Revisiting 32 Technically Successful Projects Supported by the Department of Energy, Office of Industrial Technologies

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ABSTRACT

A review was performed of the commercial outcomes of 32 technically successful R&D projects completed in the period 1980-1988, but which had not been successfully commercialized by the time of a 1989 retrospective study. To update the earlier study, the present review determined that five of the 32 original technologies entered commercial use after 1989. This review identified cases in which commercial success was delayed by three, five or more years after completion of DOE R&D programs, and confirmed that the risk of commercial failure of an industrial innovation, even after technical success is achieved, is substantial and difficult to predict. Additionally, the review confirmed findings that the eventual markets entered by the technologies resulting from R&D are sometimes different from the originally intended markets. Of the five technologies that entered markets, all had substantial non-energy productivity benefits.

Comparing the conclusions of the 1989 retrospective study with the commercial outcomes to date, it is evident that the failure of many of the remaining 27 technologies to enter a market was probably due to lower-than-expected energy prices. This supports the view that R&D funding by DOE's Office of Industrial Technologies has created a knowledge reservoir of industrial energy-efficiency research and production technology that will be utilized profitably by industry if energy prices should rise in future or if the costs of these or successor technologies are reduced.

Introduction

A 1989 study addressed 32 projects which had been completed with a technically successful result between 1982 and 1988, but which had not yet resulted in commercial sales (Energetics, 1989). The 1989 study screened and characterized all of the projects in terms of reported energy savings, reasons why the technologies had not yet been commercialized in 1989, and the qualitative potential for commercialization in the future. More detailed market and environmental impact analyses were then performed on a subset of eight projects chosen by DOE's Office of Industrial Technologies (OIT). The main purpose of the 1989 study was to determine when and under what circumstances the selected eight technologies might be commercialized in subsequent years. Market analyses of eight of the technologies were performed based on available data on the costs and financial benefits they offered to prospective users and then-current fuel prices. Based on this analysis, the potential national impacts of the eight technologies on energy use and pollutant emissions were projected.

The 1989 study assumed fuel price growth rates substantially in excess of price increases that have actually occurred during the past eleven years. As a result, the study incorrectly

projected market success by 1999 for five of the eight technologies for which detailed market assessments were performed. None of these eight technologies has been successfully marketed to date.

However, the present review of the 32 projects originally characterized in the 1989 study has identified five that have been sold commercially. This paper reviews the original list of 32 technically successful projects, relevant findings of the 1989 study, and the current status of commercial outcomes.

Approach

The present review of 32 technologies involved the examination of published documents such as the OIT annual Impacts report (DOE 2001) and limited web-based searches using commercial search engines. All five of the technologies commercialized after 1989 were represented in the most current Impacts report, and two of them were included in a report describing the unintended and unforseen, long-term ripple effects of OIT technologies (Reed 1997). Websites of performing contractors and industry associations were also visited, and web-based searches were performed on technology topics themselves. These limited searches did not identify any commercialized technology beyond the five listed in the current "Impacts" report. Tracking technologies and companies a decade after completion of their DOE supported activities is a difficult task, particularly when relatively small companies are involved. Hence it is possible that additional technologies (or successor technologies) have been commercialized but are unknown to the writers.

Findings

Table 1 identifies the 32 technically successful technologies, relevant findings of the 1989 study, and the current commercialization status of each technology. Five of the technologies addressed by the 1989 review study were commercialized in the interim period (see project names in bold type).

Two of the commercially successful technologies are no longer tracked in OIT's system and are no longer commercially available. The Fluidized Bed Waste Heat Recovery System developed by Aerojet Energy Conversion Company in 1986 was credited with commercial sales before the developer discontinued their involvement in the technology due to internal corporate problems and uncertainties surrounding patent status. This technology was designed to save energy costs in addition to being a self-cleaning alternative to conventional furnace recuperators. The Membrane Separation of Sweeteners technology development project completed by Bend Research, Inc. in 1986 also led to a commercial product that is no longer commercially available. A successful spin-off technology was later commercialized for wastewater treatment.

Two technologies have entered markets substantially different from those originally targeted . The Membrane Separation Oxygen Enrichment System developed by A/G Technology Corporation had 63 units in operation in 1997. Its primary advantage is portability, small size, and simplicity. This technology has been used more extensively for nitrogen supply applications than the intended oxygen enriched combustion air application. Other large gas suppliers now offer competing equipment. The Membranes for Solvent Recovery technology developed by

Membrane Technology Research, Inc. in 1988 was commercialized in 1990 and marketed under the trade name "VaporSep". Thirty-eight units were operational in the United States in 1997. Recently, a new market has emerged for much larger installations designed to recover monomers and other hydrocarbons from nitrogen purge gas generated in production of polyolefin resins. Each such installation will save more energy than all the smaller end-of-pipe units sold to date.

One successful technology, the Bi-phase Turbine Concentrator, was not commercially used until 1994, eight years after completion of the OIT R&D project. The Bi-Phase Turbine Concentrator was Successfully adapted for use in oil/gas separation on offshore drilling platforms, providing simultaneous on-board power generation.

Program Impacts

The 1989 study and other assessments of program outcomes resulted in a new customer-driven Industries of the Future (IOF) strategy in OIT. This strategy has given industry a greater influence in helping to set public R&D priorities and improved access to a wide array of technical expertise and facilities. By partnering with industry in prioritizing and addressing industry's technology needs for the next two decades, OIT believes that the DOE portfolio of R&D activities will help speed up the pace of technology innovation to realize the benefits of energy-efficient technologies. Through programs in nine industry-specific areas, as well as through cross-cutting R&D and financial and technical assistance programs, OIT has developed a close working partnership with energy intensive industries in the United States.

OIT "failures" have sometimes over time turned into successes as technologies have been applied in different, unexpected applications in different industries. For example, when OIT recognized that a membrane technology developed for, but not used by, the chemicals industry could be used in food processing, it enlisted the California Institute for Food and Agricultural Research to test and demonstrate the technology for that application. Together, the two organizations ran a mobile test and demonstration unit at various food industry sites, proving the feasibility of the technology in food-processing applications. One small effort is examining the possible continuing impact of older technologies which may be a significant presence in the marketplace.

Conclusions

Five of 32 technically successful OIT-funded R&D projects completed in the period 1980-1988 -- but not commercialized by 1989 -- have resulted in commercial technologies since 1989. The commercial outcomes to date of R&D funded by OIT in the period 1980-1988 were strongly influenced by non-energy productivity benefits offered by the resulting technological products. One reason was that energy prices subsequent to this period were much lower than had been projected. Some technologies commercialized after 1989 found markets substantially different from their originally intended markets. One of the most successful sparked technology competition among equipment vendors to capture new market shares, and some were replaced by improved, successor technologies building upon the knowledge base provided by the original R&D. The number of technically successful projects whose results are not to date

commercialized suggests that a reservoir of available energy efficiency technical knowledge has been produced which can lead to a variety of energy-saving production innovations if energy prices rise in future. It is conjectured that OIT's present IOF strategy has improved the chances for early commercialization of R&D sponsored since the mid-1990s by building in firmer commitments from industry partners, including increased cost sharing, at all stages of the development process.

References

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Table 1. Summary of Selected, Technically Successful Projects Supported by OIT 1980-1988

Title	Year Completed	Contractor	Reasons Not Commercialized: 1989 Study	Potential for Future Commercialization: 1989 Study	Present Commercialization Status
1. Organic Rankine Bottoming Cycle System	1986	Sunstrand Energy Systems	5-6 commercial units existed; high capital costs and current energy prices limit feasibility to regions where electricity is $0.10/kWh or more; industrial participant stopped marketing technology to pursue better financial opportunities.	Moderate to High.	Listed in "Impacts" as an historical success no longer tracked, and no longer commercially available. However, this technology was not commercialized beyond what had already occurred before 1989. It was a precursor to more advanced technologies.
2. **Bi-Phase Turbine Concentrator**	1986	Bi-Phase Energy Systems, Inc.	Industrial participant discontinued involvement in technology to pursue better financial opportunities.	Moderate to High. Technology has a variety of applications.	First commercial unit in 1994. Two units operating in 1997 for oil/gas separation on offshore platforms, providing on-board power generation.
3. **Fluidized Bed Waste Heat Recovery System**	1986	Aerojet Energy Conversion Company	Developer discontinued involvement in technology after internal restructuring following an attempted takeover of the parent company; also, uncertainties surrounding patent status and lack of patent protection have limited commercialization.	Moderate. Higher energy prices would enhance potential.	Historical success no longer tracked by OIT and no longer available, but which was credited with commercial sales.

Table 1. Summary of Selected, Technically Successful Projects Supported by OIT 1980-1988 (Continued)

	Title	Year Completed	Contractor	Reasons Not Commercialized: 1989 Study	Potential for Future Commercialization: 1989 Study	Present Commercialization Status
4.	Air/Fuel Ratio Control	1988	Thermo Electron Corporation	While the concept has been shown to be valid, technical uncertainties remain unresolved, specially there is no fundamental understanding of the processes involved.	Moderate. Technology would be applicable to any combustion system with multiple burners.	Not commercialized and essentially leapfrogged by other technologies such as the one following.
5.	**Membrane Separation Oxygen Enrichment System (Hollow Fiber Membrane)**	1986	A/G Technology Corporation	Efforts to commercialize were currently underway; mixed economics and perceptions regarding membrane performance could limit commercialization.	Moderate. Commercialization is anticipated in 3-5 years. Will generally be limited to systems under 10 tons/day.	63 units operating in 1997. Primary advantage is portability, small size, and simplicity. Technology has been used more extensively in nitrogen supply applications than the intended oxygen enriched combustion air application. Other large gas suppliers now offer competing equipment.
6.	CO_2 Recovery and Generation	1988	Argonne National Laboratory	Process is uneconomical at oil prices below $25/bbl.	Moderate. CO_2 could be used in 30% of enhanced oil recovery operations representing 7 to 21 billion barrels of crude oil per year. Environmental pressures can enhance potential of this technology.	Not commercialized.

Table 1. Summary of Selected, Technically Successful Projects Supported by OIT 1980-1988 (Continued)

Title	Year Completed	Contractor	Reasons Not Commercialized: 1989 Study	Potential for Future Commercialization: 1989 Study	Present Commercialization Status
7. Waste Tire Combustion	1982	National-Standard Company	High capital costs for the fluidized bed boiler make the system economics marginal given current energy prices and current value of waste tires.	Low to Moderate. Only about 25% of 200million passenger tires discarded annually are recycled. Potential is limited to regional facilities.	Not commercialized.
8. Fuel from Waste Tires	1982	Eastern Products	Technical and economic uncertainties remain about storing and handling tire derived fuel.	Moderate. Only about 25% of the 200 million passenger tires discarded annually are recycled. Combustion of all waste car tires would save 0.06 quad/yr.	Not commercialized.
9. Cement Kiln Dust/Fly Ash Cement Substitute	1980	Valley Forge Laboratories	County and other highway agencies were unwilling to adopt the new method, believing it had not been sufficiently demonstrated.	Moderate. Portland cement is used in more than 90% of the 700 million tons of concrete produced annually in the U.S..	Not commercialized. Durability of the pavements containing kiln dust is the issue.
10. Energy Recovery from Forest Residues	1986	Gorham International	Generally low oil prices have reduced the economic incentive for use of wood fuels.	Moderate. Logging residues represent a fuel source equivalent to 500 million barrels of oil.	Not commercialized.
11. Liquid Fuels from Waste Cellulose	1984	Arizona State University	Process is uneconomical given present yields, energy prices, feedstock values and high capital costs for the technology.	Low to Moderate. Even with higher yields and energy prices, the process will face stiff competition from alternative technologies[19]. The process may have value for converting feedstocks with hazardous components that are costly to dispose of.	Not commercialized.

Table 1. Summary of Selected, Technically Successful Projects Supported by OIT 1980-1988 (Continued)

Title	Year Completed	Contractor	Reasons Not Commercialized: 1989 Study	Potential for Future Commercialization: 1989 Study	Present Commercialization Status
12. The Cothane Process	1982	Union Carbide	Uneconomical due to low energy (natural gas) prices; additional development is needed to increase catalyst performance.	Moderate. Environmental pressures could enhance commercialization potential for this technology.	Not commercialized.
13. Compression Drying of Wood	1986	University of Minnesota	Technical and economic uncertainties remain unresolved; low oil prices have decreased the incentive to use wood fuels.	Moderate. It is estimated that compression drying could increase the recovered heat from wood fuels by 0.26 quad in 2000.	Not commercialized.
14. Re-refining of Used Oil	1985	Bartlesville Energy Technology Center	Problems related to system economics, limited feedstock availability, disposal of waste sludges, and public acceptance of used oil have limited commercialization.	Low. Problems that have limited commercialization will be difficult to overcome. Environmental pressures might enhance the concept of used oil recycling in the future.	Not commercialized.
15. Methane from Pharmaceutical Wastes	1988	Hydroqual	High capital costs, relatively low product (methane) value, product impurities, and limited product transportability have resulted in poor economics and marketability.	Low to Moderate. Conversion to higher-value products than methane will likely be more economical. About 5,000 plants are good candidates for this technology.	Not commercialized.
16. Low-Energy Cement Production	1985	Southwest Research Institute	Process was not sufficiently demonstrated due to lack of research funds in the cement industry and the lack of an industrial partner willing to participate.	Moderate to High.	Not commercialized.

Table 1. Summary of Selected, Technically Successful Projects Supported by OIT 1980-1988 (Continued)

Title	Year Completed	Contractor	Reasons Not Commercialized: 1989 Study	Potential for Future Commercialization: 1989 Study	Present Commercialization Status
17. Roof Waste Conversion	1987	Mansville Corporation	Research has only recently been completed; while commercialization is expected, limited capital availability could slow it.	Moderate to High. A market of 470 trillion Btu/yr exit in the form of land filled roofing shingle and factor roofing asphaltic wastes.	Not commercialized.
18. Improved Distribution of Over Fire Air in Wood-Fired Boilers	1982	Oregon State University	Generally low oil and gas prices have limited interest in wood fuels.	Moderate. About 1,700 industrial wood- and bark-fired boilers exist in the U.S., most of which are spreader stokers that could benefit from this technology.	Not commercialized.
19. Membrane Separation of Sweetners	1986	Bend Research, Inc.	Commercialization efforts are underway; the need for a full scale operational demonstration and resolution of normal scale-up issues remain.	Moderate to High. About 5 billion gallons of steep water are concentrated each year with energy intensive evaporate[29]. Process can extend existing reverse osmosis markets.	Historical success no longer tracked and not commercially available. A successful spin-off technology was commercialized for wastewater treatment. Technology was precursor to more advanced systems.
20. Cold Corrugation	1984	Institute of Paper Chemistry	Technical problems remain related to the lack of a suitable adhesive; limited interest in industry to continue developing the technology.	Low to Moderate.	Not commercialized. This technology was not ultimately a technical success though goals of DOE program were met.

Table 1. Summary of Selected, Technically Successful Projects Supported by OIT 1980-1988 (Continued)

Title	Year Completed	Contractor	Reasons Not Commercialized: 1989 Study	Potential for Future Commercialization: 1989 Study	Present Commercialization Status
21. Freeze Crystallization of Black Liquor	1986	Concentrex, Inc.	Process is not economical given current oil prices; original developers are no longer in business[32].	Moderate to High. About 275 paper mills could use black liquor concentration. Other industries, such as te dairy industry, can also apply freeze concentration.	Not commercialized.
22. Machnozzle	1981	Georgia Institute of Technology	Difficulty achieving acceptance versus a more established process (vacuum slot); very limited industry use exists.	Moderate. Process has potential for use with heavier fabrics and in combination with vacuum slot process.	Not commercialized.
23. Energy Efficient Grain Dryer	1981	Iowa State University	Economics favor conventional drying processes at current energy prices; technology must displace a well established practice and technology.	Moderate.	Not commercialized.
24. High Temperature Heat Pump Grain Dryer	1982	Westinghouse Electric Corporation, Purdue University	Dryer is not cost-effective at current energy prices.	Moderate.	Not commercialized.
25. Integrated Farms	1987	Various	Lower energy prices and readily available fuel supplies have reduced the incentive for farmers to implement these technologies; some aspects of demonstrated techniques have been implemented; site specific conditions dictate that only selected measure would be implemented on any given farm.	Moderate. Future commercialization potential is directly proportional to fuel availability and prices.	Not commercialized.

Table 1. Summary of Selected, Technically Successful Projects Supported by OIT 1980-1988 (Continued)

	Title	Year Completed	Contractor	Reasons Not Commercialized: 1989 Study	Potential for Future Commercialization: 1989 Study	Present Commercialization Status
26.	Improved Humidity Sensor for Grain Dryers	1988	Honeywell Corporation	Developer does not, at present, foresee a sufficiently large market to commercialize.	Moderate to High. The sensor is also applicable to residential, commercial, and other industrial humidity measurements. Potential savings of 0.001 quads have been estimated.	Not commercialized.
27.	Heat Exchanger (Multi-Deck) Dryer	1982	Johns Mansville	Developer has installed 2 units but has refrained from licensing technology to others.	Moderate.	Not commercialized.
28.	Energy Efficient Use of Textile Dryers	1980	Clemson University	Several companies have used the technology; low energy prices and staffing cutbacks/change in the textiles industry have limited interest in technology.	Moderate.	Not commercialized.
29.	Critical Fluid Extraction of Ethanol from Aqueous Solutions	1985	Critical Fluid Systems, Inc.	For waste treatment applications, commercialization is underway (3 units sold); for process applications there is a lack of operating history to satisfy industry.	Moderate to High. Numerous processes exist in which water-oxygenated organic chemicals are separated by distillation.	Not commercialized.

Table 1. Summary of Selected, Technically Successful Projects Supported by OIT 1980-1988 (Continued)

Title	Year Completed	Contractor	Reasons Not Commercialized: 1989 Study	Potential for Future Commercialization: 1989 Study	Present Commercialization Status
30. Membrane Distillation	1988	AlliedSignal (formerly UOP)	Generally, industrial perceptions on membrane technologies. Also, for 1) natural gas sweetening and 2) solvent recovery from heavy oil, the depressed state of the natural gas and oil industries have limited commercialization. For polar gas separation, technical issues remain unresolved.	Moderate to High. Generally, membranes have a broad range of applications. Higher energy prices and greater synthetic fuels development will increase potential for these technologies.	Not commercialized. Incidently, is similar to "Separex" proprietary membrane technology acquired by UOP elsewhere and widely used for gas sweetening and other carbon dioxide rejection from hydrocarbon gases such as from Enhanced Oil Recovery.
31. Ultraviolet Paint Curing	1982	Westinghouse Electric Corporation	Information not available.	Information not available.	Not commercialized.
32. Membranes for Solvent Recovery	1988	Membrane Technology Research, Inc.	Industry is reluctant to implement this new technology which it feels has not been sufficiently proven in actual industrial settings, particularly when compared to conventional technologies (e.g., carbon adsorption[8].	Moderate. As an illustration of potential, about 10 million tons of a total of 30 million tons of volatile organic solvent releases in 1975 could have been recovered using membranes. Environmental pressures (e.g., CFCs) can enhance attractiveness of this technology.	Commercialized in 1990 and marketed under the trade name "VaporSep". 38 units operating in the United States in 1997. Recently a new market has emerged for much larger installations designed to recover monomers and other hydrocarbons from nitrogen purge gas generated in production of polyolefin resins. Each such installation will save more energy than all the smaller end-of-pipe units installed to date.

Note: 49 footnote references from the 1989 study are not repeated in this table.