Technology transfer and absorption: an 'R&D value-mapping' approach to evaluation

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Abstract

Evaluating technology transfer outcomes from government supported research, development and demonstration (RD&D) projects is complicated by the variety of paths through which technology can move from producer(s) to user(s). Using a set of 31 cases studies of RD&D projects the processes of technology transfer and 'technology absorption' are examined. Technology transfer is the use by a party external to the project of the technology or technical information outputs. Technology absorption is defined as the use by contractors, sub-contractors or co-sponsors participating in the RD&D project. This is a rarely studied phenomenon but one especially important for technology policies.

The case analysis confirmed the value of viewing transfer and absorption as separate processes with separate determinants. Absorption is a more robust process stimulated by a variety of factors. Transfer is more delicate, thwarted not only by market barriers, but also coordination problems, conflicts, and resource constrains among project members.

Using models of the transfer and absorption processes a typology of transfer outcomes is created. 'On-the-shelf' projects (12 cases) were those in which no transfer or absorption impacts occurred. These projects involved large numbers of actors assisting a small private producer/contractor who was dependent upon outside resources for completing the project. While a surprising amount effort was made to transfer these outcomes the efforts failed. 'Absorption' projects (eight cases) were those in which technology was absorbed but not transferred. Absorption occurred both by design and by default. 'Market-induced' projects (four cases) were those were technology was transferred but not absorbed. These cases also involved small private producers but they experienced less project interdependence and were marketing to niches created

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through public regulation. ‘Contractor and sponsor-induced’ projects (seven cases) were those where absorption and transfer occurred. In most cases absorption was a springboard for transfer activities.

1. Introduction

During the 1980s, the United States federal government implemented a series of legislative initiatives designed to promote technology transfer and government–industry partnerships. At the same time, and generally with much less fanfare, scores of state governments continued to implement a wide array of technology-based programs aimed at spurring state and regional economic development (Feller, 1984; Czamanski, 1987; Devine et al., 1987; Burton, 1989; Forrer, 1989; Atkinson, 1991; Shapira et al., 1995). These programs include ‘centers of excellence’ at state universities (Devine et al., 1987), traditional grants and contracts for research and development (Forrer, 1989), technology and manufacturer assistance programs (Wycoff and Tornatzky, 1988), and loans and tax incentives programs (Czamanski, 1987; Leyden et al., 1989).

The returns from myriad federal and state technology transfer efforts are not yet in and, indeed, it is unreasonable to expect an overnight commercial revolution. None-the-less, the few systematic evaluations completed at the federal level (Brown and Major, 1990; Roessner and Bean, 1990, Roessner and Bean, 1991; Brown et al., 1991; Bozeman and Coker, 1992; Narin and Olivastro, 1992) suggest federal technology policies have not lived up to the rhetoric (Roessner, 1987; 1988; Schriesheim, 1990) surrounding them.

Even fewer systematic evaluations have been performed at the state level (Feller, 1984; Burton, 1989; Forrer, 1989). More often, program officers in the states hold up figures about jobs created, the tax revenues generated from these jobs, multiplier effects to the state’s economy, and various internal rate of return calculations; but, generally, these figures cannot stand up to close methodological scrutiny (Shapira et al., 1995).

Understandably agencies that sponsor RD&D projects have adopted the rationale of technology transfer as one of the benefits, if not the primary benefit, justifying their expenditure of public funds. Similarly, it is reasonable for the evaluator to attempt to ascertain whether the agency is achieving what has been promised. What confounds this sensible order is that the link between public RD&D projects and economic impacts from transfer is often a winding one having no single point of origin or completion.

The dominant metaphors in policy discourse describe technology moving from a government agency or public laboratory to a private sector firm seeking commercialization of the technology (US General Accounting Office, 1989). This rarely reflects reality. First, public-sponsored projects, even those found at federal laboratories (Roessner and Bean, 1990; Bozeman et al., 1995), often are performed by groups of organizations drawn from both the private and public sectors (Smilor and Gibson, 1991). These organizations have varying relationships to the technology under development and interests in what occurs to the outputs of the project. Second, it is a simplistic characterization that the interaction of public and private sector organizations is one of a public resource supplying raw material (in this case innovations) to the private market. The public agency role in projects may vary, as is found in this study, among owner, producer, user, consumer, sponsor, catalyst, co-funder, champion, or any combination of these.

To begin to understand such complexity it is important to examine the development and flow of

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2 Another challenge confronted in evaluating technology policies and technology transfer efforts is that none of the available evaluation techniques is entirely satisfying. Case studies provide rich contextual information but little hope for generalization (Meyer-Krahmer, 1981, Meyer-Krahmer, 1988; Mowery and Rosenberg, 1982; Luukkonen-Gronow, 1987; Moore et al., 1991; Kingsley, 1993); questionnaire-based surveys provide only a rough cut and often at too high a level of aggregation (Roessner, 1987); econometric and production function approaches often include unrealistic assumptions (Link, 1993); peer reviews of results may be futile since technology development programs lack a clear set of peers (Kingsley, 1992b; Bozeman, 1993).
knowledge and technology in projects involving multiple actors and diverse impacts. The objective of this paper is to use information from a set of case studies to develop theoretical explanations of technology transfer processes and to distil lessons about factors contributing to impacts. Two process models are developed, one for 'technology transfer,' the other for 'technology absorption.' By our usage, technology absorption is use by the contractors, sub-contractors, or co-sponsors participating in an RD&D contract of the technology or knowledge developed in the government-sponsored project. This is a rarely studied phenomenon but one especially important for state government technology policies. Technology transfer is the use by an external party of technology or technical information developed by a publicly sponsored contract. The study describes two models, interactions between the two processes, and identifies determinants of effectiveness for each.

Data presented here are from 31 intensive case studies of research, development and demonstration (RD&D) projects sponsored by the New York State Energy Research and Development Authority (the Energy Authority). The case studies were produced as part of the Program Impacts Monitoring (PIM) project during the period 1990–1992. A summary of each case is provided in the Appendix. Our objectives do not include (because accomplished elsewhere) providing an evaluation of the effectiveness of one state agency's technology transfer efforts. However, since all the cases come from a single state government agency, it is important to provide some contextual information about the Energy Authority.

2. The Energy Authority’s technology transfer activities

The Energy Authority was created in 1975 in the wake of the energy crisis. Chapter 864 of the State of New York Law of 1975 structured the Energy Authority, originally known as the New York State Atomic and Space Development Authority, as a public benefit corporation endowed with bonding authority and the ability to recoup contract RD&D investments. Considering all sources of funds, the Energy Authority is the largest state government energy RD&D organization. The Authority was charged with the following mission (New York State Energy Research and Development Energy Authority, 1988): "[T]he Authority's goals are to obtain and maintain an adequate and continuous supply of safe, dependable and economic power and energy for the State, thereby promoting the State's economic growth and protecting its environmental values."

This mission reflects a broader concern with energy, one in which economic and environmental values are often inseparable.

The primary business of the Energy Authority is sponsoring RD&D projects. Over 5 fiscal years (from 1988 to 1993) the Energy Authority provided, on average, $15 million per year for RD&D contracts. More than one-half of the 90 or so full-time employees of the Energy Authority are project man-

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3 The objective of the PIM project was to provide a broad-based assessment of the impacts of the Energy Authority’s projects with a view to developing a monitoring and evaluation system. While the case studies were a centerpiece of the project, PIM also involved a survey of users of the technology (Cimitile and Bozeman, 1992), a peer review of selected scientific and technical projects (Kingsley, 1992b), the design of a prototype computer-based evaluation system (Bretschneider and Bozeman, 1992), and an organization design and management assessment (Bozeman, 1992).

4 The evaluation of the New York State Energy Research and Development Authority’s technology transfer impacts is a secondary concern here, but is the primary concern in a set of monographs produced in the NYSERDA-sponsored Program Impacts Monitoring (PIM) study (see Bozeman et al., 1992a).

5 This discussion draws from Kingsley (1992a).

6 The Energy Authority receives funds from a variety of sources including annual state appropriations, earmarked annual assessments levied on public utilities engaged in the sale of gas and electricity in New York, an annual contribution from the Power Authority of the State of New York (PASNY) provides a yearly contribution, and grants from the federally administered Petroleum Overcharge Fund (the later ceased in 1993). In FY1992, the PASNY contribution was about $2.4 million while the utility assessment $13.6 million; about $12 million was appropriated to the Energy Authority by the State; approximately $13 million came from the Overcharge Fund.

7 The New York State Low-Level Radioactive Waste Act of 1986 established a New York State program to meet the federal low level radioactive waste guidelines for the safe disposal of such waste. The Act also gave the Authority a major role in siting, development, and operation of facilities for disposal.
agers charged with the disbursement and oversight of RD&D funds.  

Funds are provided in two program areas: (1) the Energy Efficiency and Economic Development program (EEED), and, (2) the Energy Resources and Environmental Research program (ERER). The Energy Authority has sponsored more than 1500 projects during its lifetime. The size of awards range from just a few thousand dollars to more than $1 million. The typical project is fairly large, averaging about $200,000. The Authority attempts to leverage its money by seeking co-funders for many of its RD&D contracts.

The RD&D business of the Energy Authority ensues from contracts resulting from one of three processes: unsolicited proposals, competitive bidding processes, or, rarely, sole source contracts. The Authority has a set of procedures for project selection that include extensive use of external reviewers; committee deliberations about project planning and selection; and teamwork among the technical, contracting, and legal divisions of the Energy Authority.

Throughout the project selection process technology transfer serves as one (among several) rationale for project approval. Thus, at some level, the Energy Authority's thinking about technology transfer begins very early. There is, however, a wide range in the depth of assessments of technology transfer potential. Project managers' strategies for transfer are sometimes perfunctory (for example, 'hold meetings for interested parties') and sometimes quite elaborate including multi-media presentations, trade shows, and press releases.

The vast majority of the project managers' time is spent with the development, review, and contracting of projects. In fact, their chief job is to disburse money to worthwhile projects. Typically, managers do not have enough time to be actively involved in the transfer process. Once projects commence, managers are already actively identifying prospects for next year's funding cycle. Some Energy Authority managers hold firm to the conviction that market demand will 'automatically' lead to technology transfer (Aram et al., 1992) for attractive technologies. Others assume that technology transfer is the responsibility of the contractor or the Energy Authority Communications Division (which is charged with providing news releases, responding to formal inquiries, and mailing summaries of project results to persons on the Energy Authority's mailing lists). Only one or two project managers devoted as much as 10% their work load to technology transfer.

3. RD&D case studies and the 'R&D value mapping approach'

Case study methodology has often been employed in evaluations of RD&D projects either through impact analyses (where a case study is joined with some other quantitative method to assess project outcomes) (Logsdon and Rubin, 1985; Luukkonen-Gronow, 1987; Meyer-Krahmer, 1988; Kingsley, 1993; Bozeman and Roessner, 1995) or retrospective analysis (Kreilkamp, 1971; Logsdon and Rubin, 1985). These methods have often been condemned as atheoretical, evaluating the performance of an RD&D project in the context of policy objectives without regard for potential contributions to theory (Moore et al., 1991; Kingsley, 1993). However, some scholars (Eisenhardt, 1989; Yin, 1989; Brown et al., 1991; Bailey, 1992) have convincingly discussed the use of cross-case comparisons for proposition testing and theory building. A recent multiple case study conducted by Oak Ridge National Laboratory researchers used a form of retrospective analysis, systematically charting the relationship between a set of criterial variables and the Department of Energy's contribution to the development of several innovations (Brown et al., 1991).

The method used here, which we call R&D value mapping (Bozeman and Roessner, 1995), continues...
Table 1
Contingency framework. By design, all cases covered the same core set of data. Several instruments were used in the developing and comparing the case studies. There are two types of variables used in the analysis. First are those collected by coding the individual case studies. Second are structured instruments used with respondents as a part of developing the case study. Much of this material is complementary. However, differences in information between the types of variables were resolved by referring back to the narrative or the author of the case.

Technology characteristics

**Coded variables**
- **Technology type**
  Coders characterized cases by selecting between the following contrasting descriptions: hardware vs. software; and product vs. process
- **Technology scale**
  Coders indicated the scale of the technology using the following descriptors: entire plant; system; sub-system; single machine; machine component; non-technological product
- **Technology assessment**
  Descriptions of the technological change were a part of each case.
  Coders rated the degree of change using a 5-point scale (5 = radical; 1 = incremental)
- **Market demand**
  Coders indicated (1 = yes; 0 = no) whether the project was prompted by a market demand
- **Legal demand**
  Coders indicated (1 = yes; 0 = no) whether the project was prompted by a legal demand

**Structured variables**
- **Projects technical goals**
  Respondents were asked to check all the descriptions that were applicable to their project from the following: basic or pre-commercial; demonstration; technology assessment; technology development; feasibility study; technology assistance; student project; internal management; workshop
- **Risk (technical, commercial, legal, political)**
  Respondents were asked to: “indicate your best estimate of the level of risk at the time the project began.” The scale was from 1 to 7; 1 = very risky and 7 = no risk. The following variables were created: technical risk (mean = 3.6); commercial risk (mean = 4); legal risk (mean = 5.2); political risk (mean = 5.4)

Project characteristics

**Coded variables**
- **Project objectives**
  Coders selected from the following descriptors: knowledge development; technology demonstration; technology development
- **Number of participants**
  Coders counted the number organizations participating in the case
- **Principal initiating organization**
  Coders identified which participating organization initiated the project. Two types of identity were established. First was by the organization’s project role as co-funder, contractor, or sub-contractor. Second was by the organization’s relationship to the technology as producer, end-user, or third party

**Structured variables**
- **Project acquisition**
  Respondents selected one of the following descriptions as to how the project was initiated: sole source contract; unsolicited proposal; competitive bids; legislative earmarking
- **Budget**
  Respondents provided the size of the project budget from Energy Authority records
- **Co-funders**
  The number and type of co-funders were provided from respondent records. One of the following descriptors were selected: industry; university; utility; consultant; non-profit; municipality; New York state agency; federal agency; other state agency; foreign government; foreign company; other
- **Contractors**
  The number and type of contractors were provided from contract records. The same descriptors were used as found under co-funders
- **Sub-contractors**
  The number and type of sub-contractors were provided from contract records. The same descriptors were used as found under co-funders

Implemented characteristics

**Coded variables**
- **Goal characteristics**
  Coders described how the goals of participating organizations changed over the course of the project by selecting from the following descriptors: agreement; conflict; complimentary; shift
### Implemented characteristics

<table>
<thead>
<tr>
<th>Principal implementing organization</th>
<th>Coders identified which participating organization performed most of the project research. Project roles and relationships to the technology were also identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal funding organization</td>
<td>Coders identified which participating organization provided the largest amount of funds. Project roles and relationships to the technology were also identified</td>
</tr>
<tr>
<td>Project barriers</td>
<td>Coders selected as many of the following descriptors that proved to be barriers to achieving project goals: relations with the Energy Authority; relations with other project organizations; market barriers; internal organizational barriers; loss of key personnel; availability of resources; problems with the technology. Coders also indicated which of these were the most significant barrier</td>
</tr>
<tr>
<td>Project facilitators</td>
<td>Coders selected as many of the following descriptors that proved to be facilitators to achieving project goals: relations with the Energy Authority; relations with other project organizations; market demand; internal organizational operations; key personnel; availability of resources; technology advances. Coders also indicated which of these were the most significant facilitator</td>
</tr>
</tbody>
</table>

### Implementation characteristics

#### Structured variables

<table>
<thead>
<tr>
<th>Contract modifications</th>
<th>The number of modifications to the contract were counted from respondent records</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intellectual property rights</td>
<td>Respondents indicated whether the project contract contained an agreement concerning intellectual property rights. However, this proved to be the case for all the Energy Authority projects studied and is a standard element of Authority contracts</td>
</tr>
</tbody>
</table>

#### Coded variables

<table>
<thead>
<tr>
<th>Social benefits</th>
<th>Coders selected as many of the following descriptors that proved to be general benefits resulting from the project: economic development; energy efficiency; environmental enhancement; other social benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant benefits</td>
<td>Coders selected as many of the following descriptors that proved to be benefits to participating organizations: new products; new income sources; cost savings; new plant or improvements; new or better jobs; new knowledge; new technology; education and training</td>
</tr>
</tbody>
</table>

### Output characteristics

#### Structured variables

| Project success | Respondents were asked ‘‘compared to all the projects you have managed would you say that this one was successful.’’ This was rated on a scale of 1 to 5 with 1 = much less successful and 5 = much more successful |

### Transfer and/or absorption process

#### Structured variables

<table>
<thead>
<tr>
<th>Target group characteristics</th>
<th>Respondents were asked to identify how the target was determined from the following descriptors: no target group; sector; industry; specific list of organizations; others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissemination channels</td>
<td>Respondents were asked to identify all the channels used to disseminate project outputs from the following descriptors: follow-up projects; seminars; workshops; publications; presentations; distribution of final reports; special Energy Authority publication; other</td>
</tr>
</tbody>
</table>
this tradition of multiple case analysis. R&D value mapping combines case selection based upon criterial variables with case survey analytic techniques. In a program evaluation setting this assures a rich source of data as each case examines a common pool of information.

The approach is similar in many respects to the grounded theory and qualitative research procedures developed by Strauss and Corbin (1990). In this approach, one does not begin with an elaborate theory and then set out to confirm or disconfirm it. Rather, data collection, analysis, theory-building, and theory-testing occur as parallel processes with reciprocal effects upon one another. In particular, Strauss and Corbin’s notion of ‘open coding,’ using research to break down data, conceptualize, and develop categories for data, is quite relevant to the research approach used here.

The first step was the development of a ‘contingency framework’ which identified the factors hypothesized as affecting technology transfer (see Table 1). The gist of the contingency framework is not its structure but the particular variables to be examined. These variables were identified in three stages during the life of the study: case selection, case development, and case analysis.

Case selection involved drawing 30 cases from a population of over 1500 projects performed during the life of the Authority. A random sample of 222 projects were selected (202 from the active files and 20 from the archived files). Project managers were then interviewed to identify relevant criterial variables and cases that they considered ‘successful.’ Other factors that contributed to case selection included (1) theory and models of interest to the research team, (2) time factors, (3) completeness of data, and (4) project outcomes. The research team selected 31 cases with the assumption that perhaps one or more case studies might not be completed. However, all 31 case studies were completed.

The case studies were performed by nine researchers, eight affiliated with Syracuse University’s Center for Technology and Information Policy, one a private consultant. While it was necessary to pro-

13 The entire three stages of development of the contingency framework took roughly 1 year to complete. The PIM research team relocated to Albany, NY, maintaining an office at the Energy Authority. At least two members of the team were on-site every week becoming acquainted with the work flow and the Energy Authority personnel. Development of the contingency framework only began after the team had been at the Energy Authority for 5 months and had become familiar with the operations and culture of the organization.

14 The selection of 30 was to preserve the option of statistical significance tests.

15 The option of simply taking a random sample of 30 projects from the population was rejected because the advantages of probability theory (that is, including all significant causal attributes) are generally diminished with small samples. The confidence levels associated with a sample of 31 are quite large, and the possibility that crucial variables are not adequately reflected in the sample is high.

16 The chief components of the contingency model at this stage were (1) level of funding; (2) recoupment provisions; (3) the stage of research development; (4) contractor attributes; (5) the time the project occurred; (6) contract acquisition mechanism; (7) location of the contractor (in-state, out-state); (8) intellectual property rights; (9) technical risk and liability.

17 After stipulating sampling criteria it was important to introduce another overarching consideration, namely, the perceived success of the project. There was a desire to focus on projects perceived as having an impact. Our rationale was simple. By focusing on ‘successful’ projects it might be possible to learn more about factors leading to success and, ultimately, transfer the lessons learned about one project’s success to future projects. After developing an initial list of more than 100 projects that seemed to capture variance required by criteria in the contingency framework, project managers were asked to provide a rating of the perceptions of the success of the project. Naturally, it was useful to include some average and less successful projects for comparison’s sake.

18 We wished to include, for the most part, projects that had been completed and projects that were less than 10 years old. For older projects, we felt it would be more difficult to complete the case studies due to problems of recall. Nevertheless, we chose a handful of older projects and projects in progress.

19 About one-quarter of the project files were incomplete. In a few cases, project managers had moved and there was no recollection of the history of the project. This was rarely a problem due to low turnover rates at the Energy Authority.

20 The majority of the projects chosen were identified by project managers as having been completed, having resulted in a technical product, and having had some type of impact beyond just completion of the project. This was to ensure some ability to study technology diffusion. Nevertheless, for sake of comparison we included four projects judged as having had little or no impact after the project’s completion.

21 In addition to the authors of this paper, case researchers and authors included Stuart Bretschneider, Carole Cimitile, Larry Kinney (Synertech, Inc.), Julia Melkers, Walter Meyer, and Maria Papadakis.
vide case researchers sufficient freedom to explore the directions their unique cases seem to lead them, there was also a common, thematic interview protocol (Center for Technology and Information Policy, 1992; Bozeman et al., 1992a). The protocol was based upon additional factors identified by project participants during four test cases.

The next step was to 'code the cases' assigning ordinal numbers to describe the criterial and dependent variables. Three researchers who were members of the PIM team coded each of the cases for the dependent variables. For technology transfer scores coders had a 91% agreement rate and a kappa value of 87% agreement. For technology absorption the percent agreement rate was 85% and kappa was 94%.

Two of the three researchers then coded the independent variables in the contingency framework for all 31 cases. For variables describing project characteristics little judgement was required in assigning a code (for example, number of contract modifications, number of organizations involved in the project). Variables describing the process of managing the project tended to require greater judgement (for example, determining the degree to which factors were a barrier or a facilitator to the project). The aggregate percent agreement was 90% and kappa was 75%.

After reading the cases it was apparent to the coders that a technology transfer model was not adequately descriptive of the full range of events and outcomes. Many of the Energy Authority's greatest successes have come from co-sponsors and contractors adopting the technology developed ('technology absorption'). This is not exactly 'transfer' since the organizations were a party to the project, but it may prove equally important both as an end in itself and as a factor influencing transfer. Thus, both a technology transfer model and a technology absorption model were developed and, since the processes are not mutually exclusive, each project was considered in terms of each model.

The term technology transfer has been used many ways and in a variety of contexts. The relatively encompassing definition we use here follows usage in our previous studies (Bozeman and Fellows, 1987; Bozeman and Coker, 1992). By technology transfer we mean "the use by an organization or institution of technology, either process- or product-related, either physical or social, developed in another organization or institution." In our view, technology transfer can involve the deployment of physical technology, software, craft or 'know-how.' The recipient organization may have worked closely with the source organization or they may be unknown to one another.

While our conceptualization of technology transfer shares much with the common definitions used by evaluators, the concept 'technology absorption' is much less familiar but no less important to public-sector objectives. The Energy Authority has enjoyed some of its greatest successes as 'technology absorption.' The term is used here for those cases where the technology developed or modified in a project is used by individuals or organizations who are a party to that project. In most cases, it is the contractor/researcher who absorbs the technology developed, but other parties who might absorb the technology include sub-contractors, co-sponsors, and even the Energy Authority itself. The Energy Authority designs many of its projects with the intent that the results will be used by one of the parties to the project – perhaps a public utility, or a city government, or a state agency. It is an important way of doing public-sponsored 'technology business,' but a process that has rarely been studied.

The flow chart depicted in Fig. 1 presents the technology absorption and technology transfer models. The R&D value mapping (RVM) requires a staged model and, indeed, most Energy Authority activities can be easily described in terms of sequence. In Fig. 1, transfer and absorption scores correspond with the ordinal number assigned to each stage of the models. Both models begin with the

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22 For additional information about the cases see Bozeman et al. (1992a) and Center for Technology and Information Policy (1992). Also, the individual cases studies are available from the authors of this paper.

23 The test cases were presented as a part of a conference hosted by the energy authority in which past and current participants in sponsored RD&D projects were invited to discuss lessons learned in attempting transfers of technology. The "Creating Technology Transfer Success Stories" conference was held in Albany, NY, November 26–27, 1990.

24 The lower kappa score was expected as many of the categorical variables employed nominal measures.
same first step—producing a scientific or technological outcome.\(^{25}\) From this point, the two models follow different paths. Both models were built upon the following assumptions:

1. The models assume that technology can be either a net positive or a net negative in its impact. The models track how the processes of absorption or transfer progressed without assigning positive or negative attributes to the nature of the impacts—hence, the common potential endpoint for both benefit and disbenefit.

2. Success is contingent upon the goals for the project, not the end stage of the project in the model. A project might be quite successful achieving the purposes for which it is designed and not proceed to the later stages of the model.

3. For our purposes, physical technology and scientific or technical knowledge are routed through the same processes and judged by the same criteria. Hence, trade or professional publications are rated in the same manner as a physical technology. Naturally, we recognize that different technical outputs often have very different evaluative implications and different benefits and costs. However, our chief mission is to document the processes and outcomes from those processes rather than to evaluate directly the output of projects. Thus, lumping together different technical outputs into the same models is a problem only if the character of the output can be demonstrated to be a primary consideration in the diffusion model employed.

4. Finally, while the models may seem to imply that technology transfer and absorption follow a linear progression, there is no such assumption. Many points along the flow chart can form feedback loops, as would be the case in a renewal of funding before proceeding to the next phase of a project.

A typology of transfer outcomes was created by charting the scores of each project along both models. The utilization stage in both models (scored at 6 in the transfer model, and 3 in the absorption model) was used as the dividing line for grouping the cases.\(^{26}\) Four categories were created using this procedure. The sub-sets of cases (Fig. 2) are used to analyze technology transfer and absorption outcomes.

The primary approach for the quantitative analysis was elementary—contingency analysis cross-tabulating the criterial variables with the variables from the contingency framework. Cross-tabulation is appropriate to the data. Much of the data are at an ordinal level and some data are at a nominal level (but dichotomous). Particular attention was given to determining why cases terminated at various points along the transfer and absorption models and how managerial actions influenced that outcome.

### 4. Results

Each cell of the typology of outcomes contains at least four representative cases (see Table 2). We labelled each cell according to the characteristic that seemed to best describe the outcome. By definition, the 'on-the-shelf' technologies \((n = 12)\) scored lowest on the transfer and absorption models. Cases that scored high in absorption and low in transfer \((n = 8)\) tended to be designed solely for ‘absorption’. Cases that scored high in transfer but low in absorption \((n = 4)\) tended to be ‘market-induced’ transfers. And finally, cases high in transfer and absorption \((n = 7)\) tended to be ‘contractor and sponsor-induced’ transfers.

Each category of the typology was examined using the contingency framework. The factors that contribute to each outcome are presented below and are summarized in Tables 3 and 4. Table 3 provides

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\(^{25}\) Not all projects reach even this first step failing to produce an output. It is rare for Energy Authority projects to result in no output but this can occur when the technical mission proves to be heading in the wrong direction, a key project member moves or dies, or project resources terminate before an output is achieved. All the projects examined in this study reached the first stage.

\(^{26}\) Our original intent was to use transfer and absorption impact as the dividing line (scores of 7 and 4, respectively). However, analysis of the data demonstrated that the few cases scored at the utilization stage in either model \((n = 2)\) were still in progress at the close of our study with no major barriers reported that would inhibit achieving absorption or transfer.
TECHNOLOGY ABSORPTION STAGES

(0) **No Project Impact** -- the RD&D project did not produce an output.

(1) **Project Impact** -- the project produced scientific or technological output. The nature of this achievement may be independent of the goals of technology absorption.

(2) **Transfer Object Created** -- two forms of transfer object could be created by a project: a technological artifact or a report. Often both types were created.

(3) **Transfer Strategy Created** -- one of the organizations participating in the project develops a plan for disseminating the transfer object.

(4) **Transfer Activity** -- an organization participating in the project sends out the transfer object or information about the object.

(5) **Out-the-Door** -- a potential adopter receives the transfer object.

(6) **Utilization** -- a recipient attempts to use the transfer object in some fashion. Behaviors indicating utilization ranged from tests to local adaptations of the transfer object.

(7) **Absorption Impact** -- there is evidence that the transfer object had either a positive or negative impact on the recipient.

TECHNOLOGY TRANSFER STAGES

(0) **No Project Impact** -- the RD&D project did not produce an output.

(1) **Project Impact** -- the project produced scientific or technological output. The nature of this achievement may be independent of the goals of technology absorption.

(2) **Transfer Object Created** -- two forms of transfer object could be created by a project: a technological artifact or a report. Often both types were created.

(3) **Transfer Strategy Created** -- one of the organizations participating in the project develops a plan for disseminating the transfer object.

(4) **Transfer Activity** -- an organization participating in the project sends out the transfer object or information about the object.

(5) **Out-the-Door** -- a potential adopter receives the transfer object.

(6) **Utilization** -- a recipient attempts to use the transfer object in some fashion. Behaviors indicating utilization ranged from tests to local adaptations of the transfer object.

(7) **Transfer Impact** -- there is evidence that the transfer object had either a positive or negative impact on the recipient.

Fig. 1. (a) Technology transfer and technology absorption. (b) Definition of stages in the transfer and absorption processes (dependent variable scores correspond to the stage number).
TECHNOLOGY ABSORPTION

<table>
<thead>
<tr>
<th>Low Scores (1--2)</th>
<th>High Scores (3--4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Absorption Cases</strong> <em>(scores &lt; 3)</em></td>
<td><strong>High Absorption Cases</strong> <em>(scores &gt; 2)</em></td>
</tr>
<tr>
<td><strong>Low Transfer Cases</strong> <em>(scores &lt; 6)</em></td>
<td><strong>Low Transfer Cases</strong> <em>(scores &lt; 6)</em></td>
</tr>
<tr>
<td><strong>High Transfer Cases</strong> <em>(scores &gt; 5)</em></td>
<td><strong>High Transfer Cases</strong> <em>(scores &gt; 5)</em></td>
</tr>
</tbody>
</table>

Low Absorption Cases:
- Low scores (1--5)
- Support withdrawn
- Market barriers
- Absorption by design

High Absorption Cases:
- High scores (6--7)
- Market-induced transfers
- Contractor- or sponsor-induced transfers

Absorption by default:
- 5. Railmaster
- 6. Refrigeration Compressor
- 7. Lignin and Peat
- 8. Brooklyn Ash
- 9. Rochester Heating
- 10. Acid Rain

On the shelf cases:
- Low scores (1--5)
- Support withdrawn
- Market barriers

Incomplete projects:
- 11. Landfill Leachate

Market-induced transfers:
- High scores (6--7)
- Carbon Monitor
- Radon Monitor
- Artificial Intelligence
- Lighting Research Center

Contractor- or sponsor-induced transfers:
- Diesel Filter
- Bus Plus
- Dual Fuel Buses
- NORDAX
- Weatherization
- Pittsfield
- DSM Incentives

Table 2
A typology of the cases

<table>
<thead>
<tr>
<th>TT</th>
<th>TA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low scores (1--2)</td>
<td>High scores (3--4)</td>
</tr>
<tr>
<td>Low scores (1--5)</td>
<td>On the shelf cases</td>
</tr>
<tr>
<td>Support withdrawn</td>
<td>1. Food Industry</td>
</tr>
<tr>
<td>2. Cogeneration Engine</td>
<td></td>
</tr>
<tr>
<td>3. Plasma Physics</td>
<td></td>
</tr>
<tr>
<td>4. Ice Pond</td>
<td></td>
</tr>
<tr>
<td>Market barriers</td>
<td>5. Railmaster</td>
</tr>
<tr>
<td>6. Refrigeration Compressor</td>
<td></td>
</tr>
<tr>
<td>7. Lignin and Peat</td>
<td></td>
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<tr>
<td>8. Brooklyn Ash</td>
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<tr>
<td>9. Rochester Heating</td>
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<tr>
<td>10. Acid Rain</td>
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</tr>
<tr>
<td>Incomplete projects</td>
<td>11. Landfill Leachate</td>
</tr>
<tr>
<td>High scores (6--7)</td>
<td>Market-induced transfers</td>
</tr>
<tr>
<td>Products</td>
<td>1. Carbon Monitor</td>
</tr>
<tr>
<td>2. Radon Monitor</td>
<td></td>
</tr>
<tr>
<td>3. Artificial Intelligence</td>
<td></td>
</tr>
<tr>
<td>State-sponsored center</td>
<td>4. Lighting Research Center</td>
</tr>
</tbody>
</table>

TA, technology absorption; TT, technology transfer.
a brief narrative describing the relationships between project impacts and the contingency framework. Table 4 further summarizes the findings indicating which variables were the most significant in producing an outcome. 

5. On-the-shelf outcomes

Often RD&D projects require considerable time for full accrual of benefits and those benefits are often quite diverse. But viewed only from the perspective of near-term technology transfer goals, on-the-shelf projects were 'failures.' For our purposes, this makes them particularly interesting.

On-the-shelf cases \(^{28}\) (n = 12) include those that did not reach the utilization stage in either the technology transfer or technology absorption models (scores less than 6 and less than 3, respectively). One of the striking aspects of the 12 cases is the many routes by which projects landed on-the-shelf. First, few of the projects were designed to achieve an absorption outcome. Rather, the goal of these projects was for the contractor, a private sector producer, to create marketable products. Second, projects did not land on-the-shelf for a lack of technology transfer motivation or activity – quite the contrary. Most projects were ambitious, indeed, perhaps too grandiose in vision, by pushing nascent technology into uncertain market environments.

5.1. Technology characteristics

While on-the-shelf projects generally did not attempt radical innovations there was a significant amount of technology development work yet to be done. Most projects attempted to develop a prototype hardware technology to be transferred through the marketplace. Yet the projects addressed issues in which there was little or no history of market demand for a similar technology. Two-thirds of on-the-shelf projects were considered to be 'very risky' from a technical and a commercial perspective. \(^{29}\)

5.2. Project characteristics

Compared to the other cases, a much higher percentage of on-the-shelf proposals begin as sole source contracts. Among the cases, six were sole source contracts and four had on-the-shelf outcomes. \(^{30}\) The contrast is striking. Competitiveness is a cornerstone of many agencies' granting procedures, but it was not obvious that sole source contracts would have less technology transfer impact. One might argue, for example, that sole source contracts would be more likely to result in technology transfer because the sole source basis would be unique or have superior qualifications. But our findings seem to reinforce the view that competition results in stronger projects.

While the origins were sole source, on-the-shelf cases had a large number of organizational actors (> 4) and were large grants (> $250,000). There was a great deal of interdependence among these actors as each contributed critical resources. In most of the cases (67%) contractors were very small businesses involved in starting up a new business line. In on-the-shelf projects, more funding dollars do not

\(^{27}\) The check marks in Table 4 indicate that the variable contributed to the impact associated with that cell of the typology. Since on-the-shelf cases exhibited failures in the transfer process the check marks indicate factors that contribute to that negative outcome. In other types of cases where more positive results occurred the symbol (−) is used with the check mark to indicate whether the factor detracted from a positive outcome. In absorption cases there are significant sub-groups in which contingency factors had different influences. Thus, the symbol (− default) indicates that this variable contributed to the negative aspects of absorption-by-default outcomes.

\(^{28}\) The 12 on-the-shelf results (out of a total of 31 cases) should in no way be construed as a 'success rate' or even predictive on-the-shelf rate. Indeed, two cases were classified as on-the-shelf simply because research was still in progress at the close of the PIM study. Unlike the other cases described above, the Tompkins County Leachate Treatment case and Microelectronic Manufacturing simply have not had the opportunity to reach a point in which utilization or impact from transfer is being attempted.

\(^{29}\) Since in most instances these ratings were given after the project was completed (and perhaps viewed as a technology transfer failure), there may be some post hoc rater bias in the direction of viewing them as more risky.

\(^{30}\) By contrast, only four of 15 projects which were responses to competitive solicitations ended up on-the-shelf.
perform the work supported by multiple funders (3.5 on average). In many cases the two sets (performers and funders) were mutually exclusive. In almost half of the cases the Energy Authority was not the principal funding agency.

Interdependence was a source of vulnerability for these projects. On-the-shelf cases were twice as likely as other cases to experience significant goal conflicts

### Table 3
Summary of Findings

<table>
<thead>
<tr>
<th>Technology characteristics</th>
<th>On-the-shelf</th>
<th>Absorption</th>
<th>Market-induced</th>
<th>Contractor/sponsor-induced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware innovations</td>
<td>Hardware innovations requiring some basic research. Though not radical developments, the technical risk was high. The scale of the technology was a manufacturing sub-system in most cases. Projects targeted industrial end-users and were considered commercially risky from weak market demand.</td>
<td>Complex process technologies. The scale ranged from entire energy production plants to large production sub-systems. Most were incremental developments of technology with a moderate technical risk. Projects were prompted by market demand and aimed at industrial end-users who participated in the project.</td>
<td>Products were created in the form of mechanical equipment or computer software. The scale of the products was single machines. The technical risk was relatively high. Though in response to market demand projects were considered commercially risky. Products were aimed at public utilities.</td>
<td>Projects produced either process technologies or new knowledge about how to use technology. There was a very low level of technical risk associated with these projects. Projects responded to the legal demands facing public sector end-users. High legal or political risk; low commercial risk.</td>
</tr>
<tr>
<td>Project characteristics</td>
<td>Projects were very large in terms of the number of organizations and the size of the grants. They were initiated by the contractor or the Energy Authority. Several began as sole source contracts.</td>
<td>Projects were initiated through competitive solicitations. The source of the technology for the project was typically the end-user.</td>
<td>Projects were large in the number of organizations and small in the size of grant. Most were initiated by a public sector actor.</td>
<td>Projects involved a large number of organizations but modest sized grants. Co-funders tended to be responsible for the initiation of these projects.</td>
</tr>
<tr>
<td>Implementation characteristics</td>
<td>High levels of conflict regarding the project goals and continued support of key members. The research required coordination among participants.</td>
<td>Sub-contractors took a leadership role in the implementation of these cases. Co-funders also played a significant role in the implementation of the project.</td>
<td>The contractor performed the research. Though conflict was experienced most disagreements emerged following the technical completion of the project.</td>
<td>This was the only group of cases to have few interorganizational conflicts. Projects had strong goal agreement and smooth administrative processes.</td>
</tr>
<tr>
<td>Output characteristics</td>
<td>Though the goal was hardware development the output in most cases was new knowledge.</td>
<td>Projects produced new or improved production plants resulting in new income sources and energy efficiency gains.</td>
<td>The outputs were products which provided new income sources to the contractors.</td>
<td>New knowledge was produced concerning the performance of innovative energy efficient technologies.</td>
</tr>
<tr>
<td>Transfer and/or absorption processes Impacts</td>
<td>Transfer objects got out-the-door at the prompting of contractors and the Energy Authority. No transfer and no absorption.</td>
<td>Sub-contractors led absorption by contractors. Some default absorption from market barriers. Absorption only.</td>
<td>Producer/contractor led efforts to market outputs commercially.</td>
<td>Contractor led transfers of technology. Sponsor led transfers of knowledge outputs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Transfer and absorption</td>
</tr>
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</table>
Table 4
Summary of findings

<table>
<thead>
<tr>
<th>Technology variables a</th>
<th>On-the-shelf</th>
<th>Absorption</th>
<th>Market-induced</th>
<th>CS-induced</th>
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Table 4 (continued)

<table>
<thead>
<tr>
<th>Implementation variables c</th>
<th>On-the-shelf</th>
<th>Absorption</th>
<th>Market-induced</th>
<th>CS-induced</th>
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<td>Barriers</td>
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<td>Resources</td>
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<td>New jobs</td>
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<td>New technology</td>
<td></td>
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<tr>
<td>Education and training</td>
<td>√</td>
<td></td>
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</tbody>
</table>

Transfer and / or absorption process e

| Principal disseminating org. | √ | √ | √ | √ |
| Target group characteristics |   |   |   |   |
| Sector                      | √ |   |   |   |
| Industry                    |   | √ (− default) |   |   |
| List                        |   |   |   |   |
| Other                       |   |   |   |   |

a No pattern for the Technology Assessment variable.
b No pattern for Project Objectives, or Types of Participants variables.
c No pattern for the Principal Funding Organization, Facilitator or Intellectual Property Rights variables.
d No pattern for Social Benefits or Project Success variables.
e No pattern for Dissemination Channels or the Number of Disseminating Organizations variables.

or shifts during the course of the project. They were also the most likely to have modifications to the contract (83% had two or more). The largest was the Acid Rain case (see Appendix) which had seven modifications.

The principal barriers stemmed from problems coordinating project participants (75%) and significant market barriers (58%). The former was attributed to the length of time required in administrative procedures (such as contracting, release of funds, and reporting) and goal conflicts between academic and other project participants (viz. Microelectronic Manufacturing, Acid Rain, Tompkins County, and Lignin & Peat). Market barriers were attributed to a “lack of demand for the project outputs” and that “the technology did not have a competitive advantage.”

5.4. Output characteristics

The objective of on-the-shelf projects was to produce new technological outputs. But the benefits from the projects were limited to the development of new scientific and technical knowledge (67%). Participating organizations reported a wide range of benefits accrued from the new knowledge, including economic stimulus (83%), energy efficiencies (83%), and environmental benefits (75%). However, no benefit was attributed to the use of the new technology. We found that the more a technology is used the more likely respondents were to report specific benefits. Lack of use was associated with reports of a wide range of vague and general benefits.

31 Coordination problems stemmed from difficulties managing interorganizational relationships (58%), a lack of sufficient resources (also 58%) and tense relations with the Energy Authority. Relations with the Energy Authority were more likely to be difficult for on-the-shelf cases, accounting for 50% of all the PIM cases that experienced the Energy Authority as a project barrier.
5.5. Transfer characteristics

Technology transfer did not fail from lack of effort. In ten of the 12 on-the-shelf cases there were multiple organizations that made an effort to act as transfer agents, often including the Energy Authority and a co-sponsor.

The most common reason for an absence of transfer or absorption is that a key actor in the project withdrew support at a critical time. Withdrawal was stimulated by any of variety of forces. Several are listed below along with examples from the cases:

1. Differing market assessments between the project's principal contractors and sponsors that led the later to withdraw. Both the Natural Gas Cogeneration Engine project and the Large Area Photodetector Array project resulted in successful technology demonstrations. In both cases the principal sponsor concluded that the market for the technology was not strong enough. As a result they discontinued support. The skills of the contractor, single inventors in both cases, were insufficient to overcome this barrier. The reassessment of the market was virtually independent of the project and its technical work.

2. A breakdown of interorganizational coordination among contractors in performing the project. The Food Industry Technology Transfer project fell short of its objective because the primary contractor, a national association for consulting engineers, could not attract participation from its constituency in New York. This stemmed from (1) tensions between the state and national organizations of consulting engineers and (2) liability issues involved in promoting technologies not covered under industrial codes. Again this was largely independent of the technical results of the project.

3. Differences between state and local government sponsors concerning support for the project. The Ice Pond project, which seemed a technical success, was terminated when a village-wide referendum voted down an Energy Authority requirement of co-sponsorship from the local government providing the research site.

4. Project results were not transferred because the technical solution offered was no better than existing alternatives. In the Screw Compressor demonstration, the technology did not perform significantly better than existing grocery store refrigeration technology.

In the Lignin & Peat project the technology 'worked' but there was no market demand. A single inventor successfully demonstrated an ignition additive for methanol fuels in diesel engines. But methanol has yet to penetrate the diesel fuel market and the inventor did not have the requisite promotional skills. Arguably, the project was a success in that it demonstrated the viability of a technical option which might at some future date have a market.

The Railmaster project failed to penetrate the market because the output was purchased, not by a developer but by a firm wishing to eliminate the competition. The project created a prototype freight car usable by both tractor-trailers and railroads.

In sum, technologies land on-the-shelf for a variety of reasons. Some of those reasons are entirely beyond the forecasting ability of government sponsors or contractors. In other cases, some of the factors that lead to shelving a technology can be anticipated. An interesting question is the extent to which a public agency funding RD&D should seek to anticipate the political and inter-organizational events likely to impinge on its projects' success. Can the Energy Authority anticipate village politics? Should a state agency get involved in a project dependent on the outcomes of a single inventor or

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32 Canon, Inc., a Japanese firm, is currently supporting a continuation of the research on a spin-off application in the Large Area Photodetector Array project.

33 At the time this project began, other bi-modal systems were under production in another state, though they had yet to significantly penetrate the railroad industry. Railmaster was pursued in the hope that a superior design would draw the industry to New York. During the RD&D project, RoadRailer, the competing firm, bought the Railmaster company and technology. RoadRailer then completed the final phase of the RD&D project with the Energy Authority. RoadRailer representatives report that very little of the Railmaster technology worked its way into their product. Thus, the Railmaster design has been classified as on-the-shelf.
where competition exists in another state? Or is it enough for a public agency to evaluate a project on the basis of its technical ‘sweetness,’ apart from either political or unpredictable market contingencies?

These findings also underscore the importance of evaluating organizations’ technology transfer efforts in terms of actual commercial outcomes and not just technology transfer inputs, support activities, or adoption by other parties. Almost all the Energy Authority projects were successful in getting technology out-the-door, or adopted, and adoption is often used as an indicator of transfer activity (Bozeman and Fellows, 1987).

6. Technology absorption outcomes

In the absorption cases (absorption > 2; transfer < 5) we see a very different strategy for achieving impacts. Where on-the-shelf cases tried to stimulate the development of new technologies by producers (in essence a technology push strategy), absorption cases involve private sector end-users as project participants and use them as integral parts of the impact strategy (i.e. a demand-pull strategy). All the absorption cases began as demonstrations of technology by an end-user. If successful, the demonstration resulted in the adoption of the technology by the end-user.

To varying degrees demonstrations are supposed to act as a springboard for further transfer and diffusion. This was certainly the larger objective in what we call the ‘absorption-by-default’ cases: Long Island Incinerator Ash, Flexible Fuels, Modular Hydropower, and Radio Frequency. What distinguishes these cases from on-the-shelf cases is the technology was sufficiently developed so that the end-user adopted and continues to use the technology. However, the factors inhibiting technology transfer are very similar to those found in on-the-shelf cases: market barriers and problems of interorganizational coordination.

Other cases fall in the ‘absorption-by-design’ category: Nassau County Cogeneration, Hubbard Sand & Gravel, Particulate Defects, and Aluminum Nitride. Here the goal of technology transfer was not adoption and use in a specific set of target organizations. Instead the projects focused upon (1) creating large scale production facilities which by themselves could have a substantial impact on a region or upon (2) solving highly localized production problems.

6.1. Technology characteristics

Absorption cases were designed to develop process technologies (87%) in response to prevailing market demand (75%). They are often very large complex technologies ranging from entire energy production plants, as in the Nassau and Hubbard cases, to major production processes, as in the Radio Frequency, Aluminum Nitride and Particulate Defects cases. The technologies involved were incremental innovations requiring relatively large capital investments by the end-users (100%) and significant tailoring to local conditions (100%). In general, the absorption projects were rated by project managers as moderately risky from a technical perspective and low risk from a legal and political perspective.

6.2. Project characteristics

Absorption projects were most likely to come to the attention of the Energy Authority through a competitive RFP proposal process (75%). As might be expected, two distinct types of projects were found in this category. Since ‘absorption-by-design’ cases addressed the installation and improvement of production plants they were, on average, smaller (2.2) in the number of participants and larger (> $200,000) in the size of grant. There was relatively little interdependence in these projects as the contractors were businesses which were sufficiently large enough to provide the vast majority of funds. Absorption-by-default cases were just the opposite, involving many organizations (9.5), small private sector contractors and small grants (> $100,000). As with on-the-shelf outcomes, these cases involved a high degree of interdependence among participants.

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34 Absorption cases had the strongest reliance upon the competitive proposal process of any of the PIM case categories representing 40% of all PIM projects relying on a competitive process.
6.3. Implementation characteristics

Absorption projects were unusual in that sub-contractors took the lead in performing the research (87%). Contractors provided the site at which the demonstration would be performed (and the bulk of the resources in absorption-by-design cases). Sub-contractors were specialists drawn from industry or academia. Thus, most absorption cases involved a subsidized transfer of knowledge or technology from the sub-contractor to the contractor. This was a relatively smooth process as there was strong goal agreement and few contract modifications. Only the Hubbard case followed the practice of contractor-as-research-principal.

The principal barrier confronting the performance of absorption cases was interaction among the various organizations involved in the project (75% of absorption cases). However, the reasons for this problem were similar to those found in the on-the-shelf cases. The Aluminum Nitride and Particulate Defects cases reported value conflicts between academic participants and other participants. Turf battles between public agencies and liability indemnification were also a hinderance (Flexible Fuels, Long Island Ash, Nassau). The Radio Frequency and Hubbard cases experienced problems with the supplier of the technology.

6.4. Output characteristics

Absorption cases achieved considerable benefits for the adopting end-user. Most of the cases (Nassau, Hubbard Sand & Gravel) reported the creation of new or improved plant (75%). The facilities were innovative and reported new advances in technical knowledge in all but the Nassau County case. The primary benefits attributed to the outputs were economic gains (75%) and energy efficiency (88%). Half of the projects resulted in a new income source for the technology user.

6.5. Transfer characteristics

The absorption process in this category involved a transfer of technology and/or knowledge from the sub-contractor to the contractor. The process began with the contracting organization (usually championed by one person) recognizing an opportunity posed by the Energy Authority’s RFP and assembling the necessary resources for creating or improving their production processes. The purpose of the project was to adapt an existing technology to a new geographic setting or a new use. Building from an existing technology, sub-contractors and contractors were able to agree upon the nature of the problem and how the technology might be of use. This facilitated goal agreement in the project. The fact that most absorption projects involved only one phase, i.e. one RD&D contract, and not a series of phases (as was characteristic of on-the-shelf projects) offers some evidence of the incremental nature of project innovations. The public subsidy brought expertise and a chance for greater trial and error in the adaptation process.

Transfer efforts in absorption-by-design projects were either minimal or so contentious that participants had difficulty even developing a strategy for transfer (2.5 in the technology transfer model). Transfer to third parties was not a goal for cases involving the creation of large energy plants (for example, Nassau, Hubbard Sand & Gravel). Rather impacts were measured in creating an alternative energy source for the state power grid. The issue of transfer was highly contentious in Aluminum Nitride and Particulate Defects where academic participants were hindered from doing further research and publishing results due to the proprietary nature of the project.

In the absorption-by-default cases transfer efforts followed the same pattern found in on-the-shelf cases. Market barriers were responsible for unobtained technology transfer objectives. In the Radio Frequency case, the manufacturer of the technically successful drying kiln went out of business before the technology could be diffused. In the Modular Hydropower case projections of increases in the price that utilities would pay for electricity from small cogenerators were overly optimistic. The technologies are in operation at this time, though wider dissemination will require overcoming these market hurdles.

7. Market-induced transfer outcomes

Market-induced projects are designed to assist a private sector contractor in creating a new mar-
ketable product and, unlike on-the-shelf projects, are successful in doing so (> 5 in the technology transfer model). While absorption is not a significant part of the transfer strategy (< 3 in the absorption model) contractors relied upon market demand to lead to adoption of the ‘better mousetrap’ they designed and tested through the project. Thus, a mixed strategy was pursued using a technology push in response to an identified market-pull.

7.1. Technology characteristics

Market-induced transfer cases created product technologies either in the form of hardware or computer software in response to perceived market demand. However, forecasts of demand were firmer than those found in on-the-shelf cases because the markets were regulated heavily by the public sector and usually comprised of utilities as end-users. While all projects required product development, little basic research was performed. Market-induced transfer cases followed the same pattern of riskiness found in on-the-shelf and absorption projects - high technical and commercial risk and low legal and political risk.

7.2. Project characteristics

One of the interesting aspects of these projects is that public agencies played a strong role in their initiation. Given the hopes of commercial success, more private sector impetus would be expected. However, only in the Radon Monitor project was the contractor the primary and sole actor in originating the case. In other cases, there was significant involvement of public agencies initiating private development efforts. For example, in the TEOM Carbon Monitor case, Energy Authority project managers recognized the potential application of the technology to monitoring fly ash of utilities and approached the company about exploring a new line of business.

Market-induced projects were similar to on-the-shelf projects in that they involved a large number of interdependent participants (> 4). Another similarity, with the exception of the Lighting Research Center, is that the contractors were small private companies. However, unlike on-the-shelf cases the size of grants was comparatively small and in all cases the contractor had a previous funding history with the Energy Authority.

7.3. Implementation characteristics

The form of interdependence exhibited in these cases was quite different from that found in on-the-shelf cases. The research was typically conducted by a small number of organizations (one to three), and in every case led by the contractor. Less coordination was required to perform the work. Similarly, while funding drew from many organizations, in all these cases the Energy Authority was the major funding source. Thus, there was project interdependence between funders and contractors but there was little task interdependence among contractors, sub-contractors and funding sources.

Market-induced projects also enjoyed the benefits of greater harmony among participants. There was strong agreement regarding the goals of these projects and few goal shifts. Also, the fact that contractors had a previous funding relationship with the Energy Authority resulted in few surprises in their management relationship during the project. The importance of these differences is evident in examining the barriers confronted by this category of cases. Like on-the-shelf cases, barriers stemmed from interactions among the project participants and problems with resource availability. Similarly, these problems led to the withdrawal of sponsoring organizations (Radon Monitor, Artificial Intelligence). But defections were not fatal for three reasons. First, they happened late in the project so that the technology development goals were near completion. Second, since performance of the research (i.e. task interdependence) required little coordination, defections were less problematic to contractors finishing up the

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35 This was true in three of the four cases. The Radon Monitor project was performed with a smaller number of organizations (two).

36 The only exception was the Lighting Research Center in which the Energy Authority’s commitments were through legislative earmarking.

37 The most contentious of the projects was the Radon Monitor study where disagreements emerged after completion of the project. The conflict concerned the contractor’s decision to locate production facilities for the new product out of New York State.
work. Third, project outputs did not encounter significant market barriers.

7.4. Output characteristics

Market-induced projects created new products that served as new income sources for contractors. These products were much smaller in scale than those encountered in the on-the-shelf cases or the absorption cases, ranging from sub-systems for monitoring production process (TEOM Carbon Monitor, Artificial Intelligence) to small products (Radon Monitor). The use of the products provided benefits in energy savings and efficiencies in all these cases.

7.5. Transfer characteristics

Transfer efforts reflected the market-orientation of the contractors and the public influence on the market place. Transfer activities were led by private sector contractors (three cases) who promoted their products through follow-up projects, publications, presentations, distribution of a final report, and sales promotions (the exception was the Lighting Research Center). In both the Radon Monitor and the TEOM projects, the contractor was the only vendor for the product.

The end-user market was heavily regulated by the public sector in all of the cases. In fact, demand often grew out of this regulation. For example, the Artificial Intelligence and TEOM Carbon Monitor cases were stimulated by the needs of utilities for more effective systems for monitoring energy routing and waste systems. In the Radon Monitor case the market was stimulated by government studies and regulations concerning radon-levels in residential housing. Only the Lighting Research project targeted organizations by industry. But the Lighting Research Center would often promote product innovations through public utilities. 38

8. Contractor or sponsor-induced transfer outcomes

Seven cases exhibited both technology absorption (> 2) and technology transfer to third parties (> 5). The absorption outcomes found in this category were by design, serving as both a project objective and a demonstration to stimulate transfers to third parties. However, unlike the other categories of PIM cases, transfer and absorption activity cannot be attributed solely to the workings of a private sector marketplace. Instead a mixed strategy was pursued of technology-push through innovation and demand-pull through either markets regulated by the public sector or where public sector organizations made up a significant share of the end-user market.

The two most striking characteristics about these projects is their association with the public sector and the participation of end-users. In all cases, project participants or the transfer target organizations were either public sector organizations or hybrid organizations dependent upon or regulated by the public sector (e.g. public utilities). This created two distinct dynamics from a transfer perspective. As public sector agents, they could, through regulation, create a market for the technology (as in the Instrumented Audits project where one of the project sponsors took the lead in transfer activities by requiring the use of the technology in low-income housing inspections). In other projects the contractor took the lead. For example, in the Diesel Particulate Filter case the contractor, the New York City Transit Authority (NYCTA), formed a network of suppliers and vendors from which other public organizations might draw. NYCTA was influential enough as a technology leader to attract the attention of other transit authorities and large enough as an end-user to ensure the interest of suppliers. Because of the distinctive nature of the transfer process this category was labelled 'contractor or sponsor-induced' (CSI).

8.1. Technology characteristics

CSI projects were assessments of process technologies. The assessments were performed in a variety of contexts including demonstrations of conservation technologies (Diesel Particulate Filter, Dual-Fuel Bus, Bus Plus, Instrumented Audits) and evalu-

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38 The scoring of the Lighting Research Center project in the technology transfer and absorption models does not refer to any one technology or project in which the Center engaged. Instead, it reflects the broad mission of the Center. This is consistent with the purposes of the grants received from the Energy Authority which were for the creation and early maintenance until the Center established ties with industry. This was the largest and longest commitment of resources made by the Energy Authority in the cases examined by the PIM study.
ations of technology performance (Pittsfield Incinerator, Demand-Side Management, NORDAX). Thus, the technologies were sufficiently developed that objectives centered on field-testing and assessment.

The environment stimulating innovation in public agencies is quite different than for private firms (and, accordingly, in the other categories of cases). Projects were ranked low to moderate in technical risk and commercial risk. CSI cases accounted for two-thirds of cases perceived as having low technical risk, but far more than half the cases with high political risk. Similarly, this is the only category in which legal demand (that is, mandates) outstripped market demand. Apparently, innovation by public agencies is fraught with heavy political risk and, in these cases, pursued in response to legal mandates.

8.2. Project characteristics

These cases were the most likely to be initiated by a project co-sponsor. This sponsor was a public agency in every CSI case and usually another New York State agency. Energy Authority project managers normally perceive the impetus for projects as coming from the Authority and describe the origins of projects as an "extension of the agency mission." This was found in each of the other three categories of cases. But the impetus for CSI cases was perceived to be coming from an external source, the other state agency, and was described by project managers as "in response to state needs."

The structure of the resulting project was complex involving, on average, large numbers of organizations (7.6). The majority of organizational actors were drawn from state and local agencies, but with strong interactions from the private and not-for-profit sectors. The contractors were public agencies or utilities of sufficient size and slack to support and promote the project. Over half of the projects received grants ranging from $200,000 to $500,000.

8.3. Implementation characteristics

CSI projects entailed a high level of interdependence. This was found both among the number of organizations involved in the task of performing the research as well as in relations between sponsors and contractors. There were multiple funders in all but one CSI project. These large numbers were coordinated by the contractor who was the lead or principal implementor (70%).

CSI cases reported agreement and complementarity about goals in five of the seven cases. Goal agreement was typical of contractor-induced projects, while goal complementarity was more characteristic of sponsor-induced projects. The contracting process was also relatively smooth for most of the projects in this category, perhaps because public sector organizations were working with other public sector organizations.

The agreement concerning goals combined with the size and public nature of most the project participants led to few of the coordination problems experienced by other types of cases. This is the only category in which interorganizational relations was not perceived to be a barrier to project performance. Instead, the major barriers confronting these cases were problems with resources (six projects) or with the technology under development (five projects). The two issues were inter-related.

For sponsor-induced projects, the major barriers were acquiring the resources to overcome technological limitations in the methods of evaluating the performance of the project technology. For example, new sampling techniques were required in both the Instrumented Audits and the Pittsfield cases. For contractor-induced projects, resources were needed to use the technology effectively. Examples of these barriers include (1) subsidies to local governments that kept fuel prices artificially low (Bus Plus, Dual Fuel), (2) an absence of infrastructure in the form of fueling stations with the capacity to handle alternative fuels (Flexible Fuel Vehicles), or (3) the unwillingness of participants use the technology efficiently (NORDAX).

8.4. Output characteristics

CSI projects were successful in performing assessments of technology. In all cases the primary output was new scientific and technical knowledge concerning the energy efficiencies of the technologies in question. However, there were also significant technological developments (four cases) and technical assistance outcomes (four cases). These outputs tended to be innovations in systems of tech-
nology addressing one of several themes: (1) comparing the effectiveness of a variety of demand-side management technologies and administrative systems (NORDAX, DSM, Instrumented Audits); (2) the operation of buses in the form of testing dual fuel school buses, computer software for developing fuel efficient routes (Bus Plus), or emissions filters for city buses (Diesel Particulate Filter); (3) use of alternative fuels (Flexible Fuel Vehicles, Dual Fuel Buses); or (4) testing emissions control (Diesel Particulate Filter, Pittsfield Incinerator).

8.5. Transfer characteristics

Contractor-induced transfer patterns differed markedly from those found in sponsor-induced cases. In the former, the public agency that led the development of the technology absorbed the outcomes and acted as a leader in the transfer efforts to other public agencies. In most contractor-induced cases (Bus Plus, Dual Fuel) the ultimate transfer activity deviated sharply from the original targets. State subsidies for bus fuel were found to be dampening the market for technologies that promoted fuel efficiency in school buses. In the Bus Plus case, the public sector contractor adapted the software product to emphasize efficiencies in the administrative tasks involved in developing bus routes. This adaptation was successful in promoting adoption. In the Dual Fuel case, diffusion has not occurred among school districts. However, the success of the project in the Syracuse school district, coupled with the interests of the local power utility in compressed natural gas technology, has led a regional bus supplier and local transport authority to convert several buses to dual fuel capability.

Only in the Diesel Particulate Filter case did transfer activities resemble the project plans. This case involved the development of a ceramic diesel filter trap that was installed on New York City Transit Energy Authority (NYCTA) buses. After the project, NYCTA insured an initial market by ordering many filters from private sector vendors (i.e. technology absorption). Other cities also adopted the technology, in part due to the active promotion of the technology by NYCTA officials (i.e. contractor-induced transfer).

In sponsor-induced transfer projects knowledge transfers were the goal. In all cases participants assumed that knowledge transfer and technology transfer would be interconnected in predictable ways (National Governors’ Association, 1987). In both the Electricity Conservation Incentives and NORDAX cases, the goal was to create a means for utilities to share information about their experience with demand side management programs and technologies. In the Pittsfield Incinerator case findings from an evaluation of dioxin emissions were quickly distributed to the community of public, private and not-for-profit organizations with interests in solid-waste disposal. Only the Instrumented Audits case differed from this trend by attempting to transfer hardware (blower door technology) as an tool for evaluating public weatherization programs for low-income housing. In this case the sponsor created a market for the technology by mandating the use of this technology in all evaluations whether performed by a public or private agency.

9. Conclusions

At present, technology transfer and R&D impact evaluations examine a confusing array of outcomes including estimates of the number of spin-offs, commercializations, demonstrations, and technology adoptions. This paper’s chief theoretical and conceptual contribution is the delineation between two fundamental processes for movement of technology from publicly sponsored RD&D projects: transfer and absorption. While our treatment of technology transfer does not differ markedly from others’, the technology absorption model considers a set of issues addressed rarely.

Results bear out the expectation that technology absorption and technology transfer processes differ considerably from one another, not only with respect to their target outcome but also with respect to the factors that determine those outcomes. Since many government agencies charged with putting publicly

39 The most common form of technology transfer research has no outcome measures at all (Kingsley, 1993). Rather, cases are selected according to some assessment as being ‘successful’ in transferring technology and then examined for the underlying factors contributing to that outcome. Metrics are rarely used in such case selection procedures.
sponsored technologies in use do, in fact, engage in both transfer and absorption activities we feel that implications may extend beyond the Energy Authority.

Several factors distinguish between cases achieving an impact (either absorption or transfer) and on-the-shelf cases. First, the government is an important source of demand for energy and environmental technologies (Dalpe et al., 1992). 40 This was found both in the legal mandates of CSI projects and public sector markets in CSI and market-induced cases. On-the-shelf cases were much more oriented towards market demand and targeted outputs by industry. Only the absorption cases showed significant private sector commercialization, and these were energy production facilities hoping to sell power back to the public grid. The capacity of on-the-shelf cases to penetrate the markets was further limited because the contractor was either a single entrepreneur or a small business with limited experience in production and marketing.

The findings for on-the-shelf cases are particularly interesting in their lack of success in technology diffusion though they may have succeeded in other objectives. On-the-shelf cases experienced high levels of task and project interdependence, the highest proportion of goal conflict, and the greatest number of contract modifications. This made these cases particularly vulnerable to the withdrawal of project participants. Even though other participants promoted project findings, outcomes were either (1) too distant from commercial viability or (2) dependent upon the endorsement and resources from the participant(s) who withdrew. The consequences of both were fatal to any transfer efforts.

Another common source of conflict in on-the-shelf (as well as absorption) cases was divergent values and goals between academic participants and industry or government participants. The proprietary nature of many of the projects placed restrictions on the publication of research findings. Neither government or academic bureaucracies are known for the speed of their administrative processes. Apparently, when the two are in negotiation the results are especially contentious.

The typology of outcomes also provides some empirical understanding of specific differences between successful absorption and transfer processes. First, cases achieving absorption (including absorption and CSI categories) are more complex and involve larger numbers of participants. Market-induced transfer cases required fewer organizations and less coordination of responsibilities in the transfer process. Indeed the contractor was usually the sole transfer agent when a commercial product was produced.

Second, the absorption process is fairly robust. The significant contingency factors between the CSI and absorption cases exhibited a good deal of variance. While the project characteristics were similar between these two categories, the technology characteristics, origins, outcomes, and transfer characteristics were quite different.

Third, the transfer process does not share this robustness. A variety of factors were found to thwart efforts by project participants to transfer the technology. Cases that landed on-the-shelf exhibited the greatest concentration of these factors which included the following:
1. the distance of the technology from the market at the beginning of the project;
2. conflict in the contracting procedure;
3. conflict in the working relations of project participants;
4. withdrawal in the participation of a key project participant;
5. differences in the target audience for the outcomes.

In most on-the-shelf cases a combination of these factors was found. However, it appears that the withdrawal of a key project participant did the most damage to subsequent transfer efforts. The withdrawal of a key project participant was also particularly damaging to absorption-by-default cases that attempted to use absorption as a means to third party transfers. 41

In cases where transfer impacts were achieved (market-induced and CSI) there was neither a pattern

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40 See Dalpe et al. (1992) for a discussion of the role of government as a first user of innovations.

41 This pattern was seen in the Large Area Photodetector Array, Food Industry Technology Transfer, Ice Pond, and Natural Gas Cogeneration projects from the on-the-shelf cases, and the Radio Frequency, and Modular Hydropower projects from the absorption cases.
of withdrawn support or any of the fatal combinations of factors that constrained the transfer efforts in on-the-shelf and absorption-by-default cases. Only market barriers were confronted in cases designed for market-induced transfer outcomes. Even for CSI cases, the transfer process is sensitive to market barriers. As was noted earlier, two cases (Dual Fuel and Bus Plus) achieved transfers that were different from the initial project objectives.

In cases involving absorption, it is likely that the subsidized adoption process gives participants a greater feel for the potential success of a product on the market. Thus, members drop out before a market test arises. No such intermediate stage exists for market-induced cases.

The typology of outcomes also is relevant to policy debates concerning evaluation criteria for RD&D projects. The cases show that private sector commercialization is a narrow and unforgiving criterion. By this standard many of the CSI and absorption-by-design cases (arguably some of the most successful from the perspective of putting technology in use) fare poorly. However, in these cases use of a technology by the public sector often led to adoption (Diesel Particulate Filter, Dual Fuel) or the creation of a market (Radon, Instrumented Audits, Flexible Fuels) for the private sector. Clearly the outputs from projects were put into use in the majority of the cases. However, the stimuli and the processes involved in achieving these outcomes are quite varied depending upon the character of the technology and the project participants.

Policy-makers and evaluators must be careful in assessing outcomes from RD&D projects. Current policies are on a course to de-value a range of outcomes often integral to the eventual commercialization of a technology. Even among cases selected by project managers as ‘successful,’ 39% landed on-the-shelf. Energy Authority managers were acutely aware that part of the price of public support for technology is patience with the development process and tolerance for negative outcomes. Most public agencies are, like the Energy Authority, geared for overcoming technological barriers. They are less well equipped to overcome the conflicts and coordination barriers that arise during a project or subsequent market barriers.

The findings just summarized represent only a fraction of the results of our analysis (for a more detailed contingency table analysis of the data see Bozeman et al., 1992b) and, of course, an even smaller fraction of the knowledge presented in the 31 case studies used as source data. Moreover, the question of ‘implications for future research’ is a bit clouded by the fact that future researchers will rarely have the opportunity to use source material of the sort we used here. The cost of 31 closely coordinated case studies is considerable and the complete access to files, project managers, and agency officialdom perhaps unprecedented. However, we do feel that the R&D value mapping approach has implications for smaller-scale studies, namely the coordination of cases using a common conceptual framework and the use of contingency analysis.

This study’s chief implication for future research is the need to think of technology transfer and diffusion not as a unitary process but as multiple sets of activities within multiple processes. We have made a broad distinction between transfer and absorption but the distinction leaves much room for refinement. The outreach activities now so ubiquitous in government funding agencies and government laboratories, while unfolding under the common banner of technology transfer, need to be understood in all their richness.

Appendix A. Summary of the PIM cases

A.1. On-the-shelf projects

Limited by lack of support from project participant:

1. Food Industry Technology Transfer Program – Seminars were conducted by the national association of consulting engineers to: (1) inform consulting engineers and three sectors of the food processing industry (bakery, dairy, and fruit and vegetable processors) of energy efficient process technologies; and (2) stimulate interaction between the two groups by subsidizing energy audits to be provided by the

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42 This pattern was found in the Railmaster, Screw Compressor, and Lignin & Peat cases in the on-the-shelf cases.
engineers. Preferences among consulting engineers for technologies that fall within building codes and conventional practice proved a significant barrier to project success.

(2) Natural Gas Cogeneration Engine – A cogeneration machine was developed in which the heat produced in the process of electric generation is recovered and put to use. A high-efficiency, natural-gas-fueled reciprocating power plant was developed and field tested. Support for this technology did not continue in the face of technical difficulties experienced during the project and a declining cogeneration market.

(3) Advanced Development of Ice Ponds for Desalination and Water Purification – Ice ponds were found to work cost effectively in large-scale cooling applications throughout the year. Water purification offered the most significant application of this technology. The results of this project will support the construction and operation of a commercial demonstration facility.

(4) Plasma Physics Large Area Photodetector Arrays – A technique was developed to produce efficient large area position sensitive detectors for high energy radiation (from both nuclear and atomic sources). Also this work furthered the application of amorphous silicon to the generation affordable photovoltaic devices. Though a technical success only the production of amorphous silicon has been further developed through investment from Canon, Inc. of Japan.

Failure to penetrate markets:

(5) Commercial Refrigeration Screw Compressor System Development and Demonstration – The work to date (it is still continuing) has shown that the screw compressor is not competitive as a refrigeration device for supermarkets. The project has advanced screw compressor design and manufacturing and suggested new ways to create a competitive refrigeration technology. The project also began a network between supermarket, utilities, and refrigeration manufacturers on energy issues.

(6) Conversion of Lignin and Peat to Diesel Fuel – Methanol burns clearly in a diesel engine but is difficult to ignite. The objective of this project was to develop a process to convert biomass to a chemical ignition promoter for use in methanol-powered diesels. Diesel engine tests were complicated by the inability of the researcher/entrepreneur to produce large amounts of materials to engine specifications.

(7) Railmaster Intermodal Transport System – An intermodal shipping technology was developed in which trailers from large trucks can be converted to railroad cars. A working prototype was developed. However, commercial success is questionable. The technology was bought by a competing intermodal system producer which incorporated only a few elements of the prototype in their product line. Recent regulatory approval of carless intermodal system suggests that the technology is approaching a ‘take off’ point in the shipping industry.

(8) Brooklyn Incinerator Ash – This project studied physical characteristics of ash residue in municipal solid waste (MSW) incinerators. Results indicated the possible commercial use of ash in asphalt mix. The project was a springboard to the more ambitious Long Island Incinerator Ash project.

(9) Influences of Acidic Deposition and Forest Development on Nutrient Cycling and Forest Productivity – A study to determine acid precipitation effects upon the leaching of nutrients from forests. The study found that the forests were not declining nor were nutrients being lost by leaching due to acid rain. The findings were peer reviewed, published in academic journals, and distributed to the public policy community.

(10) Rochester District Heating Case – A community movement to save a downtown district heating system was supported from deactivation. A cooperative was formed to purchase the plant and equipment. NYSERDA provided the initial infusion of capital, and the organizational legitimacy, to aid the cooperative. The cooperative was successful in purchasing and revitalizing the system. However, the list of customers has begun to dwindle due to the inability of the system to also provide cooling.

Incomplete projects:

(11) Root Zone Method of Treating Landfill Leachate – An artificial wetland was created at a landfill containing a substrate of gravel and reed plants to capture hazardous water run-off (leachate). Although the project is not complete, it is clear that a low cost on-site leachate treatment using artificial wetlands is feasible.

(12) Microelectronic Manufacturing – Two technologies were developed for semiconductor produc-
tion. The first improves energy efficiency via a chemical vapor deposition process applying thin film copper to high density micro-electronic circuitry. The second reduces the municipal waste through hollow fiber membrane separation technology for reprocessing acid-based wet etching solutions. A follow-up project will be a factory demonstration. Technology transfer has also been pursued through academic publications and SEMATECH.

A.2. Technology absorption projects

Absorption by design:

(1) Wood Risk-sharing Program: Power Production at Hubbard Sand and Gravel Corp. – Urban wood waste was used as fuel to produce electric power. The contractor, which is in the business of wood waste recycling, constructed a 3.0 MW turnkey power plant. The technology has proven successful. However, the regulatory environment has changed from conservation oriented utility rate pricing to competitive consumer oriented pricing. This discourages the diffusion of this cogeneration technology.

(2) Nassau County Cogeneration Case – The purpose of this project was to construct and begin operation of a cogeneration plant to provide energy to Nassau County. The greatest hurdle was the existing regulatory framework which is not designed for small private cogenerators. It is the only instance of a successful privatization of public utility cogeneration in New York. The plant was built, the services are being provided, the entrepreneur made a profit, and NYSERDA has enjoyed a recoupment payment.

(3) Identifying Particulate Defects in Cast Products – Analytical scanning electron microscopy (ASEM) was used to evaluate defects in cast products at a New York foundry. The cause of the inclusion was identified and eliminated. The number of reject castings went from 40% to 2% day⁻¹. The methodology and database have not been generalized or disseminated to the research community or industry.

(4) Process for Preparation of Aluminum Nitride – A polymer coating for Aluminum Nitride (Al₂N₃) powders was developed to reduce contamination from water vapors during production and handling. A successful aerosol application was developed for the coating. Transfer efforts are pending additional applied research by the contractor and sub-contractor.

Absorption by default:

(5) Long Island Incinerator Ash – Applications and products from incinerator ash produced by municipal waste burning facilities were developed to help solve some of the solid waste disposal problems. Initial tests and research have led to an asphalt demonstration mixing ash with an ash stabilizing agent. The potential for solutions to this politically charged issue has led to the involvement of 20 local and state government entities.

(6) The Flexible Fuel Vehicle – To increase interest in methanol as an alternative fuel the flexible fuel vehicle (FFV) project performed a prolonged road test, studied environmental benefits, and constructed and operated a methanol service station. The project created a network of organizations with the technical skills and interest in methanol. A new generation of FFV vehicles has been developed and fleet orders have come from California, among others. Scientific and technical findings have been reported through journals and conferences by the researchers.

(7) Report on Modular Hydropower Demonstration – This project compared the costs of constructing and operating two modular systems with conventional systems. Construction costs were reduced by replacing conventional turbines (designed for each site) with pumps, used in reverse, as a turbine for hydropower production. But this was at the expense of technical efficiency. One system was rated a marginal success and the other a failure. Changes in the market and regulatory environments has ended both the demand and support for modular hydropower technology.

(8) Radio Frequency Drying of Lumber – The radio frequency (RF) drying kiln is a means of reducing the drying time of hardwood lumber. The new kiln design used in this project reduced drying time of dimension red oak from 3 months to 3 days. The RF kiln proved economically and technically viable. Further development must overcome two limitations: (1) the need to determine drying schedules for other varieties and dimensions of lumber; (2) the creation of a supplier for the RF drying kiln technology.
A.3. Market-induced projects

Product demonstrations:

(1) TEOM Real-time Carbon Concentration Monitor – A commercially viable carbon monitor using tapered element oscillating mass (TEOM) balance technology was developed to assess the efficiency of power plant combustion. Several New York state utilities have benefitted from improved boiler operations and generation of higher quality fly ash. The contractor has experienced economic development and hopes to make the carbon monitor its major product line if it is commercially successful.

(2) The Electret Passive Environmental Radon Monitor – An affordable monitoring device for accurate and quick measurement of radon emissions in homes was developed. The electret passive environmental radon monitor (E-PERM) has experienced considerable commercial success and is currently being used by over 400 radon industry firms and agencies worldwide. A spin-off of this project was the development of a devise to measure gamma rays.

(3) Artificial Intelligence for Utility Distribution System Planning – The contractor adapted a proprietary artificial intelligence (AI) computer-aided design software system for use by utility distribution systems planners and engineers. The software facilitates the connection of cogenerators to electric and gas distribution systems. The project created a new line of business for the contractor.

(4) Lighting Research Center – This project established and provides continuing support for a Lighting Research Center (LRC) in New York State. The LRC assists designers, manufacturers, utilities, and users of lighting systems in optimizing lighting strategies with respect to energy utilization, health, productivity, and aesthetics. It has received continuing support from industry and government for performing research.

A.4. Contractor- or sponsor-induced projects

Contractor-led transfers:

(1) Diesel Particulate Filter Case Study – A ceramic diesel filter trap was installed on four New York City Transit Authority (NYCTA) uses and tested under normal operating conditions. The diesel traps reduced the particulate emissions of the buses by about 85% with modest decrements in fuel economy. NYCTA found the results encouraging and ordered 400 buses fitted with the trap. Findings were published in the technical literature.

(2) Automated School Bus Routine – A microcomputer software system was developed to route school buses to improve administrative and energy efficiency. The software is now marketed by the contractor to local school districts as an administrative tool. The energy aspects did not have a strong demand from school districts.

(3) Demonstration of Dual-fuel School Buses – Project assessed the operation, safety, and economics of school buses converted to a dual-fuel capability using both petroleum and compressed natural gas (CNG). The CNG buses were a success in one school district and a failure in two. Success was determined by organizational factors such as support from senior management, training of technicians and supervisors, and support from the local utility which maintains a fleet of CNG-fueled vehicles.

(4) Northeast Region Demand Side Management Data Exchange (NORDAX) – NORDAX is a database compiling the experience of utilities in implementing demand-side management (DSM) programs. Included are DSM technical options, market penetration, and DSM program characteristics and performance. Over 20 utilities are now sharing energy conservation data. However, participants have to date faulted the exchange for the quality of the data being shared.

Sponsor-led transfers:

(5) Pittsfield Incinerator Project – A method was developed for examining whether the burning of plastics in municipal incinerators produces harmful emissions such as polychlorinated dibenzo-dioxin (PCDD) and polychlorinated dibenzo-furans (PCDF). The study found: (1) plastics not to be a major cause of dioxin emissions; (2) harmful emissions can be avoided if incinerator temperatures are carefully monitored and controlled. Findings were distributed through research and industry journals by the researchers.

(6) Instrumented Audits for Low Income Weatherization – 'Blower door' and other alternative technology were used in energy audits of low income housing. The technology pressurizes and seals the structure while an auditor diagnoses air infiltration in
the unit. The project proved the technology useful and generated a pool of trained auditors. In 1991 the co-founder of this project issued a regulation that all weatherization audits in New York State use blower doors.

(7) Electricity Demand-side Management Incentives – A series of research reports were produced detailing: (1) alternative demand side management (DSM) programs and regulatory strategies; (2) DSM plans and rate incentive initiatives in New York State. These reports have been widely disseminated in New York and throughout the energy conservation and utility communities in the United States by the NYSERDA project manager and the contractor.

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