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Technology Transfer for the U.S. Department of Energy's Energy Storage Program

Volume 1—Recommendations

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October 1988

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TECHNOLOGY TRANSFER FOR THE
U.S. DEPARTMENT OF ENERGY'S
ENERGY STORAGE PROGRAM

Volume 1 - Recommendations

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SUMMARY

Technologies developed by the U.S. Department of Energy's (DOE) Energy Storage (STOR) Program must be converted into products, processes, or services that benefit the private sector. The process of technology transfer is the primary means of accomplishing this. The purpose of this report is to examine the technology transfer activities of the STOR Program and suggest mechanisms that might make the transfer of technologies from national laboratories and universities to the private sector more effective.

Group discussions, personal interviews, and telephone interviews were conducted with individuals at the national laboratories involved in STOR project management including Lawrence Berkeley Laboratory, Sandia National Laboratories, Pacific Northwest Laboratory, Brookhaven National Laboratory, and Oak Ridge National Laboratory. Current technology transfer activities, target audiences, and barriers to technology transfer were examined for each project.

A preliminary investigation of STOR projects indicated that while many technology transfer activities do occur, these activities are not planned or coordinated. Often the technology transfer methods are directed only to other scientists and engineers. More emphasis should be placed on the potential end-users of STOR technologies including the management of potential user industries. Another major problem is the lack of an identified introductory market for STOR technologies. Often the goals of STOR projects are long-term and ignore more feasible entry-level applications. A gap exists between the technology development conducted at national laboratories and the product and market development that private industry is willing to undertake. Effective technology transfer will aid in bridging this current gap by making it easier for the private sector to receive information concerning research conducted at DOE national laboratories.

Listed below is a brief summary of recommendations that would improve the effectiveness of the transfer of energy storage technologies from the national laboratories to the private sector. Specific recommendations for

each project are discussed in more detail in Chapters 2 and 3. Appendices that list STOR projects, publications, and presentations are in a separate document.

ENERGY STORAGE (STOR) PROGRAM RECOMMENDATIONS

- plan and coordinate technology transfer activities on a program-wide basis at the national laboratory level
- conduct workshops on technology transfer targeted toward industrial decision-makers including corporate planners and business developers
- identify technology champions, preferably within industry, or as a last resort, within the national laboratories
- perform market assessments early in technology development to identify entry-level markets
- direct research and development efforts to meet end-users' needs and preferences
- prepare brief summaries (1-2 pages) of research results
- focus on multi-year federal project planning cycles.

The implementation of these recommendations would improve the current technology transfer activities of the STOR Program. Technology transfer on a program-wide basis would standardize the flow of information from the research projects to the potential end-users of the technologies. It would then be easier to monitor the technology transfer activities of each project and make necessary adjustments when needed.

GLOSSARY

BNL	Brookhaven National Laboratory
DOD	Department of Defense
DOE	Department of Energy
C/HES	Chemical/Hydrogen Energy Systems
ECS	Electrochemical Energy Storage
EPRI	Electric Power Research Institute
ETD	Exploratory Battery Technology Development and Testing
GRI	Gas Research Institute
HTEC	Hydrogen Technologies Evaluation Center
IEA	International Energy Agency
LBL	Lawrence Berkeley Laboratory
NASA	National Aeronautics and Space Administration
NTIS	National Technical Information Service
OESD	Office of Energy Storage and Distribution
ORNL	Oak Ridge National Laboratory
PNL	Pacific Northwest Laboratory
PSE&G	Public Service Electric & Gas
R&D	research and development
SNL	Sandia National Laboratories
STES	Seasonal Thermal Energy Storage
STOR	Energy Storage
TBR	Technology Base Research
TES	Thermal Energy Storage
TESE	Thermal Energy Storage Evaluation

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1.0 INTRODUCTION

Technologies developed in federal R&D programs must be converted to products, processes, or services that can benefit the private sector. This priority is stressed in the mission statement of the Department of Energy's (DOE) Office of Energy Storage and Distribution (OESD), which states that technologies developed by OESD will find important applications throughout the nation in the electric utility, industrial, and transportation sectors. Three of the seven strategic directions listed in the mission statement are related to methods of accomplishing technology transfer: 1) conduct R&D targeted toward specific national needs; 2) identify and involve users of OESD research and development; and 3) focus external communication and outreach. This report explores actions that can be taken to improve the transference of innovative ideas and technologies from one of OESD's programs, the Energy Storage (STOR) Program, to the private sector.

1.1 ENERGY STORAGE (STOR) PROGRAM

The STOR Program supports a national R&D effort to provide a range of technological options in energy conversion and storage. The diagram in Figure 1.1 illustrates STOR's program structure. There are two subprograms within STOR: the Electrochemical Energy Storage Program, which consists of the Technology Base Research Project and the Exploratory Battery Technology Development and Testing Project; and the Physical and Chemical Energy Storage Program, which consists of the Thermal Energy Storage Project and the Chemical/Hydrogen Energy Systems Project. These projects are discussed in greater detail in the following chapters.

Technologies developed by the STOR Program include innovative concepts in battery, fuel cell, hydrogen, and thermal energy technologies that have numerous potential applications in the private sector. STOR technologies can be applied to all sectors of the economy including residential, commercial, industrial, utility, and transportation. It is vital that these sectors be made aware of potential applications of STOR technologies through the process of technology transfer. Once awareness has been established, steps should be taken to create

FIGURE 1.1. Structure of the Energy Storage (STOR) Program

an interest in and encourage the utilization of the technologies and their applications.

1.2 THE TECHNOLOGY TRANSFER PROCESS

A broad definition of technology transfer describes it as the process by which science and technology are diffused through human activity. DOE furthers this definition by calling technology transfer the transformation of R&D into processes, products, and services that can be applied in state and local government, and to private sector needs.

The process of technology transfer usually does not occur naturally. It must be coordinated during the incubation stages of an innovative technology in order to steer research efforts in directions that will meet market needs. There are several mechanisms for accomplishing technology transfer. The following is a list of mechanisms that accelerate technology transfer:

- technical reports
- publications in journals or trade literature
- media announcements
- presentations at conferences or meetings
- technical meetings/exchanges

- direct mailing
- interaction with industry associations
- conducting workshops/conferences/seminars
- formal site visits
- intergovernment agency agreements
- subcontracts with industry or universities
- personnel transfer to/from industry
- government development/joint testing
- spinoff technology development.

Many of these will be discussed in the following sections of this report. Choosing the most effective technology transfer mechanism for a specific technology depends on several factors, including the technology, potential applications, the target audience, and potential barriers to technology transfer.

1.2.1 The Technology

The complexity of a technology is a factor to be considered in the technology transfer process. The more complex the technology, the more difficult it is to perform effective technology transfer. The transfer of a complex technology should begin during the early stages of research. This enables potential users of the technology to become familiar with the technology and its applications. This familiarity reduces the apprehension and risk associated with purchasing a complex new process or product.

The stage of technological development is another variable of a technology that must be considered when choosing transfer mechanisms. During the early stages of research, mechanisms should be utilized that make potential users of the technology aware of its potential applications. However, care must be taken not to make rash and unsubstantiated promises concerning the technology and its performance. This would affect the credibility of future claims concerning the technology and compound the risk that may be associated with adoption. Early technology transfer efforts should focus on individuals, such as scientists and engineers, who will understand the technical aspects of the technology. As the technology and its potential applications become better defined, efforts should be made to reach a broader audience of potential users. The mechanisms used for this less technical audience will be different from those used to reach scientists and engineers. As the technology becomes closer to commercialization, interest in the technology, as well as awareness,

should be generated by technology transfer activities. The advantages of the new technology over existing technologies should be stressed.

1.2.2 Target Audiences

Identifying a technology's potential applications will help determine appropriate audiences to target for effective technology transfer. Potential target audiences of energy storage technologies include scientists, engineers, and managers in various industries, and the general public. An energy storage application, such as utility load-leveling, should focus on the scientists, engineers, managers, and top executives of utilities who are likely to be involved in equipment purchasing decisions. Other potential applications, such as electric vehicles, should direct technology transfer activities to the general public in addition to scientists, engineers, managers, and top executives in the transportation industry. The initial market for electric vehicles is expected to be fleets of delivery trucks or vans. Industries with short-ranged delivery requirements should be targeted for receiving information about electric vehicles.

Technology transfer activities should reflect the intended target audience(s). Factors to be considered include the technical expertise of the audience and their familiarity with the technology being transferred. Information directed to scientists and engineers will likely differ considerably from that directed to managers or to the general public. The target audiences for each STOR project are examined in this report.

1.2.3 Potential Barriers to Technology Transfer

Often barriers hinder the transfer of technologies to appropriate target audiences. These barriers may appear in several forms including insufficient budgets, underdeveloped markets, and environmental or other government regulations. The barriers to technology transfer must be recognized early in the process in order to develop strategies to overcome them. This report identifies barriers associated with STOR technologies and suggests strategies to surmount some of these barriers.

1.3 METHODOLOGY USED IN DEVELOPING TECHNOLOGY TRANSFER STRATEGIES

This report summarizes an effort to evaluate the technology transfer activities of the STOR Program. Current technology transfer mechanisms were examined, target audiences identified, barriers to effective technology transfer defined, and suggestions made to improve the technology transfer process for each STOR project.

To better understand STOR technologies and technology transfer activities, scientists, engineers, and managers involved with STOR projects were interviewed. Group discussions were held at the Lawrence Berkeley Laboratory and Sandia National Laboratories to learn the opinions of individuals involved with battery technology R&D. Interviews with project managers at Brookhaven National Laboratory and Oak Ridge National Laboratory were conducted by telephone. Personal interviews were conducted at the Pacific Northwest Laboratory.

This report is organized by STOR project. Current technology transfer activities, target audiences, barriers to effective technology transfer, and recommendations to improve the technology transfer process are included for each project. Chapter 3 considers the Electrochemical Energy Storage (ECS) Program, Chapter 4 deals with the Physical/Chemical Energy Storage Program, and Chapter 2 summarizes the findings. The appendices, which list STOR projects, publications, and presentations, are in a separate document.

2.0 CONCLUSIONS AND RECOMMENDATIONS

After a preliminary investigation of STOR projects it was determined that while technology transfer activities do occur, these activities are not planned or coordinated. Often the technology transfer methods are directed only to other scientists and engineers. More emphasis should be placed on the potential end-users of STOR technologies including the management of potential user industries. Another major problem is the lack of an identified introductory market for STOR technologies. Often the goals of STOR projects are too lofty and ignore more feasible potential applications. A gap exists between the technology development conducted at national laboratories and the product and market development that private industry is willing to undertake. Effective technology transfer will aid in bridging this current gap.

Listed below is a brief summary of recommendations that would improve the effectiveness of the transfer of energy storage technologies from the national laboratories to the private sector. These are discussed in more detail in Chapters 3 and 4. The first set of recommendations applies to the entire DOE Energy Storage Program, while the other recommendations are project-specific.

ENERGY STORAGE (STOR) PROGRAM RECOMMENDATIONS

- plan and coordinate technology transfer activities on a program-wide basis at the national laboratory level
- conduct workshops on technology transfer targeted toward industrial decision-makers including corporate planners and business developers
- identify technology champions, preferably within industry, or as a last resort, within the national laboratories
- perform market assessments early in technology development to identify entry-level markets and to better understand ultimate markets
- direct R&D efforts to meet end-users' needs and preferences
- prepare brief summaries (1-2 pages) of research results
- institute multi-year federal project planning cycles.

PROJECT SPECIFIC RECOMMENDATIONS

Technology Base Research

- initiate industrial research fellowship programs.

Exploratory Battery Technology Development and Testing

- focus more technology transfer activities on the end-user of battery technologies
- emphasize the engineering development of battery systems
- increase the emphasis on the field testing of battery systems.

Thermal Energy Storage

- conduct assessments of industries and locations in the U.S. amenable to TES
- place more emphasis on technology field testing of TES technologies.

Chemical/Hydrogen Energy Systems

- publish more articles in professional journals
- re-instate project newsletter or submit articles to the existing private newsletter
- reconvene periodic contractors' conferences
- place more emphasis on engineering development and technology illustration of hydrogen technologies.

The implementation of these recommendations would improve the current technology transfer activities of the STOR Program. Technology transfer on a program-wide basis would standardize the flow of information from the research projects to the potential end-users of the technologies. It would then be easier to monitor the technology transfer activities of each project and make necessary adjustments when needed.

3.0 THE ELECTROCHEMICAL ENERGY STORAGE PROGRAM

The goal of the Electrochemical Energy Storage (ECS) Program is to provide the technology base and exploratory development necessary for more effective use of electrochemical systems. The focus is on development of high-performance, low-cost secondary batteries and fuel cells for energy storage. Research activities are designed to ensure the availability of advanced technologies that will permit the orderly development of electrochemical storage systems for use in the transportation, utility, and industrial sectors. Potential applications include commercial utility load-leveling systems, stand-alone or grid-connected energy supply systems, and electric vehicles. The two major research projects in ECS are Technology Base Research (TBR) and Exploratory Battery Technology Development and Testing (ETD). TBR is responsible for basic battery research and ETD acts as a bridge between basic research and product engineering. The transfer of battery technologies from ECS projects to the private sector is illustrated in Figure 3.1. This chapter discusses current technology transfer activities and barriers associated with these projects, as well as suggestions for a more effective transfer of technology.

3.1 TECHNOLOGY BASE RESEARCH (TBR)

The focus of the TBR Project is to initiate innovative concepts supporting the development of secondary batteries and fuel cells. This effort is under the lead center management of the Lawrence Berkeley Laboratory (LBL). TBR's research is divided into four components: exploratory cell research, electrochemical phenomena, new materials and improved components, and air systems research. Research projects conducted by TBR and its subcontractors are listed in Appendix A. The project's objective is to identify the most promising innovative electrochemical technologies and transfer them to the ETD Project or to private industry. Supporting research to aid the development of high-performance secondary batteries and fuel cells is also conducted by TBR.

FIGURE 3.1. Technology Transfer Process of the Electrochemical Energy Storage (ECS) Program

3.1.1 Current Technology Transfer Activities

TBR is responsible for transferring energy storage technologies to both the ETD Project and the private sector. Projects are transferred to ETD when engineering development, scale-up, and/or integration into a battery technology program appears warranted. Projects are formally transferred from TBR to ETD. An ad hoc committee consisting of representatives from TBR, ETD, DOE Headquarters, and an outside consultant is established to determine the suitability of a candidate project. Criteria that allow a battery technology to be shifted to ETD include: meeting target levels of specific energy and specific power; having the potential for adequate cycle and calendar life; consisting of component materials that are available in sufficient quantities; and yielding costs that at some date in the future will allow economically competitive devices to be produced. The committee provides a recommendation to the appropriate program manager. Examples of projects that have been successfully transferred from TBR to ETD include Rockwell's (licensed by

Ceramatec) toughened beta"-alumina electrolyte project in 1985 and ELTECH's aluminum/air battery project in 1986.

Numerous technology transfer activities are conducted by TBR that target the private sector. Approximately 20 subcontracts with universities and private corporations and 9 projects at other national laboratories are managed by TBR. Corporate participation through subcontracts is an effective method of exchanging technological information. The contractors and subcontractors of the ECS Program attend a biennial conference sponsored by DOE. This conference allows the contractors to present research results and to interact informally with other scientists who are involved in battery development. TBR has the advantage of being able to transfer technologies through the educational facilities at the University of California at Berkeley. A major function of LBL is to educate the scientists of tomorrow. TBR supports approximately 30 graduate students and 9 electrochemical scientists at the LBL facility. Students who participate in battery research projects take valuable technological knowledge with them after graduation. Many of these students continue on to work for industry, universities, and other national laboratories.

Multiple communication strategies have been attempted to transfer technologies from TBR to the private sector. Numerous professional papers on battery technology have been published in journals or presented at conferences. A list of publications and presentations from 1986 and 1987 can be found in Appendices B and C. Other communication methods have been undertaken by TBR, including audio-visual presentations at conferences, media announcements, and physical demonstrations. Personal contact between scientists from TBR and industry is a particularly effective method of exchanging ideas. Attendance of conferences and meetings permits TBR scientists to interact informally with scientists from industry. More formal contact has occurred in the form of site visits. Scientists at TBR make several site visits to subcontractors or other corporations during the course of a year. Visitors from industry are also welcomed to tour the facilities at LBL.

A final area in which TBR has had definite success is the development of spin-off applications of technologies generated by federally funded battery research. Concepts developed to improve advanced batteries have been

commercialized for use in other industries. Examples of recent spinoff applications include:

- toughened beta"-alumina developed by Rockwell and licensed by Ceramatec
- improved grid design for lead/acid batteries developed by LBL and Johnson Controls, Inc.
- fluidized-bed zinc/air battery systems developed by LBL and Sorapec, Inc.
- new air electrode technology developed for use in chlorine-caustic cells by ELTECH
- hydrogen anode technology used in zinc electrowinning developed by Prototech, Inc.

3.1.2 TBR Target Audiences

Because of the fundamental nature of TBR, the primary target audience for its research results is other scientists. These scientists are located within private industry, utilities, universities, or other national laboratories (especially those involved in the ETD project). TBR has effectively reached this audience and should start to focus communications to less science-oriented audiences. This includes the top management of potential subcontracting corporations and of corporations in the utility and transportation sectors of industry. The general public will frequently be the ultimate consumer of battery technologies. Awareness of innovative technologies by the general public will facilitate the adoption of products developed from these technologies. However, care must be taken not to make unrealistic claims concerning the technology and its applications. This could severely damage the credibility of advanced battery research in the eyes of industry and the public.

3.1.3 Barriers to Technology Transfer

Despite the activities being conducted by TBR, barriers do exist that make the effective transfer of technologies and ideas to the private sector difficult. One major barrier is the difficulty in locating subcontractors who are willing to risk equipment, manpower, and funding for advanced secondary battery development. Secondary battery development is a high-risk venture that many potential subcontractors are not willing to undertake. Corporations expect a high return on investment and short payback periods before agreeing

to invest in a technology. Advanced secondary batteries cannot offer either of these incentives at the present time. The market for advanced secondary batteries is currently in the incubation stage and will probably not come to fruition for several years. The battery industry is highly competitive, with both foreign and domestic contenders. The U.S. battery industry has remained competitive by lowering costs of battery manufacture with relatively little spending on R&D. The U.S. battery industry is currently doing little to develop advanced battery technologies. The lead for advanced battery R&D must reside with the DOE national laboratories. Federal cost-sharing partially reduces the risk for battery subcontractors.

Another barrier to the effective transfer of advanced battery technology is that no comprehensive effort has been made to coordinate technology transfer activities with the TBR and ETD projects. The Stevenson-Wydler Technology Innovation Act of 1980 requires each national laboratory to have an office devoted to technology transfer. While LBL does have an Office of Research and Technology Applications, its primary function is to act as a clearinghouse for inquiries. The responsibilities of the technology transfer officer include soliciting and responding to inquiries, and writing program descriptions and application assessments for DOE. Researchers within TBR have neither the time nor resources to coordinate technology transfer activities.

Because technical reports, journal articles, and conference presentations are available to the public, technologies developed by DOE national laboratories are often transferred more successfully to Japan and other foreign countries than to U.S. industries. Greater one-on-one planning and communication between federal programs and potential U.S. users is necessary to encourage U.S. industry to adopt innovative energy-saving technologies.

Industry subcontractors are expected to commercialize battery technologies, but are given little aid in assessing, segmenting, and targeting markets for the products. Currently there is a gap between the technology development services provided by DOE's national laboratory system and the commercialization functions that industry is willing to provide. This marketing research gap must be bridged in order to successfully transfer battery technologies from TBR to the private sector.

3.1.4 Recommendations

Written communication is an effective method for developing awareness of a new technology. Professional papers in journals will be read by other scientists in the field. However, unless an individual has a specific interest in a technology, he/she will be unlikely to read a professional paper on the subject. To reach less-technical audiences, it would be helpful to distribute short summaries of research results. These "research updates" could be direct mailed to selected target audiences, used to answer inquiries, and presented as supporting documents for technology transfer presentations.

Once awareness of a technology has been established, personal contact is necessary to promote interest and encourage adoption. One method of increasing personal contact among scientists is to invite industry scientists to work at LBL for a specific period of time. An industrial fellowship program where DOE shares salary expenses with the scientist's corporation would encourage industry to participate. The scientist would return to his/her corporation after the fellowship with new information and insight on advanced batteries. The fellowship program could be advertised in professional journals and announced at meetings and conferences. A similar program is currently being conducted at the LBL Center for Advanced Materials. This could be used a model for developing a fellowship program for TBR.

One of the elements that is vital to the successful transfer of a technology is the existence of a technology "champion." This champion recognizes the potential value of the technology and oversees the technology transfer process. The role of the technology champion can be played by an individual or an organization. TBR has relied on industry subcontractors to be technology champions. At the inception of an innovative technology, it is unrealistic to expect a corporation to devote much time and effort to championing a technology with only a modest market. Efforts should be made to identify and encourage industrial partners to act as technology champions. As a last resort, the early champions of a technology may be within the national laboratory structure. However, as soon as an industrial proponent can be located, the role of technology champion should be relinquished by the national laboratories.

Planning is another element that is essential for the successful transfer of innovative technologies. The most effective method of technology transfer is project-specific, varying with the type and development stage of each technology. Planning the appropriate target audiences and technology transfer vehicles should be coordinated on a program-wide basis, with special consideration given to each project. This planning task should be performed by persons knowledgeable in both the specific technologies and strategies for technology transfer. Again, this points to the need for more intensive coordination of technology transfer activities within the national laboratory structure.

3.2 EXPLORATORY BATTERY TECHNOLOGY DEVELOPMENT AND TESTING (ETD)

The objective of the ETD Project is to develop and evaluate high-performance, long-life, economical and reliable rechargeable batteries for future mobile and stationary energy storage applications. ETD's responsibility is to fill the gap between the basic research activities of TBR and the product engineering capabilities of industry. Under the lead center management of Sandia National Laboratories (SNL), ETD currently has the responsibility of major development efforts on four battery technologies: sodium/sulfur, zinc/bromine, nickel/hydrogen, and aluminum/air.

3.2.1 Current Technology Transfer Activities

Several methods of technology transfer are being practiced at ETD. The large majority of project funding is subcontracted to private industry and universities. Approximately ten subcontractors are currently engaged in advanced battery research for ETD. Working through dedicated subcontractors is an excellent method of transferring research results to the private sector. These team arrangements offer two incentives to private industry: cost-sharing and the potential of patent waivers. The subcontractors have the opportunity to exchange ideas and research results at the biennial contractors' conference sponsored by DOE.

The ETD Project has three research priorities: technology development, technology evaluation and testing, and technology improvement. Each of these categories has ties to private industry. Technology development consists primarily of subcontractors working on advanced battery development. Technology

evaluation and testing involves analysis of battery cells developed by industry at facilities at SNL and at the Argonne Diagnostic Laboratory. The cells are manufactured by private industry and the results of the evaluations are returned to private industry. Technology improvement, which consists of less than 10% of ETD's budget, involves in-house research to provide short-term solutions to short-term problems. The problems are usually those that industry developers cannot address and are in areas which SNL has expertise. The research results are shared with industry developers.

ETD often plays a match-making role between battery developers and the ultimate users of the technologies. Potential users of battery technologies will approach engineers at ETD to determine the best technology for a specific application. This is especially true for military applications of advanced battery technology such as satellites.

The ETD project has also had successful spinoff applications from its advanced battery research. Recently an inexpensive sulfonated polysulfone membrane was developed as part of technology improvement research. This ion exchange membrane will be in direct competition with a more expensive membrane that currently dominates the market.

Several communication strategies are utilized by ETD to reach the private sector. Scientists in the private sector are contacted through published papers, conference presentations, and industrial site visits. A list of papers and presentations can be found in Appendices B and C. Industrial subcontractors are visited frequently by SNL researchers. ETD also receives approximately two industrial visits a month from both foreign and domestic corporations to the SNL site. SNL publishes a large number of reports, available to the private sector through the National Technical Information Service (NTIS), that contain results of research conducted through the ETD Project.

The general public, who will be the ultimate end-users of battery technologies, is reached through press releases and workshops. When a researcher feels that a technology is sufficiently advanced for press coverage, he/she releases a media announcement that is sent to the wire service where it can be picked up by a large number of newspapers. Usually two press releases are written, one targeted to the general public and one targeted to popular science magazines. Workshops are held in which the general public is invited.

For example, SNL recently sponsored a workshop on electric vehicles in collaboration with Public Service Company of New Mexico. This workshop was publicized by the local media and attended by individuals with an interest in electric vehicles.

3.2.2 ETD Target Audiences

The ETD Project has many of the same target audiences as TBR, although there is a somewhat different emphasis. ETD does need to communicate with scientists in the private sector, but because the technologies are closer to commercialization, there is a more-urgent need to reach the ultimate end-user of battery technologies. End-users include utilities, vehicle manufacturers, industry, and the general public. Each of these audiences needs to be targeted to receive ETD research results. Communication strategies will have to be designed to reach each specific audience.

3.2.3 Barriers to Technology Transfer

The market for advanced batteries is currently very small, but has the capacity for enormous growth. One of the major barriers to advanced battery technology transfer involves the riskiness of battery development and the short-term focus of American industry. Few corporations are willing to invest in the technological development of a product that does not have immediate sales potential.

Federal battery programs do little to reduce the risk involved with advanced battery development. The yearly funding cycle creates a margin of uncertainty concerning future funding. A subcontractor has little guarantee that funding will not be reduced or eliminated at the end of each federal funding cycle. Battery technologies are often dropped from the government laboratories too early. Little is done to integrate batteries into a functional system. Demonstrations and field testing are seldom conducted.

The market potential of advanced batteries is not fully understood. Many of the market assessments on batteries were written several years ago. The potential for advanced batteries envisioned by the federal government is very high. However, early adopters of advanced batteries will probably not utilize expensive applications such as electric fleet vehicles or utility load-leveling, but more commonplace applications such as electric wheel chairs,

golf carts, and airport baggage carts. This entry-level market needs to be examined more closely in order to target the early adopters.

No effort has been made to coordinate the technology transfer activities of ETD. Each developer is encouraged to publish papers and attend conferences, but little direction is given. In some cases, the credibility of advanced batteries has been damaged by premature press releases that have exaggerated the current capabilities of batteries.

3.2.4. Recommendations

One method of improving battery technology transfer would be to reduce the risk for private battery developers. This will enable ETD to locate a larger number of enthusiastic and dedicated subcontractors. Risk can be reduced in several ways. The DOE yearly planning cycle should be changed to focus on a multi-year project planning cycle. This would reassure subcontractors that sufficient support would be provided to complete a research project.

A thorough investigation of potential battery markets is another method of reducing risk for the subcontractors. This may result in the redirection of battery research to entry-level markets, rather than markets that will not be developed for at least another 10 years. Market assessments should be conducted near the inception of each battery research project to direct research towards market needs. Although market assessments have been conducted in the past, these need to be updated periodically. Longer-term markets such as electric vehicles and utility load-leveling should not be ignored, but some emphasis should be placed on the more feasible entry-level applications.

More attention should be paid to the end-users of battery technologies. This audience must be made aware of developments in battery research to be able to make an informed decision when it comes time to purchase a battery system. The end-users include managers of utilities, transportation companies, and industries that might use advanced batteries. This audience can be reached by presenting papers at trade shows. Workshops targeted toward a specific audience would be helpful in disseminating information about battery technologies. The general public will also be an end-user of advanced battery technology. More press releases and semi-technical articles in popular science magazines are needed to reach the general public.

The technology transfer activities should follow a comprehensive technology transfer plan that is standardized, but flexible enough to allow for differences in research projects. This coordination effort should be performed within the national laboratory system until industry is ready to initiate its own marketing efforts.

3.3 UTILIZING CORPORATE STRATEGY FOR BATTERY RESEARCH

The projects in the ECS Program can be compared with the departments of a private corporation. The TBR Project performs the role of R&D scientists, while ETD functions as an engineering department. It is hoped that at this point private industry will enter the picture to incorporate the new technologies into commercial products, processes, and services. Unfortunately, this does not usually occur. A gap often exists between the development of battery technologies in national laboratories and the commercialization of those technologies. In a private corporation, this gap is filled by the marketing department. The marketing department analyzes potential applications and markets for the newly developed technology. When an appropriate target market (or markets) is chosen, research is conducted to determine the best way in which to approach that market. The R&D scientists, engineers, and marketing staff all work together to design a product that will meet the target market's needs and preferences. The marketing department is also responsible for making the target audience aware of and interested in the new technology.

This vital marketing role is rarely performed by private industry for battery technologies developed by the ECS Program. Very little marketing research is conducted at the national laboratory level. Market assessments are usually only performed well into the development of a new battery technology. Little attention has been paid to potential intermediate battery markets such as electric wheelchairs and airport baggage carts. The responsibility for preliminary marketing research resides at the DOE national laboratory level. The conservative nature and thin profit margins of the U.S. battery industry makes it impossible to expect private corporations to expend resources in examining advanced battery technologies and applications.

The marketing tasks for advanced battery technologies must be coordinated to maximize effectiveness and to avoid duplication of efforts. The coordination

task would include conducting market assessments for battery technologies at the introductory stages of research. This would give scientists and engineers an idea of market needs and preferences. Technology transfer coordination efforts should be project-specific and include activities designed to make appropriate target audiences aware of and interested in specific battery technologies.

4.0 PHYSICAL AND CHEMICAL ENERGY STORAGE PROGRAM

The other major subprogram in the DOE Energy Storage Program is the Physical and Chemical Energy Storage Program. This program consists of two major energy storage projects: the Thermal Energy Storage (TES) Project and the Chemical/Hydrogen Energy Systems (C/HES) Project. This chapter discusses the current technology transfer activities, target audiences, and barriers to effective technology transfer of these projects, as well as recommendations for improving the technology transfer process.

4.1 THERMAL ENERGY STORAGE (TES) PROJECT

The TES Project conducts research to provide a technology base for the further development of energy-efficient and cost-effective TES systems. Potential applications of TES systems exist in the residential, commercial, and industrial sectors. TES is currently used more extensively in Europe than in the United States. However, this is partially due to the nature of energy markets in the U.S. and Europe.

The TES Project focuses on three research priorities: seasonal, diurnal, and industrial TES. The Seasonal Thermal Energy Storage (STES) Project is administered by PNL, while the Diurnal and Industrial Thermal Energy Projects are administered by ORNL.

4.1.1 Current Technology Transfer Activities

Prior to FY 1987, the technology transfer activities of the TES Project were similar to those performed by other STOR projects. Technical reports with a widespread distribution, journal articles, presentations at conferences or technical society meetings, and interactions with subcontractors were the primary methods used to transfer thermal energy storage technologies to scientists and engineers in industry, universities, and other national laboratories. ORNL has worked closely with industrial partners to develop innovative TES technologies. Some field testing has been conducted, including continuing tests by the University of Minnesota at St. Paul and the University of Alabama at Tuscaloosa. A new task, the Thermal Energy Storage Evaluation (TESE) Task, was initiated in FY 1987 to plan and coordinate technology transfer activities.

The TESE Task was created to provide assessment and evaluation services to the TES Project. In general, the goals of TESE are to:

- provide R&D decision-makers with estimates of the potential for energy savings associated with various thermal energy storage concepts
- identify opportunities for early commercialization of thermal storage concepts
- establish cost and performance R&D goals for TES technologies based on market constraints and competing technologies
- conduct technical assessments of TES concepts to determine the potential for ultimate commercialization
- assist technology development programs in field testing TES concepts.

The TESE Task will coordinate the technology transfer activities of the TES Project. It will assess market potential for TES technologies and prioritize the technologies according to their potential for commercialization.

In one case, technology transfer to the general public in the TES Project has taken the form of posters illustrating TES technologies and capabilities for the Hanford Science Center during Energy Awareness Month. A one-page research update concerning aquifer TES was completed in FY 1987. The research update is directed to a semi-technical audience and will be used for answering inquiries about aquifer TES and as a handout at thermal energy conferences.

4.1.2 TES Target Audiences

Technology transfer activities must be directed to industrial scientists, engineers, managers, and other decision-makers that are potential users of TES technologies. A study currently being conducted by the TESE Task examines the potential of various industries and locations for adopting TES technologies. Once this study is completed, it will be easier to identify potential end-users. Another important target audience is the decision-makers in federal, state, and local regulatory agencies. These individuals will make important decisions concerning the future of TES in the United States. They should therefore be aware of the TES research being conducted in the national laboratories. The general public should also be targeted for information concerning TES technologies.

4.1.3 Barriers to Technology Transfer

Several factors inhibit the adoption of TES technologies. Many of these factors deal with the high risk associated with TES. TES technologies have not been sufficiently developed and tested in the United States to assure end-users of their feasibility. The economic parameters of TES methods have not been well defined, even though TES technologies must be proven to be economically feasible before they can be adopted. Often the characteristics of a TES technology are site-specific and cannot be generalized. Potential users are unfamiliar with TES technologies and tend to be risk-averse and reluctant to invest resources in an uncertain technology. The front-end expenditures involved with the adoption of TES technologies are often quite high. Often there is a wide range of TES system configurations, which makes system selection difficult and confusing for potential end-users.

Again, the annual federal planning cycle adds to the risk associated with TES technologies. A multi-year project is required to adequately test a TES technology because of the annual nature of some TES cycles, such as STES. Also, many of the most promising STES technologies are highly site-specific and require substantial exploratory site investigation. This often involves extensive interaction with regulatory agencies. End-users may be unwilling to deal with the paperwork associated with regulatory agencies.

While TES technologies are utilized extensively in Europe, it is often not feasible to use the same technologies in the United States. Energy prices in Europe are much higher than those in the U.S.; therefore technologies that are cost-effective in Europe may do little to reduce U.S. energy prices. Also, the technical problems are different in the U.S. For example, air conditioning is common in the U.S. and rare in Europe. The potential for TES technologies in the U.S. is enormous, but requires a system that performs as well as current systems while costing less. A breakthrough in TES technology is necessary before this can be accomplished.

4.1.4 Recommendations

Implementing the TESE Task is definitely a step toward accomplishing effective technology transfer. Market and technical assessments of TES technologies must be conducted to convince potential end-users of the merits

of TES. The TESE Task can also aid in identifying the end-users with the best potential for using TES technologies. After defining the needs of potential end-users, TESE can coordinate technology transfer activities to satisfy these needs. Research projects can then be prioritized to meet end-users' needs.

More emphasis should be placed on field testing TES technologies. While TES has been successfully implemented in Europe, site-specific characteristics should be tested in the U.S. The success in Europe will act as a model, but field tests of TES technologies must be conducted in this country. Electric Power Research Institute (EPRI) has begun field testing TES technologies. DOE and EPRI should collaborate R&D efforts of innovative TES technologies.

Technology transfer activities should also focus on the general public. News releases and articles in popular science magazines would be an appropriate avenue to reach interested individuals.

4.2 CHEMICAL/HYDROGEN ENERGY SYSTEMS (C/HES) PROJECT

The C/HES Project, under the lead center direction of Brookhaven National Laboratory (BNL), conducts long-range, high-risk research concerning the feasibility of using hydrogen as a coolant, fuel, and energy storage mechanism. A list of C/HES projects is provided in Appendix A. The C/HES Project was responsible for the operation of the Hydrogen Technology Evaluation Center (HTEC) at BNL. The HTEC was established to test small-scale electrolyzers and hydrogen compressors. Its purpose was to operate as a user facility and to provide technical information on innovative hydrogen technologies. HTEC is not currently being operated because of DOE budget cuts and lack of participation by the private sector.

4.2.1 Current Technology Transfer Activities

C/HES's current technology transfer activities, while limited by budgetary constraints, are varied in nature. Researchers of C/HES have published articles and reports, presented papers, and attended conferences. A list of these activities can be found in Appendices B and C. The HTEC has conducted technology transfer by providing opportunities to illustrate new hydrogen technology developments. The center was used to study the production of

hydrogen from solar energy via advanced water electrolysis. The HTEC also provided an educational and training function. From 1984 through 1986, three sessions of Massachusetts Institute of Technology graduate students and faculty participated in a practice school at HTEC, where they designed and conducted experiments involving innovative hydrogen technologies. Visiting scientists and engineers from universities and industry were able to conduct laboratory work at HTEC. The HTEC has guided hydrogen technology familiarization tours for public officials, executives, managers, and scientists from DOE, EPRI, the Gas Research Institute (GRI), the National Aeronautics and Space Administration (NASA), the U.S Department of Defense (DOD), and private industry. Each of these HTEC functions facilitated the transfer of hydrogen technologies and potential applications from the national laboratories to the private sector.

As with other DOE Energy Storage projects, C/HES interfaces with industries and universities by using corporations and universities as subcontractors. In 1985, C/HES was involved in a joint project with EPRI, a utility, and a manufacturer at the HTEC facility to examine the characteristics of thermally-driven compressors for use in electric utilities. A cooperative research program between C/HES and the Politecnico di Milano has resulted in technology transfer on an international scale.

Several spin-off technologies have resulted from hydrogen research at C/HES. Recent spin-off technologies and the recipients include the following:

- chemical heat pump metal hydride pairs: Solar Turbine Corporation, Standard Oil of California, and Japan.
- commercialization of thermally-driven compressors, metal hydride technology: Ergenics, Inc.
- extraterrestrial liquefaction of hydrogen via metal hydrides for component cooling: JPL/Aerospace.
- scale-up of static feed water electrolysis for regenerative electric energy storage: Life Systems, Inc.
- solid polymer electrolyte electrolysis technology: General Electric Corporation
- modeling of photovoltaic electrolyzer interface: BNL HTEC

- model of Alkaline Water Electrolysis Systems (MAWES): Teledyne Energy Systems.

Another technology transfer mechanism for reaching scientists in other national laboratories and the private sector is through professional societies. The C/HES Project is active in the International Association of Hydrogen Energy, a professional organization that promotes hydrogen technology development. C/HES acts on behalf of DOE in performing technical and administrative functions related to participation of the International Energy Agency (IEA) in hydrogen research and development.

4.2.2 C/HES Target Audiences

Because of the long-term, high-risk nature of the C/HES research, the primary target for hydrogen technologies is other scientists and engineers who are associated with private industry, utilities, universities, and other national laboratories. Other government agencies such as DOD and NASA may be able to discover innovative applications for hydrogen technologies. Management of utilities and industry should be made aware of the existence and potential applications of hydrogen technologies. A manager will not be able to adopt a technology that he/she is unaware of. Specific industries and government agencies to be targeted will vary with the technology and must be determined on a case-by-case basis.

4.2.3 Barriers to Technology Transfer

The C/HES project is currently low on DOE's priority list and lacks sufficient funding to perform extensive technology transfer. Several technology transfer activities have been discontinued because of budget reductions, including a project newsletter and annual contractor review meetings. A private hydrogen newsletter is currently published monthly, but C/HES is only an informal contributor to it.

Because of the high-risk nature of C/HES research, the barriers to technology transfer are similar to those discussed earlier with batteries and thermal energy storage. There is currently a gap between the development of hydrogen technologies by DOE and the commercialization of these technologies by the private sector. As private industry is unwilling to bridge this gap by committing resources to high-risk hydrogen product development, it becomes

necessary for DOE to provide an information dissemination function until an industry champion can be located. If this is not done, innovative technologies may be shelved because of the lack of an identified market.

One cause of the gap between technology development and product engineering is the lack of systems development and field testing. Field testing of hydrogen technologies conducted at the HTEC would illustrate potential applications of hydrogen technologies to private industry. Industry may be more willing to adopt hydrogen technologies if presented with a working full-scale prototype rather than an abstract idea.

4.2.4 Recommendations

A productive method to communicate with scientists and engineers is through technical articles in professional journals. Recent publications by C/HES have primarily been DOE or national laboratory technical reports. More emphasis in journal articles would create greater awareness of C/HES's research results. Scientists and engineers do not always have time to read lengthy articles or attend conferences. One- or two-page summaries of research results would be an effective mechanism to promote the C/HES Project. These short summaries could be distributed at conferences, direct mailed to targeted audiences, or used to answer initial inquiries about hydrogen technologies. Short articles in newsletters are another method of briefly describing research results. C/HES should either reestablish its project newsletter or submit articles to the existing private newsletter.

While written communication can be effective in creating awareness of an innovative technology, person-to-person dialogue is more productive in maintaining scientists' and engineers' interest in the technology. C/HES scientists have accomplished this by attending professional conferences and presenting papers. Reconvening periodic hydrogen contractor review meetings would be a method for scientists from universities, industry, and national laboratories to discuss hydrogen technologies and applications.

Field tests of hydrogen technology would be effective in illustrating potential applications to the private sector. A greater emphasis on engineering development and technology illustration by C/HES would allow scientists, engineers, and managers from other sectors to view hydrogen technology

developments. The HTEC can be an effective arena for such field tests and evaluations.

Knowledge of potential markets is essential to effective technology transfer. Preliminary market assessments must be performed in the early stages of a technological innovation. Market needs can then be considered when technical decisions are made. An example of a near-term market for hydrogen technologies is the NASA/U.S. Air Force funded hydrogen-fueled National Aerospace Plane. C/HES work on this project would necessitate a cooperative agreement between DOE, NASA, and DOD.

It is crucial that technology transfer activities be coordinated from the inception of a research project. This coordination effort should be executed by individuals with knowledge of both the specific technologies and the technology transfer process. Different technology transfer mechanisms will be productive in individual projects depending on a variety of factors, including the target audience and stage of technological development. Appropriate transfer mechanisms must be chosen for each technology to optimize the process.

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