Promoting Innovation: 2002 Assessment of the Partnership for Advancing Technology in Housing

Committee for Review and Assessment of the Partnership for Advancing Technology in Housing, National Research Council

ISBN: 0-309-51266-2, 76 pages, 8 1/2 x 11, (2003)

**This free PDF was downloaded from:
http://www.nap.edu/catalog/10688.html**

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

PROMOTING INNOVATION
2002 Assessment of the Partnership for Advancing Technology in Housing

Committee for Review and Assessment of the Partnership
for Advancing Technology in Housing

Board on Infrastructure and the Constructed Environment

Division on Engineering and Physical Sciences

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
WASHINGTON, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS   500 Fifth Street, N.W.   Washington, DC 20001

Printed in the United States of America

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

COMMITTEE FOR REVIEW AND ASSESSMENT OF THE PARTNERSHIP FOR ADVANCING TECHNOLOGY IN HOUSING

C.R. "CHUCK" PENNONI, *Chair*, Pennoni Associates, Inc., Philadelphia, Pennsylvania
ROBERT BLANCETT, USG Research & Technology, Inc., Libertyville, Illinois
PAUL R. FISETTE, University of Massachusetts, Amherst
KAREN L. GEORGE, Primen, Boulder, Colorado
MANUEL GONZALEZ, KTGY Group, Inc., Irvine, California
ASHOK GOSWAMI, National Conference of States on Building Codes and Standards, Inc., Herndon, Virginia
CHARLES J. KIBERT, University of Florida, Gainesville
JOSEPH LAQUATRA, Cornell University, Ithaca, New York
TRICIA PARKS, Parks Associates, Dallas, Texas
TIMOTHY REINHOLD, Clemson University, Clemson, South Carolina
JOHN K. SPEAR, Richwood Development Corporation, Houston, Texas

Staff

RICHARD G. LITTLE, Director, Board on Infrastructure and the Constructed Environment
MICHAEL D. COHN, Project Officer
DANA CAINES, Administrative Associate
PAT WILLIAMS, Project Assistant
JULIA MELKERS, Consultant

BOARD ON INFRASTRUCTURE AND THE CONSTRUCTED ENVIRONMENT

PAUL GILBERT, *Chair*, Parsons Brinckerhoff Quade & Douglas, Seattle, Washington
MASSOUD AMIN, University of Minnesota, Minneapolis
RACHEL DAVIDSON, Cornell University, Ithaca, New York
REGINALD DESROCHES, Georgia Institute of Technology, Atlanta
DENNIS DUNNE, California Department of General Services, Sacramento
PAUL FISETTE, University of Massachusetts, Amherst
YACOV HAIMES, University of Virginia, Charlottesville
HENRY HATCH, U.S. Army Corps of Engineers (retired), Oakton, Virginia
AMY HELLING, Georgia State University, Atlanta
SUE McNEIL, University of Illinois, Chicago
DEREK PARKER, Anshen+Allen, San Francisco, California
DOUGLAS SARNO, The Perspectives Group, Inc., Alexandria, Virginia
WILL SECRE, Masterbuilders, Inc., Cleveland, Ohio
DAVID SKIVEN, General Motors Corporation, Detroit, Michigan
MICHAEL STEGMAN, University of North Carolina, Chapel Hill
DEAN STEPHAN, Charles Pankow Builders (retired), Laguna Beach, California
ZOFIA ZAGER, County of Fairfax, Fairfax, Virginia
CRAIG ZIMRING, Georgia Institute of Technology, Atlanta

Staff

RICHARD G. LITTLE, Director, Board on Infrastructure and the Constructed Environment
LYNDA L. STANLEY, Executive Director, Federal Facilities Council
MICHAEL D. COHN, Program Officer
DANA CAINES, Financial Associate
JASON DREISBACH, Research Associate
PAT WILLIAMS, Senior Project Assistant

Acknowledgment of Reviewers

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 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:

Dennis Creech, Southface Energy Institute,
Charles W. Graham, Texas A&M University,
Walter Grondzik, Florida A&M University,
Amy Helling, Georgia State University,
Boyd C. Paulson, Stanford University, and
Madan (Matt) Syal, Michigan State University.

Although the reviewers listed 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 Charles B. Duke (NAE), Xerox Research and Technology. Appointed by the National Research Council, 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

APPENDIXES

Acronyms and Abbreviations

BEES	Building for Environmental and Economic Sustainability
BFRL	Building and Fire Research Laboratory
CSREES	Cooperative State Research, Education and Extension Service
DAPIA	Design Approval Primary Inspection Agency
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOL	Department of Labor
DOT	Department of Transportation
EEBA	Energy and Environmental Building Association
EIFS	exterior insulated finishing system
EPA	Environmental Protection Agency
FAWG	Federal Agency Working Group
FEMA	Federal Emergency Management Agency
FPL	Forest Products Laboratory
GPRA	Government Performance and Results Act of 1993
HUD	Department of Housing and Urban Development
ICF	insulating concrete form
MHRA	Manufactured Housing Research Alliance

NAHB	National Association of Home Builders
NAHBRC	National Association of Home Builders Research Center
NASFA	North American Steel Framing Alliance
NCSBCS	National Conference of States on Building Codes and Standards
NES	National Evaluation Service
NIST	National Institute of Standards and Technology
NRC	National Research Council
NSF	National Science Foundation
NSTC C&B	National Science and Technology Council Construction and Building Subcommittee
OECD	Organization for Economic Cooperation and Development
PATH	Partnership for Advancing Technology in Housing
PATH-CoRP	PATH Cooperative Research Program
PD&R	Policy Development and Research
PIC	PATH Interagency Council
R&D	research and development
USDA	U.S. Department of Agriculture

Executive Summary

The application of technology to housing design, construction, and operation offers opportunities for improving affordability, energy efficiency, comfort, safety, and convenience for consumers. New technologies and production processes could help resolve serious problems facing housing producers, including labor shortages, interruptions due to inclement weather, quality control, and theft and vandalism losses. However, it is generally believed that realizing these benefits on a broad scale is considerably hindered by characteristics of the housing industry that inhibit the development and diffusion of innovations. The Partnership for Advancing Technology in Housing (PATH) supports activities to address issues that are perceived by the industry to be the primary causes of the problems, i.e., barriers to innovation, lack of accessible information, and insufficient research and development (R&D) (NAHBRC, 1998). PATH was initiated in 1998 when Congress appropriated funds for the U.S. Department of Housing and Urban Development (HUD) to begin implementing the concept, which was created by the National Science and Technology Council Construction and Building Subcommittee (NSTC C&B).

SCOPE OF THE STUDY

At the request of HUD, the National Research Council (NRC) assembled a panel of experts as the Committee for Review and Assessment of the Partnership for Advancing Technology in Housing under the NRC Board on Infrastructure and the Constructed Environment. The committee was asked to assess how well PATH is achieving its many program objectives to expand the development and utilization of new technologies in the U.S. housing industry. The committee has approached evaluation of the program as an exercise that also provides direction for PATH's future improvement.

2002 ASSESSMENT

The committee reviewed how the PATH program's goals have evolved from a focus on improvement of housing performance to development and diffusion of technology in housing. It addressed the

justification and roles for PATH based on economic principles and accepted theories for the development and diffusion of innovation. This evaluation considered each of the 56 PATH activities initiated between 1999 and 2001 with special attention to those activities that seemed likely to have the greatest impact on the program's goals. The committee also presents here a long-term process for program assessment that it believes is needed for continued PATH improvement. A compilation of the committee's findings and recommendations follows.

EVOLUTION OF THE PATH PROGRAM

Finding: PATH is an ambitious program intended to initiate significant change in an industry that affects 14 percent of the U.S. economy (NAHB, 2002) by sponsoring an annual program of activities valued at $8 million to $10 million. As a partnership it is intended to focus attention on the development and diffusion of technology for the housing industry and to use this attention to leverage action on related government, academic, and industry programs. PATH evolves by responding to its stakeholders and the recommendations of the committee. The committee has observed positive change as the program matures.

Recommendation: PATH should continue to respond to input from its diverse stakeholders and the evaluations of this committee by fine-tuning its mission and goals for increasing the rate at which technologies are developed and diffused in the housing industry.

PATH Approach to Advancing Housing Technology

Finding: The basis for PATH was the hypothesis that innovative technologies can improve housing performance and reduce costs and that there is a need for intervention to increase the rate of innovation in the housing industry. The committee supports this hypothesis and the need for a program like PATH. However, there are insufficient data to determine the optimum rate of innovation in the housing industry, what is needed to increase the rate of innovation, and how innovation affects housing costs and performance. Research on the development and diffusion of technology in housing is needed to validate the hypothesis, support an effective program plan, and measure its effect.

Recommendation: PATH should continue to base its work on the assumptions that (1) intervention is needed to increase the rate of innovation in the housing industry and (2) this can be accomplished by identifying, understanding, and removing barriers to innovation, increasing dissemination of information, and fostering research. Some PATH funds should be used to improve the program's understanding of how innovations are developed and diffused in the housing industry, and to measure the value of the PATH program.

Progress Toward Achieving PATH Goals

Goal 1: To Remove Barriers and Facilitate Technology Development and Adoption

Finding: Understanding and removing barriers to the adoption of innovative technologies in housing is key to the success of the PATH program. Removing such barriers will increase the rate of innovation by reducing the time needed for diffusion of new technologies, thereby providing additional incentive for private investment in R&D.

Recommendation: PATH should increase the percentage of program resources allocated to the removal of barriers to the adoption of innovative technologies in housing, plan a comprehensive research program to better understand barriers to innovation, and use the knowledge gained from this research as the basis for developing effective programs to remove barriers.

Finding: It is important for information on the performance, costs, and benefits of new technologies to be disseminated in a useful format to help remove multiple barriers to innovation. To make the program more effective, the process should include feedback on the decisions that potential new adopters make based on the information they receive from PATH. PATH's demonstration and evaluation projects have not been publicized adequately, nor has PATH developed and documented the data needed to really help homebuilders, regulators, homebuyers, and other housing industry participants understand new technologies and determine whether they should be adopted.

Recommendation: PATH should expand its program of demonstration and evaluation projects and create a database that details the relative advantages or disadvantages, compatibility with existing systems, trialability,[1] and benefits of new technologies. There should be assurance that the data are accurate, reliable, and comparable. The information should be accessible to all members of the housing industry. PATH should coordinate programs to analyze and interpret the data for the industry, regulators, and consumers.

Goal 2: To Improve Technology Transfer, Development, and Adoption Through Information Dissemination

Finding: PATH-sponsored activities like the technology inventory and technology scan can be effective in disseminating information, transferring technology, and planning PATH programs. The current focus on technologies that have achieved less than 20 percent of their potential market share hampers PATH's effectiveness. The effectiveness of the program is further diminished by the inadequate quality and consistency of materials documenting new technologies and opportunities for technology transfer.

Recommendation: The technology inventory and technology scan should be broadened into a database of information on housing technologies at all stages of development. The database should incorporate information gained from demonstration and evaluation projects as well as all performance data available. Steps should be taken to ensure that the data are complete and accurate, and that documents used to convey this information to PATH's audiences are clear, concise, and unbiased.

Finding: Effective communication for the development and diffusion of technology in housing continues to be one of the major opportunities and one of the major obstacles for PATH. PATH uses the many channels and means of communication available, but with varying degrees of success. The current funding for communication is not consistent with its role in achieving the program's mission and goals. A better understanding of channels of communication that might prove useful is needed to determine the most effective channels and means of delivery. PATH is, again, responsible for ensuring that the information it provides is unbiased, accurate, and complete.

---

[1] "Trialability" is defined by Rogers as "the degree to which an innovation may be experimented with on a limited basis" (Rogers, 1995).

Recommendation: PATH should place more emphasis on and dedicate more of its budget to understanding how its various audiences obtain and use information and to delivering its information. Use of the Internet should be continued, but the use of other means of mass communication and outreach should be expanded commensurate with their role in the housing industry. A process for independent peer review should be created to ensure the accuracy and clarity of the information disseminated.

Goal 3: To Advance Research on Housing Technologies and Foster Development of New Technology

Finding: More than 80 percent of PATH resources have been allocated to R&D, yet there is no agenda that identifies and prioritizes R&D activities. The technology roadmaps, while providing direction for specific technologies, are not a substitute for a PATH research agenda. The result has been a broad array of unrelated activities—and minimal progress toward achieving program goals. For PATH, basic and applied research on new building materials and systems with broad applications is more appropriate than research for development of specific technologies, but private investment in developmental research should be encouraged. PATH needs to set national priorities for coordinating federally funded R&D activities, minimizing duplication, and encouraging partnerships between industry, government, and academia. It is particularly important to recognize that industry investment in research is minimal, and to create a mechanism that encourages industry to invest in housing technology research.

Recommendation: PATH should increase efforts to monitor promising R&D and enhance dissemination of information about leading-edge housing technology. PATH should set a comprehensive research agenda that is coordinated with current research in government, academic institutions, and industry. PATH-sponsored research on housing technologies should emphasize basic and applied research with broad application and the potential to increase the rate of innovation. PATH should foster development of specific new technologies primarily by promoting private investment.

Goal 4: To Administer the PATH Program to Achieve Its Mission, Goals, and Objectives

Finding: Administration of the PATH program has been inconsistent and has not provided sufficiently strong direction. The committee recognizes that administration has been hampered by the initial selection of goals at the inception of the program that were overly ambitious for the size of the program. Administration has also been hampered by the uncertainty of the program's future. Unfortunately, the administrative impediments have led to a misplaced emphasis on activities (e.g., developmental research versus information dissemination and barrier removal), and a program that lacks baseline measures and an operating plan to achieve its goals. The development and diffusion of accurate and unbiased information about new technologies would increase both recognition of the program and its ability to influence innovation in the housing industry. The strengths of the program in engaging diverse stakeholders and in the skills and abilities of the PATH staff are resources that can overcome these problems.

Recommendation: PATH should draft a program plan for achieving its current goals. Research on innovation in the housing industry and channels of communication should be priorities. The information gained from this research should be used to guide writing of the program plan and collection of baseline data for future program evaluation. All stakeholders should participate in the planning process

in proportion to their roles in advancing technology in housing. PATH should enhance its relationships with the broad spectrum of housing researchers, innovators, adaptors, and consumers by establishing channels of communication for collecting and disseminating information on housing technology.

Assessment of the PATH Program as a Whole

Finding: PATH started out with goals that were influenced by many factors other than technology and that were somewhat contradictory, not measurable, and inappropriate for a small technology-focused program. Nevertheless, the program made an effort to achieve these goals. The result is an unfocused program, an array of uncoordinated activities, and a misplaced emphasis on R&D for new technologies. PATH has made an effort to refocus its goals on the program's role in promoting the development and diffusion of technology, but this effort is not yet complete.

Recommendation: PATH should be continued as a program aimed at increasing the rate of development and diffusion of innovation in the housing industry. Its activities should focus on (1) identifying, understanding, and removing barriers to, and (2) disseminating information for, the development and diffusion of new technologies, as well as (3) increasing industry investment in technology development.

Long-Term Assessment and Program Improvement

Finding: Because PATH is a new and evolving program, expert review of the program's performance and its response to reviews is especially important to its ongoing management. Effective program assessment is essential if the PATH program is to be efficiently managed. The program should be evaluated based on whether the activities it undertakes are likely to help achieve its goals, and on the quantity and quality of the results of these activities. If PATH undertakes the right mix of high-performing activities, then improvement in measures of innovation in the housing industry can be attributed, at least in part, to PATH.

Recommendation: Criteria for PATH program evaluation should be made a part of all grants and contracts. Additional performance measures should be designed to evaluate how the program is affecting innovation by individuals, enterprises, and the housing industry. Performance data should be reviewed independently so that assessment and interpretation of reported performance metrics are unbiased. This review could help analyze data on the results as well as evaluate performance of the program's strategic planning and management.

REFERENCES

NAHB (National Association of Home Builders). 2002. *Housing, the Key to Economic Recovery*. Washington, D.C.: National Association of Home Builders.

NAHBRC (National Association of Home Builders Research Center). 1998. *Building Better Homes at Lower Costs: The Industry Implementation Plan for the Residential National Construction Goals*. Upper Marlboro, Md.: NAHB Research Center.

Rogers, E.M. 1995. *Diffusion of Innovations*. New York, N.Y.: The Free Press.

1

Introduction

Technological innovations can make housing more affordable, efficient, and safe—factors that are key to the well-being of American families. The Partnership for Advancing Technology in Housing (PATH) was created to facilitate the development and diffusion of innovation in the housing industry (NSTC, 1999).

PATH was initiated in 1998 when Congress appropriated funds for HUD to begin implementing the concept, which was created by the National Science and Technology Council Construction and Building Subcommittee (NSTC C&B). PATH is different from previous programs intended to influence technology in housing (e.g., Operation Breakthrough) in that private industry and academic institutions participate in planning and directing the program, and the program addresses the development and diffusion of technologies industrywide rather than promoting selected technologies or particular segments of the industry. The program is intended to make a difference by leveraging the influence and investments of partners in government, industry, and academic institutions.

SCOPE OF THE STUDY

The Government Performance and Results Act passed by Congress in June 1993 found that congressional policymaking, spending decisions, and program oversight were seriously handicapped by insufficient attention to program performance and results. Congress determined that the confidence of the American people in the federal government could be improved by systematically holding federal agencies accountable for achieving program results. The congressional conference report accompanying the Veterans Administration, the Department of Housing and Urban Development (HUD), and Independent Agencies Appropriation Act of 1999 (P.L. 105-275) provided funding for PATH and directed it to provide an operating plan for the PATH program and draft an evaluation report describing progress toward meeting PATH goals.

HUD's October 25, 2000 *Strategy and Operating Plan* noted that independent, multiyear oversight and evaluation of PATH would enhance the credibility of the program (HUD, 2000); HUD asked the National Research Council (NRC) to provide it. The NRC assembled a panel of experts as the Commit-

6

tee for Review and Assessment of the Partnership for Advancing Technology in Housing under the NRC Board on Infrastructure and the Constructed Environment. The members of the committee have expertise in housing design and construction, manufactured housing, social impacts of the built environment, sustainable building technologies, residential energy management, material performance and durability, the use of recycled and engineered construction products, safety of the construction workplace, disaster resistance of housing, product certification, and residential building codes as applied to a wide range of housing industry segments (site-built, manufactured, affordable, not-for-profit, mass market, and custom-built) (see biographies, Appendix A). It was also determined that the committee required expertise in program evaluation and performance measurement. Julia Melkers, professor of public administration at the Andrew Young School of Policy Studies, Georgia State University, provided this expertise.

The committee was asked to determine whether the PATH program is achieving its objectives to expand the utilization of new technologies in the American housing industry. The principal goal of this effort (see statement of task, Appendix B) was to review and comment on (1) the PATH program goals, (2) the approach proposed to meet the goals and the likelihood of achieving them, and (3) the progress made toward achieving PATH's goals. The committee determined that assessing PATH's goals required it to evaluate the fundamental need and precedents for a federal program such as PATH. The committee also determined that evaluating the program's progress toward achieving its goals required metrics and a system for applying them into the future.

HUD will submit the report produced by this NRC committee to Congress to fulfill part of its reporting obligation.

APPROACH TO REVIEW AND ASSESSMENT

This review of the PATH program, which began in April 2000, was planned as a 3-year undertaking. The committee met six times to be briefed on the administration and activities of the program. Among the presenters were representatives from PATH management and from federal agencies and private organizations participating in the program, including the Department of Energy (DOE), the Environmental Protection Agency (EPA), the National Institute of Standards and Technology (NIST), and the National Association of Home Builders Research Center (NAHBRC). The committee also heard from builders participating in PATH-sponsored demonstration projects and the PATH Industry Steering Committee (see Appendix C for a list of presentations). In August 2001, the committee reviewed the PATH mission, goals, and objectives as revised by HUD with assistance from the committee consultant, Dr. Melkers. The committee and Dr. Melkers then used the revised strategic plan as the basis for the program evaluation (see Chapter 4), and the framework for future assessments (see Chapter 5).

ORGANIZATION OF THIS REPORT

This third and final report of the committee evaluates activities initiated between 1999 and 2001 and assesses how well they support the PATH program goals and the likelihood of achieving the goals as revised in 2001 (see Appendix D for a summary of the 2000 and 2001 assessments). This report also describes an evaluation framework that can be used to assess future progress in meeting the program goals. The discussion of the need for a program like PATH has been expanded to consider the possible direct impact of the program on the development and diffusion of technology for housing.

Chapter 1, Introduction, describes the background and purpose of PATH and the purpose of this 3-year assessment. It states the rationale for the selection of the committee and its charge.

Chapter 2, Evolution of PATH, describes the origin of PATH and its relationship to past activities at

HUD and the National Science and Technology Council Construction and Building Subcommittee (NSTC C&B). It describes how the program's goals evolved from the C&B's national construction goals to the housing performance goals established for PATH at its inception, and how these were revised to address the development and diffusion of technology in housing. It also describes changes in program administration and the activities supported by the program from 1999 through 2001.

Chapter 3, PATH's Approach to Advancing Housing Technology, discusses the program, which is based on the hypotheses that innovative technologies can improve housing performance and reduce costs, and that there is a need for intervention to increase the rate of innovation in the housing industry. PATH's goals are discussed in terms of general theories of the development and diffusion of innovation and of the committee's perception of barriers to innovation in the housing industry. The committee provides examples of activities that are needed to solve the problems PATH is intended to address.

Chapter 4, 2002 Assessment of PATH, presents the committee's evaluation of the program through 2002. The evaluation critiques a selection of the 56 PATH activities initiated between 1999 and 2001 that the committee considered most significant, and assesses progress toward achieving the program's goals.

Chapter 5, Process for Long-Term Performance Assessment and Program Improvement, discusses how established principles and procedures for program evaluation can be incorporated into procedures for long-term assessment of PATH. The procedures emphasize the dual purpose of evaluating past performance and planning future activities to achieve the program's goals.

The appendixes include (A) biographies of the members of the committee; (B) the committee's statement of task; (C) a summary of information presented to the committee in 2000 through 2002; (D) a summary of previous committee reports; and (E) a list of assessment questions and performance targets.

REFERENCES

HUD (Department of Housing and Urban Development). 2000. *Partnership for Advancing Technology in Housing: Strategy and Operating Plan*. Washington, D.C.: Department of Housing and Urban Development.

NSTC (National Science and Technology Council). 1999. *Construction and Building: Interagency Program for Technical Advancement in Construction and Building*. Washington, D.C.: National Science and Technology Council.

2

Evolution of PATH

GENESIS OF PATH

There are many precedents for programs in the federal government that facilitate the development and diffusion of innovation in industry. Recent examples are the Department of Transportation's (DOT's) Partnership for a New Generation of Vehicles, DOE's Building America, and EPA's ENERGY STAR. Most federal technology advancement programs are initiated in response to a specific agency mission, e.g., transportation, energy conservation, or environmental conservation, although all three of these examples advance a national priority to conserve energy.

In the 1990s the DOE Office of Building Technologies, State and Community Programs worked on advancing housing technologies through its Building America program, which is similar to PATH. Though the DOE programs emphasize technologies that improve energy performance, they also address general issues affecting the development and diffusion of new technologies. DOE has made valuable contributions to predominantly private efforts by identifying opportunities and potential benefits of new technologies, conducting laboratory and field tests of products, developing analytical tools and rating procedures, and conducting outreach and education. DOE's national laboratory system was a key resource that contributed to the success of these programs (Geller and Thorne, 1999).

It has been more than 30 years since HUD undertook Operation Breakthrough, an R&D program to improve housing construction. Its approach was to sponsor the development of selected technologies and promote their adoption in the housing industry. However, the government had neither the technical expertise nor the market experience to make the new technologies a commercial success. Operation Breakthrough was an example of the public sector attempting to direct development of specific technologies for a commercial market in which there was little or no government procurement interest. The lessons learned from Operation Breakthrough and other federal R&D projects are that successful programs are associated with government procurement or some other well-defined public sector objective; are supported by defined, nonproprietary research guided by a scientific community; and have an institutional structure that allows potential users to guide the program (Langlois and Nelson, 1983). The

9

genesis and purpose of PATH are aligned to these characteristics more closely than previous HUD-sponsored housing construction R&D programs.

Though aligned with the mission of HUD, PATH is derived from the mission of the NSTC, a cabinet-level council established in 1993 to coordinate the diverse federal R&D enterprise. An important objective of the National Science and Technology Council (NSTC) is to set clear national goals for federal investments in science and technology. Created with broad participation from government, industry, and academic institutions, PATH addresses expansive goals for developing and diffusing technology and improving the construction and performance of housing (NSTC, 1999).

The NSTC C&B was organized in 1994 to work toward goals for the construction industry. The subcommittee comprises 14 federal agencies and the National Science Foundation (NSF). It works in cooperation with U.S. industry, labor, and academia to improve the lifecycle performance, sustainability, efficiency, effectiveness, and economy of constructed facilities, including housing (Badger and Magnell, 1998). It set the following construction industry goals with a 1994 baseline and a 2003 target date for completion:

1. 50 percent reduction in delivery time, since the time from the decision to construct a new facility to its readiness for service is vital to industrial competitiveness and project cost reduction;
2. 50 percent reduction in the cost of operation, maintenance, and energy over the life of the facility;
3. 30 percent increase in the productivity and comfort of the occupants of industrial facilities and in the processes housed by the facility;
4. 50 percent fewer occupant-related illnesses and injuries caused by improper or poor building design, fire or natural hazards, slips and falls, and illnesses associated with a workplace environment;
5. 50 percent less waste and pollution at every step of the delivery process, from raw material extraction, through the construction process, to final demolition and recycling of the shelter and its contents;
6   50 percent more durability (the capability of the constructed facility to continue to function at its initial level of performance over its intended service life) and flexibility (the owner's capability to adapt the constructed facility to changes in use or users' needs); and
7. 50 percent reduction in illnesses and injuries among construction workers.

The C&B recognized that its strategies for achieving these goals needed to be tailored to the needs and capabilities of the diverse segments of the construction and building industry. To explore the needs and opportunities of the housing segment, the C&B created a government/industry residential working group. With NAHBRC serving as the secretariat, the C&B residential working group convened a meeting in 1996 to review the national construction goals and craft implementation strategies for the housing industry. The residential working group identified reduction of production costs, shortened production cycle time, and improved durability as the goals with the highest priority for immediate action, and formalized seven strategies for achieving these goals (NAHBRC, 1998):

1. Establish and maintain an information infrastructure responsive to the needs of builders, designers, subcontractors, manufacturers, code officials, and consumers.
2. Develop and implement improved methods for assessing and increasing the durability of specific types of building products.
3. Improve the efficiency of the housing production process.
4. Improve the efficiency of the regulatory and new product approval processes.
5. Develop an improved understanding of the performance of conventionally built light-frame structures.

6. Foster the development and commercialization of innovative products and systems based on input from the building community.
7. Expand markets and marketability for products and systems that reduce costs or improve durability.

In response, the C&B in 1997 organized the Partnership for Advancing Technology in Housing (BFRL, 2002), which in FY1998 was funded by Congress with an appropriation of $980,000. The administration initiated the partnership as an interagency program, with HUD and DOE leading the effort. The program was funded at approximately $10 million a year from FY1999 through FY2001 and at $8.75 million in FY2002. The congressional conference report accompanying the Veterans Administration, HUD, and Independent Agencies Appropriation Act of 1999 (P.L. 105-275) directed HUD

> to cooperate with other federal agencies and the housing industry, and to engage in PATH activities that will provide research, development, testing, and engineering protocols for building materials and methods as described in the Industry Implementation Plan of the Residential National Construction Goals.

The conference report also directed that HUD provide an operating plan for the PATH program and a draft evaluation report describing progress toward meeting PATH goals. The first operating plan was submitted on March 11, 1999, and the first report on progress toward meeting the objectives outlined in the operating plan was submitted to Congress on April 22, 1999.

PATH MANAGEMENT

The administration broadened the program's mission to establish goals and performance targets that not only were similar to the national construction goals but also were intended to change the way Americans think about and build houses (see the discussion of the goals below). To achieve these goals a PATH office was established under the HUD Policy Development and Research (PD&R) program, a director appointed, and the office staffed with people detailed from other federal programs. During its most active period, the PATH office was run by the equivalent of seven full-time federal workers. The PATH director served as the secretariat of the PATH Interagency Council (PIC), which included senior representatives from eight federal agencies (U.S. Department of Agriculture (USDA), EPA, Federal Emergency Management Agency (FEMA), Department of Commerce (DOC), Department of Labor (DOL), Department of Defense (DOD), DOE, and HUD) to help guide and monitor PATH activities. The Federal Agency Working Group (FAWG) was established with the C&B as the secretariat to coordinate federal resources and strategies that had an impact on PATH goals. At the same time a PATH Industry Steering Group was created and managed by the NAHBRC to coordinate the participation of private sector partners including builders, tradesmen, manufacturers, housing providers, model code organizations, financial institutions, utility companies, insurance providers, and academic institutions.

The program started with a high level of enthusiasm from both public and private sector participants, but as noted in the committee's earlier reports (NRC 2001, 2002), the rapid growth and complex structure led to confusion in the identity of PATH and difficulty in defining the value of the program.

From 1999 through 2001, the administration included PATH in HUD's annual budget request. With the change in administration in 2001 PATH funding was not included in HUD's FY2002 budget request, but as a result of congressional action, funds for PATH were included in the FY2002 appropriation signed by the President. Funding has been provided for FY2003 and the committee assumes that the program will continue with approximately the same level of support.

The change in administrative priorities resulted in the PATH Program Office being dismantled. PATH management responsibilities were assigned to the HUD PD&R office. The program is now administered by the equivalent of 4.5 full-time federal personnel. The PIC and FAWG were disbanded. This has not eliminated interagency cooperation but it has reduced the involvement of other federal programs in the day-to-day PATH management. PATH has continued its relationships with industry and academic institutions. As noted in the following discussion, although the change in management strategies did not diminish the level of PATH activity, it impaired the program's capacity to plan future programs and adapt to evolving goals.

Between 1999 and 2001, PATH initiated 56 active programs and projects undertaken by 11 private contractors and 7 federal agencies. Funding uncertainties and delays in the development and approval of a 2002 operating plan hampered initiation of new activities in 2002 and planning for the future.

PATH MISSION, GOALS, AND OBJECTIVES

When the plan to launch PATH was announced in 1998, the President charged the program with reducing by 50 percent the time needed to move technologies to market by 2010. The President also defined housing performance goals to be accomplished by 2010, implying that they would be achieved through PATH efforts to advance technology development and diffusion. The following housing performance goals were the focus of PATH strategic planning in 1999 and 2000 (HUD, 2000):

1. Reduce the monthly cost of new housing by 20 percent or more.
2. Cut the environmental impact and energy use of new homes by 50 percent or more, and reduce energy use in at least 15 million existing homes by 30 percent or more.
3. Improve durability and reduce maintenance costs by 50 percent.
4. Reduce by at least 10 percent the risk of life, injury, and property destruction from natural hazards, and decrease by at least 20 percent illnesses and injuries to residential construction workers.

The PATH office updated its strategy and operating plan in 2000 to address shortcomings in the plan submitted to Congress the preceding year. The new plan kept housing performance goals at its center but noted that many technologies address several goals simultaneously. The strategy identified four intermediate objectives: (1) technology needs assessment; (2) technology development; (3) technology adoption; and (4) resource coordination (HUD, 2000).

The committee could identify no evidence or baseline data to indicate that the housing performance goals were measurable and achievable. The committee noted in its 2000 report that though the PATH goals are laudable targets for improving the affordability, quality, and livability of American housing they are probably not realistic, particularly for a relatively small, technology-focused program. They can give PATH general policy direction but they are not useful in strategic planning or performance assessment. The goals are influenced by numerous and complex factors, many of which are beyond the scope of the PATH program; full achievement of the performance levels set for all goals may not be possible. The committee recommended that PATH's efforts and its performance measures should be consistent with its mission and level of funding (NRC, 2001). (See Appendix D for recommendations in the committee's 2000 assessment.)

In 2001, responding to recommendations in the 2000 assessment and to committee discussions, the newly reorganized PATH management used the intermediate objectives in the 2000 strategy and operating plan to redefine the program's mission and goals. The 2001 strategy focused more on PATH's role

in facilitating the development and diffusion of technology in housing than on how the technologies affect the construction and performance of housing. PATH's mission was redefined as follows (NRC, 2002):

> To facilitate the development of new technology and advance the adoption of new and existing technologies to improve U.S. housing by fostering partnerships among industry, government, and educational institutions.

To support this mission, the strategy set out four goals that are more closely aligned with the industry implementation plan for the residential national construction goals published in *Building Better Homes at Lower Costs* (NAHBRC, 1998). That report, documenting the findings of the C&B residential working group, noted:

> The residential construction group identified research, development, and demonstration activities needed to implement each strategy [seven strategies noted above]. At the same time, the participants recognized the importance of understanding the barriers to implementing the strategies before specific activities can be undertaken. For example, in the home building field as in others, barriers to innovation have hampered the widespread use of many currently available innovative building products and methods. In all likelihood, other useful innovations have not been developed because of the perception that the industry will respond slowly, if at all, to their availability.

> Reducing barriers to innovation and expanding and improving R&D can stimulate technology advances. In turn, barrier reduction helps spur demand while R&D helps expand supply. Even barriers that cannot be mitigated should be understood because they contribute to the environment of innovation.

PATH staff in consultation with the committee drafted the following strategic goals for the program (NRC, 2002).

1. To remove barriers and facilitate technology development and adoption.

   PATH will investigate the barriers, including regulatory barriers, that impede innovation, and will actively propose and develop programs to overcome those barriers by working directly with the housing industry. This work will guide the other goals and efforts.

2. To improve technology transfer, development, and adoption through information dissemination.

   PATH will coordinate dissemination of innovation information directed to the housing industry and consumers.

3. To advance housing technologies research and foster development of new technology.

   PATH will support "background" and applied research as well as technology development activities in the housing industry. This research will be complemented by short-term and long-term assessments of specific technologies that are on the market.

4. To support the program through appropriate management and resource allocations.

These goals lack performance targets because baseline data are not available. Insufficient baseline data and unrealistic performance targets were problems the committee recognized earlier with the housing performance goals and these problems remain. The committee has used the revised goals as the basis for the 2002 evaluation in Chapter 4 and the structure of the long-term evaluation in Chapter 5; it expects that this and future assessments will form the basis for more realistic performance targets.

PATH ACTIVITIES

In the 3 1/2 years since its inception, PATH has wholly or in part funded 56 activities. Some are short-term studies that provide incremental progress toward PATH's goals; others are long-term programs to address the development and diffusion of innovation in housing.

HUD describes the activities undertaken through the PATH program as a continuum; it has grouped activities currently funded by PATH or recently completed into three categories related to their intended roles in advancing the development and diffusion of technology. The continuum is presented in Figure 2.1 as it appears on the PATHnet Web pages. Though some activities support more than one role in the continuum, in this report each is listed only once under the category the committee considered its primary role. HUD has defined the continuum, including the following list of activities, as representing the current operating plan for PATH (HUD, 2002).
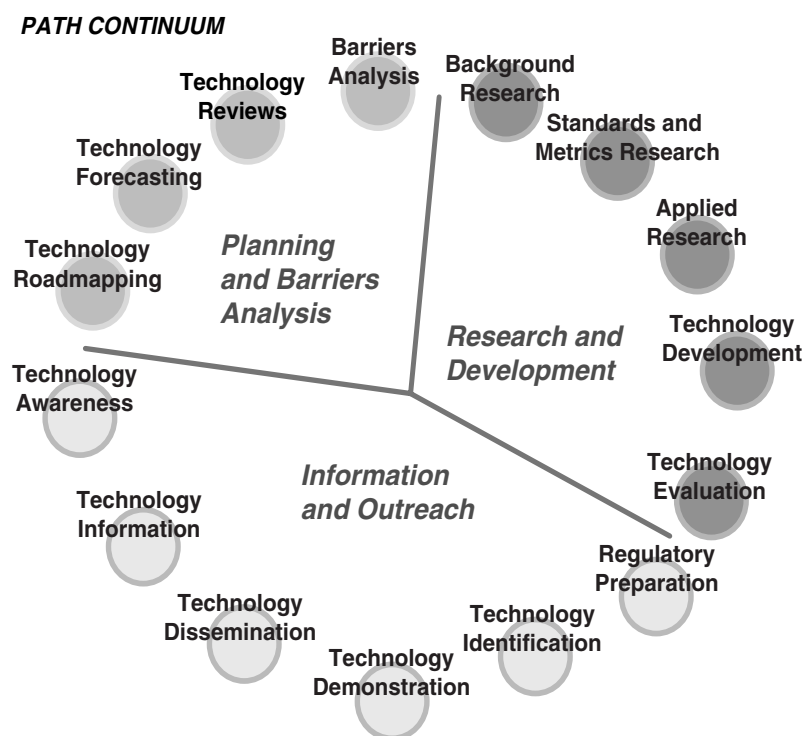
FIGURE 2.1 PATH continuum. SOURCE: PATHnet.org, HUD (2002).

1. ***Research and development*** is described as technical investigation and creation of new areas of knowledge or actual products, including innovation in materials, systems, construction processes, and management techniques. Related activities:

   - ***Technology roadmapping*** identifies industry needs by brainstorming R&D planning processes to find starting points for planning federal and private R&D investments. The PATH Industry Steering Committee, composed of approximately 150 industry representatives, identified the technology issues the roadmapping sessions were to deal with.
     — The Information Technology Roadmap addressed ways that computers, software, and communications (especially wireless and the Internet) can improve the speed, efficiency, and quality of the homebuilding process. Opportunities were identified to link information technology tools and data within and between firms to improve housing design, regulation, production, and operations.
     — The Panelized Construction Systems Roadmap addressed opportunities for shifting away from construction-in-place methods to respond to changes in the availability of skilled labor, quality control, standardization, and reduced production costs. The industry needs identified included common standards, specifications, and interfaces to give builders consistent performance choices, improved production, and delivery systems and site assembly to simplify logistics from production through assembly.
     — The Whole-House and Building-Process Redesign Roadmap took a systems-oriented view of housing construction to identify methods of building faster, at lower cost, and with higher quality. The brainstorming session explored opportunities to create an environment in the homebuilding industry that facilitates systems solutions and encourages collaboration and alliances to apply systems sciences to the process of designing and building homes.
     — The Energy Efficiency in Existing Buildings Roadmap addressed technologies that offer significant improvements in the energy consumption of existing homes. The exercise identified such promising examples as air infiltration and insulation, improvements in various elements of HVAC, and better-performing windows.
     — The Research and Development Needs for Structural Performance of Light-frame Residential Construction Roadmap explored how future R&D efforts can be directed to support better performance of light-frame residential construction. The group identified as priorities increased accessibility to existing data and technology transfer as well as methods to analyze and introduce new materials.
   - ***Background research*** encourages the enhancement of knowledge about housing applications.
     — The NSF Directorate for Engineering has a program of annual academic research grants. In the first year there was an open call for a variety of research proposals, which was refined to focus on three areas designated through PATH's technology roadmapping: information technology to accelerate and streamline home building, advanced panel systems, and whole-house and building-process redesign. NSF and PATH are also interested in partnerships between research institutions, industrial enterprises, local government, and other R&D participants in the home building industry.
   - ***Standards and metrics research*** consists of studies conducted by NIST to judge the capacities and characteristics of new and existing technologies.
     — Building for Environmental and Economic Sustainability (BEES) software is pro-

duced by the NIST Building and Fire Research Laboratory with some PATH funding. The software is intended to support building-product purchasing decisions by providing science-based information for selection of environmentally preferable products. The software, aimed at designers, builders, and product manufacturers, incorporates environmental and economic performance data for over 65 generic building products.

— PATH-D is a NIST-based program to develop and implement an Internet-based decision support system for builders, designers, and homeowners. It provides technical and economic data on the durability of alternative solutions for designing, constructing, purchasing, maintaining, and replacing the functional elements in housing. The first two building products selected for research are sealants (e.g., caulk) and coatings (e.g., paints and stains).

- *Applied research* includes work with government research laboratories to produce unbiased data on housing technologies, bridging the gap between background knowledge and actual performance.
  - — The work of the USDA Forest Products Laboratory (FPL) Advanced Housing Research Center is supported by PATH in the following areas: reliability-based design for housing in high-wind areas, effects of cyclic moisture on engineered wood-panel products, wood/non-wood composites using recycled materials, and grading rules and grade stamp criteria for recycled lumber.
  - — DOE National Laboratories are supported by PATH through the DOE Office of Building Technology, State and Community Programs, which houses the Emerging Technology program to increase awareness and demand for energy-efficient technologies while helping manufacturers and utilities bring the technologies to market.
  - — FEMA identifies and evaluates innovative techniques that may improve (1) the disaster resistance, affordability, and design efficiency of coastal construction; (2) the retrofitting of manufactured homes to improve their resistance to natural and manmade hazards; and (3) the design of home tornado shelters. PATH has funded publication and distribution of this information.

- *Technology development* covers agreements with trade associations, association-affiliated research groups, and innovative manufacturers.
  - — The NAHBRC tests new and emerging technologies, assesses technology demonstrations and field tests, develops reports on technology advances and performance, and disseminates research findings to homebuilders. PATH has funded projects on innovative structural materials and design research for residential construction, assessment of residential building engineering design and performance, and product marketing research.
  - — PATH has sponsored work at the Manufactured Housing Research Alliance (MHRA) dealing with the root causes of moisture damage, evaluation of foundation systems currently on the market and techniques for their installation, development of a Design Approval Primary Inspection Agency (DAPIA)-approved manufactured home design that replaces wood framing with cold-formed steel framing, and current regulatory hurdles that prevent use of manufactured homes in single-family attached developments.
  - — PATH-sponsored research at the American Iron and Steel Institute, North American Steel Framing Alliance (NASFA), examines corrosion of galvanized fasteners used

in cold-formed steel construction, and develops design details for hybrid cold-formed steel-wood framing, and compiles construction connection details.

— The PATH Cooperative Research Program (PATH-CoRP) gives grants to encourage innovators to rapidly introduce new products that improve housing performance. The grant program, administered by NIST, has funded work on roofing that cools and generates electricity, walls that snap together, super-insulating panels created from coal-power-industry by-products, large insulated steel forms for high-performance cement foundations and walls, energy-saving programmable thermostats, and systems engineering building techniques that cut costs and improve the quality of rural and inner-city housing.

- *Technology evaluation* makes preliminary assessments and provides market entry points for technologies.

— Field evaluation projects that have been established at 18 locations throughout the United States are helping innovative builders integrate selected technologies into housing designs; measure the cost of incorporating the technologies; evaluate how well technologies are accepted by builders, construction trade groups, and homeowners; and measure product performance.

2. *Information dissemination and outreach* covers activities that link the fragmented interests of the housing industry to facilitate sharing of information about innovation at different stages of technology development and diffusion.

- *Technology identification and demonstration* identifies emerging technologies in a wide range of categories to facilitate their speedy introduction into the market.

— The Technology Inventory, maintained by the NAHBRC, is a database listing information on new technologies that have potential for improving housing performance but have less than 20 percent of their potential market share. The inventory is used to identify technologies for field evaluations and demonstration projects.

- *Technology forecasting* keeps the homebuilding industry informed of global technological changes by monitoring the construction industry and forecasting potential applications.

— The technology scans are a series of fact sheets published by NAHBRC describing technological developments in other industries and nations and at federal laboratories. The topics include surface and interior finishes, thermal and moisture protection, safety, information technology, materials recycling and reuse, basic materials, building envelope technologies, sustainable design strategies, design and Internet tools, indoor environmental quality, electrical energy/power systems generation, plumbing, and heating, ventilating, and air conditioning.

- *Technology dissemination* documents builders' and homeowners' success stories showing how advanced and cost-effective technologies perform in real-world applications.

— The stories report the experiences of builders who are adopting new technologies.

- *Technology information* about technologies and resourceful building practices is provided at the following two Web sites.

— ToolBase is a Web portal operated by NAHBRC to provide technical information on building products, materials, new technologies, business management, and housing systems. A hotline for direct telephone assistance and an e-mail newsletter augment the Web site.

— PATHnet is affiliated with the HUD USER Web site to provide information on PATH activities and access to PATH-sponsored publications and reports.
- ***Technology awareness*** activities sponsored by PATH and other housing-related organizations around the world are listed on a calendar. They are supplemented by press releases and news updates from HUD, PATH partners, and other industry sources.
    — Activities undertaken by HUD and HUD USER include special outreach efforts: seminars; the *FEMA Design Quality Manual*; weatherization; a "Ten Most Wanted" Hazard Resistance Workshop; prescriptive packages; and the *FEMA Coastal Construction Guide*. PATH has published brochures and manuals and conducted events in coordination with other federal agencies and private industry.

3. ***Planning and barriers analysis*** activities forecast potential areas of innovation and identify institutional, cultural, regulatory, and financial barriers to them.
    - ***Regulatory preparation*** works to ensure that outdated building codes do not keep a product from entering the marketplace.
        — The National Evaluation Service (NES) prepares technical reports describing building construction materials or products and listing conditions necessary to ensure compliance with each model building code.
        — The National Conference of States on Building Codes and Standards (NCSBCS) manages the Streamlining project as a cooperative effort among 55 national organizations and federal, state, regional, and local governments to bring better management practices to regulation of the design and construction of all types of buildings throughout the United States.
    - ***Technology reviews*** are case studies that analyze the technical, regulatory, marketing, and financial factors that contribute to the success or lack of success of a technology in the market.
        — *Commercialization of Innovations: Lessons Learned* asked practitioners using exterior insulated finishing systems (EIFS) and wood I-joists to reflect on their experiences and relate what they thought worked well and what they would do differently. The report provides general advice that could be applied to the introduction of new technology by other private parties and public officials concerned with innovation in the housing industry.
    - ***Barriers analysis*** conducts market research to identify institutional barriers to housing technology research, development, and the adoption of innovations.
        — Issue groups look at housing technology problems faced by PATH partners who have found effective alternatives and solutions. The groups consider technology roadmapping, finance, insurance, quality and labor, and consumer education.
        — ToolBase Roundtables are meetings and accompanying reports on specific housing technology interest areas that intersect with PATH's work. Recent roundtables have addressed changing demographics, labor shortages and productivity in the homebuilding industry, new horizons in quality management, supply chain solutions from the senior homebuilding industry, the manufactured home, certification of products for the mature market, technology innovation, and the home appraisal industry.
        — The Technology Barriers Analysis Project is exploring industrial, institutional, financial, regulatory, and cultural barriers to the advancement of housing technology. The study is reviewing existing literature to identify issues for further exploration and alternatives for overcoming barriers.

The following organizations, as PATH partners, are undertaking the funded activities listed above; most of these partners also provide funding and in-kind support.

- Certainteed, Inc.
- Department of Energy (DOE)
- Environmental Protection Agency (EPA)
- Federal Emergency Management Agency (FEMA)
- Forest Products Laboratory (FPL)
- Manufactured Housing Research Alliance (MHRA)
- National Association of Home Builders Research Center (NAHBRC)
- National Conference of States on Building Codes and Standards (NCSBCS)
- National Evaluation Service (NES)
- National Institute of Standards and Technology (NIST)
- National Science Foundation (NSF)
- North American Steel Framing Alliance (NASFA)
- Rand Corporation
- Steven Winter Associates
- University of Georgia
- Virginia Polytechnic Institute

FINDINGS AND RECOMMENDATIONS

Finding: PATH is an ambitious program intended to initiate significant change in an industry that affects 14 percent of the U.S. economy (NAHB, 2002) by sponsoring an annual program of activities valued at $8 million to $10 million. As a partnership it is intended to focus attention on the development and diffusion of technology for the housing industry and to use this attention to leverage action on related government, academic, and industry programs. PATH evolves by responding to its stakeholders and the recommendations of the committee. The committee has observed positive change as the program matures.

Recommendation: PATH should continue to respond to input from its diverse stakeholders and the evaluations of this committee by fine-tuning its mission and goals for increasing the rate at which technologies are developed and diffused in the housing industry.

REFERENCES

Badger, W.W., and Magnell, C.O. 1998. *National Construction Goals: Creating a Vision and Direction for the U.S. Construction Industry.* Proceedings of the 31st Annual Conference of the Associated Schools of Construction. Available on the Web at http://asceditor.unl.edu/archives/1995/badger95.htm. Accessed September 18, 2002.

BFRL (NIST Building and Fire Research Laboratory). 2002. NSTC Subcommittee on Construction and Building, available on the Web at http://www.bfrl.nist.gov/860/c_b/cbpartnershipforadvancingtechnologyinhousing.htm. Accessed September 18, 2002.

Geller, H., and Thorne, J. 1999. *U.S. Department of Energy Office of Building Technologies: Successful Initiatives of the 1990s.* Washington, D.C.: American Council for an Energy-Efficient Economy.

HUD (Department of Housing and Urban Development). 2002. PATH: A Public-Private Partnership for Advancing Housing Technology. Available on the Web at http://PATHnet.org. Accessed September 18, 2002.

HUD. 2000. *Partnership for Advancing Technology in Housing: Strategy and Operating Plan*. Washington, D.C.: Department of Housing and Urban Development.

Langlois, R.R., and Nelson, R.N. 1983. Industrial Innovation Policy: Lessons from American History. *Science* 219 (2): 814-18.

NAHB (National Association of Home Builders). 2002. *Housing, the Key to Economic Recovery*. Washington, D.C.: National Association of Home Builders.

NAHBRC (National Association of Home Builders Research Center). 1998. *Building Better Homes at Lower Costs: The Industry Implementation Plan for the Residential National Construction Goals*. Upper Marlboro, Md.: NAHB Research Center.

NRC (National Research Council). 2002. "The Partnership for Advancing Technology in Housing (PATH) 2001 Assessment*,"* letter report, February 13, 2002. Washington, D.C.: National Research Council.

NRC. 2001. *The Partnership for Advancing Technology in Housing: Year 2000 Progress Assessment of the PATH Program*. Washington, D.C.: National Academy Press.

NSTC (National Science and Technology Council). 1999. *Construction and Building: Interagency Program for Technical Advancement in Construction and Building*. Washington, D.C.: National Science and Technology Council.

3

PATH's Approach to Advancing Housing Technology

INTRODUCTION

The mission of PATH is to improve the performance of housing and the housing industry by fostering the development and diffusion of innovative technology. PATH's original goals were to improve the performance and reduce the cost of housing. The NRC committee noted in its 2000 assessment report that the complexity of housing performance issues and the limited role of technology in determining housing cost made housing performance and affordability goals inappropriate measures for PATH (NRC, 2001). PATH has now refocused its goals on intermediate outcomes (removing barriers to innovation, disseminating information, and fostering research) that affect the rate of innovation in the housing industry.

By refocusing its goals, the program has created an opportunity to directly assess its impact on the housing industry. However, PATH planning and evaluation have been hampered by the lack of housing-specific paradigms to describe the development and diffusion of innovation and by the limited amount of baseline data. Other than an estimate of the dollars spent on housing-related R&D, there are no data on innovation in housing construction that measure the rate at which new technologies are developed and adopted. There is general agreement that the housing industry needs to be more innovative, but this is mostly based on anecdotal information (NAHBRC, 1998).

PATH was created on the hypothesis that there is insufficient innovation in housing. It was developed as a program that supports activities to address issues that are perceived by the housing industry to be the primary causes of the problem: barriers to innovation, lack of accessible information, and insufficient R&D (NAHBRC, 1998). Yet a number of technologies broadly adopted in the last quarter century—such as power nailers, engineered wood products, house wraps, energy-conserving glazing, and prefabricated components—have made homes easier to build and more comfortable to live in.

Although the approaches PATH has taken may be appropriate, much more information is needed to fully evaluate the lack of innovation, the appropriateness of activities to address the problem, and how they affect the housing industry. Lacking specific information on the development and diffusion of

21

technology in housing, the following discussion applies general theories of innovation to the information available on the housing industry to describe what the committee believes is an appropriate course for PATH. This general information illustrates what could be expected of PATH and is a baseline for the committee's program evaluation in Chapter 4.

ADVANCING INNOVATION IN HOUSING

The need for PATH described in the committee's 2000 assessment report (NRC, 2001) arises from economic and social factors inherent in the housing industry in the United States. These include specific market failures relating to public goods, externalities, and information asymmetries.[1] PATH has the potential to effectively address these market failures by identifying, understanding, and removing barriers to innovation, disseminating information to all participants in the housing industry, and undertaking research itself and facilitating privately sponsored research.

The application of technology to housing design, construction, and operation offers opportunities for improved affordability, energy efficiency, comfort, safety, and convenience for consumers. New technologies and production processes could help resolve serious issues facing housing producers, including labor shortages, interruptions due to inclement weather, quality control, and theft and vandalism. However, it is generally believed that realizing these benefits broadly is, to a large extent, hindered by characteristics of the housing industry that inhibit the development and diffusion of innovations. The challenge for PATH is to capitalize on the momentum of ongoing technology development in order to increase the rate of innovation in the industry. To meet this challenge, it needs to plan a program that responds to the properties of the housing industry that determine the development and diffusion of new technologies.

PROMOTING INNOVATION

A body of knowledge and research on the nature and dynamics of the development and diffusion of innovation has been built over the last 100 years (CI, 2002). Previous reports on innovation in housing (Blakely and Shepard, 1996; Koebel, 1999) have used the innovation paradigm published by Everett Rogers (1995) and provide some basis for applying this paradigm to the evaluation of PATH.

Innovation can be considered anything that seems new. It can be new to the world, the industry, a company, or a person. For this report, innovation is synonymous with new technology, both hardware (materials, tools and appliances) and software (process and information). For PATH to be successful, it needs to influence the development and diffusion of new technologies so as to increase the probability of their success.[2] By facilitating technology transfer, PATH-sponsored activities can help define the

---

[1]Public goods are goods available to all that are not diminished by use; e.g., standards for construction materials and techniques represent public goods. Externality occurs when a firm pays only part of the costs for or receives only partial benefits from its actions, e.g., adopting unproven technologies when doing so would benefit competitors, who would not bear the risks. A fundamental principle underlying competitive markets is that both buyers and sellers have all the information available about products; if they have different amounts of information, asymmetries give rise to informationally imperfect markets.

[2]Rogers has identified five characteristics of innovations that affect their rate of adoption and their ultimate success in diffusion and improving outcomes: (1) relative advantage or perceived advantage, (2) compatibility with existing systems, (3) complexity or ease of use and understanding, (4) trialability, the possibility of use on a limited basis with a limited commitment, and (5) observability, the ability of persons other than the adopter to see the results of the innovation (Rogers, 1995).

opportunities for and potential advantages of innovations. By bringing together creators and adopters of innovation, PATH can help reduce incompatibilities and address potential complexities that might become barriers to innovation. PATH-sponsored field evaluations and demonstration projects have the potential to increase the trialability and observability of products and thus reduce the time needed for the industry to observe the benefits of new technologies. By eliminating barriers and increasing the rate of diffusion, PATH can provide incentives for private investment in R&D.

Sources of innovation are many: innovation may be driven by the basic curiosity of scientists looking for new knowledge, or it may result from the need to solve a particular problem or from the synthesis of different lines of research that generate new ways of looking at old problems (Smith, 1987). The source of innovation can occur at any point in the supply chain from end-users to material suppliers, manufacturers, researchers, and others whose jobs or well-being are affected by new technologies. Eric von Hipple has shown through numerous case studies that innovation will take place where there is greatest economic benefit to the innovator (von Hipple, 1988). Thus, programs intended to stimulate innovation need varied approaches that reach all possible sources of innovation and stimulate communication among all possible stakeholders.

Earlier attempts by the federal government, including the Civilian Industrial Technology Program initiated in 1962 and Operation Breakthrough initiated in 1968, failed to have the desired effect on the housing industry in part because they emphasized the development of technology without addressing the barriers to diffusion.

> The characteristics of the existing housing production system were seen as impediments to change, but no apparent attention was paid to diffusion strategies for new technologies. Nor was there any effort to understand the benefits of an existing social system that resisted substantial change. Rather than increased understanding, the outcomes of these early efforts to promote technology in housing production reinforced a sense of failure and irrational resistance to change. (Koebel, 1999)

The committee previously recommended that, at this early stage of its development, PATH should emphasize activities aimed at increasing the diffusion and adoption of existing technologies (NRC, 2001, 2002). As Rogers noted:

> Getting a new idea adopted, even when it has obvious advantages, is often very difficult. Many innovations require a lengthy period, often of many years, from the time they become available to the time they are widely adopted. Therefore, a common problem for many individuals and organizations is how to speed up the rate of diffusion of an innovation. (Rogers, 1995)

Rogers defines diffusion as the process by which an innovation is communicated among members of a social system through certain channels over time. A federal program like PATH is ideally suited to enhance communication by developing and disseminating information about innovations.

REMOVING BARRIERS

The process that guides a technological concept from creation to ultimate market acceptance is tremendously complex. It is logical to assume that consumers would welcome technologies that perform better and are more affordable and that builders would be standing in line to provide these advances to their clients, but there are often barriers that slow or prevent this process. These barriers need to be identified, understood, and overcome if innovation is to be increased in the homebuilding

industry. A rigorous effort will be required to fully identify and understand the barriers. The following is a summary of barriers to innovation identified by the committee as possible initiatives for further action by PATH:

- **Education:** Home construction is a trades-based industry with a workforce that has relatively little formal education (EUROPA, 2002); the industry has a pervasive culture of experiential learning (on-the-job training). The level of education attained by a homebuilder has been shown to have greater influence on the adoption of new technologies than the fragmented structure of the industry, which is often cited (Blakely and Shepard, 1996). To reduce this barrier, education for the housing industry should be systemic and embrace all who are involved in the network that connects creation of an innovation to market assimilation. PATH could help the building industry examine the way it trains its workforce. Education in conventional and innovative technologies is important for those in the workplace, markets, and professional service. Collaborations between industry, employee groups and unions, professional societies, and academia can lead to much-needed workforce education programs in both traditional and innovative formats.

  It would be erroneous for PATH to focus its efforts solely on the supply side of the housing economy. A basic economic principle is that any program that attempts to affect the supply of goods or services should also pay attention to the demand for such goods or services to prevent distorting the market. This could be achieved, in part, through partnership with the U.S. Cooperative Extension Service of the Cooperative State Research, Education and Extension Service (CSREES) within the USDA. CSREES is linked to every county in the country through working arrangements with each state's land grant university. Many of these universities have Extension Housing Specialists on their faculties who are engaged in large-scale consumer education programs.

- **Risk:** Huge costs are assessed to any company that needs to defend itself in a civil suit—even if it is not at fault. The cost of damage awards can be even larger when companies are actually in the wrong. In addition, the possibility of callbacks and the expense of unanticipated repairs discourage builders from trying new products. Builders are thus pressured to adopt an ultracautious approach to protect both their profit margins and corporate reputations. Also anxious to avoid risk are the officials who are responsible for ensuring the general safety and welfare of the public. Building officials want proof that new technologies work. It is unlikely that they will encourage or even allow use of an unknown technology. Homeowners consider the purchase of a home to be complicated and intimidating. This makes consumers also unlikely to accept the risk associated with new technologies.

  Officials, builders, and consumers need to be informed about the benefits and proven performance of new technologies in order to create a consumer pull for innovation. The sharing of experiences among colleagues and peers is an important step toward removing the barrier of perceived risk due to insufficient knowledge about a process or material. PATH can also facilitate private programs for the evaluation, testing, and certification of housing innovations.

- **Fragmentation:** Participants in the system may share an interest in promoting innovations that improve the delivery and performance of housing, but a fragmented system restricts peer interaction. Participants are separated by inconsistent terminology, gaps in technical expertise, and reluctance to trust the information conveyed because of conflicting business interests. PATH has the potential to bring all the participants together to convey unbiased information about new technologies.

- **Regulations:** There are several model codes, with numerous editions and thousands of code interpretations, enforced in this country. Neighboring municipalities, even in states that have a statewide building code, often have different interpretations and requirements for a given construction application. The extent of local discretion and the resultant inconsistency in approval of new technologies increase the difficulty of introducing new technologies. Few if any regulations promote innovation and enhanced performance.

- **Cultural values:** Consumers gravitate toward traditional, familiar products that present little risk. In general, consumers' housing choices display a preference for products that resemble the homes they grew up in when making housing decisions (Deane, 2001). Off-the-shelf technologies and effective procedures to improve sustainability, such as the use of engineered framing systems that consume less lumber, reduced environmental impact of alternative materials, or construction recycling practices are not valued or even considered by most homebuyers.

DISSEMINATING INFORMATION

The transfer of information is at the heart of all phases of the development and diffusion of new technology, and the channels of communication for the housing industry are many and varied. No single approach will effectively diffuse all the information needed to advance technology in housing. Successful technology transfer for innovative R&D often requires cross-disciplinary communications that operate outside normal scientific and technical channels. Mass media have proven to be effective in the early stages of adoption, but the rapid spread of information to later adopters depends on peer-to-peer communication, which in turn requires better-defined, more specialized channels for the information adopters to understand and evaluate new technologies. In order for PATH to use information as a tool for eliminating barriers, there needs to be a thorough understanding of the myriad channels of communication and their unique qualities of language and custom.

The source and quality of the information as well as the means of communication all need to be considered when information to advance technology is disseminated. The source conveys to the receiver a sense of the authority and reliability of the information. Usually the sources that most closely resemble the receiver (peers) are the most trusted; yet interdisciplinary communication is also important to the development and diffusion of new technology (Rogers, 1995).

PATH is in the position of a switchboard to connect all the channels of communication. It can accomplish its goals by ensuring the clarity and reliability of the information and using all appropriate means to transfer it.

FOSTERING RESEARCH AND DEVELOPMENT

Section 833 of the Housing and Community Development Act of 1992 directed HUD to study the extent of research in the United States housing industry, its success in developing and marketing new technologies for housing, and the extent of U.S. competitiveness in this field. The study, prepared for HUD by NAHBRC, found that housing research in the United States was fragmented, uncoordinated, unresponsive to the needs of builders and consumers, and lagging behind the efforts of our trading partners (HUD, 1994). The result is minimal investment in R&D (0.2 percent of the value of new housing construction in 1992) compared to the construction industry overall (0.5 percent of the value of construction in 1992) and a composite of all industries (3.7 percent of the value of sales in 1992) (NAHBRC, 1998).

PATH-sponsored research needs to address the needs of the total housing system. With its limited

resources the program also needs an agenda that allows it to use its resources where they can be the most effective in achieving the program's goals. The committee believes that the program should emphasize (1) research that can be broadly applied to the development of new technologies and (2) research to better understand the processes for development and diffusion of technology in housing in order to facilitate innovation. Research is needed to plan a program that can increase the rate of innovation in housing and stimulate additional government and private investment in experimental development of new technologies.

A study published in the June 2002 *Forest Products Journal* that investigated the adoption and diffusion of building innovations among single-family homebuilders in the Pacific Northwest is an example of the type of research that is needed. The report emphasized the importance of properly targeting market segments to facilitate adoption and diffusion of new technologies. The researchers, Fell, Hansen, and Punches, state, "It is important to identify those builders who will be the first to use a product when it is launched because these customers represent early sales, but more importantly, they start the process of product diffusion." The authors mention: "A primary motivation for this study was to find out how builders learn about new building products" (Fell et al., 2002). This study suggests that successful diffusion requires a good understanding of how market segments function and that it is critical to study demographic indicators like location, customer class, and material supplier profiles.

FINDINGS AND RECOMMENDATIONS

Finding: The basis for PATH was the hypothesis that innovative technologies can improve housing performance and reduce costs and that there is a need for intervention to increase the rate of innovation in the housing industry. The committee supports this hypothesis and the need for a program like PATH. However, there are insufficient data to determine the optimum rate of innovation in the housing industry, what is needed to increase the rate of innovation, and how innovation affects housing costs and performance. Research on the development and diffusion of technology in housing is needed to validate the hypothesis, support an effective program plan, and measure its effect.

Recommendation: PATH should continue to base its work on the assumptions that (1) intervention is needed to increase the rate of innovation in the housing industry and (2) this can be accomplished by identifying, understanding, and removing barriers to innovation, increasing dissemination of information, and fostering research. Some PATH funds should be used to improve the program's understanding of how innovations are developed and diffused in the housing industry, and to measure the value of the PATH program.

REFERENCES

Blakely, D.M., and Shepard, E.M. 1996. The Diffusion of Innovation in Home Building. *Journal of Housing Economics* 5: 303-22.

CI (The Communications Initiative). 2002. Planning Models: Diffusion of Innovation. Available on the Web at http://www.comminit.com/pmodels/sld-5368.html. Accessed September 25, 2002.

Deane, D. 2001. Tried and True, in a High-Tech World, Home-Building Materials Stay Decidedly Low-Tech, with Proven Results. *Washington Post,* May 19, H1.

EUROPA (European Union On-Line). 2002. Barriers to Innovation. Available on the Web at http://europa.eu.int/comm/enterprise/construction/innov/innobar.htm. Accessed September 5, 2002.

Fell, D., Hansen, E.N., and Punches, J. 2002. Segmenting Single-Family Homebuilders on a Measure of Innovativeness. *Forest Products Journal* 52 (6): 28-34.

HUD (Department of Housing and Urban Development). 1994. *Domestic and International Housing Research, A Report to Congress*. Washington, D.C.: Department of Housing and Urban Development.

Koebel, C.T. 1999. Sustaining Sustainability: Innovation in Housing and the Built Environment. *Journal of Urban Technology* 6 (3): 75-94.

NAHBRC (National Association of Home Builders Research Center). 1998. *Building Better Homes at Lower Costs*: *The Industry Implementation Plan for the Residential National Construction Goals*. Upper Marlboro, Md.: NAHB Research Center.

NRC (National Research Council). 2002. The Partnership for Advancing Technology in Housing (PATH) 2001 Assessment, letter report, February 13, 2002. Washington, D.C.: National Research Council.

NRC. 2001. *The Partnership for Advancing Technology in Housing: Year 2000 Progress Assessment of the PATH Program*. Washington, D.C.: National Academy Press.

Rogers, E.M. 1995. *Diffusion of Innovations*. New York: Free Press.

Smith, R. 1987. The Roots of Innovation. *British Medical Journal* 295: 1335-38.

von Hipple, E. 1988. *The Sources of Innovation*. New York: Oxford University Press.

4

2002 Assessment of PATH

INTRODUCTION

The current federal interest in performance evaluation is driven in large part by the Government Performance and Results Act of 1993 (GPRA). The act requires federal agencies to develop strategic plans, performance measures, annual performance plans, and performance reporting. However, creating performance measures for R&D-related programs has proved very difficult. The nature of the innovation process and the number of factors that influence the outcome of R&D projects make it very difficult to identify performance indicators. The extended time between initiation and measurable results increases the complexity of the problem. The amount of money spent on R&D has been used as a measure, but it assesses only the level of effort and does not evaluate results achieved. Output measures need to be defined for specific research endeavors; evaluation of outcomes often depends on qualitative peer review (GAO, 1997).

The evaluation of PATH is complicated further by its dual role in fostering R&D on new technologies and increasing diffusion of existing technologies. The committee's assessment of the PATH program critiques its implementation and the effectiveness of its activities to date and makes recommendations for its continuing evaluation and improvement.

GPRA specified that performance evaluation should incorporate the following elements:

1. Performance goals to define the level of performance to be achieved by a program activity;
2. Goals expressed in an objective, quantifiable, and measurable form;
3. Resources required to meet the performance goals;
4. Performance indicators used in measuring the outputs and outcomes of each program activity;
5. A basis for comparing actual program results with performance goals; and
6. The means to verify and validate measured values.

UNCERTAINTIES AND ASSUMPTIONS

The committee's 2002 assessment of PATH is based on information provided by HUD and PATH participants (see Appendix C for a list of presentations). It relies on the judgment and expertise of the committee, whose members have expertise in a broad range of housing issues and the application of housing technology (see Appendix A for biographies of committee members). Except for PATH budget data, all of the documentation of PATH activities reviewed by the committee is available on the Internet at either the PATHnet or ToolBase Web sites (HUD, 2002; NAHBRC, 2002a). Though performance metrics of PATH activities and statistical analyses of innovation in the housing industry are needed for a truly rigorous program evaluation, they were not available. Data on the rate of development and diffusion of new technologies are also needed to make the best use of Rogers' innovation paradigm to better understand innovation in the housing industry and observe the impact of the program.

Because analytical data were not available, this evaluation relies almost entirely on opinion and anecdotal information gathered from discussions with people involved in the housing industry. Given the limits of time and resources available to a volunteer review committee, it did not collect new data by surveys or structured interviews. The committee believes that HUD should collect such data in the future as part of a continuous, comprehensive assessment of PATH activities and their effects, and to respond to all the performance evaluation elements specified in GPRA.

This evaluation assesses selected activities and addresses progress toward achieving PATH goals. It includes qualitative evaluation of the output of the activities to provide direction for improvement of the program. The committee believes that the value of PATH should be judged on its potential for correcting deficiencies and achieving the outcomes defined by its goals in the future. The assessments of intermediate outcomes (measured change in the development and diffusion of technology in housing) and the ultimate outcome (improved performance of homes and home construction) are discussed in Chapter 5 on long-term assessment.

PROGRESS TOWARD ACHIEVING GOALS

The committee recognizes the need for PATH to address the continuum of innovation and technology diffusion but, as noted in previous reports, believes that PATH should give priority to removing barriers and facilitating the adoption by the housing industry of new technologies. Though addressed as a separate goal, barrier removal is also inherent in all aspects of technology development and adoption and is therefore a part of the mission statement and of all PATH goals and objectives. The committee considers technology transfer and information dissemination to be integral to achieving all aspects of the program's goals.

The principal PATH mission is to advance technology that improves housing performance (affordability, durability, sustainability, and safety). This approach is distinct from technology advancement programs aimed at increasing the economic competitiveness of an industry. PATH goals and objectives are segments of a continuum that encompasses stimulating innovation, facilitating the diffusion of technology, and administering a true partnership of government, industry, and academic institutions.

This evaluation considered all of the 56 PATH activities undertaken by 11 private contractors and 7 federal agencies from 1999 through 2001, a few of which are addressed here (all PATH activities are discussed in Chapter 2 and described in detail on the Web at PATHnet.org). The committee chose in this report to discuss those activities it believes likely to have the greatest impact on the program's current goals, evaluating related activities together. This report describes how well the activities have

been performed and how well they support the PATH mission and goals. The total PATH program is evaluated on both achievement toward each goal and the committee's perception of accomplishments of the program as a whole.

Goal 1: To Remove Barriers to and Facilitate Technology Development and Adoption

Field Evaluations, Demonstrations, and Pilot Projects

PATH-sponsored field evaluation, demonstration, and pilot projects generate information that will benefit manufacturers, builders, consumers and most other housing stakeholders by providing examples of how technologies perform and how barriers to diffusion of innovation have been eliminated. Information from the 27 projects so far undertaken, which employ more than 35 technologies, can help manufacturers improve their products (NAHBRC, 2002a,b). This has the potential to significantly increase the rate of innovation in housing by providing data that can reduce the perceived risks of new technologies for all participants. A wide variety of technologies have been used at sites that are representative of regional variation across the country. The program emphasizes single-family homes, which is appropriate for this stage in the program.

The program contributes to achieving the PATH goals of disseminating information and eliminating barriers, but improvements are needed for it to achieve its full potential. The problems begin with the distinctions between field evaluations, demonstrations, and pilots. PATH has defined the three variations, but their applications overlap, which confuses both the meaning and the organization of the program. A single program to gather information and document the use of new technologies in the field would allow for greater administrative efficiency. Discussions on PATHnet.org note that field evaluations are generally limited to a few housing units and a few technologies; larger projects are considered demonstration sites and pilots (HUD, 2002). The committee believes that the focus should be on the technologies and that the program should be organized to elicit reliable, reproducible data on product performance with consistent and concise documentation.

The current documentation of demonstration projects is organized by housing project and builder, with no information to link the experience and outcome at one site to the knowledge gained from another. Engineers, architects, and builders coming to PATH will probably be looking for information about a technology, not a builder—the PATH Builder's Technology Stories are more appropriate vehicles for spotlighting innovative builders. Documentation for some demonstration sites provides no useful information about the technologies other than that they were used on a given project, e.g., Takoma Village Cohousing (Steven Winter Associates, 2001). The reader can search through several reports to compare outcomes, but this is difficult. The technology inventory fact sheets may be intended to serve this purpose, but they do not currently provide this information; nor is there a reference in the demonstration and evaluation reports. Though projects have been documented at inception, there is little explanation of how they proceed through to evaluation and when the reader should expect to see final results.

The reports could also benefit from further review to address inconsistencies like those found in the Washington Square project report that compared the performance of insulating concrete forms (ICFs) to 2×4 frame construction, but then stated that the builder's alternative was 2×6 frame construction (NAHBRC, 2002c). This inconsistency made it difficult for the reader to assess the builder's decision. In some demonstration and evaluation projects, such as Warren Builders' Homes, Albertville, Alabama (NAHBRC, 2002d), technologies have been combined (HVAC system and enclosure system) making it more difficult to evaluate a single technology.

There is a definite and immediate benefit from project-oriented public relations efforts for the builder, the technologies, and the PATH program, but the lasting value of demonstration and evaluation activities will come from creating a database of product performance that can be used to compare how effective a technology is across different applications over time. This will require standardizing the protocols for collecting and analyzing both metered data and anecdotal information from surveys and interviews. The performance database of the results of demonstration projects can then be of value to participants in all stages of technology development and serve as the basis of reports for specific channels of communication.

Research on Barriers

Barriers research is needed to understand the impediments to development and diffusion of technology for housing, as emphasized in the industry implementation plan, which noted the importance of identifying and understanding barriers before implementing strategies or taking specific actions (NAHBRC, 1998). It is noted also in the PATH continuum (operating plan) that "To develop successful activities and services for the housing industry, PATH must understand barriers to housing technology research and adoption. Barriers can be found in the building process; in the economic, social, or political aspects of a housing technology; or in general housing characteristics" (HUD, 2002).

PATH has initiated several projects, among them roundtables and focus groups, technical background ("white") papers, and surveys, to increase understanding of barriers to innovation in housing; however, the committee believes that the barriers research program has not been well planned and no visible progress has been observed to date.

Though the PATHnet continuum lists seven ToolBase roundtables as contributing to barriers analysis, only one, Housing Innovation and the Appraisal Process, directly addressed barriers to innovation. The others were concerned with more general housing issues, such as demographics and labor supply, senior housing markets, and quality control. Roundtable discussions can be valuable as a first step in barriers research, but collecting anecdotal information in open discussion needs to be followed by more in-depth and coordinated research and analysis.

In its 2001 interim assessment the committee applauded the development of a market survey instrument (NRC, 2002); it is disappointing that no further action has been taken to learn more about consumer response to new technologies. PATH launched a new technology barriers analysis project in September 2001 to explore specific industrial, institutional, financial, and cultural barriers to the advancement of housing technology but the results were not available to the committee. The committee concurs that barriers should be thoroughly investigated to learn more about the most effective channels of communication and identify opportunities to reduce impediments to innovation. This effort should be a priority; its scope should be broader and its schedule shorter.

Regulatory Barriers

PATH has two initiatives that deal with regulatory barriers: (1) the NES helps technology developers to address potential regulatory barriers to the acceptance of innovative technologies, and (2) the NCSBCS Streamlining project promotes better management practices for regulation of the siting, design, and construction of all types of buildings throughout the United States. The committee believes that support for these activities is worthwhile, but they are unlikely to remove regulatory barriers to innovation. PATH needs to undertake research to better understand regulatory issues and address them with coordinated programs that also improve the regulatory process at the national, state, and local

levels. As noted in the committee's earlier reports, the HUD code for manufactured housing could be used as a model for improving local codes. Programs to create tools and educational resources for local code officials should be part of PATH's comprehensive program to remove regulatory barriers (NRC, 2001, 2002).

Findings and Recommendations

Finding: Understanding and removing barriers to the adoption of innovative technologies in housing is key to the success of the PATH program. Removing such barriers will increase the rate of innovation by reducing the time needed for diffusion of new technologies, thereby providing additional incentive for private investment in R&D.

Recommendation: PATH should increase the percentage of program resources allocated to the removal of barriers to the adoption of innovative technologies in housing, plan a comprehensive research program to better understand barriers to innovation, and use the knowledge gained from this research as the basis for effective programs to remove barriers.

Finding: It is important for information on the performance, costs, and benefits of new technologies to be disseminated in a useful format to help remove multiple barriers to innovation. To make the program more effective, the process should include feedback on the decisions that potential new adopters make based on the information they receive from PATH. PATH's demonstration and evaluation projects have not been publicized adequately, nor has PATH developed and documented the data needed to really help homebuilders, regulators, homebuyers, and other housing industry participants understand new technologies and determine whether they should be adopted.

Recommendation: PATH should expand its program of demonstration and evaluation projects and create a database that details the relative advantages or disadvantages, compatibility with existing systems, trialability,[1] and benefits of new technologies. There should be assurance that the data are accurate, reliable, and comparable. The information should be accessible to all members of the housing industry. PATH should coordinate programs to analyze and interpret the data for the industry, regulators, and consumers.

Goal 2: To Improve Technology Transfer, Development, and Adoption Through Information Dissemination

Technology Inventory and Scan

The technology inventory and technology scan are lists of new technologies at various stages of development that have the potential to increase housing performance. The lists are created from information provided by manufacturers and researchers with no PATH-funded performance evaluation.

---

[1]"Trialability" is defined by Rogers as "the degree to which an innovation may be experimented with on a limited basis" (Rogers, 1995).

Potential adopters use the lists as a technology catalogue; they are also a source of ideas for further innovation and a tool for planning PATH activities, such as demonstration and evaluation projects (HUD, 2002; NAHBRC, 2002a). The committee supports the concept of the technology inventory and scan and believes they can play a significant role in the development and diffusion of innovation in housing.

The PATH technology inventory and scan cover technologies still in the laboratory through more mature technologies that still have significant barriers to diffusion. The inventory list is currently limited to technologies that have less than 20 percent of their potential market share. It is not clear to the committee how market performance is determined other than as part of the data submitted by manufacturers. Whether or not the information is reliable, the committee believes that limiting the lists to 20 percent market penetration is inappropriate. Because of this limitation only innovators and early adopters use the list—a mere 16 percent of the potential audience. By the time middle and late adopters consider a technology that is new to them it would no longer be on the list, so information would not be available from PATH. A more inclusive inventory would facilitate comparison of the relative advantages of newer technologies and more mature technologies that have overcome barriers to diffusion.

PATH documents refer to technologies that are or were on the inventory list as "PATH technologies." This designation is inaccurate and confusing. Since the PATH program has had nothing to do with the development of such technologies nor even conducted an independent evaluation, the assertion that the technology has an affiliation with the program is not warranted.

PATH documents refer to technologies that are no longer on the list as "graduates," which is also confusing. The term implies that a series of steps were taken to achieve a specified outcome, but this is not documented and probably not justified for most technologies. The committee sees potential benefit in a PATH brand identity like ENERGY STAR, but a clear definition and program plan are needed before such an effort is undertaken.

The key to making the technology inventory and scan effective tools for information dissemination and technology transfer is consistent, authoritative, and reliable documentation. The technology descriptions need to be improved because the current technology fact sheets are more like marketing documents than unbiased factual descriptions (for example, "well suited for" and "quick installation" are used to describe aluminum-plastic composite water piping and "superior performance" and "ease of installation" to describe composite window frames). The impact of marketing-like language is increased when there is no attribution for the information. Although the disclaimer states that the fact sheet does not constitute an endorsement, it does not inform the reader that it is based on unverified claims of the manufacturer.

The fact sheets are also inconsistent and often incomplete in the level of detail provided, which makes evaluation and comparison of alternative technologies more difficult. For example, for recycled plastic-wood composite deck materials, the fact sheet misses key problems of fire safety that have been published by the University of California Forest Products Laboratory. Such problems might again be due to the reliance on manufacturer-supplied information.

Technology scan information is provided in the form of a fact sheet for selected categories of building systems, consisting of a very brief (100 to 150 words) description of the new technology. Though the scan is potentially a valuable tool for technology transfer and stimulation of innovation, more extensive documentation is needed before it can be effective. The current plan for R&D presentations for prospective manufacturers seems very inefficient and the committee believes the current emphasis should be on more detailed documentation and broad dissemination of information.

ToolBase and PATHnet

Nearly half of PATH's expenditure on information dissemination went to ToolBase, making it the largest non-R&D activity in the program's budget. The amount of funding and the success of ToolBase highlight both the strengths and weaknesses of PATH.

ToolBase is intended to be the housing industry's primary resource for technical information on building products, materials, new technologies, business management, and housing systems. The NAHBRC runs ToolBase with funding from PATH and some industry sponsors. The Web site has a daily average of 900 visitors who spend about 9 minutes there. The uniqueness and purpose of these visits are not known. Related ToolBase services are a bimonthly technical newsletter, industry roundtables, e-mail and telephone hotlines, and a biweekly electronic news service.

PATHnet is intended to be an information source for a broader range of housing innovators and adopters. There are no Internet user statistics for PATHnet, but it is frequently referenced on Internet search engines. PATHnet has been allocated only a fraction of the funding provided for ToolBase but it provides effective access to information from PATH and related programs (HUD, 2002; NAHBRC, 2002a).

The information presented on the Internet highlights PATH's general lack of adequate evaluation mechanisms; consequently, it may lead consumers to products that will fail prematurely. For example, ToolBase has good information about the failures and class-action lawsuits that have plagued hardboard siding but not about similar failures in fiber-cement roofing materials (e.g., Cemwood). The committee noted in its 2000 assessment and 2001 interim assessment that ToolBase should be continually evaluated. Because ToolBase and PATHnet are key programs for disseminating information, it is essential that the information be relevant, unbiased, accurate, clear, and concise. The committee believes that both Internet portals would benefit from continuing independent review.

Publications and Outreach

PATH publications, trade journals and media articles, and conferences and workshops can be effective conduits for information dissemination and technology transfer. A recent survey of West Coast builders indicated that for them, product suppliers, trade magazines, and other builders were the most frequently used channels of communication for information on new technologies, while the Internet was ranked only tenth (Fell et al., 2002). Given PATH's limited financial resources, it is critical that its funding be devoted to the most effective forms of communication. Resources should be allocated so as to have the greatest possible impact on achieving the program's mission. Much as ToolBase is the NAHB resource for technological information, NAHB-sponsored *Builder* is the housing industry's resource for leading-edge development in homebuilding. The committee notes that while $1.3 million of the 1999 through 2001 budget were spent on demonstration and evaluation projects, exposure in trade and consumer-oriented publications was limited and ineffective. PATH should devote more of its resources to disseminating information in the full range of publications that reach its varied audiences.

Five trade publications—*Builder, Journal of Light Construction, Fine Home Building, Construction Specifier*, and *Architectural Record*—serve as primary sources of information for the housing industry and help set opinions for our nation's builders, architects, and specifiers. An informal survey of their editors produced a surprising and disappointing response. The editors-in-chief did not understand what PATH is and had never written an article about PATH; two had never even heard of PATH. The editors who were familiar with the program said that the only information they received on PATH were boilerplate press releases that did not provide information they deemed useful for publication. The

editors generally thought that if they were provided with unbiased case studies or technical field data describing how an innovative material or system was used to save time, money, and labor, or improve performance, they would publish this type of information every time it was submitted. The committee notes that successful communications through placement of articles in trade magazines depends on long-term relationships with editors, which take both time and effort to build.

Professional Builder, a magazine distributed free to the home construction industry, and its related Web site HousingZone.com have responded to PATH and NAHBRC press releases and published numerous articles on PATH and PATH-sponsored activities. The articles are generally too brief to provide detailed information but they do provide valuable exposure to the program. The committee is unable to judge the impact this magazine and its Web site have on the housing industry and consumers.

When decisions are made about how to disseminate information, the following should be considered:

- Does the communication format improve the technology transfer, development, and diffusion? Is there a real time advantage to a technology-based platform like the Internet over printed documents?
- Is there a direct correlation between resources spent and the success of the communication? If so, is increased funding for the PATH program the only way to ensure that the goals are in fact achievable?
- Will this communication, even if successful, help remove barriers and facilitate technology development and adoption?

In an ideal world, PATH would have enough funding to be able to use publications, outreach, and electronic resources together to introduce new technology to the residential construction industry. The barriers to innovation would be removed, facilitating the development and adoption of these technologies, and everyone from the do-it-yourself homeowner to the chief operating officers of the top five builders would look to PATH for information on the most current technologies for their next project. This means PATH should allocate resources to disseminating information in ways that will most significantly promote the transfer, development, and adoption of technology.

One very successful model for technology transfer is the USDA Cooperative Extension Program. In successfully delivering research data to the field, this program has effectively improved productivity in the agriculture industry. Its decentralized structure, especially its linkages with state land grant universities, helps it meet the needs of a diverse and widely distributed audience base. It is well qualified to address housing issues; a nationwide extension program, created through an interagency agreement between USDA and EPA, is already educating consumers about indoor air quality in homes in over 2,800 counties throughout the United States and its territories (USDA, 2002).

Findings and Recommendations

Finding: PATH-sponsored activities like the technology inventory and technology scan can be effective in disseminating information, transferring technology, and planning PATH programs. The current focus on technologies that have achieved less than 20 percent of their potential market share hampers PATH's effectiveness. The effectiveness of the program is further diminished by the inadequate quality and consistency of materials documenting new technologies and opportunities for technology transfer.

Recommendation: The technology inventory and technology scan should be broadened into a database

of information on housing technologies at all stages of development. The database should incorporate information gained from demonstration and evaluation projects as well as all performance data available. Steps should be taken to ensure that the data are complete and accurate, and that documents used to convey this information to PATH's audiences are clear, concise, and unbiased.

Finding: Effective communication for the development and diffusion of technology in housing continues to be one of the major opportunities and one of the major obstacles for PATH. PATH uses the many channels and means of communication available, but with varying degrees of success. The current funding for communication is not consistent with its role in achieving the program's mission and goals. A better understanding of channels of communication that might prove useful is needed to determine the most effective channels and means of delivery. PATH is, again, responsible for ensuring that the information it provides is unbiased, accurate, and complete.

Recommendation: PATH should place more emphasis on and dedicate more of its budget to understanding how its various audiences obtain and use information and to delivering its information. Use of the Internet should be continued, but the use of other means of mass communication and outreach should be expanded commensurate with their role in the housing industry. A process for independent peer review should be created to ensure the accuracy and clarity of the information disseminated.

Goal 3: To Advance Research on Housing Technologies and Foster Development of New Technology

Technology Roadmaps

PATH has conducted four roadmapping sessions, directed by the PATH Industry Steering Committee on information technologies in home construction, panelized-type construction, systems-oriented design and construction, and energy efficiency in existing homes (NAHBRC, 2000). Reports have been published that document these four brainstorming sessions. The program has produced valuable information and insights into the selected technologies but it is unclear how the topics will be combined to develop a research agenda for PATH.

Background Research

The information provided on PATHnet categorizes the research activities conducted through the NSF as background research, also referred to as basic research. This classification is confusing because most of the funded projects are clearly applied or developmental research.[2] Whatever the type of research, however, the program has been successful in engaging faculty and graduate students in 22 universities in research related to housing technologies (HUD, 2002).

A review of the project titles reveals a few potentially useful but narrowly focused technical

---

[2] The Organization for Economic Cooperation and Development distinguishes R&D activities as follows (OECD, 2001):
- *Basic research* is experimental or theoretical work undertaken primarily to acquire new knowledge and observable facts without a particular application or use in mind.
- *Applied research* is work undertaken to acquire new knowledge directed primarily toward a specific aim or objective.
- *Experimental development* is work drawing on existing knowledge directed at producing or improving products or processes.

projects. Although the 2002 projects responded to the PATH roadmapping exercises, there does not appear to be a coordinated program of research that is likely to make much difference in meeting critical housing needs. Some projects appear to be working on problems whose solutions have already been published (e.g., design details to prevent ice build-up in eaves, time and motion studies of brick-laying).

Lack of a mechanism to document and disseminate the information gained from these research projects prevents the program from significantly promoting the development and diffusion of new technologies. The program needs to set a research agenda of issues to be addressed by background (basic) academic research.

Applied Research

PATHnet lists three activities as applied research. They all engage other federal agencies—FEMA, DOE, and USDA FPL (HUD, 2002). Again, the classification is confusing because most of the federal agencies are not undertaking applied research and the activities are only part of PATH-sponsored applied research. Moreover, PATH funding has been applied to activities already in place, making it difficult, if not impossible, to determine the impact of the PATH program. Nevertheless, the activities have produced new knowledge, reports, and demonstration projects that contribute to the PATH mission and goals.

Developmental Research

PATH categorizes funded research undertaken by private organizations and corporations as technology development. These projects, which account for more than a third of PATH program funds, are a mix of product development and performance measurement. More than half of the funds are allocated to the NAHBRC; the rest support programs at the MHRA, NASFA, and NIST.

The NIST program transfers about a quarter of the PATH developmental research funds to six private corporations as one-to-one matching funds for the development of new technologies, among them three types of insulated panels of concrete and wood, an automated thermostat, insulated photovoltaic roof tiles, and computer-controlled manufactured housing (HUD, 2002). The committee has not seen the results of these undertakings but, as noted in the 2000 assessment, believes that in principle funding development of proprietary technologies should be a very low priority for PATH.

Among the NASFA projects are investigation of corrosion of galvanized steel fasteners (in conjunction with the University of Hawaii), development of construction details for hybrid wood/steel construction, and a cooperative project with MHRA to study the feasibility of steel-framed manufactured homes. The committee applauds the collaborative approach to these projects, especially the collaboration between industry and an academic institution. An MHRA project that investigated moisture problems in manufactured housing resulted in a report on their causes and possible solutions that provides practical guidance for design, manufacture, installation, and maintenance of manufactured homes.

The NAHBRC undertakes a variety of activities. It is evaluating the performance of steel frame construction and insulating concrete forms, preparing a guide for systems design in residential construction, developing a prefabricated shear wall for light-frame construction, and analyzing the market for vacuum-insulated panel construction. Because the NAHBRC projects are ongoing, it is difficult for the committee to determine how the PATH partnership has affected them.

Technology Evaluation Measures

PATH has allocated over $6 million to what it calls evaluation measures. The majority of these funds went to NIST for evaluation protocols for sealants and coatings (HUD, 2002), and to NAHBRC to support its existing program to instill quality management principles in the homebuilding industry (NAHBRC, 2002a). The committee believes that neither of these activities has contributed significantly to achieving PATH's goals. The NIST program addressed an industry-identified need and provided a forum for establishing protocols and standards, which is an appropriate PATH activity, but significant funding went to a narrow segment of old technology. The NAHBRC program, initiated before PATH with private funding, could continue as a private sector activity.

Findings and Recommendations

Finding: More than 80 percent of PATH resources have been allocated to R&D yet there is no agenda that identifies and prioritizes R&D activities. The technology roadmaps, while providing direction for specific technologies, are not a substitute for a PATH research agenda. The result has been a broad array of unrelated activities—and minimal progress toward achieving program goals. For PATH, basic and applied research on new building materials and systems with broad applications is more appropriate than research for development of specific technologies, but private investment in developmental research should be encouraged. PATH needs to set national priorities for coordinating federally funded R&D activities, minimizing duplication, and encouraging partnerships between industry, government, and academia. It is particularly important to recognize that industry investment in research is minimal, and to create a mechanism that encourages industry to invest in housing technology research.

Recommendation: PATH should increase efforts to monitor promising R&D and enhance dissemination of information about leading-edge housing technology. PATH should set a comprehensive research agenda that is coordinated with current research in government, academic institutions, and industry. PATH-sponsored research on housing technologies should emphasize basic and applied research with broad application and the potential to increase the rate of innovation. PATH should foster development of specific new technologies primarily by promoting private investment.

Goal 4: To Administer the Program to Achieve Its Mission, Goals, and Objectives

Partnerships

PATH was conceived as a program that would achieve its goals by leveraging resources through partnerships with other government agencies, industry, and academic institutions. Intragovernmental activities were curtailed when the administration changed in 2001; PATH gives limited support for FEMA publications, DOE building technology programs, and the FPL Advanced Housing Research Center. Funding for several projects at the NIST Building and Fire Research Laboratory (BFRL) makes this the most active PATH government partner.

In its 2000 assessment the committee noted that the day-to-day involvement of other federal agencies with larger, more mature programs (e.g., DOE's Building America and EPA's ENERGY STAR) tended to overpower PATH and obscure the value added to their work by the PATH program. In its 2001 assessment the committee noted that the reduced involvement of other agencies alleviates this problem but recommended continuing interagency coordination of programs that affect the develop-

ment and diffusion of technology in housing. Current coordination efforts consist of informal communications among government officials; they need to be strengthened.

As directed by Congress, PATH's relationship with industry is coordinated through the NAHBRC. This has resulted in intense involvement with builders but far less with manufacturers, designers, regulators, consumers, and other housing industry participants.

PATH's relationship with academic institutions is primarily through the NSF research program and a few institutions where it has funded projects. PATH is also building a relationship with the National Consortium of Housing Research Centers as a means of communicating with academic institutions.

The NSF research program, while needing improvement as noted above, exemplifies a potentially effective structure for a PATH partnership. The program was initiated by PATH and is conducted with matching funds from PATH and NSF. It uses an established NSF process and relationships with academic institutions to further PATH goals. Unfortunately, most of the other partnerships do not follow this model. Other relationships rely entirely on PATH funding or they are using PATH funds to supplement previously existing activities that they would probably continue on their own without PATH funds.

PATH Program Awareness

Members of the committee contacted business associates in the housing industry and housing consumers in an informal survey to gauge how aware they were of PATH. The surveys are neither scientific nor conclusive, but absent more rigorous data they provide some substantiation for conclusions drawn from the committee's personal experience. The committee has found that participants in the housing industry are generally unaware of the PATH program and have not used the results of its activities. One relatively innovative builder noted that PATH has not made its way into common use among builders. The exceptions were staff of larger builders who are responsible for identifying and evaluating new technologies. This suggests that PATH is communicating with early innovators but has not connected with the majority of homebuilders.

The lack of awareness may be because the program is relatively young, or because it has failed to open channels of communication with housing technology stakeholders. For example, there is very limited direct PATH involvement by local sustainable housing organizations and homebuilder associations that could publicize the program and gather information on the adoption of innovations through community outreach. Although its limited budget makes it impractical for PATH program managers to have direct contact with local organizations nationwide, they could be reached through national organizations and trade publications.

In an informal survey of 15 college-level housing educators, all members of the Housing Education and Research Association, 12 were aware of PATH. Of those 12, 8 expressed concerns that the program was exclusively for builders and had no consumer component, and the other 4 could not accurately describe the program. These college professors teach courses to undergraduate and graduate students in family and consumer sciences, natural resources, planning, or political science curriculum. Some are State Extension Housing Specialists. Most of those surveyed also devote some of their time to research on housing. Participants in this informal survey were primarily from nontechnical disciplines; the results of a similar survey of faculty from technical disciplines (engineering, technology, construction, building science, material science, etc.) might be different. Many university researchers from technical disciplines are members of the National Consortium of Housing Research Centers, and PATH administrators have attended consortium meetings and provided updates.

PATH's participation in the 2002 Excellence in Building Conference and Exposition sponsored by the Energy and Environmental Building Association (EEBA) and the FPL Advanced Housing Research Centers is a positive step for increasing recognition of the program. The EEBA represents over 10,000 professionals influential in advancing technology in housing. However, the committee is concerned that PATH has missed an opportunity to define itself as a leader, guiding the advancement of technology in American housing. PATH presented an Alternative Building Systems series of discussions covering: (1) An Introduction to Alternative Building Systems, (2) Structural Insulated Panels, (3) Insulated Concrete Forms, (4) Earth Building Systems, (5) Straw Bale Construction, and (6) Regulatory Barriers to Alternative Building. The program is neither cutting-edge nor is it likely to advance technology in housing. The PATH presence seems weak compared to the program presented by the DOE Building America program, which includes the results of current research and addresses cutting-edge technologies (EEBA, 2002).

PATH has published several brochures that describe the program adequately in varying levels of detail for different audiences. While the brochures have a role to play in increasing awareness of the program, the best method for increasing awareness is effective communication of high-quality, relevant information on housing technology, as noted in the Goal 2 evaluation.

Planning and Evaluation

As required by Congress, PATH published a *Strategy and Operating Plan* in October 2000 (HUD, 2000). The strategy and plan were directed at achieving the housing performance goals established at the inception of the program. The committee noted in its 2000 assessment that those goals were too broad and influenced by too many factors to be used as performance measures for PATH and that they are equally inappropriate as a structure for program planning (NRC, 2001). PATH staff and the committee addressed this problem in 2001 by revising the PATH goals (see Chapter 2).

The committee is concerned that the operating plan has not yet been revised to align with the revised goals. Many of the areas of concern noted in this report are due to inadequate planning and lack of alignment of the PATH activities and goals. This is to be expected of activities initiated from 1999 through 2001, because the activities were planned using the original goals; however, a revised plan is needed to align future activities with the revised goals and create a high-performance program.

The 2000 program plan noted that PATH would build a framework for evaluating performance and that information would be collected and tracked by contractors with oversight by the NRC committee. PATH has neither collected nor tracked contractor performance information. The committee has helped PATH to create an evaluation framework (see Chapter 5), but the information so far received from PATH contractors has been insufficient to conduct a structured assessment.

Findings and Recommendations

Finding: Administration of the PATH program has been inconsistent and has not provided sufficiently strong direction. The committee recognizes that administration has been hampered by the initial selection of goals at the inception of the program that were overly ambitious for the size of the program. Administration has also been hampered by the uncertainty of the program's future. Unfortunately, the administrative impediments have led to a misplaced emphasis on activities (e.g., developmental research versus information dissemination and barrier removal), and a program that lacks baseline measures and an operating plan to achieve its goals. The development and diffusion of accurate and unbiased information about new technologies would increase both recognition of the program and its

ability to influence innovation in the housing industry. The strengths of the program in engaging diverse stakeholders and in the skills and abilities of the PATH staff are resources that can overcome these problems.

Recommendation: PATH should draft a program plan for achieving its current goals. Research on innovation in the housing industry and channels of communication should be priorities. The information gained from this research should be used to guide writing of the program plan and collection of baseline data for future program evaluation. All stakeholders should participate in the planning process in proportion to their roles in advancing technology in housing. PATH should enhance its relationships with the broad spectrum of housing researchers, innovators, adaptors, and consumers by establishing channels of communication for collecting and disseminating information on housing technology.

ASSESSMENT OF THE PATH PROGRAM AS A WHOLE

The committee has described the goals assigned to PATH at its inception as inappropriate for a small technology-focused program (NRC, 2001). Nevertheless, PATH tried to respond to these goals by funding activities that promised improvement in one or more performance targets. After more than a year, PATH published a document that incorporated these activities into a strategy for improving innovation in housing. The result is a program with some activities that are appropriate for the long-term pursuit of current program goals (e.g., demonstration projects, technology inventory, and ToolBase) and many (particularly in developmental research) that are not. In the 3 years since its inception, PATH has failed to create a firestorm of innovation in housing. However, though there is no proof of attributable improvements, there is evidence of change in the projects of participating homebuilders, the number of visitors to PATH Internet portals, and the number of academic institutions engaged in housing research.

Although PATH's approach to diffusing innovation using demonstration projects and information dissemination is limited in its effectiveness, the committee believes these efforts should be improved, not discarded. PATH's current level of performance is in part due to a lack of knowledge about innovations in residential construction (Koebel, 1999). Koebel made his observations before results were available, but the subsequent performance of PATH-sponsored activities and program planning, as already discussed, support his argument.

> The [PATH] approach relies on industry and builder participation to assure practical application, without explicitly addressing relative advantage, compatibility, complexity, trialability (beyond demonstration projects), and observability. Information dissemination is through industry groups, mass media, and the Internet, but there has been little attention to the communications networks used throughout the diffusion cycle. Information brokers and change agents are not explicitly examined. Given the level of knowledge about diffusion of innovation in the building industry, promoting demonstration projects and information dissemination is a logical—but limited—choice. Focusing more explicitly on diffusion and the technologies required to promote diffusion would significantly expand the approach, but would require a focused research effort to establish the required knowledge about the social system that constitutes homebuilding. (Koebel, 1999)

PATH has engaged many appropriate stakeholders in the Industry Steering Committee and Roadmapping sessions but has made little progress toward achieving its goals, primarily because of inadequate program planning. This planning shortfall is due in part to inappropriate goals, the necessity

of revising the goals, and inconsistent commitment to the future of the program, but it is also due to incomplete information on the development and diffusion of technology in the housing industry. The planning process also needs baseline data on housing innovation and continuous assessment of PATH-sponsored activities.

Findings and Recommendations

Finding: PATH started out with goals that were influenced by many factors other than technology and that were somewhat contradictory, not measurable, and inappropriate for a small technology-focused program. Nevertheless, the program made an effort to achieve these goals. The result is an unfocused program, an array of uncoordinated activities, and a misplaced emphasis on R&D for new technologies. PATH has made an effort to refocus its goals on the program's role in promoting the development and diffusion of technology, but this effort is not yet complete.

Recommendation: PATH should be continued as a program aimed at increasing the rate of development and diffusion of innovation in the housing industry. Its activities should focus on (1) identifying, understanding, and removing barriers to, and (2) disseminating information for, the development and diffusion of new technologies, as well as (3) increasing industry investment in technology development.

REFERENCES

EEBA (Energy and Environmental Building Association). 2002. Excellence in Building 2002 Conference and Exposition. Available on the Web at http://www.eeba.org/conference/default.htm. Accessed September 18, 2002.

Fell, D., Hansen, E.N., and Punches, J. 2002. Segmenting Single-Family Homebuilders on a Measure of Innovativeness. *Forest Products Journal* 52 (6): 28-34.

GAO (U.S. General Accounting Office). 1997. *Measuring Performance: Challenges in Evaluating Research and Development*. Washington, D.C.: General Accounting Office.

HUD (Department of Housing and Urban Development). 2002. PATH: A Public-Private Partnership for Advancing Housing Technology. Available on the Web at http://pathnet.org. Accessed September 18, 2002.

HUD. 2000. *Partnership for Advancing Technology in Housing: Strategy and Operating Plan*. Washington, D.C.: Department of Housing and Urban Development.

Koebel, C.T. 1999. Sustaining Sustainability: Innovation in Housing and the Built Environment. *Journal of Urban Technology* 6 (3): 75-94.

NAHBRC (National Association of Home Builders Research Center). 2002a. ToolBase Services. Available on the Web at http://toolbase.org/index-toolbase.asp. Accessed September 18, 2002.

NAHBRC. 2002b. *PATH Field Evaluations and Technologies, Summary Reports*. Upper Marlboro, Md.: NAHB Research Center.

NAHBRC. 2002c. *Field Evaluation of Technologies at Bruce Davis, Inc., LaPlata, Maryland*. Upper Marlboro, Md.: NAHB Research Center.

NAHBRC. 2002d. *Final Report for Field Evaluation of PATH Technologies, Warren Builders' Homes, Albertville, Al.* Upper Marlboro, Md.: NAHB Research Center.

NAHBRC. 2000. *PATH Technology Roadmapping*. Upper Marlboro, Md.: NAHB Research Center.

NAHBRC. 1998. *Building Better Homes at Lower Costs: The Industry Implementation Plan for the Residential National Construction Goals*. Upper Marlboro, Md.: NAHB Research Center.

NRC (National Research Council). 2002. The Partnership for Advancing Technology in Housing (PATH) 2001 Assessment, letter report, February 13, 2002. Washington, D.C.: National Research Council.

NRC. 2001. *The Partnership for Advancing Technology in Housing: Year 2000 Progress Assessment of the PATH Program*. Washington, D.C.: National Academy Press.

OECD (Organization for Economic Cooperation and Development). 2001. Workshop on Basic Research Policy Relevant Definitions and Measurement, 29-30 October: Summary Report. Available on the Web at http://www.oecd.org/EN/document/0,,EN-document-47-1-no-20-4631-47,00.html. Accessed September 17, 2002.

Rogers, E.M. 1995. *Diffusion of Innovations*. New York, N.Y.: The Free Press.

Steven Winter Associates, Inc. 2001. *Takoma Village Cohousing Final Report*. Washington, D.C.: Department of Housing and Urban Development.

USDA (U.S. Department of Agriculture). 2002. The Cooperative State Research, Education, and Extension Service. Available on the Web at http://www.reeusda.gov. Accessed September 18, 2002.

5

Process for Long-Term Assessment and Program Improvement

INTRODUCTION

There are no ideal assessment processes that can be applied to evaluating programs for advancing technologies. Programs need to be considered individually to determine the metrics that best respond to the specific program and technologies. In general, the metrics need to be replicable and assess both the means (program activities) and the ends (program outcomes) (OECD, 1998). The committee attempted a systematic assessment of the PATH program but found that the data were insufficient, and that an evaluation process needed to be integrated into the program's management system. The following issues should be considered in designing a long-term assessment process for PATH.

Causality

The development and diffusion of innovation in housing is an evolutionary process that was operating before PATH was created. The challenge in assessing the impact of PATH is distinguishing between progress resulting from natural processes and economic initiative and progress resulting from the PATH program. The limited amount of research and baseline data on innovation in the housing industry increases the difficulty. The structure of PATH as a partnership makes it hard to distinguish the impact of the program from the actions of partners that would have occurred without PATH; the direct response to the collaborative effort must somehow be assessed. To do this will require a significant amount of supposition, because it is necessary to define what might have happened without the PATH initiative.

Quantitative Versus Qualitative Assessment

It is often easier to define quantitative indicators of a program's performance (e.g., the number of reports) than to work out what the program has accomplished. To be valid, an assessment should incorporate professional judgment of value. Though innovation is at the heart of economic change,

relying on economics-based measures to assess a program to stimulate innovation can be misleading. An individual firm can determine its return on investment or the cost benefit of the direct effort to develop a new product, but it cannot factor in the value of the basic research or communications with end users that made the new technology possible.

On a macro scale, counting the number of patents for new technologies that can be used in housing or the number of related articles in journals is helpful for assessing the amount of activity but not for assessing the value of new knowledge or new technologies. Economic, patent, and literature data are all helpful, but additional data measures are needed to assess how much effect PATH has on the development and diffusion of technology in housing. No single metric can assess PATH completely. Therefore, it is important to identify multiple performance measures that can be attributed directly to PATH and that reflect interim progress toward its goals (Jaffe, 1998; Hatry, 1999).

The cost of a detailed evaluation of innovation in the housing industry would be out of proportion to the size of the PATH program if it were used solely for assessment of the program; as noted in previous recommendations, research to develop this information is also needed to help understand the processes of innovation in housing. This information can be used by industry to plan R&D and product diffusion programs and it can be used by PATH to plan a more effective program.

ASSESSMENT FRAMEWORK

A continuous assessment process should do more than provide a scorecard of past activities. Analysis of assessment data can help improve management of the program and design of future activities (Hatry, 1999).

In a sound process of assessment and performance measurement, measures are linked to the program's mission, goals, and objectives (Figure 5.1). Measures should be designed to assess the potential for PATH to accomplish its goals and objectives (see the discussions of PATH goals in Chapter 2 and of the extent to which they have been accomplished in Chapter 4).
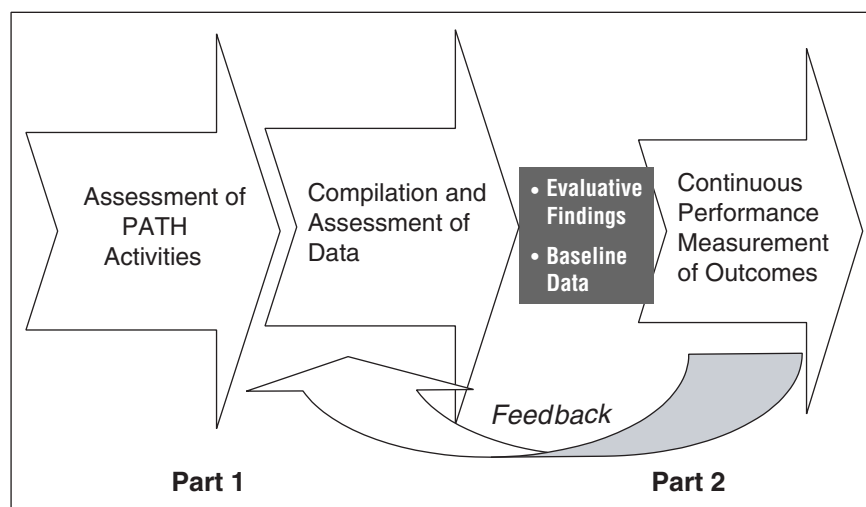

FIGURE 5.1 Assessment framework.

An assessment process should include measures of:

- **Input:** These measures reflect the resources put into the program that ultimately produce programmatic outputs and outcomes.
- **Activities:** These measures monitor the day-to-day activities of the program, addressing such issues as the objectives and procedures used to achieve the anticipated outcomes.
- **Outputs:** These measures reflect the products or services that result directly from the activities.
- **Outcomes:** These measures reflect the effect of activities and outputs on the program's mission, goals, and objectives.

In the process of formulating a framework for long-term assessment of PATH, its mission, goals, and objective statements were refined and linked to activities, outputs, and outcomes based on the following principles:

- PATH's goals and objectives should be concise and meaningful, and should emphasize activities where desired outcomes can be identified.
- There should be a logical link between PATH's mission, goals, and objectives.
- Every program activity should be clearly identified with a goal, although a single activity may support more than one goal or objective.
- Outputs, intermediate outcomes, and long-term outcomes should be identified for each major activity.

(See Appendix E for suggested evaluation questions.)

ASSESSMENT DATA

Performance assessment needs to be designed into the structure of each activity. Criteria for performance measures should be part of the annual reporting requirements of contracts and grants so that they can be easily aggregated to determine how the results affect the program's mission and goals. The metrics or performance indicators should be as precise, unbiased, and stable as possible to allow for comparisons across activities; they should also be resistant to manipulation (Jaffe, 1998). Such assessments should include a measure of outputs as defined in the activity plan and describe how well the specific activity addresses its intended scope, the credibility of the process, the quality of the information generated by the activity, and how well the information has been presented and disseminated. Research should be subject to a peer review process to evaluate the impact and quality of the effort and the written materials for publication. Web pages should also be peer reviewed to assess the accuracy, bias, and completeness of the information presented as a product of the PATH program (NRC, 1999; OECD, 1998). Assessment questions related to the program's mission and goals should be applied to each activity to assess how much it contributes to reducing barriers, disseminating information, fostering research, increasing the development or diffusion of technologies, and improving housing performance.

Because it is a partnership, assessing the collaborative effort is a critical part of assessing the effectiveness of PATH. This includes evaluating both the program's communications with its broad range of stakeholders and partner contributions of financial and in-kind support for PATH activities. It is also important to understand partner responses to PATH initiatives to determine what might have

happened without the initiatives. This will require an independent body to undertake direct discussions with PATH partners and a skilled analysis of their responses.

In addition to activity-based assessment, more general analysis of mass media exposure and surveys of stakeholders can determine how well the program is communicating with its partners and customers. The committee recognizes that there is a cost to increased performance evaluation; this cost may reduce the quantity of output, but the potential for improved quality should increase PATH's impact on the outcome measures of innovation and housing performance. Undertaking the studies over a period of 3 to 5 years can reduce the annual budget impact of generating this type of assessment data.

Program Outcome Data

Examples of efforts to measure innovation can be found in surveys undertaken to evaluate innovation for general economic development through Community Innovation Surveys (CORDIS, 2002) based on the Organization for Economic Cooperation and Development (OECD) Oslo Manual (OECD, 1997). Other examples are the Census Bureau's Manufacturer's Innovation Survey undertaken for the NSF and similar efforts by Yale and Carnegie Mellon Universities. These enterprise-based surveys ask questions that identify technologies that are new to the firm, new to the industry, or new in other ways (NRC, 1997). By reaching all levels of the housing supply-and-demand chain, innovation surveys can help explain individual roles in innovation as well as gauge the rate of technology development and diffusion.

Innovation surveys might gather data on:

- Expenditures on activities related to R&D and other innovation processes;
- Output of incrementally and radically changed products;
- Sources of information relevant to innovation;
- Technical collaboration for R&D and technology transfer;
- Obstacles to innovation; and
- Factors promoting innovation.

PATH has limited influence on the ultimate impact or market penetration of a technology—this will be determined primarily by its relative cost and performance advantages—but PATH can probably influence the rate of diffusion or the time required to realize maximum market penetration. The impact of PATH can be evaluated by tracking the rate of adoption of technologies in the PATH inventory or used in demonstration and evaluation projects.

Frank M. Bass created a model for assessing change in the rate of diffusion of innovation over time (Figure 5.2). The Bass model, in its idealized form, is represented by an "S" curve that accounts for the influence of mass communication primarily in the early stages of diffusion and the influence of interpersonal communication as it expands and declines over time (Rogers, 1995). This model is idealized because it assumes that market potential is constant over time and ignores possible changes in the nature of the innovation, competing innovations, and other variable market factors such as price, supply, and demand. It is nevertheless a valuable tool for evaluating the diffusion of innovation (Mahajan et al., 1990).

Statistical measures need to be coupled with comprehensive interviews to assess personal experience, use of or exposure to PATH activities, and actions that might have occurred without PATH activities. By including questions that determine the influence of PATH activities on innovation processes the impact of PATH on housing can be inferred. The primary outcome should be evaluated over
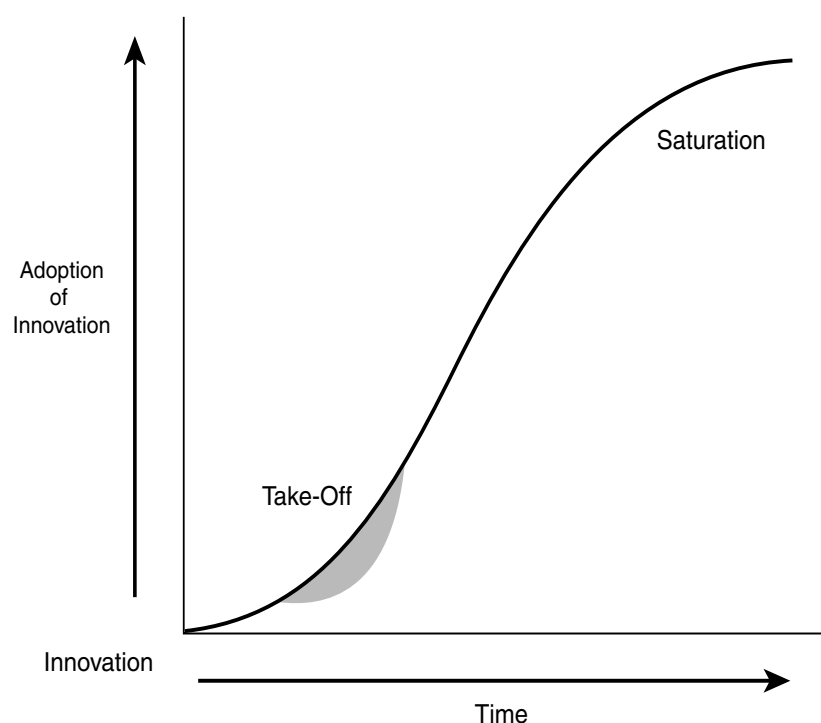
FIGURE 5.2 Bass innovation adoption curve. SOURCE: Payson Center (2001).

a longer time frame than specific program activities (NSF, 1997)—3- to 5-year intervals are appropriate. An initial effort will be needed to establish a performance baseline.

FINDINGS AND RECOMMENDATIONS

Finding: Because PATH is a new and evolving program, expert review of the program's performance and its response to reviews is especially important to its ongoing management. Effective program assessment is essential if the PATH program is to be efficiently managed. The program should be evaluated based on whether the activities it undertakes are likely to help achieve its goals, and on the quantity and quality of the results of these activities. If PATH undertakes the right mix of high-performing activities, then improvement in measures of innovation in the housing industry can be attributed, at least in part, to PATH.

Recommendation: Criteria for PATH program evaluation should be made a part of all grants and contracts. Additional performance measures should be designed to evaluate how the program is affecting innovation by individuals, enterprises, and the housing industry. Performance data should be reviewed independently so that assessment and interpretation of reported performance metrics are unbiased. This review could help analyze data on the results as well as evaluate performance of the program's strategic planning and management.

REFERENCES

CORDIS (Community Research and Development Information Service). 2002. The Community Innovation Survey Today. Available on the Web at http://www.cordis.lu/innovation/home.html. Accessed February 24, 2003.

Hatry, H. 1999. *Performance Measurement: Getting Results*. Washington, D.C.: The Urban Institute Press.

Jaffe, A.B. 1998. *Measurement Issues, Investing in Innovation: Creating a Research and Innovation Policy That Works*. Cambridge, Mass.: MIT Press.

Mahajan, V., Muller, E., and Bass, F.M. 1990. New Product Diffusion Models in Marketing: A Review and Directions for Research. *Journal of Marketing* 54 (1): 1-26.

NRC (National Research Council). 1997. *Industrial Research and Innovation Indicators: Report of a Workshop*. Washington, D.C.: National Academy Press.

NRC. 1999. *Evaluating Federal Research Programs: Research and the Government Performance and Results Act*. Washington, D.C.: National Academy Press.

NSF (National Science Foundation). 1997. User-Friendly Handbook for Mixed Method Evaluations. Available on the Web at http://www.ehr.nsf.gov/EHR/REC/pubs/NSF97-153/START.HTM#TOC. Accessed March 15, 2002.

OECD (Organization for Economic Cooperation and Development). 1998. *Policy Evaluation in Innovation and Technology: Towards Best Practices*. Washington, D.C.: Organization for Economic Cooperation and Development.

OECD. 1997. *Proposed Guidelines for Collecting and Interpreting Technological Innovation Data: The Oslo Manual*. Washington, D.C.: Organization for Economic Cooperation and Development.

Payson Center. 2001. Diffusion of ICT Innovation for Sustainable Human Development. Available on the Web at http://www.payson.tulane.edu/research/E-DiffInnova/diff-prob.html. Accessed September 18, 2002.

Rogers, E.M. 1995. *Diffusion of Innovations*. New York: Free Press.

Appendixes

A

Biographical Sketches of Committee Members

C.R. "Chuck" Pennoni (*Chair*) is chairman and chief executive officer of Pennoni Associates, Inc., a consulting engineering firm in Philadelphia. Mr. Pennoni is a member of the National Academy of Engineering; past president of the American Society of Civil Engineers; a trustee and past president of United Engineering Trustees; past president of the Accreditation Board for Engineering and Technology; and a member of the U.S. Council for International Engineering Practice. Mr. Pennoni is chairman of the Board of Trustees of Drexel University and was president of the university for the academic year 1994-1995. He has served on the engineering advisory boards of several universities and is a member of the board of Jefferson Bank, DHA Engineers, and the Greater Philadelphia Chamber of Commerce. He is licensed as an engineer in 11 states and has lectured at colleges and universities on engineering, planning, ethics, and professional development. Mr. Pennoni holds a B.S. and an M.S. in civil engineering and an honorary doctorate from Drexel University.

Robert Blancett is director of the Materials and Construction Laboratory at the USG Research and Technology Center, where he oversees the operation of five laboratories involved in product development, systems engineering, and code certification work for building materials. Prior to joining U.S. Gypsum in 1987, Mr. Blancett held various product engineering and research management positions with Owens-Corning, a large building materials manufacturer. He is coauthor of a number of publications on energy utilization in buildings and on sustainable construction. He is a member of the Building Environment and Thermal Envelope Council Board of Direction, the National Evaluation Service Building Innovation Center (NES-BIC) Board of Direction, and chair of the Membership Committee of the Industrial Research Institute. He holds a B.S. and an M.S. in mechanical engineering from the Ohio State University.

Paul R. Fisette is director of the Building Materials and Wood Technology Program at the University of Massachusetts at Amherst. Mr. Fisette was selected as a member of this committee for his expertise in light-frame construction, residential energy efficiency, sustainable building practices, and the performance of residential building materials. He has developed an innovative Web service that provides technical advice to builders and researchers regarding the performance, specifications, and use of building materials. Mr. Fisette frequently contributes articles to regional and national publications on

53

building materials and the residential construction industry. Mr. Fisette was previously senior editor of *Custom Builder Magazine,* which covers technical information and information about innovations of interest to small and medium-sized residential building firms. He holds a B.S. and an M.S. in wood technology from the University of Massachusetts.

Karen L. George is a principal at Primen and previously director of Residential Services at E Source, Inc., involved in information service for utility companies for strategic business analyses, technology assessments, and market research. Ms. George is also principal author of the *Residential Appliances Technology Atlas (*E Source, 1999), a reference book for those engaged in energy efficiency programs. Ms. George was selected for this committee for her experience in the residential energy and housing markets and her focus on product analysis and technology transfer. Prior to joining E Source, she was a consultant to many firms, such as R.W. Beck and Associates and RCG/Hagler-Bailly, Inc. She was also an independent consultant to other clients including the National Renewable Energy Laboratory, the China Association of Science and Technology, and the Pacific Northwest National Laboratory. In addition, Ms. George was manager of the Residential and Renewable Energy Programs for the Colorado Office of Energy Conservation and a professional research assistant for the Joint Center for Energy Management at the University of Colorado's Civil, Architectural, and Environmental Engineering Department. Ms. George holds a B.S. in education from California State College.

Manuel Gonzalez is a principal at KTGY Group, Inc., in Irvine, California, an award-winning planning and design firm focusing on single and multifamily residential projects. Mr. Gonzalez was selected for this committee because of his experience and expertise in architectural design and technology innovations for the homebuilding industry. Prior to joining KTGY, Mr. Gonzalez was executive director of architecture for Kaufman and Broad Home Corporation where he was in charge of residential planning and design. Under Mr. Gonzalez' direction, Kaufman and Broad received widespread industry recognition and design awards. Mr. Gonzalez was previously a partner with Johannes Van Tilburg and Partners where for 10 years he directed the design of award-winning single-family and multifamily residential projects and master-planned communities. He holds a B.A. in architecture from the University of California at Berkeley and an M.Arch. from the University of Southern California. Mr. Gonzalez is a registered architect in seven states and recently served as chair of the Housing Committee for the Los Angeles Chapter of the American Institute of Architects.

Ashok Goswami is director of the Housing and Building Technology Division of the National Conference of States on Building Codes and Standards, Inc., a nonprofit organization dedicated to promoting quality and innovation in the built environment through technical services, education, and training. Mr. Goswami was selected for this committee because of his promotion of safe new technologies in building construction and interstate acceptance of modular buildings. He oversees a program that provides third-party monitoring and associated services for state and local governments, the construction industry, and homeowners, and oversees similar services in the modular-building industry through his involvement with the Industrialized Buildings Commission and by providing construction inspections, quality audits, and contract/regulatory compliance evaluation services of builders and their factories. His division also performs plan reviews and product assessments and evaluates the performance of building systems and new construction technologies and products. He is a certified quality auditor and a registered professional engineer with a B.S. and an M.S. in civil engineering from Punjab University and an M.S. in business and public administration from Southeastern University.

Charles J. Kibert is interim director and CSR/Rinker Professor in the M.E. Rinker, Sr., School of Building Construction at the University of Florida. He was director of the Center for Construction and Environment at the University of Florida from 1991 to 1999. He was selected for this committee because of his research and expertise in construction-waste management, environmental impacts of

construction, and recycling of residential construction debris. Dr. Kibert has published more than 90 papers and books and edited several publications on construction and the environment. He is cofounder and chairman of the Cross Creek Initiative, a nonprofit industry/university joint venture seeking to implement sustainability principles in construction. He has worked with neighborhood-based housing corporations on the renovation of derelict structures into high-performance homes. Dr. Kibert has created an innovative educational outreach program and several continuing education classes for building contractors, and teaches a newly developed graduate course on sustainable construction. He is a registered professional engineer and a chartered engineer in the United Kingdom, and a mechanical and electrical contractor in Florida. He has a B.S. in engineering from the U.S. Military Academy, an M.S. in nuclear engineering from Carnegie Mellon University, and a Ph.D. in mechanical engineering from the University of South Florida.

Joseph Laquatra is a professor and extension housing specialist in the Department of Design and Environmental Analysis at Cornell University. Since 1984 Dr. Laquatra has conducted research and educational programs for Cornell Cooperative Extension and other groups on technical issues related to housing, including homebuilding, homebuying, energy efficiency, indoor air quality, and housing technology. Over the years he has educated homebuyers, homeowners, and homebuilders through partnerships with the U.S. Department of Energy, the U.S. Environmental Protection Agency, the Consumer Research Council, the American Association of Retired Persons, the New York State Energy Office, and the National Association of Home Builders, among others. Dr. Laquatra has published findings from his research in journals and trade magazines and has presented papers at national and international conferences on subjects related to environmental quality energy performance and housing economics. He is currently working on on-site management of residential construction waste. He also holds several Cornell administrative positions, including Department Extension Leader, Faculty Senator, and Chair of the Cornell Cooperative Extension's Healthy Living and Learning Environments Program Work Team. He is currently President of the American Association of Housing Educators. He holds a B.S. in hotel administration, an M.S. in consumer economics and housing, and a Ph.D. in consumer economics and housing from Cornell University.

Tricia Parks is founder and president of Parks Associates, a consulting firm that analyzes and forecasts the home networking and broadband industries, in addition to many other industries involved in service markets for residential and light-commercial technologies. She was appointed to this committee for her understanding of automation, electronic, and communication technologies in residential environments. Ms. Parks founded Habitech, a trade and training show for home systems, which was sold to the Electronic Industries Association. Parks Associates owns and cohosts Forum, an annual state-of-the-nation overview of current and emerging residential systems and services markets, and cohosts Connections, a showcase event for in-home networks and gateways. Prior to starting her own firm, she was a founder of MARTECH and a senior vice president of Future Computing. She is a contributor to industry trade magazines and is a frequent speaker at trade events. She is the founder of Wiring Americas' Home Campaign, launched in 1997, and a board member of the Home and Building Automation Association. Ms. Parks has a B.A. from Sweet Briar College and completed graduate studies at the University of Texas.

Timothy Reinhold is associate professor of civil engineering at Clemson University. He was selected for this committee for his expertise in wind effects on structures, structural dynamics, reliability engineering, and structural analysis and failure investigations. He is currently involved in wind-load studies for low-rise and specialty structures, including the resistance of structures to wind effects. Dr. Reinhold's research has included projects to improve simulation of wind loads on residential and low-rise structures; to investigate wind-loads for coastal structures; and to investigate retrofit solutions for

existing structures subjected to high winds. Dr. Reinhold is a member of the Wind Effects Committee of the American Society of Civil Engineers (ASCE), the Southern Building Code Congress International Wind Loads Subcommittee, and the ASCE-7 Standard Wind Loads Subcommittee. He received his B.S., M.S., and Ph.D. in engineering mechanics from Virginia Polytechnic Institute and State University.

John K. Spear is a practicing architect specializing in affordable housing. He was appointed to the committee because of his knowledge of technical and social issues for affordable housing and related HUD programs. He is founder and board member of the Houston Community Design Assistance Center, providing design services to help neighborhood groups and families build high-quality affordable housing. He is also president of Richwood Development Corporation, which promotes and invests in affordable homes in the Houston area. As a practicing architect he advises developers on site analysis and design review. He was chair of the American Institute of Architects Housing Committee in 2001. He holds a B.A. and B.Arch. from Rice University and an M.S. in environmental design and urban planning from Yale University.

B

Statement of Task

**THE PARTNERSHIP FOR ADVANCING TECHNOLOGY IN HOUSING: ASSESSING
PROGRESS IN IMPLEMENTING THE GOALS OF THE PATH PROGRAM**

The principal goal of this effort will be to review and comment on the following aspects of the
Partnership for Advancing Technology in Housing:

1) its overall goals
2) the approach proposed to meet the goals and the likelihood of achieving them
3) an assessment of the progress made in achieving the goals.

C

Presentations to the Committee

MAY 23–24, 2000

U.S. Department of Housing and Urban Development (Sponsor)
  William C. Apgar, Assistant Secretary for Housing-Federal Housing Commissioner
  Susan M. Wachter, Assistant Secretary for Policy Development and Research
  Ayse Can Talen, Deputy Assistant Secretary for Research, Evaluation, and Monitoring
  David Engel, Director, Affordable Housing Research and Technology Division
Executive Office of the President
  Henry Kelly, Office of Science and Technology Policy
Partnership for Advancing Technology in Housing (PATH) Program
  Diane Dorius, Senior Financial Advisor, PATH Program
National Association of Home Builders Research Center, Inc.
  G. Robert Fuller, Senior Engineer, and PATH Field Evaluation Coordinator
Building and Fire Research Laboratory (BFRL) of the National Institute of Standards and Technology
  Joel Zingeser, Manager, Standards and Codes Services, BFRL
U.S. Department of Energy
  John Talbott, Office of Building Technology, State and Community Programs
Steven Winter Associates, Inc.
  Steven Winter, President
PATH Roadmapping Strategy
  Scott Hassell, Science and Technology Policy Institute, RAND Corporation
  David Dacquisto, NAHB Research Center
PATH Performance Measure Development
  Rick Nevins, ICF Consulting, Inc.

AUGUST 29–30, 2000

HUD Housing Technology: Policy and Research Directions
  Susan M. Wachter, Assistant Secretary for Policy Development and Research

58

Status and Direction of the PATH Program
    Elizabeth Burdock, PATH Executive Director
Program Perspective from an Industry Steering Committee Member and PATH Demonstration Site Builder
    Mike Chapman, Chapman Homes, Santa Fe, NM
Overview of the Village Green PATH National Pilot Project
    Jeff Lee, Lee Homes, Marina del Rey, CA
Program Perspective from a PATH Cooperative Partner
    Gregg Ander, chief architect, Southern California Edison

MARCH 29–30, 2001

Response to the 2000 PATH Assessment and Update on Program Management Policies
    David Engle, Director, HUD Affordable Housing Research and Technology Division
Re-exploring PATH Goals and Strategies
    Bill Asdall, Member, PATH Industry Steering Committee
    Carlos Martin, HUD Policy Development and Research
Overview of Current Programs and Projects
    Carlos Martin, HUD Policy Development and Research
Review of PATH Coordination and Integration of Government and Private Activities
    Carlos Martin, HUD Policy Development and Research
    Larry Zarker, National Association of Home Builders Research Center
Review of ToolBase
    Terre Belt, National Association of Home Builders Research Center

AUGUST 23–24, 2001

Update on PATH Funding and Related Issues
    David Engle, Director, HUD Affordable Housing Research and Technology Division
Theory and Strategies for Program Evaluation
    Julia Melkers, Professor, Georgia State University
Revised PATH Strategic Plan, Program, and Outcomes
    Carlos Martin, HUD Policy Development and Research

MARCH 7–8, 2002

Goals-based Evaluation Framework
    Carlos Martin, HUD Policy Development and Research

JULY 24–25, 2002

Update on PATH Activities and Program Management
    David Engle, Director, HUD Affordable Housing Research and Technology Division
    Carlos Martin, HUD Policy Development and Research

D

Summary of Previous Reports

2000 ASSESSMENT

The committee produced its initial report, *The Partnership for Advancing Technology in Housing: Year 2000 Progress Assessment of the PATH Program*, in January 2001 (NRC, 2001). It primarily addressed the goals set for the program, provided a preliminary assessment of the program's management structure and activities, and discussed the need and precedents for a program like PATH.

The committee found that the goals established for the program by the administration, which were based on housing performance objectives, were unrealistic, somewhat contradictory, and influenced by numerous factors outside the scope of the program. Though the committee believed that the goals were laudable targets for improved housing, they were better suited to overall government policy direction than to performance measurement of a small technology-focused program.

The committee observed that the program failed to distinguish clearly between PATH and PATH-related programs, making it difficult to identify the value added by PATH. While applauding the program's structure for communications with the homebuilding industry, the committee found a need for a clearer understanding of the program's multiple audiences, mentioning code officials as key participants who were underrepresented.

In 2000 it was too early to evaluate specific initiatives; however, the committee recognized the potential for success in demonstration projects, roadmapping, technology inventory, ToolBase, and the NSF research program. The committee recommended that the program reduce its emphasis on R&D for new technologies and increase emphasis on understanding market dynamics and removal of barriers to the development and diffusion of technologies. The committee also recognized the need for continuing independent evaluation of key activities like ToolBase. The committee cited economic, social, and technological principles that supported the need for a program like PATH and noted that it was evolving and improving (NRC, 2001).

The committee made nine recommendations based on its 2000 assessment:

Recommendation 1. The PATH Program should be continued as a partnership among federal agencies and between the federal government and the private sector. The program should be reviewed continu-

ously and updated to ensure that it evolves into an effective, efficient vehicle for the development and deployment of beneficial technologies.

Recommendation 2. PATH should undertake market research on builders' and consumers' perceptions of new technologies. Information on the successes and failures of new technologies and processes for introducing them into the housing industry should be incorporated into PATH's technology development and deployment strategy. PATH strategies for disseminating information to its diverse audiences should be evaluated continuously and refined as necessary.

Recommendation 3. More realistic and achievable goals should be developed commensurate with the size and mission of the PATH Program. Performance should be measured by criteria that are directly influenced by PATH initiatives, such as the rate of deployment of identified technologies and the level of investment by the housing industry in research and development.

Recommendation 4. PATH should develop credible baseline data so that the program's performance toward achieving its goals can be objectively and independently assessed.

Recommendation 5. PATH should maintain its current management structure but should be careful to maintain PATH's independence from ongoing programs and not to become a surrogate for these programs. PATH strategic and management plans should focus on opportunities for synergies and collaboration in ongoing programs and should make a clear distinction between coordination and initiatives that are directly controlled and funded through PATH. PATH management objectives should measure the value added to ongoing programs by PATH initiatives.

Recommendation 6. PATH should continue to provide seed money for research and development of new technologies, foster PATH name recognition to promote PATH goals and technologies, and educate and transfer information among its diverse stakeholders.

Recommendation 7. PATH should expand its use of demonstration projects to help develop market recognition for the PATH Program. Demonstration projects should be planned to measure the performance and value of new technologies and disseminate information to promote and facilitate the use of the demonstrated technologies.

Recommendation 8. The roadmapping process should include basic research, applied research, technology transfer, and process and planning issues in addition to materials and hardware. Participation in the roadmapping process should be expanded to include representatives of the financial, insurance, real estate, planning, and regulatory communities, as well as trade associations and consumer groups. The roadmaps should also identify opportunities for academic/business partnerships.

Recommendation 9. PATH should develop standard evaluation procedures, including the benchmarking of technologies that have been successfully integrated into the housing industry, to increase the usefulness of the Technology Inventory. The effectiveness of the *ToolBase* program in transferring information to home builders and other audiences should be evaluated.

2001 ASSESSMENT

The committee prepared a 2001 assessment of the PATH program as an interim letter report released in January 2002 (NRC, 2002). The report addressed changes in PATH related to recommendations in the 2000 assessment and provided an interim assessment of several activities. The report noted

that there had been a substantial change in the management of the program when the PATH program office was closed, its management responsibilities shifted to the staff of the HUD Office of Policy Development and Research (PD&R), and the involvement of other federal agencies reduced. This new structure was recognized as having the potential of being more efficient. The committee commended the revision of the program's strategic plan to address goals related to the development and diffusion of technology rather than housing performance, but noted the need to identify baseline metrics. The research on market dynamics was applauded and it was suggested that additional insight could be obtained by partnering with large corporate builders who regularly conduct such studies. The report acknowledged the success of the PATH program in disseminating information on the Internet and reiterated the need to broaden the program's focus beyond homebuilders and to conduct continuous assessment of the objectivity and accuracy of the information posted on the program's Web pages. It was noted that the committee was undertaking a detailed review of the program and developing evaluation questions and performance targets to assess the program's activities and their impact on achieving the revised goals and objectives (NRC, 2002).

REFERENCES

NRC (National Research Council). 2002. The Partnership for Advancing Technology in Housing (PATH) 2001 Assessment, letter report, February 13, 2002. Washington, D.C.: National Research Council.

NRC. 2001. *The Partnership for Advancing Technology in Housing: Year 2000 Progress Assessment of the PATH Program.* Washington, D.C.: National Academy Press.

E

Assessment Questions and Performance Targets

Ideally, an assessment process should have baseline measures and evaluation questions that judge the efficacy of a program. Where there are not previous measurements, baseline performance targets need to be based on experience and expertise. The committee believes that future evaluative work should address the following questions.

EVALUATING ADMINISTRATIVE AND ACTIVITY ISSUES

The committee drafted the following questions as a starting point for future assessment. It is expected that questions would be applied as appropriate to specific activities and revised as additional data become available. This set of questions addresses PATH administrative issues.

General Administration

Process: Is the PATH process comprehensive, complete, and effective for its intended purpose?

Scope: Do the activities include a representative mix (size, location, housing type, housing cost) of housing projects? Do the activities include a representative mix (systems, materials, costs) of technologies?

Structure: Is PATH structured to achieve its mission and meet its goals?

Participants: Do the participants represent an appropriate mix of stakeholders?

Information Dissemination

Documentation: How well are the results of the activities documented?

Dissemination: How likely is it that the information from the activities will reach a broad range of stakeholders and housing segments?

Content quality: Is the information accurate, credible, objective, current, and comprehensive?

Graphic quality: Does the graphic presentation enhance dissemination of the information?

Focus: Are the content and format appropriate for the intended audiences?

Linkages: Are links to other documents or Web sites appropriate to the topic, helpful, and accurate?

Program Planning

Annual planning: Are PATH annual planning and resource allocation effective for meeting its goals and mission objectives?

Long-range planning: Are PATH long-range planning and resource allocation effective for meeting its goals and mission objectives?

Program evaluation: Is the PATH evaluation process effective?

EVALUATING EXTERNAL RELATIONS

The following questions are applied as appropriate to the administrative and support activities that deal directly with external stakeholders and audiences.

Communications: Is PATH maintaining communications with all partners?

Recognition: Is a broad base of stakeholders aware of the PATH mission? Is a broad base of stakeholders aware of PATH accomplishments?

Marketing: Are PATH efforts effective in increasing the depth and breadth of awareness of PATH and its accomplishments?

Partnerships: Is PATH creating and maintaining effective partnerships with industry (manufacturers, researchers, marketers, builders, tradesmen, architects, engineers, fanciers, insurance professionals, realtors, inspectors, and appraisers), government at all levels (researchers, administrators, and regulators from federal, state, and local agencies), and academic institutions (researchers and educators) in both regular academic programs and extension services?

EVALUATING OUTCOMES AND IMPACTS

The following questions are applied as appropriate to all activities to assess progress toward achieving the program's goals, with an emphasis on assessing programmatic outcomes.

New knowledge: Is the activity likely to produce new knowledge?

Rate of diffusion: How likely is it that the activity will affect the rate of diffusion of new technologies?

Barrier reduction: How likely is it that the activity will reduce barriers (regulatory, market, industry) to adoption of new technologies?

Rate of innovation: How likely is it that the activity will directly or indirectly increase the rate of development of new technologies?

Housing performance: Is the activity likely to contribute to an improvement in performance of one or more housing characteristics (affordability, sustainability, durability, or safety)?

EVALUATING PROGRAM PERFORMANCE AS A WHOLE

The following questions are applied as appropriate to assess progress toward achieving specific PATH goals.

Program activities: Is PATH implementing an appropriate variety of activities (subject, size, issue, stakeholders) given its total funding?

Goal 1: Is PATH making progress toward barrier reduction—Will its activities reduce barriers (regulatory, market, industry) to adoption of new technologies?

Goal 2: Is PATH making progress toward improving technology transfer, development, and adoption through information dissemination?

Goal 3: Is PATH making progress toward advancing housing technologies research and fostering development of new technology?

Goal 4: Is PATH providing administrative support that makes it possible for the program activities to make progress toward achieving PATH's goals?

Overall performance: Considering the inputs, outputs, and performance assessments, does the PATH program achieve its mission, goals, and objectives, enhance the development and diffusion of technologies, and improve housing performance?

PERFORMANCE TARGETS

For each evaluation question there should be performance targets. Ideally these targets would be derived from baseline data of the outcomes and expected output of the activities. The targets should define a range of performance from unacceptable to acceptable and the highest expected level of performance. Because this is a new program and new assessment process, interim targets will need to be established and then refined as more data become available.

Some performance targets can be easily quantified, such as the number and variety of technologies in a demonstration, or the number and variety of housing types or geographic locations in the demonstration program. Checklists can be used to assess how thoroughly an activity has been executed, but some targets will require subjective evaluation of quality. Often the performance target will need to be defined by the activity's planned objectives, with an evaluation of how well these objectives were met.

Some activities will require extensive effort to collect the data needed to answer assessment questions and determine the program outcome. Some data can be obtained from existing sources, but additional surveys using questionnaires and interviews will be needed to fully assess the PATH program and provide direction for future improvements.