Decreasing Energy Intensity in Manufacturing: Assessing the Strategies and Future Directions of the Industrial Technologies Program

Committee for Review of the Department of Energy's Industrial Technologies, National Research Council

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DECREASING ENERGY INTENSITY IN MANUFACTURING

Assessing the Strategies and Future Directions of the Industrial Technologies Program

Committee for Review of the Department of Energy's Industrial Technologies Program
Board on Manufacturing and Engineering Design
Division on Engineering and Physical Sciences

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Preface

For more than a decade, the Department of Energy (DOE) has supported the Industrial Technologies Program (ITP) as one element in achieving its overall mission and goals. The mission of the ITP is to decrease energy intensity in the U.S. industrial sector through a coordinated program of research and development, validation, and dissemination of energy efficiency technologies and operating practices. At the request of the DOE's Office of Energy Efficiency and Renewable Energy, the National Research Council (NRC) established the Committee for Review of the Department of Energy's Industrial Technologies Program. Committee members were selected from industry, academia, and government laboratories for their knowledge and experience with the Industries of the Future and supporting areas within the ITP. An overall review of the ITP was conducted by the committee on May 19-21, 2004, with ITP managers in Washington, D.C. Information from that review forms the primary basis for this report.

The committee was tasked to do the following:

- Evaluate the overall ITP strategic plan as contained in the Multi-Year Program Plan (MYPP), including whether the strategic plan is appropriate, has reasonable and achievable goals, and reflects the needs of the DOE and the broader U.S. industrial community;
- Evaluate the technical quality and appropriateness of individual subprogram plans by reviewing both the decision-making process and each prospective portfolio, including the following: how focus areas and barriers were identified; whether appropriate data sources were used; whether the data used (studies, roadmaps, industry expertise) support the selection of focus areas and barriers; whether the focus areas and barriers are the highest priority or most appropriate related to the ITP's mission; how the R&D pathways were determined and whether these pathways are likely to result in achieving program goals; whether the prospective subprogram portfolios are the right ones to achieve the goals of the ITP; whether there are unnecessary research areas or gaps in research; and whether there is a reasonable mix of near-, mid-, and far-term research; and
- Determine the prospective value of the MYPP and planning processes, including the likelihood that the program will achieve its goals; whether there is a good plan to carry out the program; how well the program is connected to the users, including non-ITP researchers; and the capacity to develop lessons learned for future interdisciplinary research activities.

This report contains the committee's assessment of the ITP strategy, how effectively it is being implemented, and the likelihood of achieving its program goals. It includes the committee's conclusions concerning the ITP and its subprograms, as well as recommendations on how to strengthen the overall program and improve each of the subprogram areas.

I wish to thank the committee members for their enthusiasm, dedication, and insights in conducting the reviews and in preparing this report. The committee operated under the auspices of the NRC Board on Manufacturing and Engineering Design and was ably assisted by Bonnie Scarborough and Marta Vornbrock of the NRC staff, for which the committee is also grateful.

Questions or comments should be directed by e-mail to bmed@nas.edu or by fax to the BMED at (202) 334-3718.

Joseph G. Wirth, *Chair*
Committee for Review of the Department of Energy's
Industrial Technologies Program

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This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report: Daniel Berg, Rensselaer Polytechnic Institute; Geoffrey Boothroyd, Boothroyd Dewhurst, Inc.; William F. Brinkman, Princeton University; Robert H. Doremus, Rensselaer Polytechnic Institute; Neil E. Paton, Liquidmetal Technologies; Bhakta B. Rath, U.S. Department of the Navy; Herman M. Reininga, Rockwell Collins; and Peter A. Thorn, Weyerhaeuser Company.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Robert A. Frosch, Harvard University. Appointed by the NRC, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Contents

Executive Summary

The mission of the Department of Energy's (DOE's) Industrial Technologies Program (ITP) is to decrease the energy intensity[1] of the U.S. industrial sector through a coordinated program of research and development (R&D), validation, and dissemination of energy efficiency technologies and operating practices. To carry out this mission, the ITP partners with industry and other stakeholders in order to reduce U.S. reliance on foreign energy sources, reduce the environmental impacts of U.S. industry, increase the use of renewable energy sources, improve the competitiveness of U.S. industry, and improve the quality of life for U.S. workers, families, and communities.

The ITP currently funds research addressing the needs of seven energy-intensive industries, known as the Industries of the Future (IOFs). These industries are aluminum, chemicals, forest products, glass, metal casting, mining, and steel. The petroleum-refining industry is also designated as an IOF. Together the IOFs account for 75 percent of the energy consumed by the U.S. industrial sector (see Figure ES-1).

The leadership of the ITP asked the National Research Council's Board on Manufacturing and Engineering Design to assess the overall technical quality and effectiveness of the program by assessing the strategy, management, and decision-making processes used by the ITP to determine research directions as well as the application of these processes to individual subprograms and the program as a whole. The Committee for Review of the Department of Energy's Industrial Technologies Program was formed to undertake this task. It was asked to include in its report findings and recommendations related to the quality and appropriateness of all projects and programs in the ITP. This report represents the consensus conclusions and recommendations of the committee.

PROGRAM-LEVEL EVALUATIONS

Strategic Plan of the Industrial Technologies Program

The ITP Strategic Plan describes the program's mission and vision and outlines six key strategies for achieving improvements in industrial energy efficiency and environmental performance:

- To focus on energy-intensive industries,
- To use public-private partnerships to plan and implement the program,

[1] Energy intensity is defined in the ITP Strategic Plan as energy consumed in British thermal units (Btu) per unit of industrial output (in U.S. dollars of gross domestic product) as compared with Btu per unit of industrial output in 2002 (DOE, 2003c, p. 2).

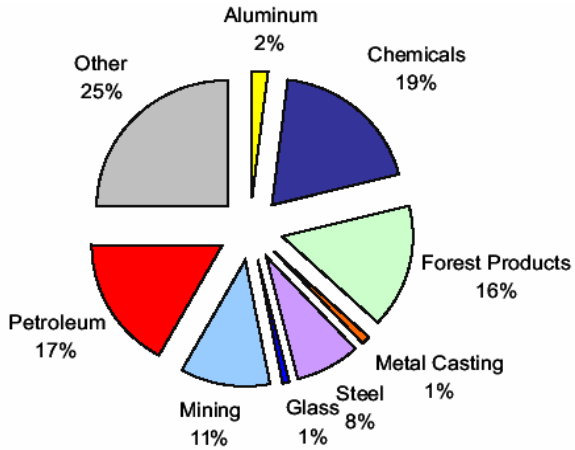

FIGURE ES-1 Estimated energy consumption of the Industries of the Future as a percentage of U.S. manufacturing and mining energy consumption for 2002. SOURCE: DOE, 2003c, p. 8.

- To identify grand challenges[2] that would dramatically improve industrial energy efficiency,
- To implement a technology portfolio that is balanced in terms of near-, mid-, and far-term research,
- To perform process-specific and crosscutting R&D to improve long-term energy efficiency, and
- To perform technology delivery activities to improve near- and mid-term energy efficiency (DOE, 2003c, pp. 8-12).

The committee finds that the ITP Strategic Plan presents a coherent link between higher-level plans (specifically, the National Energy Policy, the DOE Strategic Plan, and the Office of Energy Efficiency and Renewable Energy [EERE] Strategic Plan) and the ITP Multi-Year Program Plan (MYPP; DOE, 2004a). The ITP strategies are consistent with the mission of the ITP and address the needs of the DOE and U.S. industry for decreased energy intensity and improved environmental protection.

The ITP Strategic Plan contains two overall quantitative goals: a 25 percent decrease in energy intensity for the IOFs between 2002 and 2020 and the commercialization of more than 10 industrial energy efficiency technologies between 2003 and 2010.[3] The committee recommends that the ITP provide additional information on how these goals were selected and how their achievement will be measured. Without this information, it is difficult to assess whether or not these goals are reasonable.

Multi-Year Program Plan of the Industrial Technologies Program

The Multi-Year Program Plan translates the ITP's strategies and strategic objectives into specific technical, funding, and schedule requirements. In addition, it contains a description of the implementation strategy, including the multi-year plans for the individual subprograms. The committee recommends the continuation and an acceleration of the evolution of the MYPP toward a more manageable set of corporate milestones and recommends that, in the preparation of future MYPPs, the ITP look for opportunities to increase coordination across subprograms, especially in the area of grand challenges.

The ITP has developed and is instituting a new decision-making model to refine the project selection process and implement ITP strategies. The decision-making model is based on the following steps:

[2] A *grand challenge* is defined as an important technical problem facing an industry, or group of industries, that, if solved, holds the potential to produce large improvements in energy efficiency, environmental performance, and product yield (DOE, 2004a, p. 65).
[3] B. Garland, DOE, 2004, "Industrial Technologies Program Corporate Programmatic Review," Presentation to the Committee, Washington, D.C., May 19.

(1) the identification of focus areas that hold potential for improvement in a particular area, (2) the identification of barriers that prevent improvement in this area, and (3) the determination of pathways to overcome these barriers. Inputs to the decision-making process include industry vision documents and roadmaps, energy footprint[4] and bandwidth[5] analyses, and energy and environmental profiles, as well as ITP and industry expertise. The committee finds that these tools and processes are appropriate for guiding the prioritization and selection of projects.

Corporate Strategy of the Industrial Technologies Program

The ITP corporate strategy, described in the MYPP, is an effort to streamline business and management processes within the ITP. It consists of five components: (1) realizing a vision for the future of industry; (2) strategy for government investment; (3) understanding and awareness; (4) long-term, focused partnerships; (5) and superior business practices (DOE, 2004a, p. 46).

The committee concurs with the ITP that the realization of its vision and goals requires an understanding of the realities of both industry and government and an iterative planning process driven by measurable results. To increase the effectiveness of project selection metrics, the committee recommends that market pricing, acceptance, and the potential economic impact of all projects, including grand challenges, be estimated. The committee finds that activities undertaken by the ITP such as energy showcases and partnerships with other government agencies are effective in increasing understanding and awareness and that numerous government-industry partnerships are in place and working. In addition, the committee finds that maintaining public-private partnerships, including academic partnerships, is critical to the success of the ITP.

There appears to be considerable focus on systematic and aligned planning, analysis, decision-making, and project management processes. The data are beginning to show significant cumulative energy and cost savings. The committee observes that a high level of energy and momentum exists within the ITP staff for implementing changes and improving the ITP.

EVALUATIONS OF INDIVIDUAL SUBPROGRAMS

The committee was asked to review the ITP's seven Industry of the Future subprograms by evaluating the individual effectiveness of each subprogram, its integration with the overall ITP strategy, and the likelihood of its achieving its goals. In addition, the committee was asked to review the five crosscutting subprograms (combustion, sensors and automation, industrial materials of the future, supporting industries, and software tool development), as well as ITP's technology delivery subprogram and the ITP activities at the EERE regional offices.

Aluminum

The aluminum subprogram is dynamic, having an excellent historical and ongoing interaction with the U.S. aluminum industry. This subprogram focuses on relevant needs of the aluminum industry, and its portfolio addresses the key priorities in the current focus areas. The committee commends the staff of the aluminum subprogram on their work and recommends continued evolution and growth in the subprogram's direction as the needs of U.S. industry change. The committee further recommends:

- Combining the two focus areas on smelting R&D (alternative reduction systems and advanced Hall-Héroult cells) into one area that includes the only major project currently in the alternative reduction systems area;
- Leveraging of other ITP subprograms, such as sensors and materials, in the efficient melting

[4] A *footprint analysis* evaluates energy end-use and loss patterns to identify the areas in which the greatest energy savings are possible.
[5] A *bandwidth analysis* compares actual energy use from a process with the theoretical thermodynamic minimum in order to identify the areas in which the greatest energy savings are possible.

technologies focus area;
- Considering initiating the "Design and Build Advanced Furnace" grand challenge earlier than the proposed FY 2008 timeframe;
- Reorganizing the focus area on advanced forming technologies into a focus area named "advanced fabrication technologies";
- Leveraging efforts through Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) mechanisms to involve R&D organizations in the early stages of project development;
- Commissioning a study forecasting the growth or shrinkage of aluminum processes in the United States to guide subprogram decisions; and
- Expanding outreach activities, including dissemination of the results from plant assessments such as that done with Alcoa (DOE, 2004k).

Chemicals

The chemicals subprogram has worked closely with the Chemical Industry Vision2020 Technology Partnership to leverage public and private resources and to ensure application of research results. The efforts are appropriately focused, and the portfolio of projects is well balanced from the perspectives of topicality, risk, duration, and potential impact. The committee commends the use of exergy analysis and recommends that this analysis technique be extended to other ITP subprograms. Many of the achievements and results of this subprogram should also find wide application in the petroleum-refining and other segments of processing industries. The subprogram appears on track to contribute to the ITP's meeting its stated energy and environmental objectives. The committee recommends:

- Greater integration between the chemicals and sensors subprograms because of the obvious potential impact on the chemical industry; and
- Establishment and enforcement of clear criteria for the termination or redirection of underperforming projects or projects least likely to meet their goals.

Forest Products

The U.S. forest products industry accounts for about 16 percent of U.S. domestic manufacturing and mining energy use and must therefore remain an active part of the ITP. The committee is concerned that the recent movement of two major programs (black liquor gasification and the new forest-based materials effort) out of the ITP will create issues in uniformity of management practices in these two programs. Overall, the committee finds the research portfolio of the forest products subprogram to be consistent with the mission and goals of the ITP. To sharpen the focus on energy, environmental, and competitiveness issues in the forest products industry, the committee recommends that the ITP:

- Involve small companies, entrepreneurs, suppliers, and equipment manufacturers to a greater extent in the strategic process of defining focus areas and barriers, as well as participating in and providing constructive comments during proposal reviews;
- Undertake a critical review of the results of the 2004 paper technology summit, with the goal of updating the industry roadmap and identifying grand challenges;
- Include energy and exergy balances, as well as economic constraints of the industry, in analysis when selecting portfolio directions;
- Develop a mechanism for obtaining ideas and concepts from relevant sources outside the forest products industry, its related academic programs, and the traditional suppliers and equipment manufacturers; and

- Require key ITP personnel to attend conferences and meetings related to the forest products industry, as well as to travel to forest products companies; discussions with operations and R&D personnel need to be included.

Glass

The glass subprogram received very effective industry participation in the identification of its focus areas and barriers. The focus areas appropriately address areas in which the largest energy savings can be made, and funds have been allocated accordingly. Overall, the glass subprogram is in very good shape. The decision-making approaches used are logical and reasonable, and industry buy-in makes success likely. However, achieving adoption of radical process changes in this conservative industry is a significant challenge. The committee recommends that the following gaps in research be addressed:

- Since melting is a focus area in the glass subprogram and since cullet melting (i.e., the melting of pre-melted glass) tends to reduce energy consumption, some emphasis should be put on this area.
- The idea of recycling as it pertains to energy savings should be included in the glass subprogram, in collaboration with other ITP subprograms and with agencies such as the Environmental Protection Agency.

Metal Casting

Although the metal-casting industry is vital to the U.S. economy and national defense, the United States is losing metal-casting capabilities as a result of the decline in the number of foundries owing to low-cost imports. Significant improvements in energy efficiency have been made by this industry during the past two decades, but it needs to make additional gains to be globally competitive. Overall, the metal-casting subprogram has had good interaction with industry, and the projects selected are, in general, the right ones to achieve ITP goals. The mix of near-, mid-, and far-term research is reasonable. Significant efforts toward attracting a new workforce for the metal-casting industry are enjoying considerable success through emphasis on the participation of students in research projects. The committee recommends:

- Augmenting the project portfolio in the advanced melting focus area, for example by adding aluminum melting, since opportunities for energy savings are substantial; and
- Leveraging the metal-casting subprogram through past and current R&D from the aluminum area to gain maximum benefit from DOE and industry funds.

Mining

In the mining subprogram, cost sharing by industry is robust, at 57 percent. Overall, the mining subprogram has a high level of collaboration and cooperation with industry partners. The focus areas are appropriate and are supported by the data sources used. The composition of the project portfolio appears reasonable, in general. To further increase the impact of the mining subprogram, the committee recommends:

- Clarifying the definitions of focus areas, barriers, and pathways in the MYPP, and soliciting additional input from The Minerals, Metals, and Materials Society, particularly its extraction and processing division;
- Providing more detailed information on the assumptions and calculations used in the footprint and bandwidth analyses;
- Considering research on solid-liquid and solid-solid separations despite the fact that these processes are not common to all sectors of the mining industry;
- Considering risk-benefit analysis in project selection in order to take into account the

environmental impacts of energy efficiency measures;
- Documenting the estimates of energy savings resulting from subprogram activities including detailed information on calculations and derivations used; and
- Requiring ITP personnel to attend the annual meetings of the Society for Mining, Metallurgy, and Exploration and The Minerals, Metals, and Materials Society, as well as visit industrial sites.

Steel

The steel subprogram has a long history of interaction with the steel industry, primarily through the American Iron and Steel Institute and the Steel Manufacturers Association. Though vital to the national economy and defense, the U.S steel industry is extremely vulnerable to offshore competition and must become more resource-efficient and less capital-intensive. The majority of the projects in the subprogram portfolio appear to be appropriate for the achievement of ITP goals. The committee recommends improvement in the following areas:

- Obtaining better independent reviews of data sources and facts and figures to provide a strong foundation for policy decisions;
- Moving the power-delivery modeling focus area from the ITP steel subprogram to another DOE unit;
- Increasing the subprogram emphasis on secondary processing and specialty steels—areas in which maximum benefits can be derived from both energy and economic standpoints;
- Clarifying mechanisms and providing guidance for protecting intellectual property arising from ITP-funded projects;
- Defining more clearly what constitutes a successful project and how underperforming projects are handled;
- Leveraging of efforts through SBIR and STTR mechanisms to involve R&D organizations and universities in the early stages of project development; and
- Leveraging of resources within the EERE and other programs and with the National Science Foundation's Steel Research Centers.

Overarching Recommendations for Industry of the Future Subprograms

While evaluating the seven IOF subprograms described above, the committee identified several overarching issues and programmatic best practices relevant to all seven of these subprograms as well as to the crosscutting subprograms described below. The committee recommends the following:

- *Leveraging limited resources.* Because federal funding is limited and because not all industry goals overlap fully with government goals, it is necessary to leverage limited available funding—for example, by leveraging projects on sensors, electrodes, or refractories and by leveraging SBIR and STTR mechanisms.
- *Focusing on grand challenges.* It is critical for policy makers to establish goals, and to measure success when these goals are achieved. Overarching goals, such as grand challenges, that a number of projects can aim toward fulfilling should be instituted.
- *Managing intellectual property.* The intellectual property arising from the development of energy efficiency technologies must be managed in a policy environment that is currently contentious. Two potentially conflicting goals have been expressed by the manufacturing community: improving both U.S. and global energy efficiency through the development of new energy efficiency technologies and providing a business advantage to U.S. industry through the development of these same technologies. The committee recommends that the ITP develop a comprehensive policy to clarify mechanisms and to provide guidance for managing the intellectual property that arises from ITP-funded projects.

Combustion

The committee finds that the combustion subprogram is operating in a cost-effective manner and is well organized in terms of its overall strategy, individual project selection, and development and application of metrics. The ITP projects in this area have resulted in significant technical accomplishments. The ability of subprogram personnel to attend key industry conferences is important to communication with industry, however, and should be increased over current levels. The committee makes the following recommendations for improvement:

- Metrics should be clarified and a process developed for weighting the value to the program of emissions reductions in each specific pollutant, e.g., nitrogen oxide (NO_x), carbon monoxide (CO), sulfur oxide (SO_x), mercury, acid gases, volatile organic compounds (VOCs), and particulates.
- Legacy projects that do not fit within the new decision-making methodology should be phased out.
- ITP should attempt to incorporate projects with a more diverse range of renewable and non-renewable fuels, rather than being focused exclusively on natural gas.
- Research should be funded to improve fundamental understanding of issues important to industrial combustion, such as the chemistry of ultralow NO_x burners and modeling of the interactions between chemistry and turbulent flow mechanics.
- ITP has a role to play in identifying issues and bringing stakeholders together to improve and evaluate CFD modeling tools to meet the needs of industrial burners and furnaces, possibly in coordination with the sensors subprogram.
- More emphasis is needed on retrofit applications, which may also enhance the acceptance rate of developments relevant to new designs.
- Consideration should be given to supporting new approaches to reducing carbon dioxide (CO_2) emissions—for example, gasification and oxygen-fuel combustion with CO_2 recycling.
- Emissions control efforts should include research on key pollutants other than NO_x and CO_2.
- The waste heat recovery project is a candidate for removal from the combustion subprogram in order to focus resources more effectively.

Sensors and Automation

Sensors and automation are a problem-rich environment in which vast opportunities exist. The ITP has done a good job of administering the sensors and automation subprogram thus far. However, a new paradigm is needed to foster collaborative activities in the development, maturation, and integration of sensor technologies. The committee recommends that:

- Funding for the implementation of wireless networking of sensors be redirected toward more fundamental, high-risk development of new sensor technology;
- Research be undertaken to improve sensing of the composition and properties of multicomponent and multiphase industrial streams, especially surface and interfacial properties;
- A vehicle for joint participation in sensor and automation development be created—for example, the development of a family of sensors for which the same technology could be adapted to handle a wide range of applications across several industries;
- Better metrics be developed for determining the benefit to all ITP subprograms from investment in sensor and automation development;
- Vendors be included early in the development process and communication be improved among the IOFs on existing sensor and automation needs and activities; and
- A sensor development project be identified that can be included in a grand challenge.

Industrial Materials of the Future

The crosscutting industrial materials of the future subprogram is in a transition stage from the older, opportunity-driven strategy to the new ITP method of targeting R&D areas and using the barrier-pathway approach for identifying R&D targets and developing metrics. Overall, the committee considers that this subprogram is on the right track with the very deliberate targeting methods now used by the ITP. There is some concern about finding well-qualified teams to perform the R&D in areas such as refractories. The difficulty arises because of the consolidation and shrinkage of this industry and the trend toward foreign ownership of domestic companies. The committee recommends working with industry organizations such as the Refractories Institute or the American Ceramic Society's Refractories Division to develop sources of qualified partners.

Supporting Industries

The committee believes that the supporting industries subprogram is a vital one, and that it is unique. The industries in this subprogram are truly crosscutting and would be difficult to manage under any other subprogram. This subprogram currently exists under difficult circumstances, including coverage of a larger variety of industries than is covered by any other subprogram, limited resources, and a lack of data. However, the committee believes that the prospective portfolio for this subprogram is on track to achieve the ITP's mission and that the supporting industries subprogram has a role to play in any crosscutting grand challenges that are identified by the ITP. The committee recommends that:

- Bandwidth analyses be performed for the industrial heating equipment and fabricated metals areas;
- The different areas of the supporting industries subprogram be packaged differently, particularly in industrial heating equipment, to avoid overlap with other subprograms;
- More breakthrough projects be included in the portfolio, perhaps jointly with other subprograms; and
- More transparency for GPRA analytical data be provided.

Software Tool Development

The software tool development subprogram supports the ITP mission of increasing the energy efficiency of U.S. industry by developing software tools that allow individual plants to identify losses in energy generation, distribution, and conversion systems. Overall, the committee believes that this subprogram is an important element in the success of the ITP. Given its use of the focus area-barrier-pathway process to identify critical gaps for tool development and its focus on plantwide and user-friendly opportunity and screening tools, the committee believes that the software tool development subprogram is focused correctly to achieve ITP goals. The committee recommends:

- The continued development of plantwide assessment and value-stream mapping tools in support of the long-term goals of the ITP; and
- The establishment of an end-user feedback loop through the use of online tools, such as discussion forums.

Technology Delivery

The technology delivery subprogram of the ITP has as its mission the reduction of the energy intensity of U.S. industry by several means: developing, maintaining, and disseminating best practices in energy management and selectively investing in the development, verification, and validation of emerging technologies that offer significant energy savings. The committee views the technology delivery subprogram as being very successful; its major challenge going forward will be to find additional ways to increase effectiveness through improved communications to industry. The committee recommends:

- Modifying the ITP Web site to make it easier for different levels of industry management to get information on the potential for energy cost savings in their facilities;
- Considering the creation of links to scenario planning that would relate the magnitude of opportunities for energy cost savings to energy cost scenarios;
- Increasing efforts directed toward equipment manufacturers and engineering companies that design systems, with the goal being to encourage them to design equipment and systems for energy efficiency; and
- Looking for opportunities to create new or modify existing software programs aimed at designing for energy efficiency.

Regional Offices

The EERE regional offices are a crucial link between laboratory development of new energy efficiency technologies and deployment to U.S. industry. The burden for the delivery of ITP technology efforts has fallen primarily on the regional offices, because the field offices have remained principally focused on their core mission of project management. The committee finds that the regional offices have a proper sense of their post-reorganization mission. However, it has some concerns about the ability of ITP to disseminate program information at current levels of funding and staffing. To increase effectiveness, the committee recommends that:

- Regional offices be fully integrated into the project management loop;
- Unless issues of intellectual property exist, industry communications and outreach to other industrial partners and the public be made a condition of contract;
- The restrictions on travel by ITP headquarters staff be eased; and
- The restrictions on travel by regional office personnel be eased.

CONCLUSIONS AND RECOMMENDATIONS

The Industrial Technologies Program has evolved over time into a well-managed and effective program. Its strategy is consistent with higher-level plans of the nation and the Department of Energy, and its management and decision-making processes are solidly based. The program's scope and depth of analysis and reporting are impressive. The ITP significantly leverages its resources through a large and growing number of partnerships with industry, industry associations, and academic institutions. Project portfolios are in place to achieve subprogram goals and, presumably, overall program goals. Current ITP leadership is strong, and the enthusiasm, dedication, and knowledge of subprogram managers are noteworthy. As an overall assessment, it is clear that the ITP team works well together and that a working environment has been established that has made and will continue to make the subprograms succeed.

In the spirit of continuing to improve an already excellent program, the committee offers the following recommendations:

- Explore new ways to benefit industries other than those directly targeted through Industrial Technologies Program partnerships. Program managers should increase efforts to promote and disseminate the ITP's accomplishments and broaden its benefits to additional energy-intensive industrial locations by:
  —Increasing face-to-face contact of ITP subprogram staff with technology developers, equipment manufacturers, system designers, and technology end users by encouraging appropriate travel for headquarters personnel and mandating their attendance at technical meetings, at visits to project sites, and at potential end-user locations;
  —Allocating additional resources to the regional offices (ROs) of the Office of Energy Efficiency and Renewable Energy and refocusing the efforts of RO personnel in order to integrate them more effectively into ITP project activities and directing them to work closely with headquarters

staff and industry partners to extend the impact of ITP projects to additional industrial sites; and
—Remodeling the ITP Web site to make information more easily accessible to all levels of industry management and to emphasize the cost benefits of energy conservation technology.

- Develop more effective mechanisms for collaboration and coordination across ITP subprograms and projects to reduce stovepiping and to encourage the achievement of broader goals. As part of a grand challenge strategy, the ITP should continue to pursue plans to increase the average size of projects, but it should also continue to maintain a healthy balance of small, medium, and large projects.
- Redirect student education activities to other governmental entities that have direct educational missions, with the exception of those activities directly related to the plant assessments performed by students for the ITP's Industrial Assessment Centers. Because the mission of the ITP is energy savings, not education, any student educational activities undertaken by the ITP should be justified in terms of their energy-saving results, not their educational goals.
- Review ITP subprogram management practices to ensure clarity and consistency or, where practices differ, to ensure that differences are justified.
- Increase benefits by propagating the ITP strategy, where appropriate, to other programs in the Office of Energy Efficiency and Renewable Energy.

1

Introduction

INDUSTRIAL TECHNOLOGIES PROGRAM

The Industrial Technologies Program (ITP) is the Department of Energy's (DOE's) industrial energy efficiency program,[1] providing federal support for industrial research and development (R&D) for energy efficiency technologies. The ITP is part of the Office of Energy Efficiency and Renewable Energy (EERE), which is responsible for the majority of the research, development, and demonstration (RD&D) activities of the DOE (DOE, 2002).

The mission of the ITP is to decrease the energy intensity of the U.S. industrial sector through a coordinated program of research and development, validation, and dissemination of energy efficiency technologies and operating practices. The ITP aims to invest in high-risk, high-value R&D that has the potential to reduce the energy requirements of industry, but for which market barriers prevent adequate private-sector investment. Because energy is such an important input for many manufacturing industries, reducing energy requirements can lower energy costs, reduce greenhouse gases and other emissions, and improve productivity per unit of output (DOE, 2003c, p. 1).

The ITP currently funds research addressing the needs of seven energy-intensive industries, known as the Industries of the Future (IOFs). These industries are aluminum, chemicals, forest products, glass, metal casting, mining, and steel. The petroleum-refining industry is also designated as an IOF, but projects specifically directed at this industry have not yet been funded. Together the IOFs account for 75 percent of the energy consumed by the U.S. industrial sector (see Figure 1-1).

The ITP program goals are to contribute to a 25 percent[2] decrease in energy intensity[3] by the energy-intensive IOFs between 2002 and 2020 and to commercialize more than 10 industrial energy efficiency technologies between 2003 and 2010.[4]

Restructuring of the Office of Energy Efficiency and Renewable Energy

On March 18, 2002, DOE's Assistant Secretary David Garman announced a major reorganization of the Office of Energy Efficiency and Renewable Energy. The reasons cited were an outdated focus on sectors rather than on programs; the existence of processes and systems that duplicated and conflicted

[1] Established in 1977, this program was previously known as the Office of Industrial Technologies (OIT) and before that as the Office of Industrial Programs (OIP).
[2] The original goal was 30 percent, but due to budget cuts, this goal was reduced to 25 percent (B. Garland, DOE, 2004, "Industrial Technologies Program Corporate Programmatic Review," Presentation to the Committee, Washington, D.C., May 19).
[3] *Energy intensity* is defined in the ITP Strategic Plan as energy consumed in British thermal units (Btu) per unit of industrial output (in U.S. dollars of gross domestic product) as compared with Btu per unit of industrial output in 2002 (DOE, 2003c, p. 2).
[4] B. Garland, DOE, 2004, "Industrial Technologies Program Corporate Programmatic Review," Presentation to the Committee, Washington, D.C., May 19.

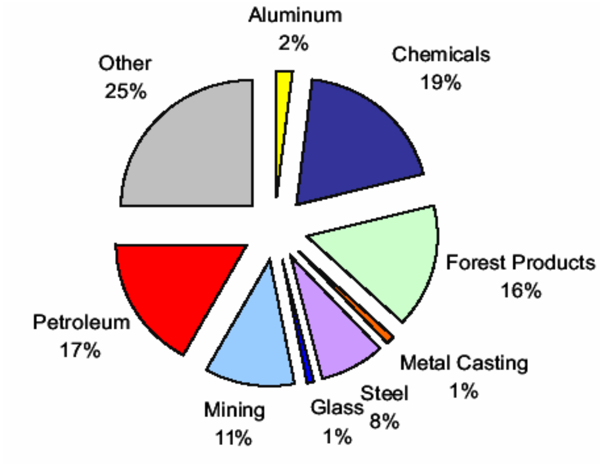

FIGURE 1-1 Estimated energy consumption of the Industries of the Future as a percentage of U.S. manufacturing and mining energy consumption for 2002. SOURCE: DOE, 2003c, p. 8.

with corporate approaches; the existence of artificial organizational layers superimposed over programs, creating inefficiencies; and too many layers of management (Garman, 2002). The EERE had been organized into five market sectors[5] and their 17 offices, resulting in a stovepipe culture. These stovepipes included business management processes and systems that fragmented EERE business management, while the market-sector organizations created layers on top of programs, resulting in inefficiencies (Garman, 2002).

The impetus for change had come from a variety of sources, including a National Academy of Public Administration review of EERE management completed in 2000, the President's Management Agenda released in 2001 (OMB, 2001), and the National Energy Policy released in 2001 (NEPDG, 2001). The President's Management Agenda called for flattening organizations to make them more responsive; focusing on results instead of process; linking budgets with performance; ending overlapping functions, inefficiencies, and turf battles; and making the most of government employees and their knowledge, skills, and abilities (Garman, 2002). The National Energy Policy directed the Secretary of Energy to review the current funding and historic performance of energy efficiency, renewable energy, and alternative energy R&D programs in light of recommendations of the National Energy Policy Development Group (NEPDG) and to propose appropriate funding for R&D programs that are performance-based and modeled as public-private partnerships (NEPDG, 2001).

In response to the National Energy Policy direction, the EERE completed a Strategic Program Review in March 2002, which concluded that EERE research had generated significant public benefits and often exhibited scientific excellence. However, this review also concluded that there were areas needing improvement, including 20 projects that should be terminated, 6 initiatives that needed redirection, a variety of programs that needed to be carefully monitored, several program areas that needed to be expanded, and an uneven application of best program practices across EERE sectors (EERE, 2002).

The EERE's management and business model was redesigned with input from the three documents cited above (DOE, 2002). After the restructuring, 31 program offices had been consolidated into 11, and only two of five deputy assistant secretary (DAS) positions remained—one for technology development and one for business administration (see Figure 1-2). The 11 current program offices are Biomass; Building Technologies; Distributed Energy and Electricity Infrastructure and Reliability; Federal Energy Management; FreedomCAR and Vehicle Technologies; Geothermal Technologies; Hydrogen, Fuel Cells, and Infrastructure Technologies; Industrial Technologies; Solar Energy Technology; Weatherization and

[5] The five market sectors were power, industry, transportation, buildings, and federal facilities.

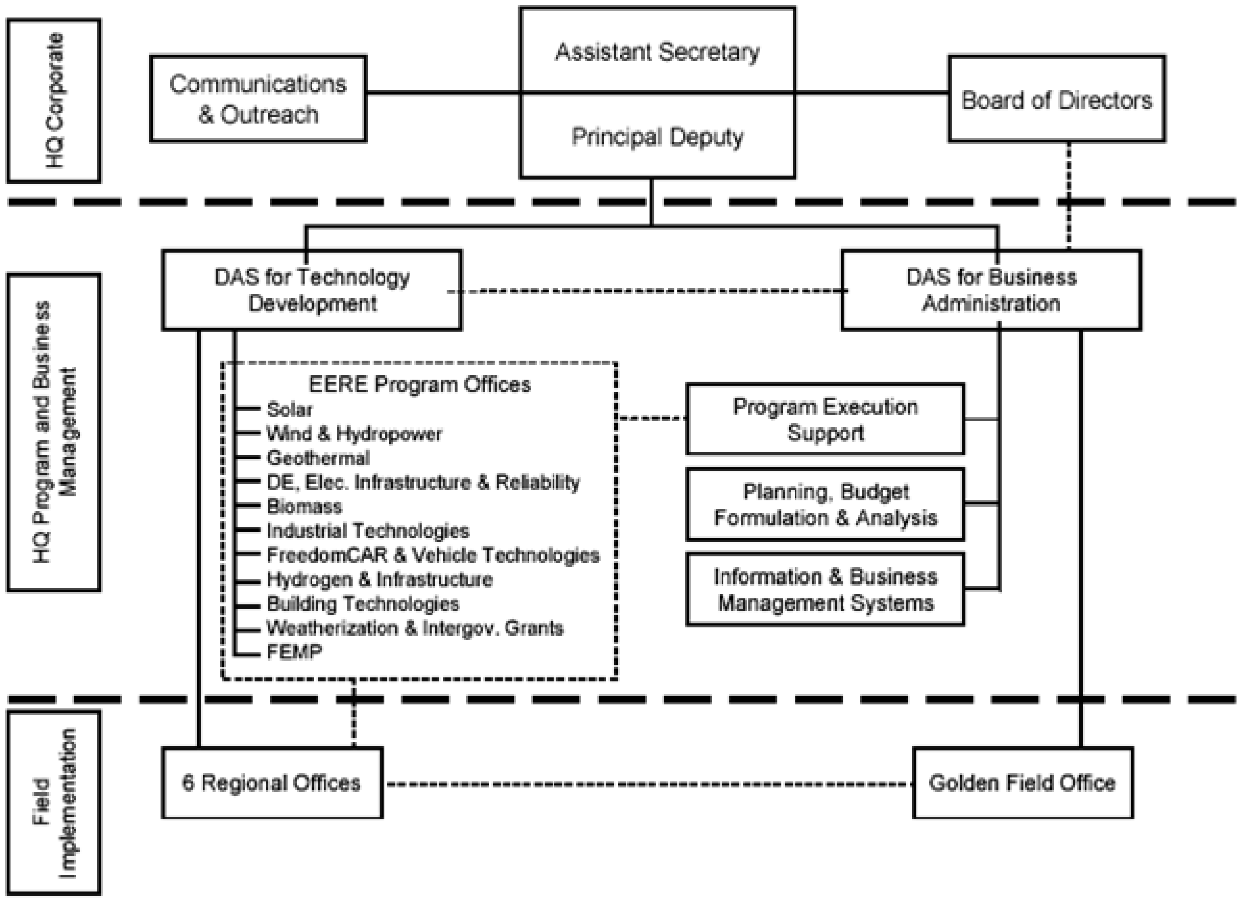

FIGURE 1-2 New organizational structure of the Office of Energy Efficiency and Renewable Energy. SOURCE: Garman, 2002.

Intergovernmental Grants; and Wind and Hydropower Technologies (DOE, 2002). The Deputy Assistant Secretary for Technology Development oversees all EERE program managers and regional offices, while the Deputy Assistant Secretary for Business Administration oversees all program support issues, planning, analysis, budget formulation, and the Golden, Colorado, field office (NHA, 2002).

Restructuring of the Industrial Technologies Program

The EERE reorganization resulted in a reorganization of the Industrial Technologies Program along the lines of the new EERE management and business system. The ITP mission, goals, and strategies were aligned with those of the EERE Strategic Plan, the DOE Strategic Plan, and the National Energy Policy (see Figure 1-3). In addition, several ITP programs and projects were moved from the ITP to the EERE Biomass Program, including the agricultural industry programs, the black liquor gasification project, and the new, forest-based materials effort. The ITP personnel at DOE headquarters in Washington, D.C., are now responsible for developing, managing, and evaluating technology portfolios to best achieve ITP goals and strategies. The Golden Field Office in Colorado is responsible for initiating, managing, and monitoring all ITP projects. The EERE regional offices in Atlanta, Boston, Chicago, Denver, Philadelphia, and Seattle are responsible for delivering technologies to ITP industrial partners.

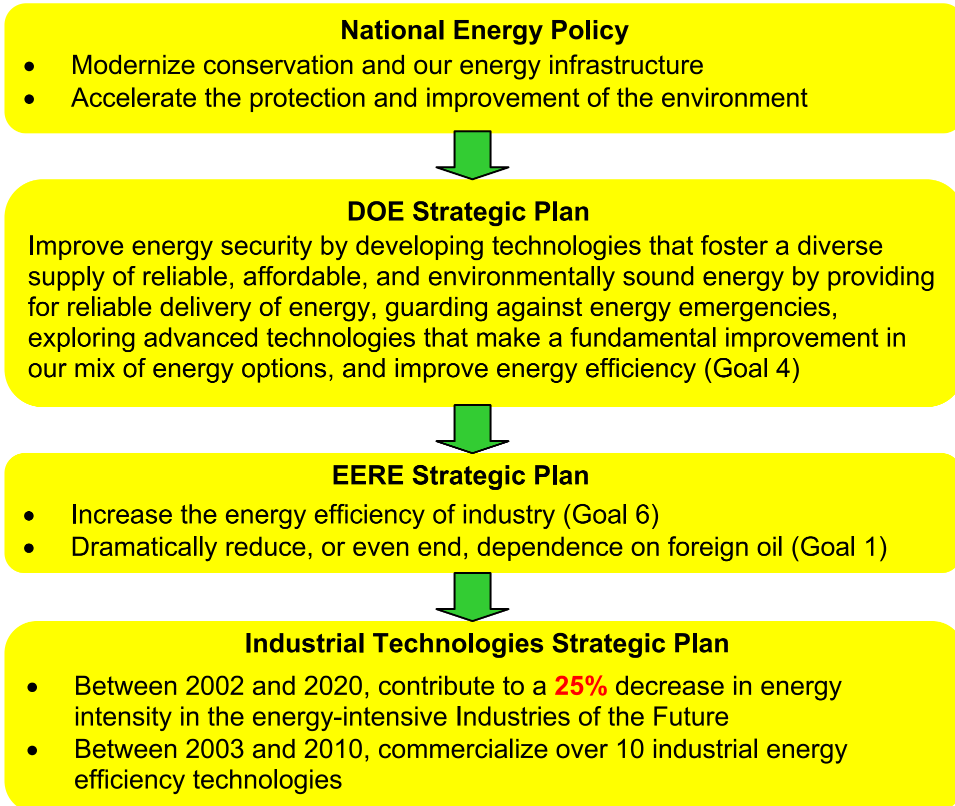

FIGURE 1-3 Goals of the Industrial Technologies Program and selected goals of the Office of Energy Efficiency and Renewable Energy (EERE), the Department of Energy (DOE), and the National Energy Policy. SOURCE: B. Garland, DOE, 2004, "Industrial Technologies Program Corporate Programmatic Review," Presentation to the Committee, Washington, D.C., May 19.

New Industrial Technologies Program Decision-Making Model

The ITP has developed and is in the process of instituting a new decision-making model that will refine the project selection process and implement ITP strategies (see Figure 1-4). The decision-making model is based on the following steps: (1) the identification of focus areas that hold potential for energy savings in each subprogram, (2) the identification of barriers that prevent improvement in these focus areas, and (3) the determination of research and development pathways to overcome those barriers.

Focus areas for the seven Industries of the Future are identified using a wide variety of sources, including industry vision documents and roadmaps, energy and environmental profiles for the industries, and other forms of industry input. The most energy-intensive stage of each process is usually identified by conducting an energy footprint analysis.[6] The areas in which the maximum potential energy savings can be achieved are then identified using a bandwidth analysis.[7] Industry expertise is also fed into the decision-making process. These help principally in defining the barriers to energy efficiency; from these definitions, development pathways can be determined. To achieve the goals of the ITP program, public-private partnerships are fostered. Each subprogram issues requests for proposals designed to achieve a balanced portfolio of both grand challenge (high-risk and high-payoff) and near-term projects.

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[6] A *footprint analysis* evaluates energy end-use and loss patterns to identify the areas in which the greatest energy savings are possible.
[7] A *bandwidth analysis* compares actual energy use from a process with the theoretical thermodynamic minimum in order to identify the areas in which the greatest energy savings are possible.

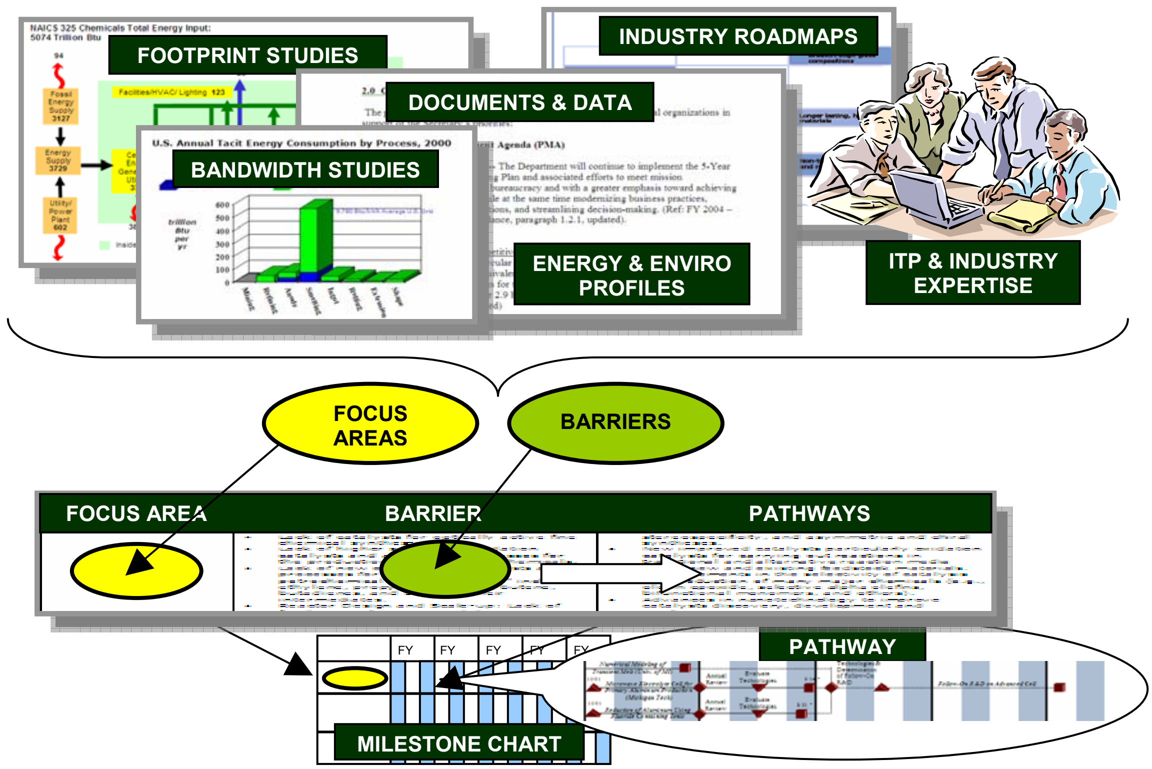

FIGURE 1-4 Focus area-barrier-pathway decision-making model of the Industrial Technologies Program. SOURCE: B. Garland, DOE, 2004, "Industrial Technologies Program Corporate Programmatic Review," Presentation to the Committee, Washington, D.C., May 19.

Peer Review

The EERE Strategic Program Review found that EERE would benefit from more systematic and rigorous application of peer review for all of its programs and major management functions (DOE, 2003b, p. vi). Recently, a wide variety of other authorities have argued that peer review practices at federal agencies need to be strengthened (OMB, 2004). In response to congressional inquiry, the U.S. General Accounting Office documented the variability in both the definition and implementation of peer review across agencies (GAO, 1999). In response to these findings, the EERE developed a peer review guide to help programs and offices establish formal peer review processes that result in intellectually fair and disinterested expert evaluation.

COMMITTEE FOR REVIEW OF THE DEPARTMENT OF ENERGY'S INDUSTRIAL TECHNOLOGIES PROGRAM

In response to the call for strengthened peer review within the EERE, the leadership of the ITP asked the National Research Council's Board on Manufacturing and Engineering Design to assess the overall technical quality and effectiveness of the program. The board was asked to assess the new decision-making process used by the ITP to determine research directions as well as the application of this process to individual subprograms and the program as a whole. The Committee for Review of the

Department of Energy's Industrial Technologies Program was formed (see Appendix A for committee biographical information) to undertake this task and was specifically tasked to do the following:

- Evaluate the overall ITP strategic plan as contained in the Multi-Year Program Plan (MYPP), including whether the strategic plan is appropriate, has reasonable and achievable goals, and reflects the needs of the DOE and the broader U.S. industrial community;
- Evaluate the technical quality and appropriateness of individual subprogram plans by reviewing both the decision-making process and each prospective portfolio, including the following: how focus areas and barriers were identified; whether appropriate data sources were used; whether the data used (studies, roadmaps, industry expertise) support the selection of focus areas and barriers; whether the focus areas and barriers are the highest priority or most appropriate related to the ITP's mission; how the R&D pathways were determined and whether these pathways are likely to result in achieving program goals; whether the prospective subprogram portfolios are the right ones to achieve the goals of the ITP; whether there are unnecessary research areas or gaps in research; and whether there is a reasonable mix of near-, mid-, and far-term research; and
- Determine the prospective value of the MYPP and planning processes, including: the likelihood that the program will achieve its goals; whether there is a good plan to carry out the program; how well the program is connected to the users, including non-ITP researchers; and the capacity to develop lessons learned for future interdisciplinary research activities.

The committee was asked to include findings and recommendations related to the quality and appropriateness of all DOE projects and programs in the ITP, including internal work, collaborative activities, and competitively sourced research, development, and analysis. While the primary objective of this review was to conduct peer assessments that provided technical advice, the committee was asked to offer programmatic advice when it followed naturally from technical considerations. The committee was not asked to make specific budget recommendations.

In early May 2004, committee members received a copy of the MYPP dated October 2003, as well as other documents describing the various subprograms and activities within the ITP. On May 19-20, 2004, the committee heard presentations from ITP personnel regarding the program. In order to evaluate the individual ITP subprograms, the ITP's technology delivery activities, and ITP activities at the EERE regional offices, committee members reviewed the MYPP, annual reports from all of the subprograms, and additional supporting documents, as well as hearing the presentations from ITP personnel. Owing to time and resource constraints, the subprogram presentations were divided into three groups (see the meeting agenda in Appendix B), with one committee member assigned as the lead on each subprogram review and two others assigned to support the lead. The committee was able to ask program managers for specific information and request additional information. On May 21, 2004, the committee met in closed session and began the process of coming to consensus on subprogram and program evaluations. This report represents the consensus conclusions and recommendations of the committee.

ORGANIZATION OF THE REPORT

Following the background information in Chapter 1 on the context within which the ITP operates and some history of the ITP itself, Chapter 2 presents the committee's program-level evaluations. Included are evaluations of the Strategic Plan, the overall program plan, the decision-making process, and the corporate strategy. Chapter 3 presents the committee's evaluation of the individual subprograms that are based on the Industries of the Future, and Chapter 4 provides its evaluations of the individual crosscutting subprograms, as well as the technology delivery subprogram and ITP activities at the EERE regional offices. Chapter 5 then presents the committee's overall conclusions and recommendations.

2

Program-Level Evaluations

The committee was asked to assess several program-level aspects of the Industrial Technologies Program (ITP), including the following:

- *Strategic Plan:* Is it appropriate? Does it have reasonable and achievable goals? Does it reflect the needs of the Department of Energy (DOE) and the broader U.S. industrial community?
- *Multi-Year Program Plan (MYPP):* How good is the decision-making process used by the ITP to determine research directions? What is the prospective value of the program? What is the likelihood of its achieving its goals? How well is it connected to users, including non-ITP researchers? Is there a capacity to develop lessons learned for future interdisciplinary research activities?
- *Corporate strategy or management plan:* Is there a good plan in place to carry out the program?

This chapter contains the committee's assessment of the ITP Strategic Plan, the ITP program plan as contained in the MYPP, the ITP corporate strategy or management plan, and the appropriateness of all of these activities with respect to the strategic plans of the ITP, the Office of Energy Efficiency and Renewable Energy (EERE), and the DOE, and with respect to the National Energy Policy.

THE ENERGY POLICY CONTEXT

National Energy Policy

The National Energy Policy (NEP) released on May 16, 2001, is the final report of the National Energy Policy Development Group (NEPDG, 2001). The report describes five goals for the current presidential administration: modernize energy conservation, modernize the energy infrastructure, increase energy supplies, accelerate the protection of the environment, and increase the nation's energy security.

The NEP states that the best way to meet the goal of modernizing energy conservation is "to increase energy efficiency by applying new technology—raising productivity, reducing waste, and trimming costs" (NEPDG, 2001, p. xi). Recommendations for modernizing energy conservation include increasing the funding for renewable energy and energy efficiency research and development (R&D) programs that are performance-based and cost-shared, and providing a tax incentive and streamlining permitting to accelerate the development of combined heat and power technology (NEPDG, 2001, p. xi). With regard to the goal of accelerating the protection and improvement of the environment, the NEP recommends further promoting improvements in the productive and efficient use of energy by enacting multipollutant legislation that would establish a flexible, market-based program to significantly reduce and cap emissions of sulfur dioxide, nitrogen oxides, and mercury from electric power generators and increase exports of environmentally friendly, market-ready U.S. technologies that generate a clean environment and increase energy efficiency (NEPDG, 2001, p. xiv).

The National Energy Policy Development Group also recommended the establishment of a national priority for improving energy efficiency. The priority would be to decrease the energy intensity of the U.S. economy as measured by the amount of energy required for each dollar of economic productivity. According to the report, this increased energy efficiency should be pursued through the combined efforts of industry, consumers, and federal, state, and local governments (NEPDG, 2001).

Strategic Plan of the Department of Energy

The overarching mission of the Department of Energy is to advance the national, economic, and energy security of the United States; to promote scientific and technological innovation in support of that mission; and to ensure the environmental cleanup of the national nuclear weapons complex (DOE, 2003a). The DOE has four strategic goals: to protect national security by applying advanced science and nuclear technology to the nation's defense; to protect national and economic security by promoting a diverse supply and delivery of reliable, affordable, and environmentally sound energy; to protect national and economic security by providing world-class scientific research capacity and advancing scientific knowledge; and to protect the environment by providing responsible resolution to the environmental legacy of the Cold War and by providing for the permanent disposal of the nation's high-level radioactive waste.

A general goal of the DOE is to improve energy security by developing technologies that foster a diverse supply of reliable, affordable, and environmentally sound energy by providing for the reliable delivery of energy, guarding against energy emergencies, exploring advanced technologies that make a fundamental improvement in the mix of energy options, and improving energy efficiency. One strategy for achieving this goal is to partner with the private sector, states and communities, national laboratories, colleges and universities, nongovernmental organizations, foreign allies, the U.S. Congress, and other federal agencies in order to develop and bring to market technologies that advance energy efficiency.

Another general goal of the DOE is to provide world-class scientific research capacity needed to ensure the success of DOE missions in national and energy security; advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental, and computational sciences; and provide world-class research facilities for the U.S. science enterprise. The DOE promotes the transfer of the results of its basic research to a broad set of technologies, such as for advanced materials, national defense, medicine, space science and exploration, and industrial processes.

Strategic Plan of the Office of Energy Efficiency and Renewable Energy

DOE Secretary Spencer Abraham challenged the Office of Energy Efficiency and Renewable Energy to revolutionize the way in which it approaches energy efficiency and renewable energy technologies, while pursuing the recommendations of the National Energy Policy. To meet this challenge, EERE officials indicate that the EERE intends to leapfrog the status quo and pursue dramatic energy and environmental benefits.

The mission of the EERE is to strengthen U.S. energy security, environmental quality, and economic vitality in public-private partnerships that enhance energy efficiency and productivity; bring clean, reliable, and affordable energy technologies to the marketplace; and make a difference in the everyday lives of Americans by enhancing their energy choices and quality of life.

The EERE has nine strategic goals: (1) dramatically reduce, or even end, dependence on foreign oil; (2) reduce the burden of energy prices on the disadvantaged; (3) increase the viability and deployment of renewable energy technologies; (4) increase the reliability and efficiency of electricity generation, delivery, and use; (5) increase the energy efficiency of buildings and appliances; (6) increase the energy efficiency of industry; (7) spur the creation of a domestic bioindustry; (8) lead by example through government's own actions; and (9) change the way that the EERE does business (DOE, 2002).

STRATEGIC PLAN OF THE INDUSTRIAL TECHNOLOGIES PROGRAM

The ITP Strategic Plan describes the program's mission and vision and outlines a long-term strategy for achieving improvements in the energy and environmental performance of energy-intensive industries (DOE, 2003c). It is intended that this plan provide the strategic link between the policies and priorities described in the National Energy Policy and the detailed plans outlined in the ITP Multi-Year Program Plan. The Strategic Plan is intended to build on DOE and EERE strategic plans and to provide specific strategies for achieving DOE and EERE goals.

Mission and Vision

As stated in Chapter 1, the mission of the ITP is to decrease the energy intensity of the U.S. industrial sector through a coordinated program of research and development, validation, and dissemination of energy efficiency technologies and operating practices. As part of its mission, the ITP partners with industry, its equipment manufacturers, and its many stakeholders to reduce U.S. reliance on foreign energy sources, reduce environmental impacts of U.S. industry, increase the use of renewable energy sources, improve the competitiveness of U.S. industry, and improve the quality of life for U.S. workers, families, and communities (DOE, 2003c, p. 2).

The vision of the ITP is to strive for a world in which U.S. goods are recognized for their extraordinary quality, are produced with minimal energy and environmental impact, are designed for durability and recyclability, and are manufactured with modern technology and practices to ensure continued U.S. economic vitality and energy security (DOE, 2003c, p. 2).

The goals of the ITP's Strategic Plan address two areas: reduction in energy intensity and commercialization of energy efficiency technologies. Quantitative goals have been set: a 25 percent decrease in energy intensity[1] by the energy-intensive Industries of the Future (IOFs) between 2002 and 2020 and the commercialization of more than 10 industrial energy efficiency technologies between 2003 and 2010.[2] The six key ITP strategies for achieving these goals are:

- To focus on energy-intensive industries,
- To use public-private partnerships to plan and implement the program,
- To identify grand challenges that would dramatically improve industrial energy efficiency,
- To implement a technology portfolio that is balanced in terms of near-, mid-, and far-term research,
- To perform process-specific and crosscutting research and development (R&D) to improve long-term energy efficiency, and
- To perform technology delivery activities to improve near- and mid-term energy efficiency (DOE, 2003c, pp. 8-12).

Conclusions and Recommendations for the Strategic Plan

The committee finds that the ITP Strategic Plan presents a coherent link between the higher-level plans described above and the ITP's Multi-Year Program Plan (DOE, 2004a). The strategies outlined are consistent with the mission of the ITP and address the needs of the DOE and U.S. industry for decreased energy intensity and improved environmental protection. The Strategic Plan is aimed at meeting the

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[1] *Energy intensity* is defined in the ITP Strategic Plan as energy consumed in British thermal units (Btu) per unit of industrial output (in U.S. dollars of gross domestic product) as compared with Btu per unit of industrial output in 2002 (DOE, 2003c, p. 2).

[2] B. Garland, DOE, 2004, "Industrial Technologies Program Corporate Programmatic Review," Presentation to the Committee, Washington, D.C., May 19.

needs of the energy-intensive IOFs that are characterized by low R&D as a percentage of sales and that face strong foreign competition.

The ITP's Strategic Plan provides no explanation of the basis for the selection of its specific quantitative goals; nor is it clear how achievement of these goals will be measured. For example, the plan lacks a definition of "commercialized technology." It is unclear whether this term refers to a technology that is available for commercial sale, a technology in use in demonstration facilities, or one widely employed in industry. The energy savings would differ greatly in each case. The committee recommends that the ITP provide additional description of how these goals were selected and how their achievement will be measured.

The committee finds that, owing to the unclear basis for the stated goals in the ITP's Strategic Plan, it is difficult to assess the likelihood that the program will achieve these goals. A 25 percent decrease in energy intensity would appear to be an aggressive goal. On the other hand, the achievement of commercializing more than 10 industrial energy efficiency technologies would appear to be quite low considering the 160 such technologies commercialized by the program between 1980 and the present (DOE, 2003c, p. 16). The committee notes that this low figure may be related to the increased focus on grand challenges and suggests that the ITP provide additional description of the reasons for setting this target.

MULTI-YEAR PROGRAM PLAN OF THE INDUSTRIAL TECHNOLOGIES PROGRAM

Starting in fiscal year (FY) 2003, EERE leadership committed to providing multi-year program plans. The development of the ITP Multi-Year Program Plan coincided with the reorganization of the ITP to provide a more focused portfolio of R&D. The MYPP is a document that results from the ITP Strategic Plan and fits within the other planning documents described above. The MYPP development process is intended to translate the ITP's strategies and strategic objectives into specific technical, funding, and schedule requirements that meet all EERE expectations and requirements, including all metrics for effective performance evaluation. The MYPP includes information on planning interrelationships; the current federal, business, industry, and technology environments; and technical goals and how they are derived. In addition, it contains a description of the implementation strategy, including the corporate strategy and multi-year plans for the individual subprograms (DOE, 2004a).

The MYPP is used to guide the allocation of resources and to identify the technology focus areas that are important to achieving the goals of the ITP. At both the corporate and industry levels, the MYPP identifies key technical focus areas, explains the primary technical barriers faced in accomplishing the objectives, lays out pathways for achieving the goals set for each focus area, and defines metrics to help evaluate and adjust the pathways. The MYPP is designed to undergo periodic review and updates, with the overall plan being reviewed annually and each technology planning element performing a quarterly update and review.

Conclusions and Recommendations for the Multi-Year Program Plan

The ITP Multi-Year Program Plan that supports the ITP Strategic Plan is clearly evolving both as a document and as an approach. A "grand challenge" is defined in the MYPP as "an important technical problem facing an industry, or group of industries, that, if solved, holds the potential to produce large improvements in energy efficiency, environmental performance, and product yield" (DOE, 2004a, p. 65). The MYPP currently lists three grand challenge projects in three different Industries of the Future. These three, along with prospective future grand challenges, are combined with a larger set of projects labeled Intermediate Term Technology Developments (major program activities that are not grand challenges) to form a list of corporate milestones, numbering more than 100 in the FY 2005 to FY 2009 time frame. A subset of 18 of these corporate milestones has been identified as having highest priority, although the specific criteria for such prioritization are not noted.

The committee recommends the continuation and an acceleration of the evolution of the ITP's Multi-Year Program Plan toward a more manageable set of corporate milestones that enable more effective corporate management. There is no apparent coordination across subprograms on milestones that have potential common elements and that could therefore experience synergy through cooperation. The committee recommends that in preparing future Multi-Year Program Plans, the Industrial Technologies Program look for opportunities to coordinate between subprograms, especially in the area of grand challenges. This is especially important for sharing lessons learned, as well as best practices, across industries and ITP subprograms.

CORPORATE STRATEGY OF THE INDUSTRIAL TECHNOLOGIES PROGRAM

The ITP corporate strategy, described in the MYPP, is an effort to streamline business and management processes within the ITP. It consists of five components: (1) realizing a vision for the future of industry; (2) strategy for government investment; (3) understanding and awareness; (4) long-term, focused partnerships; and (5) superior business practices (DOE, 2004a, p. 46). The overall approach is to align the ITP strategic goal of a 25 percent decrease in energy intensity by the IOFs with corporate goals related to increasing productivity, energy efficiency, resource conservation, environmental stewardship, and economic growth.

Realizing a Vision for the Future of Industry

The process of creating vision documents in conjunction with the Industries of the Future was developed to identify the need for industrial energy savings, to implement an iterative planning process, and to assess the success of the planning. Barriers to identifying industry needs and roles include the following: short-term, conflicting, and uncertain industrial needs; an unclear, conflicting, and uncertain strategic direction on the part of government; and the lack of a unified voice in government regarding industrial issues. Barriers to the implementation of an iterative planning process include these: difficulty in effectively using the mass of information available for strategic decision making; an insufficient understanding of industrial business and its technical environment; a constantly changing planning environment; and the insufficient engagement of industrial partners. Barriers to the assessment of planning success include insufficient and uncoordinated metrics, an unclear relationship of metrics to strategic planning, the disconnection of metrics from planning feedback, and the lack of understanding of metrics by either government or industry.

The explicit awareness in the ITP of all of these barriers to the achievement of each individual Industry of the Future vision leads to specific pathways for overcoming the barriers and identifying opportunities for success. Each pathway typically involves the use of industry-developed roadmaps, the collection of documents and data, the harnessing of ITP and industry expertise, and the use of footprint, bandwidth, and other energy and environmental profiling tools. The ITP has concluded that realization of its vision requires an understanding of the realities of both industry and government and an iterative planning process driven by measurable results. The committee finds that this conclusion is appropriate.

Strategy for Government Investment

The strategy for the government investment component of the ITP corporate strategy involves five aspects: (1) prioritization of project opportunities, (2) maintenance of a robust project portfolio, (3) synergy with other programs in the DOE Office of Energy Efficiency and Renewable Energy, (4) support of the 21st century workforce; and (5) the existence of alternative government interventions.[3] Project opportunities are generated and prioritized through program goal setting and technology planning and through the solicitation, selection, execution, and assessment and evaluation of projects. These steps are supported by the new decision-making approach; energy (and sometimes exergy) footprint, bandwidth, and opportunity analyses; expert peer reviews; metrics required by the Government Performance and Results Act of 1993 (GPRA); milestone tracking; portfolio peer review; and follow-up studies. The

[3] S. Dillich, DOE, 2004, "Strategy for Government Investment," Presentation to the Committee, Washington, D.C., May 19.

committee finds that these tools and processes are appropriate for guiding the prioritization and selection of projects.

Occasionally, grand challenges are developed to focus on technically complex issues that have lacked previous solution and which are likely to involve high-risk, high-return R&D requiring public-private partnerships. The committee suggests that grand challenges should also be fully justified from a market perspective. In fact, the committee recommends that market pricing, acceptance, and the potential economic impact of all projects be estimated. Energy-saving metrics for project selection and management are appropriate, but they would be more effective if they were augmented by an estimate of the acceptance and impact of the project technology in the marketplace.

The project portfolio consists of projects representing a range of technical and market risk, a range of relative energy benefits per investment, and a range of investments. Some projects are relatively small, involving best-practice technology delivery; others are larger, involving yield improvement; still larger projects involve process improvement; and perhaps the largest are the grand challenges. Project portfolio management involves reviewing the mix of projects by these classifications. Also, the estimated cumulative GPRA energy savings metrics for 2020 are plotted against the cumulative budget so that projects with a relatively greater ratio of energy savings per unit of budget might be considered for acceleration, while those with a lower ratio might be considered for redirection, examined for cost-sharing, or reevaluated for strategic importance. In the future, additional methodologies, software, and scenario analyses within the context of various economic, social, and technical environments will be used in order to maintain a robust project portfolio. The committee notes that there is a wide variety of management science decision tools that can be applied specifically to portfolio analysis, including such analytical tools as data envelope analysis and analytical hierarchical process.

The EERE involves a broad range of energy-related sectors, including, for example, biomass, hydrogen, fuel cells, FreedomCAR, buildings, combined heat and power technologies, solar, geothermal, hydropower, and wind. The ITP Industries of the Future and project portfolio cross almost all of these sectors and contribute to many of the Small Business Innovation Research (SBIR) programs across the EERE.

ITP support of the 21st century workforce (to help alleviate a perceived shortage in technically qualified manufacturing workers) involves making available best energy practice tools and training for manufacturing workers, training students at 26 universities to conduct manufacturing plant audits and to increase workers' energy knowledge, and participating in educational partnerships with community colleges. The committee notes that no evidence was presented that any of these efforts have been particularly effective at addressing specific 21st century workforce issues. Compared with other components of the ITP government investment strategy, the committee observes that attention to education issues appears weak, isolated, and probably misplaced. A better approach might be to hand off this aspect of its efforts to the Department of Education, the Department of Labor, or the National Science Foundation, all of which have major educational missions.

With respect to alternative government interventions to assist industry in improving energy efficiency, the ITP participates on the industrial Energy Savers Web site and has been involved with state showcases of industrial energy efficiency technologies, the Climate VISION (Voluntary Innovative Sector Initiatives: Opportunities Now) strategic thrusts for near-term reductions of greenhouse gas emissions, and partnerships with the National Institute of Standards and Technology, U.S. Environmental Protection Agency, National Science Foundation, U.S. Department of Defense, and other relevant agencies. The committee finds that all of these activities are appropriate to enhancing the effectiveness of the ITP government investment.

Understanding and Awareness

The understanding and awareness component of the ITP corporate strategy involves government, industry, and the general public. This strategic component is based on the following assumptions: that the government lacks consensus on the extent of opportunities for industrial energy efficiency; that there is sometimes a lack of understanding in government about industrial priorities and drivers and the relationship between energy efficiency and economic and environmental factors; that industry is often unaware of the resources available through the ITP and of opportunities for energy savings; and that the general public often does not understand the relationship between industrial energy efficiency and public benefits.[4]

For each of these sectors, barriers to understanding were identified and, following the visioning processes, specific pathways to overcoming these barriers were developed. Examples of strategic pathways to promote understanding include the following: establishing the DOE as the authoritative government source for industrial energy issues; developing public-private partnerships, visions, and roadmaps; providing explanatory materials regarding the relationship of energy efficiency to economic productivity, job creation, greenhouse gas reduction, and environmental performance; maintaining informative Web sites; holding showcases, energy events, and awareness workshops; publishing case studies; developing software tools, training curricula, and qualified specialists; conducting industrial energy assessments; promoting corporate energy management; and participating in Climate VISION. The committee finds that these are appropriate pathways to overcoming the various barriers to understanding and awareness, although the committee recommends that, to the extent possible, each be measured and monitored to assure effectiveness.

Long-Term, Focused Partnerships

A key component of the ITP corporate strategy is the use of public-private partnerships to plan and implement the program. The justification is threefold: (1) to bring together the strengths of business and government to solve increasingly complex and difficult energy problems; (2) to partner with industry in technology planning, collaborative R&D, and energy technology implementation; and (3) to reduce the technical and financial risk of projects in order to stimulate private investment and the development of energy-saving technology. The mechanism for carrying out this strategy has been the collaborative public-private Industries of the Future partnerships, each with a vision of industry goals, a roadmap of industry technology priorities, and a partnership plan for collaborative R&D and technology implementation. Numerous industry visions and technology roadmaps have been developed, and showcases have been held. Several hundred individual projects are underway, related to specific energy-intensive sectors, to crosscutting technologies, to grand challenges, to the development of tools and training, to energy assessments, and to demonstrations.

Barriers to long-term public-private partnerships include the difficulty in changing industry performance without adequate resources, insufficient leveraging of partnerships, the lack of understanding and awareness of how energy efficiency can improve profitability and societal benefit, concerns about partnering with government, and the lack of unified objectives and priority setting within the government. Again, pathways have been identified to address each of these barriers. They include a focus on collaborative R&D; a focus on grand challenges; the use of allied partners, such as trade and technical associations, end users, and equipment suppliers, to act as delivery channels for ITP technologies and practices; leveraged resources with other government programs, such as Innovative Energy Systems Technology for the Chemicals Industry, Climate VISION, and the National Nanotechnology Initiative; and an expanded role for the EERE regional offices to provide project management, training and technical assistance, and technology deployment. The committee finds that maintaining public-private partnerships, including academic partnerships, outside of specific industries is critical to the success of the ITP.

Superior Business Practices

Key features of the ITP include a major emphasis on partnerships; strong attention to planning, analysis, and metrics; and a balanced portfolio of projects. The business practices component of the ITP

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[4] P. Salmon-Cox, DOE, 2004, “Understanding and Awareness,” Presentation to the Committee, Washington, D.C., May 19.

corporate strategy involves strategic, multiyear, and annual operating plans; footprint and bandwidth analytical studies; project reports; GPRA and Program Assessment Rating Tool (PART) energy, environmental, and financial metrics and impacts tracking; and headquarters and field information management systems. The committee notes that there appears to be considerable focus on systematic and aligned planning, analysis, decision-making, and project management processes. The data are beginning to show significant cumulative energy and cost savings.

The way that the ITP program is managed has changed as a result of the EERE and ITP reorganizations. ITP program managers stated in their presentations to the committee that the ITP is organizationally now more science-and-technology-based than industry-based; that the portfolio is managed by analysis rather than by the industry roadmaps alone; that there are fewer but larger projects; that there are strategic, multiyear, and annual operating plans with milestones rather than industry roadmap plans alone; that project management has been moved from headquarters to the field offices; that the regional offices will now be involved in outreach; that there is more coordination and collaboration with other EERE efforts; that travel will be used to accomplish the mission rather than just to attend events; and that the staff has been reduced by more than half. The committee observes that a high energy level and momentum exist within the ITP staff for implementing these changes and improving the ITP. The committee notes that it appears as if most of the program management changes (with the possible exception of travel restrictions) should enhance the ITP's transparency and effectiveness. However, again to the extent possible, the committee recommends that these new management practices be carefully measured and monitored to assure continual improvement in fact.

Additional Challenges and Opportunities

Four additional challenges and opportunities (in addition to the 21st century workforce issue discussed previously) were identified by the ITP as having a potential influence on the relationship between industry and the Industrial Technologies Program and the robustness of the ITP strategy. These were (1) positive impact manufacturing, (2) multiscenario planning analysis, (3) environmental regulation and its impact on investment, and (4) industrial financing of energy efficiency investments.

Positive impact manufacturing goals include U.S. leadership in manufacturing technology, a positive public image of manufacturing, and the recognition among the public and policy makers that manufacturing can meet societal goals. Elements affected by positive impact manufacturing include economic security, education, technology growth, resource conservation, energy, and the environment. The current manufacturing situation was described by the ITP program managers in their presentations to the committee as being characterized by high foreign competition, high capital equipment costs, low access to cash, high technology risk, low stock turnover, low R&D investment, environmental externalities with an uncertain future, high natural gas prices, climate change, antiglobalization, inflation, substitute materials, and war. Barriers to achieving positive impact manufacturing were taken from previously identified barriers in other parts of the ITP management plan—the barriers include environmental regulations, technical and investment risk inhibiting the deployment of energy-efficient industrial technology, and a scarcity of technically skilled production workers—as were previously identified pathways to address these barriers. ITP program managers suggested that scenario planning would be an appropriate technique to address a changing manufacturing situation.

The previous ITP Strategic Plan was based on one business-as-usual scenario and contained a portfolio of strategies and projects geared to that scenario. The ITP now recognizes that multiscenario planning can enhance the understanding of important uncertainties, integrate alternative perspectives into planning, and result in greater resilience of planning decisions in the face of surprises. To this end, the ITP is now evaluating whether the overall goal (25 percent reduction in energy intensity in energy-intensive industries) is feasible under any potential scenario and whether this goal could be more aggressive. The ITP has also identified factors that could affect the achievement of this goal, including a lack of qualified technical employees, a lack of awareness of energy-saving opportunities, narrow profit margins, high investment costs, and increased foreign competition. The remaining steps of the multiscenario exercise (rank driving forces by importance and uncertainty, cluster uncertainties into affinity groups and select axes of uncertainty, characterize driving forces under different uncertainty extremes, write scenarios, exercise scenarios, establish monitoring and trend analyses) will be completed and incorporated into the next revision of the ITP Strategic Plan.

Environmental regulations impact manufacturing operations both technically and financially, as compliance represents a significant fraction of both capital spending and operating costs. Many of the IOF visions and roadmaps contain environmental as well as energy-related goals. ITP objectives include the development and promotion of energy technologies and practices that also promote resource conservation, minimize environmental impact, and promote energy and environmental sustainability, and many environmental drivers are incorporated into ITP planning. Many technologies under development within the ITP simultaneously decrease both energy intensity and environmental impact. The ITP plans to continue communication and collaboration with the Environmental Protection Agency (EPA) on environmental issues affecting manufacturing; to have EPA participation in ITP planning, project solicitation, and merit reviews; and to quantify environmental and other societal benefits of ITP technologies.

Industrial market acceptance of energy-saving technologies depends on the reduction of risk and uncertainty associated with implementing new projects. This reduction in risk is in part provided by demonstrations and other sources of technical and economic performance data. Project R&D, training, the development of decision tools, fact sheets, and case studies are now being funded. The ITP recognizes that additional engineering verification data, additional training, and more robust communication of technology benefits will be critical to market acceptance and industrial financing of energy efficiency investments. The committee notes that this is important for the market acceptance of mature energy-saving technologies and, even more so, for novel technologies developed under this program. The committee believes—and emphasizes—that the market success of mature projects must be measured in order to provide feedback for new project selection, and that the projected market acceptance of proposed projects must be properly evaluated and included in project selection and project portfolio management.

3

Evaluation of Industry of the Future Subprograms

INDUSTRIES OF THE FUTURE

As indicated in Chapter 1, the Industrial Technologies Program (ITP) currently funds research addressing the needs of seven energy-intensive industries—aluminum, chemicals, forest products, glass, metal casting, mining, and steel—known as the Industries of the Future (IOFs). The petroleum-refining industry is also designated as an IOF, although no projects specifically tailored for this industry are being funded within the ITP at this time. Together the IOFs account for 75 percent of the energy consumed by the U.S. manufacturing and mining sector (see Figure 1-1 in Chapter 1).

Since the IOF initiative began in 1992, industries have been identified as candidates for becoming IOFs on the basis of a variety of factors: high annual energy consumption coupled with high energy intensity; low investment in research and development (R&D) as a percentage of sales; capital requirements that are higher than manufacturing average capital requirements; and intense foreign competition in the market. In addition, consideration has been given to whether or not it is important to national security to maintain a domestic industrial base in the selected industry and whether or not the industry demonstrates a willingness to organize as a group, collaborate internally, and partner with the government (DOE, 2004a, pp. 17-18). Finally, there has been a historical element to the selection of IOFs, including whether an industry was able to achieve internal consensus during the early years of the initiative, whether an industry was considered within the purview of another Department of Energy (DOE) unit, and whether or not funding from ITP or its predecessors was available at the time when an industry was ready to become a member. Other energy-intensive industries that have been candidates for IOF designation include the agricultural, concrete, construction, and food-processing industries.

Prior to the IOF initiative, the DOE's industrial energy efficiency program followed a "technology push" strategy, in which research projects were selected and prioritized according to their generic potential for reducing energy consumption and waste generation. With the IOFs, a "market-pull" strategy was implemented, in which the technology needs and priorities identified by the IOFs were used to determine project selection (NRC, 1998). Advantages of the IOF approach include responsiveness to the needs of industry, the ability to leverage limited government funds with private-industry funds, and broad industrial participation, including both large and small companies. The first IOF subprogram was created in 1994, when a budget for the forest products industry was established.

Committee Evaluation Criteria

In evaluating each IOF subprogram, committee members asked the following questions derived from the committee's statement of task:

- How were focus areas and barriers identified?

- Were appropriate data sources used?
- Do the data used support the selection of focus areas and barriers?
- Are the focus areas and barriers selected the highest priority or the most appropriate ones relative to the ITP's mission?
- How were the R&D pathways determined?
- Are these pathways likely to result in the achievement of program goals?
- Are the prospective subprogram portfolios the right ones to achieve the goals of the ITP?
- Are there unnecessary research areas or gaps in research?
- Is there a reasonable mix of near-, mid-, and far-term research?

It is important to note several aspects of the committee's evaluations of the IOF subprograms. First, its evaluations of the individual IOF subprograms vary in length, emphasis, and level of detail. This is a reflection of the tremendous variety found in the subprograms, which in turn reflects the variations found in the industries and the history of the IOFs and industry participation.

Second, it is important to note again that the committee was asked to review the future program directions that were indicated by the documents available. The committee's evaluations are based primarily on the documents provided and on the presentations made by ITP personnel at meetings in May 2004 (see Appendix B). Committee members did not investigate individual projects, but rather looked at the overall research directions, the basis for decision making in the selection of research directions, and compatibility of subprogram research directions with the goals of the ITP, the Office of Energy Efficiency and Renewable Energy (EERE), the DOE, and the National Energy Policy.

Finally, the EERE reorganization and the implementation of the new ITP decision-making model took place in the context of an existing, active research portfolio of several hundred projects. In the initial stages, these new decision-making criteria have been superimposed on existing projects with the intent to see which still fit and which do not. It follows that some existing projects may not fit well with the new decision-making model, and these are likely to be phased out. The committee took this into consideration and tried to recommend clearly which legacy projects should be stopped, without using the existence of these projects as a criticism of the new decision-making process.

ALUMINUM

The aluminum industry consumes approximately 800 trillion British thermal units (Btu) of energy per year (DOE, 2004j, p. iv), which constitutes approximately 2 percent of all U.S. manufacturing and mining fuel use (DOE, 2003c, p. 8). The aluminum subprogram is dynamic, having an excellent historical and ongoing interaction with the U.S. aluminum industry. Since its designation as an Industry of the Future in 1996, the aluminum industry, primarily through its trade organization the Aluminum Association, has actively participated in the development of overall industry visions and roadmaps. The industry vision was originally published in 1996 and updated in 2002. A number of roadmaps target specific technology or application areas. In addition, the DOE has published a baseline energy and environmental profile of the aluminum industry. This process-based profile has been used in the creation of a bandwidth analysis, which identifies energy-savings opportunities within key aluminum manufacturing processes by comparing theoretical and practical levels of minimum energy consumption with current actual values.

Focus Areas, Barriers, and Pathways

Four focus areas have been identified for the aluminum subprogram: alternative reduction systems, advanced Hall-Héroult cells, efficient melting technologies, and advanced forming technologies. The first two focus areas involve the primary production of aluminum—that is, the reduction of alumina to aluminum metal, otherwise known as smelting. The focus on smelting in the current aluminum R&D portfolio is supported by the bandwidth analysis (based on year 2000 data) indicating that smelting both consumes the greatest amount of energy of all aluminum processes and offers the greatest opportunity for improvement considering the difference between the theoretical minimum and actual energy consumption (DOE, 2004a, p. 82). It is unclear why two separate focus areas for smelting R&D have been established. The projects within one smelting focus area are based on the chemistry of the Hall-Héroult process, including new concepts such as inert anode and wetted cathode that would require a different cell design. The one project within the other smelting focus area is based on an alternative to the Hall-Héroult process. The committee recommends that these two focus areas be combined into one area, which might be named, for example, “advanced reduction technologies.”

The term *melting technologies* refers to the production of secondary aluminum from recycled aluminum products. The selection of efficient melting technologies as a focus area is supported both by its identification as a top priority in the 2003 Aluminum Industry Roadmap and by the bandwidth analysis, which indicates that melting technologies are the second most energy-intensive process.[1] It is important to note that although the opportunity for energy savings is larger for smelting than for melting when 2000 data are used, this gap will most likely be significantly narrower in the future as a result of changes in the industry. These changes include the idling or closing of primary smelting capacity, particularly in the Pacific Northwest, and increased growth in recycling.

The fourth focus area, advanced forming technologies, is not well formulated. *Forming*, in aluminum industry use, refers to downstream product-manufacturing processes, such as sheet forming. Forming, as such, is neither identified as a process step with top-priority R&D needs in the 2003 Aluminum Industry Roadmap, nor is this process identified as having a large opportunity for improvement by the bandwidth analysis. Process steps such as solidification and fabrication are, however, identified by the roadmap as having top-priority R&D needs, while the bandwidth analysis identifies rolling, extrusion, and shape (presumably shape casting) as having some opportunity for improvement. To improve the opportunity for impact, this focus area could perhaps be renamed “advanced fabrication technologies” and could incorporate the specific processes identified in the roadmap and bandwidth analysis. This focus area could also incorporate downstream processes such as joining and forming (used in the conventional industry sense) in end-use industries, where appropriate stretch goals can be identified.

Barriers and pathways have been identified for each of these four focus areas. For the two smelting focus areas, the barriers described in the ITP’s Multi-Year Program Plan (MYPP) comprehensively identify the key technical issues, and the pathways described in the presentation to the committee are appropriate. However, the committee notes the substantial environmental impact of spent potliner in the Hall-Héroult process and its potential elimination via the carbothermic reduction process. Similarly, the barriers and pathways for the melting technologies focus area are consistent with information from the roadmap.

The barriers and pathways described for the fourth focus area, advanced forming technologies, lack the specificity and connectedness of the barriers and pathways identified for the other three areas. For example, the MYPP for the aluminum subprogram lists a barrier related to a specific in-line characterization technology with relevance to FreedomCAR, but there is no corresponding pathway. The presentation to the committee described barriers related to a lack of models and accurate material data, with pathways of developing models and data. These are very general and could apply to any industry or technology area. Revising these descriptions, perhaps with a view beyond forming as described above, could help focus the subprogram’s efforts.

Portfolio Management

In FY 2003, the aluminum subprogram portfolio consisted of 25 projects with a total federal budget of $6.4 million and industry funding of $2.7 million, resulting in an industry cost-share of 30 percent.[2] In the area of alternative reduction technologies, the major project is the development of a carbothermic reduction process for aluminum. This project is also one of the current grand challenges listed in the MYPP (DOE, 2004a, p. 65). The project is aggressive in its R&D scope, but it currently consists of only

[1] T. Robinson, DOE, 2004, “ITP Corporate Peer Review: Aluminum Sub-Program,” Presentation to the Committee, Washington, D.C., May 20.
[2] S. Richlen, DOE, 2005, personal communication to the committee, March 8.

one U.S. aluminum industry and one university partner, along with one non-U.S. technology contributor. The committee observes that a broader base of participants would make this a more meaningful project. In addition, if the project could be coupled programmatically with the projects in the advanced Hall-Héroult process focus area, the overall focus area would contain a desirable mix of near-, mid-, and far-term projects.

The portfolio of projects in the efficient melting technologies area includes both melting and metal treatment projects.[3] These projects are near- or mid-term in nature. In the MYPP, this focus area is identified as possibly being crosscutting, but there does not appear to be significant leveraging of nonaluminum subprogram technologies, such as sensors or materials (DOE, 2004a, p. 74). Also, the MYPP indicates a grand challenge opportunity entitled "Design and Build Advanced Furnace," to be started in FY 2008, with a 3-year R&D gap prior to that (DOE, 2004a, p. 74). If this grand challenge could be initiated sooner, the aluminum subprogram would engage significant involvement from crosscutting subprograms because of the large potential energy savings.

The advanced forming technologies portfolio contains a mix of deformation processing and casting projects that appear to be somewhat unrelated (DOE, 2004a, p. 75). The committee recommends that this focus area be given attention and restructured as dictated by revised barriers and pathways.

The committee was initially concerned upon learning that only two projects have been terminated in the history of the aluminum portfolio. However, while it would seem that more projects would be stopped owing to typical R&D risk factors, the ability of the programs to be redirected on the basis of expert review enables them to continue and to provide results. This trend, however, points to the larger issue of defining the success of a project. If multiple paths are available to achieve a stated goal, the process of interim review can be used to good effect. However, if no endpoint is identified, redirecting such projects can diffuse the focus of the overall subprogram.

The committee recommends that the aluminum subprogram explore leveraging efforts through Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) mechanisms to involve R&D organizations and universities in the early stages of project development, so as to free up resources within the ITP for projects closer to implementation.

The MYPP lists three additional activities under the aluminum subprogram that are included in the milestone chart. The first of these, "Studies and Analysis," shows plans for a case study of retrofit Hall-Héroult versus alternative reduction, which the committee supports as important to understanding the relative risks and benefits of these technology approaches in the energy-intensive smelting area. In light of the energy-cost-driven migration of primary production technology offshore, the committee also suggests that a study forecasting the growth or shrinkage of the various aluminum processes in the United States be commissioned to guide future decisions involving the ITP aluminum subprogram.

A category entitled "Best Practices for Interaction for Technology Delivery" is also included on the aluminum milestone chart. The committee believes that there is an opportunity for significant strengthening of this area for aluminum. This strengthening could include expanded outreach activities, including dissemination of the results from assessments such as that done with Alcoa (DOE, 2004k). Alternative methodologies beyond the use of allied partnerships and the distribution of software could broaden the impact, with the expanded use of the Industrial Assessment Centers[4] being one promising approach.

The category labeled "Cross-EERE Activities" in the aluminum milestone chart lists a series of other EERE programs across a 3-year time period, but it is not clear what mechanisms for involvement with these programs will be used.

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[3] T. Robinson, DOE, 2004, "ITP Corporate Peer Review: Aluminum Sub-Program," Presentation to the Committee, Washington, D.C., May 20.

[4] Free energy audits for small to medium-sized plants are carried out by faculty and students at 26 Industrial Assessment Centers, located in 22 states, at universities with accredited engineering schools.

Conclusions and Recommendations for the Aluminum Subprogram

The aluminum subprogram focuses on relevant needs of the aluminum industry, and its portfolio overall addresses the key priorities in the four current focus areas. The committee commends the staff of the aluminum subprogram for their work and recommends continued evolution and growth in the subprogram direction as the needs of U.S. industry change. The committee specifically recommends:

- Combining the two focus areas on smelting R&D (alternative reduction systems and advanced Hall-Héroult cells) into one area that includes the only major project currently in the alternative reduction systems area;
- Leveraging of other ITP subprograms, such as sensors and materials, in the efficient melting technologies focus area;
- Considering initiating the “Design and Build Advanced Furnace” grand challenge earlier than the proposed FY 2008 timeframe;
- Reorganizing the focus area on advanced forming technologies into a focus area named “advanced fabrication technologies”;
- Leveraging efforts through Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) mechanisms to involve R&D organizations in the early stages of project development;
- Commissioning a study forecasting the growth or shrinkage of aluminum processes in the United States to guide subprogram decisions; and
- Expanding outreach activities, including dissemination of the results from plant assessments such as that done with Alcoa (DOE, 2004k).

CHEMICALS

The chemical industry consumes 6.3 quadrillion Btu (quads) (DOE, 2004h, p. iv) per year, or approximately 19 percent of all fuel used by the U.S. manufacturing and mining sector (DOE, 2003c, p. 8). This makes it the second-largest consumer of energy within the U.S. manufacturing sector (DOE, 2004h, p. iv), behind petroleum refining, and it is therefore a prime target for R&D aimed at improving resource productivity and energy efficiency. The ITP chemicals subprogram has worked closely with the Chemical Industry Vision2020 Technology Partnership to leverage public and private resources and to ensure the accomplishment of roadmap goals. The Vision2020 partnership is an active one: 98 companies, 22 universities, 11 government offices and laboratories, and 11 trade and professional organizations participated in 2003. Activities in 2003 included establishing a chemical industry consensus on precompetitive R&D needs and jointly analyzing R&D opportunities to create research agendas.

The MYPP for the ITP chemicals subprogram is based on input from Vision2020 as well as on white papers, workshops, ITP’s Strategic Plan, and ITP analytic studies. These documents were used to identify and prioritize the focus areas and barriers.

Focus Areas, Barriers, and Pathways

The ITP chemicals subprogram has refined its program around three focus areas: separations, reactions, and enabling technologies. These focus areas are in alignment with the Vision2020 priorities, which include technology for alternative energy production, storage, and transmission; separations; new materials; alternative fossil-based feedstocks and chemistries; energy-efficient process alternatives; and crosscutting capabilities for research and design. The focus areas clearly relate to the direct (separations) and indirect (low conversion and selectivity reactions) causes of high energy use within the industry.

The ITP chemicals subprogram has developed footprint and bandwidth analyses for both energy and exergy[5] for 25 process technologies for 18 large-production chemical products. The extension of traditional energy loss analyses to include the concept of exergy is commendable. Exergy analyses are also being done within the forest products subprogram, and it is recommended that this second law of thermodynamics technique be extended to other ITP programs as well. These analyses are critical to meaningful prioritization of R&D pathways for ITP support, as are other metrics, including those relating to materials use, recovery and recycling, waste discharge and other forms of pollution, and other environmental and economic metrics.

Portfolio Management

In FY 2003, the chemicals subprogram portfolio consisted of 41 projects with a total federal budget of $13 million and industry funding of $13 million, resulting in an industry cost-share of 50 percent.[6] According to the chemicals subprogram managers, project funding should be distributed with about 40 percent directed at separations, 40 percent at reactions, and 20 percent at enabling technologies.[7] Using this ratio as a basis, the present portfolio is relatively overweighted in reactions and underweighted in separations, and some adjustment is being considered in the selection of FY 2005 projects from the IOF solicitation. In FY 2004, the chemicals subprogram portfolio transitioned to fewer, higher-risk, higher-impact projects with the goal of bringing about revolutionary improvements in chemical processing efficiency (DOE, 2004h).

The subprogram has already achieved significant accomplishments, as indicated by recent commercial successes such as a more selective reactor configuration, membrane and adsorption product recovery systems, and improved reactor alloys to minimize coke and tar formation. The project portfolio outlined in the *Chemicals Annual Report, Fiscal Year 2003* (DOE, 2004h) appears to be very promising.

More than half of the energy loss associated with the chemical industry occurs prior to use in chemical processes and includes losses from inefficient off-site electricity generation, transmission, conversion, and distribution.[8] Therefore, the chemicals subprogram, again in partnership with Vision2020 and an independent project integrator, is developing an innovative, energy-systems challenge competition to support research, development, and demonstration (RD&D) projects that enhance the productivity of energy systems integrated with chemical processing and energy supply within plant boundaries. The goal of the challenge will be to commercialize one or more innovative energy systems that will have widespread applicability and yield significant energy savings for the chemical industry. Specific technology-performance criteria to be used in R&D solicitations will be defined, the opportunity will be advertised to equipment and technology developers, and projects will be selected for funding. Although this distributed cogeneration challenge may not be the most technologically difficult, additional challenges are envisioned for 2006 and beyond, perhaps in new-unit operations, disruptive process technologies, or supply-chain technology innovation.

Conclusions and Recommendations for the Chemicals Subprogram

A recent peer review found that the strengths of the chemicals subprogram included its diversity of multipartner teams, a focus on commercial applications, its focus on areas of significant potential improvement, strong industrial involvement, strong ties to energy savings, bandwidth studies, and planning.[9] To these strengths the committee would add the use of exergy analyses and the leveraged use of the SBIR program, both of which are recommended for other ITP subprograms as well.

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[5] *Exergy* is a term used to describe differences in energy quality or ability to do useful work. The exergy content of a system indicates its distance from thermodynamic equilibrium.

[6] P. Scheihing, DOE, 2005, personal communication to the committee, March 8.

[7] D. Ozokwelu, DOE, 2004, personal communication with committee members J. Siirola, T.S. Sudarshan, and J. Wirth, May 20.

[8] S. Richlen, DOE, 2005, personal communication to the committee, March 9.

[9] D. Ozokwelu, DOE, 2004, "ITP Corporate Peer Review: Chemical Sub-Program," Presentation to the Committee, Washington, D.C., May 20.

Recommendations from the same portfolio review addressed the need to include data from foreign chemical processes, funding to encourage disruptive approaches, the need to pursue alternative chemistries and feedstocks, greater interaction with state programs, and more industry involvement in planning and, especially, in proposal reviews. To these, the committee adds the following recommendations:

- Greater integration between the chemicals and sensors subprograms because of the obvious potential impact on the chemical industry; and
- Establishment and enforcement of clear criteria for the termination or redirection of underperforming projects or projects least likely to meet their goals.

Recent changes in the chemicals subprogram are commendable, including the incorporation of exergy analysis in planning, greater emphasis on separations, a bias toward fewer but larger projects, and the effort to identify grand challenges. The committee recommends use of exergy analysis in the other IOF subprograms as well. The ITP chemicals subprogram appears appropriately focused and is managing a portfolio of projects well balanced from the perspectives of topicality, risk, duration, and potential impact. Many of the achievements and results of this subprogram should also find wide application in the petroleum-refining and other segments of the processing industries. The subprogram appears on track to contribute to the ITP's meeting its stated energy and environmental objectives.

FOREST PRODUCTS

The U.S. forest products industry consumes 3.2 quads per year (DOE, 2004g, p. 3) and is responsible for approximately 16 percent of the fuel use in the U.S. manufacturing and mining sector (DOE, 2003c, p. 8). The forest products industry was the first IOF to produce a vision document. This was done through the American Forest and Paper Association (AF&PA), supported by other organizations, including the Technical Association of the Pulp and Paper Industry (TAPPI) and the National Council for Air and Stream Improvement (NCASI). The vision document was published in 1994 (AF&PA, 1994), and in 1999 an industry roadmap was released (AF&PA, 1999).

The recent EERE reorganization resulted in changes for the forest products subprogram, namely, that the black liquor gasification effort and the new, forest-based materials effort were moved from ITP to EERE's Biomass Program. Black liquor combustion in the kraft pulping cycle is a high-priority process as far as energy use and conversion in the forest products industry are concerned. Gasification combined cycle holds promise for increasing the efficiency of this process. Although it is beyond the scope of this committee's review to address the efficacy of moving these program elements, the committee is concerned, from the perspective of uniformity of management, about excising selected energy research programs of the forest products industry. Black liquor gasification poses challenges different from virtually any other biomass gasification technique owing to the high load of inorganic chemicals in the feed stream. These unique challenges would probably receive more attention if black liquor gasification research were part of the ITP's forest products subprogram instead of its being part of a biomass program in which the challenge of handling inorganics is not as severe.

Focus Areas, Barriers, and Pathways

The four focus areas identified for the forest products industry are enhanced raw materials, next-generation mill processes, improved fiber recycling, and wood processing (DOE, 2004a, p. 99). Barriers to saving energy are identified and prioritized for each of these areas, as well as pathways for overcoming these barriers.

The forest products subprogram relied heavily on the industry vision and roadmap documents, as well as on statistical data published by government offices, in the identification of focus areas, barriers, and pathways. Although these data sources are appropriate, the heavy reliance on them is also somewhat of a necessity. The open literature in the forest products industry consists primarily of proceedings from conferences, with few of the kinds of dedicated technical journals found, for example, in the chemical and petroleum-refining industries. In March 2004, a summit on paper technology held in Peachtree City, Georgia, brought together the stakeholders in forest products industry research and development (TAPPI, 2004). The committee recommends that a critical review be undertaken of the results of this summit, with the goal of updating the industry roadmap and identifying grand challenges.

The lack of dedicated technical journals in the forest products industry underscores the need for ITP personnel to travel to technical meetings and conferences to gather and disseminate information. It is also important that they visit mill sites to collect and validate the data used to support decision making.

The vision and roadmap documents in the forest products industry generally reflect the executive-level views of large paper companies. However, new technology in this industry is primarily developed and implemented by industry suppliers and equipment manufacturers. The committee strongly recommends that these stakeholders be more involved in defining focus areas and barriers. The relationship between the forest products companies and their suppliers and equipment manufacturers can be an issue, however. Many equipment manufacturers are not U.S.-based companies, and in some areas of technology no U.S.-based companies exist. To facilitate inclusiveness, the committee recommends that the ITP make cooperation with industry suppliers and equipment manufacturers a condition of contract. Explicitly including suppliers and equipment manufacturers, whether they reside in the United States or not, makes sense from both a practical and policy viewpoint, although issues of intellectual property may need to be resolved.

The forest products subprogram should continue to move from the use of simple energy balances to the use of exergy analyses in its identification of opportunities for research and development. A simple energy balance analysis can lead to a focus on large amounts of low-value energy, while more valuable targets may be deemphasized. The program should be commended for steps currently being taken in this direction.

The mission of the ITP does not completely overlap with the needs of the forest products industry. The latter is primarily focused on improved capital efficiency, whereas the ITP is primarily focused on improved energy efficiency. These goals may be in conflict. Therefore, the committee recommends that economics be introduced early in the process of defining focus areas. The need for significant capital investment for a new technology may well stop any attempt at implementation, even if the long-term payback through energy savings promises to be significant. On the other hand, energy-savings approaches that improve capital efficiency (e.g., chemical additives, optimized parameters) are highly valued by the forest products industry—more so than approaches requiring investment from a strained capital infrastructure.

The forest products industry has for some time sought to lower operating costs through the early retirement of experienced personnel, by operating with a bare minimum of professional staff, and by eliminating research and development. These are serious barriers to the development and implementation of new technologies requiring technical expertise. The industry relies to a significant extent on suppliers and equipment manufacturers for technical support. The committee recommends that these barriers be incorporated into the forest products multi-year program plan.

Portfolio Management

In FY 2003, the forest products subprogram portfolio consisted of 54 projects with a total federal budget of $11.3 million and industry funding of $4.8 million, resulting in an industry cost-share of 30 percent.[10] Although the project portfolio of the forest products subprogram is adequate to achieve the goals of the ITP, it may be possible to improve the portfolio further and better address both the ITP's vision and goals and the needs of industry. Industry participation in the ITP tends to be via trade associations, which is commendable, as trade associations must be part of any attempt to cooperate with an industry. However, these associations have to support the commercial interests of their members, and

[10] S. Richlen, DOE, 2005, personal communication to the committee, March 8.

the largest member companies may have the strongest influence. This situation could lead to a biased assessment of industry needs.

The current request-for-proposals process, proposal review structure, and cofunding requirements of this subprogram do not support innovative ideas. Forest products solicitations receive a merit review, but the review panels tend to be composed of active and retired industry executives and academics, often using the subject industry's roadmap as a guide—which can lead to a restricted view of opportunities. Because of pressures for capital efficiency, large forest products corporations are hard pressed to cofund research on innovative technologies that do not provide short-term return on investment. The committee is concerned that this pressure has led in the forest products industry to a portfolio that is currently too heavily weighted toward the near term. A balanced, robust portfolio will yield a greater number of commercialized projects, with "robust" meaning fewer, more-focused programs with healthy near-, mid-, and far-term objectives.

The identification of grand challenges should lead to an increased focus on innovative technologies. In order to promote thinking "outside the box," the committee also suggests that the subprogram develop mechanisms for incorporating ideas from experts outside the forest products industry. For example, workshops could be organized at which technical overview presentations about the forest products industry were given to participants who had scientific, market, and strategic expertise, but who had no commercial or professional conflicts of interest with that industry.

Finally, the most prolific purveyors of technology tend to be entrepreneurs and small companies. In order to maximize the potential for innovation, the ITP should ensure that small companies and entrepreneurs are incorporated into decision-making processes by direct communication with smaller companies and solicitations specifically aimed at small companies.

Conclusions and Recommendations for the Forest Products Subprogram

The committee finds that the forest products subprogram is mature and that the research portfolio is consistent with the missions of the ITP and is likely to support achievement of ITP goals. The committee recommends the following actions to sharpen the focus on energy, environmental, and competitiveness issues:

- Involve small companies, entrepreneurs, suppliers, and equipment manufacturers to a greater extent in the strategic process of defining focus areas and barriers, as well as participating in and providing constructive comments during proposal reviews;
- Undertake a critical review of the results of the 2004 paper technology summit, with the goal of updating the industry roadmap and identifying grand challenges;
- Include energy and exergy balances, as well as economic constraints of the industry, in analysis when selecting portfolio directions;
- Develop a mechanism for obtaining ideas and concepts from relevant sources outside the forest products industry, its related academic programs, and the traditional suppliers and equipment manufacturers; and
- Require key ITP personnel to attend conferences and meetings related to the forest products industry, as well as to travel to forest products companies; discussions with operations and R&D personnel need to be included.

GLASS

The glass industry is energy-intensive, with large amounts of energy needed to melt and refine raw materials into glass. Annual industry energy consumption is approximately 250 trillion Btu (DOE, 2004d, p. iv), constituting about 1 percent of the total fuel consumed by the U.S. manufacturing and mining sector (DOE, 2003c, p. 8). Energy purchased in the glass industry for heat and power was responsible for an estimated 15 to 20 percent of direct production costs in 2001.[11] After its designation as an Industry of the Future, the glass industry produced a vision document in 1996 that identified industry priorities and goals. In 2002, through the Glass Manufacturers Industrial Council (GMIC), a technology roadmap was published that identified technical barriers and priority research needs. Overall, the ITP's glass subprogram has had very effective participation from the glass industry.

Focus Areas, Barriers, and Pathways

The three focus areas identified for the glass subprogram are next-generation melting systems, energy efficiency performance improvements, and advanced processing and environmental R&D (DOE, 2004a). Several publications were used in the identification of focus areas and barriers, including the glass industry's vision document, its roadmap, and a profile of the industry. In addition, well-known and well-respected consultants from within the industry were used. The data sources used correlate well with the focus areas selected and the barriers identified; in fact, the choices are almost obvious. Melting and refining are clearly the main energy consumers in all glass operations. The conservative nature of the glass industry is a barrier to the adoption of any radical changes.

The R&D pathways were determined according to a glass industry footprint analysis that identified melting and refining as the areas of maximum energy savings opportunities, as well as the areas in which grand challenges should be concentrated. It is reasonable to assume that the chosen R&D pathways will result in the achievement of program goals. A very good approach that the glass subprogram has taken is to commission studies on prior technologies that were not adopted in order to see if those technologies would now be appropriate and to ensure that none of the current projects tries to reinvent them. This efficient and logical approach might also be useful for some of the other subprograms.

A glass industry bandwidth analysis is scheduled for completion in 2005. Such an analysis would refine the ITP's decision making by estimating current average energy use, state-of-the-art energy use, practical minimum energy use, and theoretical minimum energy use by glass-manufacturing processes.

Portfolio Management

In FY 2003, the glass subprogram portfolio consisted of 13 projects with a total federal budget of $3.8 million and industry funding of $3.2 million, resulting in an industry cost-share of 46 percent.[12] The priorities of the glass subprogram are to achieve maximum energy savings. Within the prospective research portfolio, funds have been appropriately allotted in order to achieve these goals. In fact, most of the legacy R&D projects have also been aimed at melting and refining processes and have involved a diverse group of investigators. The research directions planned are consistent with the mission of the ITP and, in addition, allow for some diversity to accommodate disruptive technologies in other areas, should such proposals arise. The grand challenges, as described, will concentrate primarily on melting and refining and will aim at a radical rethinking of these processes.

Overall, the glass subprogram has distributed funds appropriately and diversified its portfolio in a reasonable way. However, the committee identified some gaps in research. Since melting is a focus area and since cullet melting (i.e., the melting of pre-melted glass) tends to reduce energy consumption, some emphasis should be put on this area. Recycling does not appear to have been considered anywhere, perhaps because it is considered the purview of other agencies. But recycled product as it pertains to energy savings should be within the purview of the ITP, perhaps in collaboration with other agencies such as the Environmental Protection Agency (EPA).

The balance of projects in the glass subprogram tends toward mid- and far-term research. The committee believes that this balance is appropriate for the glass industry. Because the glass industry is conservative, of necessity, it would be difficult to have a large impact with near-term research involving a

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[11] E. Levine, DOE, 2004, "ITP Corporate Peer Review: Glass Subprogram," Presentation to the Committee, Washington, D.C., May 20.

[12] S. Richlen, DOE, 2005, personal communication to the committee, March 8.

significant capital investment and/or loss of production time, and such research would have to be tailored to a specific segment of the industry, thereby reducing the global impact of the work.

Conclusions and Recommendations for the Glass Subprogram

Overall, the glass subprogram is in very good shape. The decision-making approaches used are logical and reasonable, and industry buy-in makes the success of this program likely. The committee recommends that the following gaps in research be addressed:

- Since melting is a focus area in the glass subprogram and since cullet melting (i.e., the melting of pre-melted glass) tends to reduce energy consumption, some emphasis should be put on this area.
- The idea of recycling as it pertains to energy savings should be included in the glass subprogram, in collaboration with other ITP subprograms and with agencies such as the Environmental Protection Agency.

METAL CASTING

Although the metal-casting industry is vital to the U.S. economy and national defense, a decrease in the number of domestic foundries is resulting in a loss of metal-casting capability. This decrease in foundries is due to an increase in the importation of low-cost metal cast products. In addition, the industry has few resources available to invest in R&D, especially for high-risk, long-term efforts on revolutionary technologies.

The metal-casting industry consumes approximately 328 trillion Btu per year (DOE, 2004i), constituting about 1 percent of the total fuel use of the U.S. manufacturing and mining sector (DOE, 2003c, p. 8). Although significant improvements in energy efficiency have been made by this industry during the past two decades, additional gains are needed.[13] The metal-casting industry has long been active within the ITP and its predecessor organizations. Under the auspices of these programs, the metal-casting industry published a technology vision in 1995 that was updated in 2002 and a roadmap in 1998 that was updated in 2003.

Focus Areas, Barriers, and Pathways

The two focus areas identified for the metal-casting subprogram are advanced melting and innovative casting processes. Within the innovative casting focus area, five metal-casting processes have been selected for energy efficiency research: sand casting, lost foam, die casting, semisolid, and permanent mold. Sand casting is by far the most widely used process, accounting for 67 percent of the total tonnage of metal castings produced in the United States. Several energy efficiency barriers unique to these processes have been determined.

A variety of data sources were used in the determination of focus areas, barriers, and pathways. These sources include the metal-casting vision document and technology roadmap, an energy and environmental profile of the metal-casting industry from 1999, a footprint analysis completed in 2003, a bandwidth analysis completed in 2004, and input from the American Foundry Society (AFS). The footprint analysis included data from 15 representative casting facilities. The data sources that were used support the selection of focus areas and barriers and are the right sources to use. The focus areas and barriers selected are a good match with the ITP's mission, and the R&D pathways developed appear likely to achieve the program goals.

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[13] E.P. HuangFu, DOE, 2004, "ITP Corporate Peer Review: Metal Casting Sub-Program," Presentation to the Committee, Washington, D.C., May 20.

Portfolio Management

In FY 2003, the metal-casting subprogram portfolio consisted of 21 projects with a total federal budget of $5.2 million and industry funding of $5.2 million, resulting in an industry cost-share of 50 percent.[14] The majority of the prospective portfolio for the metal-casting subprogram is dedicated to processes identified by analytic tools (e.g., footprint or bandwidth analyses) as areas with energy-savings opportunities. However, the largest area of opportunity identified by these analytic tools was the area of energy savings from aluminum reverberatory furnaces.[15] A number of the metal-casting subprogram projects described for the committee have an impact on minimizing scrap in the aluminum casting process. However, these projects only indirectly save energy, by reducing the amount of metal that has to be remelted. The committee believes that there is a gap in the metal-casting program in the area of advanced melting for aluminum—that is, process developments that reduce the energy required to melt a pound of aluminum.

Overall, the metal-casting subprogram portfolio is deficient in the advanced melting focus area, in which only one project is listed. That project, on yield improvement and scrap reduction in steel, is not really an advanced melting project. The bandwidth analysis for metal casting indicates that substantial energy-savings opportunities exist in this area. The committee recommends that the project portfolio be augmented in this focus area. Since this is also a focus area for the aluminum subprogram, collaboration between these two subprograms could be beneficial. The committee recommends that the metal-casting subprogram leverage the past and current R&D from the aluminum subprogram in developing the metal-casting portfolio for advanced melting. In this way, the maximum benefit will be gained from both DOE and industry funds. The mix of near-, mid-, and far-term research is reasonable.

Finally, the committee observes that the ITP metal-casting subprogram directs significant effort toward attracting a new workforce for the metal-casting industry. This goal is accomplished by emphasizing the participation of students in metal-casting research projects supported by the ITP. Students involved in such research are tracked during and after the completion of their degrees. To date, of the 326 students who worked on various ITP research projects in metal casting, 152 took jobs in the field on graduation.[16]

Conclusions and Recommendations for the Metal-Casting Subprogram

Overall, the metal-casting subprogram has had good interaction with industry and is achieving the goals of both the ITP and industry. The projects selected are, in general, the right ones to achieve ITP goals. Regarding a specific effort for improvement, the committee recommends:

- Augmenting the project portfolio in the advanced melting focus area, for example by adding aluminum melting, since opportunities for energy savings are substantial; and
- Leveraging the metal-casting subprogram through past and current R&D from the aluminum area to gain maximum benefit from DOE and industry funds.

MINING

Each year, nearly 47,000 pounds of materials per capita are mined in the United States (DOE, 2004c, p. 1). The extraction and processing of these materials consume an estimated 1.3 quads annually, constituting 11 percent of U.S. industrial energy consumption (DOE, 2004c, p. 6). In addition to consuming energy, mined materials are a source of energy, with coal accounting for 51 percent of all electric power generated in the United States (DOE, 2004a, p. 130). The mining industry was one of the

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[14] S. Richlen, DOE, 2005, personal communication to the committee, March 8.
[15] E.P. HuangFu, DOE, 2004, "ITP Corporate Peer Review: Metal Casting Sub-Program," Presentation to the Committee, Washington, D.C., May 20.
[16] E.P. HuangFu, DOE, 2004, "ITP Corporate Peer Review: Metal Casting Sub-Program," Presentation to the Committee, Washington, D.C., May 20.

final industries to be named an IOF. It produced a vision document in 1998 and three roadmaps on crosscutting, processing, and exploration and extraction technologies between 1999 and 2002.

Focus Areas, Barriers, and Pathways

Three focus areas have been identified for the mining subprogram: extraction, materials handling, and beneficiation and processing. These focus areas are in alignment with the traditional mining-industry distinction between extraction and beneficiation and processing. Materials handling is a cross-disciplinary area between the two. The focus areas selected are in alignment with the industry's vision and roadmapping documents. In addition, the bandwidth analysis showed significant opportunities for improved energy efficiency in these areas. Overall, the three focus areas are of high priority and are appropriate to the ITP's mission.

The committee finds that the description of barriers and pathways for the mining subprogram (DOE, 2004a) needs improvement.[17] First, they need to be better defined, as there appears to be confusion with regard to terminology. Typically, the term *extraction* refers to mining technologies, or the equipment and processes used to search for and dig the ore being extracted. The term *beneficiation and processing* refers to the equipment and processes used to separate, concentrate, and/or refine ore from unwanted material. *Materials handling* refers to the equipment and processes used to transport ore and waste materials. In the MYPP, however, pumps are described as a large source of the energy used in extraction, although pumps are normally attributed to materials handling. Research on abrasion- and wear-resistant materials is listed under the materials-handling focus area, although the work is aimed at extraction equipment. Barriers to improved energy efficiency in beneficiation and processing are based on comminution, sizing, and classification activities that are actually preparatory to beneficiation and processing. The committee recommends that the description of barriers and pathways for the mining subprogram in the MYPP be rewritten to clear up this confusion.

Second, single-source fuel reliance is listed as a barrier within the materials-handling focus area,[18] but this is an overstatement. Materials-handling activities are not always dependent on diesel as an energy source; some are based on electricity. The committee recommends that discussion of other power sources be included. Finally, challenges in solid-liquid and solid-solid separations should be listed as a barrier under the beneficiation and processing focus area.

Data sources used include the mining industry's vision and roadmapping documents, an energy and environmental profile of the industry, an energy footprint analysis, and an energy bandwidth analysis. In addition, input was solicited from various industry groups, including the National Mining Association; National Stone, Sand, and Gravel Association; Industrial Minerals Association-North America; and Society for Mining, Metallurgy, and Exploration (SME). The data sources used are appropriate, and they support the selection of focus areas, barriers, and pathways. However, the committee has two suggestions for improvement. First, additional input should be solicited from The Minerals, Metals, and Materials Society (TMS), particularly its extraction and processing division. TMS is an excellent group to contact for the sectors of hard rock and industrial minerals, and it could provide valuable input for crosscutting research efforts. Second, more detailed information should be provided on the assumptions and calculations used for the footprint and bandwidth analyses.

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[17] M. Canty, DOE, 2004, "ITP Corporate Peer Review: Mining Sub-Program," Presentation to the Committee, Washington, D.C., May 20.

[18] M. Canty, DOE, 2004, "ITP Corporate Peer Review: Mining Sub-Program," Presentation to the Committee, Washington, D.C., May 20.

Portfolio Management

In FY 2003, the mining subprogram portfolio consisted of 21 projects with a total federal budget of $3.3 million and industry funding of $5.3 million.[19] The average industry cost-share was therefore 61 percent, which indicates strong industrial support.

The committee finds that the mining subprogram portfolio is, in general, the right one to achieve the goals of the ITP. The committee's only suggestion is that research in solid-liquid and solid-solid separations be considered. There appears to be a reasonable mix of near-, mid-, and far-term research. In fact, one component of the mining subprogram that appears to be innovative and well conceived is the solicitation of R&D efforts at three different stages of development: phase I, II, and III. Project size and cost-sharing are scaled with stage of development, so that early-stage R&D involves smaller projects with lower cost-share requirements. This enables participation by more project partners, as well as nontraditional ones. For projects farther along in development with lower technical risk, a higher industry cost-share occurs, as required.

The committee notes that improvements in energy efficiency within the mining industry will be greatest when effort is focused on those areas common to most of the industry. This is true for extraction and materials handling. However, some research areas, such as solid-solid separations (gravity separations, flotation, leaching), should be considered even though they are not common to all sectors of the mining industry and therefore have a smaller return on investment. These areas should be considered because they may make an impact in terms of environmental issues, which play such an important role in this industry. The committee suggests that risk-benefit analysis be considered in the selection of projects in order to take into account environmental improvements and to ensure that new energy efficiency measures do not create additional environmental problems. In addition, the committee recommends that the mining subprogram maintain its current focus on coal, industrial minerals, hard rock, sand, and gravel and avoid focusing on metal and mineral commodities (e.g., copper, gold, lead, zinc, phosphate rock, limestone). Although there is nothing wrong with funding these commodity areas, the committee believes that a general approach will result in greater and more rapid energy savings.

Although mining subprogram projects have only been funded since 1999, estimates of the energy savings resulting from the implementation of these technologies should be available soon. The committee recommends that these numbers be documented with detailed information on the energy calculations and derivations used. Finally, the committee notes that effective government-industry interaction is not possible without the attendance of ITP personnel at professional meetings, such as the annual meetings of the SME and TMS. In addition, because mining operations are typically remote, it is important that ITP personnel (from headquarters or field offices) visit industrial sites to obtain information on current mining issues, as well as to disseminate the results of the ITP mining subprogram.

Conclusions and Recommendations for the Mining Subprogram

Overall, the mining subprogram has a high level of collaboration and cooperation with industry partners. The focus areas are appropriate and are supported by the data sources used. The composition of the project portfolio appears reasonable, in general. The committee recommends:

- Clarifying the definitions of focus areas, barriers, and pathways in the MYPP, and soliciting additional input from TMS, particularly its extraction and processing division;
- Providing more detailed information on the assumptions and calculations used in the footprint and bandwidth analyses;
- Considering research on solid-liquid and solid-solid separations despite the fact that these processes are not common to all sectors of the mining industry;
- Considering risk-benefit analysis in project selection in order to take into account the environmental impacts of energy efficiency measures;

[19] S. Richlen, DOE, 2005, personal communication to the committee, March 8.

- Documenting the estimates of energy savings resulting from subprogram activities including detailed information on calculations and derivations used; and
- Requiring ITP personnel to attend the annual meetings of the Society for Mining, Metallurgy, and Exploration and The Minerals, Metals, and Materials Society, as well as visit industrial sites.

STEEL

The U.S. steel industry, though vital to the national economy and defense, has been eroded as a result of the movement of manufacturing jobs offshore in the past two decades. Between 1988 and 1998, U.S. production of raw steel remained at approximately 100 million tons per year, while China's annual production increased from 62 million to 126 million tons.[20] The steel industry is the fifth-largest consumer of energy within the manufacturing sector, with 2 quads consumed in 2001 (DOE, 2004b, p. 2), representing 8 percent of the energy consumed by U.S. industry (DOE, 2004a, p. 33). In order to remain competitive, the industry must become more resource-efficient and less capital-intensive.

The ITP steel subprogram has a long history of interaction with the steel industry, primarily through the American Iron and Steel Institute (AISI) and the Steel Manufacturers Association. As an IOF, the steel industry published a vision document in 1995 and a technology roadmap in 1998, which was updated in 2001. In addition, one group of industry partners produced a report entitled *Barriers and Pathways to Yield Improvements* (Energetics, Inc., 2003b).

Focus Areas, Barriers, and Pathways

The four focus areas identified by the steel subprogram are cokeless ironmaking, next-generation steelmaking, advanced process development, and power-delivery modeling. Data sources used in the selection of focus areas, barriers, and pathways include the technology roadmap, the industry-produced report on barriers and pathways, an energy and environmental profile, an energy benchmarking and future opportunities study, a theoretical minimum energy study, an alternative ironmaking study, and footprint and bandwidth analyses. These data sources are comprehensive and appropriate, although many appear to have been developed considering only a limited sector of the steel-producing industry. The committee would like to see better independent review of the data sources, facts, and figures used to support decision making.

The selection of cokeless ironmaking as a focus area is supported by the bandwidth analysis, which identifies ironmaking as the process with the greatest opportunity for energy savings. Substantial resources ($5.5 million) have been allocated to the Mesabi Nugget Ironmaking project within this focus area. When implemented commercially, this technology has the potential to reduce energy consumption significantly, reduce emissions, and lower capital and operating costs. A smaller plant infrastructure will most likely be required, which could make plant location more palatable to small communities that would benefit economically from such a plant. In addition, plants could be located closer to the end user, thereby reducing costs associated with reconversion or transportation and making the steel very competitive.

The second focus area, next-generation steelmaking, is aimed at integrating iron- and steelmaking processes in order to reduce energy consumption. Technologies under investigation to achieve such a grand challenge include a combination of microwave, electric arc, and exothermal heating technologies; and flexible fossil-fuel-based processes. Most of the projects in this focus area appear to involve mid- to far-term research and appear to be appropriate for the achievement of the ITP's goals.

The potential energy savings from activities within the third focus area, advanced process development, are more than twice as great as those in any other focus area.[21] However, some of the changes required would be difficult to implement across the broader industry sector, so success would

[20] S. Friedrich, DOE, 2004, "ITP Corporate Peer Review: Steel Sub-Program," Presentation to the Committee, Washington, D.C., May 20.
[21] S. Friedrich, DOE, 2004, "ITP Corporate Peer Review: Steel Sub-Program," Presentation to the Committee, Washington, D.C., May 20.

depend on the characteristics of the individual sites. Accordingly, many of the projects funded in this focus area appear to be collaborative R&D with AISI members, addressing specific issues related to improvement and energy efficiency. Because many processes in the steel industry are also found in other industries, this focus area might benefit from additional input from other industry sectors. Several of these projects have been recognized as providing incremental improvements only, and there is a recognition that the focus should change to yield improvement.[22] Success may be better measured via stepped improvements in process yield or other, broader accomplishments.

The final focus area is power-delivery modeling—specifically, modeling of the delivery of electricity to electric arc furnaces and rolling mills. The goal is to develop near- and far-term load-forecasting models as well as intelligent control of electric load dispatching in order to minimize the impact of highly variable loads on processes. The cost of lost power midprocess can be very high, and better predictions and management strategies can greatly reduce waste and improve yield. Such technology could be integrated into regional steel mill operations. While this is a worthwhile goal for the steel industry and will clearly lead to energy savings, the committee believes that this focus area might be better addressed as part of a power systems portfolio within another DOE office.

Portfolio Management

In FY 2003, the steel subprogram portfolio consisted of 11 projects with a total budget of $15.8 million. Of this budget, $10.3 million was federal funding and $5.5 million was industry funding, resulting in an industry cost-share of 35 percent.[23]

For the past 30 years, the steel industry has lost an increasing market share to aluminum, composites, and plastics. Steel has increasingly become a commodity product and, as such, profit margins continue to shrink. Many policy makers believe that the focus of U.S. industry should be on higher-technology processes as opposed to commodities. For example, a focus on specialty steels for tools, stainless steel, or high-silicon steels would be of significant future benefit and might provide significant value-added exports. The U.S. steel industry needs change that takes into account global conditions; therefore, an increased emphasis on new technologies and a focus on specialty areas could provide greater economic benefits than those coming from a focus on incremental process improvements. The committee recommends that the steel program shift its focus toward the secondary processing sector and toward grand challenges.

An issue of concern for the committee was how the intellectual property generated by these taxpayer-funded projects, especially the Mesabi Nugget Ironmaking project, would be managed. It was not clear whether the results from this project are to be shared worldwide with other steel producers or whether there are restrictions in place that would allow the U.S. steel industry to have a technological advantage. The committee recommends that a comprehensive intellectual property policy be developed across the ITP. The situation could be further complicated as many steel companies move their R&D efforts overseas.

The steel subprogram has developed a series of milestones and appears to be proceeding on target in each focus area. However, the metrics used for evaluating whether or not a milestone has been reached should be better defined. It is currently unclear what metrics were used to determine whether a project should be continued or terminated. The committee recommends a clearer definition of success in funded projects. In addition, it notes that, for the steel industry, although energy savings is the primary motivator, other issues, such as infrastructure costs, environmental issues, impact on jobs, impact on strategic national needs, and treatment of intellectual property, need to be factored in when selecting or evaluating project benefits.

Finally, the committee recommends greater leveraging of resources from other areas. The steel subprogram should explore leveraging SBIR and STTR mechanisms as a means of involving R&D

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[22] S. Friedrich, DOE, 2004, “ITP Corporate Peer Review: Steel Sub-Program,” Presentation to the Committee, Washington, D.C., May 20.
[23] S. Richlen, DOE, 2005, personal communication to the committee, March 8.

organizations and universities in the early stages of project development, thereby freeing up ITP resources for projects that are closer to implementation. Research resulting from other DOE and EERE programs should be leveraged so that improvements can reach industry more rapidly and information can be disseminated more widely. This is particularly important for smaller technology projects such as sensors, electrodes, and refractories. The steel industry subprogram should also leverage the resources of the National Science Foundation's (NSF's) Steel Research Centers and promote cross-pollination of projects between the various primary metals producers.

Conclusions and Recommendations for the Steel Subprogram

The steel subprogram has a long and successful history of interaction with the U.S. steel industry. In general, the data sources used to support management decisions for this subprogram are appropriate. The majority of the projects in the subprogram portfolio appear to be appropriate for the achievement of ITP goals. The committee recommends improvement in the following areas:

- Obtaining better independent reviews of data sources and facts and figures to provide a strong foundation for policy decisions;
- Moving the power-delivery modeling focus area from the ITP steel subprogram to another DOE unit;
- Increasing the subprogram emphasis on secondary processing and specialty steels—areas in which maximum benefits can be derived from both energy and economic standpoints;
- Clarifying mechanisms and providing guidance for protecting intellectual property arising from ITP-funded projects;
- Defining more clearly what constitutes a successful project and how underperforming projects are handled;
- Leveraging of efforts through SBIR and STTR mechanisms to involve R&D organizations and universities in the early stages of project development; and
- Leveraging of resources within the EERE and other programs and with the National Science Foundation's Steel Research Centers.

OVERARCHING RECOMMENDATIONS FOR INDUSTRY OF THE FUTURE SUBPROGRAMS

While evaluating the seven IOF subprograms described above, the committee identified several overarching issues and programmatic best practices relevant to all seven of these subprograms as well as to the crosscutting subprograms described in Chapter 4. The committee recommends the following:

- *Leveraging limited resources*. Because federal funding is limited and because not all industry goals overlap fully with government goals, it is necessary to leverage limited available funding. Following are specific recommendations for leveraging:
  —Resources on such directed technology projects as sensors, electrodes, or refractories should be highly leveraged with industrial funding so that improvements can be implemented rapidly and information can be disseminated more widely.
  —Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) mechanisms should be leveraged. These programs tax all EERE funding and can be directed by program managers who volunteer to monitor the procurement and execution of the research. This has a twofold benefit. First, it allows industry to involve R&D organizations and universities in the early stages of project development and, second, it frees up allocated resources for projects that are closer to implementation.
- *Focusing on grand challenges.* It is clear throughout the industrial sectors that many projects are intended to result in incremental improvements to processes, and many of these programs have gone on for many years. It is critical for policy makers to establish goals, and to measure success when these goals are achieved. Although individual project goals are necessary and useful,

overarching goals, such as grand challenges, that a number of projects can aim toward fulfilling should be instituted. These grand challenges are a very visible way to focus program goals and to inspire individual industry and crosscutting subprograms to greater achievements.

- *Managing intellectual property.* The intellectual property arising from the development of energy efficiency technologies must be managed in a policy environment that is currently contentious. Two potentially conflicting goals have been expressed by the manufacturing community: improving both U.S. and global energy efficiency through the development of new energy efficiency technologies and providing a business advantage to U.S. industry through the development of these same technologies. The committee recommends that the ITP develop a comprehensive policy to clarify mechanisms and to provide guidance for managing the intellectual property that arises from ITP-funded projects.

4

Evaluation of Crosscutting Subprograms

As significant areas of common interest have been identified across the seven energy-intensive industries—called Industries of the Future (IOFs)—discussed in the preceding chapter, new crosscutting subprograms have been established. Currently, the crosscutting subprograms are combustion, sensors and automation, industrial materials of the future, supporting industries, and software tool development. The same criteria were used for evaluating the crosscutting subprograms as were used for the IOF subprograms (see the subsection "Committee Evaluation Criteria" in Chapter 3). This chapter contains evaluations of the five crosscutting subprograms, as well as evaluations of the Industrial Technologies Program's (ITP's) technology delivery subprogram and ITP activities at the regional offices of the Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE).

COMBUSTION

Virtually every energy-intensive industry relies heavily on combustion technologies to produce heat for process and steam-generation needs. Combustion has therefore been identified by ITP as an enabling, crosscutting technology. Although combustion is a complex process involving chemistry, heat transfer, and fluid mechanics, an improved understanding of combustion would impact both the energy efficiency and pollutant emissions of industrial processes.

ITP personnel have made considerable efforts to identify key industry stakeholders in the combustion area and to solicit industry input when determining research directions. A workshop held in January 1998 resulted in an industrial combustion vision that identified key areas for ITP support and leadership (Energetics, Inc., 1998). In addition, an industrial combustion roadmap was developed, identifying priorities and initiatives to be undertaken during the next 20 years (Energetics, Inc., 2002). These documents are a strong source of information on organization and direction for current and future combustion subprogram activities.

In addition to obtaining industry input in the development of the vision and roadmap, the combustion subprogram has been highly effective in obtaining industry involvement in individual projects. This success has resulted in projects that are larger in scope than would have been possible otherwise, and it has provided effective pathways for the industrial application of the technologies developed. In spite of relatively small budgets in recent years, this subprogram can boast of a number of technologies that have resulted in successful products.

Focus Areas, Barriers, and Pathways

A number of combustion-related issues and technologies are key to the energy efficiency of U.S. industry. The combustion subprogram is currently funding three focus areas: steam generation, process heating, and combustion components and design tools. Despite the mature state of technology in this field, there is no shortage of areas deserving funding. As a result, priorities and metrics are critical in identifying and achieving the objectives that will best satisfy the ITP's mission. Owing to the increased emphasis on environmental effects of emissions during recent decades and to the relationship between combustion, energy efficiency, and emissions, there is an inherent challenge in incorporating environmental priorities into a set of objectives. The ITP recognizes the importance of reducing emissions and has specified the goal of the reduction of environmental impacts within its mission. Consequently, many of the ITP efforts in the combustion area have an emissions focus. However, the only apparent emissions-related metric used in project selection for the ITP involves greenhouse gas reduction. The committee recommends that the ITP develop a process for weighting the value to the program of emissions reductions in each specific pollutant, e.g., nitrogen oxide (NO_x), carbon monoxide (CO), sulfur oxide (SO_x), mercury, acid gases, volatile organic compounds (VOCs), and particulates.

The reorganization of the EERE in 2002 and the subsequent ITP reorganizations have led to substantial changes in ITP's decision-making methodology. Prior to this reorganization, the combustion subprogram had committed to a number of long-term projects. Some of these are not a good fit with the current methodology. Historical inertia may have led to a bias in the application of the focus area-barrier-pathway methodology to the extent that some existing projects appeared to be a good fit under the new approach. The committee supports the new decision-making methodology and recommends that focus areas, barriers, and pathways be identified independently of legacy projects, so that existing projects do not skew the future selection process. In addition, the committee recommends phasing out legacy projects that do not fit within the new decision-making methodology.

Portfolio Management

Fuel Emphasis

In recent years there has been a clear shift toward natural gas as a convenient, cost-effective, and clean source of fuel. However, the danger of developing a fuel-selection strategy that relies solely on one fuel has been demonstrated during the past few years, as the price and regional availability of natural gas have caused significant problems for a number of industries. The project portfolio in the combustion subprogram at the ITP is almost entirely focused on the use of natural gas. The committee therefore recommends that the ITP attempt to incorporate projects with a more diverse range of renewable and non-renewable fuels. For example, coal, wood, waste, oil, hydrogen, and other fuels are now, or could soon become, important to industry.

Fundamental Research

While the ITP's emphasis on partnering with and transferring technology to industry is laudable, effective development is limited in a number of combustion-related areas by a lack of fundamental understanding. For example, key aspects of the chemistry of ultralow NO_x burners and fundamental weaknesses in the development of techniques for modeling the interactions between chemistry and turbulent fluid mechanics make it difficult to employ sound science in the development of burners. Although there may be other avenues for funding fundamental research and development (R&D), certain fundamental issues that are particularly important to industrial combustion are not attracting the attention of other agencies or programs and will continue to be neglected without ITP support.

Computational Fluid Dynamics Modeling

With the rapid improvement in computational resources, techniques, and combustion-specific experience, computational fluid dynamics (CFD) modeling tools have shown significant potential. The improvement and evaluation of the capability of these tools to meet the specific needs of industrial burners and furnaces were identified by the industrial combustion roadmap as an important priority.

However, progress in this area has been limited. Although these tools have proven extremely useful in the utility industry, their expense and complexity have limited their use in the industrial boiler sector. The ITP, with its familiarity with the variety of industrial combustion technologies and challenges, can identify broader issues and bring a number of industries and companies together in order to support projects. In addition, the combustion and sensors subprograms would both benefit from joint projects providing insight into combustion issues involving the complementary use of both sensors and CFD.

Retrofit Applications

Government funds are often used to support technologies that are too high risk to attract industry investment. The ITP's combustion projects also tend to assume that approach, as specific project deliverables are typically new designs. However, the capital-intensive nature of combustion equipment often necessitates unusually long life spans and slow replacement. Although there are exceptions (e.g., burners), the subprogram is missing a significant opportunity with its limited support of retrofit applications. In addition, technology transfer is often accomplished more effectively and with less risk through the evaluation of new concepts in a retrofit application. By increasing emphasis on retrofit applications, the subprogram may also enhance the acceptance rate of developments relevant to new designs.

Mitigation of Carbon Dioxide Emissions

The contribution of EERE programs to the reduction of carbon dioxide (CO_2) emissions through improvements in energy efficiency and the use of renewable energy sources is obvious. A number of developing technologies receiving worldwide attention seem particularly relevant to this subprogram and should be considered for support—for example, gasification and oxygen-fuel combustion with CO_2 recycling.

Breadth of Emissions Control

The focus of the ITP's emissions control efforts is largely on NO_x and CO_2. However, combustion plays a key role in the production and control of a number of other key pollutants, including SO_x, mercury, acid gases, VOCs, and particulates. Further consideration of these pollutants, which are or could be regulated in industrial environments, may be important to the nation's environment.

Waste Heat Recovery

Limited budgets require ITP personnel to define the core focus of each subprogram carefully. Although heat recovery equipment is related to combustion, the committee suggests that this area be pared from the combustion subprogram in order to apply subprogram resources more effectively.

Conclusions and Recommendations for the Combustion Subprogram

In general, the committee finds that the combustion subprogram is operating in a cost-effective manner and is well organized in terms of its overall strategy, individual project selection, and development and application of metrics. The ITP projects in this area have resulted in significant technical accomplishments. The majority of the committee's recommendations for improvement involve prioritization, either external or internal to the subprogram:

- Metrics should be clarified and a process developed for weighting the value to the program of emissions reductions in each specific pollutant, e.g., NO_x, CO, SO_x, mercury, acid gases, VOCs, and particulates.
- Legacy projects that do not fit within the new decision-making methodology should be phased out.

- ITP should attempt to incorporate projects with a more diverse range of renewable and non-renewable fuels, rather than being focused exclusively on natural gas.
- Research should be funded to improve fundamental understanding of issues important to industrial combustion, such as the chemistry of ultralow NO_x burners and modeling of the interactions between chemistry and turbulent flow mechanics.
- ITP has a role to play in identifying issues and bringing stakeholders together to improve and evaluate CFD modeling tools to meet the needs of industrial burners and furnaces, possibly in coordination with the sensors subprogram.
- More emphasis is needed on retrofit applications, which may also enhance the acceptance rate of developments relevant to new designs.
- Consideration should be given to supporting new approaches to reducing CO_2 emissions—for example, gasification and oxygen-fuel combustion with CO_2 recycling.
- Emissions control efforts should include research on key pollutants other than NO_x and CO_2.
- The waste heat recovery project is a candidate for removal from the combustion subprogram in order to focus resources more effectively.

Many of the committee's recommendations provided above were raised during the preparation of the 2002 industrial combustion roadmap. The combustion program would benefit from a review of this recent effort. In addition, although funding limitations are always present, the ability of personnel in the combustion subprogram to attend key industry conferences is important to communication with industry and should be increased over current levels.

SENSORS AND AUTOMATION

A critical core competency for the achievement of increased industrial energy efficiency is the development of reliable, integrable, and robust sensors that can provide real-time information on thermally dependent processing parameters. Currently, control of industrial processes is limited by the fact that most of these processes are truly dynamic in nature. Most processing technologies are therefore experience-based, and accurate modeling and simulation are difficult. Sensors can provide data needed to better understand industrial processes, thereby improving the accuracy of models and simulations. This type of dynamic output information can move energy efficiency measures from the experience-driven arena to the more accurate, science-driven arena. The use of sensors, combined with computerized modeling and simulation, has the potential to save significant amounts of energy, lower costs, and improve overall product quality.

Improved sensors and automation technologies are needed in all of the IOFs, with many applications being sufficiently similar that crosscutting development can take place. Although the sensors and automation subprogram does not have its own roadmap, the need for sensors in burner research is clearly presented in the crosscutting combustion subprogram. Other high-profile sensor needs include those within the aluminum and steel melting and processing industries, as well as the heat treating industry. The sensors and automation subprogram supports the return on investment of all of the other subprograms.

Focus Areas, Barriers, and Pathways

The ITP identified the focus areas for the sensors and automation subprogram by tabulating and generalizing the most frequently cited sensor and automation needs indicated in the IOF roadmaps. The focus areas are advanced sensor technologies, improved information processing, next-generation control and automation technologies, robotics, and affordable industrial wireless technologies (DOE, 2004a, p. 192). Additional industry input was obtained from a workshop on the applicability of recent advances in sensor and control technologies (January 2001) and a workshop on wireless technology (sponsored by the ITP in San Francisco, California, in July 2002). The focus areas, barriers, and pathways identified for this subprogram are appropriate, as are the data sources used to identify them.

Portfolio Management

Five projects involving the implementation of wireless networking of sensors are listed in the existing project portfolio for the ITP sensors and automation subprogram (see http://www.eere.energy.gov/industry/sensors_automation/active_rd.html). While wireless technology is clearly a growth area for sensor use, this effort is now virtually risk-free and has little promise of extraordinary rewards. All of the technology and software concepts essentially exist, as evidenced by the current implementations. The committee recommends that funding for work in this area be redirected toward the more fundamental and high-risk development of new sensor technology.

In addition, great challenges exist in rapid sensing of the composition and properties of multicomponent and multiphase industrial streams. For example, information is needed on the crucial interfacial properties of fibers suspended in water before this stream enters the papermaking processes. Materials-recycling streams and streams including multiple phases, such as suspensions, also present challenges. The opportunities presented by nanotechnology amplify the importance of surface and interfacial properties. If nanotechnology is to enable new properties of materials in industrial production, these properties must be able to be sensed for process control. Much of nanotechnology is concerned with surfaces and interfaces. One project in the current portfolio appears to clearly tackle a challenging stream (the project entitled Remote Automatic Material On-Line Sensor). However, there do not appear to be any projects involving interfacial or surface properties. The committee recommends that this gap in the project portfolio be addressed.

The development of sensors and automation is a high-risk, expensive, and protracted process. This is particularly true for sensors, for which the development process almost always involves innovation. The development, testing, field validation, and maturation of a sensor technology to the extent necessary to meet industrial performance standards require an extended, close working relationship between the innovator or developer and the industrial user. The initial development, proof-of-concept, and hardware implementation phase is usually neither the real economic challenge nor the highest risk. The extended maturation activities needed, including exposure to a sufficiently wide range of harsh industrial operating conditions, are responsible for the major costs. Industry wants implementation-ready hardware and sensor and automation systems. The development of a proven, robust, industrially hardened sensor usually requires this joint developer-and-user maturation cycle. As a result, the development of sensors, in particular, and of automation has largely been limited to single, specialized, company-specific applications.

A definite need exists for some form of joint participation in sensors and automation involving a wide range of individual companies but sidestepping competitive issues. In terms of developing an effective project portfolio, one challenge lies in the diversity of industries that the ITP is working with, as well as the variety of sensor applications within those industries. This is a problem-rich environment within which the ITP needs to figure out what its niche is and decide how to allocate funding.

Within each industry, the market for a specific sensor application is often not large enough to drive the extended development costs. One strategy, therefore, is to work on the development of a group or family of sensors for which the same basic technology could be adapted in order to handle a wide range of applications across several industries with reasonably similar technical needs. Improved process sensors could have a synergistic effect in the energy savings in all of the IOFs, as well as improvements in productivity, environmental factors, and quality.

The Timken Company and O.G. Technology have collaborated on a project focused on an in situ “hot eye” sensor to detect surface flaws. This program started out with a single company, and the application is now being successfully expanded to numerous users. This project might be a good case study for review.

Just selecting the right project is not enough, however. A critical mass of support must be marshaled, including a workable joint team structure, resources, talent, and drive. A more detailed analysis of the benefits of improved sensors and automation is needed, and new metrics should be developed that give a more accurate picture of these benefits with respect to other ITP subprograms. This information would facilitate industry support and thereby attract the funding necessary for small projects with a high return on investment. Alternatively, a high-profile sensors and automation application could perhaps be found that would have a major impact on the success of a grand challenge.

Sensor technologies must be implementation-ready in order to be widely disseminated within industry. The ITP needs to bring vendors into the development process in order to achieve that level of sensor maturity. The ITP has collaborated with national laboratories on sensor development, but national laboratories do not have experience with taking technologies through development and hardening them into field instruments. Greater communication between ITP subprograms regarding active projects and needs would foster more collaborative customer-and-vendor shared research.

Conclusions and Recommendations for the Sensors and Automation Subprogram

Sensors and automation are a problem-rich environment in which vast opportunities exist. The ITP has done a good job of administering the sensors and automation subprogram thus far. However, a new paradigm is needed to foster collaborative activities in the development, maturation, and integration of sensor technologies. The committee recommends that:

- Funding for the implementation of wireless networking of sensors be redirected toward more fundamental, high-risk development of new sensor technology;
- Research be undertaken to improve sensing of the composition and properties of multicomponent and multiphase industrial streams, especially surface and interfacial properties;
- A vehicle for joint participation in sensor and automation development be created—for example, the development of a family of sensors for which the same technology could be adapted to handle a wide range of applications across several industries;
- Better metrics be developed for determining the benefit to all ITP subprograms from investment in sensor and automation development;
- Vendors be included early in the development process and communication be improved among the IOFs on existing sensor and automation needs and activities; and
- A sensor development project be identified that can be included in a grand challenge.

INDUSTRIAL MATERIALS OF THE FUTURE

The mission of the crosscutting subprogram focused on industrial materials of the future is to lead a national effort to research, design, develop, engineer, and test materials needed for improvements in energy efficiency in the IOFs. The subprogram is aiming for a crosscutting portfolio, with emphasis on longer-range materials needs common to multiple industries and the encouragement of multi-industry partnerships.

Focus Areas, Barriers, and Pathways

The ITP analyzed the materials needs expressed in IOF roadmaps to identify focus areas for the industrial materials subprogram. Analytical studies were then used to prioritize areas across the IOFs. The following four focus areas were thereby identified as recurring themes worthy of ITP funding: degradation-resistant materials, thermophysical databases and modeling, materials for separations, and materials for engineering applications.

According to an analysis undertaken by the ITP using metrics defined by the Government Performance and Results Act of 1993 (GPRA) on 35 ongoing studies in the 2003 portfolio, the degradation-resistant materials focus area has by far the greatest potential energy-savings benefit projected for 2020 (150.4 trillion Btu), with materials for engineering applications coming in a distant second (50.1 trillion Btu), followed by materials for separations (38.7 trillion Btu) and thermophysical database and modeling (7.1 trillion Btu). Additional analytic studies are underway to further quantify the energy opportunities in each area.

The pathways identified to surmount barriers appear well defined for those focus areas being funded and capable of achieving program goals. The industrial materials subprogram as a whole, however, is currently in transition between the previous opportunity-driven project selection strategy and the new focus area-barrier-pathway approach to identifying R&D targets and developing metrics. Currently, approximately one-third of the projects have been selected by the new method.

Portfolio Management

Specific R&D opportunities are being addressed in the degradation-resistant materials focus area. Projects have been identified in the other focus areas and, while some new projects have been initiated, others await clearer opportunity identification and funding.

The industrial materials subprogram tends to focus on mid- and far-term projects in terms of commercialization. This is because new materials are slow to be adopted, particularly in the commodity businesses that are the focus of the IOFs. The committee finds that such a focus is appropriate for this subprogram. The thermophysical database and modeling focus area, however, does have near-term payoffs in terms of the evolutionary modification of existing materials as well as broader use of existing materials across the IOFs. The existence of near-term components in this focus area is also appropriate, as a little bit of funding goes a long way in this area.

Conclusions and Recommendations for the Industrial Materials of the Future Subprogram

Overall, the committee finds the industrial materials subprogram to be on the right track with the very deliberate targeting methods now used by the ITP. The committee notes that there is some concern about finding well-qualified teams to perform the R&D in areas such as refractories because of the consolidation and shrinkage of this industry and the trend toward foreign ownership of domestic companies. The committee recommends working with industry organizations such as the Refractories Institute or the American Ceramic Society's Refractories Division to develop sources.

SUPPORTING INDUSTRIES

The IOFs rely on a number of supporting industries to supply them with the processes and materials needed to form and finish their products. Several of these supporting industries have been identified by the ITP as improving the overall energy and environmental profile of the IOFs by their use of alternative manufacturing processes that are faster, more cost-effective, or that utilize waste materials in the production of parts, components, and products (DOE, 2004f, p. 1). The supporting industries subprogram consists of six specific industries: heat treating, forging, welding, powder metallurgy and particulate materials (PM^2), advanced ceramics, and carbon products. In addition, the subprogram includes one crosscutting industry, industrial heating equipment (process heating).

The six specific supporting industries perform secondary processing activities for a number of IOFs. Although total energy use and energy-savings opportunities vary widely among the supporting industries, some, such as heat treating, are energy-intensive. The industrial heating equipment industry is less well defined, although it is based on an existing trade association, the Industrial Heating Equipment Association. The supporting industries subprogram is still defining the area that it covers and its goals. A new area was recently identified—the forming and fabrication of metals (metal sheets, rods, and other shapes for end-use industries such as bridge construction)—which is comparable to heat treating in terms of energy intensity.[1]

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[1] R. Jain, DOE, 2004, "ITP Corporate Peer Review by NAS: Supporting Industries Subprogram," Presentation to the Committee, Washington, D.C., May 20.

Each of the seven supporting industries (six specific and one crosscutting) developed a roadmap and/or vision document between 1996 and 2001. These roadmaps outline specific research needs and prioritize them according to the potential impact on industrial competitiveness. The roadmaps also outline the strategies needed to achieve these goals. Energy-savings research is one of the needs defined by the roadmaps, with, for example, the particulate matter vision document setting a goal of 50 percent reduction in energy consumption by 2010 and 80 percent by 2020.

Focus Areas, Barriers, and Pathways

It is unclear from the ITP's Multi-Year Program Plan (MYPP) what the focus areas are for this subprogram, although it appears that each of the seven industries can serve as a focus area (DOE, 2004a, pp. 159-162). Barriers and pathways have been defined for five of the seven industries: industrial heating equipment (process heating), heat treating, forging, powder metallurgy and particulate materials, and welding. In addition, general barriers and pathways have been identified that apply to the entire subprogram. In addition to the vision documents and roadmaps, information used in determining barriers and pathways included an energy and environmental profile for the supporting industries, a profile of total energy use for U.S. industry, a RAND study on research priorities for the supporting industries, a draft study on furnace demographics, and a draft study on energy savings for industrial energy systems. The committee finds that the available data sources were appropriate for defining barriers and pathways.

The identification of focus areas, barriers, and pathways for the supporting industries subprogram was more difficult, however, than for other subprograms. According to ITP personnel, a lack of data and resources made it difficult to develop other analytic tools such as footprint and bandwidth analyses.[2] After reviewing the subprogram's energy and environmental profile (Energetics, Inc., 2003a), the committee found that the energy data were indeed sketchy. Some industries (carbon products, welding) provided annual energy consumption figures, while others provided only energy consumption per weight of product or material used or the energy efficiency of equipment. ITP personnel noted, however, that the subprogram's industrial partners are willing to cooperate in generating the necessary data.[3] The committee recommends that bandwidth analyses be performed for the industrial heating equipment and fabricated metals areas.

For the most part, the barriers identified were the most appropriate with relation to the ITP's mission, for example: the lack of modular hybrid furnaces in heating aluminum forgings, the lack of predictive tools for microstructure, and the lack of interactive controls for process optimization. In addition, the different pathways selected are ones that will most likely result in the achievement of ITP goals. The general strategic R&D pathway for all of the supporting industries is to develop opportunity assessments and studies. The R&D priorities identified are then incorporated into specific supporting-industry or joint solicitations. Lately, joint solicitations have been favored owing to the modest funding available. The supporting industries subprogram is currently emphasizing the development of grand challenges, such as the furnace of the future. Other pathways, such as the optimization of welding processes, are more evolutionary in nature.

Portfolio Management

The supporting industries subprogram has recently experienced a major restructuring and a funding cut of close to 50 percent. As a result, efforts are underway to find commonalities with other ITP subprograms and to integrate the supporting industries subprogram into them. These efforts have been successful thus far. Although the supporting industries subprogram currently has only nine projects, a large number of projects that significantly overlap with supporting industry needs are being funded under other subprograms. The committee recommends that the different areas of the supporting industries

[2] R. Jain, DOE, 2004, personal communication to the committee, May 20.
[3] R. Jain, DOE, 2004, personal communication to the committee, May 20.

subprogram be packaged differently, particularly in industrial heating equipment, to avoid overlap with other subprograms.

The cut in funding for the supporting industries subprogram reflects the ITP's strategy of focusing on fewer, larger, and more substantial energy-saving projects. The current supporting industries portfolio consists of some more revolutionary approaches to energy savings, such as the infrared heating of aluminum billets, as well as some projects with large energy savings at a relatively low level of funding, such as high-temperature carburizing and friction stir welding. There is currently an emphasis on developing grand challenges.

Overall, the prospective portfolio as outlined in the pathways is on the right track to achieve ITP goals. Some projects may place more emphasis on energy savings than others (e.g., welding and particulate matter). The committee recommends the inclusion of more breakthrough projects, that is, the development of novel processes rather than the optimization of existing ones. At the moment, the majority of projects are near-term; the committee recommends the inclusion of more far-term projects either on its own or jointly with other subprograms.

The goal of the supporting industries subprogram is to cultivate partners, particularly among trade associations, and to promote energy efficiency by leveraging resources. However, in the five fact sheets for current projects provided to the committee,[4] only one project lists a trade association's being involved (the Forging Industry Association). The project on aluminum castings, however, has numerous industrial partners, including Alcoa, Deere GM, and IPSEN.

For some projects, the amount of energy savings that can be expected is unclear, such as friction stir welding and de-binding processes in particulate matter. A better quantification of expected energy savings is needed in order for these projects to determine if they serve the ITP mission. The committee recommends more transparency for GPRA data. If the expected energy savings is not large, these projects should be discontinued.

Conclusions and Recommendations for the Supporting Industries Subprogram

The committee believes that the supporting industries subprogram is a vital one, and that it is unique. The industries in this subprogram are truly crosscutting and would be difficult to manage under any other subprogram. This subprogram currently exists under difficult circumstances, including coverage of a larger variety of industries than is covered by any other subprogram, limited resources, and a lack of data. However, the committee believes that the prospective portfolio for this subprogram is on track to achieve the ITP's mission and that the supporting industries subprogram has a role to play in any crosscutting grand challenges that are identified by the ITP. The committee recommends that:

- Bandwidth analyses be performed for the industrial heating equipment and fabricated metals areas;
- The different areas of the supporting industries subprogram be packaged differently, particularly in industrial heating equipment, to avoid overlap with other subprograms;
- More breakthrough projects be included in the portfolio, perhaps jointly with other subprograms; and
- More transparency for GPRA analytical data be provided.

SOFTWARE TOOL DEVELOPMENT

Of the energy consumed by the U.S. mining and manufacturing industries, 51 percent represents energy losses that occur in generation, distribution, and conversion systems, rather than being used for industrial processes (DOE, 2004a, p. 194). The ITP software tool development subprogram supports the

[4] Titles of the five fact sheets on current projects of the ITP's supporting industries subprogram: "Innovative Die Materials and Lubrication Strategies for Forging Technology," "Materials and Process Design for High Temperature Carburizing," "Integrated Heat Treatment Model for Aluminum Castings," "Hybrid Integrated Model for Gas Metal Arc Welding," and "Enhancement of Aluminum Alloy Forging."

ITP mission by developing tools that can be used by individual plants to identify energy losses in these systems and to implement energy savings.

Focus Areas, Barriers, and Pathways

Prior to the reorganization of the EERE and the ITP, the software tool development subprogram developed tools on an ad hoc basis in collaboration with different industrial partners and organizations to address specific energy systems. Since the reorganization, the tool development subprogram has used the focus area-barrier-pathway decision-making model as a more systematic method of directing its efforts.

The one focus area in the subprogram is tool development. Barriers to realizing the full energy-saving potential of this focus area have been identified, including low industry awareness of the existence of ITP software tools, differences in software tool formats that inhibit the use of multiple tools by the same user, gaps in software tool capabilities, and limited training opportunities for software tool use.

Pathways for addressing these barriers have been identified. The first pathway is tool integration, including the setting of design and capability standards to give all tools the same “look and feel,” the distribution of tools on common platforms, and the development of a plantwide energy-assessment tool that can be used as an entry point to using a suite of tools. The second pathway is the expansion of existing tool capabilities and the development of new tools to fill gaps, including a building and facility energy tool, a waste heat recovery tool, a refrigeration or chiller assessment tool, and a plant decision-maker tool. The third pathway is the increased use of industrial partners to develop and disseminate tools, including the publishing of tool case studies in technical and financial publications and the developing of methods to track the use of tools. The fourth pathway is the development of new methods of tool training, including Webcasts and videos or DVDs of training sessions, improved help features, and continued technical support.

Data sources used by the software tool development subprogram in defining barriers and pathways include industry input in the form of a workshop on energy loss reduction and recovery in industrial energy systems, a workshop on tool and training strategy development, and peer review meetings. In addition, the documents and analyses used include an energy-loss and energy-use analysis report that identifies energy system hotspots for specific industrial processes, energy footprint and bandwidth analyses, and the energy-savings roadmap process.

ITP personnel managing the software tool development subprogram recognized that there had been inadequate metrics for measuring the success of software tools. Energy savings had been used as the overall metric; however, software development also requires the use of metrics that address specific user issues. The energy-assessment software tools developed by this subprogram are a critical component in the success of the ITP, and changes have been put in place to ensure that the tools are developed to meet the ITP goals of strengthening energy-intensive industries. Overall, the committee finds that appropriate steps are being taken to ensure that all of the software tools do the following: meet critical industrial needs, are user-friendly, look and feel the same to the user, are available for common operating-system platforms, and are properly publicized and made available to key industrial users. The committee believes that, by using the focus area-barrier-pathway process as well as energy footprint and bandwidth analyses, the ITP will generate adequate metrics for judging the success of its software tools.

Portfolio Management

The software tool development subprogram currently has 10 opportunity and screening tools: (1) Steam System Survey Tool (SSST); (2) Steam System Assessment Tool (SSAT); (3) Process Heating Assessment and Survey Tool (PHAST); (4) NO_x and Energy Assessment Tool (N_xEAT); (5) a tool for the assessment of motor and motor-driven systems (MotorMaster+); (6) a tool for the assessment of compressed air systems (AirMaster+); (7) Pumping System Assessment Tool (PSAT); (8) an insulation assessment tool (3E+); (9) Combined Heat and Power (CHP) Tool; and (10) Fan System Assessment Tool (FSAT). These tools are available to the public free of charge through the ITP Web site.

In addition, the ITP is in the process of developing a Plantwide Energy Profiler (PEP) tool for the chemical industry, which is currently in the beta phase of testing. This tool will serve as a template for the development of plantwide energy-assessment tools specific to other industries. The committee finds such plantwide assessment tools to be more suitable for the long-term benefit of industry than the existing tools that focus on a particular type of system, since these current systems may not exist in the future. The use of plantwide assessment tools will enable the identification of specific generation, distribution, conversion, or process systems for improvement. This information will help the ITP identify needs for software tool development in areas such as value-stream mapping, in which plantwide assessment tools can be integrated to identify energy savings in all stages from the initial production steps until a final product reaches the end user. The committee recommends the continued development of plantwide assessment tools.

Because of the unique nature of software tools, the committee also recommends that the ITP develop feedback mechanisms, such as online discussion or user forums. Such mechanisms will not only allow software tool users (e.g., qualified specialists, plant energy specialists, plant owners) to provide direct feedback to ITP personnel, but they will also allow users to provide each other with technical support and to seek support from ITP tool developers and implementers. The importance of this feedback loop cannot be overemphasized, especially in light of the Internet communication technologies existing today.

Conclusions and Recommendations for the Software Tool Development Subprogram

Overall, the committee believes that the software tool development subprogram is an important element in the success of the ITP. Given its use of the focus area-barrier-pathway process to identify critical gaps for tool development and its focus on plantwide and user-friendly opportunity and screening tools, the committee believes that the software tool development subprogram is focused correctly to achieve ITP goals. The committee recommends:

- The continued development of plantwide assessment and value-stream mapping tools in support of the long-term goals of the ITP; and
- The establishment of an end-user feedback loop through the use of online tools, such as discussion forums.

TECHNOLOGY DELIVERY

The ITP's technology delivery subprogram has as its mission the reduction of the energy intensity of U.S. industry through the development, maintenance, and dissemination of best practices in energy management and through selective investment in the development, verification, and validation of emerging technologies that offer significant energy savings (DOE, 2004e, p. 1). As the technology delivery subprogram is a relatively mature component of the ITP, the subprogram's strategy has been refined over several years for maximum impact. Technology delivery has adequate metrics in place and an evolving track record of accomplishments—evidenced by the completion of more than 40 plant energy-performance assessments since the year 2000, with $29 million annual plant energy savings realized, an average energy savings of l0 to 15 percent per plant, $200 million annual energy savings identified, and seven companies with replications at sister plants in progress.[5] Goals for this subprogram are being met or exceeded.

The technology delivery subprogram operates via a large number of industry, trade association, and academic partnerships and a series of tools, techniques, and incentives created to promote industrial participation and energy awareness, including the following:

[5] P. Salmon-Cox, DOE, 2004, "ITP-Program Peer Review: Technology Delivery," Presentation to the Committee," Washington, D.C., May 20.

- Ten software tools available via the ITP Web site to assess the energy performance of individual unit operations, as well as a tool under development for assessing the energy performance of entire plants.
- Extensive software training and software specialist qualification activities offered through the DOE and its partners—in 2003 there were 77 end-user workshops with 1,777 end users trained, and 9 qualified-specialist workshops with 64 participants passing the qualified-specialist examination.
- Cost-shared plant energy-performance assessments for larger plants with annual solicitations and about six new awards per year of up to $100,000 to pay for third-party analysis.
- Free energy audits for small- to medium-sized plants (those with an annual expenditure on energy of less than $2 million) carried out through 26 Industrial Assessment Centers, located in 22 states, at universities with accredited engineering schools. Assessments conducted by students and faculty in 2003 resulted in 691 assessment days at 612 plants, with an average energy savings of $21,000 per plant and $35,000 savings in waste reduction and productivity gains. The education of students is an important added benefit.
- Four emerging technology projects in various stages of progress in plastics and metals production and processing.
- Outreach activities such as documents on energy-saving case studies and operation tips to save energy (50 documents published in 2003), major energy technology showcases and other regional events, technical assistance through six regional offices, and a well-maintained Web site that has several thousand contacts per day.

The committee supports ITP management plans to focus strongly on updating and improving the Web site as an opportunity to increase technology delivery through improved communications to industry. As part of this effort, the committee suggests that the Web site be modified to make it easier and more attractive for various levels of industry management, from plant managers to chief executive officers, to quickly get information on the potential for energy cost savings in their facilities. This assistance could include items such as links to case studies and results of recent plant energy assessments.

Another possibility for improving communications to industry is to create links to scenario planning, which would relate the magnitude of energy cost-saving opportunities to energy cost scenarios. It seems likely that energy generated from crude oil or natural gas will remain at current high cost levels for a prolonged period or rise to even higher levels in the future. This situation should make investments in energy conservation more attractive and shorten their payback period.

Finally, the committee recommends that ITP consider increasing efforts directed toward equipment manufacturers and engineering companies that design systems, with the goal being to design equipment and systems for energy efficiency rather than just to retrofit existing installations. Present efforts are primarily and appropriately directed toward plant operators. There may be an opportunity to create or modify existing software programs aimed at designing for energy efficiency.

Conclusions and Recommendations for the Technology Delivery Subprogram

The committee views the technology delivery subprogram as being very successful; its major challenge going forward will be to find additional ways to increase effectiveness through improved communications to industry. The committee recommends:

- Modifying the ITP Web site to make it easier for different levels of industry management to get information on the potential for energy cost savings in their facilities;
- Considering the creation of links to scenario planning that would relate the magnitude of opportunities for energy cost savings to energy cost scenarios;
- Increasing efforts directed toward equipment manufacturers and engineering companies that design systems, with the goal being to encourage them to design equipment and systems for energy efficiency; and

- Looking for opportunities to create new or modify existing software programs aimed at designing for energy efficiency.

REGIONAL OFFICES

The Office of Energy Efficiency and Renewable Energy (EERE) maintains six regional offices throughout the United States: Southeast Regional Office in Atlanta, Georgia; Northeast Regional Office in Boston, Massachusetts; Midwest Regional Office in Chicago, Illinois; Central Regional Office in Golden, Colorado; Mid-Atlantic Regional Office in Philadelphia, Pennsylvania; and Western Regional Office in Seattle, Washington.[6] These regional offices have approximately 120 employees and represent approximately 25 percent of the EERE workforce.[7] Regional office employees are responsible for implementing 15 EERE programs at the regional, state, and local levels, including the Industrial Technologies Program (ITP).[8] Only the Southeast and Western Regional Offices have an employee dedicated full-time to ITP.[9]

As a result of the reorganization of EERE in 2002, the role of the regional offices in implementing the ITP at the regional, state, and local levels changed. Previously, regional offices were primarily responsible for implementing the Industries of the Future program at the state level, for conducting outreach to develop state vision documents and roadmaps, and for developing regional partnerships for coalition building. Since the reorganization, the regional offices have been tasked with ITP technology delivery, outreach to target the top energy-use plants, and the development of regional partnerships for the deployment and replication of technologies.[10]

The EERE reorganization involved a reduction in ITP headquarters staff; part of the rationale for that change was a greater reliance on the regional offices, field offices, and industrial/academic research partners for technology delivery. The field offices, however, have remained principally focused on project management, so the national burden of technology delivery at the regional, state, and local levels has fallen primarily on the regional offices.[11]

The committee has some concerns about the ability of the ITP to increase effectiveness in disseminating program information at the current level of funding and staffing. The committee recommends that the field offices be tasked with getting information to the regional offices about projects that are underway. The regional offices may lack real-time knowledge about the ITP's research programs if they are not fully integrated into the project management loop. Such information would enable the regional offices to provide more depth in their public outreach mission.

Academics, suppliers (developers of innovations), and users (companies that have discovered how to apply them) are key nongovernment means of ITP technology transfer. It is unrealistic, however, to expect that suppliers and users benefiting from the sale and use of new technologies will readily share detailed knowledge about important breakthroughs with competitors. The committee recommends that, unless issues of intellectual property exist, industry communications and outreach to other industrial partners and the public be made a condition of contract. Making this function a condition of contract will ensure a broader dissemination of ITP program breakthroughs.

With reduced travel by ITP managers as well as regional and field office personnel, no effective way remains to reach the public by direct contact. The ITP's electronic information delivery system, though comprehensive, is no substitute for direct personal contact in the dissemination of information. The committee recommends that the restrictions on travel by ITP headquarters staff and regional office

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[6] Regional Offices Fact Sheet, August 2004, Office of Energy Efficiency and Renewable Energy, Washington, D.C.
[7] D. Godfrey, DOE, 2004, "DOE Regional Offices: Delivering and Managing the ITP Program at the State/Local Level, Mississippi Program Review," Presentation to the Committee, Washington, D.C., May 20.
[8] D. Godfrey, DOE, 2004, "DOE Regional Offices: Delivering and Managing the ITP Program at the State/Local Level, Mississippi Program Review," Presentation to the Committee, Washington, D.C., May 20.
[9] D. Godfrey, DOE, 2004, personal communication to the committee, on or about May 20.
[10] D. Godfrey, DOE, 2004, "DOE Regional Offices: Delivering and Managing the ITP Program at the State/Local Level, Mississippi Program Review," Presentation to the Committee, Washington, D.C., May 20.
[11] D. Godfrey, DOE, 2004, personal communication to the committee, on or about May 20.

personnel be eased. The regional offices are the only direct link between laboratory development and field deployment. Without such travel, ITP managers are deprived of important feedback that could be useful for determining program direction and growth. The regional offices are the frontline for reaching industry at large so that energy saving technologies made possible by ITP research can be applied.

Regional offices are the best operational link to state and local authorities that provide revenue bonding, tax relief, energy credits, and other incentives to suppliers and users of ITP innovations. State and local authorities have become the main source of these types of incentives by default. Unless the economic and social benefits of the ITP's programs are convincingly and consistently communicated, it may be difficult to obtain such incentives.

Conclusions and Recommendations for the Regional Offices

Since the EERE and ITP reorganization, the regional offices have been tasked with ITP technology delivery, outreach to target the top energy-use plants, and the development of regional partnerships for the deployment and replication of technologies. This makes the regional offices a crucial link between laboratory development of new energy efficiency technologies and deployment to U.S. industry. The committee finds that the regional offices have a proper sense of their post-reorganization mission. However, it has some concerns about the ability of ITP to disseminate program information at current levels of funding and staffing. To increase effectiveness, the committee recommends that:

- Regional offices be fully integrated into the project management loop;
- Unless issues of intellectual property exist, industry communications and outreach to other industrial partners and the public be made a condition of contract;
- The restrictions on travel by ITP headquarters staff be eased; and
- The restrictions on travel by regional office personnel be eased.

5

Conclusions and Recommendations

The Industrial Technologies Program (ITP), an activity of the Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE), has evolved over time into a well-managed and effective program. The ITP approach to project selection—that of identifying focus areas, barriers, and pathways—is solidly based, using a variety of sources, including industry roadmaps, footprint and bandwidth analyses, energy and environmental profiles, and other documents and data, together with ITP and industry expertise. A highly detailed Multi-Year Program Plan (DOE, 2004a) is in place, and annual reports are issued on the overall program and on the subprograms.

The program significantly leverages its resources through a large and growing number of partnerships with industry, industry associations, and academic organizations. To help transfer energy-saving technologies, numerous documents are published on energy best practices and energy-saving tips. Regional energy showcases are held periodically to highlight energy conservation technologies, including ITP investments in demonstration projects. The scope and depth of analysis and reporting are impressive.

The ITP has two overall goals: the achievement of a 25 percent decrease in energy intensity for the energy-intensive Industries of the Future (IOFs) between 2002 and 2020 and the commercialization of more than 10 energy efficiency technologies between 2003 and 2010. The program is on track to achieve its goals and has an opportunity to exceed them if it continues to focus on improving performance. Current ITP leadership is strong, and the enthusiasm, dedication, and knowledge of subprogram managers are noteworthy.

In the spirit of continuing to improve an already excellent program, the committee offers the following recommendations.

Recommendation 1. Explore new ways to benefit industries other than those directly targeted through Industrial Technologies Program (ITP) partnerships.

Several additional industries, including the petroleum-refining, food-processing, and concrete industries, could benefit from energy-saving technologies. The opportunities for reducing energy intensity in these other industries are too large to ignore. For example, as noted in the Multi-Year Program Plan, petroleum refining accounts for 17 percent of the energy consumed by industry (DOE, 2004a, p. 33).

While the committee encourages finding ways to include additional industries in the ITP, it is important that this not be accomplished at the expense of other subprogram areas. Disagreements with current industry partners over funding could prove disruptive to the ITP and a distraction for the staff. Possible ways to include other industries without cutting existing industry subprograms include emphasizing applications of crosscutting technologies (e.g., sensors and automation, and combustion), using funds available from the elimination of peripheral education activities, or seeking new funding for grand challenges. However, the ITP may not have to start from scratch with each additional industry. Program managers should increase efforts to promote and disseminate the ITP's accomplishments and broaden its benefits to additional energy-intensive industrial locations by:

- Increasing face-to-face contact of ITP subprogram staff with technology developers, equipment manufacturers, system designers, and technology end users by encouraging appropriate travel for headquarters personnel and mandating their attendance at technical meetings, at visits to project sites, and at potential end-user locations;
- Allocating additional resources to the regional offices (ROs) of the Office of Energy Efficiency and Renewable Energy and refocusing the efforts of RO personnel in order to integrate them more effectively into ITP project activities and directing them to work closely with headquarters staff and industry partners to extend the impact of ITP projects to additional industrial sites; and
- Remodeling the ITP Web site to make information more easily accessible to all levels of industry management and to emphasize the cost benefits of energy conservation technology.

Finding ways to increase the quantity and quality of face-to-face and Web site communications to industry is indispensable for broadening the ITP's impact and creating the opportunity to exceed program goals. It is especially important to understand who the key industry decision makers are and to tailor communications to reach them and their personnel.

Recommendation 2. Develop more effective mechanisms for collaboration and coordination across Industrial Technologies Program (ITP) subprograms and projects to reduce stovepiping and to encourage the achievement of broader goals.

It appears to the committee that in some cases there is inadequate communication among subprogram areas and that opportunities for synergy are not being realized. More crosscutting communication and sharing of ideas between project teams are needed (to prevent stovepiping). Areas in which increased collaboration could be realized include melting technologies and sensors.

Options to consider include the following: (1) holding topical workshops that highlight projects from different subprogram areas but that have a common theme, such as improved energy efficiency in melting; (2) modifying the solicitation process to include review by personnel from different industries to look specifically for increased collaboration; and (3) for projects that have both environmental and energy benefits, conducting reviews with the Environmental Protection Agency to look for ways to multiply those benefits.

However, the most important option to consider is the creation of a class of grand challenges that integrate projects in several industries toward a greater goal. The important factors in defining a grand challenge are these: (1) the definition of a starting point in time, (2) the identification of an endpoint at which success is achieved, and (3) a level of difficulty that is challenging but not impossible. The difference between a challenge and a grand challenge is that the latter can only be achieved through the cooperation and collaboration of a number of partners in different industries, carrying out projects of different sizes, but all aimed at achieving a shared goal. As part of a grand challenge strategy, the ITP should continue to pursue plans to increase the average size of projects, but it should also continue to maintain a healthy balance of small, medium, and large projects. The trend toward larger projects offers opportunities for correspondingly larger energy savings and is therefore attractive.

Pursuing success in grand challenges may increase the risk of large failures and fewer successes. An additional risk is that small to medium-sized companies may lose out in the program opportunities when compared against large firms with ample resources and influence to commit to large projects. Loss of the creative energies and viewpoints of small and medium-sized companies would be undesirable. The committee urges caution.

Recommendation 3. Redirect student education activities to other governmental entities that have direct educational missions, with the exception of those activities directly related to the plant assessments performed by students for the Industrial Technology Program's (ITP's) Industrial Assessment Centers. Because the mission of the ITP is energy savings, not education, any student educational activities undertaken by the ITP should be justified in terms of their energy-saving results, not their educational goals.

Grants to states for educational purposes appear to the committee to be peripheral to ITP goals. State educational goals are not primary to the industrial program, and so these funds might effectively be reallocated to areas that directly impact ITP goals. Other government entities that have major educational missions, such as the National Science Foundation, are more appropriate for managing student education initiatives. Note that the Industrial Assessment Centers, for which students carry out on-site energy assessments for small to medium-sized manufacturing facilities, are an integral part of the ITP. Engineering students involved in these assessments gain an educational benefit that is a by-product of the activity, not the primary goal. Small and medium-sized facilities gain significant insight into energy-saving opportunities.

Recommendation 4. Review Industrial Technologies Program (ITP) subprogram management practices to ensure clarity and consistency or, where practices differ, to ensure that differences are justified.

Differences in management practices exist among the ITP subprograms. For example, the American Iron and Steel Institute manages steel solicitations outside the ITP for a management fee. Mining subprogram solicitations are managed internally by the ITP, and contract management appears divided between the ITP and industry for the forest products subprogram. If these differences are appropriate, the reasons should be clearly understood and communicated to stakeholders. This disparity raises some concern about the uniformity of criteria used to discontinue funding of marginal or failing projects and, indeed, about how the ITP judges them. Greater uniformity in program management practice is urged.

Recommendation 5. Increase benefits by propagating the Industrial Technologies Program (ITP) strategy, where appropriate, to other programs in the Office of Energy Efficiency and Renewable Energy.

Divestitures to other parts of the EERE (e.g., agricultural industries to the Biomass Program) may make sense organizationally, but they currently dilute the practices of the ITP and increase the chance for management and budgetary inconsistencies. However, if the ITP model (also used in the Partnership for a New Generation of Vehicles and FreedomCar programs) can be channeled to other programs in the EERE, the benefits would increase overall.

The strategy of partnering with the end user of the technology to determine overall program goals, set grand challenges, and share in the project costs is a proven success. The energy savings are easily quantified, and the satisfaction of the industry partners is clear. Expanding the strategy to other programs in the EERE is a clear tactic to improve both.

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APPENDIXES

Appendix A

Committee Biographical Information

Joseph G. Wirth, *Chair*, retired as senior vice president and chief technical officer at Raychem Corporation, where he served as manager of worldwide technology with responsibility for corporate manufacturing and new business development. Dr. Wirth integrated new business directions into Raychem's existing manufacturing structure. Previously, he had worked at General Electric (GE), where he served as technology leader for the silicones business and vice president of the technology division for GE's plastics business. He is the inventor of polyetherimides, a fire-resistant plastic used in aircraft interiors and other industrial and consumer applications. He holds various patents in the high-performance polymer area and is the author of numerous publications. Dr. Wirth has served on several National Research Council (NRC) committees, including as chair of the Board on Manufacturing and Engineering Design and as a member of the National Materials Advisory Board.

Viola L. Acoff is associate professor in the Department of Metallurgical and Materials Engineering at the University of Alabama, where she has taught for 10 years. Dr. Acoff teaches courses in welding metallurgy, physical metallurgy, and scanning electron microscopy. Her research interests include the following: the microstructural evolution of the fusion- and heat-affected zones; high-temperature materials; electron microscopy; weldability and computer modeling of advanced materials; the effect of orientation on weld properties; indentation behavior of materials, particularly joining and interfacial structures; processing of alloys by cold-roll bonding; and the evaluation of contact angles of lead-free solders on copper substrates. Dr. Acoff is the recipient of numerous national and international awards, including the Adams Memorial Membership Award (2000), presented by the American Welding Society; Best Paper Award for TMS (The Minerals, Metals, and Materials Society) Symposium on Gamma Titanium Aluminides (1999); TMS Young Leader Intern (1998); National Science Foundation CAREER Award (1997); Warren F. Savage Memorial Award (1996), from the American Welding Society; International Business Machines Award for Excellence (1992); and First Place Award for Best Physical Sciences Paper (1991), from the Microscopy Society of America. Dr. Acoff is active in professional societies, including the American Welding Society, TMS, and ASM International.

Alexis G. Clare is a professor of glass science at Alfred University. Her research interests include relationships of structure and optical properties in glasses, biological applications of glasses, optically active glasses, and the structure of glasses by neutron and X-ray diffraction. She is the author or co-author of more than 65 published papers and 6 book chapters, and the editor of 3 books. She also holds a U.S patent. Dr. Clare has been active in many professional societies, serving as president of the National Institute for Ceramic Engineers (2003) and chair of the Glass and Optical Materials Division of the American Ceramic Society (1998). She is a fellow of both the United Kingdom's Society of Glass

Technology and the American Ceramic Society. Dr. Clare has received numerous awards, including the Vittorio Gottardi Prize for Glass Science from the International Commission on Glass (2000) and the Karl Schwartzwalder PACE (Professional Achievement in Ceramic Engineering) Award from the National Institute of Ceramic Engineers. She was a member of the NRC Committee on the Utilization of Russian Technologies.

Kevin A. Davis is manager of business development at Reaction Engineering International, a research and development consulting firm with expertise in combustion and environmental solutions, where he has led projects in combustion research and product and technology development. His efforts have included successful programs spanning a range of technical areas, including nitrogen oxide/limiting oxygen index relationships in coal-fired boilers, heterogeneous catalysis/adsorption/reaction, mineral concentrate combustion, and fluidized-bed applications. Previously, Dr. Davis had worked at Sandia National Laboratories, serving as principal investigator of research programs in the areas of droplet and char combustion. His service there included work acknowledged by the Combustion Institute with its Silver Medal. His graduate research developed a thermodynamic foundation and experimental evidence establishing the feasibility of a flame synthesis technique for producing nanoscale particles of several important classes of ceramics. Dr. Davis has authored several publications on these topics.

Nicholas J. Gianaris is senior engineering specialist in materials and processes engineering at General Dynamics Land Systems. His responsibilities include technical management of system design and integration for the Future Combat System program. Prior to joining General Dynamics, he served as lightweight materials specialist for Ford Motor Company-Visteon Chassis Systems. There he was responsible for technical management and implementation of cost-effective optimized designs and processes, with the goal of providing low-mass solutions to improve vehicle fuel economy, performance, and safety. Dr. Gianaris has also served as senior technical specialist in the Helicopter Division of the Boeing Company, where he was responsible for the integration of all technical requirements for all design and manufacturing functions of the commercial tiltrotor program and for management of the materials and processes laboratories. He is the owner or co-owner of six U.S. patents, the co-founder and co-owner of a nondestructive evaluation company, and the author of numerous technical publications. He is active in several professional societies, including ASM International, for which he is chair of the Ground Transportation Committee; the Society for the Advancement of Material and Process Engineering, for which he is also chair of the Ground Transportation Committee; and the Society of Automotive Engineers. Dr. Gianaris is a fellow of ASM International.

Joanna R. Groza is professor in the Department of Chemical Engineering and Materials Science at the University of California, Davis. Her research interests include materials processing and characterization, mechanisms of nanoparticle consolidation, plasma effects in plasma-activated sintering, and processing/microstructure property relationships. She is the author of numerous publications. Dr. Groza previously served on the NRC Panel to Review Air Force Office of Scientific Research Proposals.

Warren H. Hunt, Jr. is president of Aluminum Consultants Group, Inc., a consulting firm in aluminum metallurgy and processing. Prior to forming Aluminum Consultants, Dr. Hunt spent 19 years at the Alcoa Technical Center, where he held positions in aluminum materials development and research and development management. His responsibilities included the implementation and management of materials development projects in a range of markets such as automotive, aerospace, and electronic packaging. This work resulted in eight patents for innovative alloys and processes, two of which were recognized with Industrial Research (IR) 100 Awards and internal Alcoa awards. Dr. Hunt is the author of more than 40 technical papers and the editor of 3 books on materials development. He is active in professional organizations, serving as chair of the Public and Governmental Affairs Committee of TMS and as a member of the Aluminum Association Technical Advisory Committee. He is a fellow of ASM International.

George D. Pfaffmann is (semiretired) vice president of technology for Ajax Magnethermic TOCCO, Inc., a developer, designer, and manufacturer of furnaces for induction heating and melting manufacturing systems and a contract heat-treating company. Mr. Pfaffmann has broad expertise in heat-treating process engineering. He has worked for TOCCO since 1952 through a number of mergers and consolidations. Previous positions that he held at the company include the following: director of TOCCO heat-treating operations, vice president of technology laboratory and service operations, vice president of international marketing and technology, and director of marketing and technical services. Mr. Pfaffmann is the author of numerous technical publications and the owner or co-owner of 29 U.S. patents. He has served in a number of professional associations, including the American Society of Mechanical Engineers, ASM International, the Society of Manufacturing Engineers, and the Society of Automotive Engineers. He is a fellow of ASM International.

Peter H. Pfromm is Cargill Fellow in Bioprocessing and associate professor in the Department of Chemical Engineering at Kansas State University. His expertise includes gaseous membrane separations, electrochemical separations, specialty separations, separation processes for closed-cycle manufacturing, paper recycling, and polymer science. Previously, Dr. Pfromm worked at the Institute for Paper Science and Technology, Membrane Research and Technology, Inc., and the Fraunhofer Institute for Interfacial Engineering and Biotechnology in Stuttgart, Germany. Dr. Pfromm is active in a number of professional societies, including the North American Membrane Society, the American Chemical Society, and the American Institute of Chemical Engineers, for which he has served as secretary of the Forest Products Division. He served on two previous NRC committees—the Committee on Materials Technologies for Process Industries and the Panel on Separation Technology for Industrial Recycling and Reuse. Dr. Pfromm is the co-owner of two U.S. patents and has published more than 30 peer-reviewed scientific articles.

William H. Plenge is founder and president of Potomac Services International, a consulting firm specializing in technology insertion, market development, and strategic planning. He spent 10 years at the American Concrete Institute where he served concurrently as managing director of the Strategic Development Council, a strategic forum for senior executives from 65 member organizations, and as director of Washington operations. His responsibilities included the following: creating and managing the concrete industry's Strategic Development Council; organizing and facilitating the industry's production of a 30-year vision document, a 30-year research and development master plan, and a strategic solution document for reducing technology acceptance times; establishing the Washington office; and co-authoring a $320 million proposal for the Focused Program Area for High-Performance Concrete of the National Institute of Standards and Technology's Advanced Technology Program. Prior to that, he spent 21 years at Deere & Company, rising to the position of vice president of John Deere Technologies International and head of Deere's Washington Technology Marketing Office.

Jeffrey J. Siirola (NAE) is Technology Fellow at Eastman Chemical Company. His research interests involve chemical process engineering and conceptual process design theory and application, including the synthesis of process flowsheet alternatives, process simulation, optimization, capital and operating cost estimation, waste minimization, resource conservation and recovery, technology assessment, and financial analysis. He has been involved in the development, implementation, and application of computer-aided chemical process synthesis methods and tools in both academic and industrial settings. Dr. Siirola has served on a number of NRC committees and boards, including the Board on Chemical Sciences and Technology, the Chemical Engineering Peer Committee, and the Committee on Challenges for the Chemical Sciences in the 21st Century. He is a member of the National Academy of Engineering.

T.S. Sudarshan is president and chief executive officer of Materials Modification, Inc. He is responsible for the management and technical development of innovative materials, processes, and techniques, and for the coordination of federally and industrially sponsored research programs within several industries, including the steel industry. Dr. Sudarshan has served as the principal investigator of several programs in the development of diamond thin films, solid lubricants for space structures in conjunction with the European Space Agency, nontoxic lubricants for automobile applications, accelerated corrosion testing, synthesis and consolidation of nanostructured materials, and development of lightweight carbon-carbon pistons. He has been the recipient of numerous awards and honors, including the Design News Award and R&D 100 for the microwave plasma technique Nanogen and for the Plasma Pressure Compaction technique. He has served on numerous committees of the National Science Foundation, the National Institutes of Health, and ASM International. Dr. Sudarshan is the author of more than 125 published proceedings and journal articles and presentations. He is the co-editor of two journals, *Materials and Manufacturing Processes* and *Surface Engineering*, and has co-edited 18 books on various aspects of surface modification technologies. He is a fellow of ASM International and the International Federation for Heat Treatment and Surface Engineering.

Richard E. Tressler is professor emeritus in the Department of Materials Science and Engineering at Pennsylvania State University. His research interests include the following: thermodynamic stability of advanced ceramics in energy conversion systems and high-temperature processing plants; improvements in materials and protection schemes through understanding the rate-limiting reactions and local thermodynamic equilibria of the processes that control corrosion and substrate degradation; long-term reliability of advanced structural ceramics, ceramic fibers, and ceramic-ceramic composites under static or cyclic stresses at elevated temperatures in energy-usage and energy-recovery applications; and development of a design database of reliable tensile properties of commercially available materials. Dr. Tressler has served on many NRC committees, including the Committee on Materials Research for Defense After Next, the Panel on Structural and Multifunctional Materials, the Committee on Advanced Fibers for High-Temperature Ceramic Composites, and the Committee on Ceramic Technology for Advanced Heat Engines.

Courtney A. Young is ASARCO Distinguished Professor of Metallurgical Engineering and head of the Department of Metallurgical and Materials Engineering at Montana Tech of the University of Montana, where he has taught for 10 years. His areas of expertise include surface chemistry, electrochemistry, and spectroscopy as applied to all areas of process technology, particularly resource recovery in primary production (i.e., copper, gold, flotation, physical separations, sulfide electrochemistry, and adsorption) as well as secondary production (i.e., cyanide destruction, acid-rock drainage remediation, spent pot liner recycling, and other areas of waste treatment and minimization). Dr. Young has served as principal investigator on numerous research projects and as a consultant for several companies involved in selecting and testing ore-processing options and researching and developing solutions to environmental problems. He is active in professional organizations, including the TMS and the Society for Mining, Metallurgy, and Exploration, from which he has received several awards. He is the author of 100 publications and presentations.

Appendix B

Agenda of May 19-21, 2004, Meetings

WEDNESDAY, MAY 19, 2004
FORRESTAL BUILDING
DEPARTMENT OF ENERGY, WASHINGTON, D.C.

Closed Session—Committee and NRC Staff Only

8:30 a.m.	Welcome and Introductions	Joseph Wirth, Chair
8:45 a.m.	Introduction to the National Research Council (NRC): Policies and Procedures Bias and Conflict of Interest Discussion Composition and Balance Discussion	Dennis Chamot, Division on Engineering and Physical Sciences

Open Session

10:30 a.m.	Setting the Context for the Committee Review —Introduction to the Industrial Technologies Program (ITP) —Description of Mission and Organizational Logic —Constraints Under Which ITP Operates (Congressional, Historical, etc.)	Buddy Garland, Department of Energy (DOE)
12 noon	Lunch (NRC and DOE ITP Management Team)	
1:30 p.m.	Presentation of Corporate Strategy —Realizing a Vision for the Future of the Industry —Strategies for Government Investment —Understanding and Awareness —Long-Term Focused Partnerships —Superior Business Practices	 Scott Richlen, DOE Sara Dillich, DOE Peter Salmon-Cox, DOE James Quinn, DOE Harvey Wong, DOE
3:45 p.m.	Question-and-Answer Session	All Participants
5:00 p.m.	Adjourn	
6:00 p.m.	Dinner (NRC and DOE ITP Management Staff)	

THURSDAY, MAY 20, 2004
FORRESTAL BUILDING
DEPARTMENT OF ENERGY, WASHINGTON, D.C.

Open Session

8:00 a.m.	Continental Breakfast (NRC and DOE ITP Staff)	
8:30 a.m.	Key Components, Session One: Five Breakout Groups —Aluminum —Forest Products —Technology Delivery —Glass —Supporting Industries	DOE ITP Staff
9:45 a.m.	Key Components, Session Two: Five Breakout Groups —Metal Casting —Chemicals —Sensors and Automation —Software Tool Development —Regional Offices	DOE ITP Staff
11:00 a.m.	Key Components, Session Three: Four Breakout Groups —Steel —Mining —Combustion —Materials for the Future	DOE ITP Staff
12:00 noon	Lunch (NRC and DOE ITP Staff)	
1:30 p.m.	Towards a More Robust Strategy —Positive Impact Manufacturing —Multi-Scenario Planning Analysis —Environmental Compliance —Industrial Financing Practices —21st Century Workforce	 Buddy Garland, DOE Jordan Blackman, TMS Isaac Chan, DOE Peter Salmon-Cox, DOE
3:45 p.m.	Question-and-Answer Session	All Participants
5:00 p.m.	Adjourn	
6:00 p.m.	Dinner (Committee Only)	

FRIDAY, MAY 21, 2004
KECK CENTER
THE NATIONAL ACADEMIES, WASHINGTON, D.C.

Closed Session—Committee and NRC Staff Only

8:30 a.m.	Subgroup Leads Present Draft Conclusions
10:30 a.m.	Drafting of Initial Conclusions and Recommendations
11:00 a.m.	Writing Assignments
12:00 noon	Adjourn and Lunch

Appendix C

Abbreviations and Acronyms

AF&PA	American Forest and Paper Association
AFS	American Foundry Society
AISI	American Iron and Steel Institute
CFD	computational fluid dynamics
Climate VISION	Voluntary Innovative Sector Initiatives: Opportunities Now
DAS	deputy assistant secretary
DOE	U.S. Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy
EPA	U.S. Environmental Protection Agency
GMIC	Glass Manufacturers Industrial Council
GPRA	Government Performance and Results Act of 1993
IOF	Industry of the Future
ITP	Industrial Technologies Program
MYPP	Multi-Year Program Plan
NCASI	National Council for Air and Stream Improvement
NEP	National Energy Policy
NEPDG	National Energy Policy Development Group
NRC	National Research Council
NSF	National Science Foundation
OIP	Office of Industrial Programs
OIT	Office of Industrial Technologies
PART	Program Assessment Rating Tool
PM^2	powder metallurgy and particulate materials
R&D	research and development
RD&D	research, development, and demonstration
RO	regional office
SBIR	Small Business Innovation Research (program)
SME	Society for Mining, Metallurgy, and Exploration
STTR	Small Business Technology Transfer (program)
TAPPI	Technical Association of the Pulp and Paper Industry
TMS	The Minerals, Metals, and Materials Society
VOC	volatile organic compound