EPA and NSF
Technology for a Sustainable Environment
Evaluation Meeting Report

Arlington, VA
May 19, 2004

Executive Summary

The panel members strongly endorse continued funding of the Technology for a Sustainable Environment (TSE) program because such research is critical to protecting our environment, maintaining our quality of life, and ensuring the economic competitiveness of the United States. Failure to continue this program would have drastic consequences on our environmental and economic future, not only because it is producing beneficial sustainable technologies, but also because it is educating a new generation of scientists and technologists that will bring about a paradigm shift in environmental science from command-and-control to prevention and conservation. By fostering a sustainable research community, the TSE program is acting as a catalyst in redefining environmental science.

The goals of the TSE program should be more focused for impact on its target audiences – academic researchers, industry, the public, and policy makers. A more cohesive statement of goals would promote synergy and focus within the program and would facilitate communication of the goals to industry and other stakeholders. A compelling vision that identifies what is unique about the TSE program is needed. The program could benefit from redefining its goals in terms of economy, environment, and community, which would make the goals more meaningful to policy makers (i.e., linked to economics, safety, and societal/quality of life benefits). The key role of education of researchers with regard to sustainability also should be highlighted as a goal and outcome of the program.

The outputs of the TSE program have been of high quality. There have been several examples of important scientific advances, and the investigators have published numerous high-quality publications in high-impact journals. Many of these publications have been extensively cited in the literature. There are dozens of patents resulting from the program, and numerous technologies have been commercialized and adopted by industry. The investigators are high-quality scientists and many have received honorary awards for their research contributions. In addition, numerous students have been trained in sustainable research.

Measurable outcomes should be expected within 5-10 years for a program such as TSE. The panel recognized the value of the TSE program and the fact that it has produced measurable outcomes; however, most of the outcomes have not been measured or documented. The outcomes of the program also are not linked to the program goals. Some of the measurable outcomes that should be tracked and documented for the program include: data on the former students trained under the TSE program to determine the impact of the program on their careers, quantitative reduction in pollution and use of toxic materials as well as economic savings resulting from sustainable technology, industrial collaborations including pilot tests by industry of technologies developed under the TSE program, citation of TSE researchers' publications in patents and patent applications, technologies that have been commercialized and are being used in industrial processes, the amount of funding received by TSE grantees from other sources to continue their research, the number of sustainable research centers established as a result of "seed" money from the TSE program, the number of patents licensed, and number of start-up companies resulting from TSE research projects.

The metrics from decision support tools being developed by TSE investigators should be used to assess the outcomes as TSE research moves into commercialization. For example, a life cycle assessment model developed under TSE could be used to assess the outcomes of TSE projects. It also would be beneficial to track the fundamental research that feeds into applied research that leads to the development and commercialization of sustainable technology, as well as applied research that leads to fundamental questions that feed into basic research. The TSE portfolio should include a balance of fundamental and applied research and the metrics should account for both.

The broad approach taken by EPA and NSF was appropriate for the first 5 years of the program and it has been relatively successful in funding good science. The program now has matured to the point that more focus is needed. The goals need to be more specific and the desired outcomes should be clearly articulated. Given the limited budget for TSE research, a sharper focus and more collaboration among the investigators will allow the program to maximize its future impact. In addition, the products of the TSE research should be linked to the program goals.

More outreach is needed to educate the scientific community, policy makers, and other audiences about the tremendous value and contributions of the TSE program. Periodic meetings of the investigators should be organized to foster interaction and collaboration among the investigators and to build the community of sustainability researchers. EPA also should make a concerted effort to transfer the results of the TSE program to the Regions and states, and consider outreach to the pollution prevention community.

The TSE program would benefit if the efforts and areas of research were focused and better integrated so that synergies could be realized among the projects. Given the current limited funding level of the program, there is too much breadth and too little depth. A workshop attended by leading academics and industrial participants should be organized to identify and prioritize new research areas for the TSE program. This input is critical for better defining the program s goals and setting priorities for future research.

The partnership between EPA and NSF has been quite successful and should be continued. The dedication and commitment of the EPA and NSF staff have been key to the partnership s success. There was strong support among the panel members for increasing federal funding for the TSE program. There also was agreement that TSE research is crucial to environmental health and the economic competitiveness of the United States. The TSE program has stimulated innovative research that probably would not have been funded by NSF or EPA outside of this program. The education of a new generation of scientists and technologists aware of sustainability issues and solutions is a very important government responsibility. By fostering a sustainable research community, the TSE program is acting as a catalyst in redefining environmental science and bringing about a paradigm shift toward prevention that will benefit our environment, economy, and quality of life.

Background and Overview

In 1995, the U.S. Environmental Protection Agency s (EPA) Office of Research and Development (ORD) entered into a partnership with the National Science Foundation (NSF) to jointly fund competitive TSE grants. NSF and EPA provide funds for fundamental and applied research in the physical sciences and engineering that will lead to the discovery, development, and evaluation of advanced and novel environmentally benign methods for industrial processing and manufacturing. The competition addresses technological environmental issues of design, synthesis, processing, and the production, use, and ultimate disposition of products in continuous and discrete manufacturing industries. Projects must employ fundamental new approaches, and address, or be relevant to, current national concerns for pollution avoidance/prevention (at the source). Projects that are on the cutting edge or are high-risk/high-payoff are encouraged. Also considered are projects that show the potential to change research infrastructure by developing teams, using systems approaches, and introducing new ways of conducting research. Since the program s inception, EPA and NSF have funded 204 TSE research projects totaling $60.7 million ($27.1 million from EPA and $33.6 million from NSF).

On May 17-18, 2004, EPA and NSF brought together the TSE grantees to discuss their research projects and to share their experiences with regard to the TSE program. A panel of external experts was invited to attend this meeting to learn more about the TSE program and to provide the panel members an opportunity to interact with the grantees. The expert panel then convened on May 19, 2004, to review and evaluate the TSE program. In the morning, EPA and NSF provided presentations on the TSE program and responded to questions from the panel members. Following the question and answer session, Dr. Darlene Schuster, Chair of the Review Panel, presented the charge for the evaluation. She identified five questions to be addressed during the review:

1. Are the program goals clearly articulated and appropriate?
2. Have the outputs been high quality?
3. Has the program led to measurable outcomes?
   - What are the appropriate metrics for these outcomes?
   - In what time frame would you expect to see outcomes?
4. Has the approach taken been appropriate to meet program objectives/desired outcomes?
   - Are the outreach efforts appropriate and successful?
   - Has the program responded to external changes in the TSE research areas?
   - Is the partnership working?
5. Is federally funded research still needed in this area?
   - What improvements should be made?
   - Are there obvious unanswered research questions, and is TSE a good way to answer them in the context of other federally funded research?

The panel was divided into two groups to discuss each of these questions and develop responses. The entire panel then reconvened to discuss the responses and develop the evaluation report.

1. Are the Program Goals Clearly Articulated and Appropriate?

EPA s goal for the TSE program is to research, develop, and promote implementation of scientific and technical advances to reduce water, material, and energy intensity and increase the use of benign material and energy. The program funds research that advances the discovery, development, and use of innovative technologies and approaches to avoid or minimize the generation of pollutants at the source. Individually, the EPA and NSF missions for the program are well understood and stated, but they are somewhat disparate. It was not clear that the TSE investigators had a common understanding of the TSE program goals; this may be attributable to the fact that NSF s goals are simpler and easier to understand than

EPA s goals. The panel members thought the goals should be more focused for impact on the target audiences academic researchers, industry, the public, and policy makers. A more cohesive statement of goals would promote synergy and focus within the program and would facilitate communication of the goals to industry and other stakeholders. A compelling vision that identifies what is unique about the TSE program is needed. The program could benefit from redefining its goals in terms of economy, environment, and community. The goals should be made more meaningful to policy makers (i.e., linked to economics, safety, and societal/quality of life benefits). The concept of sustainability means that multiple goals such as a safe, clean environment and a healthy economy can be achieved simultaneously without tradeoffs. Sustainability goes beyond compliance because it is economically and environmentally attractive to industry and good for the community because it decreases the environmental footprint of industry.

The panel members also thought that the key role of education of researchers with regard to sustainability should be highlighted as a goal and outcome of the program. The TSE program could play a key role in fostering a paradigm shift in environmental science from command-and-control to prevention and conservation.

2. Have Outputs Been High Quality?

There was general consensus that the outputs of the program have been of high quality. There have been several examples of important scientific advances, and there are numerous high-quality publications in high-impact journals. Many of these publications have been extensively cited in the literature. There are dozens of patents resulting from the program, and numerous technologies have been commercialized and adopted by industry. The investigators are high-quality scientists and many have received honorary awards for their research contributions. In addition, numerous students have been trained in sustainable research.

3. Has the Program Led to Measurable Outcomes?

The panel recognized the value of the TSE program and the contributions if its research. The panel members expected measurable outcomes from a program such as this within 5-10 years. They acknowledged that the time frame often is longer for fundamental research than for applied research, and the metrics for these two types of research vary. The TSE portfolio should include a balance of fundamental and applied research and the metrics should account for both.

The panel members agreed that the TSE program has produced measurable outcomes; however, most of the outcomes have not been measured or documented. The outcomes of the program also are not linked to the program goals. The science outcomes (e.g., number of publications cited, number of graduate students supported) are better documented than the environmental outcomes (e.g., pounds of pollution prevented, pounds of toxic materials eliminated from a production process). Nonetheless, there are many anecdotes that point to program contributions with industrial relevance (e.g., the efforts of Drs. DeSimone, Lave, and Subramaniam).

The panel members identified a number of measurable outcomes that should be tracked and documented by the program. EPA and NSF should consider gathering data on the former students trained under the TSE program to determine the impact the program has had on their careers. Are they conducting sustainability research or pursuing careers in the field of sustainability? Has the program had an impact on their career choices and the way they approach environmental science? Quantitative reduction in pollution and use of toxic materials as well as economic savings resulting from sustainable technology should be tracked and documents. Key examples with pollution prevention/economic impact should be provided (reporting pounds of pollutant eliminated and dollars saved).

Industrial collaborations could be better documented to demonstrate outcomes. Pilot tests by industry of technologies developed under the TSE program is another metric to determine the program s impact. The citation of TSE researchers publications in patents and patent applications should be tracked as an outcome of the program. The metrics from decision support tools being developed by TSE investigators could be used to assess the outcomes as the TSE research moves into commercialization. For example, a life cycle assessment model developed under TSE could be used to assess the outcomes of another TSE project.

Other measurable outcomes identified by the panel include:

Technologies that have been commercialized and are being used in industrial processes.

Number of grantees who receive funding from other sources (and amount of additional funding) to continue research begun under the TSE program.

The number of sustainable research centers established as a result of seed money from the TSE program.

Licensing of patents.

Fundamental research that feeds into applied research that leads to the development and commercialization of sustainable technology, and applied research that leads to fundamental questions that feed into basic research.

Number of start-up companies resulting from TSE research projects.

The panel members thought the Department of Energy s (DOE) energy conservation model could be adapted to improve the measurement of outcomes. Because industrial companies often are reticent to provide data on pollutants prevented and toxics reduced, the Toxics Release Inventory (TRI) could be used to demonstrate selective impacts of the program. Also, annual reports of individual companies could possibly be used to determine pollutant emissions reductions.

4. Has the Approach Taken Been Appropriate To Meet Program Objectives/Desired Outcomes?

Most of the panel members thought the broad approach taken by EPA and NSF was appropriate for the first 5 years of the program and it has been relatively successful in funding good science. However, the program has matured to the point that more focus is needed. The approach used in the past should not be the approach employed in the future. The goals need to be more specific and the desired outcomes should be clearly articulated. Given the limited budget for TSE research, a sharper focus and more collaboration among the investigators will allow the program to maximize its future impact.

The products of the TSE research should be linked to the program goals. Ideally, the projects should be held more accountable to support roll-up of outcome data. The panel members thought there may be some value in benchmarking the TSE program outcomes against those for programs of other agencies that do industrially relevant research and development, such as DOE, National Institute of Standards and Technology (NIST), and U.S. Department of Agriculture (USDA).

The outreach for the TSE program appears to be limited to the annual Green Chemistry Conference, the EPA and NSF Web sites, and peer-reviewed publications. More outreach is needed to educate the scientific community, policy makers, and other audiences about the tremendous value and contributions

of this program. Periodic meetings of the investigators should be organized to foster interaction and collaboration among the investigators and to build the community of sustainability researchers. The panel members did not think that the annual Green Chemistry Conference was adequate to fill this need.

Most of the panel members thought that collaboration between individual investigators and industry was appropriate and successful. The panel also supported the program s encouragement of industrial collaboration for investigators seeking subsequent TSE grants. (Several members thought it may be appropriate to require collaboration for all TSE grants.) However, the program needs to promote something beyond individual investigator-industry interactions. The program could benefit from additional outreach efforts, particularly to industry. Formal and informal mechanisms should be developed to seek input and feedback from industry about needs, program goals, priorities, and outcomes. The TSE program could act as the stimulus for collaboration between industry and academia. There has been little outreach to communicate the goals and results of the program within EPA, and most of the states, which work directly with industry, are not aware that the TSE program exists. EPA should make a concerted effort to transfer the results of the TSE program to the Regions and states. Although the Web page is informative and necessary, it should not be the primary means of outreach for the TSE program. EPA also should consider outreach to the pollution prevention community. One suggestion was to have several TSE investigators make presentations at National Pollution Prevention Roundtable meetings. One panel member noted that the investigators could do a better job of publicizing TSE as the program that has funded their research. It may be beneficial to require the investigators to provide two abstracts of their research one for the scientific community and one for the public.

Although EPA and NSF have not clearly articulated how the program responds to changes in the TSE research areas, it is clear that there is response to change. For example, the inclusion of industrial ecology in the program was clearly a response to the need to broaden the scope of sustainability research beyond green chemistry. Another example is the addition of environmentally friendly construction. One panelist commented that the inclusion of recycling projects in TSE is another example of how the program responds to external changes. Because recycling was not included in the pollution prevention paradigm, these projects, despite their obvious environmental benefits, probably would not have been funded by EPA outside of the TSE program.

The panel members agreed that the partnership between EPA and NSF has been quite successful and should be continued. The dedication and commitment of the EPA and NSF staff have been key to the partnership s success. One panel member thought the TSE program was one of the most successful interagency programs in existence.

5. Is Federally Funded Research Still Needed in this Area?

There was strong support for increasing federal funding for the TSE program. There was agreement that TSE research is crucial to environmental health and the economic competitiveness of the United States. The TSE program has stimulated innovative research that probably would not have been funded by NSF or EPA outside of this program. The uniqueness of the TSE program should be stressed it is the only federal source of funding for certain parts of the sustainability research community. Further, it is the only example outside of the National Institutes of Health in which science and engineering are linked to achieve public benefit.

The education of a new generation of scientists and technologists aware of sustainability issues and solutions is a very important government responsibility. Although pollution prevention is both environmentally and economically preferable to cleanup and waste disposal, sustainable research is still considered outside of mainstream environmental science. By fostering a sustainable research community,

the TSE program is acting as a catalyst in redefining environmental science and bringing about a paradigm shift toward prevention.

The program would benefit if the efforts and areas of research were focused and better integrated so that synergies could be realized among the projects. Given the current limited funding level of the program, there is too much breadth and too little depth. There already are many unanswered questions and with new innovations, new questions arise. A workshop attended by leading academics and industrial participants should be organized to identify and prioritize new research areas for the TSE program. This input is critical for better defining the program s goals and setting priorities for future research.

Each investigator funded by TSE should be required to clearly articulate the research objectives in the application, as well as the environmental and economic benefits that will result from the research if it is successful (e.g., pounds of waste reduction, dollars saved). Although this may be more difficult for fundamental research, the investigators should at least provide some prediction of the impact if the research is successful.

There was some concern that the current level of TSE funding is not adequate to sustain the paradigm shift in environmental science. One panel member suggested increasing TSE funding so that a center for sustainable research could be established. The center could conduct workshops to teach investigators how to use TSE tools. A center also would facilitate more synergy and increased collaboration.

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