MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES

3 4456 0352097 3

ornl

ORNL/CON-339

OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

The Energy-Related Inventions Program: A Decade of Commercial Progress

Marilyn A. Brown
C. Robert Wilson
Charlotte A. Franchuk

OAK RIDGE NATIONAL LABORATORY
CENTRAL RESEARCH LIBRARY
CIRCULATION SECTION
4500N ROOM 175
LIBRARY LOAN COPY
DO NOT TRANSFER TO ANOTHER PERSON
If you wish someone else to see this report, send in name with report and the library will arrange a loan.

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401, FTS 626-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ORNL/CON-339

THE ENERGY-RELATED INVENTIONS PROGRAM: A DECADE OF COMMERCIAL PROGRESS*

Marilyn A. Brown
C. Robert Wilson**
Charlotte A. Franchuk

**University of Tennessee

December 1991

*Research sponsored by the Office of Conservation and Renewable Energy
U.S. Department of Energy

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831

Managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. Department of Energy
Under Contract No. DE-AC05-84OR21400

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES
3 4456 0352097 3

TABLE OF CONTENTS

LIST OF FIGURES v
LIST OF TABLES v
ACKNOWLEDGEMENTS vii
ABSTRACT ix
EXECUTIVE SUMMARY xi

1. INTRODUCTION 1.1
    1.1 GOALS OF THE EVALUATION 1.1
    1.2 OVERVIEW OF THE PROGRAM 1.1
    1.3 MEASURES OF PROGRAM SUCCESS 1.2
    1.4 OVERVIEW OF THE REPORT 1.3

2. EVALUATION DESIGN 2.1
    2.1 SAMPLING STRATEGY 2.1
    2.2 INTERVIEW PROCESS 2.2
    2.3 ANALYTICAL APPROACH 2.4

3. COMMERCIAL PROGRESS OF THE ERIP INVENTIONS 3.1
    3.1 CURRENT STATUS OF ERIP INVENTIONS 3.1
    3.2 THE NUMBER OF COMMERCIALIZED ERIP INVENTIONS 3.3
    3.3 SALES OF THE ERIP INVENTIONS 3.10
        3.3.1 Sales Based on 109 Inventions 3.11
        3.3.2 Estimated Sales from Unsampled Inventions 3.11

4. COMMERCIAL PROGRESS OF SPIN-OFF ACTIVITIES 4.1
    4.1 DEFINITION AND EXAMPLES OF SPIN-OFF TECHNOLOGIES . . 4.1
    4.2 SALES OF SPIN-OFF TECHNOLOGIES 4.4

5. JOB GENERATION AND TAX REVENUES 5.1
    5.1 JOBS GENERATED BY ERIP TECHNOLOGIES 5.1
    5.2 TAX REVENUES FROM ERIP-GENERATED EMPLOYMENT 5.4

6. ACQUIRING FINANCIAL SUPPORT 6.1
    6.1 THE NATURE OF ERIP'S FINANCIAL ASSISTANCE 6.1
    6.2 THE COST OF TECHNOLOGICAL INNOVATION 6.2
    6.3 SOURCES OF FINANCING FOR ERIP INVENTIONS 6.4

7. CONCLUSIONS 7.1

8. REFERENCES 8.1

APPENDIX A: QUESTIONNAIRE A.1

APPENDIX B: SALES OF ERIP INVENTIONS B.1

APPENDIX C: JOB GENERATION C.1

APPENDIX D: ACQUIRING FINANCIAL SUPPORT D.1

LIST OF FIGURES

Fig. A-1 Indicators of program impacts xiii
Fig. 3.1 Classification of 122 commercialized inventions. 3.4
Fig. 3.2 Commercialized inventions: 1984, 1986, 1988, and 1990. . . . . 3.6
Fig. 3.3 Distribution of cumulative gross sales for ERIP inventions through 1990. 3.7
Fig. 3.4 Inventions entering, in, and exiting the market, by year. 3.8
Fig. 3.5 Grants, program appropriations, and cumulative reported sales. 3.13
Fig. 4.1 Typology and illustrations of spin-offs from ERIP technologies 4.2
Fig. 4.2 Cumulative sales of spin-off technologies 4.6
Fig. 5.1 Number of full-time equivalent (FTE) employees working on 143 ERIP technologies: 1984 through 1990. . . . . 5.3
Fig. 6.1 Distribution of the costs of technological innovation for 143 inventions 6.3
Fig. 6.2 Classification of funding sources. 6.5
Fig. 6.3 Funding sources for ERIP inventions with and without sales. 6.6
Fig. 7.1 Cumulative reported sales of ERIP inventions and spin-off technologies 7.2

LIST OF TABLES

Table 2.1 Summary of interviews 2.3
Table 3.1 Level of activity of ERIP projects in 1991 . . . . . 3.2
Table 3.2 Stage of development of ERIP technologies in 1991 . . . . . 3.3
Table 3.3 Number of ERIP technologies in the market by date of NIST recommendation 3.10
Table 3.4 Total cumulative sales of ERIP inventions 3.10
Table B.1 Yearly sales based on 109 inventions for which annual sales data are available B.3
Table C.1 Sales per FTE employee C.3
Table C.2 Number of full-time equivalent (FTE) employees supported by sales of ERIP inventions C.3
Table D.1 Average funds raised per inventor, by source (in thousands of dollars) D.3

ACKNOWLEDGEMENTS

While this impact evaluation was being conducted, a group of experts in invention commercialization completed in-depth case studies of 12 ERIP technologies. The results of these case studies provided valuable data and insights, and their authors are gratefully acknowledged: Herbert Kierulff, Gerry Udell, Harold Livesay, David Lux, Art Ramseur, and Marcia Rorke. Three additional researchers helped the authors with telephone interviewing: Randy Curlee, Colleen Rizy, and Anthony Schaffhauser. Their assistance is appreciated.

We would also like to thank Howard Kuff for developing a data entry and querying system that immensely facilitated this evaluation. In addition, assistance with graphics was capably provided by Ed Lapsa.

Valuable comments on earlier drafts of this paper were provided by Jack Aellen (DOE), Randy Curlee (ORNL), Harold Livesay (Texas A&M University), David Lux (Bryant College), and Colleen Rizy (ORNL). Their suggestions are greatly appreciated.

Most of all we would like to thank the inventors who graciously agreed to be interviewed as part of this research. Without their willingness to share their experiences with us, this evaluation would not have been possible.

Finally, we dedicate this report to Ray Barnes, Director of the Energy-Related Inventions Program from 1990 through 1991, who worked tirelessly to incorporate innovative approaches into the management of ERIP.

ABSTRACT

This report provides information on the recent commercial progress of inventions supported by the U.S. Department of Energy's Energy-Related Inventions Program (ERIP). It describes the results of the latest in a series of ERIP evaluation projects that have been completed since 1980. It focuses on the economic impacts of the program, notably sales and employment benefits. The period of interest is 1980 through 1990. The evaluation is based on data collected through mail and telephone surveying of 143 participants in the Program.

As of October 1989, a total of 486 inventions were recommended to DOE by the National Institute for Standards and Technology, which screens all submitted inventions in terms of technical merit, potential for commercial success, and potential energy impact. By the end of 1990, at least 109 of these inventions had entered the market, generating total cumulative sales of more than $500 million. With $25.7 million in grants awarded from 1975 through 1990, and $63.1 million in program appropriations over the same period, ERIP has generated a 20:1 return in terms of sales values to grants, and an 8:1 return in sales versus program appropriations. It is estimated that 25% of all ERIP inventions had achieved sales by the end of 1990. While it is difficult to make exact comparisons between these percentages and other indicators of the success rates of technological innovations as a whole, the ERIP figures remain impressive.

The commercial progress of spin-off technologies is also documented. Altogether, 23 spin-off technologies have generated sales of $32 million, and these are additional tangible impacts of the Program. Further, it is estimated that more than 750 full-time equivalent employees were working on ERIP technologies in 1990, and that this resulted in a return of approximately $3.2 million in individual income taxes to the U.S. Treasury.

EXECUTIVE SUMMARY

This report contains the results of an evaluation of the economic impacts of the Energy-Related Inventions Program (ERIP), a joint program of the U.S. Department of Energy (DOE) and the National Institute of Standards and Technology (NIST). The evaluation was undertaken primarily to obtain up-to-date information on the commercial progress of ERIP inventions - including estimates of invention sales and employment benefits through 1990. In addition, the evaluation seeks to: (1) document and assess the amount and sources of funds that have been used to develop the ERIP inventions, and (2) identify alternative market applications and second-generation technologies that have spun-off from funded ERIP technologies.

As of October 1989, a total of 486 inventions were recommended to DOE by NIST, which screens all submitted inventions in terms of technical merit, potential for commercial success, and potential energy impact. In order to reduce the cost of data collection, maximize the coverage of successful ERIP technologies, and obtain a representative sample of the remaining inventions, a sampling design involving two subsamples was employed. The first subsample includes 107 inventions identified by past research and key informants to be most promising in terms of market entry and commercial success. The second subsample of 76 inventions was randomly drawn from the remaining inventions.

A 17-page questionnaire was developed to collect sales, employment, fund-raising, and other data for 1989 and 1990. Mail and/or telephone surveys were completed with program participants, inventors, and other key contacts covering 143 of the 183 inventions in the sample. From these data, an assessment was made of the commercial progress of ERIP-sponsored inventions. The progress of an invention was measured primarily in terms of market entry, level of sales, and length of time on the market.

By the end of 1990, at least 122 ERIP inventions had been "commercialized" - either sold directly by the inventor's firm or licensed or sold to another company for further development. Of these 122, at least 109 had achieved sales. This represents a significant amount of progress since 1988, when the program was last evaluated. Based on the data gathered in this study, it is estimated that 28% of all ERIP inventions had been commercialized, and 25% had achieved sales by the end of the study period. While it is difficult to make exact comparisons between

these data and other indicators of the success rates of technological innovations as a whole, the ERIP figures remain impressive.

By the end of 1990, ERIP inventions had achieved total cumulative sales of $503 million. With $25.7 million in grants awarded through 1990, and $63.1 million in program appropriations over the same period, ERIP has generated a 20:1 return in terms of sales of ERIP technologies to grants, and a 8:1 return in sales versus program appropriations.

An analysis of spin-off technologies provides numerous examples of derivative program impacts. Over time, these second-generation technologies and alternative market applications of ERIP inventions have grown in importance as by-products of the program. Altogether, 23 spin-off technologies have generated sales of $32 million through 1990. Thus, the program's total cumulative sales are $535 million when the sales of ERIP's spin-offs are included.

Between 1984 and 1990, the number of technologies entering the market each year has been counterbalanced by the exit of older technologies from the market. Through this process, the total number of technologies in the marketplace has remained relatively stable. During earlier years of the program, market entries far outpaced market exits.

Financial and other barriers are problematic for many of those ERIP inventors who have yet to achieve sales or whose sales have not yet been significant. Work on several promising technologies was suspended during the 1989-90 evaluation period. During the 1991 interviews, inventors often cited low energy prices, the general lack of concern about energy issues, and the recession as causes of their difficulties.

Nevertheless, this evaluation reveals that 1989-90 was a successful period for many ERIP technologies. In addition to creating new businesses, products, and sales, ERIP participants have also produced significant employment and tax benefits. In 1990, it is estimated that more than 750 full-time equivalent employees were working on ERIP technologies. Assuming the national per capita earnings for these workers, this employment resulted in estimated individual income tax payments of $3.2 million in 1990. Additional tax revenues are associated with royalty payments on ERIP inventions, corporate income taxes, state and local sales and income taxes, and personal income taxes paid by indirect employment beneficiaries of the program.

Figure A-1 summarizes some of the indicators of program impacts that are discussed in the report.

• At least 109 ERIP technologies have entered the market.
• More than $500 million in sales have been generated by these inventions through 1990.
• An additional $32 million in sales have been generated by 23 spin-off technologies.
• For every ERIP grant dollar, participants have raised an additional four dollars to develop their ERIP technologies.
• 758 full-time equivalent jobs were supported by ERIP technologies in 1990.
• $3.2 million in ERIP-related tax revenues were returned to the U.S. Treasury in 1990.

Fig. A-1. Indicators of program impacts.

1. INTRODUCTION

1.1 GOALS OF THE EVALUATION

Since the inception of the Energy-Related Inventions Program (ERIP), the U.S. Department of Energy has systematically monitored the progress of the inventions it has supported. Case studies of ERIP inventions have been completed (Rorke and Livesay, 1986), and the economic impacts of the Program have been assessed (Brown, et al., 1987a; Brown and Snell, 1988; Brown and Wilson, 1990). Past evaluations have also examined characteristics of the inventions, inventors, markets, and business strategies that contribute to success; reasons for failure; and characteristics of the commercialization time-line. This report presents the results of the most recent evaluation of the Energy-Related Inventions Program.

The evaluation was undertaken primarily to obtain up-to-date information on the commercial progress of ERIP inventions - including estimates of invention sales and employment benefits through 1990. In addition, the evaluation seeks to:

- document and assess the amount and sources of funds that have been used to develop the ERIP inventions; and
- identify alternative applications and second-generation technologies that have spun off from ERIP technologies.

1.2 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 individual and small company inventors with promising technologies develop their inventions to a stage of development 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. 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 inventions submitted, assessing them for technical feasibility, energy conservation or supply potential, and commercial possibilities. The most promising inventions are recommended to DOE for consideration of support.

DOE grants are provided to most of these recommendees to pay for technical research, prototype development, testing, and a variety of other activities that help move the technologies 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.

1.3 MEASURES OF PROGRAM SUCCESS

A program such as ERIP has an impact on diverse stakeholder groups (such as independent inventors, the business community, policy makers, and taxpayers), each of which evaluates the program's success in different ways. Inventors want to know the benefits of program participation in terms of technical assistance, commercialization planning, and help with the subsequent acquisition of funding. The business community might want to know about the relationship between the program and the creation of viable businesses, and would evaluate the technologies in terms of profit margins, sales levels, return-on-investment, or comparative advantage. Policy makers are concerned about whether the program meets its objectives of conserving or producing energy, the creation of new businesses and employment, and development of promising new energy technologies. Taxpayers are most concerned about the relationship between program costs and the extent to which these costs are counterbalanced by economic returns to the treasury. This evaluation attempts to address the concerns of several of these stakeholder groups. It addresses business creation and sales in Chapters 3 and 4, job

creation and returns to the treasury in Chapter 5, and funding patterns in Chapter 6. Prior evaluations have assessed the Program in terms of its energy objectives. The energy impacts of the program could not be assessed here due to limited resources.

1.4 OVERVIEW OF THE REPORT

This report begins by describing the evaluation design employed here, including the sampling strategy and collection of data (Chapter 2). Results are then presented. Chapter 3 focuses on the market status of ERIP inventions and estimates of invention sales. Chapter 4 documents the Program's spin-off activities, including alternative market applications and second-generation technologies. Chapter 5 examines the employment and tax revenues generated by the program. Attention then turns to the funds raised by program participants (Chapter 6). The report ends with a brief discussion of the results (Chapter 7).

Along with presenting current statistics for the Program and its technologies, previous research is reviewed and findings compared with the results for ERIP. Since this report culminates a decade of ERIP impact evaluations, a particular effort is made to compare and contrast the commercial success of ERIP technologies over time using historic data in an effort to assess longitudinal aspects of the Program and the technologies it has supported.

2. EVALUATION DESIGN

2.1 SAMPLING STRATEGY

Between October 1976 and October 1989, a total of 486 inventions were recommended to DOE's Energy-Related Inventions Program by the National Institute of Standards and Technology. These inventions are described in the most recent ERIP annual status report (U.S. Department of Commerce, 1990), and they are the technologies of interest to this evaluation. To reduce the cost of data collection, information is collected on only a sample of these ERIP technologies. The sampling design was developed to maximize the coverage of commercially successful inventions, while at the same time providing data on a representative sample of the remaining inventions.

The sampling design involves two samples. The first sample includes 107 inventions identified by past research (Brown and Wilson, 1990) and key informants (the program's invention coordinators, managers, and evaluators) to be most promising in terms of market entry and commercial success. This "promising sample" was selected to maximize the inclusion of inventions that had achieved sales by 1990.

The second sample was randomly drawn from the population of 486 inventions, excluding the 107 inventions already included in the first sample. This "random sample" allows us to test the hypothesis of complete sales coverage by the promising sample. It also enables analysis of the full range of inventions--from the least to most successful. The sampling procedure involved drawing a random number between 1 and 5 and then applying a sampling interval of five to the list of 379 (i.e., 486 - 107) inventions which were ranked by DOE number. The random sample contains 76 inventors, bringing the total sample to 183 inventions. Despite its label, the random sample is not representative of all ERIP inventions because it excludes those technologies predicted in advance to be most promising.

Some of the analyses reported here also draw upon historic data not collected during the 1991 interviews. To illustrate, an invention that reported sales during the 1985 evaluation would still be included in the cumulative count of inventions that have experienced sales, even if further information was not obtained in subsequent phases of data collection. Altogether, some

evaluation data are available for 205 of the inventions that were not included in the current sample of 183 inventions.

2.2 INTERVIEW PROCESS

Unlike the three previous ERIP evaluations conducted by ORNL for DOE, the current evaluation initiated the collection of data via a mail survey to the sample of ERIP participants. The mail survey was seen as having two benefits: (1) it offered an opportunity for previously interviewed ERIP participants to review the data collected from them during earlier evaluations, and (2) it is less expensive than telephone interviewing.

Of the sample of 183 participants, 122 had previously been interviewed. Thus, they were sent a questionnaire that was completed, as much as possible, from information in the existing ORNL database. The 61 participants who had not been included in any of the previous impact evaluations were mailed a questionnaire that was blank except for the information on the contact, inventor, and a technology description obtained from ERIP files. Thus, the questionnaires were identical in all respects but the amount and type of data that they contained when mailed to each respondent.

The 17-page questionnaire was divided into sections (see Appendix A), including:

- technology description
- contact information
- timing of conceptualization and development
- sales data and licensing revenue
- employment
- spinoff technologies
- sources of funding
- distribution strategy
- additional comments.

Because of the spacious layout of the questionnaire, the 17 pages typically required less than 20 minutes to complete. However, the telephone interviews ranged widely, from perhaps 10 minutes for participants who had been interviewed before and had little activity to report, to 45 minutes for those participants who wanted to elaborate on the status of their ERIP project.

After the one-month deadline for return of the mail survey, nonrespondents were called to determine the status of their questionnaires, to conduct a telephone interview, or to encourage

return of the mail survey. Altogether, 70 of the sampled participants eventually returned their questionnaires by mail, although several of these participants required follow-up telephone contact to collect missing data.

Approximately the same number of participants (N=73) were interviewed entirely by phone. This resulted in completed questionnaires for 143 of the sample of 183 participants (or a 78% response rate) (Table 2.1). The response rate was slightly greater for the promising sample (87%) than for the random sample (66%). Many of the random sample could no longer be located, reflecting the fact that they tend to have been less successful and were typically not included in previous impact evaluations, which is the only periodic communication with DOE/ERIP that takes place once an ERIP project is completed. Of the 40 participants who could not be interviewed, 19 could not be located, 15 refused to provide data, 5 were deceased or ill, and 1 was removed from the sample because the same participant had two other technologies in the sample and had provided data on them. This latter omission was allowed only as a courtesy to the multiple Program participant.

Table 2.1 Summary of interviews

	Promising Sample	Random Sample	Totals
Completed by Mail	41	29	70
Completed by Telephone	52	21	73
Not Completed	14	26	40
Totals	107	76	183

Most of the questionnaires were completed by the ERIP participant, who in most cases is also the inventor of the ERIP technology. In other instances, the ERIP participant is the entrepreneur and/or the licensee who developed the invention or some other designated contact who is familiar with the technology. For perhaps a dozen of the 143 completed questionnaires,

information was collected from multiple sources. These additional sources were contacted to obtain a fuller picture of the technology, its development, and its commercial impact. This was particularly valuable when the development of a technology was complicated and involved multiple parties (e.g., the inventor and one or more licensees, or the inventor and the Vice President of marketing for the inventor's company).

2.3 ANALYTICAL APPROACH

A subset of the analyses presented in subsequent chapters of this report draws exclusively on information collected in 1991 for the sample of 143 ERIP technologies. For instance, discussions of the current status of inventions and the amount of funding raised to support ERIP inventions in 1989 and 1990 are based on this limited sample. Analyses that are cumulative in nature, on the other hand, capitalize on the full database of 348 technologies--143 from the 1991 sample and 205 from previous years of data collection. Thus, cumulative sales of ERIP technologies and total numbers of new businesses started up to commercialize ERIP technologies, rely on this larger base of data.

The evaluation design does not involve a comparison or control group against which the progress of ERIP inventions can be compared. Rather, the literature at large is relied upon for insight into the invention and innovation process as it occurs without government intervention. Thus, as is true of most innovation program evaluations (Roessner, 1989), a precise assessment of the net benefits of the Energy-Related Inventions Program is beyond the reach of this evaluation.

3. COMMERCIAL PROGRESS OF THE ERIP INVENTIONS

Each year, new ERIP technologies are introduced on the market while others are withdrawn. New licensing agreements are signed to develop ERIP technologies; some result in sales, while others expire or are terminated. Many ERIP inventions continue to undergo development, while others fail or are temporarily or indefinitely shelved.

This chapter begins by assessing the current status of ERIP inventions in terms of level of activity and stage of development. This focuses on the sample of 143 ERIP technologies. The chapter then documents the number of ERIP technologies that have been in the market (i.e., generating sales) during various years over the past decade. This assessment draws on the full database of information on 348 ERIP technologies. The chapter further extends this analysis of commercialized inventions to assess the length of time technologies have remained in the market and the signing of licensing agreements. Attention then turns to assessing the performance of ERIP based on the total sales of ERIP technologies relative to the program's appropriations and grants.

3.1 CURRENT STATUS OF ERIP INVENTIONS

An analysis of the status of ERIP technologies in 1991 indicates that many of the inventions are actively being developed (Table 3.1). Only 20% of the random sample and 6% of the promising sample represent projects that have been suspended or failed. (Recall that the random sample is biased against success because it excludes those inventions deemed most promising.) These estimates would increase to 50% and 19% if we assume that all of the incomplete interviews are associated with technologies that are no longer being developed. Indeed, it is likely that at least some nonrespondents have gone into bankruptcy, been reorganized, or have otherwise failed in their commercialization efforts--in contrast to the blank cells shown in Table 3.1 for these situations. Because such inventors are difficult to locate due to address changes, and they are typically less willing to talk, it is not possible to characterize the causes of such failures, using the current data. However, inventors who were interviewed this year about their suspended projects often cited low energy prices, the general lack of concern

Table 3.1 Level of activity of ERIP projects in 1991

	Random Sample		Promising Sample	
Activity Status	Number of Inventions	Percent	Number of Inventions	Percent
Activity being pursued	25	57	68	77
Low level of effort	10	23	15	17
Suspended temporarily	2	4	1	1
Suspended indefinitely	7	16	4	5
Failed	-	-	-	-
Chapter 11 reorganization	-	-	-	-
Chapter 7 bankrupt	-	-	-	-
Totals	44	100	88	100

about energy issues, lack of financial capital, and the economic recession as causes of their difficulties.

At least 31 of the inventions included in the 1991 survey were being actively developed, but had not yet experienced sales by the end of 1990. For many of these, their ERIP grant periods have lapsed, and development funds are coming from non-government sources. For other technologies that have not yet entered the market or have only minimal levels of sales, financial and other barriers are problematic.

Table 3.2 describes the status of ERIP technologies in 1991 using a typology of seven stages of technology development. These stages are consistent with a model of the innovation process developed by Livesay, Rorke, and Lux (1989). This model was developed as a pedagogical tool for ERIP's Commercialization Planning Workshop, and it emphasizes the inter-related technical, market, and business tasks required to bring an invention to market. Applying the typology of technology development to our data indicates that few of the random sample of inventions have advanced to a production prototype stage or further (30%), while 63% of the

Table 3.2 Stage of development of ERIP technologies in 1991

	Random Sample		Promising Sample	
Stage of Development	Number of Inventions	Percent	Number of Inventions	Percent
Concept definition and development	4	11	0	0
Working model	4	11	4	5
Prototype development, testing, engineering design	9	25	15	19
Pre-production prototype testing	8	22	11	14
Production prototype	2	6	8	10
Limited production and marketing	7	19	18	23
Full production and marketing	2	6	23	29
Totals	36	100	79	100

promising sample has progressed to a production prototype stage or beyond, thus validating the selection of the "promising" group.

A crosstabulation of activity status and stage of development indicates that many of the random sample of technologies have been suspended at early stages, while most of the promising technologies in these same early stages are still being actively pursued. Again, this confirms the validity of the perceptions of our key informants, regarding the identity of promising technologies. It is likely that many of the promising technologies that have not yet experienced sales will have been commercialized by the time of the next impact evaluation, scheduled for 1993.

3.2 THE NUMBER OF COMMERCIALIZED ERIP INVENTIONS

Significant commercial progress has been made by ERIP inventions during each of the most recent evaluation study periods. By the end of 1990, 109 ERIP inventions are known to have achieved sales. Another 13 inventions were licensed or sold to another company for development or sales, but had not achieved sales by 1990. The status of these 122

"commercialized" inventions is shown in Fig. 3.1, using a typology of three different commercialization strategies:

(1) the inventor of the ERIP technology uses his/her existing company as a business infrastructure for developing and marketing the technology;

(2) the inventor starts a new business venture to launch his/her ERIP technology; and

(3) the inventor licenses or sells the ERIP technology as a means of bringing the technology to market.

The inventor typically retains an instrumental role in the innovation process with either of the first two strategies. The sales resulting from both strategies are therefore called "direct." This is not usually the case when the technology is licensed or sold by the inventor to another

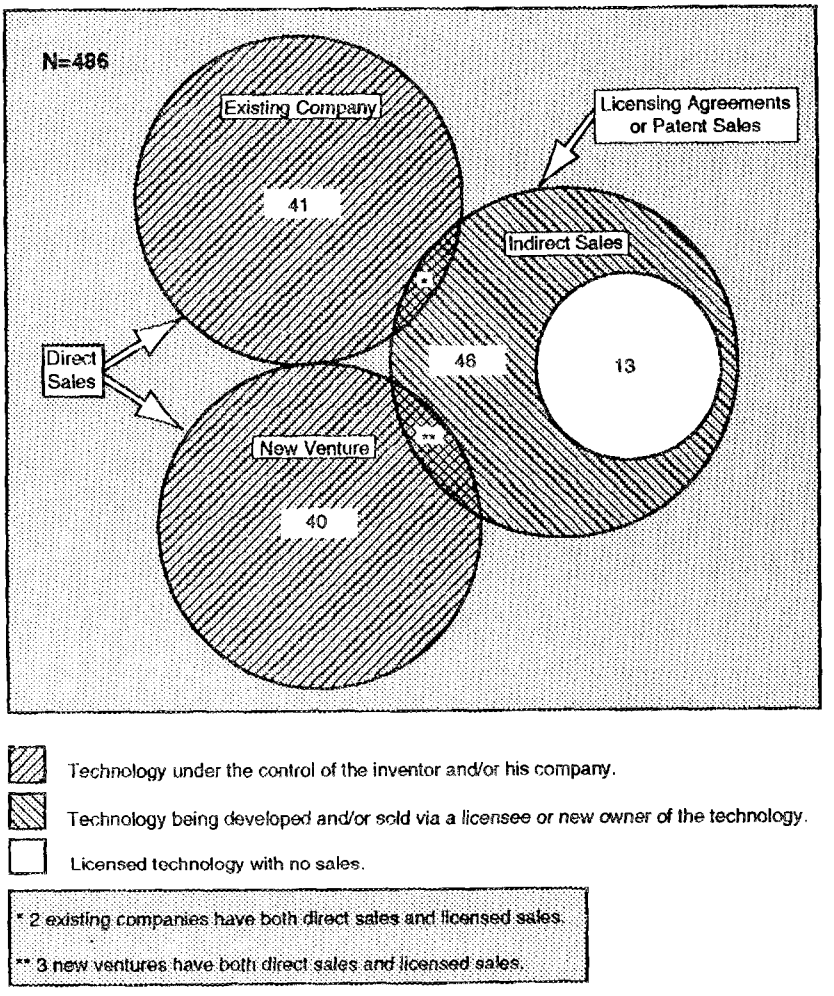

Fig. 3.1. Classification of 122 commercialized inventions.

enterprise. Sales resulting from this third strategy are therefore called "indirect."

Between 1980 and 1990, approximately 30% (N=33) of the 109 ERIP inventions with sales were commercialized by a licensee. This proportion decreased slightly between 1988 and 1990. Over the same period, the proportion of technologies with sales through new ventures has increased somewhat to 37%, and the proportion of successful technologies with sales through pre-existing companies has remained steady at about 38%. The reason these percentages sum to 105% is that five ERIP technologies have been commercialized via licensing agreement and sales through the inventor's new venture (N=3) or existing company (N=2). These trends are documented in Table B.1 in Appendix B.

Figure 3.2 illustrates the number and types of commercialized inventions between 1984 and 1990. The bar diagrams show that the total number of commercialized inventions with sales has grown steadily since 1984. The number of licensing agreements that have never generated sales, on the other hand, has diminished over time.

As is typical of new products and new technologies in general, there is great variation in the levels of sales generated by the ERIP inventions (Fig. 3.3). Cumulative sales for individual inventions range from $7,000 to $112 million through the end of 1990. Fifty-three (or almost half) of the inventions in the market have cumulative sales of less than $500,000, while 56 of the inventions are above this threshold. The average cumulative sales of these 109 ERIP technologies (approximately $4.6 million) is much larger than the median, reflecting the impact of a small number of very successful technologies.

Three of the inventions with sales in 1989 and 1990 were identified by surveying the randomly drawn sample - the 76 inventions that were included to test the hypothesis of complete sales coverage by the promising subsample. Since the random subsample represents 20% of the inventions about which information was being estimated, we can deduce that other inventions for which data were not collected had probably generated sales, and our best estimate is 12. None of the random sample had license agreements without sales. This brings the total number of commercialized inventions to 134 (122 + 12), of which 90% [121 (109 + 12)] had sales. Using the base population of 486 inventions, then, it is estimated that 28% of the inventions were commercialized and 25% had achieved sales by the end of 1990.

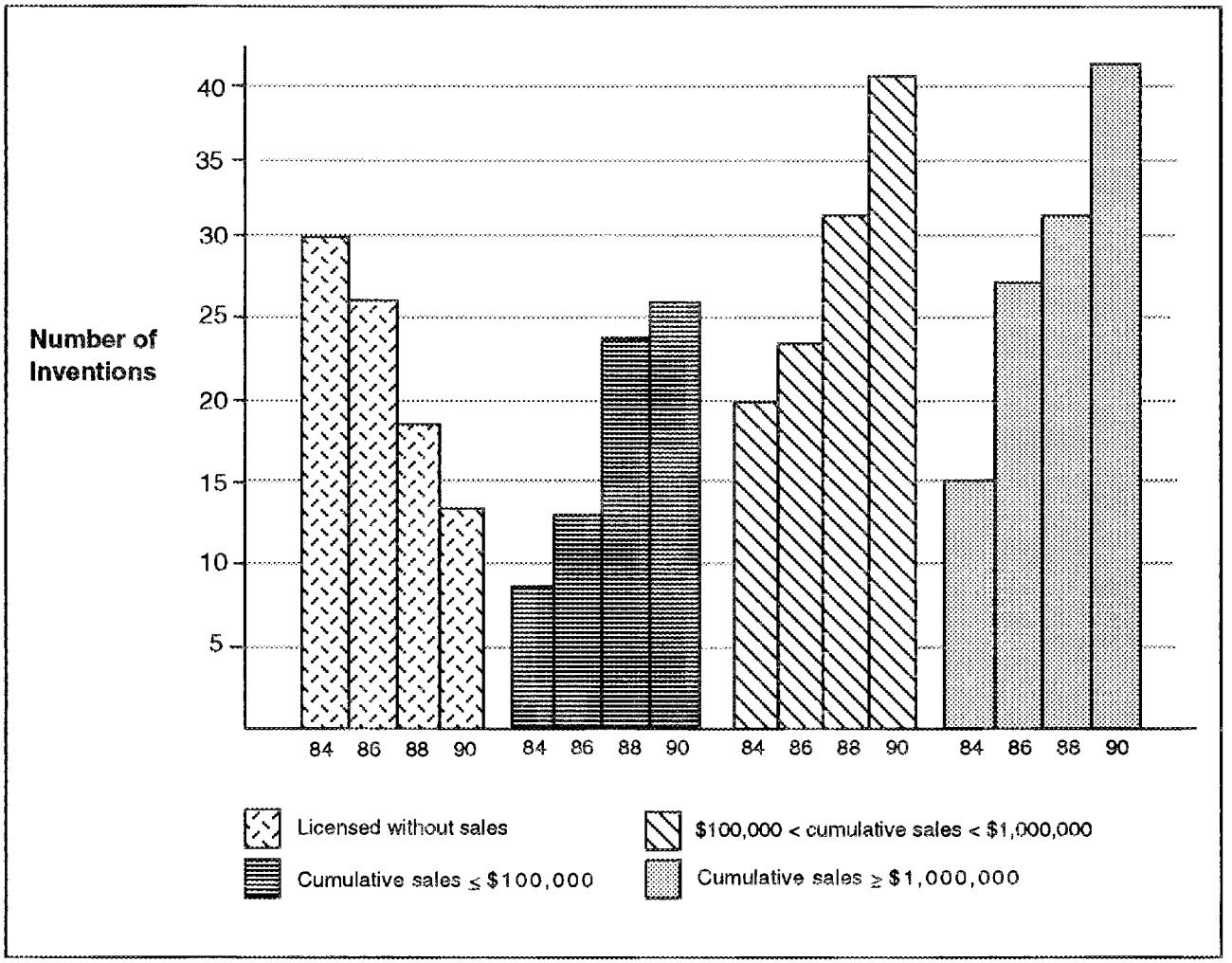

Fig. 3.2. Commercialized inventions: 1984, 1986, 1988, and 1990.

This finding compares favorably with the success rates of technological innovations as a whole. The widely cited Booz-Allen & Hamilton studies (Booz-Allen & Hamilton, 1982), for instance, reported that despite considerable investments in up-front stages of exploration, screening, and business analysis, it still takes seven new product efforts to get one product to market - that is, only 14% of new products are successfully introduced. This suggests that ERIP inventions may be at least as successful as technological innovations generally, though meaningful comparisons are difficult to make because of differences in products, technologies, and measures of success. The literature has reported success rates ranging from 1% to 85% (Cooper, 1983; Crawford, 1987).

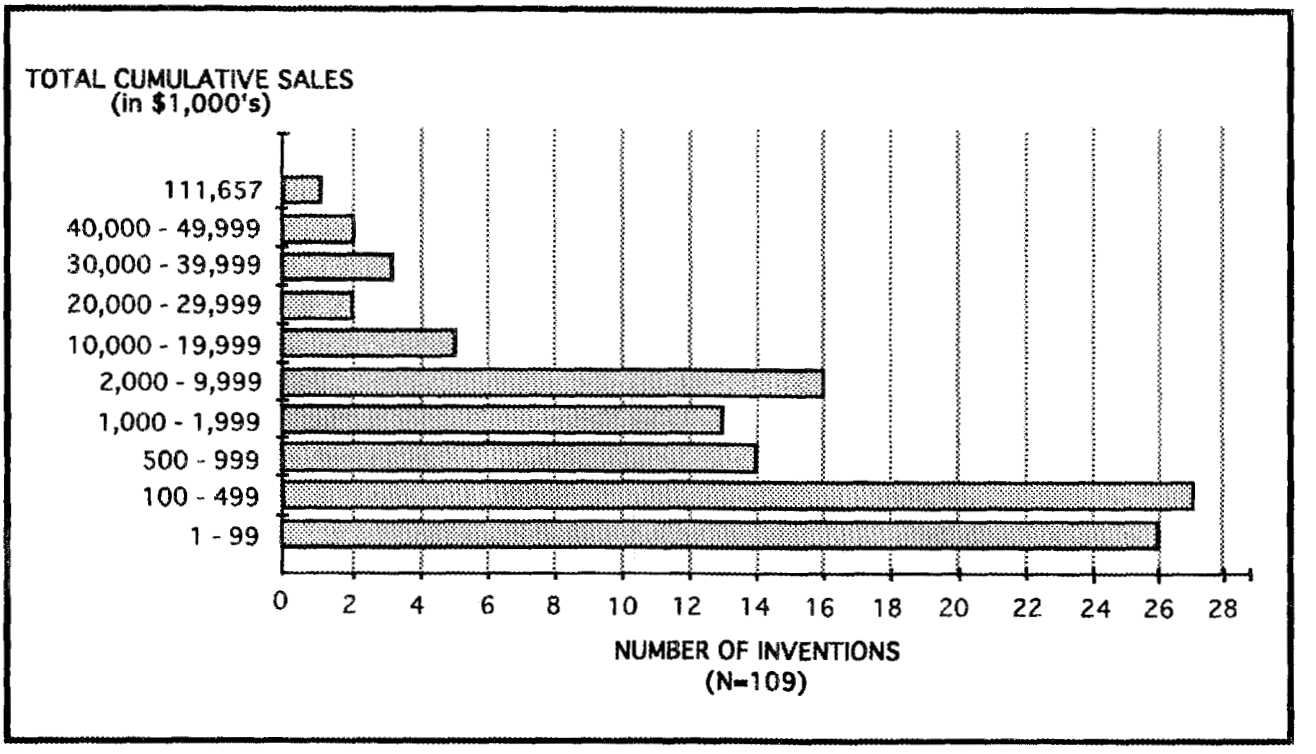

Fig. 3.3. Distribution of cumulative gross sales for ERIP inventions through 1990.

Another way to quantify commercial success is by comparing the number of ERIP technologies that have experienced sales to the cost of the Program. Between 1978 and 1990, ERIP expended $63.1 million, and at least 109 of the technologies it has supported have entered the market. Similar statistics are available for (1) the Gas Research Institute (GRI), which has operated an R&D program since 1978, and (2) the European Community (EC), which has operated a promotion and exploitation program since 1968 (*Chemistry and Engineering News*, July 8, 1991). By early 1991, 111 new or improved products, processes and techniques had been sold or were in commercial service, resulting from GRI's R&D budget of $1.41 billion (Dobrowski, et al., 1991). By 1990, approximately 50 inventions supported by the EC had been put on the market as the result of several billion dollars of R&D funding. ERIP's accomplishments compare favorably with both of these other programs.

The market entries and exits of ERIP inventions over the past decade are portrayed in Fig. 3.4. A market entry in a particular year is an invention that had sales that year, but not the previous year. A market exit occurs when an invention did not have sales in the year in

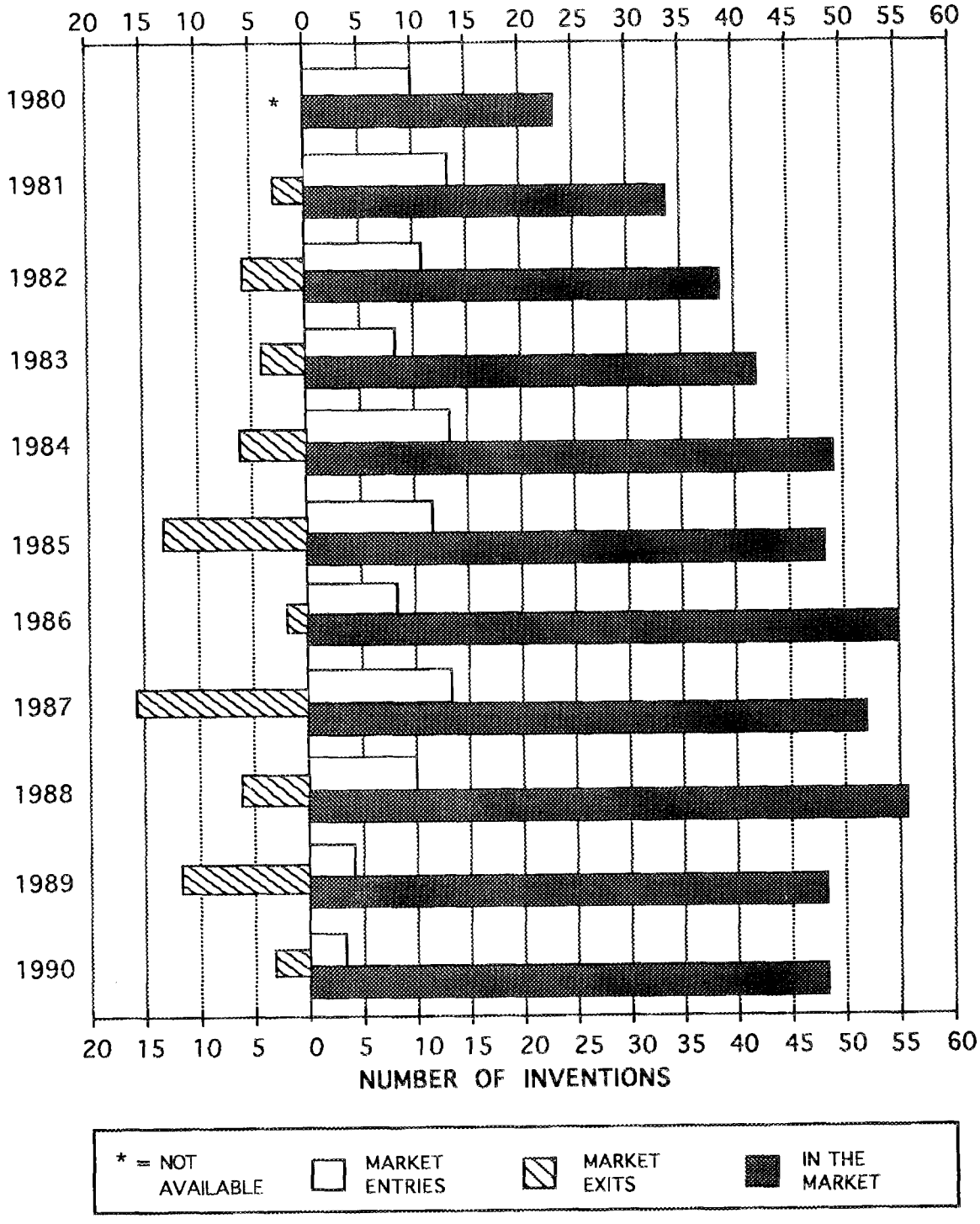

Fig. 3.4. Inventions entering, in, and exiting the market, by year.

question, but did have sales in the previous year. Inventions "in the market" had sales during the year in question; they may or may not have had sales in the previous year.

The number of ERIP technologies in the market more than doubled from 1980 to 1984 with market entries in most years outnumbering market exits by a wide margin. Between 1985 and 1990, the numbers of ERIP technologies in the market have fluctuated between 48 and 56. Compared to other years during this nine-year period, 1985, 1987, and 1989 had large numbers of market exits. These are also the three years where exits outnumbered entries. Five of the 12 exits in 1985 were due to license agreements that had been successful for two or more years prior to 1985, but which failed to generate continuous sales. Of the 17 market exits in 1987, four are due to missing sales data for technologies that may in fact have had sales. The same is true for several of the 12 market exits in 1989. The relatively low oil prices that typified the second half of this decade also had a perverse effect on a subset of ERIP technologies. Some of the market exits during this period were technologies whose market acceptance was tightly linked to energy prices. Most recently, several market exits have been severely impacted by the nation's recession.

Just as an entry into the market does not ensure continued success, not all exits are permanent. Indeed, ERIP offers several examples of technologies that were withdrawn, redesigned based on initial market feedback, and then reintroduced. Such a pattern is unusual, however. Most of the 109 ERIP inventions with sales have sustained product life cycles. Nearly two-thirds of the inventions that entered the market before 1987 were in the market for three or more years, and half of the inventions that entered in 1984 or earlier were still in the market by the end of 1990. These product longevity proportions compare closely to Crawford's (1987) observation, based on a review of the literature, that around 65% of new products succeed.

As the ERIP program has gained experience in identifying and supporting innovation, one would expect an increasing percentage of ERIP awardees to succeed in reaching the marketplace, assuming all other major factors were constant--quality of applicants, strength of the overall economy, energy prices, etc. Such a pattern is exhibited in Table 3.3 for those cohorts that have had sufficient time to realize their commercial potential (i.e., DOE numbers 1 through 300). The pattern of cumulative sales is significantly impacted by the longer time period that the earlier

Table 3.3 Number of ERIP technologies in the market by date of NIST recommendation

DOE Numbers	Date of NIST Recommendation	Numbers of Inventions in the Market	Total Cumulative Sales (current-$)
1 - 100	02/12/76 - 03/30/79	22	$184,530
101 - 200	04/20/79 - 01/27/82	33	$104,176
201 - 300	02/26/82 - 04/30/85	25	$ 69,447
301 - 400	04/30/85 - 06/24/87	17	$134,131
401 - 486	06/30/87 - 09/26/89	12	$ 7,192

technologies have been in the market. The large cumulative sales of inventions with DOE numbers between 301 and 400, include the $112M in sales of a single technology (see Fig. 3.3).

3.3 SALES OF THE ERIP INVENTIONS

It is estimated that the total cumulative sales of ERIP inventions for the 1980 through 1990 period is $504 million. This total is the sum of the cumulative sales for those ERIP inventions for which we have some data about sales (known sales=$503 million), and an estimate of sales for those inventions about which sales data were not collected in 1991 (estimated sales=$500,000). These two estimates, shown in Table 3.4, are discussed below.

Table 3.4 Total cumulative sales of ERIP inventions (in thousands of dollars)[a]

Component	Sales (in $000's)
Sales based on 109 inventions[a]	503,025
Estimated sales from unsampled inventions[b]	500
Total	503,525

[a]Sales of 109 inventions for which data are available.
[b]Estimated sales of inventions that are not in the 1991 sample of 183 inventions, based on data from a 20% random sample.

3.3.1 Sales Based on 109 Inventions

The total cumulative sales for the program based on 109 inventions for which annual sales are available is estimated to be $503M through 1990. The yearly sales reported for 1980 through 1988 differ somewhat from the sales previously reported in Brown and Snell (1988) and Brown and Wilson (1990). The current evaluation has filled in some of the missing data for the 1980 to 1988 period, and in some cases the historic data have been corrected. In particular, some of the sales previously credited to ERIP technologies have been redefined as sales of spin-off technologies, as discussed in Chapter 4. The net effect is to reduce by 30M the estimated sales of ERIP technologies through 1988.

After a rise in annual ERIP sales between 1980 and 1982, annual sales remained fairly steady for several years and then jumped to $60M or more for each of the years between 1986 and 1990. These sales are bolstered significantly by several innovations that have gained substantial market shares and have experienced sustained commercial success. (Table B.1 presents annual sales totals by commercialization mode for each year from 1980 through 1990.)

In aggregate, license agreements have generated more sales than inventions marketed directly by the inventor's existing company or through new ventures. On an invention-by-invention basis, the difference is even more pronounced. For each invention on the market through a license agreement, cumulative sales have averaged $9.3M. For each invention sold directly by an inventor's existing company or through a new venture, average cumulative sales are only $0.9M and $4.0M, respectively.

The greater sales resulting from licensing may be attributed to several factors. License agreements are likely to be concluded when the licensor finds a firm that has access to channels and markets that the inventor could not tap on his own, and the licensee perceives a considerable market for the technology. Licensees tend to be established enterprises that have already gone through the start-up phase that new ventures or recent enterprises still must experience. Licensing thus provides an avenue for rapid market entry (Weigand, 1986).

3.3.2 Estimated Sales from Unsampled Inventions

The random sample of 76 inventions drawn to test the comprehensiveness of this study identified total sales of $125K. Since this sample represents 20% of the inventions about which

information needs to be estimated, for every dollar attributed to the 20% sample, an additional four dollars can be assumed to characterize the remaining 80% of the population. Thus, the $125K can be multiplied by four to obtain an estimated $500K increment to the program's total sales.

This extrapolation brings the estimate of total cumulative sales to $504M for the 1980 through 1990 period. However, because the $504M figure is based on extrapolation and is not very different from the $503 million based on documented sales, the slightly lower figure is the one used in summarizing the Program's accomplishments.

Besides omitting these extrapolated sales, the $503M sales total is an underestimate due to two additional omissions:

- direct sales prior to 1980; and
- foreign license agreements and instances of multiple licensing, where royalties and sales data are often missing from our data base.

The total also does not include the sales of spin-off technologies. These sales are estimated separately in Chapter 4.

Figure 3.5 compares the estimates of gross invention sales to program appropriations and grant awards, on a cumulative basis using "current" dollar values. It vividly illustrates the substantial increase of invention sales over grant expenditures and appropriations.

As an indicator of the effectiveness of ERIP, the $503M in cumulative gross sales known to have been generated by ERIP inventions can be compared with program costs. Approximately $25.7M in grants were awarded through 1990, and program appropriations totaled $63.1M over the same period. Thus, the ERIP program has generated a 20:1 return in terms of the value of sales to grants, and an 8:1 return in terms of sales to total program appropriations (including grants). These ratios are slightly lower (19:1 and 7:1) when "constant" dollars are used. This is because the grants and program appropriations have been more evenly distributed over the program's history, while sales only begin in 1980.

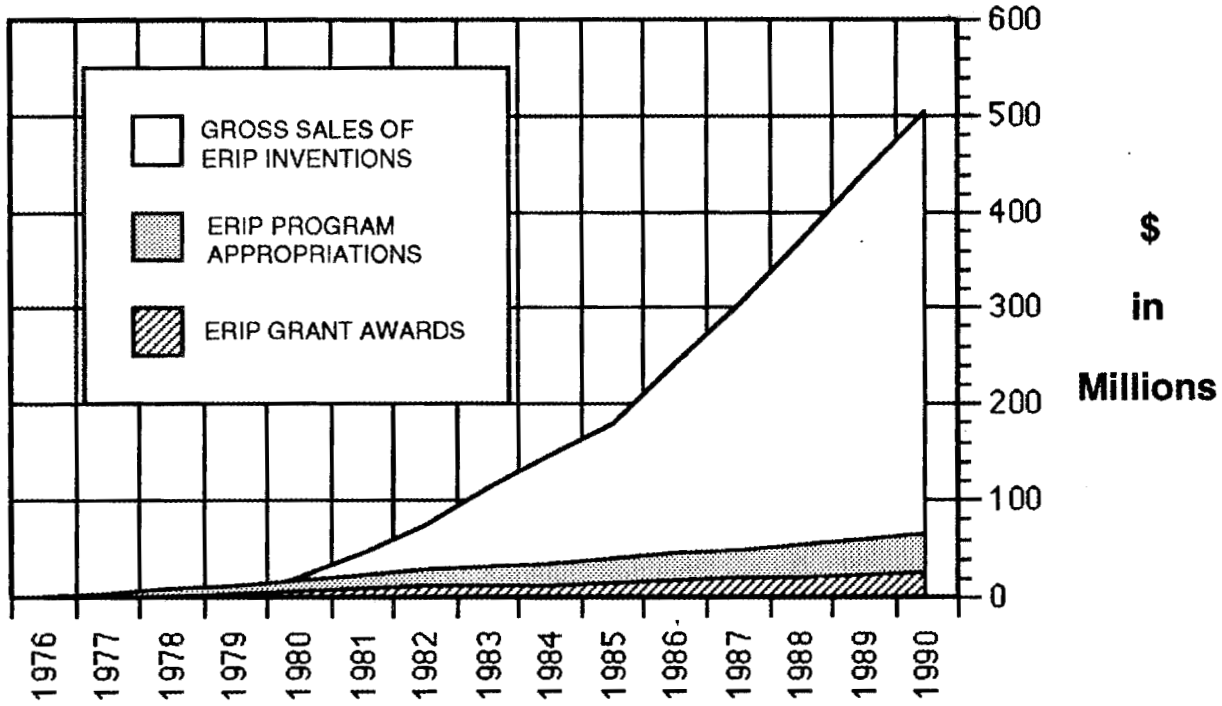

Fig. 3.5. Grants, program appropriations, and cumulative reported sales.

4. COMMERCIAL PROGRESS OF SPIN-OFF TECHNOLOGIES

4.1 DEFINITION AND EXAMPLES OF SPIN-OFF TECHNOLOGIES

Chapter 3 documented the commercial progress of the energy conservation and supply technologies supported by ERIP. This chapter focuses on commercial activities that have resulted in part, or in total, from completion of an ERIP project, but that do not involve the ERIP technology as defined in the original invention disclosure to NIST. These spinoff activities are often serendipitous by-products--they were unplanned, unforeseen, and unintended when the ERIP project was initially conceived. Nevertheless, they represent tangible benefits that have accrued from the Program.

The term "spin-off" has acquired a number of meanings in the technology transfer literature. It is often used to refer to any commercialization of a government-funded R&D project. This definition is common in the context of military and space R&D where a case can be made that any commercial product is a spin-off in that it is an alternative application of the original technology. Thus, the focus is on the technology's market applications. Another frequently encountered use of the term spin-off refers to the creation of firms organized to pursue the private development of technology initially supported with public funds. This use of the term focuses not on the technology and its market applications, but on the corporate ownership of the technology, which may pass through different businesses on its way to an array of markets.

Our definition of spin-off activities differs from both of the above concepts. It incorporates technology and market factors: to be an ERIP spin-off, an activity must be significantly different from the original ERIP project (either along technology or market dimensions). Further, the activity must have been significantly facilitated or enabled by the original ERIP project (which may include the support of a business that otherwise would not have been able to engage in the activity). The market and technology dimensions are the basis of a typology of two different types of spin-offs: alternative market applications and second-generation technologies. This typology and some examples of each type of spin-off are shown in Fig. 4.1. In discussing and illustrating the typology, we also address the requirement that the ERIP project was instrumental to the occurrence of the spin-off activity.

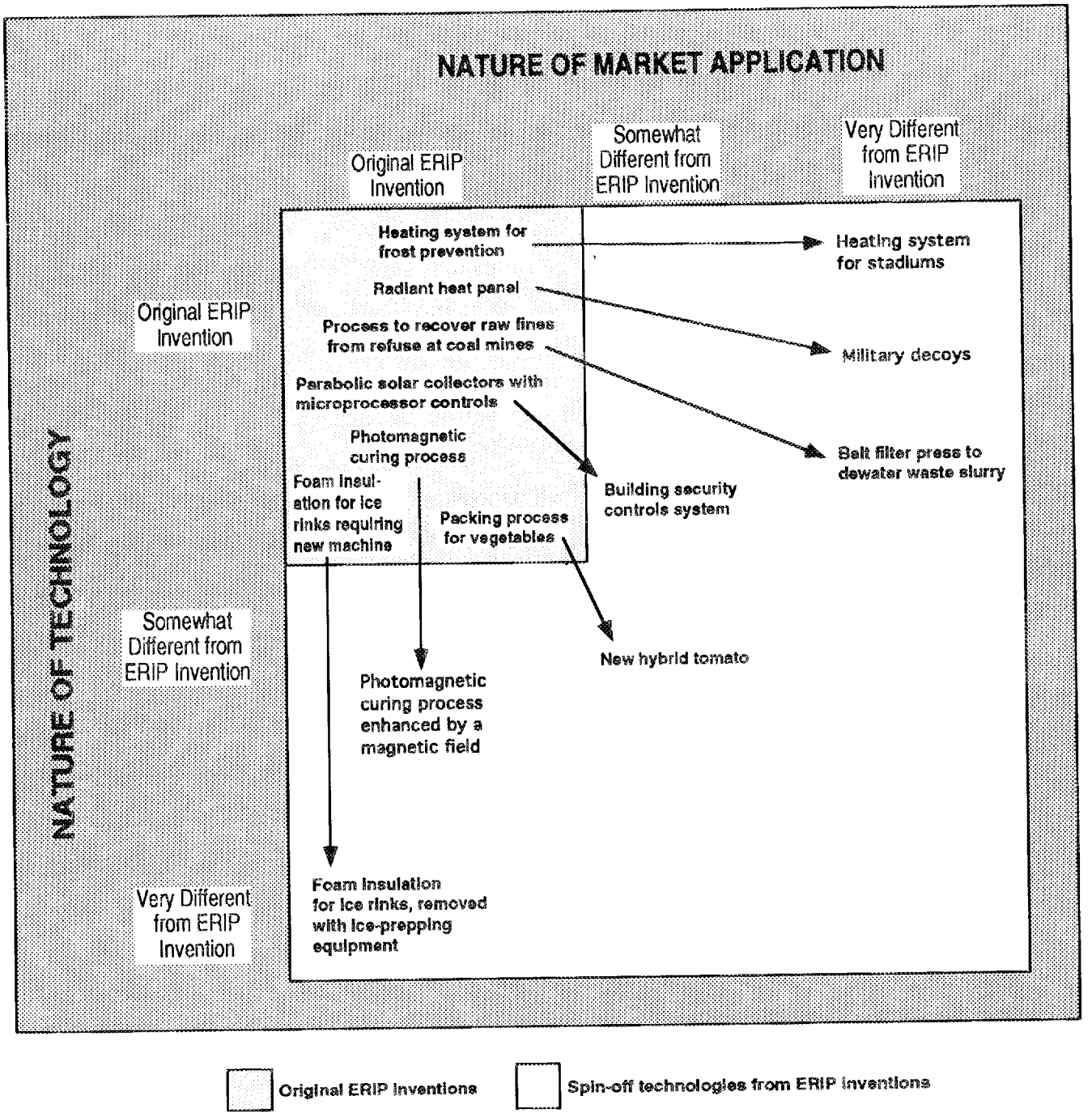

Fig. 4.1 Typology and illustrations of spin-offs from ERIP technologies.

Alternative market applications occur when an ERIP technology that was supported to solve a specific energy-related problem, is subsequently successfully applied to an entirely different market or use. For instance, one ERIP inventor received a DOE grant to develop a thin conductive paint to provide radiant heating in buildings. The paint was subsequently used to create military decoys (for heat-seeking missiles) that were successfully deployed in Operation Desert Storm. Similarly, DOE provided a grant to an inventor to develop a process to recover raw fines from refuse piles at coal mines. This application proved non-economic, but the technology has been successfully adapted as a belt filter press to dewater municipal wastes.

Alternative market applications may require little follow-on development to be useful in their new context. For instance, one ERIP participant developed a portable space heater and gas burner to prevent frost damage to crops. The heater draws a large volume of warm air through a duct from above the crops by means of a large blade fan; the warm air is then directed across a propane-fired flame heater where it is heated and then directed out of the apparatus at ground level into the crops to be protected. The technology has subsequently been used to heat football stadiums, without any significant redesign. This is considered a spin-off activity. The technology's subsequent use in greenhouses was incorporated in Chapter 3 as sales of the core ERIP technology, and not as spin-off sales, since the technology is essentially unaltered and the market niche is similar to the original application--i.e., preventing frost damage of crops.

Other alternative market applications have required significant redesign and technology development of the original ERIP technologies to prepare them for their new uses. Examples include several components of ERIP technologies that have been taken and used in whole new systems. Such possibilities are particularly likely in more complicated technologies that themselves comprise an ensemble of separate parts. For instance, ERIP supported the development of a lightweight frame and tension form to ease production of parabolic solar reflectors. The technology included a microprocessor that allows remote monitoring of the device's performance. The solar collector device proved difficult to sell, but the microprocessor control technology has been successfully used in building security systems. Another ERIP project focused on the development of a temperature control system for buildings. This technology and line of business failed for the ERIP participant, but as a result of ERIP funding, the inventor's start-up company gained expertise with microprocessors and was able to move into

a new product area--the design and construction of microcomputers for specialized laboratory and corporate uses.

Second-generation technologies are ERIP technologies that have been significantly altered and enhanced through subsequent R&D. Typically this occurs after the original technology was found to be technically or economically impractical. For instance, one ERIP inventor received a grant to develop a polymerizing process for thermosetting resins that used pulsed xenon arc discharge lamps. With DOE funds in hand, the inventor imbedded the polymerization process within an electromagnetic field, significantly accelerating the curing process. This was an unanticipated technological breakthrough which significantly altered (and improved) the nature of the product.

Usually these second-generation technologies build on experiences in addressing a particular market or industry-specific need. This was the case with an energy conservation measure for ice rinks. The original technology involved applying a foam directly to the ice at night, using a specially-designed machine, and then removing the foam to a storage area during the day. The "new and improved" technology involves a low-cost retrofit to the standard Gamboni ice-prepping machine, and requires no storage. ERIP enabled the inventor to develop the more marketable second-generation technology as the result of the market knowledge acquired in trying to commercialize the original technology.

Second-generation technologies can sometimes be characterized as "enabling technologies"--that is, they make possible the realization of other product improvements. For instance, one ERIP participant received a grant to develop a packing process that allows fruits and vegetables to be transported without refrigeration. With this packing system successfully in place, the inventor commissioned the development of a new hybrid tomato with a particularly appealing flavor that can be retained in the non-refrigeration packing and shipping process developed during the ERIP project.

4.2 SALES OF SPIN-OFF TECHNOLOGIES

Numerous spin-offs from ERIP projects are in early stages of development by ERIP participants--in fact, some are simply ideas that remain to be pursued. Others have already generated sales. Information on the commercial progress of spin-off technologies was first

collected during the 1989 ERIP evaluation. This year the data collection benefitted from greater clarity in the definition of spin-off technologies. In particular, many sales that were initially classified as sales of an ERIP technology were redefined as sales of a spin-off. The result is that by 1991, we have identified 23 spin-off technologies generated from 20 ERIP projects, where the spin-offs have accumulated $32 million in sales through 1990.

Most of these 23 spin-off technologies are alternative market applications. Eighteen of them spun off from ERIP technologies that themselves had experienced sales. Five spin-off technologies are associated with ERIP technologies that had no sales because they were significantly flawed either technically or economically.

The commercial impact of ERIP's spin-off activities has grown substantially over the lifetime of the program. Most of the spin-off technologies identified in this evaluation are fairly recent developments, with sales beginning in 1985 (see Fig. 4.2). It is likely that the role of alternative market applications and second-generation technologies as ERIP by-products will continue to increase in importance as long as energy markets remain soft and inventors are forced to find alternative applications for their technologies to achieve commercial success. The growth in spin-off technologies is a natural concern for entrepreneurs who wish to maximize the profits associated with their portfolio of inventions. One challenge for the Program is to find ways to assist inventors who have robust core technologies that can benefit a wide array of different markets and industries.

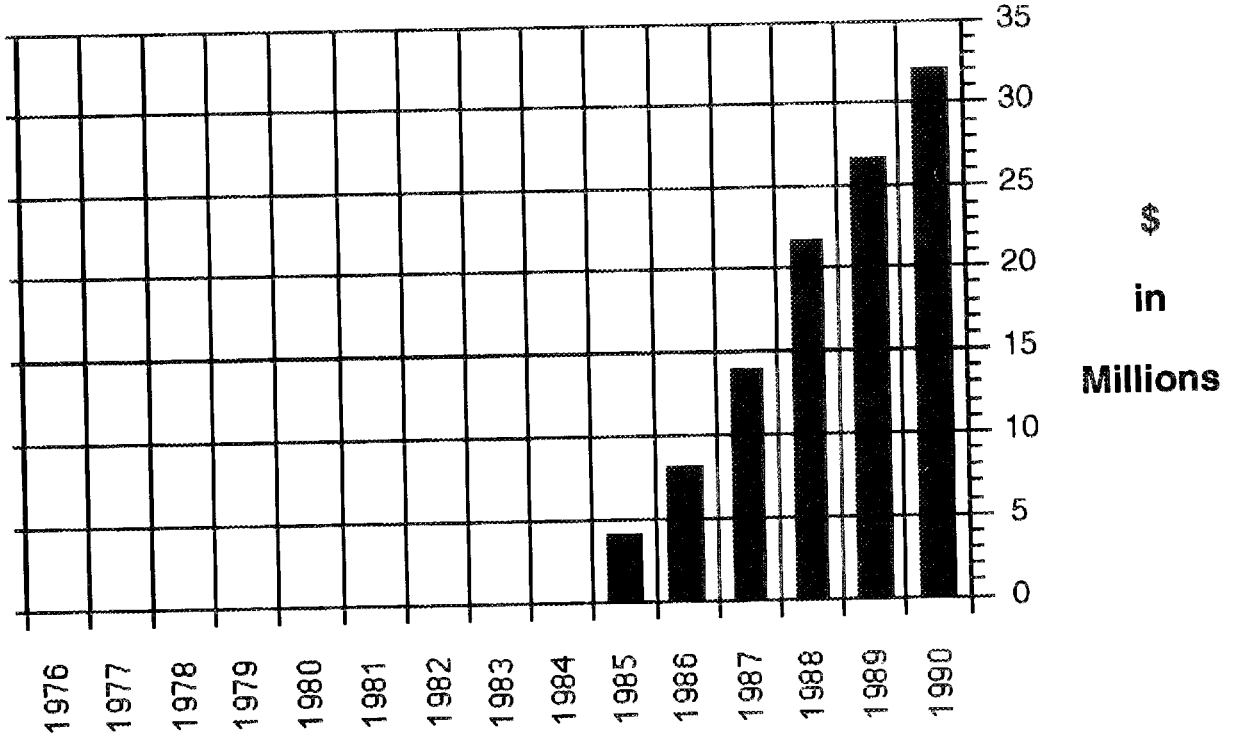

Fig. 4.2. Cumulative sales of spin-off technologies.

5. JOB GENERATION AND TAX REVENUES

Technological innovation is a major determinant of economic growth. It is a critical driving force in creating jobs, enhancing tax revenues, and expanding exports. Small businesses have been particularly successful in producing creative innovations for the marketplace (The Futures Group, 1984) and are seen as key players in employment and economic growth (Birley, 1987; Presidents Commission, 1984). Firms with less than 500 employees dominate job creation: the vast majority of new companies are small, and most of the jobs derived from business expansions occur within small businesses. Between 1976 and 1984, small firms accounted for 60.5% of the 17.0 million net new jobs in the United States (Kirchhoff and Phillips, 1988).

This chapter looks at the impact that ERIP's support for small business innovation has had on the generation of employment and tax revenues.

5.1 JOBS GENERATED BY ERIP TECHNOLOGIES

The direct employment associated with the marketing of inventions is the Program's most visible employment impact. Our data indicate that there is a significant amount of direct job generation that has resulted from the technical development, production, and sales of ERIP technologies. Previous data documented that the largest impact on direct employment occurs at the production/marketing stage, although significant numbers of jobs can be generated while developing prototypes (Brown, et al., 1987b). Further, it is not until the production phase that employment can be fully supported by revenues generated by the invention itself. In prior stages, work on the technology is largely subsidized by other sources. Results from this evaluation correspond closely with previous findings.

The 1991 survey solicited data on the number of full- and part-time employees working on the ERIP technologies in 1989 and 1990. Part-time employees were assumed to work half-time for the purpose of calculating numbers of full-time equivalents (FTEs). Employment data for 1984 through 1988, published in previous ERIP evaluations, are also presented for comparison purposes.

Employment data for 1989 and 1990 are available for most of the inventions with direct sales (since the inventors themselves tended to be interviewed), but they are available for less

than half of the inventions being commercialized through license agreements (since not all of the licensees were interviewed). When sales are known, but employment data are unavailable, employment estimates are generated from ratios of ERIP sales to FTEs. (These ratios are provided in Appendix C, Table C.1.) For example, in 1990, the sales-to-FTE ratio for ERIP inventions with known sales and employment, was $72,000. An additional $2.7 million of sales in 1990 is associated with an unknown number of full-time equivalent employees. Using the $72,000 ratio, the estimated FTEs supported by $2.7 million of direct sales is 37. Table C.2 shows the values of known vs. estimated FTEs, for ERIP technologies sold either directly or indirectly.

The ratio of sales to jobs is quite low for inventions sold directly by an inventor's business, with mean values ranging from $67,000 to $84,000 for the years 1984 through 1990. This is somewhat lower than the national average for small businesses with some R&D -- the U.S. General Accounting Office (1984) estimates the ratio to be $107,000 (in 1982 dollars).

The dollar volume of sales per employee working on an ERIP project under a licensee is much higher, ranging from $100,000 to $266,000 over the same seven-year period. The ratios of sales to full-time equivalent employees in 1989 and 1990 are $117,000 and $114,000, respectively.

On the basis of these results, Fig. 5.1 portrays the estimated numbers of FTEs supported by ERIP technologies - 582 FTEs in 1984, 470 in 1985, 788 in 1986, 671 in 1987, 716 in 1988, 768 in 1989, and 758 in 1990. Thus, the total number of jobs generated by the Program since 1986 has remained steady, ranging from 671 to 788 FTEs.

The FTEs supported by technologies for which sales have not occurred, have varied widely over the past seven years. This is partly an artifact of the different sample sizes used during the four different evaluation surveys conducted in 1984, 1987, 1989, and 1991. The 1984 sample (Brown, et al., 1987a) was the largest of the four samples (N=204) and thus included a high proportion of non-commercialized inventions. It therefore documented a high number of jobs for inventions without sales. The 1985 and 1986 values (48 and 59 FTEs) are particularly low because the 1987 sample of randomly-drawn inventions was quite small (Brown and Snell, 1988), and it is the random sample which contains a disproportionate share of technologies that have not yet entered the market.

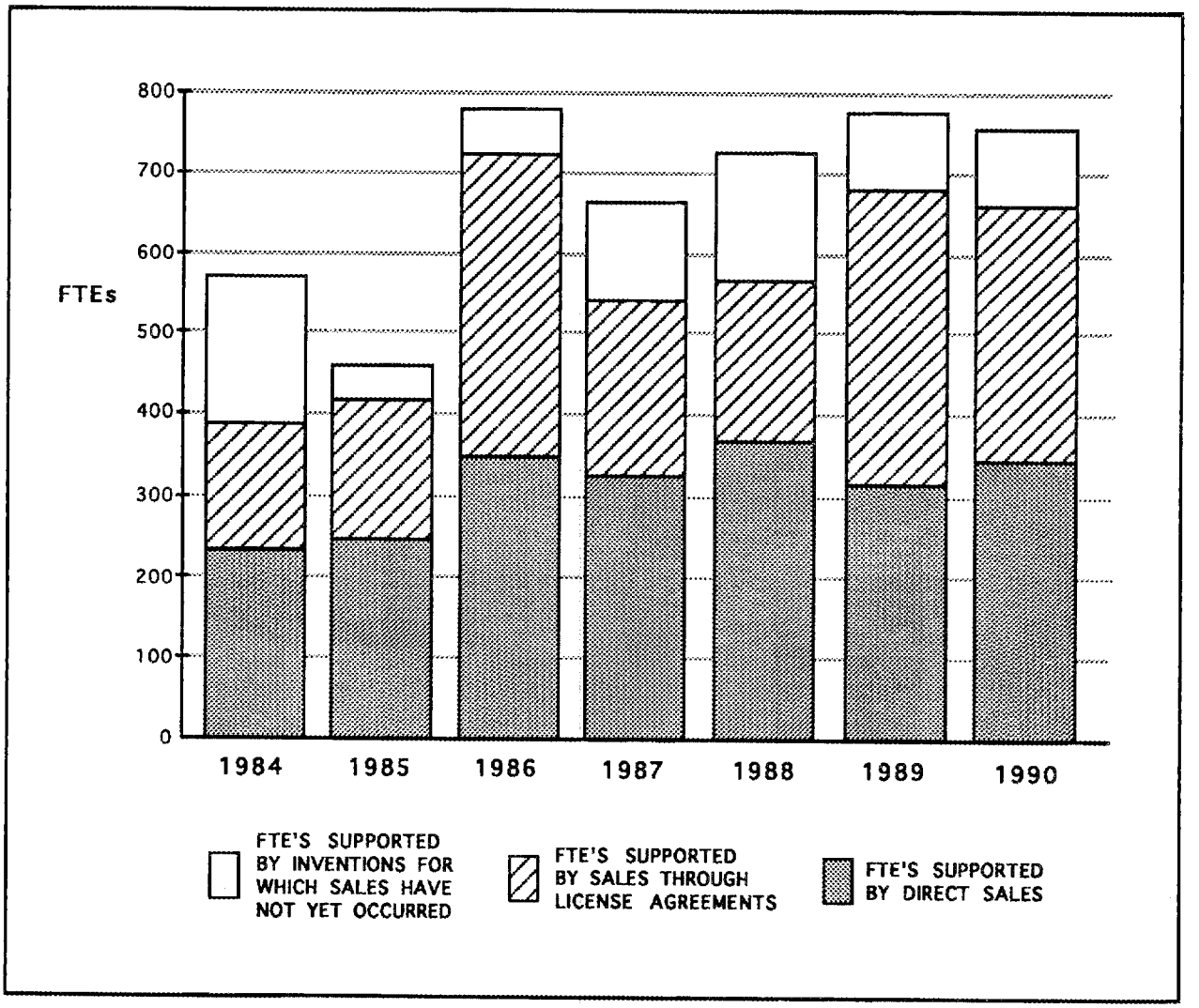

Fig. 5.1. Number of full-time equivalent (FTE) employees working on 143 ERIP technologies: 1984 through 1990.

The distribution of jobs per invention is highly skewed. In 1990, for example, three inventions with known employment each supported more than 40 FTEs, for a total of 200 FTEs. Another six inventions with known employment each supported 20 or more FTEs for a total of 192. Thus, out of 92 technologies with known employment in 1990, 9 technologies account for 71%. These same 9 technologies with a total of 392 FTEs support more than half (51%) of the

total of 758 FTEs supported by all ERIP projects in 1990. This is similar to the trend documented in previous ERIP evaluations.

Figure 5.1 indicates that since 1984, more jobs have been supported by inventions sold directly by inventors than by licensed inventions, despite the fact that licensing has generated greater sales. This is because the ratio of sales to jobs is lower for inventions sold directly than for licensed sales.

For a variety of reasons, our figures probably underestimate the Program's direct and indirect employment benefits. First, the sample of 143 ERIP technologies does not include many ERIP projects that have undoubtedly attracted outside funding, are supporting employees, but have fallen short of market entry. Second, the production of many ERIP inventions in the market relies on numerous subcontractors and suppliers that are not included in our estimates. Another significant group not represented here are the individuals (retailers, wholesalers, etc.) responsible for the distribution and sales of these products. Our estimates of employment benefits also do not discount for the jobs that have been displaced or lost by competitors and others. The diversity of consumer and industrial markets served by ERIP inventions argues against the use of a single multiplier to estimate the total employment impact.

5.2 TAX REVENUES FROM ERIP-GENERATED EMPLOYMENT

This section employs a simple and conservative approach to estimate the returns to the U.S. Treasury resulting from the Energy-Related Inventions Program. It focuses on the employment generated by the Program, and weights this employment by the average federal individual income tax to estimate the total federal taxes that can be attributed to the Program. A similar methodology has been used in other program evaluations (Chrisman, Hoy, and Robinson, 1987).

In 1987, the average federal individual income tax per return was $4,280 (U.S. Department of Commerce, Bureau of the Census, Table No. 514, 1990). Based on the statistics presented in the previous section, 758 FTE employees worked on ERIP technologies in 1990. Assuming that each of these employees paid $4,280 in federal individual income taxes, this amounts to a total return of $3,244,000 to the U.S. Treasury in 1990. This total is more than half the 1990 ERIP appropriations.

Additional tax revenues are associated with royalty payments on ERIP inventions, corporate income taxes, state and local sales and income taxes, and personal income taxes paid by indirect employment beneficiaries of the program.

6. ACQUIRING FINANCIAL SUPPORT

Small firms tend to face significant financial barriers to technological innovation. They typically have a pressing need for funds to support the testing, feasibility studies, market analysis, and business planning necessary to gain an adequate assessment in the marketplace. Small firms often lack internal resources to support technological innovation and find it difficult to obtain loans due to insufficient collateral and inadequate business skills. This sometimes leads to mergers or equity financing with larger firms - thereby compromising the relative advantage that the small business brings to the innovation process (Horesh and Kamin, 1983). Perhaps more often they simply are unable to secure adequate financial resources, a failure that causes premature project termination or an under-financed product that fails in the marketplace. The inability to fully fund the development of inventions is a major cause of failure to translate R&D into useful products and marketable processes.

6.1 THE NATURE OF ERIP'S FINANCIAL ASSISTANCE

The monetary grants awarded by the Energy-Related Inventions Program are provided to address the financial needs of small firms and individuals engaged in developing energy-related technologies. But not all ERIP inventors receive grants, and for those who do, the grants provide only a small contribution toward the total amount of capital required to bring a new technology to market. The average ERIP grant has been approximately $70,000.

In addition to the direct financial assistance provided by ERIP grants, the program can indirectly help meet the inventor's need for financing. Inventors often use their ERIP award as a source of credibility to aid them in attracting additional resources to further develop their technologies. ERIP support makes the inventor's company more credible in the eyes of potential investors. Finding a first investor when seeking capital is perhaps the most challenging part of the whole process. No one wants to be first, but if someone else is willing to participate, especially a federal agency based on an impartial evaluation of an invention's technical and commercial promise, others will follow.

For example, in one instance, an inventor parlayed a $50,000 ERIP grant into a $1 million award from a private industrial research institute. In several other cases, inventors have been

able to secure matching state or local grants, based on their ERIP support. Given the fact that very few inventors can fully develop, much less commercialize, their inventions solely on the funding provided by ERIP, it is important to study the amounts and sources of non-ERIP inventor funding.

Finally, the Program performs a brokering function for many of its inventors. It directs inventors to alternative sources of funding, and it disseminates information about promising inventions to potential sources of development and venture capital through the distribution of fact sheets and involvement in technology fairs.

6.2 THE COST OF TECHNOLOGICAL INNOVATION

A review of the literature indicates that ERIP inventions are typical of technological innovations at large, in terms of their development and commercialization costs. At the lowest end of the cost spectrum, Myers and Marquis (1969, p. 60) found that two-thirds of 567 surveyed innovations cost less than $100,000 (or approximately $325,000 in 1990 dollars) for development to the point of use. They examined a broad range of innovations, mostly minor, that were named as commercially significant by firms in five manufacturing industries. Kamin, et al. (1982) found that 82% (N=18) of the 22 small-business technological innovations they studied required total technological expenditures of $1 million or less. Their innovations were sampled from two major industrial sectors - electronics and chemicals. At the more expensive extreme, a 1973 survey of innovation cost patterns for Canada found that the average cost per project was $3.3 million for a diverse sample of 83 process and product innovations. Sixty percent of the innovations cost less than $1 million to develop (Stead, 1976).

Current information on total costs of technological innovation is available for 67 of the 109 ERIP inventions with sales (i.e., those that were interviewed in 1991). Seventy-six percent of these inventions cost less than $1 million to develop to the point of market entry or beyond (Fig. 6.1). The average total costs incurred by ERIP inventions with sales is $904,000. This high mean value reflects the skewed distribution of the cost data: 4 inventions with sales have incurred costs of more than $3 million, while 26 inventions with sales have incurred less than $100,000 in development costs. This wide variation in funding levels is due in part to industry, firm, location, and technology differences.

Some of the most successful ERIP inventions are products - simple in both their manufacture and content - with minimal capital requirements. There are several "do-it-yourself" solar technologies for homeowners, for instance. Other successful ERIP technologies require only nominal capital input for commercialization because they are simply a unique way of combining and utilizing components that are already available. These technologies frequently are assembled and distributed through subcontractors, thereby allowing the inventor to achieve considerable sales on a relatively small capital outlay.

At the other extreme, several ERIP inventions with large capital requirements are process technologies in the steel and related industries. Technical problems related to testing and refining industrial processes are costly, and these technologies often require the operation of full-scale pilot plants or expensive retrofits and demonstrations in fully-operating plants.

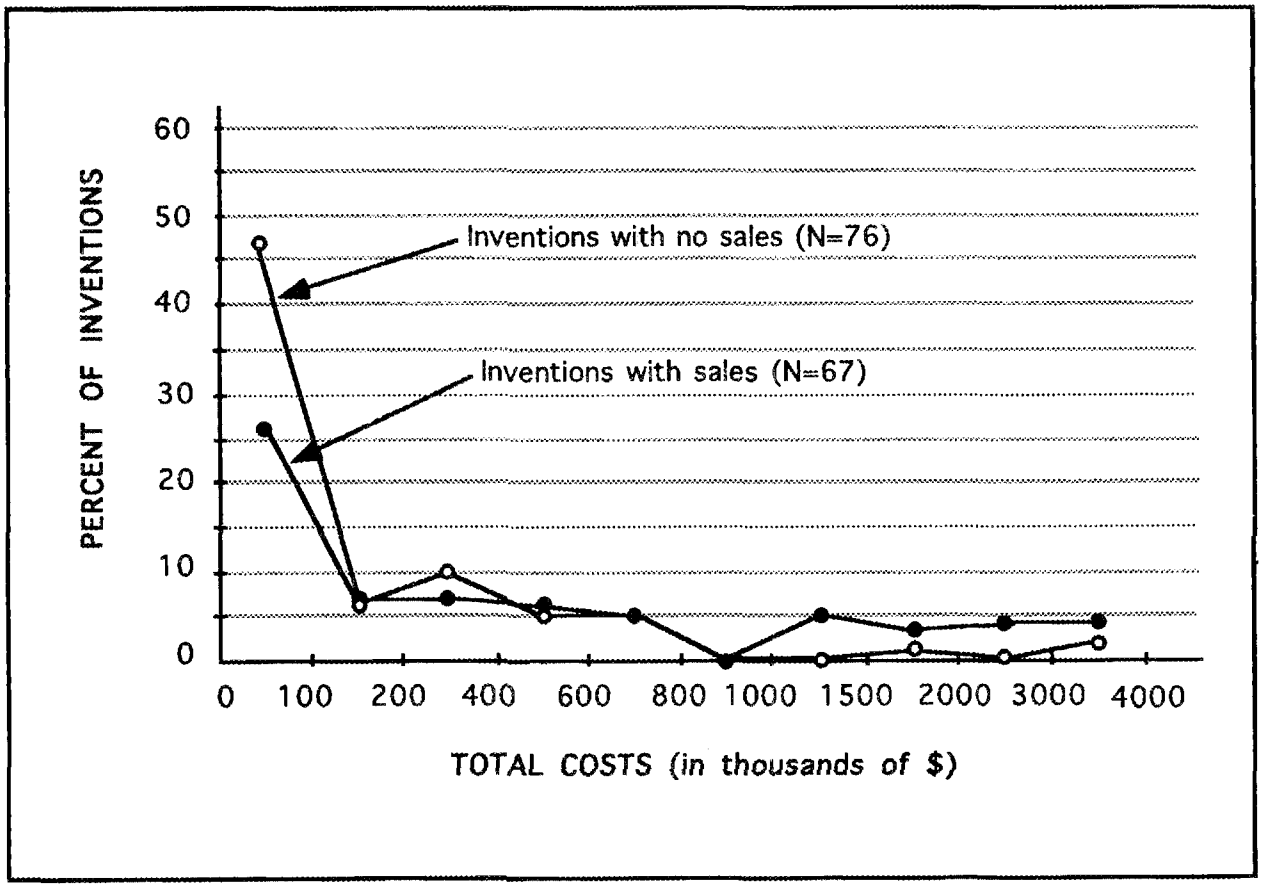

Fig. 6.1. Distribution of the costs of technological innovation for 143 inventions.

In contrast to the average cost of $0.9 million per invention with sales, the average ERIP grant is quite small. Its importance is due to its timing; the grant often arrives at a critical juncture when the inventor's funds are exhausted and other sources are unwilling to assist.

Inventions with sales have attained considerably higher levels of funding than those without sales. Funds raised to develop the 76 inventions in our 1991 sample that have no sales totalled only $305,000. The development of many ERIP inventions without sales has been retarded by lack of development capital. It is noteworthy that some 62% of the 76 inventions without sales raised less than $100,000 above and beyond DOE's ERIP grant.

6.3 SOURCES OF FINANCING FOR ERIP INVENTIONS

The financing of small business innovation has been portrayed as proceeding from personal resources and other informal sources of "friendly money" to more formal sources of capital, including equity financing by venture capital firms and stock offerings. Unfortunately, there is little systematic evidence concerning why the various sources of innovation financing become available and when they tend to be exhausted. "Start-up" capital has been shown to be dominated by the personal resources of the founder. However, since the start-up phase occurs early in the long process of product development, and since in any event many small business innovations are developed by existing companies, start-up capital is only one piece of the financing puzzle.

To facilitate analysis of the sources of funding for ERIP inventions, six types of financing were studied (see Fig. 6.2). This classification is used in Fig. 6.3 to characterize funding for ERIP inventors, with and without sales, before and after participation in ERIP, and excluding all ERIP grants. (Table D.1 in Appendix D provides the data from which Fig. 6.3 was derived.) Since a majority of the participants shown in Fig. 6.3 were part of the subsample of inventions identified as having the greatest near-term sales potential, these data are not representative of ERIP inventions as a whole. Rather, they over-represent those inventions in the later stages of development and those that have been more successful.

The ERIP inventors in our sample were able to raise three times as much capital after entry into ERIP as before. This is true of inventors with sales (with $241,000 before ERIP and

CLASSIFICATION OF FUNDING SOURCES
INTERNAL SOURCES
Personal -inventor's own savings -friends and relatives -funds from the development team -private stock offerings
Corporate -revenues generated through sales or royalties of the ERIP technology -internal funds from other sources of revenue -loans or in-kind contributions of customers or suppliers
EXTERNAL SOURCES
Commercial -R&D limited partnerships -venture capital firms -other outside investors
Public Stock Offerings
Lending Institutions
Public Agencies -local contracts, grants, and loans -state contracts, grants, and loans -federal contracts, grants, and loans

Fig. 6.2. Classification of funding sources.

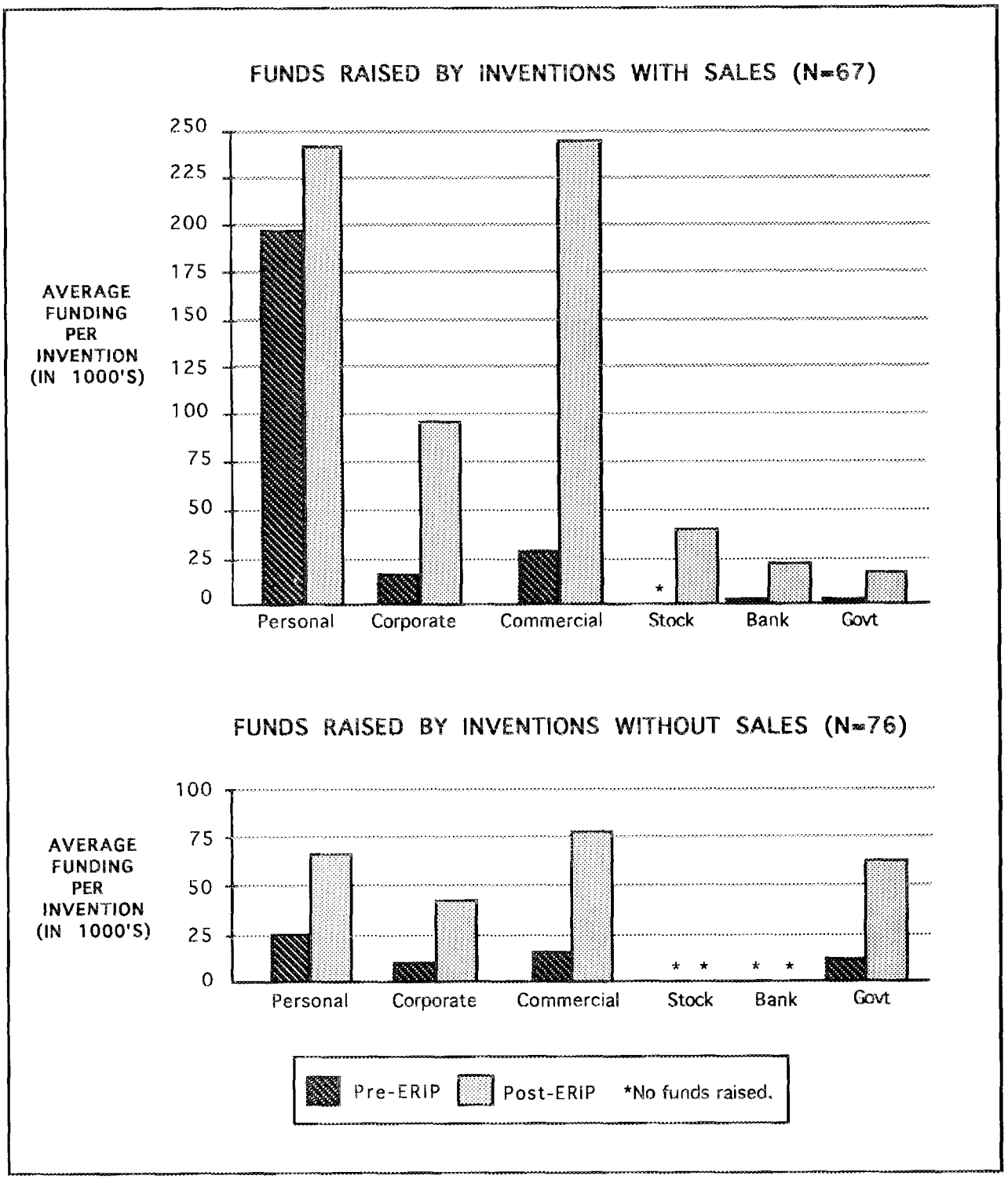

Fig. 6.3. Funding sources for ERIP inventions with and without sales.

$662,000 after ERIP), as well as those without sales (with $62,000 before ERIP and $242,000 after ERIP). This is consistent with the fact that both the need and the ability to attract funds increases as technologies get closer to market entry. Nevertheless, this dramatic increase suggests that participation in ERIP enhanced the ability of the inventors to attract commercial funding. Inventors often comment that participation in the program enhances their credibility with investors, and there is strong anecdotal evidence that ERIP has facilitated the acquisition of funds by program participants.

Figure 6.3 indicates that success in the market goes to inventors who invest personal resources and raise significant amounts of corporate and commercial money. Technologies that have entered the market have acquired considerably greater funding than those that have not yet had sales. This holds true in aggregate and for each of the six types of funding except government support, where ERIP inventions with no sales have, on average, received more than twice as much support as ERIP inventions with sales.

The two types of inventions have drawn upon different funding sources. Before application to NIST, inventors who eventually achieved sales applied eight times more personal funding (from sweat equity, their own funds, family and friends) than inventors who have not entered the market. What is perhaps more surprising is the level of continued reliance on personal sources of funding by both successful and unsuccessful inventors even after entry into the program. A third of the inventors without sales and nearly half of those with sales invested personal funds in their ERIP technology after entering ERIP, with successful inventors investing nearly three times as much, averaging $243,000. Many ERIP inventors are unwilling to solve their financing problem through licensing or venture capital because they are fiercely against losing control of their inventions. In some cases, significant funding is acquired via private stock offerings to business associates and members of the management team.

Commercial funding (e.g., venture capital and money from other outside investors) and corporate funding (reinvestment of revenues generated by the ERIP technology and subsidies from other business operations) are, after personal funding, the two most common sources of post-ERIP funding for inventions with sales. An average of $242,000 of commercial funding has been obtained by 25% of the successful ERIP technologies since participation in the Program.

Corporate funding was acquired, after entry into ERIP, by 36% of the ERIP technologies with sales, averaging $96,000.

Other sources of funding play a less important role for ERIP inventions. Throughout the innovation development process, lending institutions are much less important source of funds than are personal sources, internal corporate sources, or outside investors. Loans from commercial banking institutions have been utilized by 9% of the inventions with sales and only 1% of those without sales. Public programs other than ERIP have contributed funds to 7% of ERIP inventions with sales and 21% of those without sales.

Figure 6.3 summarizes the data from Table D.1 in graphical form to focus on the timing of internal versus external funds for the successful versus unsuccessful inventors. Whether or not ERIP has been responsible for this trend, the figure vividly documents the enhanced ability of ERIP inventions to attract external funding after participation in ERIP. It also highlights the continued reliance of ERIP participants on internal funds.

In aggregate, the 143 inventions for which financing data are available raised a total of $22.3M before ERIP and $62.2M after ERIP. These figures are undoubtedly low estimates for the Program as a whole because of the small sample size on which they are based, and the presence of a significant number of young technologies in the current sample. Technologies that have been sampled in previous years but which were not captured by the current sample design accumulated an additional $27.5M before ERIP and $39M after ERIP. Thus, altogether we can document that ERIP technologies attracted $50M in financing prior to Program application, and $101M in funding subsequent to Program application--excluding the ERIP grant. For every dollar provided by an ERIP grant (totalling $25.7M through 1990), participants have been able to raise almost four dollars of additional funding (i.e., $101M) to develop the same technology.

In addition to financial support, ERIP participants have sustained the development of their technologies by the application of sweat equity as well as non-financial support from their industries and the communities in which they live. While the value of this sweat equity is difficult to establish, there is a considerable commitment of personal time by ERIP participants which in some cases represents several years of uncompensated labor. In addition to sweat equity, ERIP participants have received non-financial support from diverse sources. Some ERIP

participants have received raw materials and advice from companies in their industries. Others have been provided access to laboratories or machine shops at universities. The dollar value of the non-financial support received is typically less than $5,000, but can come at a critical time during the development of the technology.

7. CONCLUSIONS

This evaluation reveals that 1989-90 was a successful period for many ERIP technologies. By the end of 1990, at least 109 ERIP inventions had entered the market, generating total cumulative sales of more than $500 million and offering the U.S. economy many energy conservation and supply benefits. With $25.7 million in grants awarded through 1990, and $63.1 million in program appropriations over the same period, ERIP has generated a 20:1 return in terms of sales values to grants, and a 8:1 return in sales versus program appropriations. It is estimated that 28% of all ERIP inventions are commercialized, and 25% achieved sales by the end of 1990. While it is difficult to make exact comparisons between these percentages and other indicators of the success rates of technological innovations as a whole, the ERIP figures remain impressive.

Spin-off activities are becoming increasingly important as tangible outcomes of the Program. Altogether, 23 spin-off technologies have generated sales of $32 million. Most of these involve alternative market applications, but some of them are second-generation technologies. Figure 7.1 portrays the cumulative sales of ERIP's inventions and spin-off technologies over the lifetime of the program, and compares these values to ERIP program appropriations and grant awards.

Employment and tax benefits were also significant. In 1990, it is estimated that 758 FTE employees were working on ERIP technologies, and that this resulted in a return of approximately $3.2M in individual income taxes to the U. S. Treasury. An analysis of sources of funding provides additional evidence of positive program impacts.

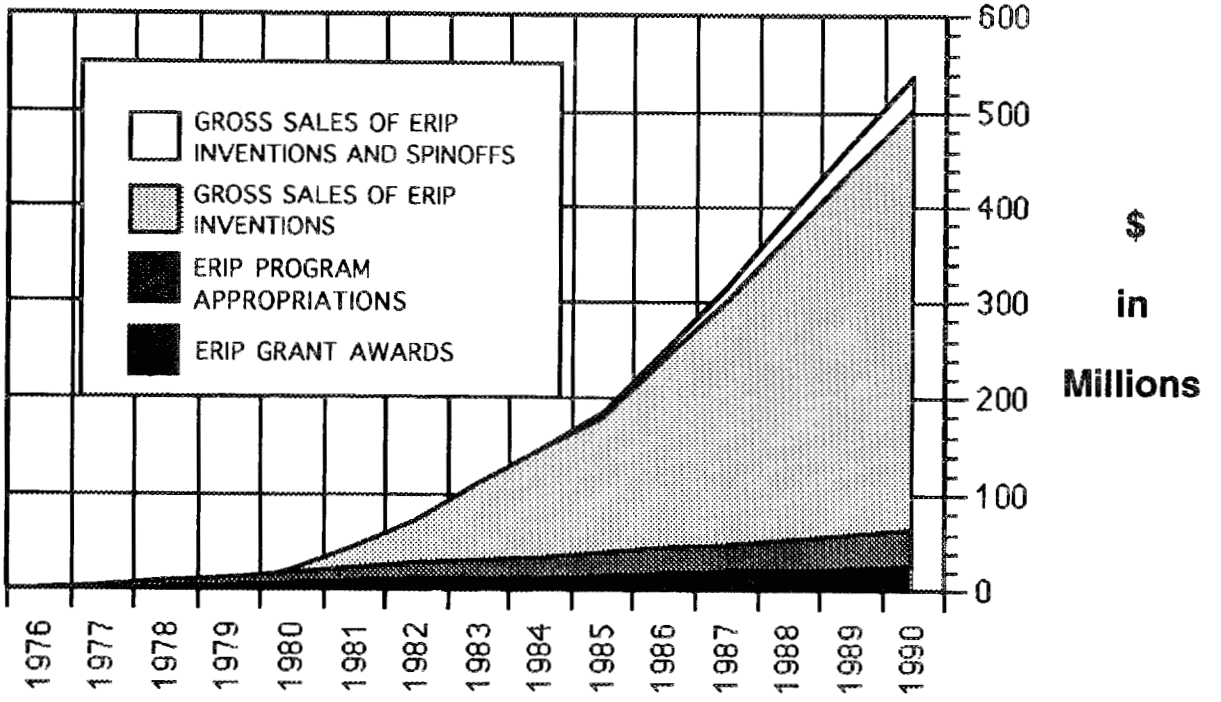

Fig. 7.1. Cumulative sales of ERIP inventions and spin-off technologies.

8. REFERENCES

Birley, S. 1987. "New Ventures and Employment Growth," *Journal of Business Venturing* 2(2): 155-165.

Booz-Allen & Hamilton. 1982. *New Products Management for the 1980's.* New York, New York: Booz-Allen & Hamilton, Inc.

Brown, M. A. and S. A. Snell. 1988. *The Energy-Related Inventions Program: An Assessment of Recent Commercial Progress.* Oak Ridge, Tennessee: Oak Ridge National Laboratory, ORNL/CON-252, October.

Brown, M. A., J. A. Morell, S. A. Snell, E. J. Soderstrom, and W. Friggle. 1987a. *Evaluation of the Energy-Related Inventions Program; An Empirical Analysis of 204 Inventions.* Oak Ridge, Tennessee: Oak Ridge National Laboratory, ORNL/CON-225, March.

Brown, M. A., J. A. Morell, S. A. Snell, and C. R. Kerley. 1987b. "Impact of the Energy-Related Inventions Program on the National Economy," *Proceedings of the Technology Transfer Society's 12th Annual Meeting and International Symposium,* Washington, D.C., June 22-25.

Brown, M. A. 1990. "The Cost of Commercializing Energy Inventions," *Research Policy,* 19(2): 147-155, April.

Brown, M. A. and C. R. Wilson. 1990. *The Energy-Related Inventions Program: Commercial Progress of Participants Through 1988.* Oak Ridge, Tennessee: Oak Ridge National Laboratory, ORNL/CON-301, May.

Chrisman, J. J., F. Hoy, and R. B. Robinson. 1987. "New Venture Development: The Costs and Benefits of Public Sector Assistance," *Journal of Business Venturing,* 2: 315-328.

Cooper, R. G. 1983. "Most New Products Do Succeed," *Research Management,* 26(6): 20-25, November-December.

Crawford, C. M. 1987. "New Product Failure Rates: A Reprise," *Research Management,* 30(4): 20-24, July-August.

Dombrowski, L. P., G. D. Pine, and R. C. Rinholm. 1991. "Benefits of GRI R&D Products Placed in Commercial use Through Early 1991," Chicago, Illinois. Gas Research Institute, *Gas Research Insights,* May.

The Futures Group. 1984. *Characterization of Innovations Introduced on the U.S. Market in 1982*, Washington, D.C.: U.S. Small Business Administration, Office of Advocacy, March, NTIS #PB84 212067.

Horesh, R. and J. Y. Kamin. 1983. "How the Costs of Technological Innovation Are Distributed over Time," *Research Management*, 26(2): 21-24, March-April.

Kamin, J. Y., I. Bijaoui, and R. Horesh. 1982. "Some Determinants of Cost Distributions in the Process of Technological Innovation," *Research Policy*, 11(2): 83 - 94.

Kirchhoff, B. A. and B. D. Phillips. 1988. "The Effect of Firm Formation and Growth on Job Creation in the United States," *Journal of Business Venturing*, 3: 261-272.

Livesay, H. C., M. L. Rorke, and D. S. Lux. 1989. "From Experience: Technical Development and the Innovation Process," *Journal of Product Innovation Management*, 6: 268-81.

Myers, S. and D. G. Marquis. 1969. *Successful Industrial Innovations: A Study of Factors Underlying Innovations in Selected Firms*, (NSF 69-17). Washington, D.C.: National Science Foundation.

President's Commission. 1984. *Entrepreneurship and its Impact on the U.S. Economy* Washington, D.C.: President's Commission on Industrial Competitiveness.

Roessner, J. David. 1989. "Evaluating Government Innovation Programs: Lessons from the U.S. Experience," *Research Policy*, 18: 343-359.

Rorke, M. L. and H. C. Livesay. 1986. *A Longitudinal Examination of the Energy-Related Inventions Program*. Rockville, Maryland: Mohawk Research Corporation.

Stead, H. 1976. "The Cost of Technological Innovation," *Research Policy*, 5: 2-9.

U.S. Department of Commerce, Bureau of the Census. 1990. *Statistical Abstract of the United States, 1990, 110th Edition*. Washington, D.C.: U.S. Department of Commerce.

U.S. Department of Commerce, National Institute of Standards and Technology. 1990. *Energy-Related Inventions Program: Status Report for Recommendations 1 through 250, and 251 through 486*. Gaithersburg, Maryland: National Institute of Standards and Technology, NISTIR 4313 and 4319, May.

Weigand, R.E. 1986. "Marketing Through Foreign Subsidiaries and Joint Venture Arrangements," *Handbook of Modern Marketing*, Victor P. Buell, eds. Cambridge, Massachusetts: Massachusetts Institute of Technology.

APPENDIX A
QUESTIONNAIRE

Project Number:

TECHNOLOGY DESCRIPTION

The following title and description are based on the status of the technology when ERIP support was initially requested. Please revise them if they are no longer correct.

TITLE	
BRIEF DESCRIPTION	
Project Coordinator:	

Project ID Number:

CONTACT INFORMATION

To be sure that we have up-to-date contact information, please complete or correct the following data.

CONTACT		Additions or changes?
Name		
Company		
Address		
City & State		
Zip code		
Phones		
INVENTOR		**Additions or changes?**
Name		
Company		
Address		
City & State		
Zip code		
Phones		

Project Number:

CONTACT'S ASSOCIATION WITH THIS PROJECT

We would like to know how you are related to this ERIP technology. Please check one or more boxes below. If your circumstance does not fit any of the listed categories, please describe it in the space provided.

Association with this project		Description
	Inventor & applicant	Inventor of the ERIP technology as well as applicant to the ERIP program.
	Inventor & not applicant	Inventor of the ERIP technology but not applicant to the ERIP program.
	Applicant/not inventor	Applicant to ERIP, but not inventor.
	Licensee	Either my company or I have licensed this technology.
	Owner of technology	Either my firm or I have purchased patents on this technology.
	Designated contact	I am the individual designated by the inventor to interact with DOE.
	Developer	Either my company or I am developing this technology.
	Other	

Project Number:

CONTACT'S BACKGROUND INFORMATION

We are interested in understanding where our contacts come from and how they get involved with the technologies ERIP reviews and supports. Please update this background data.

EMPLOYMENT HISTORY

Contact's Current Employment, if different from below					Additions or changes?			
Company								
Your Position or Job Role								
Number of employees in company	1-15				500-999			
	16-49				1000-9999			
	50-99				10000+			
	100-499							
Number of years there	First year:		Last year:		First year:		Last year:	

Contact's Most Recent Employment					Additions or changes?			
Company								
Your Position or Job Role								
Number of employees in company	1-15				500-999			
	16-49				1000-9999			
	50-99				10000+			
	100-499							
Number of years there	First year:		Last year:		First year:		Last year:	

Contact's Previous Employment					Additions or changes?			
Company								
Your Position or Job Role								
Number of Employees in company	1-15				500-999			
	16-49				1000-9999			
	50-99				10000+			
	100-499							
Number of years there	First year:		Last year:		First year:		Last year:	

Project Number:

EDUCATIONAL BACKGROUND

Please check the boxes next to those categories that apply to your educational background.

High school		Trade School		In-service training		Junior College Degree	
BS		BA		MS		MA	
MBA		JD		MD		PhD	

Please make any necessary additions or corrections to the information in the boxes below.

Type of Study	Course of study	Additions or corrections?
Trade school/high school		
Undergraduate Major		
Graduate Major		
Other certifications or educational experience		

DEMOGRAPHICS

Please make any necessary additions or corrections to the Year of Birth noted below.

CONTACT DEMOGRAPHICS	Year of Birth	Additions or corrections?
In what year were you born?		

Project Number:

PATENTING ACTIVITY

We are interested in understanding the degree to which developers of ERIP sponsored technologies employ patent protection. A patent can be considered to be related to the "ERIP technology" if it is a direct outgrowth of the technology for which you applied for an ERIP grant, even if the intended application of the technology has changed.

In most cases, our contact is the original inventor, and patenting activity would go in the first column below. Occasionally a technology is further developed by individuals or groups other than the original inventor. If you are not the initial inventor but you or your company have received patents, please record this in the second or third columns below.

Please change or update the table below as necessary.

RELATIONSHIP to ERIP	PATENTS ISSUED TO: The inventor		The contact, if different from inventor		Company developing the ERIP-sponsored technology	
	U.S. Patents	Foreign Patents	U.S. Patents	Foreign Patents	U.S. Patents	Foreign Patents
Related to ERIP technology						
Unrelated to ERIP technology						

INVENTOR SOCIETY MEMBERSHIP

ERIP has supported the activities of several inventor societies in the U.S. We would be interested in knowing whether you are a member of one of these groups.

INVENTOR SOCIETY MEMBERSHIP	Please check one:			
Are you a member of an inventor's organization or society?	YES		NO	

Project Number:

INVENTOR'S POSITION AT TIME OF CONCEPTUALIZATION

We would like to know how ERIP technologies get started and how long the development process takes from start to finish.

The following questions should be answered from the perspective of the original inventor of the ERIP technology. If you do not have knowledge of the initial conceptualization and early development of the technology, please leave this section blank.

Please make any necessary additions or corrections to the information in the boxes below.

INVENTOR'S BACKGROUND			Additions or corrections?	
Inventor's Name				
Company in which inventor worked during the initial period of conceptualization				
Inventor's Position at time of conceptualization				
Number of employees in company	1-15		500-999	
	16-49		1000-9999	
	50-99		10000+	
	100-499			

TIMING of CONCEPTUALIZATION and DEVELOPMENT

Please make any necessary changes or corrections to the information in the boxes below.

CONCEPTUALIZATION HISTORY	YEAR	Additions or corrections?
What year was this technology originally conceptualized?		
What year did active development begin?		

Project Number:

DEVELOPMENT STATUS OF THIS TECHNOLOGY

This information helps us track the chronological development of the ERIP technology. Please review the seven categories and the time frames listed below, and note any additions, changes, or comments.

DEVELOPMENT CATEGORIES

1 = Concept definition and development
2 = Working model
3 = Prototype development, testing, engineering design
4 = Pre-production prototype testing
5 = Production prototype
6 = Limited production and marketing
7 = Full production and marketing

YEAR	DEVELOPMENT STATUS	Changes or comments?
1985		
1987		
1989		
1991		

LEVEL OF ACTIVITY OF THIS TECHNOLOGY

We would like to know the status of your ERIP technology at present and over the past several years, using the following categories.

ACTIVITY CATEGORIES

1 = Actively being pursued
2 = Low level of effort
3 = Suspended temporarily
4 = Suspended indefinitely
5 = Failed
6 = Chapter 11/Reorganization
7 = Chapter 7/Bankrupt

YEAR	ACTIVITY STATUS	Changes or comments?
1987		
1989		
1991		

Project Number:

SALES DATA

Information on sales of your ERIP technology is essential to our assessment of the assistance provided by ERIP. Gross revenue helps us understand the relationship between technical development and the growth of small business. If your firm is a division of a larger firm that transfers a significant amount of development funds to you, please give us an estimate of the revenues of the parent company. If your company is independent but has revenues from other products or services, please note the revenues of your own company in the boxes below.

Direct sales: Direct sales are sales of the ERIP technology that are taking place out of your company.

Indirect sales: If other organizations that are not your customers are selling the ERIP technology, these sales are indirect sales. For example, this would include sales by a licensee or a company that has purchased the technology.

Year of first sales: This is the year of first sales of the ERIP technology.

Please make any appropriate additions or changes to the table below.

Year of first sales of this technology	Year	Additions or corrections?

Please make any appropriate additions or changes to the table below.

YEAR	SALES CATEGORY			
	Number of units sold	Direct Sales by you to end users or distributors ---($000)---	Indirect Sales ---($000)---	Gross Sales of your company across all product lines ---($000)---
1980				
1981				
1982				
1983				
1984				
1985				
1986				
1987				
1988				
1989				
1990				

Project Number:

LICENSING REVENUE

Information about licensing revenue helps us examine the relative success of different approaches to commercialization. If your ERIP technology has not been licensed and its patent has not been sold, skip to the next page.

Royalties: These are royalties received or paid out based on actual sales of the ERIP technology.

Royalty Rate: This is the average royalty percentage rate. If multiple royalty rates are in operation, please give us a weighted rate.

Other licensing payments: This includes up-front payments, bonuses, or other licensing revenues not tied to actual sales.

Please make any appropriate additions or changes to the table below.

LICENSING ACTIVITY	(Yes or No)	YEAR of license or purchase	With or from whom?
Have you signed a licensing agreement?			
Are you the licensee?			
Have you purchased the technology?			

Please make any appropriate additions or changes to the table below.

YEAR	LICENSING REVENUES ASSOCIATED WITH THE ERIP TECHNOLOGY		
	Royalties ----($)----	Royalty Rate ---(XX.X%)---	Other Licensing Payments ---($X)---
1980			
1981			
1982			
1983			
1984			
1985			
1986			
1987			
1988			
1989			
1990			

Project Number:

EMPLOYMENT

Information about employment generated by the ERIP technology helps us examine the degree to which the ERIP program has been successful in generating jobs.

Direct ERIP employment: Please list only the number of employees of your company that can be directly attributed to the technology sponsored by the ERIP program.

Indirect ERIP employment: If other organizations employ individuals whose jobs are related to the production, marketing or distribution of the ERIP technology, please estimate these. Indirect ERIP employees could include suppliers, subcontractors, retailers, licensees, or others whom you do not directly employ. Please describe in the comments section.

Please make any appropriate additions or changes to the table below.

EMPLOYMENT ASSOCIATED WITH THE ERIP TECHNOLOGY					
YEAR	DIRECT EMPLOYMENT		INDIRECT EMPLOYMENT		COMMENTS
	Number of FULL TIME Employees	Number of PART TIME Employees	Number of FULL TIME Employees	Number of PART TIME Employees	
1980					
1981					
1982					
1983					
1984					
1985					
1986					
1987					
1988					
1989					
1990					

Project Number:

'SPINOFF' TECHNOLOGIES

Please describe the two most promising or successful spin-off technologies that you have developed as a result of your ERIP project (if any).

There are several ways in which **"spinoff technologies"** can arise.

1. Development of an initial technology results in new product characteristics that adapt the product for new markets.

2. Efforts to solve a problem with an initial technology fail, so a different approach is used to resolve the same problem and a new technology results.

3. A new application is found for a component of an initial product.

Please describe the primary spinoff (if any) and indicate its sales below.

DESCRIPTION OF SPINOFF TECHNOLOGY #1					
SALES in $(000)					
1985	1986	1987	1988	1989	1990

Please describe a secondary spinoff (if any) and indicate its sales below.

DESCRIPTION OF SPINOFF TECHNOLOGY #2					
SALES in $(000)					
1985	1986	1987	1988	1989	1990

Project Number:

SOURCES OF FUNDING FOR YOUR ERIP TECHNOLOGY

This information helps us understand the nature of the funding that goes into the development of ERIP technologies. A sheet of definitions of funding types is attached.

Application Date		Award Date		ERIP Grant($000)	

Please make any appropriate additions or changes to the table below.

SOURCES OF FUNDING FOR YOUR ERIP TECHNOLOGY		
Year	Amount --($000)--	Description of sources of funding

Project Number:

DEFINITIONS OF CATEGORIES OF FUNDING

Please use the following funding types when describing your sources of funding on page 13.

TYPES of EQUITY INVESTMENT	
Sweat Equity	Estimated value of uncompensated labor.
Personal/Mgt Team	Personal funds and those from the development team.
Informal Equity Investment by friends and family	Equity investment from friends and relatives who are not associated with formal investment organizations and who are not professional private investors. May involve distribution of private stock.
Venture Capital	Equity investments from formal venture capital organizations. This includes funding from SBDIC's and venture partnerships developed to invest in the technology, as well as professional or sophisticated private investors.
Non-financial Corporations	Equity funds from other companies, including joint venture linkages. These are firms investing for strategic position in the ERIP technology.
Public Stock	Public stock offerings.
Federal Grants other than the ERIP grant	Federal grants, such as SBIR, DOE, DOD, etc. This does not include the grant you got from the Energy-Related Inventions Program.
State & Local Grants	Grants from State and Local agencies.
Retained Earnings from sales	Reinvested profits from sales. This is that portion of profits from sales that is reinvested in the company.
Other Equity	Equity funding from other sources, e.g., preferred stock subordinated debentures.
TYPES of DEBT INVESTMENTS	
Supplier & Customer Credit	Trade credit from suppliers and Work-in-Progress payments from customers.
Banks	Commercial bank loans. This would include long term to cover development costs, real estate purchases, etc., as well as short term to cover inventory, etc.
Federally Guaranteed Loans	Loans guaranteed by Federal agencies, including loans guaranteed by the Small Business Administration.
State & Local Guaranteed Loans	Loans guaranteed by State and Local agencies.
Informal Debt Investment	Debt investment from friends and relatives who are not associated with formal investment organizations and who are not business angels as defined above.
Other debt	Debt funding from any other sources, e.g., operating or capitalized leases.

Project Number:

DISTRIBUTION STRATEGY

How do you intend to distribute your ERIP technology? Please circle one of the options below. If your intended distribution strategy falls outside the categories below, please describe it briefly in the space provided.

0 = N/A.

1 = Direct Sales. Direct sales from contact's company to end users

2 = Distributors/resellers. Distributors or resellers outside this company will be used to reach end users

3 = Both direct and indirect sales. Sales will be conducted through outside resellers as well as directly from within this company.

4 = Indirect sales. This technology will either be licensed or sold, and the licensee or new owner will manage distribution.

5 = Services. The primary product is a technical service that this company provides to end users.

6 = Other. (Please describe)

Please make any appropriate additions or changes to the table below.

Intended Distribution Strategy	Changes or Comments?

Project Number:

CONTACT'S EXPERIENCE WITH STARTUP COMPANIES

Please give us some information about startup companies with which you have been involved.

How many startup companies have you been personally involved with?	ERIP related	Not ERIP Related

Please describe your involvement with startup companies in the boxes below.
If you have not been involved with startup companies, please leave this section blank.

MOST RECENT STARTUP		Additions or changes?
Company Name		
Location		
Year company started		
Your job role		
Business type (e.g., Sole proprietorship, Partnership, Joint Venture, S Corp, Other Corp)		
What connection, if any, was there between this startup company and the ERIP technology?		
PREVIOUS STARTUP		**Additions or changes?**
Company Name		
Location		
Year company started		
Your job role		
Business type (e.g., Sole proprietorship, Partnership, Joint Venture, S Corp, Other Corp)		
What connection, if any, was there between this startup company and the ERIP technology?		

Project Number:

ADDITIONAL COMMENTS

APPENDIX B
SALES OF ERIP INVENTIONS

Table B.1 Yearly sales based on 109 inventions for which annual sales data are available (in thousands of dollars)[a]

	Direct sales by the inventor through:			
Year	an existing company	a new venture	Sales from license agreements	Totals
1980	1,267 (N=6)	3,833 (N=10)	14,155 (N=7)	19,255 (N=23)
1981	2,444 (N=10)	6,779 (N=13)	15,826 (N=10)	25,049 (N=33)
1982	1,899 (N=13)	8,337 (N=15)	18,881 (N=9)	29,117 (N=38)
1983	3,120 (N=15)	10,969 (N=14)	23,859 (N=13)	37,948 (N=12)
1984	3,818 (N=17)	14,307 (N=17)	15,771 (N=15)	33,896 (N=49)
1985	4,189 (N=18)	13,944 (N=15)	15,523 (N=15)	33,656 (N=48)
1986	5,196 (N=25)	17,893 (N=16)	37,683 (N=15)	60,772 (N=56)
1987	3,048 (N=17)	17,678 (N=19)	38,890 (N=17)	59,616 (N=53)
1988	3,209 (N=16)	21,993 (N=21)	43,816 (N=20)	69,018 (N=57)
1989	3,486 (N=15)	22,019 (N=18)	46,038 (N=19)	71,543 (N=52)
1990	4,566 (N=15)	20,988 (N=20)	37,601 (N=17)	63,155 (N=52)
Grand Totals	36,242 (N=41)	158,740 (N=40)	308,043 (N=33)	503,025

[a]"N" represents the number of inventions. Grand totals for N do not equal the sum of the column N's because several technologies have been sold via two commercialization modes, simultaneously.

APPENDIX C
JOB GENERATION

Table C.1 Sales per FTE employee

	Sales to FTEs ratios (in thousands of dollars):	
	Direct sales	Indirect sales[a]
1984	67	119
1985	84	100
1986	67	109
1987	73	223
1988	72	266
1989	82	117
1990	72	114

[a]Sales through a licensee or new owner of the ERIP technology.

Table C.2 Number of full-time equivalent (FTE) employees supported by sales of ERIP inventions

	Known FTE's supported by direct sales	Estimated FTE's based on direct sales	Known FTE's supported by indirect sales	Estimated FTE's based on indirect sales	FTE's supported by inventions without sales	Totals
1984	172	67	85	69	189	582
1985	229	20	77	96	48	470
1986	234	118	80	297	59	788
1987	185	138	46	173	129	671
1988	237	133	41	159	146	716
1989	282	29	160	219	78	768
1990	316	37	146	168	91	758

APPENDIX D
ACQUIRING FINANCIAL SUPPORT

Table D.1 Average funds raised per inventor, by source (in thousands of dollars)[a]

	Without Sales (N=76)		With Sales (N=67)	
	Pre-ERIP	Post-ERIP	Pre-ERIP	Post-ERIP
Personal	25 (N=31)	63 (N=39)	196 (N=38)	242 (N=40)
Corporate	10 (N=5)	40 (N=8)	15 (N=8)	96 (N=24)
Commercial	15 (N=7)	78 (N=16)	28 (N=7)	242 (N=17)
Public stock offerings	0	0	0	40 (N=3)
Lending institutions	0	0	1 (N=1)	24 (N=6)
Public[b]	13 (N=6)	61 (N= 16)	1 (N=1)	18 (N=5)
Total funds	62 (N=37)	242 (N=52)	241 (N=42)	662 (N=59)

[a]Numbers are average amounts of funding raised by the 143 inventions for which financing data are available (76 inventions without sales and 67 inventions with sales). "N" represents the number of inventions that have attracted funding from a particular source. Thus, for instance, the 76 inventions without sales raised an average of $25,000 from personal sources before applying to the program. But only 31 of these 76 inventions actually raised personal funding.

[b]ERIP grants are excluded from this table.

INTERNAL DISTRIBUTION

1. T. D. Anderson
2. R. A. Balzer
3. L. G. Berry
4. D. J. Bjornstad
5. M. A. Brown
6. R. S. Carlsmith
7. W. Carpenter
8. G. E. Courville
9. T. R. Curlee
10. E. Z. Faby
11. D. L. Feldman
12. C. A. Franchuck
13. W. Fulkerson
14. E. L. Hillsman
15. E. Hirst
16. R. B. Honea
17. M. S. Hubbard
18. D. W. Jones
19. C. H. Kerley
20. J. O. Kolb
21. M. A. Kuliasha
22. P. N. Leiby
23. V. C. Mei
24. W. R. Mixon
25. R. L. Noe
26. D. E. Reichle
27. C. G. Rizy
28. A. Schaffhauser
29. M. Schweitzer
30. R. B. Shelton
31. W. D. Siemans
32. W. B. Snyder
33. E. J. Soderstrom
34. P. J. Sullivan
35. J. N. Stone
36. E. W. Whitfield, III
37. T. J. Wilbanks
38. C. R. Wilson
39. K. H. Zimmerman
40. Central Research Library
41. Document Reference Section

42-44. Laboratory Records

45. Laboratory Records-RC
46. ORNL Patent Office

EXTERNAL DISTRIBUTION

47-71. J. P. Aellen, Inventions and Innovation Programs, U.S. Department of Energy, CE-122, 5E-052, 1000 Independence Ave., SW, Washington, DC 20585.

72. Dr. B. G. Buchanan, Computer Science Department, University of Pittsburgh, 206 Mineral Industries Building, Pittsburgh, PA 15260.

73. Dr. A. Hirsch, Vice President, Environmental Sciences and Director, Washington Operations Midwest Research Institute, 5109 Leesburg Pike, Suite 414, Falls Church, VA 22041

74. Dr. H. M. Ingram, Director, Udall Center for Studies in Public Policy, The University of Arizona, 803/811 East First Street, Tuscon, AZ 85719.

75. H. C. Livesay, Cliffard A. Taylor Professor in Liberal Arts, Department of History, Texas A&M University, College Station, TX 77843-1227

76. D. S. Lux, Bryant College, 450 Douglas Pike, Smithfield, RI 02917-1284

77. C. D. MacCracken, President, Calmac Manufacturing Corporation, 101 West Sheffield Avenue, P.O. Box 710, Englewood, NJ 07631

78. R. Nader, P.O. Box 19367, Washington, DC 20036

79. Office of the Assistant Manager, Energy Research and Development, Department of Energy, P.O. Box 2008, DOE Field Office, Oak Ridge, TN 37831-6269.

80-89. OSTI, U.S. Department of Energy, P.O. Box 62, Oak Ridge, TN 37831.

90. R. W. Peplies, Department of Geography, East Tennessee State University, Johnson City, TN 37814.

91-92. M. Rorke, Mohawk Research Corp., 915 Willowleaf Way, Rockville, MD 20854-317.

93. J. B. Shrago, Director, Office of Technology Transfer, 405 Kirkland Hall, Vanderbilt University, Nashville, TN 37240

94. D. L. White, Oak Ridge National Laboratory, C/O Martin Marietta Energy Systems, Inc., Suite #306 West Wing, 600 Maryland Ave., SW, Washington, DC 20024

95-400. Energy Program Planning and Evaluation Distribution List, Marilyn A. Brown, Oak Ridge National Laboratory, P.O. Box 2008, 4500N, MS 6206, Oak Ridge, TN 37831-6206.