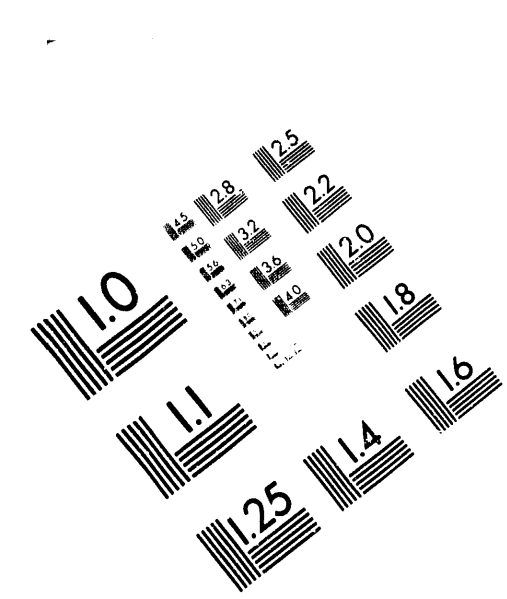

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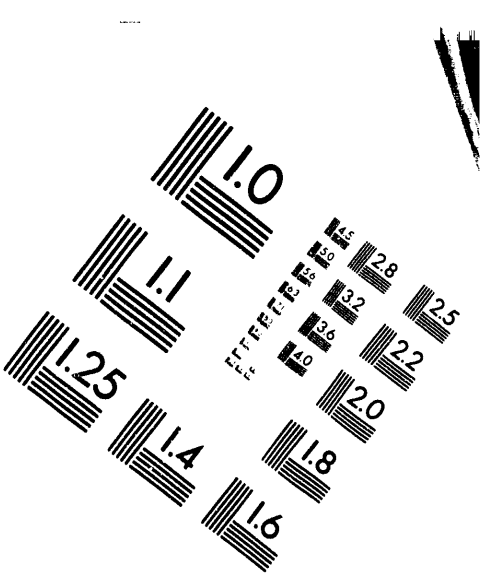

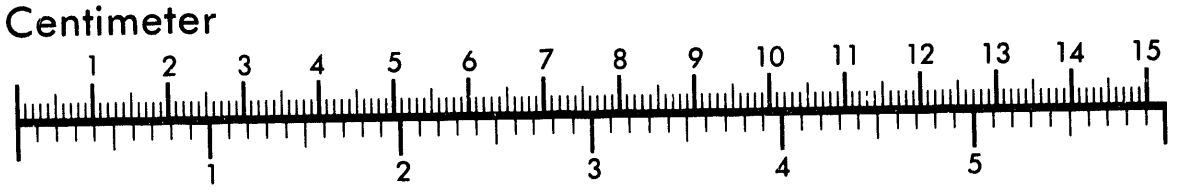

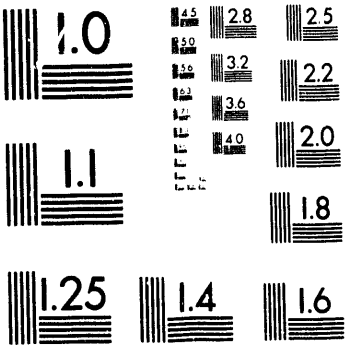

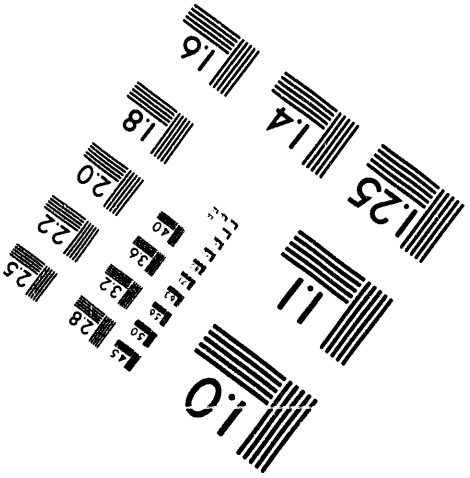

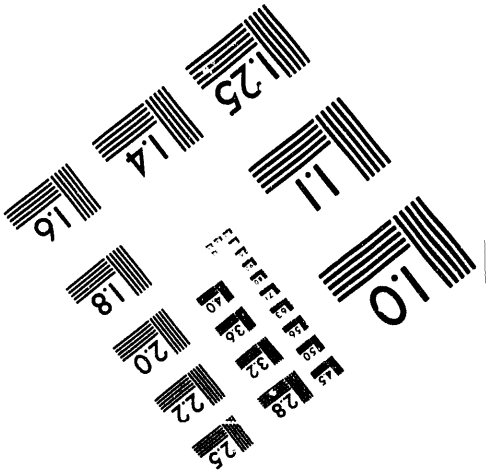

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A COMPARISON GROUP ANALYSIS OF DOE'S ENERGY-RELATED INVENTIONS PROGRAM

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EXECUTIVE SUMMARY

Appropriately designed program evaluations should be able to isolate the effects of the program from the host of other factors that influence the progress of participants. The simultaneous tracking of program participants and a matched comparison group is a common means of achieving this goal. To our knowledge, however, no previously published evaluation of a government-sponsored technology commercialization program has employed a comparison group design.

In this report, a comparison group approach has been used to evaluate the impact of participation in the U. S. Department of Energy's (DOE) Energy-Related Inventions Program. The comparison group is composed of inventors who applied to the program and were judged to be technically feasible and commercially valuable but were rejected because they appeared to offer insufficient energy benefits. These inventors (called "program referrals") were encouraged to take their inventions to other government programs for assistance in further development. Thus, we were able to identify a comparison group that had many similarities to ERIP participants, but lacked the direct support of DOE.

The population of 179 program referrals was mailed a questionnaire, and a telephone follow-up was used to increase the response rate to 44% (i.e., 79 respondents). Information on 143 ERIP participants (sampled from the population of 486) was collected by a similar combination of mail and telephone surveying, as part of a previous ERIP evaluation. Statistics on a variety of technology performance measures were then compiled and compared for the two samples.

One unanticipated difference between the samples of program referrals and ERIP participants added to the complexity of the comparison group analysis. Of the 28 program referrals who reported sales of their technologies, none had applied to the program for assistance in research and development. All had significantly developed concepts and were applying for marketing and management assistance. Of this number, 24 (or 86%) experienced some kind of sales before or during the year they applied to the ERIP program. Only four of the applicants experienced their first sales AFTER they had applied and been turned down for support by the ERIP program.

In contrast, only 29 (or 27%) of the 109 ERIP inventors with sales achieved their first sales prior to or during the year they applied to ERIP for support. As a result of this difference, when comparing sales figures, we emphasize the subsets of program referrals and ERIP participants with first sales after their ERIP application.

There are large differences between the program referrals and the ERIP participants in terms of several indicators of commercial success. Average dollar sales by ERIP participants are an order of magnitude greater than the program referral group. Further, our analysis suggests that

only a handful of program referrals who reported sales were not in production and marketing phases when rejected for participation in the ERIP program. That is, very few program referrals who did not have sales before they applied to the program were able to achieve commercial success afterwards. Further, of the four inventions that did experience initial commercial success after rejection from the program, only one was able to remain viable for more than a few years.

A variety of additional indicators of success are examined, with the following conclusions.

- The development of ERIP inventions appear to be actively pursued for a longer period of time than are the inventions of program referrals.
- A higher percentage of ERIP inventions are protected by patents (90%), compared with program referrals (72%).
- Program referrals and ERIP participants are associated with comparable levels of employment per invention, but this is primarily because of the success of two applicants. Only 6% of the program referrals were associated with employment in recent years, compared with 58% of the ERIP participants.

There are also major differences between the funding of program referrals and ERIP participants. In total, program referrals raised half as much funding, per invention, as ERIP participants. In addition, the program referrals relied mainly on personal funding in the development of their inventions. This is in contrast to the ERIP participants who received much of their funding from non-personal sources such as corporate profits, banks, stock offerings, and government programs in addition to the ERIP. Further, the ERIP participants were able to raise substantially more money than their counterparts. This undoubtedly has a significant impact on the success of this former group, and probably reflects, to some extent, the assistance provided by ERIP. Even in the interviews with successful program referrals (Section 4), we see that the biggest problem reported by these four cases is a lack of sufficient funding for product improvements, business planning, and marketing.

Thus, it is likely that one of the benefits that ERIP supplies to its participants is not only funding in and of itself, but the knowledge and connections to secure more funds. Many ERIP participants are able to acquire large-scale funding to help them better prepare and market their technologies. It appears that ERIP support consistently opens doors to funding and ultimately to success in the market that is missed by most other inventors, even ones that are referred to traditional sources of support such as the comparison group of program referrals.

Table A.1 summarizes the results of the comparison group analysis. It demonstrates the superior performance of the ERIP-supported technologies, relative to that of the program referrals, along a wide range of dimensions.

Table A.1 Relative Performance of ERIP Participants and Program Referrals

Performance Indicator	ERIP Participants	Program Referrals
Percent entering the market, after application to NIST	18%	7%
Average cumulative sales, per technology	$3,370,000	$230,000
Percent with patent protection	90%	72%
Cumulative funds raised, per technology	$693,000	$335,000
Percent that raised non-personal funds	80%	25%
Percent supporting employees in 1991-92	58%	6%
Percent actively pursued in 1991-92	61%	34%

In conclusion, the comparison group analysis provides strong evidence that the ERIP technologies achieved their considerable commercial success, at least in part because of the support provided by the Energy-Related Inventions Program.

1. INTRODUCTION

1.1 BACKGROUND

Over the past decade, Oak Ridge National Laboratory (ORNL) has conducted four evaluations of the economic impacts of the U. S. Department of Energy's Energy-Related Inventions Program (ERIP). In particular, ORNL has performed impact evaluations of the progress of ERIP inventors in 1984, 1986, 1988, and 1990. Each of these evaluations has involved surveying approximately 150 to 200 ERIP-supported inventors with the ultimate objectives of assessing the effectiveness of ERIP assistance and documenting the progress of ERIP technologies.

None of these evaluations has involved the use of a comparison group. Instead, statistics on the innovation process have been compiled from a review of the literature. These statistics have been used as benchmarks for assessing the progress of ERIP technologies. Based on rates of market entry, time to market, and other indicators of commercial progress, ERIP technologies have generally outperformed samples of inventions studied by others (see Brown and Wilson for an overview of these comparisons).

Unfortunately, the types of technologies and inventors documented by previous studies do not match those supported by the Energy-Related Inventions Program. ERIP-supported technologies are diverse in both application and technical complexity. They span the spectrum from industrial process applications to energy-efficient improvements for automobiles and buildings; and they include complex oil platform and drilling equipment as well as simple, do-it-yourself solar technologies for homeowners. ERIP-supported inventors, on the other hand, are a particular subset of inventors: the Program targets inventors who are either independently employed or are employees of a small business. The literature does not provide statistics on the commercial progress of a comparable population of technologies and inventors.

The purpose of this task is to identify and characterize a matched comparison group of inventors whose progress can be compared with the progress of ERIP inventors. With this comparison group, we will be able to assess more accurately the impact of the ERIP support and thereby strengthen the program's impact evaluations.

1.2 ORGANIZATION OF THE REPORT

This report is divided into six sections. As background to understanding the comparison group design and the results provided in this report, section 1.3 provides an overview of the Energy-Related Inventions Program. Section 2 describes the research design used to define and characterize a suitable comparison group. Section 3 presents comparative statistics describing both

the comparison group and the ERIP technologies. Section 4 is more qualitative in nature; it describes four technologies in the comparison group that were commercially successful, focusing on how they succeeded in the absence of DOE/ERIP support. The report ends with a summary of its findings (section 5) and a list of references (section 6).

1.3 OVERVIEW OF THE PROGRAM

Established in 1974 under the Federal Nonnuclear Energy Research and Development Act (P.L. 93-577), the Energy-Related Inventions Program is directed to assist the development of nonnuclear energy-related inventions with outstanding potential for saving or producing energy, "particularly those submitted by individual inventors and small companies." The goal is to help inventors with promising technologies develop their inventions to a stage that would attract the investment necessary for private sector commercialization. Many of these technologies face significant market and industry barriers that reduce their ability to attract early funding and intensify the difficulties of product development. In addition, individual and small business inventors often lack the business experience needed to surmount these hurdles.

Anyone can submit an invention at any stage of development to the program for a free, confidential evaluation. The legislation provides for the National Institute of Standards and Technology (NIST), previously called the National Bureau of Standards (NBS), to evaluate the invention's technical feasibility and commercial potential. The most promising inventions are recommended to DOE for consideration of support.

DOE grants are provided to most of these recommendees. These funds are used for technical research, prototype development, testing, and a variety of other activities that help move the technologies at least one step closer to the market. In addition, ERIP conducts Commercialization Planning Workshops for inventors in the program. To find inventors and encourage innovation, ERIP holds several National Innovation Workshops each year in different regions of the country, jointly sponsored by local businesses, inventor organizations, and universities.

Since 1975 (when the program began), more than 25,000 inventions have been submitted to NIST for evaluation, and more than 500 of these have been recommended to DOE for support. Approximately 80% of these recommendees have received DOE grants averaging $70,000.

2. RESEARCH DESIGN

2.1 DEFINITION OF THE COMPARISON GROUP

To be effective for assessing the impacts of the Energy-Related Inventions Program, a comparison group should include technologies and inventors that are similar to ERIP participants. The comparison group also should be feasible and not too costly to characterize. Five potential comparison groups were considered:

- technologies developed by members of inventor societies;
- technologies developed by participants in innovation or incubator centers;
- inventions of independent inventors with unassigned patents in selected energy areas;
- near-participants - these are ERIP applicants that successfully passed through all but the final phase of the NIST evaluation; and
- program referrals - these are ERIP applicants that were found by NIST to be technically sound and commercially competitive, but appeared to offer insufficient energy benefits and therefore were referred to other programs for possible support.

Each of these potential comparison groups offers particular strengths and weaknesses. These strengths and weaknesses are discussed below, in order to justify our selection of the "program referrals" option. Evaluations of innovation programs involving different types of inventors, technologies, or program goals might find that a different comparison group is more appropriate.

Inventor Societies. Over the past several decades, hundreds of inventor societies have been created to serve the needs of U. S. inventors. These societies tend to be broad in scope, with no particular technology or product thrust, and no limitations in terms of the inventor's current employment. The technologies of interest to members, however, do tend to be more "low tech" than ERIP inventions.

The latest impact evaluation of the Energy-Related Inventions Program (Brown, Wilson, and Franchuk, 1991) collected information on the membership of ERIP inventors in these societies, as a basis for assessing inventor societies as a comparison group option.[1] Only 12% of

[1] This survey of ERIP participants involved the collection of data from two samples of ERIP participants. The first sample of 107 inventions ("promising sample") was selected to maximize the inclusion of inventions that had achieved sales by 1990. The second sample was randomly drawn from the remaining population. This "random sample" allowed us to analyze the full range of inventions -- from least to most successful. Because of this stratified sampling technique, weights were established to provide a more accurate description of the population of ERIP inventors. The weight for inventors in the promising sample was defined as 107 divided by

the ERIP inventors surveyed indicated that they were members of inventor organizations or societies.[2] This limited overlap reduces the validity of inventor societies as a basis for assessing the relative progress of ERIP inventors.

Innovation and Incubator Centers. Innovation or incubator centers are companies or not-for-profit organizations that help small businesses get started. They typically provide office space and equipment as well as entrepreneurial advice in return for an equity position in the new enterprise.

It appears that few ERIP inventors have participated in innovation or incubator centers. As a rule, ERIP inventors have avoided assistance of any kind that diminishes their control over the destiny of their inventions. This is corroborated by their minimal reliance on venture capital companies for financial support (Brown, Wilson, and Franchuk, 1991). Thus, inventors that obtain assistance from innovation or incubator centers would appear to be distinct from the typical ERIP inventor, reducing the validity of this population to provide a comparison group for evaluating ERIP.

Patent Holders. Patent holders offer an alternative but not necessarily a better comparison group option. Based on the last survey of ERIP inventors, it is estimated that in 1990, 90% of ERIP-supported technologies were patented.[3] Thus, ERIP inventors overlap more with the population of patent holders than with the first two comparison group populations (i.e., members of inventor societies and participants in innovation or incubator centers). However, at the time of application to the Program, ERIP technologies have a much lower (although unknown) rate of patent protection. Indeed, patenting is encouraged by the Program and could even be used as a measure of the Program's success. Thus, many of the technologies in a comparison group derived from patent holders would be one step closer to the market than many ERIP technologies, leading to a biased comparison.

One advantage of using patent holders as a comparison group is that their technologies could easily be screened on technical grounds to match the technologies being developed by ERIP inventors. This could probably be accomplished without too much difficulty or cost. However, it would be quite costly to assess patent-holder technologies to match the potential commercial viability of ERIP technologies, which is a key criterion in ERIP's evaluation process. Thus, the

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the number of respondents from the promising sample. The weight for inventors in the random sample was defined as (486-107) divided by the number of respondents from the random sample. In some cases data are available for all 486 ERIP inventors (e.g., year of application to NIST). In these instances, no weighting is required.

2 The random and promising samples of ERIP inventors have nearly identical rates of participation in inventor societies: 12% for the former and 11% for the latter.

3 The percentages of ERIP-supported technologies that were patented in 1991 are identical for the random and promising samples.

potential for commercial success might be considerably lower for this group than for ERIP participants. In addition, the fact that some patent holders do not all apply for ERIP funds suggests another possible bias.

Near-Participants. Near-participants are applicants who are judged to be almost as promising as the applicants who ultimately receive program support. In the case of ERIP, they are part of the 5% of applicants who pass the first two review steps:

(1) the disclosure review and analysis; and

(2) the first-stage evaluation consisting of a series of independent and successive reviews by technical experts inside and outside the NIST.

Near-participants fail the second-stage evaluation, which involves in-depth assessments by one or more external evaluators. Having reached the 95th percentile of the review process (at the end of the first-stage evaluation), but falling short of the 98th percentile (which results in a recommendation of support by NIST to DOE), it can be argued that there is no difference between the technical merits and market potential of near-participants and ERIP inventors. It has been shown that "rater error" (that is, inconsistencies between the judgments of alternative raters) in similar types of evaluations (e.g., of job applicants and graduate school candidates) exceeds 5% (Bozeman, 1991 and Humphries, 1991). Thus, the similarity between ERIP participants and near-participants is an attractive feature of this comparison group option.

Nevertheless, this comparison group option has two drawbacks. The first drawback is that participation in the NIST screening process may influence the progress of near-participants.[4] There may be a positive impact resulting from the technical and market knowledge provided by the reviewers. The interaction of ERIP applicants with NIST reviewers at each step in the screening process is likely to improve the probability of commercial success for all technologies considered at that step. This process, termed here as the "interaction effect," results from the technical and market expertise provided by NIST reviewers to inventors and from program-induced networking with individuals and firms that may ultimately play a direct or indirect role in the technology's commercialization. This interaction effect is likely to increase with each stage of the NIST evaluation, as the evaluation becomes more thorough. In contrast, the review process may reduce the probability of commercial success for technologies that are rejected. Referred to here as "tainting," this effect results from the negative signal sent by NIST to the inventor and indirectly to potential funders of further technology development. This effect is likely to decrease with each stage of the NIST evaluation, as inventions passing through successive stages can claim some

[4] The impact of the NIST review process on the applicants and their technologies (both those that ultimately receive ERIP support and those that do not) is a fundamental question that warrants consideration.

increasing degree of public validation. Failure to pass the final, second-stage evaluation does taint the near-participants and not ERIP participants, but the differential is expected to be small.

The second drawback is related to the costs of using near-participants as a comparison group. In the case of ERIP, near-participants are typically very vocal in correspondence, objecting to NIST rejections and requesting reconsideration and reevaluation. More than 40% of this group contact NIST to appeal its decision, and a large proportion of these inventors continue to protest and object to NIST's decisions over a period of several years (Lewett, 1991). Contacting near-participants would significantly increase NIST's correspondence and reevaluation workload as "closed" cases are reopened. This drawback was the fatal flaw of the near-participant approach.[5]

Program Referrals. Among ERIP's applicants is a subset of technologies that are found by NIST to be technically feasible and commercially competitive, but appear not to offer sufficient energy benefits for program participation. They are labeled "program referrals" because NIST refers them to other programs for support, such as the Small Business Administration's Small Business Development Centers located across the U.S. These program referrals have certain advantages as a comparison group.

One major advantage of using "program referrals" as a comparison group is that overall its technologies and inventors appear to be well matched to the population of ERIP participants. This is because program referrals have been judged by NIST to be technically sound and commercially valuable, important criteria for ERIP participation. In addition, the inventors are either independent or employed by small businesses, who knew about, and were sufficiently motivated to apply to the Program for support. This is in contrast to the first three possible comparison groups where this information and motivation were much less certain.

It should also be noted that these individuals differ from those in the "near-participants" category. The program referrals, while rejected for DOE support, were informed that it was not on the basis of technological feasibility or commercial viability, but because the potential energy benefits were deemed to be insufficient. They received positive letters explaining that while they had significant inventions, they fell short of the rigorous energy-related requirements of the program. They were encouraged to pursue their work through other governmental sources of support.

While this may seem a small distinction, it has considerable impact. First, by having the positive tone and supportive referral it should not have as strong a negative effect as a rejection based on technical or market limitations. Second, rejection based on insufficient energy benefits

[5] See Appendix A for a more detailed discussion of the steps in NIST's ERIP evaluation and the effects that "interaction" and "tainting" may have on the commercial success of an invention.

does not generate the administrative costs associated with appeals that were seen as a "fatal flaw" of the near-participant option.

There are three possible disadvantages of using "program referrals" as a comparison group.

(1) Only 25% of ERIP's program referrals received a phase two evaluation. Thus, their technical and commercial feasibility are less certain than those of ERIP participants.

(2) A broadly based portfolio of energy-related technologies may encounter distinct market and technical barriers or opportunities that are not experienced by a broadly based portfolio of non-energy related technologies.[6]

(3) The fact that program referrals offer insufficient energy benefits suggests that their technical and market characteristics might differ from those of ERIP participants.

However, it is believed that these factors do not seriously undermine the advantages of using this category of applicants as the comparison group. Thus, we elected to use the population of program referrals as a comparison group.

Specifically, the comparison group consists of those 179 program referrals who applied to NIST prior to October 1989. This allows the group at least three years to have attained some commercial progress. The same cut-off date was used to define the population of ERIP participants studied in the latest economic impact evaluation (Brown, Wilson, and Franchuk, 1991).

2.2 DATA COLLECTION AND ANALYSIS

Development of a Mail Survey. A cover letter and 4-page mail survey was developed for this study (see Appendix B). The survey form was designed to collect the same performance indicators that were measured in the latest ERIP impact evaluation, which collected information about progress through 1990 and status of the invention in 1991 (see Brown, Wilson and Franchuk, 1991). One notable difference is that the survey of program referrals solicited data about progress through 1991 and status in 1992 to maximize the currency of the information. Thus, the program referrals had the advantage of one additional year in which to make progress. This bias is in a conservative direction - making it more difficult for the progress of ERIP participants to exceed that of program referrals.[7]

The survey of program referrals collected information on:

(1) the current activity status of the invention (e.g., active vs. suspended),
(2) its current stage of development,

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[6] One possibility, for instance, is that the considerable uncertainty surrounding energy prices introduces a unique barrier to the market penetration of energy-related inventions that other technologies do not encounter.

[7] When the next ERIP impact evaluation is conducted, it will provide concurrent data to perfectly match the 1991 time frame of the comparison group.

(3) the number of patents associated with the invention,
(4) year of first sales,
(5) cumulative sales,
(6) cumulative funds raised to develop the invention, and
(7) number of full-time equivalent (FTE) employees working directly or indirectly on the technology in 1991.

Additional information on the program referrals was available from NIST's databases, including the year of application to NIST and the stage of review at which the rejection occurred.

All of the program referrals were mailed the questionnaire in June 1992. Where the contact and inventor were different individuals, the inventor was mailed a questionnaire if the contact did not respond, to maximize the response rate.

Follow-up Survey of Nonrespondents. During August 1992, nonrespondents were contacted by telephone and asked to complete the survey either over the phone or by mail. The purpose of this step was to maximize the response rate. As a result of this two-pronged approach, the response rate was increased to 44%. Surveys were completed for 79 of the population of 179 program referrals: 45 of the respondents completed a survey by mail and 24 by telephone.

Analysis of Survey Results. Frequency distributions and mean values were tabulated for each of the performance measures, and comparable statistics were derived from the database of information on ERIP participants. Statistical tests are not used to compare the pairs of statistics because of the small sample sizes.

3. COMPARATIVE STATISTICS

3.1 INTRODUCTION

Of the 79 program referrals who responded to our survey, 28 reported sales of their invention. Because this represents a substantial percentage (35%) of the respondents, it was deemed important to more closely investigate each of these 28 program referrals. The NIST files and evaluation reports on these 28 applicants were examined. In addition, we studied the NIST files and evaluation reports for a random sample of seven of the 51 program referrals who indicated in our survey that they had not experienced sales. This step was taken to identify any systematic differences between the respondents who had experienced sales and those who had not.

Of the 28 program referrals that reported sales of their technology, none had applied to the program for assistance in research and development. All had mature concepts and were applying for marketing and management assistance. Of this number 22 experienced some sales before or during the year they applied to the ERIP program. Only four of the applicants experienced their first sales AFTER they applied to the ERIP program. These four participants were surveyed a second time, by telephone, to obtain an in-depth accounting of the experience they had in commercializing their technologies. These details are discussed in Chapter 4.

Each of the seven randomly sampled program referrals that had not experienced sales at the time of our survey were in early stages of concept and technology development when they applied to ERIP. Some had patents or patents pending, but none were at or near the production and marketing stage. All were applying for R&D support. Thus, we are reasonably confident that those program referrals who experienced some sales either before or after applying to the Program were, on the whole, further along the development path.

3.2 YEAR OF APPLICATION TO ERIP

Turning our attention to a more detailed examination of the results, Table 3.1 and Fig. 3.1 indicate that program referrals and ERIP participants are well matched in terms of project age. In particular, program referrals and ERIP participants applied to ERIP over approximately the same time frame between 1975 and 1988. Neither of the groups applied to the Program in consistently earlier years than the other. This similarity is important, since many years may be required to take an invention from conception to market, and an older cohort of inventions would have had longer to achieve commercial success. This gives us more confidence in the appropriateness of the sample of program referrals as a comparison group for ERIP participants.

Table 3.1 Year of Application to ERIP: Program Referrals and ERIP Participants

Year Applied to Program	Population of Program Referrals N=179	Sample of Program Referrals N=79	Program Referrals With Sales N=28	Population of ERIP Participants N=486	ERIP Participants with Sales N=109
1975	—	—	—	35	4
1976	2	—	—	41	10
1977	5	1	—	43	16
1978	12	4	2	29	6
1979	14	4	1	35	13
1980	28	12	3	36	9
1981	20	7	3	24	5
1982	15	9	3	15	4
1983	34	23	9	29	7
1984	24	9	3	53	11
1985	19	7	3	52	11
1986	2	1	1	37	6
1987	1	1	—	33	5
1988	3	1	—	20	2

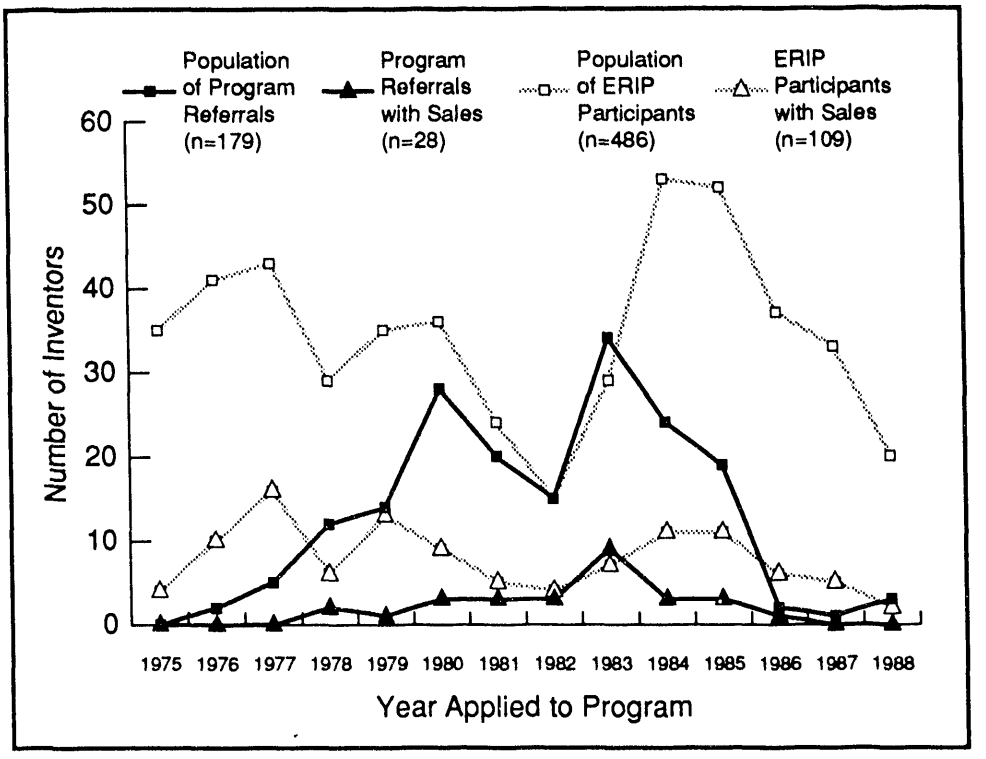

Fig. 3.1 Year of Application to ERIP: Program Referrals and ERIP Participants

3.3 ACTIVITY STATUS

Fig. 3.2 and Table 3.2 suggest that the development of ERIP inventions is actively pursued for a longer period of time than are the inventions of program referrals. In particular, 61% of the ERIP inventions were actively being pursued in 1991, while only 34% of the program referrals were actively being pursued when they were surveyed in 1992. Only 13% of the ERIP inventions were suspended indefinitely, and based on the 1991 survey, no ERIP technologies had failed or been subjected to Chapter 11/reorganization or chapter 7/bankruptcy.[8] In contrast, 22% of the program referrals were suspended indefinitely and an additional 8% had failed or their businesses were bankrupt. Some, but certainly not all of the differences may be attributable to the fact that ERIP participants are in earlier stages of development, compared to program referrals, when they apply to the Program.

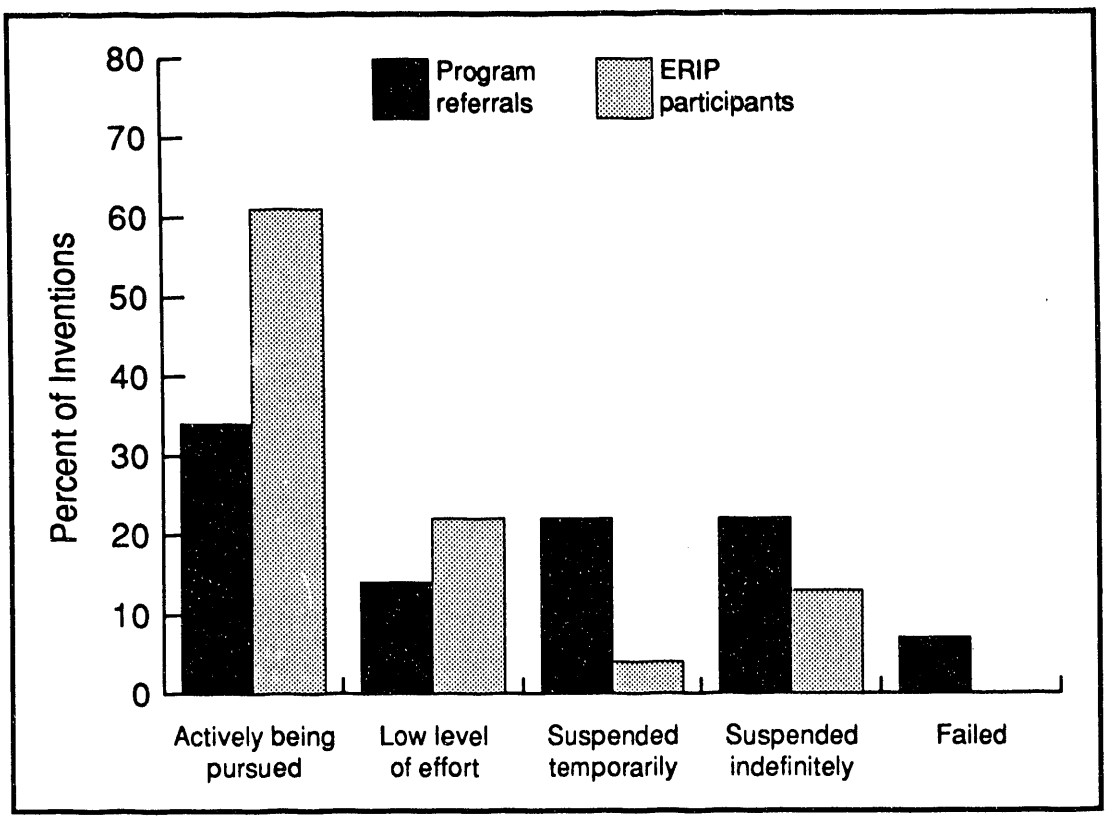

Fig. 3.2 Status of Inventions: Program Referrals and ERIP Participants

[8] Other sources of information on the progress of ERIP participants have identified at least one participant that has gone bankrupt.

Table 3.2 Status of Inventions: Program Referrals and ERIP Participants

Program Referrals (1992):		
Activity Status	**Number of Inventions (N=73)**	**Percent of Inventions**
Actively being pursued	25	34
Low level of effort	10	14
Suspended temporarily	16	22
Suspended indefinitely	16	22
Failed	5	7
Chapter 11/Reorganization	—	—
Chapter 7/Bankrupt	1	1

ERIP Participants (1991):				
			Weighted Total[a] (N=486)	
Activity Status	**Random Sample (N=44)**	**Promising Sample (N=88)**	**Number of Inventions**	**Percent of Inventions**
Actively being pursued	25	68	299	61
Low level of effort	10	15	105	22
Suspended temporarily	2	1	18	4
Suspended indefinitely	7	4	65	13
Failed	—	—	—	—
Chapter 11/Reorganization	—	—	—	—
Chapter 7/Bankrupt	—	—	—	—

[a] To calculate the weighted total, the random sample was multiplied by 379/44 and the promising sample was multiplied by 109/88.

3.4 NUMBER OF U.S. PATENTS

Patenting activity is examined here as an indicator of technical and commercial performance. Patent protection generally enhances the value of a technology; investors are more willing to provide developmental financing if the technology is protected. The existence of multiple patents suggests that the technology is highly robust and that it is a "discontinuous" innovation, rather than a continuous or incremental one. Since patent disclosures and applications require the commitment of resources, multiple patents also indicate access to some level of financial support.

Table 3.3 indicates that only 72% of the program referrals had one or more patents compared with 90% for the ERIP participants. In addition to this higher rate of patent protection, more U.S. patents have resulted from the development of ERIP technologies than from the development of the inventions of program referrals. On average, each program referral resulted in 1.4 U.S. patents, while the average ERIP invention generated 8.7 patents. The average number of patents held by inventors who had at least one patent was 2.4 for the program referrals and 12.2

Table 3.3 U.S. Patents: Program Referrals and ERIP Participants

Program Referrals (through 1991):		
	Total Number[a] (N=79)	Weighted Total (N=179)
U.S. Patents	109	247
Average per Invention	1.4	1.4

[a] 57 inventions are associated with one or more patents (i.e., 72%).

ERIP Participants (through 1990):			
	Random Sample[a] (N=50)	Promising Sample[b] (N=93)	Weighted Total[c] (N=486)
U.S. Patents	405	1,022	4,266
Average per Invention	8.1	11.0	8.7

[a] 45 inventions are associated with one or more patents (i.e., 90%).
[b] 84 inventions are associated with one or more patents (i.e., 90%).
[c] To calculate the weighted total, the random sample was multiplied by 379/50 and the promising sample was multiplied by 109/93.

for the ERIP participants — that is, the ERIP participants with patents held five times the patents as their program referral counterparts. To the extent that patenting is an indication of technical and commercial success, these statistics suggest that the ERIP technologies have been considerably more successful.

3.5 SALES

We now focus our attention on those technologies that experienced sales. Of the 28 program referrals who reported sales by the end of 1991, all had mature concepts and were applying for marketing and management assistance. As noted earlier, fully 24 (or 96%) of the 28 with sales experienced their first sales before or during the year they applied to NIST for support.[9] If we exclude these from the sample of program referrals, then we can conclude that of the 55 program referrals that had not experienced sales by the time of application to ERIP, 7% had achieved sales by 1991 [i.e., (4/55)*100].

By the end of 1990, 109 (or 22%) of the 486 ERIP participants were known to have achieved sales.[10] In contrast to the sample of program referrals, only 29 (or 26%) of these ERIP technologies with sales had entered the market before or during their year of application of the Program.[11] If we remove these from the population of ERIP participants, then we can conclude that of the 457 ERIP participants that had not experienced sales by the time of application to ERIP, 18% had achieved sales by 1990 [i.e., (80/457)*100].

Perhaps more distinctive are the differences in cumulative sales achieved by program referrals vs. ERIP participants. The total cumulative sales of those program referrals that entered the market after application averages only $229,500, while the comparable statistic for ERIP participants is $3,336,000.

The distribution of cumulative sales across technologies is positively skewed for both ERIP participants and program referrals. Most technologies are commercially unsuccessful, while a few technologies are highly profitable and achieve significant sales. This skewness makes mean values highly sensitive to the results of the small fraction of inventors who are highly successful. For instance, three ERIP inventors account for 42.5% of the sales achieved by the 80 inventors that did not have sales before applying to the Program. The average cumulative sales per inventor are

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[9] The more developed a technology, the more accurately its energy benefits can be appraised. This may explain, in part, the high percentage of program referrals (i.e., applicants rejected because of their insufficient potential for offering energy benefits) with sales at the time of their application to ERIP.

[10] Three of these ERIP inventions with sales were part of the 1-in-5 random sample surveyed in 1991. Using a weighting scheme to extrapolate to the population of 486 ERIP inventions, the estimated number of inventions with sales is 121, or 25% of the population (Brown, Wilson, and Franchuk, 1991).

[11] DOE tries not to fund technologies that do not require grant monies to succeed as commercial products. Many applicants that have experienced sales prior to applying to ERIP are probably of this type, thereby reducing the proportion of pre-ERIP successes.

$2,011,000 for the 77 remaining inventors in this group. The distribution of sales for the program referrals is even more positively skewed: one inventor accounts for 99% of all the sales. The average cumulative sales per inventor is only $4,000 for the three remaining inventors in the comparison group. Section 4 contains a more in depth discussion of these four technologies.

Table 3.4 Sales of Program Referrals and ERIP Participants

Program Referrals (through 1991):	Inventions with First Sales Prior to ERIP Application N=17	Inventions with First Sales During Year of ERIP Application N=7	Inventions with First Sales After ERIP Application N=4
Percent of Inventions with Sales	61%	25%	14%
Total Cumulative Sales	$43,078,000[a]	$724,500	$918,000[b]
Percent of Total Cumulative Sales	96%	2%	2%
Average Sales Per Invention With Sales	$2,534,000	$103,500	$229,500

[a] One of these applicants experienced total sales of $30 million.
[b] One of these 4 applicants experienced total sales of $905,000.

ERIP Participants (through 1990):	Inventions with First Sales Prior to ERIP Application N=20	Inventions with First Sales During Year of ERIP Application N=9	Inventions with First Sales After ERIP Application N=80
Percent of Inventions with Sales	18%	8%	74%
Total Cumulative Sales	$226,347,000[a]	$4,242,000	$269,300,000
Percent of Total Cumulative Sales	45%	1%	54%
Average Sales Per Invention With Sales	$11,317,000	$471,000	$3,366,000

[a] One of these ERIP participants experienced total sales of $112 million, and another had sales of $47 million.
[b] One of these ERIP participants experienced total sales of $50 million.

3.6 EMPLOYMENT

Program referrals and ERIP participants generated comparable levels of employment per invention (Table 3.5). Program referrals perform well in this regard primarily because of the success of two applicants: altogether, these two technologies account for 97% of the total employment shown in Table 3.5, and both of these technologies achieved substantial sales prior to

Table 3.5 Employment Associated with Program Referrals and ERIP Participants

Program Referrals (1991):		
	Number of FTE Employees[a] (N=79)	Weighted Total (N=179)
Total FTE Employment	168	381
Average FTE per Invention	2.1	2.1
Number of Inventions Associated with Employment in 1991	5	11
Number of Inventions Associated with Employment in 1991	6%	6%

[a] One invention supported 100 FTE's in 1991. Another supported 250 part-time employees (working approximately quarter-time), totaling 62.5 FTE's. Almost all (163) of the 168 employees associated with the program referrals in 1991 were working on only two technologies.

ERIP Participants (through 1990):			
	Number of FTE Employees		
	Random Sample[a] (N=50)	Promising Sample[b] (N=93)	Weighted Total[c] (N=486)
Total FTE Employment	39.5	718.5	1,140
Average FTE per Invention	1.5	9.6	2.3
Number of Inventions Associated with Employment in 1991	26	75	283
Number of Inventions Associated with Employment in 1991	52%	81%	58%

[a] The randomly sampled invention with the greatest employment had only 12 FTE's in 1990.

[b] The promising invention with the greatest employment had 155.5 FTE's in 1990; the second and third highest had 95 and 65 FTE's, respectively.

[c] To calculate the weighted totals, the random sample was multiplied by 379/50 and the promising sample was multiplied by 107/93.

applying for ERIP support. In contrast, the bulk of the employment attributable to ERIP technologies was achieved by technologies that entered the market after receiving ERIP support.

3.7 FUNDS RAISED

Table 3.6 describes the funds raised by program referrals and ERIP participants to support the development of their technologies. While each group had a similar percentage of projects that received funding (55 out of 79 or 70% for program referrals and 409 out of 486 or 84% for ERIP participants), there is a noticeable difference in the level of this funding. In fact, ERIP participants with funding raised more than twice as much money, per invention, as program referrals. This suggests that one possible key to the success of the ERIP participants may be their ability to raise necessary funding at sufficient levels, an ability which may have been enhanced by participation in ERIP.

Table 3.6 Funds Raised by Program Referrals and ERIP Participants

Program Referrals (1991):	
	Funds Raised[a] (N=79)
Total Funds Raised	$18,420,000
Average Funds per Invention	$334,909
Number of Inventors that Raised Funds	55

[a] One inventor reported personal funding of $4,500,000 and another reported personal funding of $7,000,000.

ERIP Participants (through 1990):			
	Funds Raised		
	Random Sample[a] (N=50)	**Promising Sample[b] (N=93)**	**Weighted Total[c] (N=486)**
Total Funds Raised	$18,434,000	$127,902,000	$336,603,000
Average Funds per Invention	$450,000	$1,523,000	$693,000
Number of Inventors that Raised Funds	41	84	409

[a] The randomly sampled inventor with the most funding had raised $2.9 million through 1990.

[b] The three promising inventors with the most funding had raised $13 million, $9 million, and $5 million through 1990.

[c] To calculate the weighted total, the random sample was multiplied by 379/50 and the promising sample was multiplied by 109/93.

Table 3.7 looks more closely at the funds raised by both samples, based on when the technologies first experienced sales. In particular, the table breaks down sales by whether they first occurred before, during, or after the year of application. Funding levels are examined in terms of the total amount raised in each category, the percent of total funding, the average funding per invention, and the number of inventions receiving non-personal funds.

Table 3.7 Funds Raised by Program Referrals and ERIP Participants: Breakdown by Timing of First Sales

Program Referrals (through 1991):	Inventions with First Sales Prior to ERIP Application N=17	Inventions with First Sales During Year of ERIP Application N=7	Inventions with First Sales After ERIP Application N=4
Total Funds Raised	$1,981,000	$296,000	$4,742,000[b]
Percent of Total Funds	28%	4%	68%
Average Funds per Invention	$116,529	$42,286	$1,185,500
Number of Inventions with Non-personal funds[a]	6 (35%)	2 (29%)	1 (25%)

[a] Non-personal funds include: corporate funds, commercial funds such as venture capital, private stock offerings, loans from lending institutions, and support from government agencies and programs other than the ERIP.
[b] One of these reported $4.5 million in funding (all personal).

ERIP Participants (through 1990):	Inventions with First Sales Prior to ERIP Application N=20[a]	Inventions with First Sales During Year of ERIP Application N=9	Inventions with First Sales After ERIP Application N=80[a]
Total Funds Raised	$19,003,000	$6,482,000	$79,745,000
Percent of Total Funds	18%	6%	76%
Average Funds per Invention	$950,000	$720,000	$997,000
Number of Inventions with Non-personal funds	14 (70%)	8 (88%)	70 (80%)

[a] 5 of 20 reported no funding.
[b] 2 of 80 reported no funding.

At first glance we see that both groups have the majority of funding accruing to the inventions with first sales after the year they applied to the program. Further, it appears that the

program referrals in this group have raised marginally more money per invention in that group. However, as is noted in footnote b, one program referral in this category accounts for most of this funding. If we remove him from this sample, we see that the average funding per invention between the two groups is different by an order of magnitude in favor of the ERIP participants: $80,600 for each program referral and $997,000 for each ERIP participant.

It should also be noted that only 25% of the program referrals who obtained funding after their ERIP application, had non-personal backing. This compares with 76% of the same subset of ERIP participants who received non-personal funding. This suggests that the program referrals are having to "go it on their own" when raising funds for their invention. The ERIP participants seem much better connected to investment monies from sources other than their personal bank accounts and the financing of friends and relatives. Again, this may be as a result of ERIP training, networking, and the enhanced credibility associated with a favorable NIST review.

This observation makes the program referrals who experienced sales after the year they applied even more interesting. They seem to have prospered for a time in a situation where the odds were stacked against them. For this reason, we chose to study them in greater detail. Section 4 reports the results of a follow-up study of this group to try to understand what made them able to succeed, while the sample of 51 other program referrals in their cohort failed.

4. DISCUSSION OF PROGRAM REFERRALS WHO EXPERIENCE SALES *AFTER* REJECTION

In-depth telephone interviews were undertaken with the four respondents who reported first sales of their invention AFTER they had applied to ERIP and been rejected for support. The follow-up survey was designed to better understand the details of each inventor's "success," and to attempt to identify any special strategies he had employed (all four were male). The survey began by asking about the first year that the inventor had experienced a sale of his invention. This acted as a control to insure that information procured in this secondary effort matched that from the original survey effort.[12]

The next question asked respondents for detailed information about the sales of their product. Respondents were asked to identify the year of last sale, and the dollar sales volume in each year since the first sale. In the case of annual sales, respondents were told that approximations were acceptable. This was done (1) to expedite the survey process and (2) to alleviate fears about the survey. The surveyors wanted to make sure that respondents would answer honestly without fear that exact answers would somehow "come back to haunt them."

The final question asked the respondent to recount the major events that led to the success of their product. This question was designed to be free form, allowing subjects to tell the story of their invention. It was hoped that through this question technological changes or innovations to the original product could be identified. It was felt that the invention that was sold by the respondents might have been modified or upgraded, and therefore the product being sold was not the product that originally had been specified in the application. While it is not always inappropriate to attribute sales of a current technology to its historical antecedent, it is very important to understand and document the path of the technological progress.[13]

Before calls were placed to the respondents, a letter was sent to each explaining that this follow-up interview would be conducted. It also explained the nature of the information that would be needed. In particular, respondents were advised that they would be queried on their annual sales, and that they need only have approximations.

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12 It should be noted that information supplied in this second survey matched that received in the first. This is important because in a few cases some of the information supplied by the original survey was not fully backed up by the information in the applicant's file, mainly in the area of when first sales occurred. Some respondents to our original survey had not reported initial sales of their invention until after they had applied and been rejected by the program. Yet, in their application they reported sales of their invention, and often supplied NIST with sales materials. This was another reason for the random file search described above. None of these random checks produced any contradictory information.

13 For a discussion of the role of technological and market spin-offs see Brown and Wilson [1993].

Table 4.1 Year-by-Year Sales of Program Referrals with First Sales Following Application

Year	09266 John White	10748 Istrate Ionescu	15347 Donald Boyle, Jr.	18151 Quinto Bocchi
1978	Applied			
1979		Applied		
1980	5,000	100	Applied	
1981	2,000	600		
1982	1,000	300		Applied
1983	1,000			
1984	1,000		100,000	
1985			100,000	
1986			110,000	2,000
1987			110,000	
1988			120,000	
1989			115,000	
1990			125,000	
1991			125,000	
TOTAL	**$10,000**	**$1,000**	**$905,000**	**$2,000**

Table 4.1 presents the annual sales figures for each of the three inventors of interest along with the year that they applied to the program. Except for Mr. Boyle, all the sales were for a limited time, and reflect only small dollar amounts. Further, as we have referred to above, three of these inventors were not able to sustain sales of their product for more than just a few years.

What follows below is a summary of the information reported by the four respondents who experienced sales after they had been rejected by ERIP. Before discussing the survey results, each section contains a short description of the technology described in the original application, and a summary of the evaluation of the technology.

4.1 COMPOSITE ILLUMINATION FIXTURE AND CONTROL CIRCUIT
(Inventor: J.S. White #9266)

This invention allows for the installation of a multiple electrical switch to be installed in pre-existing single switch wiring. The invention thereby makes it possible to run a fan and a light independently from a wall switch originally designed to handle only one or the other (or both if they worked at the same time). In discussions with the inventor, this product was aimed at two

markets. The first was a residential market where individuals could install a combination ceiling fan and light fixture and operate them independently from an existing wall switch designed to handle only one of these units. The second market niche that the inventor saw for this product was in retrofitting hotel and motel bathrooms that had a single switch that turned on a bathroom light and the vent to the outside simultaneously. The inventor saw energy savings in both applications as less power would be used to heat or cool a room. In the first case, the ceiling fan could be used to better circulate heat that had risen to the top of high ceilings. To this end he included a lengthy article on the use of ceiling fans to reduce heating costs to a manufacturing firm that was in a large, open, hard-to-heat building. In the second case, the energy savings came as heat was not necessarily vented outside each time the bathroom light was turned on. No supporting evidence was given as to this application.

The technical evaluation, while agreeing that the invention did work as described, was unable to support the energy savings as described in the inventor's application. In the official communication to Mr. White, NIST said that, "[r]esidential application [did] not seem to be necessary but the elimination of stratification in high ceiling industrial areas can be helpful as shown in [the inventor's] report." As with the other respondents in the sample, Mr. White was referred to other government programs for possible assistance.

As Table 4.1 shows, this invention first experienced sales two years after this rejection, in 1980. The retrofit kit was sold for five years, with the sales being greater early during the five years the invention was sold. Sales were mainly to the second market niche described above, and therefore multiple units were sold in a single deal. In point of fact, only two or three motels purchased the kit. In 1984 sales of the product fell to zero, and the inventor took the invention back to the research stage.

As described by Mr. White, the original product that was submitted to ERIP and was the basis of the sales reported, had a major drawback. In the hotel bathroom example, the retrofit would allow the use of the light independent of the fan, but it was not possible to turn on the fan without also turning on the light. (There was one switch with three positions; off, light on, and light and fan on.) Mr. White now says that the product has been modified such that it has two switches and the two devices can work independently. He has made a video of the product and its benefits, and is currently sending it out to prospective clients and funding agents. The market has been restricted to the hotel and motel niche previously described. At the time of the interview, neither funding agencies nor customers had responded. However, Mr. White is committed to the product and is promoting it at various trade shows and through other marketing approaches. As with many of the inventors contacted, he volunteered to send materials in for study if it might somehow help to identify funding sources or agencies that will help him promote this invention.

4.2 WATT CLOCK
(Inventor: I. Ionescu #10748)

The Watt Clock is a simple device that measures the amount of electricity used by an electric appliance. The owner attaches the clock to the device or appliance of interest, and it measures the electricity used and converts this into an estimated utility cost. The Watt Clock (as described in the ERIP application) assumes a price of $0.10 per kWh in its calculation and subsequent cost reporting. It was this fixed input price and the fact that it was only designed for use with 110-Volt sources that formed the basis for the reviewer's rejection of this technology. The reviewer felt the fixed input price chosen might not be representative of prices all over the country, or into the future. Further, the fact that the invention could not be attached to appliances running on 220 Volts (which he argued were the largest electricity consumer in a house) was a major disadvantage.

In the subsequent interview, the inventor explained that he took the comments and incorporated them into some product revisions before he tried to sell the Watt Clock. (That is, the technology benefited from an program "interaction effect".) He says the most important change was allowing the user to select the input price level. In this way the Watt Clock could be adjusted to reflect various input prices. He said that he considered designing a Watt Clock that worked with 220 appliances, but never got very far with it.

As for sales, the inventor says that they were "pretty insignificant." The units he sold were mostly to friends and neighbors. He said he was not able to generate significant demand through expensive advertising. Also, at the time he was trying to market the Watt Clock, the economy began to turn around. All of a sudden the cost of electricity was not as important as it had been just a few years before. Also, he said that he felt that changes in the tax regulations dealing with energy-saving devices hurt demand.

Since suspending sales of the Watt Clock the inventor has not made any changes to the device. Investment money has been short, and he has had other ideas. Mr. Ionescu still feels that he has a technology and a device that could help people understand how they are using electricity within their homes and offices, but that this is just not the time to try to sell the Watt Clock. He says he would love to work on it further if he could find the funding, that he has put a lot into it so far, and gotten too little back to continue at this point.

4.3 CAULKING, SUPPORTED DEFORMABLE MASTIC ADHESIVE
(Inventor: D. Boyle #15347)

It should be noted that of the four respondents to the original survey who experienced sales after being turned down for ERIP support, David Boyle is the only one still actively selling his

product. As will be discussed in greater detail below, he has a small but steady volume of sales that has existed since he introduced the product to the market.

Mr. Boyle began work on his invention in early 1980, some four years before he applied to the ERIP program. He describes his product as a caulking material that comes in a roll and easily goes in places that are traditionally difficult to caulk. In essence, the product is yarn that is saturated with an adhesive compound. After the saturated yarn cools and dries, it is wound up in small rolls for distribution and sale. The consumer unrolls the caulking, and is able to apply it where it is needed. Examples of use include around windows and in cracks on walls and ceilings. The inventor explains that the benefit of his material over the more conventional caulking substances is ease of use and re-use. He explains that because this material is malleable, it can go places that the more standard caulking tape cannot, areas such as curves or more jagged cracked areas. Further, because it is easy to unroll and apply, it has many benefits that standard caulk from a gun cannot touch, such as overhead applications. Also, because the yarn maintains its tackiness, it can be removed, stored, and used again.

The inventor pointed out that during the development years, before he submitted the concept to ERIP, he had presented his caulking product to an energy-related invention program administered by the Boston Edison Company, a large electrical utility. He said that his product had won an award. It was after winning this award that he decided to submit the product to the ERIP program for further support. He was surprised at the rejection from the ERIP program after his success in this other competition, but says he didn't let it bother him too much. After being turned down for Program participation, Mr. Boyle said he continued with his own private efforts on the product.

When asked what he saw as the key to the success of his product, Mr. Boyle unhesitatingly points to mail-order catalogue sales. He says that it is too difficult to get large-scale sales from normal retail outlets. These places are looking for a line of products that can be distributed to the buying public. Mr. Boyle says that by promoting sales through mail-order catalogues, the product gets large-scale visibility amongst a clientele that is interested in the product. Further, he does not need to supply a complimentary line of products to get his single product to the public. Using this approach he says he is able to sell all the product he can make. The key to sales of this type of product is in the carefully targeted mail-order catalogue business -- especially the ones that go out to the person who really likes to "do-it-yourself."

In fact, he suggests that he could easily sell more of this product if he chose to but that this kind of sustained increase in activity would take away time for his work on new products. The inventor says that the profit from the sales of this product are plowed right back into R&D on other energy-related inventions on which he is currently working. It is this product that allows him to invest time and money in what he sees as the energy products of the future.

The product has gone through only minor changes in the past eight years. The majority of changes have come in the form of modifications to the adhesive that impregnates the yarn, and makes it stick to surfaces. There have been no other changes in manufacturing techniques, uses, or the like. From the tenor of the interview, none of Mr. Boyle's new inventions are a direct spin-off of this product. Thus, he seems to have found a good product that people buy and use, and takes the profits from this successful product and rolls them into the development of other unrelated energy products.

4.4 A REMOTE CONDITION REPORTING SYSTEM WITH DESIGN FOR LOAD MANAGEMENT (Inventor: Q. Bocchi #18151)

In 1982, Mr. Bocchi, along with William Campbell, submitted their invention, the Mikro-Tel system, to the ERIP program. The device monitors electricity use by homes and businesses, and used existing telephone lines to report the information to a utility so it could better understand its load profile, and more effectively initiate load management programs. The inventors conceptualized the device in the late 1970's, but weren't able to make serious progress until the early 1980's when telephone line use regulations were greatly reduced by the FCC.

Technically, the device works in the same way that many remote alarm systems work today. Information on electricity use is gathered by a processing unit. At regular time intervals this information is sent to a monitoring center over the existing phone network. The monitoring center collects information from all the individual processing units and makes this information available to the utility. The system was also designed so that burglar alarm and fire alarm options could be added. For example, if a fire were to begin in the home, the same processing unit would send an alert to the monitoring center where the emergency would be reported to the proper authorities.

The rejection of this technology was based on the conclusion that, "the technology involved is not new but is rather an integration of existing technology." Further, "The energy saving made possible by the use of [this] system [was] possible by using existing methods of control, load shedding, and meter reading." The reviewer did say that the system offered many useful benefits (such as the integration of fire and burglar protection), and that this might make the system an economically viable product, but that the energy savings potential just was not there.

As with many of the other respondents to this survey, this inventor enlisted the aid of his Senator and Representative to lobby NIST. In all cases, the NIST staff kept these interested Congressmen and women appraised of each step and action they took for each case. In the case of Mr. Bocchi, he reported that he had gone to his Representative because he felt that any help he could bring to bear in this review process would be good. He was convinced he had an important technology, and very much needed the financial support in order to get the invention on market.

The first sale of the Mikro-Tel was in 1987. This sale, to a small electrical utility represents the only sale of the product. This was the working prototype system. The inventor said that there were more orders on the books, but that they simply did not have the financial backing to produce units. He felt that if the capital could have been raised, the market at the time would have been substantial.

Because the financial backing did not exist to fill the orders, demand for the technology also disappeared. The inventors were forced to permanently suspend work on the system. Mr. Bocchi still believes in the system, and points to the expanding market and demand for such systems in the home protection market. He also suggested that if he had been able to get into this area at the time that he would have had a very dominant market position. However, because of many changes and advances in the technology in this area, they have lost any advantages they might have had. When asked whether or not the inventor considered any modifications to the system in order to reintroduce it, he said he did not. The technology had advanced so far in the last few years that this just wasn't practical. Fiber optic systems, and cable technology, combined with the already excessive number of firms competing in this field made another attempt at entry impractical.

4.5 CONCLUSIONS

In conclusion, our sample suggests that only a handful of inventions not in production and marketing phases when rejected for participation in the ERIP program later are able to achieve commercial success. Further, of the four inventions that did experience initial commercial success after rejection from the program, only one was able to remain viable for more than a few years.

5. CONCLUSIONS

Appropriately designed program evaluations should be able to isolate the effects of the program from the host of other factors that influence the progress of participants. The simultaneous tracking of program participants and a matched comparison group is a common means of achieving this goal. To our knowledge, however, no previously published evaluation of a government-sponsored innovation program has employed a comparison group design.

In this report, a comparison group approach has been used to evaluate the impact of participation in the Energy-Related Inventions Program. Five potential comparison groups were considered:

- technologies developed by members of inventor societies;
- technologies developed by participants in innovation or incubator centers;
- inventions of independent inventors with unassigned patents in selected energy areas;
- near-participants - these are ERIP applicants that successfully passed through all but the final phase of the NIST evaluation; and
- program referrals - these are ERIP applicants that were found by NIST to be technically sound and commercially competitive, but appeared to offer insufficient energy benefits and therefore were referred to other programs for possible support.

The "program referral" option was judged to be most appropriate for this evaluation.

Specifically, the comparison group is composed of inventors who applied to the program and were judged to be technically feasible and commercially valuable but were rejected because they appeared to offer insufficient energy benefits. These inventors were encouraged to take their inventions to other government programs, such as those supported by the SBA, for assistance in further development. Thus, we were able to identify a comparison group that had many similarities to ERIP participants, but lacked the direct support of DOE.

One unanticipated difference between the samples of program referrals and ERIP participants added to the complexity of the comparison group analysis. Of the 28 program referrals who reported sales of their technologies, none had applied to the program for assistance in research and development. All had significantly developed concepts and were applying for marketing and management assistance. Of this number, 24 (or 86%) experienced some kind of sales before or during the year they applied to the ERIP program. Only four of the applicants experienced their first sales AFTER they had applied and been turned down for support by the ERIP program.

In contrast, only 29 (or 27%) of the 109 ERIP inventors with sales achieved their first sales prior to or during the year they applied to ERIP for support. As a result of this difference, when comparing sales figures, we emphasize the subsets of program referrals and ERIP participants with first sales after their ERIP application.

As we saw in Section 3, there are large differences between the program referrals and the ERIP participants in terms of several indicators of commercial success. Average dollar sales by ERIP participants are an order of magnitude greater than the program referral group. Further, our analysis suggests that only a handful of program referrals who reported sales were not in production and marketing phases when rejected for participation in the ERIP program. That is, very few program referrals who did not have sales before they applied to the program were able to achieve commercial success afterwards. Further, of the four inventions that did experience initial commercial success after rejection from the program, only one was able to remain viable for more than a few years.

A variety of additional indicators of success are examined, with the following conclusions.

- The development of ERIP inventions appear to be actively pursued for a longer period of time than are the inventions of program referrals.
- A higher percentage of ERIP inventions are protected by patents (90%), compared with program referrals (72%).
- Program referrals and ERIP participants are associated with comparable levels of employment per invention, but this is primarily because of the success of two applicants. Only 6% of the program referrals were associated with employment in recent years, compared with 58% of the ERIP participants.

Section 3 also revealed that there was a major difference between the funding of program referrals and ERIP participants. In total, program referrals raised half as much funding, per invention, as ERIP participants. In addition, the program referrals relied mainly on personal funding in the development of their inventions. This is in contrast to the ERIP participants who received much of their funding from non-personal sources such as corporate profits, banks, stock offerings, and government programs in addition to the ERIP. Further, the ERIP participants were able to raise substantially more money than their counterparts. This undoubtedly has a significant impact on the success of this former group, and probably reflects, to some extent, the assistance provided by ERIP. Even in the interviews with successful program referrals (Section 4), we see that the biggest problem reported by these four cases is a lack of sufficient funding for product improvements, business planning, and marketing.

Thus, it is likely that one of the benefits that ERIP supplies to its participants is not only funding in and of itself, but the knowledge and connections to secure more funds. Many ERIP participants are able to acquire large-scale funding to help them better prepare and market their

technologies. It appears that ERIP support consistently opens doors to funding and ultimately to success in the market that is missed by most other inventors, even ones that are referred to traditional sources of support such as the comparison group of program referrals.

In conclusion, the comparison group analysis provides strong evidence that the ERIP technologies would not have achieved as great commercial success if they had not been supported by the Energy-Related Inventions Program.

6. REFERENCES

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APPENDIX A

DISCUSSION OF THE NEAR-PARTICIPANT GROUP OPTION

This appendix gives a short summary of the steps in NIST's evaluation. It also describes how interaction and tainting effects can bias the probability of commercial success of a given invention.

Both near-participants and ERIP inventors go through three stages before a recommendation for financial support is made -- i.e., disclosure review and analysis, a first-stage evaluation, and a second-stage evaluation. All ERIP applicants are first subject to a **disclosure review and analysis**. This step removes from further consideration technologies that are classified as one of the following:

- not energy-related
- nuclear energy-related
- a proposal to invent (i.e., no invention yet involved)
- being of insufficient technical depth or detail
- obviously technically flawed
- requiring excessive feasibility analysis
- unclear or with communication difficulties

After passing the disclosure review and analysis, an inventor's disclosure proceeds to a **first-stage evaluation**. This step consists of a series of independent and successive reviews by technical experts inside or outside the NIST. For each review, the disclosure is sent to an evaluator in the appropriate field. The evaluator assesses the adequacy, completeness, and logic of the disclosure. The evaluator also considers the validity of the technical assumptions and statements made in the disclosure, the potential for energy savings, and the commercial feasibility, economics, practicality of the invention, and uniqueness. The evaluator provides NIST with brief written comments and a recommendation for or against support. A staff engineer from the Office of Energy-Related Inventions (OERI) considers the invention in light of the reviewers' opinions and does one of the following:

- informs the inventor that the invention is not to be recommended to DOE
- selects an appropriate expert to conduct an additional review, or
- initiates action to perform a second-stage evaluation if the invention shows promise or a more in-depth review is required.

The **second-stage evaluation** entails an in-depth analysis. An OERI staff engineer is assigned as coordinator of the invention. The coordinator, in turn, selects one or more second-stage evaluators. The inventor is notified that the second-stage evaluation has begun, and the evaluators are encouraged to contact the inventor for additional information or data as required. The evaluation normally includes:

- reexamining the validity and accuracy of technical assumptions and statements,
- determining the uniqueness of the invention,
- defining the development process required to bring the invention into use,
- projecting energy savings, and
- identifying existing technologies that would be replaced or affected.

A formal report is submitted by the evaluator, the report is reviewed by the coordinator and possibly other OERI staff, and a decision is made whether or not to recommend the invention to DOE. Inventions are rejected for one or more of the following reasons: (1) they are not competitive with available technologies, (2) they are not technically feasible, or (3) they are not promising for practical applications. The inventor is notified of the decision and sent a copy of the evaluation report. Those inventors who are rejected at this stage are labeled near-participants for the purposes of this study.

Based on past experience with the evaluation process, approximately 5% of the inventors undergo the second-stage evaluation: about 60% of these fail the second-stage review and 40% are recommended to DOE. Through October 1, 1989, there were 486 ERIP participants and approximately 700 near-participants.

The three-step process by which ERIP applicants become either ERIP inventors or near-participants is essentially a screening process which selects the most promising technologies in terms of the stated selection criteria. We can assume that the groups of ERIP applicants that pass successive stages of this screening process have a higher potential for commercial success than do the groups of applicants that become rejectees of the program. Therefore, we can assume that the probability of commercial success for the group of technologies that proceeds beyond the disclosure-review-and-analysis step is higher than for the group of technologies that is rejected at this initial step of the screening process. Likewise, the probability of commercial success for the group of technologies that passes the first-stage evaluation is greater than for the group of rejectees at the first step. Following the same logic, the probability of commercial success for technologies that pass the stage-two evaluation and are recommended to DOE for funding (i.e., ERIP inventors) can be assumed to be greater than the probability of success for technologies rejected at the second stage (i.e., near-participants).

In addition to screening applicants, the process of selecting ERIP inventors may serve two additional functions that can increase, as well as decrease, the probability of commercial success for ERIP applicants. First, the interaction of ERIP applicants with NIST reviewers at each step in the screening process is likely to improve the probability of commercial success for all technologies considered at that step. This process, labeled here as the "interaction effect," results from the technical and market expertise provided by NIST reviewers to inventors and from "networking" with individuals and firms that may ultimately play a direct or indirect role in the technology's

commercialization. This effect is likely to increase with each stage of the NIST evaluation, as the evaluation becomes more thorough. This positive effect impacts near-participants and ERIP participants alike; it therefore does not weaken the validity of using near-participants as a comparison group.

The second function may reduce the probability of commercial success for technologies that are rejected. Referred to here as "tainting," this effect results from the negative signal sent by NIST to the inventor and indirectly to potential funders of further technology development. This effect is likely to decrease with each stage of the NIST evaluation, as inventions passing through successive stages can claim some increasing degree of public validation. Failure to pass the final, second-stage evaluation does taint the near-participants and not ERIP participants, but the differential is expected to be small. Having reached the 95th percentile of the review process, but failed the 98th percentile, these near-participants can argue that their technologies have been found to be meritorious. Indeed, it has been shown that "rater error" in most evaluations (e.g., of job applicants and graduate school candidates) exceeds 5% (Bozeman, 1991 and Humphries, 1991). If true of the ERIP program, as is likely, one could argue that there is no difference between the merit of near-participants and ERIP inventors.

Figure 1 provides a simple representation of the screening functions that occur at each evaluation stage, as well as the directional shifts in probability of commercial success that result from tainting and the interaction effect. Probability of commercial success is represented on the vertical axis. Evaluation stages are listed along the horizontal axis.

If near-participants were used as the comparison group, the measure of ERIP effectiveness would be measured by the difference between the probability of commercial success that corresponds to points 1 and 3 -- i.e., the difference between the probability of commercial success for ERIP inventors and near-participants. Note, however, that this measure of "effectiveness" does not take into consideration the positive interaction effects that may occur in the three evaluation stages. Nor does it include the negative tainting effects that rejectees may observe at the first-stage evaluation or the disclosure-review-and-analysis step.

Because these interaction and tainting effects are not considered, the use of near-participants as the comparison group will not provide a measure of the effectiveness of the ERIP program in total. Rather, an evaluation of near-participants only provides an assessment of the effectiveness of ERIP funding and recognition. (Note that in some cases, technologies recommended to DOE for funding do not, in fact, receive funding. In these cases, ERIP recognition may provide benefits to the inventor in terms of facilitating funding from alternative sources or provide other benefits.

The true measure of the effectiveness of ERIP funding and recognition in terms of increasing the probability of commercial success is measured by the difference between points 1

and 2 in Figure 1. The difference between points 2 and 3 is a measure of the effects of tainting on near-participants.

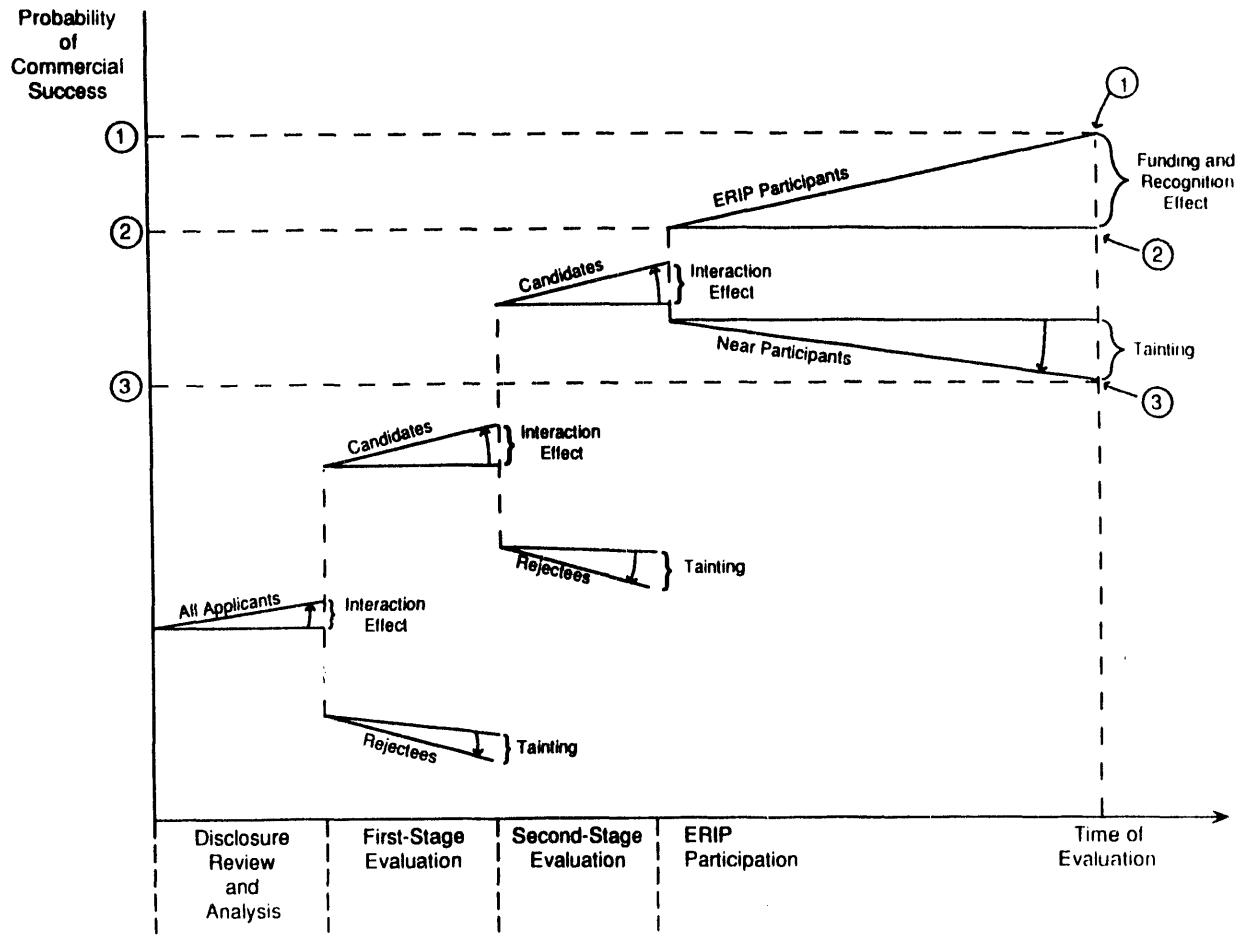

Figure 1. The "Near Participant" Comparison Group Option

APPENDIX B

COVER LETTER AND QUESTIONNAIRE

FOR PROGRAM REFERRALS

June 15, 1992

1~
2~
3~

Dear Mr. 4~:

Since 1981 the U.S. Department of Energy (DOE) and the Oak Ridge National Laboratory (ORNL) have periodically collected information on the progress of technologies recommended to DOE for financial support in the Energy-Related Inventions Program (ERIP). We are now in the process of collecting information about ERIP applicant technologies that were found to be technically sound and commercially competitive but judged to be insufficient energy benefits to warrant recommendation for DOE financial assistance. While DOE did not provide financial assistance to these technologies, applicants were directed to other government programs for potential financial and other support.

This evaluation effort, in which we hope you will participate, has several purposes.

- to guide ERIP in the improvement of its program, particularly that part of the program which refers applicants to other potential sources of funding;
- to help determine the success of ERIP applicants in obtaining funding from other sources;
- to compare the commercial success of technologies funded by ERIP with the success of ERIP technologies that do not receive ERIP support; and
- to help researchers, government agencies, and the business community better understand the processes of invention and technical development.

Enclosed is an ERIP evaluation questionnaire designed for these purposes. The "technology" we are interested in tracking is identified on the questionnaire by a technology description and ERIP application date. Please note that this questionnaire is not intended to reopen your ERIP applications for further review or consideration.

We are very sensitive to your requirement for confidentiality. The information we collect from you will be held in strict confidence. No one outside the ERIP team will see information concerning your technology. The only data we report are condensed statistics that will not allow your firm or your technology to be singled out. Should an occasion arise in which we would want to report specific information about your technology, we would contact you first for permission.

We may have overlooked one or more issues concerning ERIP or your proposed technology that are most important to you. In addition, you may have comments for ERIP that can help it do its job better in the future. The last page of the questionnaire gives you the opportunity to express your comments and observations about your experience with ERIP and the status of your technology.

We would appreciate receiving your response by July 15, 1992. Enclosed is a self-addressed envelop for your convenience.

If your have any question concerning this information request, please feel free to call Charlotte Franchuk or Marilyn Brown, the ORNL project manager.

Marilyn A. Brown
Oak Ridge National Laboratory
Building 4500N, MS 6206
Oak Ridge, TN 37831-6202
Phone: 615-576-8152

Charlotte Franchuk
Oak Ridge National Laboratory
Building 4500N, MS 6206
Oak Ridge, TN 37831-6202
Phone 615-574-8341

Thank you very much for contributing to our program evaluation effort. We look forward to hearing from you.

Sincerely,

Marilyn A. Brown, Group Leader
Energy Program Planning and Evaluation

MAB/caf

Enclosure

cc/enc: Jack Aellen (DOE/ERIP)
Gil Ugiansky (NIST/OERI)
RC

QUESTIONNAIRE FOR APPLICANTS TO THE ENERGY-RELATED INVENTIONS PROGRAM (ERIP)

Please correct any of the following information about yourself or the technology for which you requested support from the Energy-Related Inventions Program (ERIP):

Identification Number:

BACKGROUND

CONTACT INFORMATION
NAME:
ADDRESS:
PHONE:

TECHNOLOGY DESCRIPTION

ERIP APPLICATION DATE

DEVELOPMENT OF THE TECHNOLOGY

CONCEPTUALIZATION HISTORY	YEAR
In what year was this technology originally conceptualized?	
In what year did active development begin?	

In what year, if any, did the technology achieve each of the following six stages of development?

DEVELOPMENT CATEGORIES	YEAR
Working model	
Prototype development, testing, engineering design	
Pre-production prototype testing	
Production prototype	
Limited production and marketing	
Full production and marketing	

Please check the category that best describes the technology's current activity status.

ACTIVITY CATEGORIES	STATUS
Actively being pursued	
Low level of effort	
Suspended temporarily	
Suspended permanently	
Failed	
Chapter 11/Reorganization	
Chapter 7/Bankrupt	

How many U.S. patents have resulted from the development of this technology? (Include all patents that are a direct outgrowth of the technology for which you applied for an ERIP grant.)

Number of U.S. Patents

EMPLOYMENT

How many full-time and part-time employees were associated with this technology in 1991? Please include all employees in your company that worked directly on this technology, as well as any individuals in other organizations whose jobs were related to the production, marketing, or distribution of this technology.

Number of full-time employees in 1991	
Number of part-time employees in 1991	

During the course of this technology's development, production, marketing, or distribution, has the number of employees associated with this technology ever exceeded the number for 1991? (Circle one: YES or NO) If yes, please indicate the year the largest employment level occurred and the number of employees associated with this technology in that year. Please use the same definition of employment as above.

Year of largest employment level	
Number of full-time employees	
Number of part-time employees	

SALES

If the technology for which ERIP funding was requested has resulted in sales, please indicate the year that the first unit was sold. If sales occurred, please estimate in dollars the total sales of this technology in 1991 and the technology's cumulative sales from the time the first unit was sold through 1991. Please include all sales of the technology that took place out of your company, as well as sales of the technology by other companies, such as a licensee or a company that has purchased the technology.

Year of first sales	
Estimated total dollar sales in 1991	$
Cumulative dollar sales	$

4

FUNDING

Please estimate the total amount of internal and external funding that was spent on the development of this technology in 1991 and the cumulative funding over the time period from the technology's conceptualization through 1991.

Please divide internal sources of funding into two categories: personal funding and corporate funding. (Do not include the value of your uncompensated time as part of personal funding.)

Please divide external funding into four categories: commercial, public stock offerings, lending institutions, and government agencies.

	Internal Funding		**External Funding**			
	Personal (own savings, friends and relatives)	**Corporate** (e.g., re-invested profits from sales)	**Commercial** (e.g., venture capital)	**Private Stock Offering**	**Lending Institution**	**Government Agencies**
Estimated total funding in 1991						
Cumulative funding through 1991						

ADDITIONAL COMMENTS

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259-260 OSTI, U.S. Department of Energy, P.O. Box 62, Oak Ridge, TN 37831

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