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Evaluation of the Energy-Related Inventions Program Volume 1: Analysis of Case Studies of Supported Projects

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UNION CARBIDE CORPORATION
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Energy Division

EVALUATION OF THE ENERGY-RELATED INVENTIONS PROGRAM

VOLUME 1: ANALYSIS OF CASE STUDIES OF SUPPORTED PROJECTS

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ABSTRACT

This volume reports the analysis of the results of 30 case studies of grantees funded by the Energy-Related Inventions Program (ERIP). ERIP is one of several federal programs supporting invention and innovation in the private sector. It is a relatively small program with an annual budget of $5-6 million that focuses its attention on the independent inventor or small business with an energy-related invention. Support to the inventor or small business comes primarily in the form of a grant. The overall goal of the program is to stimulate innovation by individuals and small businesses and to assist in the development of promising energy-related inventions for eventual commercialization.

This volume is an aggregation and synthesis of the data gathered in the case studies. (Volume 2 contains the case studies.) The case studies explore in-depth the characteristics, perceptions, and experiences of inventors and agency personnel who have participated in the ERIP. Thus they are a rich source of information for use in evaluating the process by which the program's goals and objectives are implemented and for evaluating the program's usefulness in producing the results intended by the legislative mandate.

This report is organized around the evaluation issues:

- the target audience,
- the program operations and services, and
- the outcomes attributed to the program.

With respect to the target audience there are several conclusions.

- ERIP is fulfilling its congressional mandate by accepting only energy-related inventions from small businesses and by independent inventors.
- The program has encouraged a diverse group of individuals and businesses to submit their inventions for evaluation.
- The program tends to provide financial support to individuals with technical education and/or experience in areas related to their inventions.

- The NBS evaluation results in the recommendation of appropriate inventions, given criteria of technical feasibility, commercial feasibility and energy-relatedness.

With respect to ERIP operation and services, the following conclusions are made:

- ERIP provides two major services to grantees — money and credibility. These services are appropriate, given the mandate of the program to evaluate and support promising energy-related inventions.

- The NBS is performing its mandated service for DOE (i.e., evaluation and recommendation of promising inventions).

- The DOE meets its objective of developing a mutually acceptable course of action to be pursued by each recommended applicant with federal assistance. Given the number of grantees who complete the work statements, DOE is effective in defining an appropriate next step.

- While the evaluation process at NBS seldom provides technical assistance to grantees, it is not obvious that such assistance is needed or wanted.

- The perceived need for credibility, visibility and money suggests that financial support is not always the most effective means of supporting inventors who come to the program with a wide range of business/technical experience and with limited resources.

- On the whole, ERIP is effectively delivering the mandated services. However, there are a number of areas which need attention (e.g., communication, expansion of the range of services, time to process the grant, and the mechanism for NBS evaluation).

- A joint-agency mode of operation has worked and provides special benefits for program grantees.

The outcomes from the 30 cases have led to the following conclusions.

- The outcomes indicate that ERIP is meeting its goals and objectives.

- The number of cases which reached commercialization was unexpectedly large, given the short period of time in which the program has been operating. This outcome was a consequence of funding a number of technologies closer to commercialization. For short-term, higher-yield payoffs the program should continue to support technologies closer to commercialization.

- Given the number of cases which were able to either commercialize or obtain further support, the DOE policy of one-step, one-time-only funding is effective in preparing the grantee to continue development at the termination of the grant.

- The intangible outcomes of credibility and visibility suggest that careful attention be paid to the utility and importance of these outcomes before modifying the existing evaluation process.

PREFACE

The Energy-Related Inventions Program (ERIP) was established in 1974 by Public Law 93-577, Section 14, as a joint Department of Energy (DOE) and National Bureau of Standards (NBS), Department of Commerce, program. The NBS was charged with (1) evaluating energy-related inventions submitted to it and (2) recommending promising inventions to DOE for support — financial or nonfinancial. The ERIP is one of several federal government programs designed to stimulate technological innovations. The legislation clearly states that special emphasis is to be placed on inventions submitted by individuals and small businesses.

In 1979, the ERIP chiefs contracted for the development of a program evaluation methodology and in 1980 for the implementation of the evaluation. One task of the evaluation was to conduct a series of case studies of the program grantees and their technologies. The purpose of these case studies was to gather qualitative information by which to assess the performance of the Energy-Related Inventions Program and the outcomes resulting from its implementation. The evaluation effort included the following subtasks:

- interviewing a select number of participants supported by the Energy-Related Inventions Program,
- interviewing personnel of the National Bureau of Standards and the Department of Energy, Energy-Related Inventions Program,
- developing case studies,
- meeting with consultants and conducting field work to discuss results, problems, selections, and potential recommendations, and
- producing a final report.

Volume I is divided into three parts. Section I contains background information. Section II describes the ERIP program and presents the results of the evaluation. Section III presents our conclusions and recommendations.

ACKNOWLEDGMENTS

In developing Volume I of the evaluation of the Energy-Related Inventions Program, the authors relied on the case studies of 30 grantees funded by the program (Vol. II, Bronfman et al., 1982). We are indebted to these grantees, and we thank them for giving their time and for sharing their experiences. We especially thank the consultants who developed the case studies with the authors, lending their individual expertise in the areas of evaluation, entrepreneurship, venture financing, economics, invention, innovation, and small business.

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Eugene, Oregon

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SECTION I: BACKGROUND

THE INNOVATION PROCESS*

As background to the ERIP evaluation the authors consider it important to introduce and define the basic concepts used in describing the innovation process, to describe important characteristics of that process, and to provide a framework for the evaluation of any federal program designed to stimulate innovation. This framework and the underlying assumptions contained in it have guided the development and implementation of the ERIP program evaluation and are therefore essential to understanding the role ERIP plays in stimulating innovation in the United States.

The following points, which may not be readily apparent, should be kept in mind about the innovation process.

- The innovation process is not static but dynamic.
- The terms and the classifications used to describe the innovation process are neither static nor rigid.
- The process is not linear.
- An individual may enter the process at any point; however, most all the steps must be taken at some point in the process.
- The process may be iterative; that is, some activities may be repeated more than once.
- There is a large gap between the innovation and commercialization stages and participants in invention and innovation activities most often are reluctant to become part of the commercialization of their invention or innovation.

To complete the innovation process, an individual must possess or have access to a variety of different skills and resources.

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*The literature on invention and innovation is bountiful and spans a number of disciplines. For a comprehensive introduction to the technological innovation process see Kelly, P. and M. Kranzberg eds., *Technological Innovation: A Critical Review of Current Knowledge*, San Francisco Press, Inc., San Francisco, 1978.

- At the idea stage, creativity is the essential element.
- At the technical R&D stage, technical expertise is significant.
- At the market introduction stage, marketing skills are of paramount importance.

Invention and Innovation

The words "invention" and "innovation" have created considerable confusion — in part because they are often used interchangeably by the uninitiated. When considering how to stimulate the technological innovation process, it is critical to distinguish between invention and innovation.

An invention (i.e., a new concept, discovery, or device) is only the beginning of the technological innovation process. It has value if, and only if, it is put to use by society as (1) a building block for further development (i.e., another invention) or (2) a new process, product or service (i.e., innovation). All those activities, including invention, which precede and follow the development of an innovation are part of the innovation process.

Innovation is a complex series of activities, beginning at first conception or when an original idea is conceived, proceeding through a succession of interwoven steps of research, development, and management decision-making and culminating in a product, which might be a thing, a technique, or a process which is accepted in the marketplace.

The Nature of the Technological Innovation Process

The technological innovation process can be graphically presented as a sequence of events or a cycle through which new products, processes and services normally pass (see Fig. 1). Rarely does one individual have all the skills and resources necessary to traverse the innovation process. Thus it is appropriate to view the process in terms of component activities, participants and needs (see Fig. 2). The very nature of the innovation process *mandates* that any program designed to stimulate

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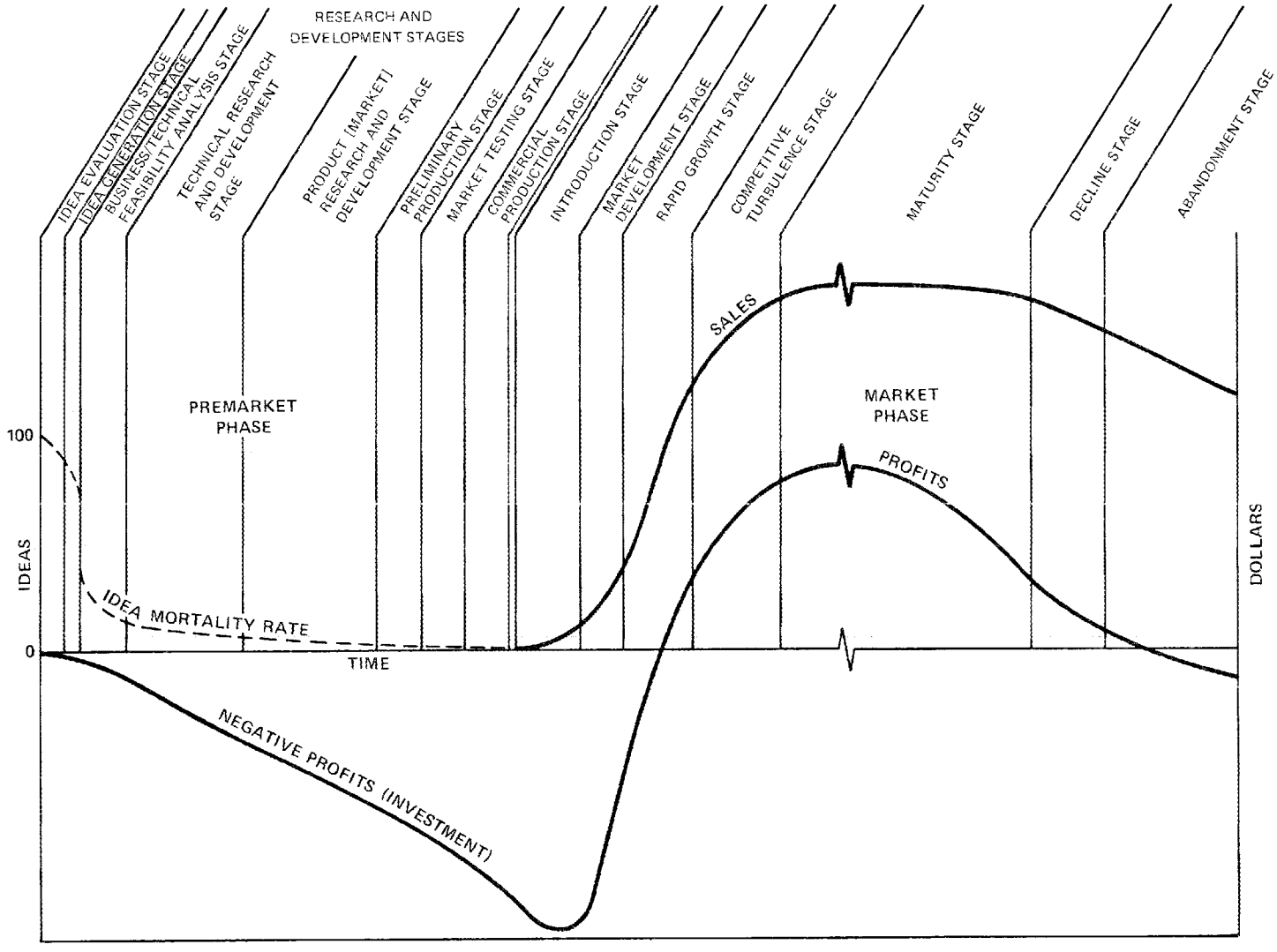

Fig. 1. The technological innovation process: a sequence of events through which new products, processes, and services normally pass (Udell 1982).

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COMPONENTS	INVENTION/INNOVATION (PREMARKET)			COMMERCIALIZATION (MARKET)		
ACTIVITIES	IDEA GENERATION	IDEA EVALUATION AND DEVELOPMENT	PRODUCT/PROCESS EVALUATION AND REFINEMENT	NEW VENTURE INITIATION; NEW PRODUCT/PROCESS INTRODUCTION	VENTURE GROWTH; SPIN-OFF OF PRODUCTS AND PROCESSES	BUSINESS AND TECHNOLOGY MATURATION
PRIMARY PARTICIPANTS	CORPORATE, CASUAL, AND PROFESSIONAL INVENTORS	TECHNOLOGICAL INNOVATORS		TECHNOLOGICAL ENTREPRENEURS; ENTREPRENEURIAL MANAGERS; MANAGEMENT TEAM		MANAGERS
OTHER NECESSARY PARTICIPANTS	SOURCE OF CAPITAL FOR RESEARCH AND DEVELOPMENT		SOURCES OF DEVELOPMENT CAPITAL (GENERALLY SMALL AMOUNTS); BUSINESS AND MARKETING PLANNING	VENTURE/RISK CAPITAL SOURCES; LAWYERS; ACCOUNTANTS; MARKETING AND FINANCIAL		SOURCES OF EXPANSION CAPITAL
SKILLS NEEDED BY PARTICIPANTS	SCIENTIFIC EXPERTISE	TECHNOLOGY/ ENGINEERING EXPERTISE	TECHNICAL, ENGINEERING, AND SOME BUSINESS EXPERTISE	MANAGEMENT EXPERTISE; R&D CAPABILITY; NEW PRODUCT DEVELOPMENT CAPABILITY		BUSINESS SKILLS INCLUDING TECHNICAL MARKETING AND MANAGEMENT

Fig. 2. Technological innovation process: component activities, participants, and needs (Grad 1981).

technological innovation must be sufficiently flexible to meet participants' needs throughout. Recognition of the various skills and needs of participants in the process is the basis which should be used to define a target audience and to determine appropriate services that a program might provide to a specific person at a specific point in the process.

Innovation Process Components and Activities

As noted in Fig. 2, there are two general components of the innovation process: invention/innovation and commercialization. Although an idea may begin as an invention (i.e., an entirely new product/process) or innovation, if the idea acheives commercialization, it must complete most of the activities depicted in Figs. 1 and 2 at least once. It should be noted that the closer it comes to the point of commercialization, the more likely there is to be overlap in the activities.

It is clear that skills in two basic areas are essential for an individual to participate effectively in this process: engineering/scientific and business. While a combination of these skills is necessary throughout the technological innovation process, the skills vary in importance at various points in the process. At the risk of oversimplifying the issue, it can be said that early-stage activities require the participant to have scientific or engineering skills himself or require him to be able to interact sufficiently well with a second individual who can bring his idea to life. Latter-stage activities require that the participant understands the marketplace well enough to bring the prototype into it in such a manner that it will achieve commercial success.

Participants in the Innovation Process

Inventors

Inventors are persons who create an entirely new product or process. Most inventors are called "casual inventors;" that is, they perceive a problem that needs to be solved or think of a better way to do something

and then proceed to invent a device or process which will solve the problem or do the thing better. There are a few professional inventors (i.e., those who derive their incomes from inventing) and there are some corporate or industrial inventors who invent as a part of their jobs. There are only a handful of inventors who have the skills or desire necessary to bring their invention into the marketplace.

Innovators

Innovators are occasionally inventors. More often than not, innovators have engineering backgrounds and so are able to adapt existing inventions to other environments.

Technological innovators are a subset of inventors/innovators who perceive applications of their technological invention which may be commercialized or an application of technological inventions developed by others which may be commercialized. These individuals have sufficient technological and/or scientific backgrounds to develop and adapt an engineering prototype to meet a need of the marketplace and, therefore, achieve commercialization. They generally will not participate in commercializing the technology.

Entrepreneurs

An entrepreneur is defined as a person who owns and manages his own business. He may establish a technology-based venture by developing and commercializing his own technology, or he may buy or license someone else's technology for commercialization purposes. A successful entrepreneur must possess or acquire a variety of business skills such as financing, marketing, and business planning.

Since it is the nature of entrepreneurs to maintain control, their businesses often remain small and are designed to commercialize an existing invention or innovation but not to develop it.

On the one hand, the technological innovator is both an inventor and innovator. He has sufficient scientific background to develop new products and a strong engineering background which enables him to apply and adapt them in view of perceived market needs. On the other hand,

the technological entrepreneur is both an entrepreneur and innovator. That is, he typically owns and operates his own business and has an engineering background.

Technological entrepreneurs, then, as participants in the innovation process, are those persons who perceive the value of an innovation (regardless of who developed it) in the marketplace and have the skills to commercialize it. In a sense, *this person bridges the gap between innovation and the marketplace*. He must have sufficient technological and/or scientific skills at least to generate and direct development and application activities related to the product or process, while at the same time possess sufficient business skills to commercialize the product or process. If he does not possess these skills himself, he will acknowledge his need and buy the service. Generally, he has more business skills than technical ones. Although he may participate in the initial stages of the innovation process, it is more likely that he will enter the process at midstream, interfacing with a technological innovator in the process of reducing the idea to practice, assessing the market potential for the innovation, developing the business plan, acquiring the capital, and establishing the business.

The literature (Cooper 1973, Roberts 1969) indicates that technological entrepreneurs experience a greater number of successes, which are often of greater magnitude than the typical entrepreneur's. The failure rate of technological entrepreneurs is estimated to be one-quarter that of all entrepreneurs during the first five years of business. The lower failure rate is generally attributed to the fact that technological entrepreneurs have a sound educational background (either in business or in engineering), and, therefore, tend to plan their ventures more carefully and to engage in technology-oriented businesses which grow more rapidly and have a higher rate of return.

Participants' Skills and Needs

Bearing in mind that the steps noted in Fig. 2 are grossly defined, that the process is interactive and dynamic but is not necessarily linear, the discussion of relationships among activities, participants

and needs of participants are important to the examination of any effort intended to stimulate innovation. The point emphasized by describing the process in this way is that the participants and the skills needed to be successful in their efforts change throughout the process. That is, both the participants and the skills required to be successful generally change in the process of conceiving, developing and commercializing a technology. Furthermore, when the technology is ready for production/commercialization, there is a "gray" area where steps (e.g., market strategies, business planning, and capital acquisition efforts) are frequently repeated. This "gray" area is ill-defined and described by existing research, and the pre-market and market segments are often treated as different disciplines – just as engineering and business curricula are maintained as distinct disciplines in most educational institutions.

Generally, the first two steps in the process require inventors/small businessmen to have scientific and/or engineering expertise together with capital to perform the required research and development. Most often an individual inventor or small businessman can "bootleg" resources, utilizing existing materials and slack resources to develop, evaluate and continue developing an idea. However, about the time he completes development and moves toward commercialization, full-scale production prototypes must be built, business plans developed, and capital acquired for venture initiation. In short, greater and greater resources are needed. And that is most often the time at which an individual or small businessman has reached the limit of his resources, and perhaps the limit of the resources of those who have been financing him.

Two things change as an individual or small businessman enters the "gray" area between completion of the technical work and initiation of a venture based on the technical work: the sources of capital and the skills required to pursue the project. Personal assets, friends, and the government may be major sources of capital for research and early development, but as commercialization is approached more formal sources of capital (e.g., bank, venture capital organizations) are used

to obtain start-up or expansion capital. At the same time, skills required to survive venture initiation change. Rather than technical skills, the individual needs business skills that range from financial to marketing, planning, legal, and management skills, and he must be able to demonstrate these skills in order to acquire capital. Thus, the typical developer of a technology is faced with a new set of associates with whom he has difficulty conversing. Bankers, venture capitalists and other sources of capital expect to deal with an experienced manager of a growth-oriented company or with a larger corporation when, in fact, they may be dealing with an inexperienced extrepreneur, an experienced small businessman, or an individual inventor/engineer/scientist. The individual expects that he will be able to sell his idea to the new sources of capital in the same way he sold them to his family and friends. Clearly, neither expectation is realistic.

EVALUATION APPROACH

In undertaking an evaluation of any program designed to provide services and support to a population, the desire is present to have an evaluation strategy which utilizes a rigorous experimental research design to establish causal relationships. Evaluators and politicians alike would like to relate the actions of the program to the perceived changes in the population in a causal manner. This desire, however, is most often unrealistic. Such is the case when evaluating the Energy-Related Inventions Program.

An experimental design was ruled out for several reasons. First, random assignment to the program is not possible: the program was already underway when this evaluation effort began, and it is obviously administratively unacceptable to alter its operation for random assignment of grants to program applicants now. In addition, the task of identifying a comparable control group is difficult, given the number of variables which can be used to distinguish one subset of the participant/technology population from another (e.g. education, experience/stage of development, type of technology). Finally, inventors and small businesses function within a dynamic environment where many factors may affect the decisions which the inventor makes or the progress of the technology toward commercialization. Identifying and separating these factors from the effect of the program is in many instances not possible.

The inability to utilize an experimental design does not rule out a quantitative approach to the evaluation. A sample survey is clearly one option open to the evaluators. There were several reasons why this alternative was not considered an optimal first choice, however, in the ERIP evaluation. Two important factors in the decision against a survey were the time required to complete the survey (estimated at over a year) and the amount of money. These factors were of greatest concern to the program managers who needed to obtain information in a timely fashion at minimal cost in order to modify the program. In addition, the evaluation team felt that more information was needed on the characteristics of the target population before a survey could be

used effectively. The team also recognized that the program had been in existence a relatively short period of time from the perspective of defining its impact on the innovation process, and that any survey results at this time would be preliminary. For these reasons the evaluation plan was designed using initially a qualitative rather than quantitative approach, and case studies of 30 grantees were undertaken. These case studies are to be supplemented later, using a variety of research techniques (Grad, M. L. and J. Halpern, 1980).*

Case Studies

The case studies explore the characteristics, perceptions, and experience of inventors and agency personnel who have participated in the ERIP process. The case studies address three broad program evaluation issues:

- the target audience,
- the program services/operation, and
- the outcomes attributed to the program.

Given the limitations of the sample — its size and composition — the conclusions are necessarily preliminary. However, the data from these cases do provide a solid foundation on which to build hypotheses about the operations and utility of the program. Moreover, they suggest a variety of avenues of research which need to be pursued not only for evaluating the program but for understanding the needs of the individual, non-corporate inventor. This latter information is an important, if secondary, result of the evaluation.

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*Future evaluation research will build on the case studies. Further case studies of grantees are planned, as well as a survey of those rejected from the program. In addition, experts from the private sector are being consulted through a series of workshops to explore further the role which the ERIP program has been playing in the innovation process and to develop possible changes in the operation of the program. Finally, individual members of the evaluation team will develop issue papers on topics related to the inventor or small business position in the private sector and the role of government in promoting innovation in this sector.

To develop the cases analyzed in this volume, a team of consultants with expertise in evaluation, entrepreneurship, venture financing, economics, invention and innovation, and small business development was recruited to conduct the field work and write the cases. Each consultant was responsible for three case studies and was expected to contribute a unique perspective to the overall evaluation given his/her expertise on the innovation process. Because of the time and budget constraints on this project, other individuals with various areas of expertise were added to the basic evaluation team.

Sample Selection

The list of potential interviewees for the case studies was developed (see Table 1) cooperatively by the ERIP personnel and the evaluation team. The universe of the 191 grantees was diverse with respect to type of technology, stage of development of the technology, time of entry into the program, geographical location, and success in the program. The sample was selected primarily on the basis of time, budget, and geographic constraints. However, an effort was made to select a number of projects determined to be successful by the program officers equal to the number believed to be unsuccessful. No specific criteria were established to determine "success"; rather, the opinion of the program officer was sought concerning the extent to which he believed the project successful.

Of the 191 participants recommended to DOE for funding by September 1981, 30 cases were finally selected for in-depth study. Of the 30 cases, 29 had received funding and one had not. The exception was Case #72, Agar, who submitted his invention for evaluation in 1976 and sold his company to Redland Automation in May 1979. Redland did not want to pursue the development of the inventions and refused the DOE grant. Of the 29 funded cases, 27 had completed their grant-related work with DOE, and two were still in progress at the time of the interview. The 29 funded projects represent an average investment of approximately $85,000 per case; only eight projects received over $100,000 in funding.

Table 1. Grantee name, project title, and level of funding

Grantee	Project title	Level of funding
Agar (72)[a]	Utilization of Waste Gas for Boilers and Furnaces in Refineries and Petrochemical Plants	N/A
Arthur (47)	Wastewater Aeration Power Control Device	$ 58,200
Bagby (91)	Bagby Brattice, Highly Flexible Mine Tunnel Wall	62,664
Baum (86)	Coke Desulfurization Process	82,500
Ben-Shmuel (66)	Heat Extractor Demonstration	125,000
Chill (98)	Process Development to Conserve Energy and Material by Cold-Working, Roll-Forming, and Stamping Leaded Bronze Plates and Strips to Manufacture Bearings and Bushings	123,994
Cromwell (108)	Recovery of Aluminum Metal from Aluminum Dross	158,029
Dornier (56)	Flexaflo—The Wet Fuel Dryer	87,051
Durbin (69)	Ionic Fuel Control for the Internal Combustion Engine	111,220
Engdahl (31)	Chemical Vapor Deposited (CVD) Ceramics Turbine Rotor	125,000
Fitterer (18)	The Control of the Analysis of Low-Carbon Aluminum Steel Using Oxygen Sensors and Iron-Aluminum Alloy	99,000
Fowler (45)	Bulk-Cure Tobacco-Barn Demonstration Program	54,980
Gordon (99)	Light-Weight Composite Trailer Tubes	96,000
Haspert (111)	Haspert Mining Systems	125,000
Jablin (75)	Coke-Quenching Steam Generator	119,400
Jones (27)	Waste Heat Utilization for Commercial Cooking Equipment	65,000
Karlson (104)	Low Continuous Energy Mass Separation System	83,015
Kennick (109)	Hydrostatic Pressurization of Pre-Rigor Red Meat	86,000
Mahalla (64)	The Mahalla Process: A Hydrometallurgical Method for Extracting Copper	88,933
Marks (9)	Heat/Electric Power Conversion via Charged Aerosols	50,000
Mattson (117)	Solar Span Prism Trap	98,700
Norris (21)	Waste Oil Utilization System	50,000
Parker (43)	Thermal Gradient Utilization Cycle	40,000
Ross (76)	The Ross Furnace for Expanding Perlite and Other Materials	82,150
Sachs (73)	Integrated Concrete Technologies	87,230
Secunda (46)	Thexon Dehydration Process	48,000
Spelber (7)	Hydraulically Powered Food Waste Disposal Device	28,000
Wahrman (79)	Ablative Oil Well Bit Insert	57,150
Wood (53)	Eldon Direct-Fired Gas Heating System	72,600
Zinn (100)	SolaRoll, A Solar Collector Construction System	110,390

[a]Case numbers are indicators of when the grantee applied to the program. Those with low numbers were among the first to enter.

The cases were geographically dispersed:

- 12 in the Northeast and Atlantic states (New York, New Jersey, Massachusetts, Pennsylvania, Virginia);
- 4 in the Southwest (Texas, Arizona);
- 5 in the South (Louisiana, North Carolina, Kentucky, Tennessee);
- 3 in the Midwest (Michigan, Wisconsin, Ohio); and
- 6 in the West (Oregon, California).

Some of the cases are early applicants to the program, while others applied late: 6 applied in 1975, 5 in 1976, 13 in 1977, and 5 in 1978.

Data Collection

Data for this evaluation were collected from a number of sources. These sources include files on submitted inventions maintained at NBS and DOE, discussions with DOE and NBS program personnel responsible for review and support of the various inventions, and onsite interviews with a sample of grantees.

After selecting the cases and recruiting the necessary consultants, a briefing meeting was held in September 1981 to acquaint the consultants with the program and evaluation data requirements and to distribute an interview protocol. Interviews were conducted during September and October. By the first week in November the cases were completed and a debriefing meeting was held. This meeting's purpose was to discuss individual cases as well as general results of the field work, problems identified during the field work, and program and policy issues that emerged from the data.

The interviews were conducted with the grant recipient. In 24 of the cases the grantee was the inventor of the technology. In six cases, the grantee and the inventor were different people or there was a joint application. In most cases where someone other than the inventor received support, both the inventor and the grantee were interviewed. (See case studies for Dornier, Engdahl, Gordon, Mahalla, Baum, and Secunda.) This procedure was followed in order to provide as full a picture as possible of the technology, its problems, and the impact of ERIP.

Interviews with grantees and program personnel were guided by open-ended interview protocols. The grantee interviews were structured to provide information on the following:

- background of the grantee,
- development of the invention prior to ERIP contact,
- the inventor's experiences with ERIP,
- the current status of the project,
- outcomes of the ERIP experience (tangible and intangible), and
- identification of specific operational and policy issues of concern to ERIP.

The following issues were explored in discussions with program personnel:

- services —
  - those the project officer feels were needed by the grantee
  - those services provided via the award statement of work
- problems encountered during the project period —
  - related to the grantee
  - related to the statement of work
  - related to the agency
- outcomes of the project —
  - tangible
  - intangible
- issues of concern —
  - operational
  - policy

Data Analysis

In Section II the data from the cases are aggregated and organized to provide insight into how the program is fulfilling its mandate and to what extent the results indicate its effectiveness. Specifically the data are organized around (1) the characteristics of the target audience (i.e., the grantee and the technology), (2) a description of the program

services/operation (i.e., the grantee's experience with and assessment of the ERIP), and (3) the tangible and intangible outcomes of the projects. This information is used to address specific evaluation questions.

- Target audience:

  What is the mandated target audience?

  Is the program reaching the mandated target audience?

- Program services/operation:

  What services are mandated?

  What services are provided — mandated and others?

  How does the program operate, and is it an effective technique for delivering mandated services?

- Outcomes of the program:

  What are the tangible and intangible outcomes of the program?

  To what extent are the anticipated outcomes achieved?

In Section III, program/policy issues that emerged from the cases are discussed. These issues are looked at more broadly to evaluate the role which ERIP is playing in the innovation process. While the discussion draws heavily on the data in the case studies, the experience and expertise of the evaluation team members with the dynamics of the innovation process are reflected in the interpretation.

SECTION II: THE ENERGY-RELATED INVENTIONS PROGRAM AND EVALUATION RESULTS

DESCRIPTION OF THE PROGRAM

With the passage of the Federal Non-Nuclear Energy Research and Development Act of 1974, the U.S. Congress directed ERDA to initiate a program to evaluate "all promising energy-related inventions, particularly those submitted by individual inventors and small companies for the purpose of obtaining direct grants from ERDA." In the Joint Explanatory Statement of the Committee of Conference, Congress further directed NBS "to keep ERDA currently advised of promising inventions that should be considered for inclusion in the energy research, development, and demonstration programs." Eligible inventions were defined in P.L. 93-577 as "any invention which may be used to conserve energy, provide a new source of energy or improve a method of harnessing known or discovered energy supplies except nuclear energy."

As a result of this legislation, a new Federal program designed to stimulate invention and innovation in the private sector was formed. The program is relatively small with an annual budget of $5-6 million. The important characteristics of the program are:

- a target audience limited to individual inventors and small businesses with energy-related inventions,
- a broad definition of invention which permits consideration of innovations as well as inventions,
- acceptance of technologies at any stage in the R&D process except "idea generation" and "full commercialization,"
- in-depth evaluation of the intrinsic technical merit of inventions,
- small amounts of money to move a grantee one step toward commercialization,
- one-time-only funding, and

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*The legislative history of the program indicates that its development was a consequence of a perceived need by Congressmen who found themselves inundated with requests from inventors with ideas to solve the energy problems confronting the U.S.

- joint operation by two federal agencies.

ERIP Goals and Objectives

The overall ERIP goals are to stimulate innovation by individuals and small businesses in the field of energy-related products/processes and to assist selected individual inventors or small businesses in developing promising energy-related inventions for eventual commercialization. To accomplish this goal, each agency has identified a set of objectives. For NBS, the objectives are:

- to provide appropriate services to all individuals and small businesses who submit energy-related inventions,
- to improve the quality of submissions by reaching inventors with more relevant education and experience,
- to respond to requests for technical evaluation in a timely fashion and, when appropriate and possible, to reduce the times currently required (in April, 1980) to evaluate energy-related inventions, and
- to correctly evaluate the technical merits of submitted energy-related inventions.

For the DOE, the objectives are:

- to develop with each recommended applicant a mutually acceptable course of action, with federal assistance as a next step in developing the invention,
- to encourage and assist each applicant in planning follow-on action when federal assistance is completed, and
- to reduce the time required to provide federal assistance to applicants to not more than six months from the receipt of a recommendation by NBS.

If the above objectives are achieved, it is anticipated that inventors receiving federal assistance will be able to do one or more of the following:

- compete effectively in obtaining contracts from other sources, including existing public programs, so as to permit further development of the invention,

- assemble, with some confidence of success, the people and capital necessary to produce and market the invention through a business enterprise in which the inventor is a major participant, and
- negotiate mutually beneficial arrangements with an existing company to develop the invention for commercialization.

Program Operation

The program plan resulted in the ERIP being jointly operated by the Office of Energy-Related Inventions (OERI) at NBS and the Inventions Support Division (ISD) at ERDA (Federal Register, June 6, 1975). NBS evaluates all submitted inventions and recommends to DOE those inventions considered relevant, feasible, and having intrinsic technical merit. DOE reviews all recommended inventions to determine if federal assistance can be granted, negotiates the terms and conditions of each project, and administers a grant award.

National Bureau of Standards

Since its inception, the Office of Energy-Related Inventions at NBS has been headed by George Lewett and has remained within the same division of NBS. During the seven years of operation the staff size has fluctuated between 15 (1975) and 28 (1980). At present, 21 full-time-equivalent persons are employed by the office. Of these, ten are administrative personnel, eight are evaluators, and three are evaluation support persons. In addition, NBS has an active list of outside evaluators consisting of personnel from seven contract firms, 13 government agencies, and 240 individual consultants (of whom 150 are university professors).

The budget for NBS has ranged between $1,500,000 (1975) and $2,500,000 (1980). Approximately 45% of the budget is used for evaluations, 35% for operations, and 20% for supplementary activities. These activities include program development and support as well as special efforts to improve the quality of submissions by sponsoring the National Innovation Workshop series, Inventor Information Resource Centers, and the formation of the National Congress of Inventor Organizations.

Requests for evaluations were received as soon as the federal Non-Nuclear Energy Research and Development Act was passed by Congress in 1974.

1975, when both the NBS and DOE offices had been established, more than 100 requests were awaiting evaluation. As of September 1981, NBS had received and processed over 17,489 applications; of these, 191 inventions had been recommended to DOE for funding (see Fig. 3).

The NBS evaluation process consists of four basic steps:

- disclosure review analysis (DRA),
- first-stage evaluation,
- second-stage evaluation, and
- recommendation to DOE.

These steps are discussed on the following page and the process is diagrammed in Fig. 3.

Disclosure Review Analysis. The process for submitting an invention for consideration by ERIP begins with the inventor completing and signing NBS Form 1019 and providing an invention disclosure. NBS Form 1019 requests data regarding the source of the invention and contains a Memorandum of Understanding setting forth the conditions under which NBS accepts an invention for evaluation (*Federal Register*, Oct. 1, 1976).

Upon submission of the completed forms, NBS reviews the invention disclosure to determine whether ERIP requirements have been met. Submissions which will not be considered for evaluation include:

- non-energy-related inventions,
- nuclear-energy-related inventions,
- proposals to invent something where an idea, a product, or a process presently does not exist,
- those with insufficient technical depth or detail,
- perpetual motion machines and those with obvious technical flaws,
- those requiring excessive feasibility analysis, and
- those with unintelligible disclosures or other communication problems.

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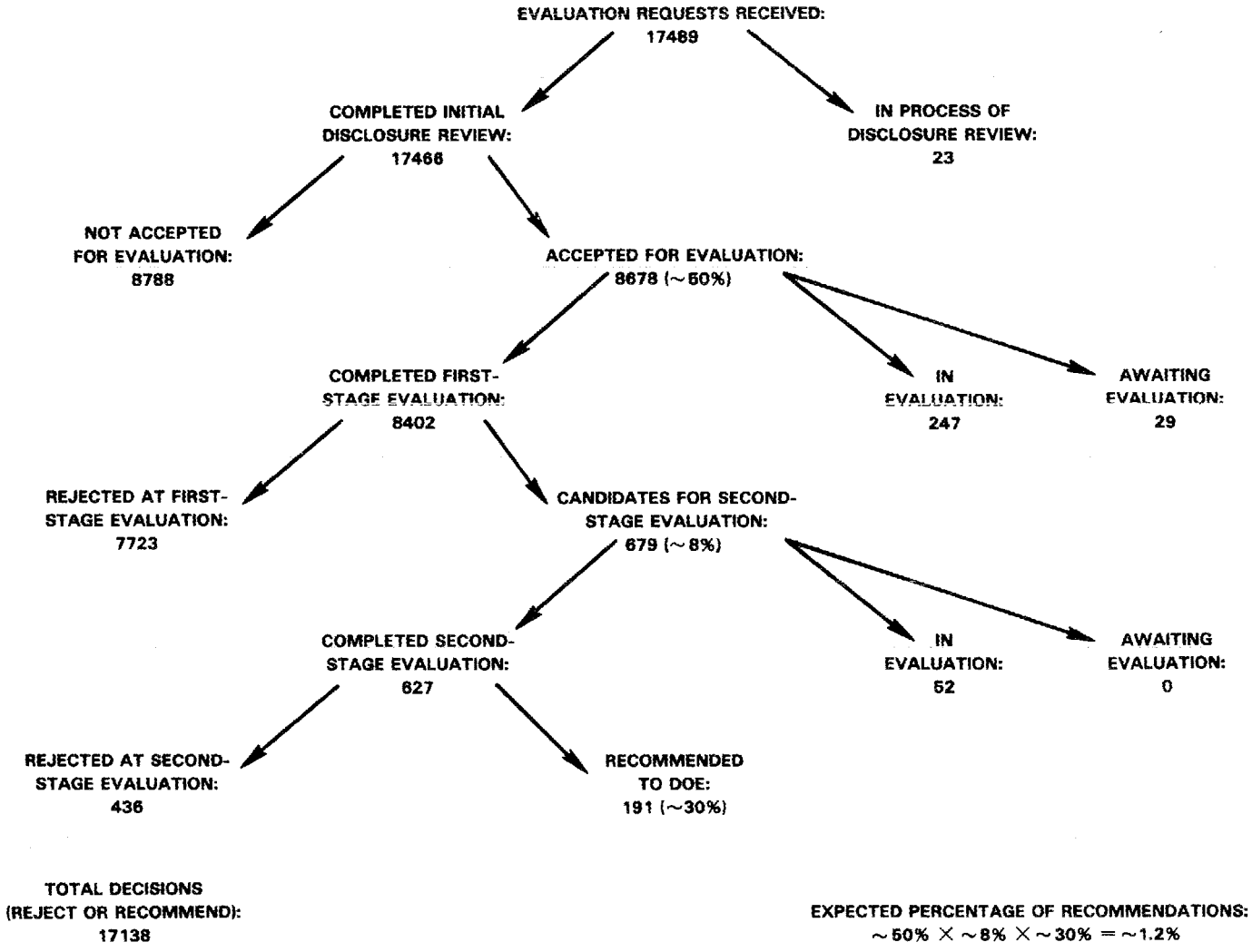

Fig. 3. Cumulative flow statistics as of September 1981. Source: U.S. Department of Commerce, National Bureau of Standards, *Status Report on the Energy-Related Inventions Program as of September 30, 1981.*

Technically feasible submissions considered to fall within the scope of the program are forwarded for first-stage evaluation. Inventions identified as having particular promise may be expedited by skipping stages in the evaluation process. Others that have promise and are outside of the scope of the program may be referred to appropriate agencies.

First-Stage Evaluation. First-stage evaluation consists of a series of brief assessments of the invention's technical merit and, to a limited extent, its potential for commercialization/utilization. At any point in the series a decision may be made to reject the invention or to forward it into second-stage evaluation as "promising," given the following criteria for evaluation.

- potential for energy conservation, utilization, or production,
- technical feasibility, and
- potential for commercialization/utilization.

Assessments or reviews are conducted by one of seven firms specifically contracted to perform first-stage evaluations, or by an individual vendor with appropriate technical expertise. Upon receiving the review results, an NBS staff evaluator reviews the file and determines:

- if the invention should receive another first-stage assessment,
- if the invention should be rejected, or
- if the invention should be forwarded into in-depth or second-stage evaluation.

If another review is desired, the invention is sent to a different contractor, individual vendor, or NBS staff member, one of whom conducts an independent first-stage review and reports the results. All reviews are performed independently, with only the NBS staff evaluator assigned to the project having access to all review data. Most inventions receive two independent reviews during this stage; at minimum, one staff evaluator assesses the invention.

If an invention does not warrant further review, the key reasons for rejection are identified by an NBS staff member who drafts a rejection

letter for signature by the program chief. While a rejection letter is not intended to discourage an inventor from further activity, it must be written so that it cannot be misinterpreted as an NBS endorsement. The reasons for rejection must be clearly stated and, when appropriate, the letter must indicate that NBS will reconsider its position if the inventor can provide sufficient additional information justifying reconsideration. The rate of reconsiderations is approximately 15-20%.

Second-Stage Evaluation. If an invention appears to be promising, it is analyzed in depth by a consultant with expertise in the technical field. It is the responsibility of this individual to determine the technical and/or commercial feasibility of the invention and to report his findings to NBS. When this analytic report is received by NBS, staff evaluators review the project and decide whether to recommend it to DOE, based upon their technical expertise as well as that of the consultant reviewer(s). If the merit (either technical, commercial, or energy-impact) of the invention is still in doubt, a staff evaluator may elect to obtain another second-stage review.

If the invention is rejected, the completed consultant report is sent to the inventor with a letter which is reviewed and signed by the program chief. Again, the inventor may decide to request reconsideration of the evaluation if he provides additional information upon which to base another evaluation. Approximately 75% of the second-stage rejections are returned to NBS for reconsideration.

Recommendation to DOE. When an invention receives a positive second-stage evaluation, a report is developed which includes a letter of recommendation, all evaluation results, and a case summary. The letter also contains suggestions concerning the type of support DOE could provide. This package is reviewed by the NBS senior evaluator as well as the program chief.

Department of Energy

Administration of the program on the DOE side has been less stable than at NBS. The program's organizational location within the DOE has been shifted frequently, as has its physical location. Turnover in program chiefs has been high, with four chiefs and no fewer than three acting chiefs appointed over the seven years of operation. In addition, the number of positions allocated to the program has been low. When first organized, the program operated for a year with only one person on the staff. Over the years, the staff has expanded and currently numbers six people.

Despite these administrative problems, by September 1981 the DOE office had processed approximately 95 of the 191 inventions recommended by NBS. The grants awarded totaled over $7 million, with an average grant size of $73,000. The annual DOE budget has ranged from $1-2 million (excluding the allocation to NBS).

Once a recommendation is forwarded to DOE, staff members perform the following tasks:

- review and analyze the NBS evaluation report to determine possibilities for DOE assistance,
- negotiate with inventors the nature and amount of support to be provided by DOE,
- seek additional assistance for inventors from other resources, and
- monitor grants awarded.

Financial assistance is provided on a "one-time-only" basis, although DOE program personnel may continue to provide non-monetary assistance (e.g., advice or contacts) as needed to further develop the invention.

Funding may be provided for the following activities:

- proof of concept/applied research,
- technology development,
- engineering development,
- testing to generate data related to economics and institutional conformance, and
- development of marketing and business plans.

CASE STUDY RESULTS

The Target Audience

The Grantees

The program is mandated and designed to assist a specific target group: individuals and small businesses with energy-related inventions. It is therefore appropriate to review the background of the selected grantees to determine what population the program appears to be funding. Two primary characteristics were examined: (1) current employment status and (2) size of business. Additional information, used to further define the target groups and assist in understanding the grantee's experience with the program, include

- invention activity,
- job experience,
- education,
- previous government funding experience, and
- cash or in-kind resources invested in technology prior to submission.

Current Employment Status. At the time of the interview, 27 out of the 30 grantees were principals or owners of private-sector firms or were self-employed. Two (Bagby and Ross) were also employed by private-sector firms, and four considered themselves to be retired or semi-retired even though they were consulting. Of the three remaining cases in the sample, one (Dornier) was employed by a small firm (Quality Industries) which applied to the programs for funding, and two were employed by universities.

Size of Business. All of the grantees are classified as individuals and/or small businesses, using the Small Business Administration's definition of small business (i.e., less than 500 employees). All 27 businesses existed at the time the invention was submitted. Twenty-two interviewees reported businesses with 20 or fewer employees; three interviewees reported

having firms with 21-100 employees; only two interviewees had firms with 101-500 employees. Nine of the above firms were engaged primarily in R&D; nine were engaged in manufacturing; the remaining were engaged in both R&D and manufacturing.

Invention Activity. Most of the grantees had some invention experience prior to submitting their invention (i.e., they were the inventors of the technology submitted to ERIP, had a history of patent activity, or described their work activities as inventive or creative). Twenty-four grantees are the inventors of the technology supported by DOE.

Excluding any patent activity related to the ERIP technology, 15 of the 30 grantees had no prior patent history. However, of the 15 remaining grantees, four hold between one and five patents; five hold 6-10 patents; two hold between 10 and 15 patents; one holds 30 patents; one holds 38 U.S. patents and 150 foreign patents; one holds more than 100 U.S. patents; and one holds 100 U.S. patents and 250 foreign patents.

When invention activity related to the ERIP technology is combined with the above information, most of the grantees can be characterized as inventive (see Table 2). However, only two of the thirty grantees can be clearly defined as professional inventors (i.e., the primary source of their income is their inventions). The remainder are identified as casual inventors.

Job Experience. A review of the grantees' job experience over their professional lives indicates diverse work experiences. Many grantees mixed a considerable number of years as employees of industry, government, and/or universities with entrepreneurial efforts (see Table 2). A number of the technologies developed by the grantees clearly grew out of their considerable experience in a particular industry (e.g., Chill, Cromwell, Mahalla, Jablin, and Jones).

Table 2. Grantee experience

	Education	Work experience	Invention activity	Experience with government
Agar	Master's (physical chemistry)	Worked in instrumentation field since 1957; owns Agar, Inc.	Six U.S. patents in conservation/pollution fields	Limited
Arthur	Doctorate (environmental engineering)	Teacher for 16 years; owns three interrelated companies	Four U.S. patents plus one for ERIP invention	Extensive
Bagby	High school	Employee in mining firm; built brattices	No patents or inventions prior to ERIP invention	None
Baum	Master's (chemistry)	Consultant on government projects	No patents	Limited
Ben-Shmuel	High school	Self-employed as realtor, sculptor, poet, entrepreneur	30 U.S. patents on non-ERIP technology; 10 more applied for	None
Chill	High school	Bronze industry 45 years, now semi-retired from company he helped form	Worked on improvements of products; only ERIP invention patented; one applied for	None
Cromwell	Some college training	Employee and entrepreneur in aluminum industry for 30 years	One foreign patent	None
Dornier	Bachelor's (mechanical engineering)	Related manufacturing industry for 20 years; 10 years with Quality Industries, designers and manufacturers of marsh equipment	Ten patents on marsh equipment; not inventor of ERIP invention	None
Durbin	Doctorate (physics)	Professor and researcher in university environment	12 U.S. patents plus many ideas not patented	Extensive
Engdahl	Bachelor's (mechanical engineering)	Employee in industry for more than 30 years	No patents but described as creative	Extensive
Fitterer	Doctorate (metallurgical engineering)	An academic for 38 years; consultant to industry throughout career; formed own company	Ten patents plus other "inventiveness evidence"	Extensive
Fowler	Bachelor's (mechanical engineering)	Director of marketing for GTE, Sylvania; started three companies	Six patents plus ERIP invention	None
Gordon	Doctorate (nuclear engineering)	Owner of firm manufacturing commercial high-pressure vessels	Five patents	Limited
Haspert	Some college training	Owns mining/construction R&D company	15 patents	None
Jablin	Bachelor's (mechanical engineering)	Steel mill engineering/environmental control projects, 35 years. Now owner of Jablin Assoc. Construction	Ten patents plus ERIP invention	Limited
Jones	Bachelor's (geology)	18 years in design and sales, ventilation systems; sells building products	No patent history; ERIP technology not patented	None

Table 2 (continued)

	Education	Work experience	Invention activity	Experience with government
Karlson	Doctorate (physics)	Several years employee of Atomic Energy Commission; formed several companies; professor	100-plus patents in several fields; 2 applied for, 5 or 6 patents in preparation	Extensive
Kennick	Doctorate (animal science)	Professor	None	Limited
Mahalla	Bachelor's (metallurgical engineering)	20 years engineer private industry; 12 years as consultant to various copper industries	Innovator in copper industry for many years; no patents	None
Marks	Bachelor's and graduate work in related fields (electrical engineering)	Inventor in field of optics, electro/thermo dynamics; president of R&D firm	100 U.S. patents, 250 foreign patents; ERIP technology patented	Extensive
Mattson	Technical training	Carpenter	Creative but no previous patents; 26 patents on ERIP technology applied for	None
Norris	Bachelor's	Chemical engineer for large oil company for many years; established own company 15 years ago	None	None
Parker	Bachelor's (electrical engineering)	20 years as R&D engineer with Lenox Industries	38 patents in refrigeration and power generation plus 150 patents worldwide	None
Ross	Some college training	Employee of various companies in private sector; now consultant with Sil-Flo	No previous patents; ERIP technology patented	None
Sachs	Bachelor's (architecture)	27 years architect with own firm	One previous patent plus four on ERIP technologies	Limited
Secunda	Master's (chemical engineering)	13 years as petroleum engineer for major oil company; then joined AMA, a think tank	No previous patent history; developer of innovative classroom techniques	None
Spelber	Bachelor's (aeronautical engineering)	Variety of engineering management positions in large and small firms; now president of Wastemate Corporation	No previous patent history; two for ERIP technology and two applied for	None
Wahrman	Some college training	Chief contract administrator of aerospace company; consults; owns firm conducting R&D and production of diamond elements for drilling	No patent history but inventive	Extensive
Wood	Bachelor's (mechanical engineering)	Chemical engineer, QC supervisor for several large companies, 10 years self-employment as inventor/designer/consulting engineer	No patents; extensive inventive history	None
Zinn	Some college training	Variety of industrial contractor jobs; learned system design along the way	No previous patents	None

Education. Three grantees only completed high school; one also went to a technical school. Five had some college; twelve have bachelor's degrees (eight in science and four in the arts); three have master's degrees; six have doctorates. It is important to note that nearly all have worked many years in the industry in which their invention is applicable. It is also interesting to note that, while they are well educated, only nine have advanced college degrees.

Previous Government Experience. Seventeen out of the thirty cases have no previous government funding experience or familiarity beyond a layman's knowledge of the government grant process. Six grantees worked for the government and are identified as having limited experience; those who have secured numerous government grants as a part of their work experience — sophisticated grantsmen — are identified in Table 2 as having extensive experience. Seven grantees fall into this latter category.

Resources Invested Prior to Submission. One important dimension of these cases is the nature and level of resources the grantees have invested in developing the invention prior to submitting it to ERIP. All in all, the grantees have invested a great deal of time, cash, and other resources in the invention's development. While this information does not indicate either the potential success of the invention in the marketplace or its technical viability, it does indicate that the inventors are serious about their work and that they have been working in their respective technical fields for some time.

The average elapsed time the grantees have worked on the problem is 10 years, while inventors' estimates of cash investment range from $10,000 to more than $1,000,000. These estimates frequently do not include in-kind investments (e.g., in time and equipment).

Technologies

The ERIP audience is made up of individuals and small businesses with energy-related inventions. The previous section reviewed one

dimension of this target group — the grantees. In this discussion, attention is focused on the technologies. The specific task is to describe the 30 funded technologies and to determine in the broadest sense whether these technologies are appropriate for funding, given the mandate of the program to support energy-related inventions and the specific selection criteria applied by program managers. We are not attempting to replicate the efforts of the NBS staff — such a task is beyond the scope of this evaluation. Instead, using the NBS program chief's definition of energy-related invention, we describe if and how the 30 supported technologies fall within the scope of this definition. Then, after reviewing the specific selection criteria used by NBS, the 30 cases are analyzed to provide information about how these criteria have been applied and their effectiveness. Finally, by reviewing the potential contribution of the technologies to *both* energy-related and non-energy-related fields, we comment on the importance of the technologies. Such a perspective contributes to the understanding of ERIP's value to the nation and its importance within the context of other federal programs. Tables 3 and 4 summarize the major characteristics of the technologies.

Energy-Related Inventions: The Definition. A brief review of the 30 cases indicates that all are energy-related, and in most instances the energy-related dimension is obvious. The qualities which permit one to define the technologies as energy-related *inventions* are not so obvious, however.

The ERIP's definition of invention is nontraditional. While the program's definition includes the dictionary's notion of invention (i.e., a new device or process developed for experimentation and study) and the popular notion of a major scientific advance which is unique, it is also more specific and at the same time broader. It is more specific in that the new device or process must represent a new potential for saving energy or enhancing energy supply. Thus an advance over the state-of-the-art would not quality an idea for consideration by the program unless it were energy-related.

Table 3. Description of technologies

	Technology	Perceived potential applications	Energy-related characteristics (other uses noted)
Agar	Control system to use waste gas/oil[a]	Oil refining industry	Incremental energy conservative measure—refineries would utilize waste oil which is now flared or burned
Arthur	Wastewater aeration power control device[a]	Wastewater treatment plants	Incremental energy conservation measure—system, regulates oxygen flow in wastewater-treatment plants
Bagby	Cheap, light barrier for control of gases in underground mine tunnels[a]	Application in copper, coal, salt mines—may also be used as roof supports and stoppings for subways; estimated $90 million market in future sales	Production improvement in energy. (To improve mine safety worker health)
Baum	Chemical process whereby organic sulfur (up to 99%) can be removed from coke made from high-sulfur coal; process requires the introduction of sulfur during the coking process[b]	Manufacture of metallurgical grade coke for steel industry, electrode grade coke for aluminum industry, production of pollutant-free fuel	If successful, the process would permit use of high-sulfur coals with impact of increasing useable coal reserves; (production of pollutant fuel supply)
Ben-Shmuel	Heat extractor which utilizes water or an alternative fluid in direct contact with industrial stack gases to extract heat[a]	Widespread potential for adoption in any industrial or large residential unit that consumes significant quantities of energy in a combustion process	Incremental energy conservation device which utilizes waste heat; (reduces pollutants—its pollutant removing capacity makes it particularly promising for use in power plants)
Chill	Process for the continuous casting of bronze alloy in the form of a strip, of any width and thickness desired, that can be rolled and welded to form bushings and bearings[b]	Production of bushings and bearings; the process also makes available applications and markets for bronze not now open, e.g., for ammunition and cladding steel	Process uses less energy than existing process. Because process is completely enclosed with metal and the bronze enters and exits cold, it appears to be the only process available that can meet all the safety requirements of OSHA with regard to lead fumes)

Table 3 (continued)

	Technology	Perceived potential applications	Energy-related characteristics (other uses noted)
Cromwell	A mechanical process for recovering aluminum from dross (a waste product from the production of aluminum)[b]	Aluminum industry	Low energy consumption; recovery of useable metal from waste produced by energy intensive aluminum industry; (Eliminates negative environmental impact of current process; no waste by-products; high metal recovery, i.e., increases available supply at low cost)
Dornier	Device which uses boiler flue gas to dry combustible process residues of fiber, pulp, and bagasse so as to improve burning characteristics, increase fuel value and assure useability as boiler fuel[a]	Application was intended for sugarcane industry but potential for use in any industry which uses or could use dried waste material for fuel, e.g., wood pulp, grain, garbage	With broad application, the process could increase supplies of biomass fuels
Durbin	A system designed to measure the air intake of each cylinder of an engine and to determine the appropriate amount of fuel to mix with the existing air; key to system is ion-drift air mass, flow sensor meter[b]	Automobiles and other combustion engines	May improve fuel consumption by making engines more efficient; (cuts hydrocarbon emissions, nitrogen oxide, and carbon monoxide)
Engdahl	Process that makes possible the deposition of solid silicon carbide (SiC) from gaseous state; SiC is circulated in a gaseous state either into a pattern mold or over a metal part, preformed in desired final shape[b]	Variety of important scientific applications; Engdahl's concern is with developing a turbine rotor for small generating systems	Ceramic rotor would permit power generation at higher efficiencies which would lead to energy savings (would permit more efficient decentralized power supply systems)
Fitterer	An industrial process which provides better control of the production of low-carbon, aluminum-killed (LCAK) steel by using iron-aluminum alloys in place of pure aluminum in deoxidation process and by use of oxygen probes[a]	Application in the LCAK steel industry and may have use in copper industry	Incremental energy savings as a consequence of more efficient process and the use of iron aluminum alloys instead of pure aluminum

Table 3 (continued)

	Technology	Perceived potential applications	Energy-related characteristics (other uses noted)
Fowler	A tobacco curing barn fitted with roof-top solar collectors[b]	Drying tobacco	Incremental energy savings—limited seasonal use
Gordon	Lightweight composite trailer tubes for transportation of hazardous materials such as compressed gases[a]	Trucking industry	Substantially reduces shipping costs and gasoline use by supplanting existing heavier tubes
Haspert	A piece of mining equipment which could drill a large rectangular hole on a sloped heading[a]	Coal, shale, gilsmite mining	Improves mining techniques which would eliminate cutting into overburden and underburden
Jablin	Method to recover waste heat from hot coke coming from coke ovens[a]	Steel and allied industries	Incremental energy conservation measure to the extent that waste heat is utilized for production or heating activities. (Eliminates air-pollution problem resulting from existing techniques for processing coke)
Jones	Waste heat recovery system for use on gas-fired cooking appliances or other low-grade heat sources[a]	Gas-fired cooking appliances in hotels, hospitals, schools, commercial kitchens and restaurants	Incremental energy conservation measure which utilizes waste heat from low-grade heat source for other purposes
Karlson	Low-energy, continuous process for separation of chemical species or different isotopes in either the gas or liquid phase; invention combines any two or all three current separation techniques—chromatography, electrophoresis, and centrifugation[b]	Extensive commercial and scientific applications, e.g, uranium isotope separation, nuclear waste disposal, oil and chemical industries, pharmaceutical production, saltwater purification	Current separation techniques are energy intensive; Karlson's process is not—substantial savings in energy use could result if technique adopted
Kennick	Process of hydrostatic pressurization of pre-rigor red meat round muscle to induce tenderness[b]	Meat packing industry	Incremental energy-saving measure in that it eliminates the necessity to cool and age meat; reduces fuel costs in shipping due to reduction in weight and volume; indirectly results in substantial energy savings by making it possible to substitute tenderized, grass-fed beef for grain-fed beef

Table 3 (continued)

	Technology	Perceived potential applications	Energy-related characteristics (other uses noted)
Mahalla	Hydrometallurgical process for extracting copper; the process eliminates the electrorefining step currently used in copper refining process and requires no external energy source[b]	Copper industry	No external energy source is required (including electrical or thermal). Mahalla claims process offers a potential energy savings of 10-20% over existing technologies in copper industry. (In contrast to existing methods, Mahalla process results in no air pollution.)
Marks	The heat/electric power conversion via charged aerosols is a basic process for converting heat to electricity without the use of a mechanical generator[b]	Power generation and pollution control industries	Heat/electric conversion process is claimed to be more efficient; when combined with cogeneration the technology would, according to inventor estimates, reduce energy consumption of non-renewable fuels by 40%; has pollution control applications
Mattson	A solar collector which is all plastic and which utilizes black liquid both as absorber and energy-transfer fluid[a]	For home and industrial solar and radiant heat	Low-cost solar collector could make solar energy cost-effective, thus increasing use and reducing U.S. dependency on non-renewables
Norris	Boiler-fuel additive that reduces corrosion and scaling[a]	Utilities and other boiler users, e.g., ships	Utilizes waste oil from automotive crankcase oil; in addition, Btu yield of boiler fuel with additive may be increased
Parker	System for power generation utilizing atmospheric temperature gradients resulting from large and abrupt elevation differences to drive a natural circulation system; the system could also use solar or geothermal energy as heat source[b]	Power generation	Alternative power generation system would not rely on oil

Table 3 (continued)

	Technology	Perceived potential applications	Energy-related characteristics (other uses noted)
Ross	Process for heating, not melting mineral products such as perlite; the types of heating are expanding, exfoliation, calcining, sintering, roasting and drying; he has two types of furnaces for process[a]	Ross envisioned product being used to expand perlite—other commercial and scientific applications probable	Furnaces used in process are more efficient; product produced in process (perlite insulation) would assist in reducing energy consumption
Sachs	Building fabrication methodology utilizing permanent forms for construction of reinforced-concrete buildings; the panels, which compose the framework for the reinforced-concrete structural members of the building, come complete with thermal and sound insulation, vapor barrier, fireproofing, and interior and exterior veneers[a]	Although fabrication methodology can be utilized for all types of buildings, specified application was for high-rise structures	Insulation in panels results in reduced energy use; existing high-rises constructed with panels use 50% more energy
Secunda	Process which removes solutes such as coffee from solution by spraying the solution at high speeds, resulting in dried crystals[b]	Food industry (coffee, sugar, potatoes) is promising application; other applications may be found in area of pollution control	Incremental energy conservation measure in that existing process—spray drying—requires massive induced energy; Secunda's Thexon process does not; (process may be used for pollution control)
Spelber	Hydraulically powered waste-disposal device that utilizes rotary-driven cutters which move in an oscillary cutting motion and operate in conjunction with fixed cutter[a]	Home and commercial waste disposal	Incremental energy conservation measure in that invention operates on water power not electricity; inventor estimates up to 1% savings in home energy consumption
Wahrman	New composite bit insert made up of layers of complex microstructures, including tungsten and other carbides as well as cobalt nickel, cubic boron, nitride, diamond powder and carbon reinforcements[a]	Wide variety of applications in drilling and mining industries; other applications are in ballistics and for materials processing in space	The new inserts are stronger, have sharper edges, and last longer than conventional types; as a result, downhole bit life is extended and drilling time reduced by a factor of 3

Table 3 (continued)

	Technology	Perceived potential applications	Energy-related characteristics (other uses noted)
Wood	The Eldon direct-fire gas-heating system is a highly efficient gas-fired water heater in which a natural gas flame is blown directly into a "rain of water"[a]	For commercial and industrial water heating	Incremental energy conservation measure; inventor claims 100% efficient for his water heater as compared with existing hot water heaters which are about 70% (+10) efficient
Zinn	Heat-plate solar collector which uses EPDM (Ethylene propylene diene monomer) synthetic rubber as the principal component[a]	For home and industrial solar and radiant heating	Low-cost, high-efficiency solar collector enhances the cost-effectiveness of solar energy and could result in its increased use

[a]Product category.
[b]Process category.

Table 4. Stage of development at time of submission[a]

Idea evaluation and development	Product/process evaluation and refinement	Venture initiation; product/process introduction or expansion
Agar	Bagby (prototype development/ testing)	Ben-Shmuel (limited production/marketing)
Arthur (3rd-generation respirometer)	Chill (prototype development/ testing)	Dornier (limited production/marketing)
Baum	Cromwell (prototype development/ testing)	Fitterer (limited production/marketing)
Engdahl	Durbin (prototype development/ testing)	Fowler (limited production/marketing)
Gordon	Haspert (laboratory testing)	Norris (limited production/marketing)
Jablin	Mahalla (laboratory testing)	Sachs (limited production/marketing)
Marks	Jones (prototype development/ testing)	Zinn (limited production/marketing)
Parker	Karlson (laboratory testing)	
	Kennick (working model)	
	Woods (working model)	
	Mattson (working model)	
	Ross (working model)	
	Secunda (testing/evaluation)	
	Spelber (prototype development/ testing)	
	Wahrman (prototype development/ testing)	

[a]In reviewing technologies, NBS places them into one of nine separate categories: concept definition, concept development, laboratory testing, engineering design, working model, prototype development, prototype test, production engineering, and limited production and marketing.

At the same time, ERIP's definition of "invention" is broader because of the interpretation which the program gives to the concept of "new." ERIP's definition of "new" is linked to the concepts of "energy savings" and "increasing energy supply." An idea may be quite familiar and have originated with others, but if in its present application it represents a new potential for saving or producing energy, it is defined by the program as an invention. Also, an idea proposed years ago might have become potentially feasible because of changes in market or technological conditions. Because of the above definition which ERIP applies to invention, many of the ideas submitted to the program are innovations as defined in the innovation literature.*

The 30 cases fall within the scope of ERIP's broad definition of invention. A number of cases represent advances over the state-of-the-art in a certain field. Haspert's, Karlson's, Kennick's, Mahalla's, Wahrman's, Agar's, Bagby's, Chill's, Engdahl's, and Spelber's technologies are examples. Another group of cases represents old ideas with new applications to energy-related problems. In this group one finds Gordon, Jones, Marks, Secunda, Wood, Ben-Shmuel, Dornier, Baum, Fowler, and Norris.† A third group of cases represents ideas whose time may have come; that is, the idea, product or process may have been around awhile but conditions in the past were not right for its development or use. Of the 30 cases, we consider the following to fall into this latter

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*There are a number of factors which have made an idea attractive and/or workable now as opposed to an earlier time. A basic factor is economics; that is, how costly is it to develop the idea and how cost-effective is the product or process? The change in fuel prices has dramatically altered the economics of energy production and has made a variety of conservation strategies cost-effective. As scarcity of resources can make a new product or process attractive, so can the availability of new resources. A plastic solar collector is not a new idea; however, a durable plastic for such a collector was not available until recently.

†For example, heat extractors have been around for many years. Ben-Shmuel, however, applied the idea to heating systems in multiunit housing in the hope of realizing a new potential for energy savings.

category: Cromwell, Jablin, Mattson, Parker, Sachs, Zinn, Durbin, and Fitterer.

Selection Criteria. To be accepted for evaluation, submitted technologies must be:

- energy-related,
- nonnuclear,
- not obviously fallacious, and
- accompanied by sufficient information to proceed with the evaluation.

All of the 30 cases are energy-related and nonnuclear. In addition, because each made it through the NBS evaluation, none were obviously fallacious. One could also conclude that all were accompanied by sufficient information to proceed with the evaluation. Such a conclusion is only partially correct, however. There are two examples in our 30 cases in which, at the time the case was originally submitted to NBS, the information provided was not sufficient. In one case (Mattson), the application initially was rejected, in part because his forms were poorly completed. When Mattson protested and when NBS saw his invention first-hand — and liked what they saw — the agency gave him assistance in filling out the forms.

Once a technology is accepted by NBS, the following criteria are used for evaluation:

- technical soundness or intrinsic technical merit (i.e., the technology has the potential to work),
- potential energy impact, and
- commercial feasibility.

Technical Soundness or Technical Merit. This concept is interpreted by NBS to mean that all of the development and technical problems can be solved for production. After funding, in 24 of the 30 cases the concept has at least been demonstrated. In 16 cases a stage of development has

been reached in which *all* important developmental and technical problems have been solved. In only one case was the technical soundness or intrinsic merit of the concept refuted: the coke desulfurization process (Baum). Its technical infeasibility was demonstrated with ERIP funds which were used to replicate the inventor's results: the effort to replicate was unsuccessful. Of the remaining cases, the stage of development is so early that a definitive answer cannot be given, or other factors (unrelated to technical problems) have prevented commercialization.

Potential Energy Impact. Potential energy impact is interpreted by NBS to mean the potential for *significant* energy impact. Clearly, "significant" is a relative term and, as will be seen when reviewing the 30 cases, is interpreted quite broadly.

While all of the technologies reviewed address energy-related problems or needs, their relative importance varies in terms of the potential contribution or impact of each. More than half of the cases are designed to use less energy (see Table 3) which, given utilization, result in energy savings. As with most conservation technologies, the potential impact of each of the above 17 cases, with a few exceptions, is incremental (i.e., adoption results in small rather than massive energy savings).

Five of the 30 cases reviewed for the evaluation were also evaluated by MIT (Jansson and Neuton, 1980). The five cases were Dornier's Flexaflo dryer, Jones' waste heat utilization for commercial cooking equipment, Wood's direct flame-contact, high-efficiency water heater, Arthur's aeration power-control device, and Fitterer's process for analysis of low-carbon aluminum steels using oxygen sensors and iron aluminum alloy. In investigating the energy savings potential of each, the study found the potential energy savings to range from 0.03% to 0.6% of total U.S. energy consumption. Such figures reflect only the market potential and not penetration. They do, however, support the evaluation of the NBS staff and of the inventors themselves that the inventions could save energy if adopted.

Given the similarities of these cases with the other cases reviewed for this study, there is reason to believe that similar results might also

be found if an energy-savings-potential study were to be done for each. This is not to say that there are not relative differences in potential impact. Factors such as size of market, number of alternative applications, and energy use affect the relative importance of one technology when compared with another. For example, relative to the other technologies, Karlson's process for separation of chemical species or different isotopes may be more important. Not only is it a low-energy process which could replace an energy-intensive process if successful, but the range of potential applications also is substantial.

Some of the technologies, if viable, commercialized, and adopted, would expand our nation's energy supplies or improve our ability to obtain these supplies. These technologies include Baum's coke desulfurization process, Haspert's mining drill, Mark's power generation process, Wahrman's drilling bit, Mattson's plastic solar collector, and Zinn's rubber solar collector. Of these technologies, the potential contribution of some was more obvious than others. In the authors' opinion none could be written off as being of no benefit.

Mattson's and Zinn's different solar collectors offer inexpensive alternatives to the existing glass and metal collectors which at present are only cost-effective with the assistance of tax credits. When such credits are eliminated in 1985, these inexpensive collectors may be the salvation of the solar industry. Another important invention was the coke desulfurization process. While ultimately it was found to be technically infeasible, the energy-supply potential of the technology was considerable. There is no doubt that the problem addressed by the invention was important; unfortunately, the solution was wrong.

Commercial Feasibility. The third major criterion applied by NBS for evaluation is commercial feasibility. More than half of the cases are still at a stage in the R&D process where determination of the ultimate commercial feasibility is impossible. Of these, two are potentially commercially infeasible: Mark's heat/electric power conversion via charged aerosols and Parker's system for power generation utilizing atmospheric temperature gradients. The costs of developing Marks' are so high and the benefits to be derived so undefined

that the long-range commercial prospects of the technology are questionable. Indeed, Marks has met considerable opposition to his idea within the technical community for these and other reasons. Likewise, Parker's technology, while not out of bounds, is still costly according to the economic feasibility study undertaken with ERIP funds. The position of both Parker's and Marks technologies could change drastically, however, if there were more dramatic increases in oil prices and/or shortages. Of the remaining cases in which there is firm evidence of commercial feasibility, only three appear to have been demonstrated at this time to have failed commercially: Fowler's solar tobacco barn, Norris' boiler fuel additive, and Dornier's Flexaflo wet fuel dryer. The ultimate potential for commercialization of these technologies could change if there are changes in the market or if new applications for the invention are realized. For example, Dornier's Flexaflo wet fuel dryer appears to have failed because of a depression in the sugar industry in the United States. If this situation were to change or if new markets were sought outside of this industry, the product might ultimately be fully commercialized.

Selection Criteria Not Applied. Having reviewed the criteria which are applied by NBS in evaluating the technologies recommended to DOE for support, it is important to briefly discuss more traditional project selection criteria which are not applied and which significantly affect the scope of the inventions which are supported by the program. In evaluating the technologies NBS does not consider:

- stage of development of the technology (e.g., concept, engineering prototype),
- type of technology (e.g., product, process),
- type of industry (e.g., automotive, metal processing),
- incremental vs "quantum-leap" advance in the technical field, and
- newness in the patent sense (i.e., not previously invented, uniqueness).

As would be expected, the 30 cases were also distributed across the R&D spectrum (see Table 4) as identified when their applications were accepted by ERIP.* They fall generally within three broad R&D categories: eight were in the idea evaluation and development stage; 15 were in the stage of product/process evaluation and refinement (including laboratory testing, engineering-design working models, and prototype development); and seven were in venture initiation (including production, marketing and production engineering).

Likewise, the technologies are scattered across a wide range of invention subject areas and industries with no discernible areas of concentration. Of the 30 cases, 20 are classified as product inventions and 10 are classified as process inventions. However, in several of the 30 cases the invention can be defined as both a product and a process.

While most of the technologies can be defined as "incremental" advances as opposed to "quantum leaps," this is expected, given the conventional view of invention in the 20th century which holds that there are very few new ideas. The fact that some of the technologies can be classified as "quantum-leap" technologies is, we think, evidence of the willingness of ERIP to support more long-range, high-risk technologies.

Finally, newness in the patent sense is not a selection criterion applied; however, it is interesting to note that, by the time the grantees were interviewed, 27 of the 30 technologies had been patented.

Non-Energy-Related Characteristics. So far, technologies have been described along dimensions deemed important to program managers. There are other attributes of these technologies that deserve attention and help us understand the ERIP's value to the nation as well as its contribution to solving other national problems.

In addition to a potential for saving energy, or for increasing the energy supply, some of the technologies contribute to the resolution of

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*As mandated, the program does not fund projects for idea generation; one must already have an idea already before coming to the program.

other national problems. Bagby's mine brattice, if adopted, would substantially improve mine safety and the health of mine workers. Baum's coke desulfurization process would have solved a major pollution problem resulting from the use of high-sulfur coals. The inventions of Ben-Shmuel, Cromwell, Chill, Durbin, Jablin, and Mahalla could, through application, reduce pollution from existing production processes. In addition, both Engdahl's and Marks' inventions are designed in the long run to permit decentralized power systems. Finally, Cromwell's aluminum dross invention increases the availability of a scarce resource.

A number of inventions are also important because they have the potential to alter an industry and to effect the development of other technologies, and/or their applications are diverse and plentiful.

The coke desulfurization process, if it had been successful, would have brought about a major change in the coal industry. The same may be said for the impact of Karlson's process for low continuous mass separation on the uranium isotope separation industry. Other examples of inventions which could change an industry are Wahrman's ablative oil well bit insert, Mahalla's hydrometallurgical method of extracting copper, and Sach's integrated concrete technologies.

Several of the inventions would affect the development of other technologies: Engdahl's CVD ceramics technology, if successful, will further the development of other technologies that are dependent on the availability of the ceramics technology.

Finally, many of the inventions have multiple, diverse applications which enhance their usability; for example, Secunda's Thexon process, Bagby's brattice, Dornier's Flexaflo wet fuel dryer, Engdahl's ceramic process, and Karlson's new continuous mass separation system. To illustrate: Karlson's process is applicable to radioactive waste disposal, uranium isotope separation, pharmaceutical production, and water purification. The diverse applications expand the marketability of the technology greatly and enhance its importance.

Summary

The target audience includes both the grantees and the supported technologies. With respect to the grantees we conclude the following:

- The 30 grantees are either independent inventors or small businesses.
- Their job experience is diverse, with many grantees mixing a considerable number of years as employees with entrepreneurial efforts.
- The grantees are moderately well educated, although there is a mix of educational background, and most have considerable technical experience in the industry in which the invention is applicable.
- Most grantees have some inventive history; however, relatively few have had experience in obtaining government grants.

With respect to the technologies we conclude that:

- The 30 inventions are energy-related.
- The inventions funded were diverse and spanned the R&D spectrum.
- Given the criteria of intrinsic worth, potential energy impact, and economic feasibility, the 30 technologies were appropriate.
- Most of the inventions are interesting, important and have characteristics which are in the national interest.

Experience with the Program

Services and Operation

Given the above background on the grantees and their technologies, the focus of this discussion turns to the expectations and experiences of the grantees relative to the operation of the program and to their assessments of NBS and DOE.

Awareness of Program. Grantees heard of the program through a variety of channels: relatives, newspapers, popular magazines, trade journals, ERIP pamphlets, and Congressmen were all mentioned as sources of information. They came to the program, however, with certain similar needs

and expectations. While most of the grantees had technical problems to resolve before their technologies were ready for commercialization, nontechnical problems were most often cited as the reason for applying to the program. When grantees were asked explicitly why they submitted their ideas for evaluation, nontechnical reasons (e.g., the need for money and/or to establish credibility) were most often cited (see Table 5). Similarly, their expectations of both NBS and DOE with few exceptions focused on acquiring money and gaining credibility. The similarity of responses regarding NBS and DOE suggest that a few respondents did not clearly distinguish between the roles of NBS and DOE, at least at the beginning of the program. In some instances the confusion was due to a lack of information, while in others the grantees knew that the activities of DOE were dependent on those of NBS.

Experience with NBS. NBS receives all applications to the ERIP. It is the responsibility of NBS to evaluate these applications, using the criteria discussed previously, and to reject them or to forward inventions to DOE for funding. The review process consists of three stages: (1) an initial disclosure review stage, (2) a preliminary evaluation stage where an outside consultant reviews materials presented by the inventor and submits comments together with a recommendation to continue evaluating the technology or to reject it, and (3) an in-depth evaluation stage where an NBS staff evaluator selects a consultant to conduct a detailed analysis and prepare a report.

An inventor can be rejected at any stage, and not many inventions are finally recommended to DOE for support. If the invention is rejected, the applicant receives a letter stating the reasons for rejection; if a technical evaluation report is available (as with the second-stage evaluations), it is included. Inventors who are turned down may resubmit inventions with new information for reconsideration. Only two of the 30 cases reviewed were formally rejected — Zinn and Mattson. Both had problems presenting information, and both persisted and resubmitted. Several others had troublesome review processes: Dornier's and Sach's inventions were rejected by outside consoltants, but NBS overruled the decision; Secunda

Table 5. Grantees expectations of agencies

Grantee	Reason for submitting invention for evaluation	Expectations of NBS	Expectations of DOE
Agar	Technical assistance and money	Evaluation (2nd opinion)	Money, marketing
Arthur	Money	Evaluation	Money
Bagby	Concept validation	Credibility	Advice and help in testing; not money
Baum	Money	Money	
Ben-Shmuel	Credibility, money	Credibility, money	Money
Chill	Money	Credibility	Not aware of shift
Cromwell	Money	Nothing	Nothing
Dornier	Money	Money	Evaluation, fast action
Durbin	Money	High expectations	Evaluation process over; funding expected
Engdahl	Money, support	Money	Expected recommendation would be followed and would get support
Gordon	Money	Money	Contract within 30-45 days for money
Fitterer	Concept validation	Money	Money
Fowler	Money, credibility	Credibility	Money
Haspert	Money, credibility, technical assistance	Evaluation	Request for statement, growth, funding
Jablin	Money	Evaluation	Money, lab study, pilot plant
Jones	Money	Evaluation, money	Money after prompt evaluation
Karlson	Money	Money	Money
Kennick	Money	Money, market	Approve grant
Mahalla	Money, endorsement	Money, evaluation, endorsement	No more evaluation—"action" and grant
Marks	Money	None/maybe recommendation	Money

Table 5 (continued)

Grantee	Reason for submitting invention for evaluation	Expectations of NBS	Expectations of DOE
Mattson	Money	Positive evaluation	More paperwork
Norris	Evaluation, money	Prestige which would follow positive evaluation	Get money quickly
Parker	Patriotic duty	Expected by 1981 to have a few power plants built	Site visit/get-together with Corps of Engineers to build
Ross	To raise money (had tried banks, SBA)	Evaluation and recommendation to DOE	Money and technical assistance
Sachs	Evaluation, credibility, money	Recommendation to DOE	Money
Secunda	Money	Technical assistance, recommendation to DOE	Money
Spelber	Money	Money	Determine grant size and task to be performed
Wahrman	Money	Money	Unclear
Woods	Money	Money	Receive expedient positive evaluation and get money
Zinn	Credibility, money	Evaluate feasibility	Credibility, money

and Woods were about to be rejected, but discussions with NBS changed the agency's decision. In Wood's case, NBS telephoned to reject on grounds that the invention couldn't work. Woods told them that he had a working model. NBS came to see the model and recommended the invention for funding.

Three issues regarding NBS' activities were examined:

- technical evaluation,
- length of time required to complete a technical evaluation, and
- NBS administration.

Technical Evaluation. The evaluation of each invention is the primary service provided by NBS, and that service is provided to DOE, not to the inventor. NBS expects, however, that the evaluation should also be useful to the inventor.

Questions were asked during the interviews to elicit the grantees' opinion of the technical evaluation. The grantees were asked to rate the technical content and quality of the evaluation, its clarity, and the helpfulness of the evaluation (see Table 6). The following results were obtained:

- A majority of respondents (16) were satisfied or very satisfied with the technical content and quality of the evaluation. Only five of the respondents were dissatisfied or very dissatisfied. The remainder rated the evaluation "average."
- Only three grantees were dissatisfied with the clarity of the evaluation. Eighteen were either very satisfied or satisfied.

The response of the grantees changed somewhat when asked to rate the helpfulness of the evaluation:

- Nine respondents were either dissatisfied or very dissatisfied with the helpfulness of the evaluation, while ten rated it as average, and only ten were satisfied or very satisfied.

For many of these grantees the evaluation was of limited usefulness in solving their technical problems. The qualitative statements in Table 7 suggest that this may be because many of the inventors learned nothing new

Table 6. Grantee evaluation of NBS

Questions	Very satisfied	Satisfied	Average	Very dissatisfied	Dissatisfied	No response
Technical content and quality of the evaluation	13	3	9	2	3	
Personal contact with NBS	14	6	4	3	1	2
Helpfulness of evaluation	7	3	10	6	3	1
Time required for evaluation		6	4	9	11	
Clarity of evaluation form	13	5	6	3		3
Tone and wording of correspondence	13	6	5	3		3
NBS attention to confidentiality	16	5	6			3

Table 7. Comments on evaluation process

Grantee	Technical assistance from NBS	Comments on evaluation process
Agar	No	OK, but took too long.
Arthur	No	His expectation was that NBS would perform a technical evaluation. He was surprised that an outside consultant was used as an evaluator; in NSF proposals, peers are used. In July, he was contacted by second-stage evaluator whom Arthur believes knew little about the wastewater treatment field.
Bagby	No	According to Bagby, the NBS evaluation had an enormous impact on his invention. This impact may be attributed to the exceptional quality of the evaluator chosen for the second-stage evaluation. Dr. Ernest M. Spokes is an articulate and respected authority in mine ventilation who is known both academically and commercially as an expert and authority.
Baum	No	Evaluation was fair—no technical assistance.
Ben-Shmuel	No	Never talked to an NBS evaluator; the evaluation merely confirmed what he already knew. He speaks positively of NBS. Since NBS evaluation substantiated his own claims, he thinks the evaluators had a "lot on the ball."
Chill	Yes	Obtained "services" in the form of contact with one of the technical evaluators at the University of Maryland whom he visited and who gave him useful advice.
Cromwell	No	The NBS evaluation didn't tell him anything he didn't already know. The only direct contact Cromwell had with the program came via second-stage evaluator, a professor from Carnegie-Mellon University who visited the plant, observed the process in operation, then submitted his report to NBS. Cromwell talked to him on the phone two or three times.
Dornier	Unclear	He did not expect nor did he receive much technical assistance. In fact, Dornier couldn't recall very much contact with NBS.
Durbin	No	Durbin feels that he had to "educate" the NBS evaluators—both internal and external—and clearly states that he did not receive any technical assistance from them. He had been working on the solution to the problem for many years, and he did not need assistance. He did need funding to continue his work.
Engdahl	No	NBS provided no special services to the inventor, because the situation did not require such services. The inventor is a sophisticated technical person who knows his field.

Table 7 (continued)

Grantee	Technical assistance from NBS	Comments on evaluation process
Fitterer	No	Felt that technical content/quality of the evaluation was good but of no particular value to him.
Fowler	No	Rated the technical content, personnel contact, and helpfulness of the evaluation very high. Furthermore, while not requiring technical assistance, Fowler did feel that NBS evaluation forewarned him of the LP gas industry's reluctance to accept his invention.
Gordon	No	Dissatisfied with helpfulness of evaluation—technical content/quality average.
Haspert	No	He "had no idea" what NBS would do for him "other than some kind of evaluation." What resulted from submission was two conversations with a Dr. Chugh of the University of Southern Illinois at Carbondale. Dr. Chugh contacted the Bureau of Mines and found out that the Bureau was evaluating this same technology. BOM concluded that the technology would work.
Jablin	No	He feels that the NBS evaluation was an unnecessary delaying factor in obtaining a DOE grant. Jablin is a sophisticated inventor and a knowledgeable, expert consultant to the steel industry.
Jones	No	The fact that the invention being passed on to DOE was the greatest benefit derived from the NBS technical evaluation process. He did not change the hydrocoil system in any way because of the evaluation.
Karlson	No	Overall assessment of the NBS evaluation is that it was good, but the time was too long.
Kennick	No	No direct contact; impressed with the quality and thoroughness of the NBS technical evaluation.
Mahalla	No	Expectation of NBS minimal; hoped for good review and positive evaluation. Had contact with second-stage evaluator; no change in invention as result of NBS influence.
Marks	No	Only expected to lend credibility to concept; thought NBS did a fair and professional job.
Mattson	Yes	Expected NBS to show interest, maybe evaluate product firsthand, and eventually provide money for future development. Received a form letter saying technology was state-of-the-art and one that government could not encourage them to pursue. Initially Mattson was disappointed. At Mattson's resistance, NBS sent out a set of application forms to him for completion. Application rejected; Mattson persisted. NBS responded by sending a consultant. After seeing product and assisting with application, the invention was accepted.

Table 7 (continued)

Grantee	Technical assistance from NBS	Comments on evaluation process
Norris	No	Thirteenth in program, two years to get through. Wanted program to give credibility and prestige to product.
Parker	No	Sees no real benefit from NBS evaluation. Worst experience was getting the evaluators to believe it worked.
Ross	No	Expectation was to get positive evaluation and hopefully a recommendation for funding to the DOE. Talked to NBS contact (Robb) several times. He feels he received no technical assistance during the evaluation process. He was not encouraged to talk to second-stage evaluator. Perception was that NBS did not want a lot of communication. Evaluation confirmed idea.
Sachs		View of function of NBS was to validate concept at best. At worst, the analysis and report would provide additional valuable information. Sachs was turned down by outside evaluators and NBS overruled them. Sachs viewed this overruling as confirmation of the working of NBS staff.
Secunda	No	NBS provided no technical assistance, but did recommend. Secunda thinks highly of Sidney Weiser.
Spelber	No	His only reported contact with NBS was receiving copies of the NBS letter of recommendation and the NBS final report. His experience with NBS was not negative; however, it was not strongly positive.
Wahrman	No	Very supportive of NBS: "They gave me encouragement by their expert analysis in the latter-stage evaluation. It was very much appreciated."
Wood	No	The inventor did not approach NBS for technical assistance, because he believed that he already had the technical skills to develop the product. Expected to be recommended for funding. NBS rejected once because it said it couldn't be done. Wood told them he had it working on his carport. NBS saw it and asked him to resubmit.
Zinn	No	Experience "a loser." As far as he was concerned, NBS provided no services except ultimate endorsement and that took an "unbelievable" length of time. Never talked to second-stage evaluator. NBS did reject twice. Zinn fought back and NBS helped him marshal his arguments, rewrite proposals, and assemble demonstration that eventually reversed rejections.

from the technical evaluation. Some found the evaluation a nuisance; some understood that it was necessary. In a few cases, the inventor did learn something from the evaluation which he recognized as being useful.

When asked explicitly about assistance provided by NBS, most felt that no technical assistance had been provided, or that services were minimal. None of the grantees felt that their invention changed during the evaluation process as a consequence of the evaluation.

A positive evaluation was not, however, ignored by some grantees. When they were asked to cite the greatest benefit from completing the NBS process, one "felt better," six stated there was "no benefit," 13 cited either the "recommendation for funding" or the "funding" itself, and 10 cited *credibility* resulting from evaluation.

Time. For ALL applicants to NBS, the average time for evaluating an accepted application is 10 weeks, with a range of between two and 36 months. NBS is aware that for some applicants the evaluation process seemed to take too long. As a consequence, the grantees' perceptions of the time required for the process were explored.

As indicated in Table 6, 20 of the respondents are "dissatisfied" or "very dissatisfied" with the time required for the evaluation, six were "satisfied," and four thought the time required was "average." This perception was again expressed when interviewees were asked to cite the worst thing about NBS; 20 cited the time required to move through the NBS evaluation process; two cited communication; one found that convincing NBS of the worth of his idea was the most difficult thing.

Table 8 indicates the actual length of time it took each applicant to get through the NBS process. We checked the time-in-process of those 20 who were dissatisfied and found that the range of time was from 9 to 27 months and for those satisifed from 13 to 20 months. Dissatisfaction as well as satisfaction appears to be unrelated to the actual time involved — at least for these 30 grantees. One suspects that, for the grantees, any time period is too long, and that their responses are affected more by experience, personality, and need than by the actual time. These perceptions, however, seem to support NBS' continuing efforts to reduce the evaluation period, if for no other reason than to reduce the applicants' frustrations.

Table 8. Months in ERIP process

NBS				
1–6 months (1)	7–12 months (7)	13–18 months (12)	19–24 months (8)	27 months (1)
Cromwell	Gordon	Baum	Arthur	Agar
	Ben-Shmuel	Chill	Fowler	
	Karlson	Jablin	Sachs	
	Dornier	Bagby	Durbin	
	Wood	Zinn	Engdahl	
	Parker	Kennick	Jones	
	Spelber	Haspert	Secunda	
		Mahalla	Wahrman	
		Mattson	Ross	
		Norris		
		Fitterer		
		Marks		

DOE		
1–6 months (2)	7–12 months (19)	13–18 months (6)
Dornier	Ross	Marks
Ben-Shmuel	Fitterer	Norris
	Jones	Secunda
	Spelber	Wahrman
	Durbin	Mahalla
	Engdahl	Cromwell
	Haspert	
	Parker	
	Sachs	
	Fowler	
	Arthur	
	Mattson	
	Wood	
	Karlson	
	Jablin	
	Baum	
	Bagby	
	Zinn	
	Kennick	
	Chill	
	Gordon	

It is important to remember that the evaluation is a service provided to DOE. While many grantees perceived the time required for processing to be too long, from the perspective of DOE personnel the rate at which recommendations are received is satisfactory.

Administration. The grantees are quite positive about other aspects of the program administration at NBS. Most found the personal contact with NBS satisfactory; most were satisfied with the clarity of the evaluation form, the tone and wording of the correspondence, and NBS attention to confidentiality.

Experience with DOE. Upon being recommended for support, the inventor receives a letter from DOE acknowledging the recommendation and defining what the inventor needs to do to actually receive funding.

The most important step involves the development of a mutually agreed-upon work statement. Potential grantees are asked to submit a proposal to which DOE responds. The process usually involves a period of negotiation during which DOE not only evaluates the proposal but also the inventor. In determining what should be included in the work statement, DOE is influenced mainly by three factors: (1) the stage of development of the invention, (2) the NBS evaluation which usually defines the "next step" the inventor should take, and (3) the amount of funding available.

During the time when these cases were being processed, DOE considered it appropriate to fund a range of activities in the pre-commercialization phases of the R&D process. The activities fall into five major categories: basic R&D, early testing, late testing, prototype building, and business and production planning. As an administrative decision the DOE has not funded tasks specifically directed at marketing, although some grantees perceived that the office gave some indirect marketing assistance.

As with the NBS, we reviewed the experiences and perceptions of the grantees relative to the DOE process. At the time of the interview

all of the interviewees had negotiated work statements and, with the exception of Agar, had received funding. Some of the grantees, however, were still completing the work required under the DOE contract.

When the work statements were negotiated, eight grantees were in the idea-evaluation-and-development stage; 15 were in product/process evaluation and refinement (e.g., early or late testing and prototype construction), and seven were at the new-venture initiation stage. Table 9 includes a summary of the tasks defined in the work statement for all the grantees. Cases are grouped according to the stage of development of the technology at the time of submission. Six grantees received money for basic research. This work included feasibility studies, development of bench scale models, etc. Two grantees received funds to undertake early testing of their product/process; 11 were funded for late testing; 14 were funded to construct prototypes; four were given funds for business and production planning. (The total number exceeds 30, because some work statements included two or more tasks.

In addition to receiving funds which permitted them to further develop their inventions, the grantees identified other forms of assistance received from DOE (see Table 10): contacts/referrals to government, business, or academia; technical and clerical advice; and information.

While the expectations of many inventors were that as soon as they were recommended to DOE the money would be forthcoming, their experience was different. The time from receipt of the negotiation letter to receipt of the first check ranged from 6 to 15 months. As with NBS, a number of grantees (12) experienced frustration with the time required to process their project (see Appendix for Harry Wood's colorful account). One specific concern of the grantees was the delay resulting from the procurement process (that is, the time it took from finalizing the work statement with a program officer, to receipt of contract, to receipt of funds).

In addition to the above operational problems, the paper-pushing and bureaucratic maze were identified by several grantees as the greatest

Table 9. DOE work statement summary

Stage at time of submission	Grantee	Task in work statement	Work statement completed	Results
		Idea generation		
Concept development	Agar	Testing and monitoring (never completed because Richland, who bought Agar's firm, did not accept grant)	N/A	Agar now wants to get DOE money to pursue idea on his own
Concept development	Arthur	Preliminary design and prototype development	Yes	Prototype development/ testing, limit marketing (Arthur had built and sold two units; he recognizes the need for an energy-saving analysis)
Concept development	Engdahl	Laboratory work to improve the material properties of CVD SiC deposited on metal (funds from ERIP co-mingled with other funds)	Yes	Concept development
Concept development	Gordon	Build prototype and test	No progress made (work statement may have been too ambitious)	Nearly completed prototype—needs to find way to close ends of tube
Concept development	Haspert	Preliminary design of a prototype mining machine; locate a shale mine site for testing	Yes	Concept development
Concept development	Jablin	Design and build prototype	Yes	Prototype tested
Concept development	Baum	Validation of concept	Yes	Concept invalidated
Concept development	Marks	Build bench scale model	No progress made (work statement may have been too ambitious)	Concept development partial completion of bench scale

Table 9 (continued)

Stage at time of submission	Grantee	Task in work statement	Work statement completed	Results
		Product/process evaluation and refinement		
Prototype development and testing	Bagby	Build and test brattice in mine; refine design	In progress	Limited production and marketing
Prototype development and testing	Chill	Completion of prototype development and tests by respectable technical organization	Yes	Chill is between prototype development and limited marketing
Prototype development, testing (Cromwell had a working model which was used in limited production of product)	Cromwell	Construct prototype to test design and complete modifications; solve remaining technical problems; acquire impact mill and define an appropriate design	Yes	Six months away from full production/marketing (orders are in hand, factory being completed)
Prototype development and testing	Durbin	Build test facility; Build and test three breadboard prototypes; assess production factors; select most promising prototype	Yes	Prototype development testing; two working models have been tested, and research laboratory in Canada established to continue work
Prototype development and testing	Jones	Safety testing by reputable laboratories	Yes	Limited marketing
Prototype testing	Karlson	Build larger prototype and do more testing	Yes	Larger prototype testing
Working model prototype	Kennick	Test initial consumer acceptance studies	In progress	Larger prototype test facility
Laboratory examination	Mahalla	Identify variables that influence growth rate of crystals; alter physical geometry of the cell	Yes	Bench-scale prototype
Prototype development testing/engineering	Mattson	Build full-scale model of improved collector	Yes	Limited marketing
Engineering design	Parker	Feasibility study; economic analysis; power generation estimates	Yes	Concept development
Working model	Ross	Testing of working model	Yes	Bench-scale prototype

Table 9 (continued)

Stage at time of submission	Grantee	Task in work statement	Work statement completed	Results
Laboratory testing	Secunda	Tests to explain process	Yes	Working prototype. (Can't move forward, however, because no manufacturer capable of building an industrial sized Thexon apparatus will do so without order in hand; can't get orders without adequate size machine. Prospective manufacturers will not agree to secrecy.
Prototype development	Spelber	Business plan	Yes	Poised at full-scale production
Prototype development	Wahrman	Test of performance of bits	Yes	Limited production
Working prototype	Wood	Test of working prototype	Yes	Fully commercialized
		New venture		
Limited production and marketing	Ben-Shmuel	Test of installed heat extractor at Mohawk and Ben-Shmuel's plant	Yes	Full production and marketing
Limited production and marketing	Dornier	Redesign inventory and solve technical problems that emerged when product was first marketed	Yes	All technical problems solved, products *ready for marketing, no products sold*, however, because of slump in sugar industry
Limited production and marketing	Fitterer	Invention operationally tested with cooperation of McClouth Steel Company	Yes	Company bankrupt; because of positive results from tests, venture capital people who invested in company moved to control company—instituted price increase which led to loss of sales

Table 9 (continued)

Stage at time of submission	Grantee	Task in work statement	Work statement completed	Results
Limited production and marketing	Fowler	Operate demonstration project to manufacture four barns; install and monitor performance (In conjunction with effort received $360,000 line of credit from SBA)	Yes	Discontinued production
Limited production and marketing	Norris	Market study	Yes	Discontinued
	Sachs	Testing by reputable laboratories for seal of approval on product	Yes	Limited
	Zinn	Testing of product	Yes	Full production and marketing

Table 10. Other forms of assistance

Contacts/Referrals	Publicity	Advice	Information	Miscellaneous
Arthur	Arthur	Bagby	Haspert	Kennick (time extension)
Durbin	Dornier	Jablin	Baum	Marks (additional support to Naval Postgraduate School at Monterey)
Ben-Shmuel	Mahalla	Mattson		
Karlson	Sachs	Sachs		
Secunda	Wahrman	Baum		
Ross				
Norris				
Wahrman				
Zinn				

difficulty with the DOE operation. Two mentioned that the money wasn't enough; two stated that the additional evaluation of the invention by DOE was unnecessary; one cited a rude secretary; and for one the greatest difficulty was getting marketing assistance. Six grantees had no difficulties.

When asked to cite the "best thing" about the DOE operation, a more personal dimension of the program was revealed. While getting the money was most frequently cited, a number of grantees made specific reference to helpful program personnel.

Overall Assessment of the Program by Grantees

With few exceptions the grantees are very positive about the program. They would resubmit to the program if they had other inventions, or they would recommend the program to other inventors. Moreover, their response to the question "What is the best thing that happened to you as a result of participating in the ERIP?" indicates that most inventors got what they wanted from the program (i.e., money and/or credibility or endorsement of their idea). The time required to get funding from the program was most often cited as the most difficult thing about participating in the program.

When the grantees were queried as to specific changes which each would make in the operation of the program, their responses are specific. Interestingly, they do not focus on the time problem as much as one might expect from previous comments but include issues related to communication, marketing/publicizing, level of funding, and technical evaluation (see Table 11).

Summary

Based on the preceeding discussion we conclude:

- The grantees' opinion of the services provided by NBS and DOE is satisfactory.
- NBS is most frequently perceived as a conduit through which an invention must pass to get funding, although a few grantees perceive benefits to be derived from an independent evaluation.

Table 11. Grantee recommendations for changing the program

Time	Level of funding	Technical evaluation
• Speed up (Wahrman, Spelber, Agar, Kennick, Dornier, Baum, Haspert, Norris, Karlson, Sachs) • Fast track for some technologies (Jablin, Wahrman) • Improve procurement process time (Baum)	• More funds (Agar, Engdahl, Fowler, Marks, Wahrman) • Don't drop after one-step funding (Gordon) • Increase budget for more administrative attention (Wahrman) • Follow-up method to continue funding (Zinn, Ross)	• Consult inventor on outside evaluators (Arthur) • Reevaluation by scientists at end of process (Parker) • Give "Energy Seal of Approval" (Spelber)

Communication	Marketing/publicizing
• Greater contact (Arthur, Fitterer, Gordon, Kennick) • Communicate information about invention to other agencies (Bagby, Sachs) • Feedback (Karlson, Kennick) • More direction to inventor on how to manage support (Mahalla) • Change tone of rejection letter (Mattson) • Wider distribution of final reports (Parker)	• Recommend invention to other agencies (Arthur) • Assess market potential better (Arthur) • Subsidize potential purchases of invention products (Ben-Shmuel) • Follow- through for successful grantees to facilitate entry into marketplace (Secunda) • Publicity on program (Chill) • DOE assistance in marketing; and acquiring venture capital (Gordon) • Follow-through program that gets Federal agencies to use inventions (Jones) • More marketing expertise (Parker) • DOE provision of field reps to help inventor make contacts with business (Ross)

Miscellaneous
• Expand scope of program to other areas of need (Wahrman)

- The time required to move the invention from the submission stage to the funding stage is perceived to be too long.
- All phases of the ERIP process are perceived to contribute to the time delays.
- The NBS evaluation is perceived to provide little technical assistance to the grantee.
- Individual DOE staff members were specifically cited as having performed their jobs well.
- The recommendations for funding and credibility are most frequently mentioned as a benefit from the NBS evaluation.

Additionally, program participants made the following general assessment of the program:

- Grantees are positive about the program.
- The best things about the program which were cited were "money" and "credibility."
- The time required for processing was most often cited as the most difficult thing about participating in the program.
- In addition to time, problems are cited relative to communication, marketing, publicizing, level of funding, and technical evaluation.

Outcomes

In this section we review the outcomes of the program. Because the program is relatively young, and the time required for some funded technologies to progress through the innovation process is so long, the outcomes identified do not include all possible outcomes. However, there is sufficient evidence at this early date to state that the program is meeting its goals and objectives. Not only did the projects move one step as defined by the work statement, but nearly 50% obtained additional support and, surprisingly, six of the grantees have already commercialized products. This latter fact exceeds all expectations for so early a review of the outcomes of the program.

In exploring the question of outcomes, grantees were asked to identify two classes of outcomes: tangible and intangible.

Tangible outcomes are defined as those which are directly observable; intangible outcomes are those which cannot be seen, touched, or easily quantified (e.g., an increase in knowledge, improved ability to establish a commercial venture). When these are combined a reasonably complete picture of the outcomes resulting from participation in the program is obtained.

Tangible Outcomes

A review of the events identified as tangible outcomes by respondents resulted in our selecting four general classifications:

- completion of work statement,
- things that resulted in increasing the credibility and visibility of the grantee which in turn improved his chances of acquiring capital in order to continue his work or to license, sell, or otherwise commercialize the invention,
- events/occurrences that changed the status of the grantees' businesses, and
- increased sales of product or other events indicating the product/process achieved commercialization.

Work Statement. Completion of the work statement is considered a tangible outcome: it represents the mutually negotiated scope of work setting forth the ERIP and grantee perceptions of the "next step" which must be completed with the one-time funding in order to progress toward commercialization. Completion of the work statement should leave the grantee in a good position to obtain support from other sources if necessary.

If the grantee completes the work statement, then according to the DOE anticipated outcomes (see Sect. I) he should be able to:

- compete effectively in obtaining contracts from other sources, (including existing public programs) to permit further development of the invention; or
- assemble, with some confidence of success, the people and capital necessary to produce and market the invention through a business enterprise in which the inventor is a major participant; or

- negotiate mutually beneficial arrangements with an existing company to develop the invention for commercialization.

Table 9 identifies and describes the status of the project and briefly describes the work tasks contained in the grant.

Of the 25 grantees who completed the work statement, 48% (12)* reported being in the process of taking the next step or having already taken it (i.e., having achieved the ERIP anticipated outcome). This percentage would be over 50% if Bagby were included, because he is currently selling his product.

In one case, that of Agar, the grant was not made; therefore, he is not included in the tabulation of results. In four cases the work statement is not complete; in two of these cases (Kennick and Bagby) progress was made, but the grant is not yet terminated; in two cases (Marks and Gordon) the grantees were unable to complete the work with the funds received — it appears that there was too much work required for the funds allocated. For the purpose of this section, completion is defined as having the final report in progress or already submitted to the ERIP.

Credibility and Visibility. In some cases, events occurred that led to increased credibility and visibility for the grantee and his product or process. The interviewees reported these as tangible effects. Most of these events fell into two categories: published articles or reports and attendance at the Dr. Dvorkovitz Technology Exposition in Atlanta. The first resulted in public acknowledgment of the technology's validity and value; the second had the same effect and was also an opportunity for the grantee to display his technology and meet others who were interested in its development and commercialization. Whether these contacts will result in actual sales or licensing agreements remains to be seen. Nonetheless, the interviewees reported them as tangible outcomes of their participation in ERIP (see Table 12).

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*Jablin, Cromwell, Durbin, Mattson, Spelber, Wahrman, Wood, Zinn, Sachs, Ben-Shmuel, Arthur, and Chill.

Table 12. Tangible outcomes

Grantee	Credibility and visibility	Financial and business	Product/process commercialization
Agar	N/A	N/A	N/A
Arthur	Exhibited at "Tech Ex"; MIT case study; 5-Star Award from *Pollution Engineering Magazine*	$100,000 SBA loan; submitted other proposals to support related work; wrote business plan; hired one technician	Sold two units; developing new applications
Bagby	*Coal Age* article by well-respected member of mining industry	Used NBS evaluation report in technical report and business brochure	Sold some units to western coal companies
Baum	None	None	None
Ben-Shmuel	None	$400,000 SBA loan; now has 250 employees	Increased sales from a few units to $25 million per year
Chill	Exhibited at "Tech Ex"; testified at OSHA hearings	Grant from Department of Defense for $40,000 to develop specific application of cold process	Bearings and bushings are being sold
Cromwell	NBS technical evaluation and DOE grant generated credibility in acquiring capital	$200,000 SBA-guaranteed loan; $450,000 private capital $700,000 from city; leased building with option to buy	Letters of commitment in hand represent an excess of $10 million in first-year sales; production initiated early in 1982
Dornier	Technical paper published by MIT professor	None	None
Durbin	Established R&D lab in Vancouver; Canadian policy changes including a $6 million commitment from government for R&D; conducted a world conference on use of methane in motor vehicles	None	None
Engdahl	None	None	None
Fitterer	None	Business bankrupt	Increased use of product by industry
Fowler	None	Kept business alive one year	None

Table 12 (continued)

Grantee	Credibility and visibility	Financial business	Product/process commercialization
Haspert	*World Mining* article	Hired two people	None old
Gordon	None	None	None
Jablin	None	Company offered to buy his company; he refused	None
Jones	None	Grant covered administrative and overhead costs; helped him start business	None
Karlson	None	None	None
Kennick	Published research findings	Hired scientist	None
Mahalla	Exhibited at "Tech Ex"; formulated a solid technical report	None	None
Mattson	None	Established contact with marketing firm; employed about six people; business became "real" upon DOE funding	Established small production facility; sold turnkey plant to Phillipines; increased sales to about $2,600,000 per year
Marks	None	Referred to another funding source; obtained R&D funds	
Norris	None	None	None
Parker	None	None	None
Ross	None	None	None
Sachs	Exhibited at "Tech Ex"; received three awards	Finalized two new business arrangements to market his technology; developing business plan	Bid jointly on construction venture; awaiting news of award; negotiating for support from State of Michigan
Secunda	None	None	None
Spelber	None	None	Raised $2 million from public offering

Table 12 (continued)

Grantee	Credibility and visibility	Financial business	Product/process commercialization
Wahrman	Exhibited at "Tech Ex"; generated publicity and contacts; appointed to President Reagan's Energy Council	Expanded business; Sandia Labs performed tests valued at over $150,000	None
Wood	None	Sold design rights to a company that subsequently sold five units	Sold 8 custom-built units
Zinn	Exhibited at "Tech Ex"	$350,000 SBA loan at 7% interest	None

Business and Financial. In nearly all of the cases, events occurred which impacted on the business and financial status of the grantee. These events include hiring personnel to work on the project, capital acquisition, business expansion, and making contacts with potential buyers.

Product/Process Commercialization. Items noted in Table 12 are tangible outcomes identified by interviewees which demonstrate commercialization (i.e., sale of at least one unit) of inventions.

The reader will note that in nine cases the product has been sold or the amount of product sold has increased. This outcome is only an indicator of the potential impact of the program, since most of the grant work statements have been completed during the past year. An annual interview over a period of seven to ten years would provide much more reliable information regarding commercialization of ERIP-supported technologies.

Intangible Outcomes

During the course of the interview, grantees were asked to identify intangible outcomes of their participation in the ERIP. Although a broad spectrum of such outcomes were identified, most fell within groups which could be termed "increased knowledge" and "increased skills." Table 13 contains of list of these outcomes.

Intangible outcomes are important to this evaluation, because they are results of program participation that may obviate the need for a grantee to seek government support or assistance in the future. It appears that, upon completing an ERIP project, a grantee is more aware of the importance of carefully completing such tasks as planning; therefore, he is better prepared to complete the necessary tasks successfully without government guidance or financial support.

Table 13. Intangible outcomes

Increased skills	
Learned to deal with federal bureaucracy	Ben-Shmuel
Increased ability to get federal funds	Dornier, Parker
Learned how to patent inventions and make money	Mattson
Gained experience in developing funding sources	Cromwell
Learned importance of planning	Cromwell
Increased knowledge and awareness	
Increased knowledge of industry interest market	Durbin, Fowler
Heightened interest in technology by industry	Kennick, Fitterer
More knowledge about licensing process	Durbin
Awareness of the "painfully slow rate of innovation within large American auto companies"	Durbin
Better knowledge of how to deal with major manufacturers	Durbin
Increased knowledge of the technical field/problem	Dornier, Ross
Improved knowledge of government system/ERIP	Haspert, Gordon Marks
Enlarged knowledge base in technical field	Mahalla, Wood
Better understanding of product development process	Arthur, Parker
Increased contacts, publicity, visibility, credibility	Sachs, Karlson, Fitterer, Arthur, Engdahl
Increased rate of progress on project	Kennick, Cromwell
Other	
Government seal of approval is useful	Agar
Able to help another ERIP participant	Chill
Opportunity to work with industry	Durbin
Positive working relationship with ERIP personnel	Dornier, Wood
Lost time	Jablin
Developed negative view of ERIP	Norris
University gained some increase in stature	Mahalla
Negative view of functioning of bureaucracy	Zinn
Learned energy conservation was not a critical national concern	Fowler
Developed spin-off invention/idea	Cromwell, Karlson Wood
Opportunity for inventor's professional development	Mahalla
Established good relationship with local financial community	Cromwell

Summary

Based on the preceding discussion, the outcomes may be summarized as follows:

- The tangible results of participating in the program identified by the grantees included increased visibility and credibility as well as additional business and financial support.
- Five of the 30 cases achieved full commercialization.
- In all but three cases the grantees have moved one step as defined by the work statement.
- In 48% of the cases the grantees were able to acquire other support after completing the work statement (representing "one-step, one-time" funding), thereby achieving ERIP's anticipated outcomes.
- Intangible results most frequently mentioned were credibility and visibility.

CONCLUSIONS

Having reviewed the above results, we have arrived at several conclusions about the operation and impact of the program. These conclusions are based on the experience of the 30 grantees and will be discussed further in the following sections within the broader perspective of the innovation process.

The conclusions are organized around four evaluation questions:

- Is the program serving the audience (i.e., clients), mandated by the Congress?
- Is the program providing its mandated services?
- What are the outcomes/results of providing the services to the audience and are the outcomes related to the goals and objectives of the program?
- Is the program operating effectively?

With respect to the mandated *target audience*, there are several conclusions:

- ERIP is fulfilling its congressional mandate by accepting only energy-related inventions from small businesses and independent inventors.
- The program has encouraged a diverse group of individuals and businesses to submit their inventions for evaluation.
- The program tends to provide financial support to individuals with technical education and/or experience in areas related to their inventions.
- The NBS evaluation of submitted inventions results in the recommendation of appropriate inventions, given criteria of technical feasibility, commercial feasibility and energy-relatedness.

With respect to the *services* provided to the grantees in the program operation, the following conclusions are drawn:

- ERIP provides two major services to grantees — money and credibility. These services are appropriate, given the mandate of the program to evaluate and support promising energy-related inventions.

- The NBS is performing its mandated service for DOE -- evaluating and recommending promising inventions.

- The DOE meets its objective of developing a mutually acceptable course of action to be pursued, by each recommended applicant, with federal assistance. Given the number of grantees who complete the work statements, DOE is effective in defining tasks which can be accomplished with the money provided.

- While the evaluation process at NBS seems to provide little technical assistance to grantees, it is not obvious that such assistance is needed or wanted.

- The perceived need of the mandated audience for credibility, visibility, and money suggest that financial support is not always the most effective means of supporting inventors who come to the program lacking business experience and/or having limited resources.

- On the whole, ERIP is delivering the mandated services. However, there are a number of areas which need attention (e.g., communication, expansion of the range of services, time to process the grant, the mechanism for NBS evaluation).

- A joint-agency mode of operation has survived the test of time and provided special benefits for program grantees.

The *outcomes* from the 30 cases have led to the following conclusions:

- Given the number of cases which have moved (one step) forward, acquired additional support, or achieved commercialization, the program is meeting its mandated goals and objectives.

- The number of cases which reached commercialization was unexpectedly large, given the short period of time in which the program has been operating. This outcome is a consequence of funding a number of technologies closer to commercialization.

- Given the number of cases where commercialization or further support was achieved, the DOE policy of one-step, one-time funding is effective in preparing the grantee to continue development at the termination of the grant.

- The intangible outcomes of credibility and visibility assigned to the technical evaluation report suggest that careful attention be paid to the utility and importance of these outcomes before modifying the existing invention and evaluation process.

SECTION III: DISCUSSION ISSUES AND RECOMMENDATIONS

DISCUSSION ISSUES

This section of the report contains a discussion of the major evaluation issues identified prior to and during the evaluation, as well as the recommendations of the evaluation team. The discussion issues are those typically raised during a federal program evaluation to provide program managers with information on which to base management decisions and to develop and reconsider policies for the program. They are:

- the target audience,
- the ERIP services,
- the ERIP operation, and
- the role of the program in the innovation process as defined by the outcomes (both tangible and intangible).

In discussing these issues, both the evaluation data and expertise of evaluation team members are taken into account. The reader will find conventional wisdom, results of previously conducted research, and the ERIP evaluation results interwoven in the discussion of each issue.

Finally, recommendations are made without any discussion because they are self-evident when the issue discussion and the evaluation results are considered.

Target Audience

The term "target audience" refers to the specific group a program attempts to reach and serve. In the case of the Energy-Related Inventions Program, the target audience is mandated by existing legislation; the program must evaluate "all promising energy-related inventions, particularly those submitted by individual inventors and small companies..." With respect to the first element, "all promising energy-related inventions," the NBS program chief has defined the target

audience as technologies (newly invented or already existing) which have applications that will result in generating or saving energy.*

Given this definition and the results of this evaluation, it is clear that the ERIP is evaluating and supporting such technologies; so it is serving an appropriate target audience as set forth in the existing legislation.

With respect to the second element of the target audience, it is clear that ERIP focuses its attention on individual inventors and small companies with energy-related inventions. This is demonstrated in the literature regarding the program, discussions with program personnel, and in the cases recommended to DOE for support. All grantees interviewed as part of this evaluation are individuals or small businesses.

Given the results of the field work and the information presented in the previous section, the evaluation team concluded that the audience is even more appropriate than is obvious at first. The grantees interviewed are hard-working, serious, creative, persistent people with a strong interest in ensuring that their inventions are utilized and consequently reaping the attendant economic benefits. Indeed, we found the interviewees particularly adept at identifying and describing the energy-related characteristics of their inventions and persisting in overcoming the problems involved in dealing with the federal government. We found that *they did not fit the Rube Goldberg stereotype of inventors* as eccentric, isolated individuals interested in collecting patents.

Over the lifetime of the program, DOE personnel have increasingly emphasized supporting potential grantees with an entrepreneurial bent, thereby increasing the potential for commercialization; this has developed

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*This interpretation of the definition of the term "invention" is at odds with that used by the U.S. Patent and Trademark Office, as well as that of most students of innovation. A discussion of these differences may be found in Section II of this document. Because innovations as well as inventions are accepted by the program, the stage of development of an idea need not be a criterion applied. As a consequence, technologies across the R&D spectrum are funded — even those that are nearing commercialization.

into an informal criterion for prioritizing cases recommended by NBS for support. This kind of grantee may be termed a "technological entrepreneur" as described previously. A review of the data presented in the previous section identifies most of the grantees interviewed as principals in or sole owners of small businesses. Thus, *program personnel have selected those most likely to succeed in commercializing a technology* of any type — the technological entrepreneur. This is also the type of person who establishes a business that falls into the 20% average failure rate as opposed to the overall failure rate for small business (approximately four times greater than that of the technology-based business).*

> In summary, the evaluation team found that the ERIP met its mandate with respect to the target audience and exceeded it to the extent that it especially encourages technological entrepreneurs who are shown by the literature, conventional wisdom, and our experience to have the greatest potential for success in commercializing technology.†

Program Services

Another element of the ERIP is the service it provides to its target audience:

- technical evaluation of inventions and recommendations of promising inventions for DOE support and
- support of recommended inventions.

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*During our interview and subsequent discussions, the issue of expanding the target audience to include inventors of non-energy-related devices and processes was raised. While we report this finding, we believe it is outside the scope of this effort to explore it.

†Studies indicate that technological entrepreneurs experience greater numbers of successes, often of greater magnitude than the typical entrepreneurs. The failure rate of the technological entrepreneur is estimated to be one-quarter that of all entrepreneurs during the first five years of business. The lower failure rate is generally attributed to the fact that technological entrepreneurs have a sound educational background (either in business or in engineering); they therefore tend to plan their ventures more carefully and to engage in technology-oriented businesses which grow more rapidly and have a higher rate of return. (Roberts, 1968 and Copper, 1973)

Technical evaluation and DOE support are mandated by law, whereas the one-step, one-time approach to support and mutually agreed-upon definition of the work statement are means used to provide the mandated services.

Technical Evaluation

Clearly, NBS is conducting technical evaluations of energy-related inventions to identify and recommend the most promising for DOE support; over 17,000 inventions have been evaluated to date, and close to 200 have been recommended.

While it is not within our scope of work to review the technical aspects of the NBS effort, our review of thirty cases yielded the information that about one-third of them have achieved commercialization in the form of production and sales. The percentage achieving commercialization increases if one includes those producing samples for buyer testing. Thus *the evaluation team agrees that NBS has developed a very good means of sorting out the energy-related inventions that hold promise for being utilized,* thereby achieving the objective of improving the energy situation in the United States.

It is important to remember that the purpose of the technical evaluation is to provide DOE with information regarding recommended inventions. In this respect, we note that the NBS technical evaluation report or "black book" is used as a guide by DOE program personnel to help define the next step the inventor needs to take to move toward commercialization.

From the inventor's perspective, the technical evaluation process is too long (regardless of the time it takes) and does not teach him much, if anything, but most concede that it's "worth it" to get to the DOE grant, and some actually have used the "black book" as leverage to obtain capital.

Thus, not only is NBS fulfilling its mandate to evaluate technologies, but it is providing useful information to DOE and important benefits to the target audience.

One-step, One-time Support

Support by DOE is also mandated, and over the lifetime of the program it has been interpreted as providing one-step, one-time assistance. That means that the potential grantee is advised that he will only receive funding once, in the form of a grant which can not be renewed. Furthermore, the grant money is to be used to carry the technology development one step forward. The definition of "one step" is based on the recommendation made by NBS, information obtained from the potential grantee, and the knowledge of the DOE program officer. In reviewing the 30 cases, we found only two examples in which the "next step" as defined by the work statement may not have been appropriate (i.e., too much work was required, given the amount of the grant and the grant period). Throughout the development of a work statement, the DOE program officer bears in mind the program objective that after the termination of the grant the grantee should be in a position to obtain any support needed to continue development or commercialization.

To determine if this service and the technique used to provide it were reasonable, we made preliminary inquiries in the venture capital community to explore whether the service provided meets unmet financial needs in the private sector. We were told that capital is most difficult to obtain when the technology is simple, unsophisticated, and represents an incremental development in the technical field. When these factors are combined, many individual and small business inventors are hard pressed to generate the capital required to commercialize their invention regardless of its worth. Thus, providing development capital for these inventions seems most appropriate.

At the same time, "cutting-edge" technologies that are attractive to investors are very costly, risky investments in the early stages. In general, the investment community is hesitant to make any substantial investment until the potential returns are clear. Many government agencies are also reluctant to invest in them because of the high cost (e.g., in the cases of Engdahl, Karlson, Marks). By funding such innovations early in the R&D process, ERIP may be fulfilling an unmet need in the private sector as well as supplementing government investment efforts.

The ERIP one-step, one-time funding has helped grantees to reach a point where they can attract other support and, in some cases, to the point where the technology is commercialized. This approach to funding (i.e., minimal financing for a short period of time with no second-round financing to follow) is virtually useless for long-term research or research in "cutting-edge" areas, because of risk, cost, and the length of time required to complete development of the projects — unless the funding is bridging capital used to obtain R&D funds required to achieve commercialization in the long term. Thus, if inventions of this nature are to be recommended to DOE for support there must be sufficient ERIP personnel to develop contacts in the public and private sectors. This will help grantees to secure ongoing support from other groups contingent upon successful conclusion of the DOE grant.

Other Services

In addition to the congressionally mandated services and the policy of providing support, ERIP personnel provide more informal services and assistance, such as developing contacts with private-sector groups and organizations that can help the grantee, facilitating his contacting of other federal agencies and federally funded programs, obtaining information, and being available to work through ideas and problems. In short, the program officer in many instances is a "helpmate" for the grantee. The credibility resulting from an NBS technical evaluation and a DOE grant are important factors in continuing technical development, and they are recognized as such by the grantees.

In addition to developing their inventions, inventors would like more assistance in dealing with the bureaucratic processes — from filling out the applications to dealing with the procurement process and managing their budgets. When such assistance was available, the inventors were quite vocal in expressing their appreciation. There are some instances in which the desire of a grantee for more assistance is unquestionably justified. There is no reason a grantee should have to make a special trip to Washington or make long-distance telephone calls every day in order to secure contract funds from DOE. Moreover, while an argument

may be made that the rest of the problems (e.g., filling out forms) are all part of securing government funds, one should not lose sight of who the grantees are. The ERIP funds individuals and small businesses who may not be experienced grantsmen (most of the 30 grantees were not). These people do not have the resources or expertise to get through the process alone, and specific attention should be given to facilitating their progress.

Summary

It is clear, based on the interview data, that *the ERIP is providing the mandated services*. Furthermore, based on the fact that at least one-third of the cases reviewed are in some stage of production, it is the consensus of the evaluation team that *the one-step, one-time financial support approach to stimulating innovation is an excellent technique*.

As noted in the first part of this section, capital is most difficult to obtain just prior to venture initiation — especially for the first-time businessman with no track record who has invested a large part (if not all) of his personal assets in his invention. Over the life of the Energy-Related Inventions Program, it has provided a "small delta of money needed for the inventor to get a fair hearing in normal market channels" (Shapero 1982). It is the opinion of the evaluation team that this is a valuable and necessary service not available in the private sector, that it is within the appropriate role of the government, and that providing this service will stimulate the development and utilization of energy-related technologies.

Program Operation

The operational elements of a program are those methods and techniques used to provide services and the resources necessary for the ongoing maintenance of a program. Important operational elements in this program are:

- joint NBS/DOE operation,
- budget,

- administration,
- the ERIP as a special investor,
- size of grant awards,
- invention stage of development, and
- developing linkages with other resources.

Joint NBS/DOE Program Operation

The Congress mandated that NBS and DOE would cooperatively operate the ERIP program. Over a period of time, leadership at NBS has remained constant, while the leadership at DOE has changed frequently. Nonetheless, the two agencies have worked cooperatively to achieve the goals and objectives of the program. Furthermore, the separation of the evaluation and funding functions enhances the value of the technical evaluation, because the reputation of the National Bureau of Standards as a repository of objective scientific and technical expertise is great and, over time, it has been less influenced by political pressure. Thus, the NBS can provide great credibility by providing a positive technical evaluation. The fact that the government, via the Department of Energy, actually provides grant monies (i.e., invests in) for the development of a technology also generates credibility and visibility for the inventor and his invention.

Budget

With respect to the budget allocation for the program, from its inception it has been small in comparison to other government programs.

Based on our discussions with program personnel, it appears that the current budget is sufficient to perform the mandated activities, considering the requirement of working with individuals and small businesses and the limited level of staffing at DOE. When viewed in terms of the outcomes produced — especially considering the fact that about one-third of the cases indicate sales of product — the government is generating a great deal of private-sector activity with a very small investment.

A major portion of the ERIP budget is allocated for technical evaluations. Bearing in mind that this task is designed to select the most promising inventors and technologies and that the information contained in the "black book" provides the initial basis for determining the grant scope of work and level of funding, it is not surprising that the budget is allocated unequally. Furthermore, it is clear that the small staff at DOE would have difficulty in handling more work than they already have even if they had more funds available for inventors. Several DOE program chiefs have stated this position and articulated the need for an expanded staff to better serve the grantees. (This issue is discussed in greater detail below.)

Administration

Program administration is a particularly important element to examine in evaluating innovation-related federal programs because these are most often low-budget, misunderstood programs that are considered mavericks within the federal agency structure. It is important to look at the staffing of such programs, as well as program management. In the case of the ERIP, the evaluation team was also asked by both program chiefs (who suspected the time required might be too long) to carefully examine the length of time it took from the submission of an invention to NBS for evaluation to the completion of a grant.

Staffing. On the one hand, staffing at NBS has grown with the program and appears to be adequate to complete the evaluation tasks; management of the program at NBS has been in the hands of one person from the program's inception. On the other hand, DOE has seen many program chiefs come and go, and the staffing level has not grown with the program. Moreover, during the time this evaluation has been underway, the physical location of the office has changed at least three times — disrupting files, time schedules, and the provision of services to grantees. And experienced qualified staff have been arbitrarily transferred. All of these problems have created many difficulties in performing the tasks assigned to ERIP.

The reader is reminded that DOE program officers are responsible for negotiating a statement of work with potential grantees, monitoring grants, and providing miscellaneous services to grantees. All these tasks are very time-consuming and involve direct contact with an inexperienced grantee. Thus, it is difficult to handle a large number of cases at any time and do the job well. If the ERIP is to continue working primarily with individuals and small businesses that typically do not have the expertise or resources to deal with the federal government, the staffing level at DOE will have to be increased and stabilized.

Staffing and Services. A review of the data indicates a need to move some communication and service tasks into the field that are now performed by program officers. With the decrease in support for the program (both financial and nonfinancial) over a period of time, it has become very difficult for DOE program officers to make site visits to grantees to ensure their ability to complete the scope of work, to observe progress in completing the scope of work, or to determine what can be done to help the grantee.

Some attempts have been made to use consultants to provide specialized help, but they have not been particularly effective. The evaluation team agrees that several mechanisms to provide onsite assistance should be examined. These include:

- cooperating with existing federally funded projects focusing on innovation and technology development,
- recruiting and training individuals who own (or owned) small, technology-based business,
- working through universities and/or research institutes to provide direct assistance,
- working through larger, private-sector companies interested in innovation and new technological products, or
- a combination of the above.

The evaluation team suggests that ERIP also develop a network of contacts among researchers in the field who in turn can help identify and qualify the resources needed by grantees. This approach would permit the DOE program officer to assign the most appropriate individual to help a grantee.

Management. The relationship between DOE management and ERIP personnel has been poor at best. It appears that DOE management, like that of most other federal agencies, has difficulty integrating and supporting small business programs operating within private-sector guidelines (e.g., promptly, effectively, without a great deal of red tape). In addition, dealing with individuals and small businesses is difficult because of their inexperience with federal contracting procedures, their cash flow needs, and the additional, perceived risk with respect to performance and quality of work. Over the years program management has changed frequently, as has the organizational placement of the program. The result has been substantial disruption in the ERIP operation within the DOE as well as disruption in grantee services.

Every change in ERIP leadership requires that the new program chief learn the program tenets and procedures "from the ground up" and that he establish working relationships with his superiors and peers as well as with ERIP personnel. From the grantee's perspective, service is often disrupted in the sense that everything takes longer to get done, the program officer is unavailable more often, and it is difficult to reach anyone to talk to.

From an organization placement perspective, moving the ERIP from place to place within DOE means the program goals, objectives and procedures change to a greater or lesser extent each time ERIP is affiliated with another program, office, or branch. Furthermore, the program is perceived differently depending upon the group of programs with which it is affiliated. A special effort should be made to find a stable organizational niche for the ERIP and to "educate" management and program personnel as to the needs, constraints, and goals of both these groups and of the ERIP grantees.

As noted earlier, interviewee comments regarding the time required to complete the process appears to be unrelated to the actual time involved. One suspects that for the grantees, any time period is too long and that their responses are affected more by their experience, personality, and need than by actual time. The grantees are not alone,

however, because NBS and DOE program personnel also believe that the process takes too long. Thus, the grantees' perceptions seem to support the managers' continuing efforts to reduce the time required to move a technology through the evaluation and support processes. In particular, interviewees were dissatisfied with the time required to complete the DOE procurement process and to obtain funds from DOE disbursements. Once committed to providing support, DOE's inability to issue a contract and pay for contracted work may do more damage than good to an individual or small company.

There are two questions which we think need to be asked in addressing the time problem: (1) what changes can be made? and (2) should they be made?

Something can be done to improve the rate at which grant papers move through the procurement process at DOE. We are not sure, however, if or how the evaluation process at NBS and DOE could be speeded up. A number of suggestions for shortening the process have been made (e.g., fast-tracking certain inventors or inventions and/or altering the technical evaluation procedures). We have learned nothing about the operation of this program which provides evidence that these other approaches would be better or worse than the present system. Shortening the time for evaluation would better meet the expectations of the inventors. At the same time, for some inventions, delays may contribute to survival in the program. The intrinsic worth of an idea is often not readily apparent even to experts: rejections and reconsiderations take time. If new information emerges which alters previous judgements by the agency, then the additional time may be worth it to the inventor.

Given the foregoing ambiguities, the evaluation team suggests tabling the question of how to speed up the process until more information is obtained. Specifically, we think it appropriate to determine how other organizations (e.g., corporations, federal agencies) perform similar tasks and how long it takes for them to complete the process. Comparison with ERIP would point out which time delays are inevitable as opposed to those which can be changed.

The ERIP as a Special Investor

While all the grantees we interviewed identified specific technical problems they encountered, a brief review of the five cases in which full production was achieved reveals they submitted their technology to the government in order to obtain the capital needed to continue their work, and they identified lack of capital as their primary nontechnical problem. In these cases the government functioned as an investor providing "pre-venture" or "seed" capital; in other words, the bridging capital necessary for the owner of a technology to develop or acquire the expertise, documentation or other materials necessary to acquire the major capital needed to establish a solid, technology-based venture.

The government (i.e., ERIP) supported inventions at a point in the innovation process where they were not supported by either the venture capital community or industry.

To illustrate, the formal venture capital community is very interested in investing in companies with solid, experienced management and a track record. As one investor put it, he likes to invest in individuals who have substantial experience in top-level corporate management. The inventors supported by this program do not meet that criterion — they are more entrepreneurial than management oriented and they do not have the required management experience.

Also, many formal venture capitalists are seeking projects involving "sexy" technologies — technologies on the "leading edge" of technological development — that represent quick potential and large returns on their investment. While some of the ERIP inventions may be characterized as "leading edge," few of them would be classed as "sexy" by the venture capital industry. One investor specializing in R&D limited partnerships indicated that he had so many interesting and high potential projects submitted that he would only consider those with a high probability of going public in six or seven years; that is, ventures that would grow very quickly.

There are also reasons why industry fails to support new technologies. As one evaluator notes, industry rejects certain "innovation misfits" (e.g., bridesmaid technologies and invasionary technologies).

> A bridesmaid technology is a technology which may be attractive to a particular company but, given other investment opportunities is not attractive enough to be included in the development plan of that company. (Always a bridesmaid, never a bride.)
>
> Another innovation misfit is the invasionary technology. This is a technology that looks threatening to most firms in an established industry. They don't want it to happen. If such technology were developed it might force the industry to change the way it goes about doing things, particularly the way it produces things. Don Schon of MIT wrote a classic article about this called 'Innovation by Invasions,' and Bill Abernathy at Harvard in his book *The Productivity Dilemma* describes how ideas for new products are squelched in the interests of maintaining the high productivity that comes with manufacturing old products.
>
> When an established industry is confronted with an invasionary technology the industry either pretends the technology doesn't exist or hopes it will simply go away and die. I certainly agree that government should not sponsor what industry will develop on its own. But the government should consider sponsoring the *misfits* that industry rejects based on fear, blindness, opportunity costs, or gambler's ruin. (Myers, 1982).

Of the 30 cases reviewed, most were not likely prospects for investment before participating in the ERIP — by either industry or the venture capital community. The projects are not "sexy," in many instances they are "misfits" and many grantees often seen to lack the skills to gain support when they come to the government for assistance. Thus, in our view, the government has functioned at a point in the marketplace and under conditions where the private sector is not functioning. More importantly, in doing so the government — like any good investor — has funded projects that are most likely to succeed.

Size of Grant Awards

Through the life of the program, grants have been small in comparison to those for other research and development programs. The policy has been to provide smaller grants that would enable the grantees to complete specific, well-defined tasks, permitting an individual grantee to continue developing the technology. Our interviews indicate

that while most grantees would have liked larger grants, the outcomes indicate that the small grant has been successful in helping grantees determine if they should pursue development and commercialization and, if so, how.

The evaluation team notes that this approach is more effective in cases nearer to commercialization that for those in the early stages of the innovation process.

Invention Stage of Development

As previously pointed out, neither the type of technology nor the stage of development are selection criteria applied by the NBS or DOE in evaluating and supporting an energy-related invention. Whereas type of invention as a criterion is overridden by the energy-related criterion, the stage of development criterion is directly related to the issue of services (i.e., size of grant awarded) and is discussed below.

The 30 case studies reinforced the evaluation team's view that invention without commercialization/utilization is not in the public interest. That is, supporting an invention that has little potential for utilization is not an appropriate role for the government. Thus, those inventions that are sufficiently well developed to determine their potential utilization/marketability would be candidates for preferential treatment in the evaluation/support system. In conjunction with this conclusion, the team concluded that one-time-only support is most appropriate for better developed (i.e., closer to commercialization) technologies. Thus, the stage of development at which inventions are submitted for evaluation should be considered as a criterion for providing "fast-track" evaluations and support grants.

That is not to say that early-stage inventions which are believed important and in the public interest should not be evaluated and supported. Smaller grants provided on a one-time basis may be considered "bridge funding" for early stage technologies. However, it will be important to link inventors of such technologies with other agencies, corporations or programs which could provide long-term funding at the levels necessary

to continue development. This conclusion is based on our review of those cases in very early stages of development and those on the "cutting edge" of their technical field.

Developing Linkages with Other Resources

To improve program service and increase contact with grantees, we recommend that linkages be developed with private sector groups.

A review of the data indicates that grantees could effectively use contacts and assistance in several program areas; three, in particular, are important:

- risk capital,
- licensing/selling to large corporations, and
- new product development.

Capital is necessary for the grantee to progress toward commercialization of his invention; licensing the rights to or selling a patent are fairly straightforward, easy ways to facilitate commercialization. The new-product development literature and practitioners are a rich resource which has not yet been tapped by the ERIP.

We suggest that a series of meetings be held with active practitioners in each field to determine how the linkages can be effected so the ERIP grantees and practitioners will profit.

Summary

Based on an examination of the tangible and intangible results of the 30 cases, the program is successful in several dimensions. *It is meeting its Congressional mandates as well as its internally developed objectives.*

It is noteworthy that these results were unexpected at the beginning of this evaluation because of the short life of the program, the nature of the innovation process, and the length of time it generally requires to initiate a new venture. The number of successes in the ERIP is high, both in terms of technologies reaching the marketplace and unanticipated benefits (e.g., environmental impact, importance of technologies).

If the ERIP program elements were overlaid on a chart of the innovation process, it would clearly show that the ERIP is targeting an appropriate audience, and that the nature and extent of ERIP services provided are appropriate, given the needs of participants in the innovation process.

RECOMMENDATIONS

The recommendations are divided into two groups: program recommendations designed to improve the daily operation of the program and policy recommendations intended to improve the overall effectiveness and impact of the ERIP.

Program Recommendations

Several areas of concern were articulated by interviewees as well as interviewers and are presented in the sequence in which they would be encountered by an inventor who had submitted an invention to the ERIP:

- The NBS promotional materials should be clearer with respect to what an inventor should anticipate in terms of time and services.
- The role of second-stage evaluation should be reviewed.
- The contracting process at DOE should be facilitated to enable grantees to continue their work in a timely manner.
- Staffing at DOE should be increased to handle the flow of recommendations from NBS.
- Regional field reps should be made available to grantees to provide onsite assistance.
- Evaluation and follow-up of grantees should continue.

More specifically:

- We recommend that the publicly available ERIP documents be reviewed for clarity.
- We recommend that the role of the second-stage evaluator as an independent, expert consultant be reviewed with an eye to determining the nature and extent of his contribution to the overall technical evaluation process.
- We recommend that the DOE contracting process be reviewed and streamlined.

- We recommend that the DOE staffing level be increased by two program officers to free the program chief to administer the program and work with DOE management; this would also facilitate bringing the backlog of NBS-recommended projects up to date.

- We recommend that alternative means to provide grantees with onsite assistance be examined, tested, and evaluated.

- We recommend that the ERIP develop a network of contacts among researchers in the field who, in turn, can identify and qualify the resources needed by grantees. This approach would permit DOE program officers to assign the most appropriate individual to help a grantee.

- We recommend that program evaluation and/or monitoring be continued at least at a minimal level.

- We recommend that linkages be developed with private-sector groups to improve and broaden the spectrum of services for grantees.

Policy Recommendations

- We recommend that the ERIP funding be continued and maintained at least at the FY 1982 level.

- We recommend that emphasis be given to improving the relationships between DOE management and ERIP personnel.

- We recommend that the one-step, one-time funding policy be continued.

- We recommend that for the time being the ERIP concentrate its funding efforts on projects in the final stages of the R&D process (i.e., those closest to commercialization) where it is most difficult to obtain support — especially support in the form of financing. Earlier-stage technologies should continue to receive support, with a special effort being made to develop linkages for such grantees with other government and private-sector research programs.

APPENDIX

INTERVIEW WITH HARRY WOOD, INVENTOR

APPENDIX

INTERVIEW WITH HARRY WOOD, INVENTOR

[Wood's response to the question, "What has been your greatest difficulty with the Department of Energy?"]

Let's start from ground one. Time is number one, okay? Then, I waited and waited and waited and waited and waited and finally I just took an airplane one morning and went to Washington and was sitting at his door when they opened up the door. And I said, "Look, man, I'm going broke," — 'cause I was using my own money all this time, you know, wasn't taking any work because it was taking all my time just playing with this. And I said, "You already told me I'm going to get the grant — what's happened?" And I found out it was lost on a secretary's desk for three months. That doesn't give you a very good feeling.

So then we found it and they said, "Well, it's going to take ..." (it took nine signatures or something like that) "it's going to take a couple of months to get that through all the signatures." I said, "Where are all these people?" "Oh, they're next door, next floor." I said, "Well, give it to me," I said, "and aim me. I'll go get 'em." You know?

So I walked to one place and the secretary said, "Yes, just leave it here and I'll get him to sign it just as soon as I can get to it." And I shocked her. I said, "Honey, let me tell you: I'll buy you a bottle of whiskey, I'll buy you dinner, I'll make love to you, whatever it takes for you to walk in the next room there and ask your boss to sign this thing." She got up and did it and came back with a signature.

Then I went to the next office, and I walked through the whole damn thing that afternoon. I came back and handed it to Pat and said, "Okay, Pat, what happens to it now?" And he said, "Well, now I got to sign it and send it over to ..." (It was the place that actually typed it up and gave me the money — it was the final thing.) I said, "Well, where are they?" And he said, "Well, what else do you want?" And I said, "Well, Pat, you've got two choices: you can tell me where they are, you sign it and let me bring it there, or you can tell me to go to hell

and I'll get on a plane and go home." He said, "I can't tell you to go to hell," so he signed it, told me where it was.

I walked it over there, and I gave it to them. And I said, "Now, how long is this going to take?" And they said, "Well ..." (this guy here has his thumb broken; it's in a cast) he says, "We got to type it up." I looked at him; I said, "Are you right-handed or left-handed?" He said, "I'm right-handed." And I said, "You do the typing?" He said, "Yeah." He says, "I'll get to it; it'll take a couple of weeks, you know, to get around to it." I said, "Why is it going to take a couple weeks? It's one form; you just fill in the blanks on the typewriter." And he said, "Well, I got so many to do, and it's got to go through the typing pool, and they've got so much work." And I said, "Look, man, let me bring it back to New Orleans and I'll get a stenographer; we'll get it done." "Well, we can't do that; that's government forms." I said, "Well, then, move over and I'll sit behind your typewriter and I'll type it right now." And he said, "Well, I can't do that either." So, what it finally turned out is, I told him, "If I don't see that thing in three days, when you come into work the next day, the fourth day, I'm going to be sitting on top of the file cabinet looking at you." And I got it in three days. But that's what you just have to do, you just have to literally brow-beat them to get something done.

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