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Time to Overhaul Federal Energy R&D

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Executive Summary

The U.S. Department of Energy is one of six large federal agencies that manage the multi-billion-dollar federal budgets for scientific research. Private markets for research and development (R&D) have some inefficiencies, termed market failures, because some of the benefits spill over to third parties that do not pay the R&D cost. Government-sponsored R&D, however, has its own set of problems. Whereas private markets underinvest in R&D programs that have a high public payoff, government overinvests in R&D programs with a low public payoff. The R&D market requires choosing between imperfect alternatives.

DOE's energy programs in particular have serious problems. First, existing public policy objectives are largely unrelated to correcting market failures. The market does not "fail" to deliver energy supply, energy efficiency, or energy security—the chief objectives of DOE's R&D activities. Second, there is insufficient competition among potential research communities—for example, universities—to obtain DOE funding for research and scientific facilities. As a consequence, energy R&D programs are unlikely to ever provide net benefits to taxpayers. Third, the incentives inherent in government-managed R&D are seldom compatible with the public interest.

The problems surrounding existing energy R&D programs are, unfortunately, a consequence of the normal functioning of government. Accordingly, simply improving the budget process will not improve matters. Taxpayers would obtain a higher return on their R&D investments if Congress merged energy programs into a larger budget for scientific R&D or, even better, if Congress eliminated those programs altogether and established in their place tax allowances to supplement private-sector R&D.

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Introduction

Although government funding of basic and applied research and development (R&D) in the United States has received public and political support for several decades, an increasing chorus of criticism has been directed at the R&D programs of the U.S. Department of Energy, particularly those undertaken in the national laboratories.[1] That criticism is in some ways surprising. The pressure to reduce federal spending has abated with the appearance of large government surpluses. Moreover, there is little public criticism of government spending on other science-oriented R&D programs, and little criticism of other government research agencies, such as the National Institutes of Health.

DOE-sponsored research is primarily concerned with the improvement of America's nuclear weapon capabilities, basic energy sciences, and the advancement of various energy technologies. Yet each of those missions has become less pressing over the past decade or two. First, the end of the Cold War drastically diminishes the need to continue developing and testing nuclear weapons. Second, despite the occasional spike in energy prices, private markets have over the long run delivered reliable energy supplies at stable or declining prices.[2]

A recent report by the Committee for Economic Development—explicitly undertaken to make a compelling case for continued government support for basic research—argues: "Basic research in science and engineering has made a major contribution to the growth of the U.S. economy. Economic returns on investments in basic research are very high."[3] Yet the CED is critical of the DOE and its national laboratories for continuing to fund programs to advance missions of declining importance:

> We argue for an end to political earmarks for research, and we are concerned about "mission creep" in those sectors of the basic research establishment—particularly certain of the Department of Energy's national laboratories—that have completed or lost their mandates.[4]

If the benefits of government-supported R&D are as high as the CED suggests, why are the benefits of the DOE energy R&D programs so questionable? The CED indicates that part of the answer may be a loss of DOE mandates, both in energy programs and in nuclear weapons. The real answer, however, is more complex: Private markets make imperfect decisions, but government also makes imperfect choices.

The economics of market failures and of nonmarket (government) failures provides the underlying conceptual framework for this paper. The question this study addresses is whether DOE's R&D programs provide net benefits to taxpayers. Estimating net benefits of government R&D programs in quantitative dollar terms, however, is not feasible. While previous studies undertaken by "blue ribbon panels" have reviewed DOE programs with generally positive endorsements, those reviews have amounted to scientists assessing the value of scientific programs.[5] This, of course, is not particularly helpful to the policy analyst, who must examine both benefits and costs. This study takes a different tack; it uses economics and particularly the principles of market failures and nonmarket failures to assess DOE's R&D programs.

The Economic Rationale for Government Promotion of R&D

The benefits of any market transaction, public or private, are most appropriately measured by the value of that transaction to consumers on a present value basis. In private markets, firms make a profit only by providing goods and services that add value to consumers. This value is measured as consumers' willingness to pay. The price of the good or service is the vehicle by which markets achieve efficient outcomes. In well-functioning markets, prices of goods and services reflect the cost to the producer at the margin and the benefit to the consumer at the margin. Private markets automatically perform cost/benefit analyses and ensure that long-run benefits to consumers are maximized. Hence, as a general matter, few economists challenge the notion that, under normal circumstances, private market actors are more likely to efficiently invest, produce, and consume goods and services than are governmental agents.

Accordingly, economists maintain that government intervention in the economy is appropriate only when there is something fundamentally dysfunctional with the market. This dysfunction results when market prices do not accurately reflect costs to producers or benefits to consumers. Such dysfunctions are termed "market failures," and they have been cataloged extensively by economists.[6] For governmental interventions to prove beneficial, they must either remedy a market failure or promote a policy end that is outside the normal reach of markets.[7]

It's worth pointing out, however, that the federal government cannot just go about intervening in the marketplace hither and yon as long as such interventions are deemed beneficial by economists. The intervention must also pass a constitutional test, which means in our case that the federal government must find the power to promote beneficial research and development in art. 1, sec. 8, of the Constitution. The Constitution does indeed grant the federal government such powers, but only in the form of patents to promote research and development. This has led one of the authors of this study to argue that the energy R&D programs discussed herein are unconstitutional on their face and should thus be eliminated.[8]

Nevertheless, there have been three market failures identified in the market for energy R&D: public goods, externalities, and the lack of collective insurance. In each case, the potential net benefit of a government program is positive because benefits are not totally reflected in market prices.

Public Goods. Public goods are consumed collectively, not individually like private goods. This joint consumption means that no one is excluded from consumption, even if one does not explicitly choose to consume. Furthermore, the use of a public good by one person does not reduce the amount available for others.

Basic scientific research is something of a public good in that it produces findings that are consumed collectively by the scientific establishment through widespread distribution in scientific journals. The value of using the fruits of this research is positive, but the cost of consumption (the price of the journal bringing the findings to the scientist) is near zero. Private markets will underproduce a good when its marginal value is positive but its marginal cost and market price are zero.

Externalities. Externalities are costs or benefits imposed on individuals not party to an economic transaction. When a third party obtains significant benefits without payment (or is burdened with costs that are not compensated), the market is not sending appropriate price signals about the true costs or benefits of the good or service. Markets will accordingly underproduce goods characterized by external benefits.

A textbook example in which the output of one firm benefits other firms is the discovery of knowledge. Private firms invest in R&D to the extent that the investor appropriates the benefits and the benefits exceed costs. A market failure occurs when the firm investing in R&D does not appropriate all the benefits, because some spill over to other firms. Because the firm captures only part of the benefits, the firm underinvests in R&D.

Collective Insurance. Insurance companies insure individuals by pooling risks over a large number of persons. However, private companies cannot insure the entire country against national contingencies. For instance, individuals provide for their security, but they have insufficient incentives to provide the optimum level of national defense given that they can "free ride" off the investments of others. National defense programs can be seen as the purchase of collective insurance.

Supporters of basic energy R&D for cer-

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tain technologies argue that it is a form of collective insurance. The oil dislocations of the 1970s convinced many people that finding alternatives to petroleum-based fuels would provide a collective insurance policy against the risk of future disruptions. That the rate of return for such investments is minimal is somewhat beside the point. We do not expect national defense expenditures to yield a high rate of return either, and, just like personal life insurance, we hope that national defense does not "pay off."

The theory of public goods, externalities, and collective insurance seems clear, but practical applications are much less clear. For instance, libraries, schools, roads, and bridges are commonly thought of as public goods. Libraries benefit a community, but some library services, such as borrowing books, directly benefit consumers and could require a fee. Public schools are a classic case of a public good, but private elementary and secondary schools require tuition. Roads and bridges are likewise widely assumed to be public goods, but some roads and bridges require a toll. In the case of a new housing development, one assumption is that required roads and schools are a public good that general tax revenues should support. Another assumption is that incremental expenditures on roads and schools are a private good primarily benefiting new users. Hence, incremental users should pay these investment costs in the form of a marginal development tax.

Moreover, the categorization of market failures as examples either of "public goods" or "externalities" is in some ways confusing because they both refer to the same phenomenon (spillover costs and benefits outside of the pricing mechanism). The distinction is actually more one of degree than one of concept. In a public good, almost all the benefits accrue to the public. In the case of an external cost or benefit, much of the cost or benefit accrues to the private producer. The issue here is not the degree of external benefit. The issue is whether government investment in R&D provides a net public benefit.

A better model for allocating science dollars is one based not on picking potential technological "winners" but on putting in place the proper investment incentives.

The Importance of Incentives

Government expenditures on different scientific disciplines represent a taxpayer investment in those disciplines. Yet for such investments to have positive net benefits, funding must be allocated to those investments where the public receives a net benefit that is not reflected in market prices. The rate of return on investments in science, however, is unknown. Unfortunately, the government is in no better position to accurately estimate the benefits from R&D than is the private sector.

While it's certainly true that private markets may underinvest in, say, theoretical physics because the rate of return on that investment is uncertain, governmental agents have no better information at their disposal to judge the matter. The authors of this paper, not being omniscient, cannot determine the optimum investment in theoretical physics. We can, however, look at market processes and judge whether the incentives are in the direction of efficiency or inefficiency.

Therefore, a better model for allocating science dollars is one based not on picking potential technological "winners" but on putting in place the proper investment *incentives.* If the incentive is to produce the largest public benefit, investments may provide such benefits. However, if the decision to fund a scientific area is based on political, institutional, or other considerations not relating to public benefits, the investment is less likely to be in the public interest.

Simple observation of private markets suggests a model based on incentives. Suppose we observe a firm undertaking an investment in a plant and equipment. We ask whether the investment is in the public interest. Is the initial decision to invest in this plant a wise investment choice? If the investment provides benefits to the public, will the investment continue? If the investment fails to benefit the public, will the government cancel the investment? How should a government policymaker, concerned with the public well-being, answer these questions? The policymaker has no empirical evidence on the expected rate of return on the investment.

The incentives characterizing investment decisions indicate whether the investment is likely to be in the public interest. The business firm acts in its self-interest, which is to make money. However, to make money, the firm must provide a product or service that customers are willing to pay for. As long as the firm expects that investing in the plant will provide a good or service that customers value, the firm continues to invest. If the firm learns that the investment is of insufficient value, the firm cancels the investment. Just as explained by Adam Smith, private markets operate as if guided by an invisible hand to produce public benefits. Although the government policymaker has no empirical data, a reasonable assumption is that the investment is in the public interest, because the incentives characterizing the investment reflect the public interest.

Observation of private markets may reveal behavior that does not benefit the public. For instance, suppose we observe a firm operating a plant with high emissions of pollutants in a country where there exist minimal restrictions on these emissions. These emissions impose a cost on others not considered by the firm. The cost is an external cost that results from a market failure. In this case, the firm does not have incentives that contribute to public benefits.

This study examines government markets for R&D and considers the incentives characterizing the public investment. We ask whether state actors have the incentive to invest in R&D programs that are likely to provide net public benefits. If there is a government policy goal, we first ask whether achieving that policy goal reduces a market failure. We then ask whether the R&D project is likely to make a cost-effective contribution to that policy goal.

The simple insight from this analysis is that private markets tend to underinvest in good programs but that government tends to overinvest in bad programs. As we shall see, the energy policy goals of energy supply, energy efficiency, and energy security do not reflect the failure of private markets to meet those needs. DOE's energy R&D programs thus appear unlikely to reduce market failures in private markets and more likely to produce government failures in government markets.

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Market and Nonmarket Failures: The Choice between Imperfect Alternatives

Most analysts believe that private markets will not produce an economically efficient level of investment in R&D. Although government support for R&D may improve overall economic efficiency in theory, the market for government goods and services has its own inefficiencies.

Charles Wolf, an economist at both the Hoover Institution and RAND Corporation, has developed a theory of government inefficiencies, which he terms "non-market failures."[9] The following four nonmarket failures identified by Wolf apply to the market for R&D. Each of the nonmarket failures stems from the disconnection between benefits, costs, and market prices, and from the lack of incentive in the funding process to provide public benefits.

The Problem of Quantification

First, the output provided by government is difficult to define and to measure. The output of basic research is an intermediate product that may find application elsewhere. However, we cannot define or measure the value of this output. Nor can we easily determine the quality of government programs.

During the last two decades for instance, the DOE has spent millions of dollars developing renewable energy technologies, such as wind energy and various solar forms of energy. The cost of obtaining usable energy from these technologies continues to decline over time, but the technologies only serve tiny niche markets.[10] The market test of DOE's renewable energy program so far indicates large costs and low benefits. On the other hand, if we measure the benefit of the renewable energy programs as the dollars spent, which is its contribution to gross domestic product, then the program has substantial benefits. However, this contribution to GDP is the cost of the input rather than the economic value of the output.

Whither the Bottom Line?

The second nonmarket failure is the absence of a "bottom line" and termination mechanism. There is no profit and loss statement comparable to those of the private sector. There is no reliable mechanism to discontinue unsuccessful programs. Even the blue ribbon panels of outside experts seldom recommend discontinuing programs, perhaps because the scientific community typically favors government's spending money on science and is loath to offend politicians who control the spigot of dollars that fund their activities.

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The lack of a termination mechanism has everything to do with political incentives. Small programs require approval at the assistant secretary level, rather than the congressional level, and an assistant secretary has little incentive to discontinue an internal program that might, after all, reduce the department's budget, prestige, and political influence. Large programs, however, require congressional approval and have to pass a political test. With few exceptions, large, visible programs with concentrated benefits obtain political support and may continue for years regardless of performance.

For instance, the Atomic Energy Commission announced the Clinch River Breeder Reactor in 1972. The idea was to build a reactor that would produce (breed) its own fuel, a technology that might prove cost-effective in a world of increasing uranium prices. Even when the Atomic Energy Commission initiated the project, however, its own cost/benefit studies were unfavorable and the capital costs of developing the breeder reactor escalated over time. Meanwhile, uranium prices steadily declined. The economics of the breeder reactor, never that attractive to begin with, quickly became untenable. In 1981, the breeder reactor became one of the few programs that the Energy Research Advisory Board ever recommended terminating.[11] The Senate discontinued funding for the project in 1983.

Although the breeder reactor received some funding from the private sector, it is a clear case of government-industry failure, which is how the project was defined by the committee of Advisors on Science and Technology.[12] According to the committee, one of the lessons learned is that such projects should have an oversight process with independent evaluation of cost, performance, and schedule.

Although DOE energy programs have experienced large budget swings throughout the agency's history, with several programs scaled back or even cancelled, compared with the private sector, government programs are less accountable to investors (the tax-paying public) than privately funded programs are to their investors (stockholders). As the Clinch River Breeder Reactor experience suggests, there is a tendency for government programs to have significant inertia that encourages their continuation even when the initial need for those programs disappears. When a program is adopted—especially a large program—the political, scientific, and governmental coalition that succeeded in launching the program in the first place will lobby to continue financial support of the program. There is little political incentive to cancel large programs when the benefits are concentrated. Recipients of those benefits are inevitably well organized to ensure that the costs are borne by the many, and the many are not well organized.

The difficulty of scaling back or eliminating programs that are no longer useful (if indeed they ever were) was highlighted recently in a report by the Committee for Economic Development:

> With the end of the Cold War . . . the missions of the massive federal laboratory system have changed, and in some cases disappeared. . . . But

> some, particularly among the national laboratories at the Department of Energy, have not acted forcefully to eliminate work in areas no longer relevant to their missions, nor to expose themselves to merit-based peer review processes.[13]

The absence of a bottom line that reflects benefits to the public results when interest group influences and policy objectives do not reflect the public interest. That is, energy policy goals may reflect the goals of special interests, including government, rather than the public interest.

The DOE is now using "business line objectives" as a measure of whether R&D programs have helped the department achieve its bottom line.[14] However, the bottom lines are energy policy goals, and those policy goals are not necessarily worth pursuing in themselves. A DOE program may provide net benefits, for instance, if it contributes to energy security where the definition of energy security reduces a market failure. A DOE program will not provide net benefits if the definition of energy security does not imply reducing a market failure.

The Invisible Hand of Government

The third nonmarket failure is that internal incentives facing government program managers do not produce results that coincide with public benefits. This particular nonmarket failure has been thoroughly investigated and establish by academic researchers, several of whom have won Nobel prizes for their work, in what is known as the theory of "Public Choice."[15]

The premise of the public choice school of economics is that private goals and incentives influence managerial behavior in both public and private organizations. Departmental empire building, for instance, is a phenomenon that can arise in both private- and public-sector enterprises. Private firms, however, have a measurable output and a financial bottom line that influences firm behavior. Firms therefore have an incentive to provide a good or service that customers value and to eliminate counterproductive managerial behavior that is detrimental to consumer welfare. Yet as Wolf notes, the internal incentives facing governmental managers "do not bear a very clear or reliable connection with the ostensible public purpose that the agencies were intended to serve."[16]

The fundamental problem is that self-interest incentives within government are to add value to government but not to add economic value to taxpayers. Program goals are more likely to be technical than economic, and program managers are technical optimists about their own programs. Economists Linda Cohen and Roger Noll, for instance, reviewed six large government commercialization programs and concluded that a systematic bias exists to continue programs long after their failure becomes imminent.[17] According to Cohen and Noll, the Clinch River Breeder Reactor, the supersonic transport plane, and many synfuels survived long after they were unjustifiable. The "bottom line" in government programs is political and not economic. Cohen and Noll conclude:

> The overriding lesson from the case studies is that the goal of economic efficiency —to cure market failures in privately sponsored commercial innovation—is so severely constrained by political forces that an effective, coherent national commercialization R&D program has never been put in place. The internal incentives within government organizations, the absence of a financial bottom line, and the difficulty of measuring output work together to produce inefficiencies in government.[18]

An example of the incentive within government to meet the interest of government rather than the public can be found in several federal programs advertised as global warming mitigation initiatives. Federal agencies that have internal incentives to protect their existing programs now rationalize

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those programs as providing climate change benefits. For instance, the Energy Star program of the U.S. Environmental Protection Agency seeks to obtain voluntary agreement from suppliers of personal computers to reduce energy requirements. In exchange for participating, the computer manufacturers put an energy star label on their product. Unfortunately, the relationship between energy use by computers and global warming is dubious at best.[19] An honest climate change program would focus on carbon emissions and other greenhouse gas emissions rather than on energy efficiency.[20] However, once the program is established, the "internal" incentives are to protect it and, in this case, to argue that it reduces the threat of global warming.

Another example of this dynamic at work is the incentive facing program managers in the public sector to fund research projects that will advance their careers. While it's always possible to fund programs on the basis of their potential to contribute to scientific progress, regardless of their policy implications, supporting research designed to buttress an administration's policy position is a better career move than presenting scientific evidence that conflicts with an existing policy position. Program managers in the Clinton administration were motivated to fund research likely to conclude that global warming is an imminent threat.[21] Researchers, attempting to secure funding from the DOE or the Environmental Protection Agency, are more likely to obtain government funding if their research record and proposal supports the government view rather than the skeptics' view.

Lack of Competition

The fourth nonmarket failure results from the lack of competition in the selection of projects and scientific facilities. Institutional factors influence the selection of projects and facilities, and, consequently, meritorious scientific projects are often at a disadvantage when it comes to the chase for public research dollars.

For instance, universities, national laboratories and privately owned non-profit laboratories frequently have comparable expertise in and performance costs for basic and applied energy research programs. Unfortunately, the bureaucratic transaction costs associated with simply handing over research programs to the national laboratories are far lower than the administrative transaction costs associated with competitive procurement. Accord-ingly, projects that can be performed in the national laboratories (even if they're less promising than others) have a greater chance of being funded, simply because the DOE national laboratories were founded to perform DOE-sponsored research.

The political process also influences project selection by favoring large research project and the location of large scientific facilities. The congressional delegations of California, Tennessee, and New Mexico, after all, have political incentives to both protect and increase the funding of the large national laboratories in those states as well as their program portfolios. Since funding for those facilities is a line item in the federal budget, elected officials have ample opportunity to exert such control.

All told, the four "non-market failures" identified by Wolf are at least as serious as the alleged "market failures" that have obsessed policymakers for decades. Moreover, as the next section reveals, DOE R&D programming is almost completely unrelated to the market failures that ostensibly justify those programs in the first place.

DOE Policy Goals and Government Failure

For more than two decades, DOE's national energy policy goals were primarily to ensure an adequate supply of energy, improve energy efficiency, and achieve energy security. Meeting those goals, however, confers an internal benefit to the DOE, not an external benefit to the public. Hence, even if a program contributes to achieving a goal, the program will not pass a benefit/cost test.

The wording of these goals evolves over time, but the goals themselves remain the same. The Clinton administration's plan was titled *The Comprehensive National Energy Strategy*, referred to here as *Energy Strategy*. This document continues the history of energy policy plans in defining DOE policy goals and objectives.[22] The "National Energy Policy" of the present Bush administration retains most of the history of energy policy plans, even though it was prepared by a development group consisting mostly of administration representatives from outside the DOE.

A review of the three main federal energy policy objectives explains why DOE's R&D programs—which are justified as necessary ingredients to achieve such objectives—are riddled with problems.

Energy Security

Providing energy security was an explicit energy policy goal during much of the 1980s and it continues to be today. The *Energy Strategy* states that Goal 2, Objective 1, is to "reduce the vulnerability of the U.S. economy to disruptions in oil supply."[23] The DOE expects to achieve this goal with programs that "stabilize domestic production, maintain readiness of Strategic Petroleum Reserve, diversify import sources, [and] reduce consumption."[24]

Other DOE documents elaborate on the concept of energy security and the programs designed to achieve it. For instance, the DOE *Accountability Report* lists the strategies to achieve energy security, which include research and development, minimizing reliance on foreign supplies, and ending the decline in domestic oil production before 2005.[25] DOE's *Annual Performance Plan for FY 2000* lists the DOE programs and FY 2000 budget request that contribute to energy security, a list that includes virtually the entire portfolio of major departmental undertakings.[26] These programs include solar and renewable energy programs ($399 million), transportation-sector initiatives ($252 million), fossil energy programs ($364 million), continued support of Power Marketing Administrations ($200 million), and maintenance of the Strategic Petroleum Reserve ($164 million)—programs that together total $1.38 billion of a total "energy security" budget of $1.8 billion.[27]

Yet none of the three DOE policy documents mentioned includes a detailed discussion of energy security, how it is measured, or how these programs would enhance energy security. This is a serious problem because the energy security rationale for government programs depends critically on the definition of energy security.

During the 1970s, the percentage of America's oil needs imported from abroad was the accepted measure of energy security. The larger the share of imports, the argument went, the larger the potential economic impact of curtailments in foreign supplies. Government R&D programs that enhance the supply of oil or oil substitutes were thought to enhance energy security. Yet, from an economic perspective, this definition of energy security makes no sense. Variations in OPEC production affect the world oil price, which affects U.S. consumers. Oil produced domestically is part of the world oil market and that oil sells at the world oil price. Hence, prices to U.S. consumers are unaffected by the location of oil wells. A government R&D program that increases domestic oil supplies does not provide energy security because it does not dampen fluctuations in world oil prices.[28]

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In its 1991–92 *National Energy Strategy*, the DOE provides a stronger definition of energy security, one based on abrupt changes in world oil prices. Referring to the 1970s and 1980s, the DOE states:

> These two decades have shown that *sudden* dramatic changes in world oil prices are far more harmful to the United States and other nations than a persistent but gradual rise in price—even if the average price over the long term in both sets of circumstances is identical. Popular opinion aside, our vulnerability to oil price shocks is not determined by how

> much oil we import. The economic impacts depend more on *price,* as set by world market, than on the level of our imports.[29]

The concern over price volatility rather than product availability was largely the result of the emergence of spot and futures markets for oil and other fuels 20 years ago. Energy supply restrictions—from the Middle East or elsewhere—would result no longer in shortages or rationing but in higher market prices. Accordingly, the DOE in 1990 opposed such policies as gasoline taxes, fuel efficiency standards, and subsidies for alternative fuel production because those policies would not enhance national security according to the above definition, which underscored (rightly) that long-term changes affecting average prices do not affect energy security.

The vulnerability of the economy to world oil price fluctuations, rather than quantity restrictions, correctly defines energy security.[30] But even so, energy price volatility is more an internal good that persons can insure against than an external good requiring government attention. Those who wish to reduce the risk posed by volatile oil prices can do so by purchasing fuel-efficient vehicles or reducing their driving. They can also invest in the oil futures market or in oil companies. They can sign long-term, fixed contracts with home heating oil or natural gas providers.[31]

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Even if there is an externality cost associated with price volatility, federally funded R&D programs are unable to address it. First, the DOE's R&D budget from 1977 to the present reveals that little of the budget is used for oil-related research. Most is used for electricity-related programs such as various renewable energy technologies, coal, and nuclear power, and oil has only a tiny market share in the electricity sector. Second, DOE R&D programs, by their nature, provide little insurance against sudden and temporary spikes in world oil prices. Such programs may influence the average price of various fuels over time, but as noted by the DOE, this has nothing to do with energy security per se.

Government programs to develop alternative fueled vehicles could provide a substitute for oil and thus reduce the economic cost of price volatility. For such technologies to prove effective in providing energy security, however, they would have to be highly responsive to incremental oil price increases, even in the short run. Yet, that's clearly not the case. Oil and natural gas are partial substitutes, and would be closer substitutes if each powered vehicles. When the demand for oil increases and drives up its price, the demand for natural gas likewise increases and leads to natural gas price hikes. Consequently, shifting out of oil and into natural gas–fueled vehicles—or even into electric vehicles, since 92 percent of all power plants under construction today are fired by natural gas—does not necessarily mitigate energy security risks. Accordingly, the development and use of vehicles powered by natural gas or electricity would provide little security against oil price increases.

The Strategic Petroleum Reserve, although not at all related to federal energy R&D programs, in principle provides some insurance against increases in world oil prices. The mission of the Strategic Petroleum Reserve is to mitigate the economic impact of disruptions and to discourage producers from excessive cuts in production.[32] However, the Strategic Petroleum Reserve has been used only sporadically over the past two decades and has played little role in mitigating price volatility.

In sum, DOE R&D programs neither insure against short-term oil price instability nor contribute to America's "energy security." By defining energy security, however, as anything that either increases energy supply or reduces energy demand, the DOE gives its R&D programs a political justification, if not an economic one.

Energy Supplies

During the 1970s energy prices increased by a factor of four and experienced wide fluctuations. Energy market analysts interpreted this experience to mean that private markets would fail to meet our nation's energy requirements. Accordingly, an explicit energy policy goal emerged, as stated in the 1983 *National Energy Policy* plan—to provide "an adequate supply of energy at reasonable costs." As stated in the *Energy Strategy*, Goal 3, Objective 1, is to "increase domestic energy production in an environmentally responsible manner."[33] The programs that contribute to this goal attempt to "increase domestic gas production, recover oil with less environmental impact, develop renewable technologies, and maintain a viable nuclear option."[34] During the Clinton administration, the DOE reaffirmed its energy supply objective with respect to oil: "The goal is to end the decline in domestic oil production before 2005 through research and development."[35] The current *National Energy Policy* reaffirms long-term objectives of increasing energy supplies in both traditional and alternative fuels.[36]

The consensus position at the time, that private markets would fail to produce sufficient oil supplies for the world market absent government help, has proven incorrect. Inflation-adjusted oil, gas, and electricity prices declined from 1980 to 2001.[37] This is a clear indication that private markets, encouraged by deregulation, have contributed to a growing abundance (as opposed to scarcity) of energy.

Although the DOE recognizes that private markets can supply energy, it continues funding energy supply programs. There is no apparent market failure characterizing the market for energy supply. In the absence of market failures, DOE energy supply programs cannot produce net public benefits.

Energy Efficiency

The promotion of energy efficiency has long been a major goal of the Department of Energy. In DOE's current *Strategic Plan*, established during the Clinton administration, Goal 1, Objective 2, is to "significantly increase energy efficiency in the transportation, industrial and buildings sectors by 2010." The Bush administration's May 2001 *National Energy Policy* likewise calls for the federal government to "promote further improvements in the productive and efficient use of energy" through "energy efficiency research" and other long-established energy efficiency programs.[38]

Harkening back to our earlier discussion of market failure as the only convincing rationale for government intervention, it should be pointed out up-front that the promotion of energy efficiency is indefensible from an economic perspective. That's because the benefits of reducing energy costs or energy use accrue to the household or business that reduces those costs. Reducing costs is an internal benefit to those who reduce costs. There is no externality benefit in providing energy efficiency. Government efforts to increase energy efficiency do not provide an externality benefit and do not reduce a market failure.

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That having been said, energy efficiency is not an economic concept; it's an engineering concept—the ratio of an input to an output. Just as we define the energy efficiency of a motor, we define the energy efficiency of hot water heaters, refrigerators, washing machines, and other appliances. The common view is that an improvement in energy efficiency occurs if the appliances can produce a given level of energy services with less energy input.

Accordingly, energy efficiency is different from, and not related to, the efficient use of energy resources in an economic sense. In simple terms, energy efficiency means using less energy. Using energy resources efficiently means using energy at a level that maximizes net benefits. When we use energy resources efficiently, we use more energy when prices are low and less energy when prices are high. Government programs that "improve energy efficiency" discourage energy use regardless of price. In fact, energy consultants Eric Hirst and Marilyn Brown consider low energy prices to be a "market barrier" that discourages energy efficiency investments.[39]

A few hypothetical questions illustrate the point:

If we observe the price of energy to decline, as in the 1980s, and the use of energy to increase, what do *we conclude about efficiency?* The law of demand states that more of a good will be used as its price falls. Observing that consumers use more energy at a lower price indicates that markets are functioning properly, and using more energy is consistent with economic efficiency. With more energy used per unit of GDP, energy efficiency has diminished.

When we observe that electric utilities use various fuels, such as nuclear, hydro, natural gas, and coal, are they choosing the most efficient fuels possible? Economic efficiency suggests that electric utilities should minimize costs and diversify their fuel selection to reduce risk. Capital intensive technologies, such as coal and hydroelectric power, are economically efficient for meeting base-load demand, whereas natural gas is more economically efficient for peak demand use. The British thermal unit (BTU) input of these fuels is ambiguous and irrelevant for fuel choice. Certainly there is no reason to select fuels on energy efficiency grounds, such as maximizing kilowatt-hour (kWh) per BTU of fuel input.

When we note that Canada has a high ratio of BTU energy use per unit of GDP, while Japan has a low ratio of energy use per unit of GDP, what does that tell us about efficiency? Canada has abundant energy resources and low energy costs, so using and exporting energy intensive goods is economically efficient. Japan has limited indigenous energy resources, high energy costs, and imports many of its energy intensive goods, which is likewise economically efficient. Although some might conclude that Japan is "energy efficient" while Canada is "energy inefficient," each country uses its energy resources efficiently.

Suppose we observe a large and abrupt structural change in the economy, where energy intensive industries experience a loss of output and employment. What do we conclude about efficiency? Energy efficiency proponents interpret the decline in energy per unit of GDP as an improvement in energy efficiency. However, achieving energy efficiency through reduced output and employment is not economically efficient. This improvement in energy efficiency, along with unemployment and reduced output, does not indicate increased efficiency in the use of energy resources.

Does the imposition of standards requiring less energy use in appliances improve efficiency? Energy efficiency standards result in appliances requiring less energy, which increases energy efficiency. However, mandates requiring less energy use seldom contribute to the efficient use of energy or other resources. There is no evidence that consumers save money by the application of these standards. There is no evidence that manufacturers produce appliances that meet consumers' needs, except for their energy use. Efficiency standards probably contribute to using less energy but not to the efficient use of energy.[40]

The rationale for asserting that economic efficiency is an appropriate policy goal is that it results in the highest GDP for a given level of resources, and policies that enhance economic efficiency make us better off. But increasing energy efficiency will retard GDP unless it increases economic efficiency. As the examples above illustrate, using more energy at a lower price often contributes to economic prosperity; restricting energy use would reduce our economic well-being.

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Although advocates of government-mandated and government-subsidized improvements in energy efficiency agree that such programs must make economic sense (defined as the present value of energy saved over the lifetime of the investment exceeding the initial capital cost of the technology in question), economists seldom find that such programs pass a cost/benefit test. That's because energy efficiency proponents use unique definitions of costs and benefits— definitions that are inconsistent with those commonly used elsewhere in the economy.[41]

For instance, textbook economics demonstrates that the benefits of a government program can be ascertained by calculating the net willingness of consumers to pay for that particular policy change. This measure of benefits is the monetary value that consumers place on the policy outcome. In contrast, the proponents of DOE energy efficiency programs calculate program benefits by adding up the present value of energy saved by those programs.[42] The widespread practice of using an artificially low discount rate to estimate future energy savings inflates these numbers even higher.[43]

Another problem is that proponents of government-sponsored energy efficiency programs ignore opportunity costs when calculating net benefits. In the case of a firm, the best investment minimizes overall costs rather than energy use per se. A manufacturer, for instance, might find that upgrading office lighting technologies with the newest, most energy efficient equipment easily passes a narrow cost/benefit test and will likely save $x over five years, but investing in upgrading production technology in manufacturing facilities would likely save $5x over five years. In the case of a household, the best use of limited resources may be to send junior to college or to take a needed vacation. In this case, forgoing the opportunity to add attic insulation, even it would save energy, may be the best investment.

Finally, there is the issue of whether the goal of enhanced energy efficiency works at cross-purposes with the goal of increased energy supply. Energy efficiency programs, after all, focus on reducing energy use. In contrast, the goal of enhancing energy supplies means providing more energy. The DOE has programs to enhance the supply of coal, oil, natural gas, and electricity. At the same time, it has programs to discourage the use of these fuels. The problem is that a successful energy supply program increases the supply of a fuel and, all things being equal, reduces its cost. This enhanced supply reduces the cost/benefit ratio of energy conservation programs. Similarly, if energy conservation programs made economic sense, government energy supply programs would be less cost-effective. Achieving one policy goal reduces the economic payoff of achieving a different policy goal.

A good example of the bureaucratic imperative to defend dubious government programs regardless of economic merit (one of Charles Wolf's aforementioned government failures) is a 1997 report by five DOE national laboratories on the costs of reducing carbon emissions in the United States. The Five-Lab study concluded that by the year 2010, carbon emissions could be reduced to their 1990 levels at little or no cost. All that would be necessary would be a carbon fee of $50 per tonne of carbon and aggressive, but unspecified, government policies. A critique of the Five-Lab study by the lead author of this study reached the following conclusions:

- The main conclusions expressed in the executive summary and analysis results sections are not derived from or supported by the technical chapters. Some of the main conclusions of the Five-Lab study are merely ad hoc assumptions.[44]
- The study uses a methodology to estimate costs and benefits that is inconsistent with the economic principles of cost/benefit analysis. Consequently, both costs and benefits of scenarios to reduce carbon emissions are estimated incorrectly.[45]
- The study underestimates the costs of reducing carbon emissions in the electric utility sector.[46]

The fundamental problem with the Five-Lab study is its faulty methodology, which focuses on alleged market barriers instead of concrete market failures.[47] Moreover, the benefits of government actions are measured not as benefits to consumers but as the present value of energy saved assuming an artificially low discount rate.

The Five-Lab study is certainly convenient from the DOE's perspective. The study, in contrast to other comparable analyses, concludes that the carbon taxes necessary to reduce greenhouse gas emissions are minimal. From the department's perspective, this is an ideal message: good energy policy (defined as reducing our use of fossil fuels, the primary source of industrial greenhouse gasses) requires DOE R&D programs and the

Proponents of government-sponsored energy efficiency programs ignore opportunity costs when calculating net benefits.

The idea that without government help markets will underprovide energy resources has no economic support.

national laboratories, not additional energy taxes (politically unpopular and without immediate benefit to the DOE).

In sum, the concept of energy security as presently understood by the DOE is meaningless. The idea that without government help markets will underprovide energy resources has no economic support. The concept of energy efficiency has never made economic sense because it does not relate to the efficient use of resources.

Why then are those objectives the major energy policy goals of the DOE? The answer is simple: Those objectives are in the self-interest of the DOE. Those objectives ensure that almost any conceivable federal energy program has some justification. From a bureaucratic perspective, those objectives are far superior to the objective of improving economic efficiency by addressing market failures. The DOE, after all, would not find market failures prevalent in energy markets, which means that it would not be funding energy programs and would probably not be in the energy business. The goals of increasing energy supplies, improving energy efficiency, and securing “energy security” are essential to protecting the DOE and its budget, not to improving the public welfare.

Basic Questions about Basic Science

So far, this paper has discussed issues surrounding the public funding of applied energy R&D—that is, the kind of scientific research that governmental officials think is most likely to contribute to the energy policy goals discussed in the previous section. Yet, basic science research is also a part of DOE’s energy research portfolio.

Basic science is scientific research that is not expected to directly advance any of the immediate policy goals discussed above but is nonetheless fundamental to the pursuit of scientific knowledge in the long term. That knowledge might eventually provide an economic value or a social-cultural value.[48] Investigating the nature and properties of so-called dark matter is an example of basic science. Learning about dark matter does not result directly in new consumer goods or technologies. Instead, it is intended to develop the underlying theories that support future applied research. On the other hand, investigating how to efficiently build and operate a nuclear fusion reactor and to make such a reactor economically competitive is considered applied science (the practical application of scientific fundamentals already known to us). While the theoretical case for federal support of basic science is far stronger than the theoretical case for federal support of applied science (it is far harder for an investor to capture the full benefits, if any, of the former than it is to capture the benefits of the latter), the nonmarket failures that haunt federal R&D in the applied sciences likewise haunt federal R&D in the basic sciences . . . perhaps even more so.

The economic value of basic research is its contribution to the productivity of applied research and technology development.[49] However, the economic benefits of basic research—the when, where, and what it might contribute to society—are not known in advance. We cannot determine in advance whether basic research will lead to the advancement of science, nor can we determine whether a scientific advance will contribute to commercial success. Technological development derives benefits from previous basic research, but the link may not be identifiable. For those reasons, the appropriate level of basic research funding is difficult to determine, as is the optimum portfolio of basic research projects.

Basic research can, however, produce a social-cultural value without resulting in a monetary payoff. The U.S. space exploration program, for instance, is pursued for social, cultural, and political reasons, not primarily economic reasons (although it is often defended on those grounds). Economic benefits may accrue from the program, but they are only incidental; most of the scientific advances are highly esoteric and not commercially important. The social-cultural gains that may result from such basic science, it's important to note, primarily benefit a small segment of the scientific community rather than the public. Accordingly, there is reason to question whether basic research provides a social-cultural benefit that the public is willing to pay for.

Unfortunately, federal science programs make little effort to tie specific undertakings to the goals that are supposedly being sought by those undertakings. If research projects are undertaken for social-cultural reasons, for instance, there should be clear performance goals and metrics to quantify success or failure. If a scientific endeavor is supposed to make an economic contribution, the link between the research area and its potential economic contribution should also be explicit, as should the performance goals and timetables. Refraining from establishing such performance metrics reduces accountability.

Rather than establish specific goals and metrics for basic scientific research, the federal government routinely cites the pursuit of "international scientific leadership" and "fortifying scientific foundations" as the main objectives for particular programs.[50] The goal of "international leadership" is obviously difficult to oppose; certainly, we cannot advocate being "international followers." But the United States cannot realistically be expected to be the world leader in each scientific discipline and in each field within that discipline. Budget choices have to be made. The goal of international leadership accordingly provides no guidance as to the allocation of a science budget.

The goal of universal scientific leadership could actually be counterproductive. Assume, for instance, that foreign countries allocate their R&D budgets where they expect to obtain the largest economic benefits. Nations that follow that strategy would gain far more economic "bang for the buck" than they would by spreading their efforts among various disciplines. Indeed, by not investing dollars in disciplines with the greatest potential for success out of some misguided attempt to lead the world in all scientific endeavors, the United States would actually harm, not help, its march toward that goal.

Moreover, scientific research, especially basic research, is subject to an international free rider problem. As a public good, the results of basic research are widely available, even to foreign countries. If one country allocates its scientific research budget between basic and applied research and another country specializes only in applied research, the second country may obtain larger economic benefits. The first country has a smaller applied research budget because it allocates part of the total scientific budget to basic research, leaving fewer funds for applied research. Each country benefits from the basic research expenditures of the first country. However, the second country benefits even further from its large applied research expenditures. By investing in scientific leadership in basic research, the U.S. may subsidize technology development in other countries and may even receive a negative rate of return on its scientific investment.

In sum, basic scientific research may well merit public support, but the means by which it is pursued must be seriously rethought.

Agendas for Reform

The above discussion suggests that publicly funded energy R&D programs, even if theoretically defensible, have two fundamental problems. First, they have little relationship to the market failures that they're ostensibly intended to address. Second, they are poorly managed and heavily politicized.

Publicly funded energy R&D programs have little relationship to the market failures that they're ostensibly intended to address.

An examination of the data bears this critique out. Economist William Niskanen estimated the effects on the annual productivity growth rate of different aggregations of real federal R&D outlays per civilian employee for the years 1956–95.[51] After controlling for the business cycle and other factors, Niskanen found that a $100 increase in real (1987) federal R&D outlays per employee (which would somewhat increase current federal outlays) might increase the annual productivity growth rate by about 0.25 percent within five years. Niskanen observes:

> All the near-term effects of R&D outlays on productivity growth, however, appear to be specific to defense R&D. Civilian and space R&D outlays appear to have no effect on near-term productivity growth, either independently or in combination with other types of R&D spending. The long-term effects on productivity growth may be higher but cannot be estimated from this sample.[52]

There are two potential roads for reform. The first is outlined by Niskanen. He maintains that "science policy would probably make a larger contribution to economic growth by merely augmenting private R&D expenditures, leaving allocation decisions entirely to private organizations."[53] His proposed means for doing so would be to establish a robust tax credit for private R&D expenditures and a matching grant to universities to supplement funds raised from private sources.[54]

> Private organizations almost surely have better information and incentives to support the type of R&D that most contributes to economic growth, but their incentives are probably not sufficient to induce the optimal level of R&D. A market imperfection, however, does not imply that government can improve this outcome. Government-sponsored science programs may increase the total level of R&D expenditures, but the allocation of the incremental expenditure is unduly influenced by vocal user and supplier interests . . . The case for government support of civilian R&D is that the return to the economy is higher than the return to the firm, not that the government has better information on what R&D has the highest return.[55]

Unfortunately, in the course of establishing such a credit, Congress would be in a position to decide who receives the tax allowances and how they are defined, and special interests would undoubtedly influence the answers to those questions in a mischievous manner.

Although "government failure" can probably never be completely remedied, reforming institutional arrangements can minimize some of the problems. Unfortunately, the very existence of governmental agencies dedicated to energy R&D subverts the process. That's because energy agencies must by their nature promote governmental energy interventions—no matter how weak the case—often to the detriment of consumers and other sectors of the economy. The DOE, after all, cannot be expected to contend that energy markets behave much like any other market and thus need no special attention. An office of energy efficiency, likewise, cannot be expected to argue that labor markets are far more inefficient than energy markets and that scarce federal R&D dollars are better spent on the former than the latter. Bureaucracies will invariably act to justify their own programs even when they don't contribute to economic efficiency.

Accordingly, a second reform suggests itself. Suppose the Congress didn't legislatively earmark R&D for various economic sectors. Suppose it simply dedicated funds for the improvement of industrial productivity and empowered an agency to distribute the funds among competing projects. How would such an agency allocate the funds?

Presumably, such an agency would consider the various industries that underinvest in R&D, or perhaps industries in which productivity improvements could be best enhanced by increased R&D. Some energy efficiency proponents, for instance, believe that highly competitive industries never acquire sufficient profits to make R&D investments. Home building is just such an industry: there are a large number of small builders, profit margins are small, and there is no research institute.[56]

Although "government failure" can probably never be completely remedied, reforming institutional arrangements can minimize some of the problems.

Yet, considerations such as these play no role in the work of DOE's Office of Industrial Technology. Instead, the OIT focuses on energy intensive industries—such as aluminum, chemicals, forest products, glass, metal casting, and steel production—to the exclusion of industries that are not energy intensive.[57] Since the OIT's goal is to reduce energy use per unit of output by 25 percent by 2010,[58] that may make sense. Yet, as we've seen, such a goal is not necessarily compatible with the goal of improving overall economic efficiency. First, if the OIT allocated its R&D budget with an eye toward improving industrial productivity, there is no reason to believe that it would select energy intensive industries over other industries. And even if energy intensive industries were selected, the objective of the agency would be to improve overall productivity and reduce the costs of production, not to reduce energy use.

When an industry invests with the objective of improving productivity and reducing costs, its objective is to improve overall productivity, not the productivity of a single factor. If a single factor were critical, it would be labor, because labor costs are typically the largest share of total costs. Technical improvements that are most cost-effective tend to improve overall productivity. Energy intensity may decline, but only as a byproduct of overall productivity increases.

A better approach is pursued by the DOE's Office of Science, which manages most of the federal government's energy-related basic science programs. The OSC does not limit itself to programs that promote energy production or efficiency or even to programs that address energy use in the first place (the human genome program, for instance, is run out of the OSC). The OSC uses competitive procurement to allocate budgets for some of its undertakings. Accordingly, program management at the OSC is not subject to the same inefficiencies found in the applied energy programs managed by the OIT and others.

Still, the OSC and other DOE offices of necessity make use of large and unique physical facilities, such as the complex of national laboratories, to pursue many large-scale scientific undertakings, and the existence of those facilities can distort government decisionmaking. The location of DOE scientific facilities inevitably influences the allocation of funding in the long run. DOE ostensibly bases its recommendations on merit, but it also makes decisions based on equity, where each lab receives a share of the capital budget over time. Since Congress makes the final budget choices, politics inevitably interferes with efficient decisionmaking. For example, the end of the Cold War and the Nuclear Test Ban Treaty should reduce the need for nuclear weapons development and its funding, much of which goes to the Los Alamos and Sandia national laboratories in New Mexico. However, the political process continues such funding.

Because the construction of a major laboratory is, in a sense, a long-term commitment to fund research at that facility, competition for research funds is largely constrained. Universities cannot realistically compete with national laboratories for most large-scale scientific projects given that the labs represent sunk costs for such undertakings and would be rendered less valuable without a steady stream of well-funded federal projects. The process that precludes the universities from competing for DOE funds may also preclude funding the most meritorious facilities at the most meritorious locations.

While some of the problems related to publicly funded R&D are relatively intractable, many could at least be somewhat attenuated by refining the OSC model and applying it to all of DOE's present R&D programs. The National Science Foundation also provides an alternative funding model that appears to allocate federal dollars more appropriately than the existing process at DOE. The National Science Foundation obtains its budget from Congress and decides internally on the allocation of the budget between scientific disciplines and policy areas. A competitive merit review process that includes peer review provides the basis for project selection.[59]

When an industry invests with the objective of improving productivity and reducing costs, its objective is to improve overall productivity, not the productivity of a single factor.

At the very least, DOE's basic research and applied energy programs should be merged with other government science programs into a government office that funds scientific research.

The DOE is not unique in its ability to undertake basic research, other than that related to nuclear weapons. If the DOE basic research budget were part of the government budget for basic research, universities and national laboratories could compete on equal grounds for scientific facilities and scientific dollars. Such competition would diminish the role of Congress in allocating budgets, and thus the role of politics, and the related governmental failures that haunt economic decisionmaking. Furthermore, funding decisions could be based on truly national objectives, such as expected contribution to economic productivity, rather than on internal objectives of an agency, such as energy efficiency and energy security.

Conclusion

The private sector tends to underinvest in research that provides public benefits. The government tends to overinvest in research that yields insufficient public benefits. The inefficiency that characterizes the DOE energy and basic research programs is not merely overinvesting in bad programs but also inefficient allocations between programs and between research institutions.

The energy policy goals—enhancing energy supply, increasing energy efficiency, and providing energy security—do not provide a benefit to the public that private markets cannot provide. The DOE energy policy goals are goals for DOE prosperity, not for the benefit of the public. The DOE goal of international scientific leadership, or even of doing the highest quality science, is similarly limited. "Merit" is the criterion used to select such undertakings, but whether merit refers to social-cultural value or to expected economic value is never specified. There is little evidence that scientific contributions relate to benefits to taxpayers. The taxpayers appear to serve the scientific community rather than the other way around.

At the very least, DOE's basic research and applied energy programs should be merged with other government science programs into a government office that funds scientific research. Moving the DOE programs to the National Science Foundation is one possibility. Universities, national laboratories, and perhaps others could then compete on equal grounds for scientific facilities and for scientific projects and programs. Energy supply and conservation programs would continue to receive funding but on a competitive basis with those that promise economic or environmental benefits. The allocation of the scientific budget should be determined by an assessment of how those dollars could best enhance long-term economic productivity.

The methodology and conclusions of this study are in marked contrast to those of the Yergin task force.[60] That task force observed that the end of the Cold War and the stability of energy markets reduce the required level of funding for nuclear weapons programs and for energy programs. The task force recommended that the laboratories be restricted to their historical missions and that the laboratories adjust to declines in funding. This study suggests allowing the national laboratories to broaden their missions in order to compete for public and private research contracts.

In the absence of costly bureaucratic reorganizations, Congress could make an enormously positive contribution by simply reflecting on the meaning and significance of energy security and energy efficiency. With budgets for those goals in the hundreds of millions of dollars, that should not be asking too much.

Notes

1. Committee for Economic Development, "America's Basic Research: Prosperity through Discovery," New York, 1998. Cited hereafter as CED.

2. The average price of electricity decreased continuously throughout the 20th century, from 92 cents/kWh (in 1967 terms) to 2 cents/kWh by 1967. Richard F. Hirsh, "Regulation and Technology in the Electric Utility Industry: A Historical Analysis of Interdependence and Change" in *Regulation: Economic Theory and History,* ed. Jack High (Ann Arbor: University of Michigan Press, 1991), p. 156.

3. CED, p. 2.

4. Ibid.

5. Throughout the 1980s, the Energy Research Advisory Board conducted numerous assessments of DOE programs and typically endorsed those programs. More recently, the secretary of energy's advisory board offered a similar assessment. See U.S. Department of Energy, *Energy R&D: Shaping Our Nation's Future in a Competitive World*, June 1995. Hereinafter the Daniel Yergin report. Also see President's Committee of Advisors on Science and Technology, *Federal Energy Research and Development for the Challenges of the Twenty-First Century,* November 1997.

6. For a review of the literature, see *The Theory of Market Failure: A Critical Examination*, ed. Tyler Cowen (Fairfax, Va.: George Mason University Press, 1988).

7. The other rationale for government involvement in markets is "equity." Government programs designed to assist low-income people are based on equity, not efficiency.

8. Jerry Taylor, testimony before the House Committee on Science, Subcommittee on Energy and Environment, April 9, 1997.

9. Charles Wolf, M*arkets or Government: Choosing between Imperfect Alternatives* (Cambridge, Mass.: MIT Press, 1991).

10. Nonhydro renewable energy technologies constitute only about 2 percent of the electricity market, and prospects for increased market share absent major new subsidies are dim. See Jerry Taylor and Peter VanDoren, "Evaluating the Case for Renewable Energy: Is Government Support Warranted?" Cato Institute Policy Analysis, forthcoming. For a review of the strides made in nonhydro renewable energy research over the past two decades, see James McVeigh, Dallas Burtraw, Joel Darmstadter, and Karen Palmer, "Renewable Energy: Winner, Loser, or Innocent Victim? Has Renewable Energy Performed as Expected?" Discussion Paper 99-28, Resources for the Future, Washington, June 1999.

11. Energy Research Advisory Board, *Federal Energy R&D Priorities,* U.S. Department of Energy, Washington, DOE/S-0031, November 1981.

12. President's Committee of Advisors on Science and Technology.

13. CED, p. 3.

14. U.S. Department of Energy, *Annual Performance Plan for FY 2000,* DOE/CR-0066.

15. For a good introduction, see William C. Mitchell and Randy Simmons, *Beyond Politics: Markets, Welfare, and the Failure of Bureaucracy* (Boulder, Colo.: Westview, 1994).

16. Wolf, p. 67.

17. Linda R. Cohen and Roger G. Noll, *The Technology Pork Barrel* (Washington: Brookings Institution, 1991).

18. Ibid., p. 378.

19. See generally Jerry Taylor, "Energy Efficiency: No Silver Bullet for Global Warming," Cato Institute Policy Analysis no. 356, October 20, 1999.

20. Ibid. and Ronald J. Sutherland, "'No Cost' Efforts to Reduce Carbon Emissions in the U.S.: An Economic Perspective," *Energy Journal* 21, no. 3 (2000): 89–112.

21. Patrick J. Michaels and Robert C. Balling Jr., *The Satanic Gases: Clearing the Air about Global Warming* (Washington: Cato Institute, 2000) pp. 191–98.

22. U.S. Department of Energy, *Comprehensive National Energy Strategy,* DOE/S-0124, April 1998.

23. Ibid., p. viii.

24. Ibid.

25. U.S. Department of Energy, *Fiscal Year1998 Accountability Report,* DOE/CR-0067, February 1999, p. 8.

26. U.S. Department of Energy, *Annual Performance Plan for FY 2000,* p. 9.

27. Ibid.

28. For a brief discussion, see Jerry Taylor, "No Matter What, the Oil Will Flow," *Los Angeles Times,* October 12, 2001. For a more complete discussion, see Douglas Bohi and Michael Toman, *The Economics of Energy Security* (Norwell, Mass.: Kluwer Academic Publishers, 1996).

29. U. S. Department of Energy, *National Energy Strategy: Powerful Ideas for America,* 1st ed., February 1991, pp. 3, 6.

30. For a more complete discussion of the topic, see Philip Verleger, *Adjusting to Volatile Energy Prices* (Washington: Institute for International Economics, 1993); and Bohi and Toman.

31. For an analysis that indicates small externality values for energy security see Bohi & Toman.

32. U.S. Department of Energy, *National Energy Strategy,* p. 84.

33. Ibid., p. viii.

34. Ibid.

35. *Fiscal Year 1998 Accountability Report,* p. 8.

36. National Energy Policy Development Group, *National Energy Policy* (Washington: U.S. Government Printing Office, May 2001).

37. For data regarding increasing energy abundance, see Robert L. Bradley Jr., *Julian Simon and the Triumph of Energy Sustainability* (Washington: American Legislative Exchange Council, 2000).

38. National Energy Policy Development Group, p. xii.

39. Eric Hirst and Marilyn Brown, "Closing the Energy Efficiency Gap: Barriers to the Efficient Use of Energy," *Resources, Conservation and Recycling* 3 (1990): 267–81.

40. Glenn Schleede, "Statement for the Department of Energy's Advisory Committee on Appliance Efficiency Standards," Energy Market & Policy Analysis, Inc., March 28, 2000; "Statement on Statistical Deficiencies in the U.S. Department of Energy's Energy Efficiency Standards Program," Presented to the Committee on Energy Statistics of the American Statistical Association, Energy Market & Policy Analysis, Inc., November 5, 1999; and "Letter to Bill Richardson, Secretary of Energy," Energy Market & Policy Analysis, Inc., October 28, 1999.

41. A classic economic text on cost/benefit analysis is E. J. Mishan, *Cost-Benefit Analysis* (New York: Praeger, 1976).

42. For one of many examples, see R. Carlsmith et al., *Energy Efficiency: How Far Can We Go?* ORNL/TM-114441, Oak Ridge National Laboratory, Tennessee.

43. For a critique of DOE appliance standards, including the use of unrealistic discount rates, see Glenn Schleede, "Will Congress or the New Administration Protect Consumers from DOE, Clothes Washer Manufacturers and Self-Appointed Energy Efficiency Advocates?" Energy Markets and Policy Analysis, www.consumeralert.org/issues/enviro/2SchleedeWash.htm.

44. Ronald J. Sutherland, "A Critique of the 'Five Lab' Study," The American Petroleum Institute, June 1998, www.api.org.

45. Ibid.

46. "The Costs of the Kyoto Protocol: A Multi-Model Evaluation," ed. John Weyant (1999), a special issue of the *Energy Journal,* presents the results of 13 modeling analyses, none of which supports those of the Five-Lab study.

47. Henry D. Jacoby, "The Uses and Misuses of Technology Developments a Component of Climate Policy" in *Climate Change Policy: Practical Strategies to Promote Economic Growth and Environmental Quality* (Washington: American Council for Capital Formation, May, 1999).

48. Harry G. Johnson, "Federal Support of Basic Research: Some Economic Issues" in *Basic Research and National Goals,* National Academy of Sciences, March, 1965, pp. 127–46.

49. Most technological innovation, however, stems from other advances in applied research and not from recent advances in basic scientific research. The long-term contribution of basic research generally takes 20–30 years to come to economic fruition. William Niskanen, "R&D and Economic Growth—Cautionary Thoughts," in *Science for the 21st Century: The Bush Report Revisited,* ed. Claude Barfield (Washington: American Enterprise Institute, 1997), pp. 84–86.

50. National Science Foundation, *National Science Board Strategic Plan,* Arlington, Va., November 19, 1998.

51. Niskanen, pp. 90, 92–93.

52. Ibid., p. 90.

53. Ibid., p. 91.

54. Niskanen's proposed R&D tax credit would differ from the present R&D tax credit in two ways. First, it would apply to all R&D expenditures by a firm and not merely to an increment of investment above some base period. Second, it would also be refundable to avoid any bias against start-up firms with no near-term tax liability. Ibid.

55. Ibid.

56. Hirst and Brown.

57. *Fiscal Year 1998 Accountability Report.*

58. Ibid., p. 10.

59. Office of Technology Assessment, *Federally Funded Research: Decisions for a Decade,* Washington, May 1991.

60. Daniel Yergin report.

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