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TECHNICAL
REPORT

Long Range Energy R&D

A Methodology for Program Development and Evaluation

JAMES T. BARTIS

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1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
1200 South Hayes Street, Arlington, VA 22202-5050
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Summary

This report presents a disciplined planning process that links long-range strategic goals to detailed long-term energy research and development (R&D) needs and opportunities. The method begins with an articulation of long-term energy R&D goals, accounting for the difficulty of predicting the far future. It then covers evaluation of the potential of a technology to meet these long-term energy R&D goals, determines the fundamental technical problems that underlie development risks and uncertainties, and identifies alternative development approaches that are directly related to long-term R&D goals.

Most long-term energy planning at the U.S. Department of Energy (DOE) has been based on developing a limited number of projections of future energy supply and demand using large econometric models. Prior projections (made 15 to 25 years ago) of energy use patterns in the year 2000 generally missed the mark by wide margins. Major problems included overestimating energy prices and energy demand. In general, the role of new technologies was overrated, and the evolution of existing technologies was generally underrated. Reviewing more recent energy projections, we conclude that fundamental problems remain. For example, if the Organization of Petroleum Exporting Countries (OPEC) were to lose influence or if highly efficient automotive technologies were to be developed and deployed, world oil supply and demand would change significantly. The approach developed in this report is independent of quantitative projections of energy prices, supply, and demand.

Projecting Energy Needs to 2050

If projecting 25, or even 15, years into the future is so difficult, is it reasonable to attempt to project energy needs nearly 50 years from today? Fortunately, long-term technology development needs can be established without detailed projections of future supply and demand. What we can say with confidence is that 50 years from now, there will be a huge domestic and international demand by end-users for the following types of energy:

- Electric power to meet stationary and some transportation energy needs
- Processed liquid fuels to meet transportation energy needs
- Gaseous fuels to meet stationary and possibly transportation energy needs

For developing a long-term federal R&D portfolio, the amount of any type of energy that may be needed in 2050 is far less relevant than the fact that the amount will be extremely large. For example, even if, contrary to almost all projections of energy demand, de-

mand for electric power drops by as much as 50 percent, a huge amount of electric power will still be needed.

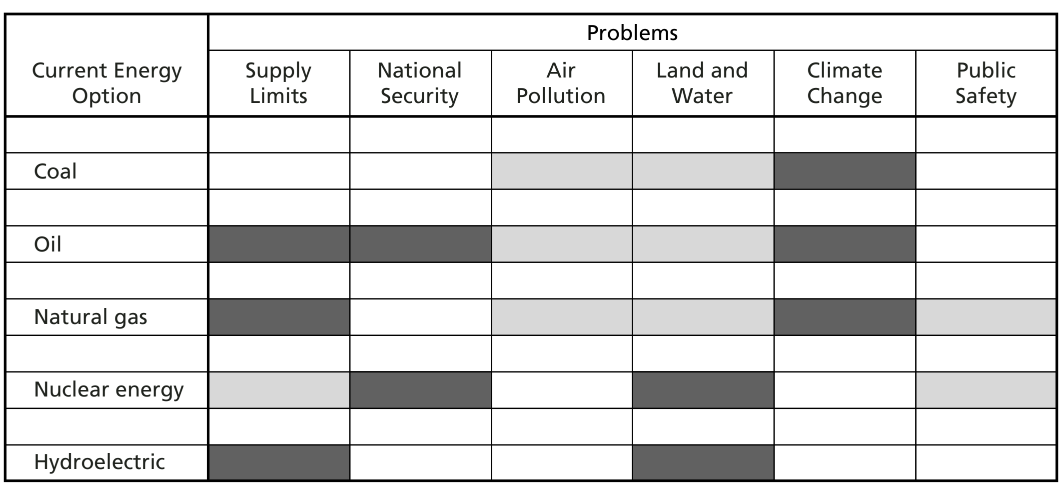
While the U.S. government's energy policies have varied over time, our analysis indicates that the high-level goal of ensuring a steady supply of affordable, environmentally sound energy for America's homes, businesses, and industry has endured for the past 25 years. Consequently, we have adopted this goal and applied it to the long-term portion of the federal energy R&D program. More specifically, the purpose of long-term R&D is to develop technology options that will provide a hedge against future scenarios in which current technologies will no longer be capable of providing steady supplies of affordable electricity and liquid and gaseous fuels.

Long-term threats to adequate supplies of affordable energy fall into the following categories: supply constraints; national security; safety problems; and three environmental issues—air pollution, global climate change, and degradation of land and water. Figure S.1 illustrates how these six problem areas map onto the five main energy sources that currently underlie the U.S. economy.

Strategic long-term energy R&D goals follow directly from the threat matrix and are shown in Table S.1. The prioritization shown in Figure S.1 is neither unique nor static. Future users of this methodology can review problem areas and develop appropriate sets of long-range R&D goals.

The major advantage of the threat-matrix approach, in contrast to scenario-based planning, is that it clearly separates the problem from the solution. This is critical for R&D planning and not easy to achieve with scenario-based approaches, which are generally designed for near-term policymaking rather than long-term R&D planning. Any realistic long-term scenario must include national as well as global responses to problems encountered. If

Figure S.1
2050 Energy Threat Matrix



NOTE: Potential problem areas that threaten the ability to rely on current major energy options in 2050 are indicated in dark gray (most serious) and light gray. The five energy sources listed in the first column provide 97 percent of the energy currently used in the United States.
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Table S.1
Long-Range Strategic R&D Goals

Priority R&D areas are those that offer affordable means of:

For electric power
- Providing electric power
  - — With significantly reduced emissions of greenhouse gases, and
  - — Avoiding nuclear fuel cycle problems, especially proliferation of fission materials and waste fuel disposal
- Reducing demand for electricity from power plants
- Significantly enlarging the technically recoverable resource base for natural gas

For processed liquid fuels
- Meeting transportation energy needs with significantly reduced greenhouse gas emissions
- Reducing energy demand in transportation
- Significantly enlarging the global technically recoverable petroleum resource base
- Providing, with low or no greenhouse gas emissions, non-petroleum sources of liquid fuels

For gaseous fuels
- Increasing supplies of natural gas, including
  - — Enlarging the domestic and global technically recoverable natural gas resource base
  - — Manufacturing synthetic natural gas with low or no greenhouse gas emissions
- Reducing energy demand in traditional and potential new applications for natural gas
- Manufacturing hydrogen with low or no greenhouse gas emissions

such problems and responses are not addressed, the scenarios result in Malthusian projections with, for example, energy becoming very scarce or disastrous climate changes occurring. In some cases, scenarios guess about the costs and performance of technologies that are years away from commercial application. They may also incorporate legislative and regulatory changes that raise ideological controversies not relevant to planning and prioritizing the long-term federal energy R&D program.

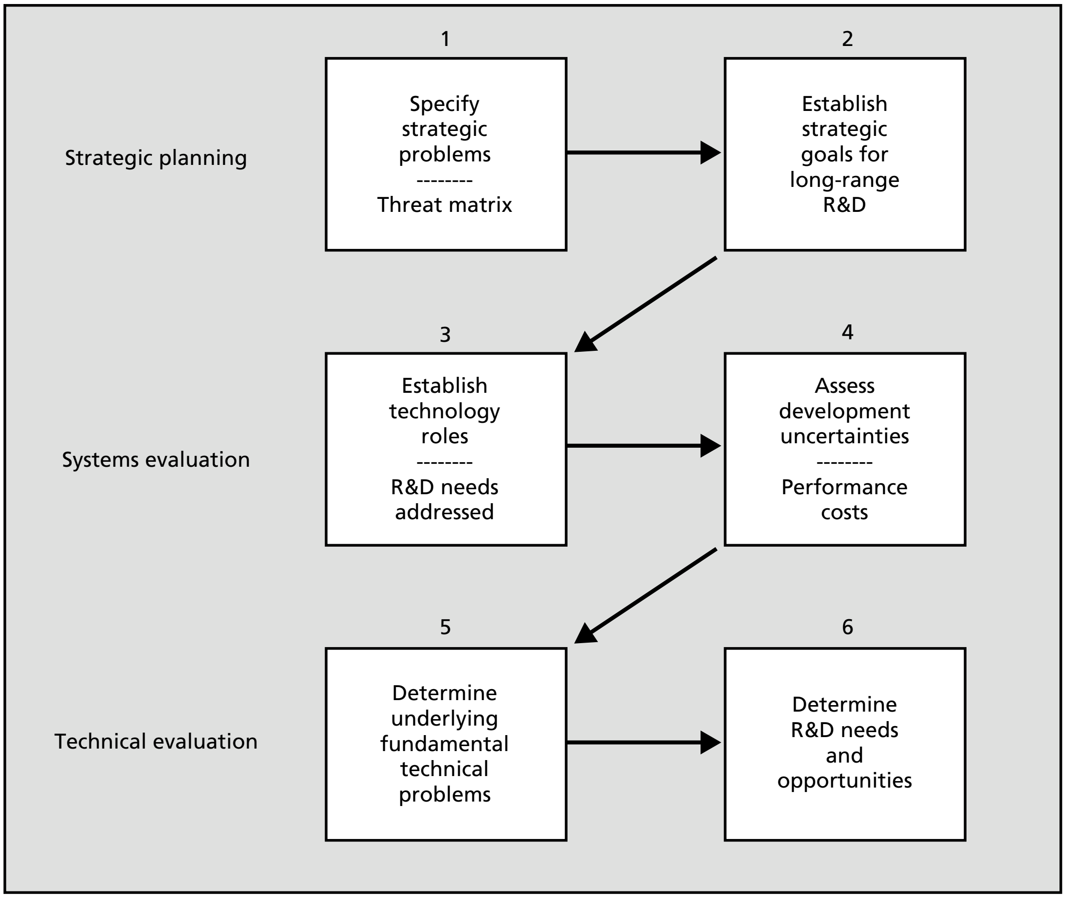
The IntraTech Approach

For the purpose of conducting technology-specific analyses, we developed a six-step method, which we call the IntraTech approach. The name reflects its use for linking long-range strategic R&D goals *within* a technology area to detailed, long-term energy R&D needs and opportunities. The IntraTech approach is diagrammed in Figure S.2. The first two steps are directed at understanding the long-term strategic problems that potentially threaten continued reliance on the current predominant energy sources—coal, petroleum, natural gas, nuclear energy, and hydroelectric power. The results of this analysis are the threat matrix and strategic R&D goals described in the previous section.

The next four steps in the IntraTech approach are directed at evaluating a particular technology. The third step consists of determining the specific threats and strategic R&D goals addressed by the technology of interest. This is important because strategic priorities within DOE have evolved since the initiation of development work on many technologies. Additionally, long-term strategic R&D goals are likely to be significantly different from short-term goals.

The fourth step consists of engineering and systems analyses that allow performance uncertainties and affordability risks to be identified. For these analyses, guidelines are provided to establish an even playing field for evaluating affordability risks of advanced energy technologies.

Figure S.2
The Six-Step IntraTech Approach for Long-Range R&D Planning



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The fifth and sixth steps consist of technical analyses that determine the fundamental technical problems that underlie performance and cost uncertainties (Step 5) and, using that information, establish R&D needs and opportunities (Step 6).

Case Study: Power Generation Based on Coal Gasification

To illustrate and evaluate the IntraTech approach, we undertook a case study of an ongoing major program area within the DOE Office of Fossil Energy. To limit the scope of this case study, we focused Steps 5 and 6 on two long-term, high-risk areas: low-oxygen gasification and solid oxide fuel cells for central station applications. The case study shows that the IntraTech approach can identify long-term energy goals that a technology concept addresses, identify the key performance factors and risks, identify R&D needs and opportunities, and provide insights regarding alternative development options.

Findings

An advantage, as well as a limitation, of the IntraTech approach is that it stays within a technology area. The method compares the prospective performance and costs of an advanced technology to what is currently commercially available for achieving the desired product. Thus, this approach may be especially useful to DOE officials responsible for planning, justifying, and implementing long-term R&D programs directed at specific technology concepts or groups of related technology concepts.

However, at its current state of development, the IntraTech approach is not appropriate for portfolio management. This limitation became evident in the case study during the analysis of program balance within the DOE solid oxide fuel cell program. Whether the IntraTech "single technology" approach can evolve into a tool suitable for portfolio management remains an open issue. Meanwhile, it can be used to provide senior-level federal officials with uniform information on individual technologies that might better inform the current intuitive/consensus-based process of portfolio management and budget allocation.