supported nuclear light-water reactor technology, which currently produces about 22 percent of the nation's electricity.	The electricity currently produced by light-water reactors would cost $20 billion per year if produced by conventional power plants. Also, over the past 20 years, nuclear power plants have replaced the equivalent of $400 billion of fossil power, thereby displacing significant amounts of air pollution. Ongoing research is directed at procedures to extend the life of existing nuclear plants. DOE estimates that each plant that is allowed to extend its operating life by 20 years will save about $800 million in replacement costs.			●		
High-energy batteries	DOE's research resulted in the development of high-energy lithium batteries used in security systems, robotics, and medical instruments.	Commercial use of such batteries has accompanied and enabled the explosive growth of the multi-billion-dollar portable electronics industry, including lap-top computers.	●				
Advanced energy-efficient windows	DOE, in a partnership with industry, developed a window that uses low-emissivity coatings to block heat gain or loss. DOE invested $3 million in this technology.	Cumulative consumer energy savings are $1.8 billion. Every major glass and window manufacturer offers low-emissivity products.			●		

ENCLOSURE

Technology	Description	Benefits claimed	GAO's analysis				
			Adequate support for all benefits claimed	Inadequate support for benefits claimed[1]			
				Math error	Economic analysis problem	Benefits not directly linked to DOE's role	Technology not directly linked to benefits
High-efficiency refrigerator compressors	From 1978 through 1980, DOE sponsored a project that resulted in a 44 percent improvement over the compressor technology used in refrigerators at that time.	Use of the improved compressors pioneered by this research saved consumers at least $6 billion in energy costs from 1980 through 1990.	●				
Flame retention head oil burner	In the early 1970s, a DOE field test established the energy conservation benefits of a new flame retention head oil burner. DOE later published its findings in a consumer-oriented information booklet. Within several years, the flame retention head burner dominated the market for new and replacement oil burners.	Consumers' energy cost savings to date from this innovation total more than $5 billion.				●	

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