Program Review & Strategy,

Performance Metrics,

& Operating Plan

DRAFT

Carlos Martín, PhD
US Department of Housing and Urban Development
(202) 708-0614 x5845; carlos_martin@hud.gov
Version: 8/26/2005

Table of Contents

Executive Summary

The Partnership for Advancing Technology in Housing (PATH) is a public-private initiative dedicated to accelerating the development and use of housing technology. Because accomplishing this mission is broad and the partnering approach is complex, the program has experimented with numerous strategies and activities since its 1998 inception. The need to critique the overall mission and these specific activities became apparent during the 2000-2002 National Research Council's (NRC) PATH evaluation. The White House's Office of Management and Budget (OMB) also articulated the need for all Federal programs to develop quantifiable measures of performance in 2003—the same year as the final NRC report's release.

This document is the first full strategic plan for the operations and objectives—and performance measures towards those objectives—since the 2002 National Research Council Evaluation. It is both a response to that evaluation and an operating strategy.

In general terms, the new PATH goals adopted from the NRC's recommendations focus on the ***process of innovation*** in the homebuilding industry rather than the products of innovation. As opposed to all other previous Federal programs, PATH is charged with reducing the multiple constraints throughout the innovation pipeline, and developing the infrastructure for increasing innovations in that pipeline. Specifically, PATH must:

- Identify and reduce barriers, including regulatory ones, impeding innovation (Goal 1)
- Disseminate information to speed innovation development and adoption (Goal 2), and
- Advance housing technology research and development (Goal 3)

Overview

This document describes the reasons why such an approach is intellectually sound and necessary in policy terms. It also details the targets for those goals, including the short- to long-term outcomes of specific activities that are needed to satisfy those goals.

Although primarily directed towards the Performance Assessment Rating Tool (PART) Evaluation for PATH, this document is also a strategic plan for PATH, and an operating plan for PATH staff and industrial partners. It is particularly important to highlight the following details:

- In previous efforts to deal with barriers to innovation, little to no attempt was ever made to comprehensively understand how specific barriers arose in daily practices, nor to measure their subsequent effects. So, lastly, but certainly not of least importance, PATH must ***record, quantify, and prioritize perceived barriers*** to innovation before attempting to reduce them. Based on extensive industry analysis, PATH must then determine ways to ***circumvent these barriers in practical ways*** in the short-term. Only after that can the program undertake the ***longer-term removal of barriers***. A current listing of barriers—both measured and perceived—are included in this document.

- PATH must continue developing and advocating reliable ***non-commercial information*** on housing technologies so that stakeholders can make reasoned and informed decisions regarding housing technology adoption. Yet, PATH must begin to do this in a more effective and directed manner through ***targeted marketing campaigns*** and strategic alliances that take account of each stakeholder group's unique behavior. As a precursor to these campaigns, PATH must also undertake extensive ***market research*** studies on the behaviors, practices, and motives of each of these groups in relation to housing technology.

- Where past R&D covered a wide variety of systems and technologies, the creation of the PATH Roadmaps was instrumental in focusing and prioritizing. ***Roadmap-based R&D*** should continue, but must also be complemented with the institutional structures that will allow R&D to proceed regardless of PATH funds. This includes: developing long-term commitments from multiple stakeholders for ***investing in housing technology*** R&D; developing clear and consistent mechanisms for firms to ***commercialize innovations*** (particularly smaller firms);

creating industry-based guidelines for ***testing and confirming performance*** of innovations so as to create a level analytical playing field.

Contents

As the first strategic plan, this document includes the following sections. Future annual updates will not be necessary include the introductory materials.

Review & Background

- A program review of PATH and similar Federal efforts
- A conceptual review covering the intellectual and industrial literature on technology management needs in the homebuilding industry, alternatives for improvement, and the explicit strategy recommendations for PATH
- A description of the search for appropriate performance measures and tools

Strategy and Performance Metrics

- The statement of outcomes, outputs, activities, and inputs with—appropriate performance measures for each—needed to accomplish the revised Goals. These strategic maps are referred to as the "PATH Metrics" in this document

Fiscal Year 2005 Operating Plan

- The first year's requirements from the Metrics are listed as the year's activities

Next Steps

This document is based on a variety of expert interviews, focus groups, academic literature reviews, and additional analysis. PATH staff and the PATH Industry Committee will review it while the NRC confirms its overall direction. Afterwards, submission and approval by the OMB will lead to the implementation of these performance measures in the first, formal PATH program evaluation.

Background

The Partnership for Advancing Technology in Housing (PATH) is a public-private initiative dedicated to accelerating the development and use of technologies in and for housing; with this investment, PATH believes that the quality, durability, energy efficiency, environmental performance, and affordability of America's housing will radically improve.

Many scholars argue that the meager investment in residential technology research necessitates a program like PATH. Despite the importance of the housing industry to the American economy, this innovative chasm is especially true for detached, single-family housing—a market that makes up most of America's housing stock. It can purportedly take 10 to 25 years for a new housing technology to achieve full market penetration. Often, it takes that much time to simply introduce an innovation to the market. As such, PATH spurs new research and development (R&D) initiatives, enhances the access to and quality of information resources about them, and decreases the institutional barriers to their development, adoption, and diffusion in housing.

Yet, the time has come to give a full accounting for PATH's previous activities, to review alternative strategies, and to lay out a strategic plan (with appropriate evaluation objectives and transparent metrics) for the future. This document is the first of a series of annual performance reports and strategic plans.

PATH History

In 1994, the White House convened representatives from all segments of America's construction industry to consider a broad set of National Construction Goals, which were subsequently published and disseminated as potential goals for the industry and strategies for reconsidering governmental investments in research and diffusion efforts. Over the next three years, the residential segment of the construction industry, represented by homebuilders, code officials, product manufacturers, Federal

researchers across the cabinet, and other interested parties, developed a research plan for implementing the National Construction Goals for the housing sector. PATH is the outgrowth of those proposals, and was officially launched on May 4, 1998. The US Department of Housing and Urban Development was selected as the appropriate agency to house PATH because of the compatibility of both entities' missions; with a focus on the housing market and industrial context rather than on individual home performance issues like energy, HUD was well-suited for PATH's innovation goals. Likewise, PATH's emphasis on affordability and quality supported HUD's overall mission and its specific goals for increased homeownership and expanded, decent housing options.

From its inception and through its continued authorization by the US Congress, PATH has shown significant improvements towards the industry's rate of technological change. More importantly, the program has experimented with, tested, and occasionally re-implemented a variety of strategies for that improvement. This is the central achievement of PATH to date, and its potential benefit in the future.

Precedents

PATH is the first, broad-based, major technology-based initiative in the US housing industry in several decades. Viewed in the historical context of interventions by the US Federal government into research and development efforts in housing technology, the program has learned many lessons from its predecessors. Most notable of these was Operation Breakthrough, a 1969-1972 initiative by the Federal government to promote R&D in housing that—as determined after its termination—failed to meet its overall objectives. Through Operation Breakthrough, the public sector attempted to direct the development of specific technologies for a commercial market in which the government had neither the technical expertise nor the market experience.[1]

[1] U.S. Department of Housing and Urban Development, *Feedback: Operation Breakthrough* (GPO: Washington, DC, 1973); Comptroller General of the United States, *Operation Breakthrough—Lessons Learned about Demonstrating New Technology* (GAO: Washington, DC, 1976); Richard Bender, "The Industrialization of the Building Site: An Analysis of Experience in Operation Breakthrough," (UC Berkeley Center for Planning and Development Research Monograph: Berkeley, CA, 1977); R. Langlois and R. Nelson, "Industrial Innovation Policy: Lessons from American History" *Science* 219 (2) 1983; C. Martín,

As described in the National Research Council's Year 2000 PATH Evaluation, the lessons learned from Operation Breakthrough and other federal R&D projects are that successful programs have the following characteristics: association with government procurement or some other well defined public-sector objective; support of defined, nonproprietary research guided by a scientific community; and an institutional structure that allows potential users to guide the program."[2] Further, other analyses of Operation Breakthrough have expanded on those gaps and errors, pointing to the program's inability to transform the very institutions it was created to change. In particular, the program created an industrial bubble by circumventing the existing market and processes of residential production though building codes exceptions, direct funding of R&D, and direct capital investment in implementation on non-market (HUD subsidy housing). In short, Operation Breakthrough demonstrated that you can take the technology out of the housing industry, but you cannot take the housing industry out of the technology. As a public-private partnership for dealing with the actual industrial process of and markets for innovation, PATH has overcome this one strategic flaw.

Despite the creation of numerous programs since Operation Breakthrough, however, there are still significant problems with innovation rates in homebuilding; at best, these problems were acknowledged though little effort was invested in overcoming them. At worst, the problems became more entrenched since the 1970s despite the significant number of energy-related technologies and appliances that surfaced in response to increased regulations, energy costs, and, consequently, energy research investments.[3] By focusing on direct basic and applied research funding, government effectively turned a blind eye to the full innovation process. Indeed, no single governmental or industrial program wanted to take on the leviathan of the day-to-day realities of poor R&D processes that affected all innovation types and sources.

"Riveting: Steel Technology, Building Codes, and the Production of Modern Place" (Unpublished Doctoral Dissertation: Stanford University, 1999)

[2] National Research Council, *The Partnership for Advancing Technology in Housing: Year 2000 Assessment* (National Academies Press: Washington, DC, 2001)

[3] National Research Council, *Energy Research at DOE: Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000* (National Academies Press: Washington, DC, 2001)

Two recent Federal programs shed additional light on how best to structure Federal interventions in this field: Building America and affiliated research programs within the Department of Energy (DOE), including the national energy laboratories; and EnergyStar, whose Federal collaborators include DOE and the Environmental Protection Agency. These programs have altering levels of industrial partnerships; the former relying on homebuilders primarily to assist with and apply research findings, and the latter using product manufacturers and homebuilders to jointly market the EnergyStar label. With its focus on improving energy performance, Building America has primarily funded basic and applied research for new technologies, thereby potentially improving the energy-efficiency and quality of housing. EnergyStar, though similarly focused on the ultimate energy performance of housing products, has relied on technical standards and marketing strategies to get current builders and consumers to adopt existing technologies. Aside from the obvious difference from PATH with regards to energy focus, both programs are also focused primarily on the product of housing innovations. Both only address the process of innovation by implication—that is, insomuch as it prohibits specific measurable improvements in energy consumption.

While such an approach is entirely reasonable given that these programs are focused on improving a specific attribute in the home (e.g., energy efficiency), its focus somewhat obscures the impediments and institutional practices that impact all technologies, regardless of the attribute. By looking at the patterns in these practices—or, "barriers to innovation," to use another name—the homebuilding industry and Federal government have the opportunity to dramatically increase the field's innovation rates while maintaining an efficient Federal intervention and a minimal Federal investment. Aside from these programs' focus on energy-related technologies, then, their conceptual approaches vary significantly from that of PATH.

Goals

PATH is charged with dealing with the complexities of the full innovation process (from basic research to market penetration), particularly the institutional barriers to housing

innovation. This mandate requires partnership with a unique breadth of partners, from research investors and peer Federal programs to local regulatory officials to home appraisers and financiers. Its success, as noted by the NRC, requires that "…cooperative relationships with both private and public sector partners be established."[4]

At its inception, PATH was organized to mimic its sibling Federal programs of EnergyStar and Building America; it was charged with goals that focused on the *product* of housing innovation (namely, specific home performance issues). This mandate came directly from the National Construction Research Goals, whose goals were to:

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

All of these were to be accomplished by the year 2010. In its early stages, PATH then took on numerous activities under the umbrella concept of innovation and housing R&D. In its operations, PATH was therefore pulled in many directions. It had far-reaching goals that were inconsistent with its resource base or partnership alliances. For the first four years of its existence, 148 separate projects were implemented and managed—a number that not only seemed out of proportion to the program's size but also suggested a lack of clarity and priorities. It could often not distinguish its own initiatives from those of other Federal programs. PATH often had difficulty attracting private-sector partners for projects and, when it did, it had problems with clearly defining the roles between public and private partners on specific projects and for the overall running of the program. No long-term agreement, such as a Cooperative Research and Development

[4] NRC, op. cit, (2001).

Agreement (CRADA) was established between government and industry and, therefore, responsibility and accountability (and failures and successes) were not measurable.

Despite such ambiguity, PATH did hit the ground running. Along with experimenting with a variety of different research strategies and approaches, the program staff gained the interest of a broad cross-section of industry experts. As the NRC stated:

> "PATH is playing an appropriate role by bringing together the diverse groups involved in the U.S. housing industry and facilitating discussions of PATH-related issues. Despite the dual and difficult requirements of being open to all stakeholders and at the same time narrowly focused on achieving program goals, PATH has accomplished several important interim objectives. Perhaps most important are the communication and collaboration links that have been forged between government and the housing industry, which will be key to the ultimate success of the program. Links among U.S. government agencies have also been developed, and the organizational and management infrastructure to carry out coordinated projects and programs has been put in place."

Most importantly, PATH's central mission and differentiation from other Federal programs was firmly planted in the industry's conscious. In its 2002 Final Evaluation, the NRC affirmed PATH's conceptual basis — that "innovative technologies can improve housing performance… and that there is a need for intervention to increase the rate of innovation in the housing industry."

The NRC upheld PATH's core assumption that sustained innovation results in social benefits. With that in mind, the NRC suggested a mission and set of goals:

- Mission: To facilitate the development of new technology and advance the adoption of new and existing technologies to improve US housing
- Goal 1: Remove barriers and facilitate technology development and adoption

- Goal 2: Improve technology transfer, development, and adoption through information dissemination
- Goal 3: Advance housing technologies' research and foster development of new technology

It should be noted that no specific timeline was suggested for these goals since, it was believed, each goal has very different constraints and opportunities. Also, both the NRC and PATH clearly note that housing technology is not the only factor in housing production and performance, nor is innovation the only technological method for improving production and performance. Yet, the hypothesis that technological innovation can substantially contribute to rates of industrial production and, in turn, to the quality of industrial products has been regularly supported in all the literature and in numerous examples from other industries. But, just *how* to do this is the source of much debate.

Activities

The problem, as stated, is that there is insufficient housing innovation. So, PATH has three options:

- Simply give more funding to increase housing research with the hope that it will pay off downstream along the supply chain
- Increase regulations thereby forcing mandatory searches for innovation
- Removing the institutional reasons for the lack of innovation

The first option is unlikely given the history and availability of funds, and the long-term success of such drastic public expenditure is questionable. Historically, increasing regulation has only lead to short-term increases in innovation and the regulatory development process has often unfairly lead to biases for only certain innovations. As such, the most consistent and equitable method of improving housing innovation is by looking at the impediments to the supply of innovations reaching the demand. These are the experiments with which PATH has struggled.

PATH has been a work-in-progress since its inception, though such change has largely been incremental to date. Many external insights colluded between the years 2002 and 2003 that led to the radical changes presented in this document. First, the NRC rejected the original PATH Goals as “not realistic… not useful as performance measures… [and whose scale is] beyond the scope of the PATH Program.” This was reaffirmed in all the years of NRC’s evaluation, with the additional recommendation that PATH’s efforts should “be focused” and should develop performance measures “consistent with its mission and level of funding.” In short, the NRC suggested that the entire mission, goals, and strategy for PATH be reconsidered so that it directly addresses the literature and industrial need for innovation intervention.

At the same time, the White House Office of Management and Budget began implementing a thorough review and assessment method of all Federal government programs formally known as the Performance Assessment Rating Tool, or PART. OMB was familiar with PATH’s externally evaluation from the NRC and the stated recommendation that PATH reconsider all of its major activities and strategies. So, the OMB agreed to hold off on performing a full assessment; PATH received a "No Results Demonstrated" score for the PART 2003 Cycle.

As the first only research program in HUD to be assessed under the PART, PATH was then uniquely charged with developing a full set of metrics and baseline measures based on the new NRC goals and strategy in order to begin long-term performance assessment.

PATH immediately consulted with the RAND Science and Technology Policy Institute to explore the role and potential for governmental intervention in housing innovations. The result of this study was published in 2003 as “Building Better Homes: Government Strategies for Promoting Innovation in Housing.” This report examined the structure, characteristics, and motivations of major participants in the housing industry to explore how innovation might be accelerated. It identified options and strategies for the federal

government to consider as it attempts to further advance innovation in housing, including the need to: enhance research activities; strengthen the knowledge base; support the technology innovation pipeline; and improve market linkages.

Subsequent to that publication, PATH undertook a series of other activities in order to accurately and comprehensively develop sound objectives and activities, as well as feasible performance metrics. For the barriers to innovation goal (Goal I) as presented by the NRC, PATH sponsored an overarching literature review into all stated barriers and sponsored a series of roundtables focused on dominant themes in the barriers literature. These were held in October 2004. To begin the detailed specification for the marketing and information goal (Goal II), PATH again turned to peer-reviewed literature on information dissemination and perceptions in the homebuilding industry. Because of the paucity of work in this field, PATH also commissioned a series of focus groups, interviews with housing marketing experts, and began a series of major market research projects on its own. These have occurred from August 2004 through to April 2005. Finally, for the research and development goal (Goal III), PATH was able to rely significantly on the existing literature since this has been the central focus of innovation studies work. Additionally, PATH consulted with a variety of peer partnerships in other Federal agencies to review their respective R&D needs assessments, their organizations, and their performance metrics.

This report is a compilation of all of these reviews, interviews, studies, and analyses. PATH staff and the PATH Industry Committee will review it before its submission to both the National Research Council (for confirmation of its overall direction) and to the Office of Management and Budget (for approval). Once accepted, PATH will undergo its first full year's assessment based on these performance measures. That first year assessment will look at baseline data, develop performance trends and future estimated performance, and suggest a plan to perform later assessments feasibly and thoroughly. These later assessments will be submitted to the OMB for an ongoing "Federal grade," and for potential revisions to the metrics.

Review

An incredibly complex, but potentially fruitful, exercise for determining what a national research and development program should do is to review the past academic and industrial studies of what has been done, and what could be done. Past innovation programs and policies often overlooked basic fundamental intellectual work in the field, or did not sponsor such work when it did not exist.

PATH has the unique opportunity to reconsider its goals, strategic approach, and specific activities. So, the program has the chance to ground itself in the many empirical studies and needs assessments that question whether there is a lack of technological innovation in the US housing industry, and how best to change that state. The following is a review of the key work in the related fields, centering on literature that explores the management of construction innovation. All of the following discussion, including the literature's implications—or, "lessons"—for innovation programs in general are summarized in **Table 1. Literature Summary** at the end of the section.

Surprisingly, there has been very little work done to define and document technological innovations in housing either by academic or industrial researchers. A finite group of historians of technology have documented how specific technologies came to dominate US homebuilding practices, yet few have done comparisons of technological change historically, or look at the processes of contemporary technological change.[5] This work

[5] Carl Condit, Henry Cowan, David Billington, Robert Mark, and Tom Peters are often credited with creating the fundamental work in the history of building and building innovation. See, for example: Condit's *American Building: Materials and Techniques from the Colonial Settlements to the Present* (Chicago: University of Chicago Press, 1968); Cowan's *Science and Building: Structural and Environmental Design in the Nineteenth and Twentieth Centuries* (New York: Wiley, 1978); Billington's *The Innovators: The Engineering Pioneers Who Made America Modern* (New York: John Wiley & Sons, 1996); Mark's [ed.] *Architectural Technology up to the Scientific Revolution: The Art and Structure of Large-Scale Buildings* (Cambridge: MIT Press, 1993) and Peters' *Building the Nineteenth Century* (Cambridge: MIT Press, 1996). Gwendolyn Wright provided the preliminary insights into American housing design in *Building the Dream: A Social History of Housing in America* (New York: Pantheon Books, 1981). More recent relevant work that details the links between social contexts and technological changes include work by Maureen Ogle *All the Modern Conveniences: American Household Plumbing, 1840-1890* (Baltimore: Johns Hopkins Press, 1996); Ted Cavanagh, "Balloon Houses: The Original Aspects of Conventional Wood-Frame Construction Re-examined" *Journal of Architectural Education* 51:1 (September 1997); Gail Cooper *Air-Conditioning America: Engineers and the Controlled*

does argue, though, that housing innovation is as much social as it is technological—if not more so. So, any intervention into the innovation process can be no small effort as it implicates numerous other changes in practices and beliefs.

Some recent work describes the characteristics of contemporary technological changes, particularly in contrast to technological change in other industries.[6] Three particular defining characteristics can be noted. First, it is understood that most current homebuilding innovation is "incremental" in nature. Innovation studies classify technologies along a spectrum from easily-adopted, incremental product changes on one end, to business- and industry-altering, radical product delivery system changes on the other. When an innovation is radical, the requirements for coordination and collaboration within and external to adopting construction firms increase exponentially.[7] Example of radical innovation in housing technology would include near complete prefabrication of customized homes—an innovation that would have both product and process implications. With the exception of Scandinavian countries and Japan, radical innovations in prefabrication and industrialization in housing have failed to take root to any significant degree anywhere in the world for any extended period of time historically, though there have been changing trends in the US as of late.

Environment, 1900-1960 (Baltimore: Johns Hopkins Press, 1998); Peter Galison and Emily Thompson [eds.], *The Architecture of Science* (Cambridge: MIT PRESS, 1999); and Sara Wermiel, *The Fireproof Building: Technology and Public Safety in the Nineteenth Century American City* (Baltimore: Johns Hopkins Press, 2000).

[6] Recent work in the area of housing innovation, adoption, and diffusion can be found at Laborde and Sanvido, "Introducing New Process Technologies into Construction Companies," *Journal of Construction Engineering and Management*, 120:3 (1994); Blackley and Shepard, "The Diffusion of Innovation in Homebuilding," *Journal of Housing Economics* 5:4 (1996); Ball "Chasing a Snail: Innovation and Housebuilding Firm's Strategies," *Housing Studies* 14:1 (1999); Koebel "Sustaining Sustainability: Innovation in Housing and the Built Environment," *Journal of Urban Technology*, 6:3 (1999); Menanteau and Lefebvre, "Competing Technologies and the Diffusion of Innovation: the Emergence of Energy-Efficient Lamps in the Residential Sector," *Research Policy* 29:3 (2000); and NAHB Research Center *Commercialization of Innovations: Lessons Learned* (Washington: US Department of Housing and Urban Development, 2001).

[7] Slaughter, "Builders as Sources of Construction Innovation." *Journal of Construction Engineering and Management* 119:3 (September, 1993); Toole "Uncertainty and Home Builders' Adoption of Technological Innovations," *Journal of Construction Engineering and Management* 124:4 (1998) give further examples of this.

Second, innovations in housing technology can be classified as "product-" and "process-related," or both. An example of the former would be a new appliance, a new material for roof shingles, or any physically-constrained substitute for a current technology or material. An example of the latter would be a web-based construction scheduling system, or any way of producing the same current product in faster, more cost-effective, or higher-quality fashion. Prefabricated structural panels are an example of a combined product-process innovation because they change both the final product performance (higher energy-efficiency and structural performance) and the method of delivering that performance (decreased production time and increased quality).

Last, on balance, the literature contends that innovation in the homebuilding and broader construction industries is underestimated; it is more prevalent, robust, and efficient than indicated by conventional wisdom.[8] Some studies have suggested that there are numerous innovators both in the manufacturer-product sectors (as evidenced simply by the sheer number of products and vendors available for retail and direct purchase), as well as numerous site-specific process changes often undertaken by small builders or by the work crews of larger builders. One of the most significant consequences of the latter phenomenon is that process changes are not readily documented or diffused within a firm—let alone throughout the industry. As such, there is little acknowledgment of innovations, and little reward for innovating.

But, what implications do these three characteristics have?

We know that most innovations are small-scale. The fact that so many innovations exist in incremental rather than radical form in the industry suggests two major approaches to the "innovation dilemma;" if an intervention is made to increase the rate of innovations, is must aim for two drastically different targets. The vast majority of current practices have an abundance of small-scale innovations that simply need to be nurtured and diffused. At the same time, showing the potential and vision of radical change can

[8] Along with the previous references, see also Arditi and Kale "Innovation in construction equipment and its Flow into the construction industry," *Journal of Construction Engineering and Management* 123:4 (1997).

serve as a battle cry for an industry that too often believes its self-fulfilling prophesy of technological stagnancy. Looking at what broader institutional barriers exist in getting radical innovation understood and accepted is critical. A successful intervention fosters both incremental and radical innovation, while taking into account how much—and why—the industry currently falls along either of the two streams.

The second lesson we take from this definition comes from the fact that homebuilding innovations come in all shapes and forms; both product and process innovations require very different strategies for development and diffusion. Knowing that homebuilding is marked significantly by both kinds of innovation means that an intervention cannot be uniform, nor can it remain neutral in terms of prioritizing and comparing innovations. A successful intervention requires comparative methods and evaluations of technologies, provides different kinds of funding and investment for different innovations, and provides different kinds of technical assistance for innovators attempting to bring their product to market or process to fruition.

Knowing that numerous innovations already exist but are underutilized tells us that one of the biggest problems is the diffusion and communication of those innovations; in fact, communication of research is as important as innovation research and development itself. If innovations are not documented, shared, discussed, nor re-applied, they will never have any effect on the industry's productivity or subsequent product quality beyond the one home or subdivision. Insuring adequate information and communication flows (along with their non-commercial nature and reliability) is critical for getting the word out and priming the innovation pump.

The Innovation Process

Now that we know what innovation in housing is, how does it happen? Most of the relevant literature comes from studies of other industries, with some construction-industry wide experiences shedding a bit more focused light.

A vast wealth of literature in economics and industrial engineering describes the major role that innovation has on the productivity of an economy and the transformation of that economy's markets.[9] In fact, research and development are paramount not only for overall economic welfare, but for individual industries. This is obvious in sectors with as long a history as agriculture, and with more recently created markets like the semiconductor and computing industries or biotechnology.

Much work looks at where the actual innovation comes from and how it develops in the R&D process.[10] The study of innovation's adoption and diffusion, however, has generally fallen along two strands of inquiry. One looks at the willingness of an individual or organization to adopt an innovation by studying both the internal decision-making and the group's inherent characteristics that could be classified as "innovativeness." In so doing, scholars have come up with classifications both for the different phases of the innovation decision-making process (knowledge, persuasion, decision, implementation, and confirmation) and the category of characteristic behavior during it (innovators, early adopters, early majority, late majority, and laggards).[11]

The other strand of inquiry looks at market or industry-level abilities to innovate, thereby analyzing the structural characteristics of an industry or group of firms within a sector or across sectors. From these, models of diffusion were developed, though most of the early "classic" models were based on research for heavy manufacturing and the high-tech industries. More recent work looks at a variety of industries and markets and, therefore, complicates the traditional linear models of the R&D process. Hall, for example, proposes an economic model that views the process of diffusion of innovation

---

[9] Major economic scholars have documented this phenomenon since Marx through Joseph Schumpeter and, most recently, by Nathan Rosenberg, Giovanni Dosi, and William Abernathy with James Utterback. See for example: Rosenberg's *Technology and American Economic Growth* (New York: Harper & Row, 1972) and *Inside the Black Box: Technology and Economics* (New York: Cambridge University Press, 1982); Dosi's *Technical Change and Industrial Transformation* (New York: St. Martin's Press, 1984) and *Technology and Enterprise in a Historical Perspective* (Oxford: Clarendon Press, 1991); and Abernathy and Utterback's "Patterns of Industrial Innovation." Technology Review (June, 1978)

[10] These works usually focus on—and are referred to as—"process modeling." The work relies on the sociology of technology and science, and focuses on both the innovator and the iterations of development.

[11] Rogers, *Diffusion of Innovations (5th Edition)* (New York: The Free Press, 1995).

as cumulative decisions made in an environment of uncertainty and limited information. Innovations change over time, and the diffusion process enhances them via the feedback of information about their operation or utility under varying conditions and across different users.[12]

These studies show that the innovation process is not quite as simple as once described. They also rely more on empirical analysis of specific firms or industries to better gauge that complexity. While most of these studies have neither accomplished a broad survey of innovations or of firms to prove causal links, they have proven only a few overarching principles of innovation—like, for example, that uncertainty in adoption decision making decreases as the overall level of innovation adoption increases, or that odds that a firm will adopt increase as the fraction of the population that has already adopted increases.[13] It should be noted, though, that this literature does identify some general determinants of innovation and diffusion including:

- the adopter's human resources;
- organizational structure;
- organizational culture and decision process;
- market context;
- industry characteristics;
- communication channels and social networks;
- technical attributes of the innovation;
- economic attributes of the innovation; and
- supplier/vender characteristics.

[12] Hall, Bronwyn H. I*nnovation and Diffusion. Working Paper 10212* (Cambridge: National Bureau of Economic Research, January 2004).
[13] Jaffee and Stavins, "Dynamic Incentives of Environmental Regulations: the Effects of Alternative Policy Instruments on Technology Diffusion," *Journal of Environmental Economics and Management* 29:3 (1995); Mahajan and Peterson, *Models for Innovation Diffusion* (Beverly Hills: Sage Publications, 1985); Attewell, *Technology Diffusion and Organizational Learning: The Case of Business Computing Organization Science* 3:1 (1992); Damanpour, "Organizational Innovation: A Meta-Analysis of Effects of Determinants and Moderators," *Academy of Management Journal* 34:3 (1991); Bass, "A New Product Growth Model for Consumer Durables," *Management Science* 15 (1969).

What is apparent, then, is that industry-specific studies and models are much more relevant and necessary to shed light on each of these determinants.[14]

The Innovation Process in Housing

Eyes have turned the focus onto the construction industry largely because a variety of measures have suggested that it lacks innovations, innovative processes, and innovators despite its central importance to the national economy. Traditional measures of "innovativeness" such as numbers of patents are particularly difficult to apply to construction because of both the number of products and industries that could be classified as building-related, and because of the inability to enforce patents in this environment (and therefore, the lack of interest in filing patents to begin with). So, alternative measures such as productivity increases (holding for non-technological changes to labor and material costs) have been put forth, almost always with less than optimistic findings.[15] The total investment by construction firms into research and development is also used as a general and comparable metric, though this too is fraught with methodological problems.[16] In either case, the argument that housing in particular—and construction in general—are not as innovative as other sectors is put forth.[17]

---

[14] This specificity was further argued by scholars and practitioners within the construction industry itself, who argued that the "immobility, complexity, durability, costliness, and high risk of failure" of constructed products cannot imply similar patterns of innovation behavior as in other industries. See Nam and Tatum, "Toward Understanding of Product Innovation Process in Construction," *Journal of Construction Engineering and Management* 115:4 (December, 1989).

[15] For example: National Research Council. *Construction Productivity* (Washington, DC: National Academy Press, 1986); Allmon, E., Haas, C., Borcherding, J., and Goodrum, P. "U.S. Construction Labor Productivity Trends from 1970 – 1998," *Journal of Construction Engineering and Management* 126:2 (March/April 2000); Goodrum and Haas, "Closure to Discussion of U.S. Construction Labor Productivity Trends, 1970-1998," *Journal of Construction Engineering and Management*127:5 (September 2001); Rojas and Aramvareekul, "Labor Productivity Drivers and Opportunities in the Construction," *Journal of Management in Engineering* 19:2 (April 2003); and Prieto, "Productivitiy—How It's Measured and What It Teaches Us'--CERF Corporate Advisory Executive Board Series," (Unpublished monograph: Washington DC; April 2003).

[16] The most commonly cited statistics come from the Research and Development Statistics Program within the National Science Foundation's Division of Science Resources Statistics.

[17] Ventre offers one critique of this argument and the quantitative data upon which it is based. See, "On the Blackness of Kettles: Interdisciplinary Comparisons of Rates of Technological Change," *Policy Sciences* 11 (1980).

Work in the last twenty years has begun to focus on the process of innovation in the construction industry in general and, to a much lesser extent, in the homebuilding industry.[18] This significant amount of work demonstrates that management of innovation has been an integral part of the construction industry's consciousness in name at least, if not in actual practice.[19] Just as in the general innovation literature, construction innovation studies fall along those looking at 1) the behavior of individuals and individual firms compared to 2) the whole industry's capacity.

Innovative Firms

Scholars have applied the same terms and classifications regarding individual firm behavior when looking at the construction firm.[20] Specifically, they argue that construction firms, on the whole, are less likely to be innovators and early adopters than in other sectors. While their decision-making processes might be similar, the criteria and context in which they apply these processes, however, is vastly different and oftentimes more complex.[21] In fact, much of the work argues that innovation can occur and be adopted at any point along the homebuilding supply chain, including among the consumers. These studies have described the reasons a builder would innovate or adopt innovation, including the need for basic profit, for improved product quality or service, for regulatory reasons, or for competitive advantage with firms.[22]

---

[18] For the purposes of this discussion, the literature on the general construction industry will have to be viewed as applicable for housing, though much more sector-specific work is needed.

[19] Donald S. Barrie and Boyd C. Paulson, Jr., *Professional Construction Management*, (New York: McGraw-Hill, 1978 and 1984); Clarkson H. Oglesby, Henry W. Parker, and Gregory A. Howell, *Productivity Improvement in Construction,* (New York: McGraw-Hill, 1989); R. L. Peurifoy, *Construction Planning, Equipment, and Methods, 5th Ed.*, (New York : McGraw-Hill, 1996).

[20] Laborde and Sanvido, op. cit. (1994); Tatum, 1986; "Process of Innovation in Construction Firm," *Journal of Construction Engineering and Management* 113:4 (December, 1987); CERF, "Action Plan: An Enhanced Building Technology Evaluation Process- The Partnership for Building Innovation: Enhancing the Process for Implementing New Technology (CERF Report #96-5021-02)," and "Deploying Design and Construction Innovation: Symposium on Engineering and Construction for Sustainable Development in the 21st Century." (Unpublished monographs: Washington, DC; Civil Engineering Research Foundation; (1996).

[21] Sarah Slaughter, "Simulation of Structural Steel Erection to Assess Innovations," *IEEE Transactions on Engineering Management* 44 (May 1997) and "Builders as Sources of Construction Innovation," *Journal of Construction Engineering and Management* 119:3 (September 1993). For a revealing study that is particular to housing, see NAHB Research Center, op. cit., 2001.

[22] See Tatum C. B., "Potential Mechanisms for Construction Innovation," *Journal of Construction Engineering and Management*, 112:2 (June 1986), and "Technology and Competitive Advantage in Civil Engineering," *Journal of Professional Issues in Engineering* 114::3 (July 1988); Julia Harkola and Arent

When looking at the characteristics of those firms that do adopt—that is, those that are "innovators" or "early adopters"—the studies have found that a variety of demographic and psychographic markers apply for both firms and individuals within those firms.[23] These markers are often differentiated based on the specific sectors in which these firms work, too; innovative homebuilding firms tended to be either modular builders and multifamily builders, single-family custom home builders, or national and regional builders. Generally speaking, smaller builders are often first to adopt technologies where high consumer awareness of a material exists, the price of the new technology is significantly higher than what it replaces, or the home construction process must be substantially altered. Large builders seem to be first to adopt new materials that offer a cost savings, improvements in production, reduced callbacks, or reduced exposure to liability.

Some other notable innovative firm attributes include:

- Having a technology advocate within the building firm;
- Stressing the importance of being creative and the first to use new products;
- Using technology transfer programs like the Partnership for Advancing Technology in Housing (PATH) and universities;
- Using union labor at least sometimes;
- Stressing the role of homebuyers who are aware of and want new products and materials;
- Relying on established manufacturers standing behind their building and construction products.

Greve, "Diffusion of Technology: Cohesion or Structural Equivalence?" in *Academy of Management Best Papers Proceedings. Academy of Management Meeting* (1995); Mitropoulos and Tatum, "Technology Adoption Decisions in Construction Organizations, *Journal of Construction Engineering and Management,* 125:5 (September 1999).

[23] Nam and Tatum, "Leaders and Champions for Construction Innovation," *Construction Management and Economics* 14 (1996) provides an interesting look into individual behaviors while Koebel et al *The Diffusion of Innovation in the Residential Building Industry* (U.S. Department of Housing and Urban Development Office of Policy Development and Research; January 2004) looks at individual firms. Most of the following discussion comes from this latter document.

Interestingly, geographic differences could also shape the innovation potential of builders. Homebuilders in geographic areas where both builders and homebuyers have an increased awareness of a new technology or find a technology most useful are likely to be first to adopt. This hypothesis also calls non-builder participants of homebuilding into the innovative process, and the scope of study here.

The behavior and practices of homebuyers, who are currently often identified as impediments to innovation, are an especially interesting area of study. To date, however, the study of consumers and other participants has been even more limited than even the study of homebuilders.[24] In general, homebuyers are supposedly risk-adverse and want the "tried and true." Consequently, the reasoning goes, builders have no choice other than to avoid innovation and manufacturers, in turn, have no incentive to provide new products or develop new processes. Some evidence suggests, though, that innovative builders actually emphasize educating their customers about new technologies.

Studies also suggest that building code officials are behaviorally adverse to innovation as well.[25] Yet, there are still many gaps in empirical work for all of the individual groups involved in homebuilding, and their respective characteristics, behaviors, and decision-making processes.

Innovative Industry

Industry-wide studies, however, have been the focus of some significant scholarship. Many of the studies that focused on the innovative behavior of individual construction firms have also referenced the market's structural characteristics; in so doing, they point

[24] The few examples of this work include: Duke, R., "Local Building Codes and the Use of Cost-Saving Methods" (Washington, D.C.: Federal Trade Commission, 1989), who correlates homebuyer demographics with adoption of residential construction innovations, and Beamish, et al, "Not a trailer anymore: Perceptions of manufactured housing," *Housing Policy Debate* 12:2 (2001) which looks at actual perception of one technological system.

[25] Ventre, "Social Control of Technological Innovation: The Regulation of Building Construction," (Unpublished doctoral thesis: MIT Department of Urban Studies and Planning, 1973).

to the apparent innovation gaps that exist industry-wide.[26] These gaps are regularly referred to as "barriers" to the innovative process. Most of the market-level literature, then, focuses on impacts of specific industry characteristics on the rate and quality of innovation—that is, on defying the "barriers."[27]

Consequently, the underlying question that now drives analysis of the existence of innovation in homebuilding and its measurable pace digs more deeply into the contexts, motives, and behaviors for innovation among the various parties who determine or are impacted by technological innovation in housing. This work is beginning to provide answers to the questions: "Under what conditions would housing innovate? For what explicit and implicit purposes? Which individuals innovate, and in what kinds of organizations do they work? Which technological means and methods do they innovate? And, by which processes?"

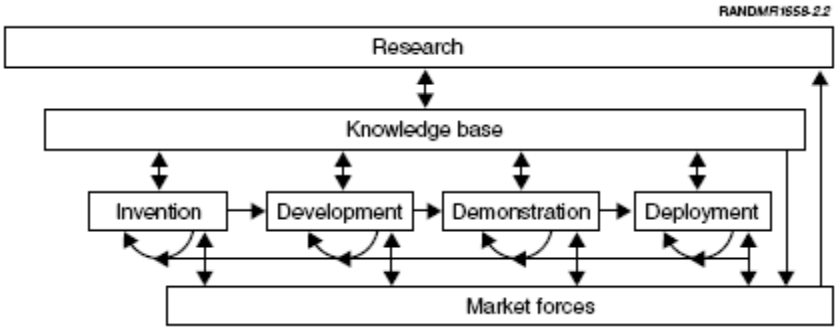
This line of inquiry reflects a rejection of earlier, linear models of communication theory that posit the transfer of information from one individual to another as sufficient. Insights into the nature of innovation in the housing industry have resulted in a new model of housing innovation that recognizes the influence of research, the knowledge base and market forces on an adapted linear model that tracks progress from invention

---

[26] Business Roundtable, *Technological Progress in the Construction Industry* (New York: Business Roundtable, 1982); National Research Council, *Construction Productivity* (Washington, DC.: National Academy Press, 1986); C. H. Nam and C. B. Tatum, "Toward Understanding of Product Innovation Process in Construction," *Journal of Construction Engineering and Management* 115:4 (December 1989) and "Strategies for Technology Push: Lessons from Construction Innovations." *Journal of Construction Engineering and Management*. 118:3 (September 1992). Nam, C.H., and C. B. Tatum, "Major Characteristics of Constructed Products and Resulting Limitations of Construction Technology," *Construction Management and Economics*, 6:2 (Summer 1988); Bernstein and Lemer, *Solving the Innovation Puzzle: Challenges Facing the US Design and Construction Industry* (New York: ASCE Press, 1996); Slaughter, "Models of Construction Innovation," *Journal of Construction Engineering and Management* 124:3 (1998).

[27] Winch, "Zephyrs of Creative Destruction: Understanding the Management of Innovation in Construction," *Journal of Building Research and Information* 26:5 (1998); Oster and Quigley, "Regulatory Barriers to the Diffusion of Innovations: Some Evidence from Building Codes" in Cooke, *Research and Innovation in the Building Regulatory Process: Proceedings of the First NBS/NCSBCS Joint Conference* (Washington: US Department of Commerce, 1977); Gann et al, "Do Regulations Encourage Innovation? - The Case of Energy Efficient Housing," *Journal of Building Research and Information* 26:4 (1998) and "Innovation in Project-based, Service-Enhanced Firms: The Construction of Complex Products and Systems," *Research Policy* 29 (2000).

to development, demonstration and deployment. This dynamic new model allows for the feedback and interaction within and between stages lacking in earlier models.



Revised Model of the Innovation Process
(RAND's "Building Better Homes," p 16)

As with market-level studies of innovation in other industries, this work attempts to model the innovation and diffusion process. A very recent work sponsored by the PATH program, however, has generated a more complex "expanded nonlinear model" of housing innovation.[28] This model is conceptually more appropriate because it incorporates a variety of key actors and key relationships within homebuilding, accounts for the potential for innovation at many points within the industry, provides for feedback from downstream participants, and begins to recognize consumer preferences and market forces. It is also more plausible because it assumes that the "barriers" exist for practical reasons. As such, they require pragmatic adjustments rather than a total overhaul.

It should be noted that this new model and approach are *critical* to PATH's strategic changes for a variety of reasons. One significant aspect of the model is that it actually attempts to articulate and study these perceived "barriers" and their impacts rather than relying on qualitative, anecdotal, and, oftentimes, conjectural insight. In the model, this

[28] Hassell, Scott, Anny Wong, Ari Houser, Debra Knopman and Mark Bernstein. 2003. Building Better Homes : Government Strategies for Promoting Innovation in Housing, RAND Science and Technology Policy Institute, Arlington, VA. Similar reconsiderations of the traditional diffusion model are described in John E. Taylor and Raymond E. Levitt A New Model for Systemic Innovation Diffusion in Project-based Industries CIFE Working Paper #WP086May 2004 Center for Integrated Facility Engineering Stanford University

is represented in the dynamic additions of research, the knowledge base, and market forces as *part* of the innovation process—rather than *exogenous* to it.

This inclusion of "barriers" as an inherent component of technological change is critical to PATH's new strategy and goals because it directly confronts the real and the perceived reasons for the lack of housing technology innovation. In previous studies, scholars and industry analysts described the "barriers" as both having ambiguous sources and as being incredibly insurmountable. In either case, no real causality was proven and no policy enacted. This acceptance of the industry's market and production realities is a major shift towards full analysis and pragmatic "barrier" reduction. As such, the conceptual review will end with the following discussion of the "barriers."[29]

Housing Innovation Strategies

The National Academy of Sciences, "Promoting Innovation: 2002 Assessment of the Partnership for Advancing Technology in Housing (2003)" makes repeated reference to barriers to innovation and removal of barriers to innovation; in fact, they suggest that PATH be charged with "removing barriers and facilitating technology development and adoption." Unfortunately, the identification and classification of these "barriers" has yet to be done either comprehensively or with any practical application. Some examples of the many suggested barriers include:

- Cyclical nature of construction
- Dominance of small firms
- Lack of integration of the industry, particularly the heavy reliance on subcontractors
- Diverse building codes with local peculiarities in details and administration
- Lack of product approval systems that establish and certify to well-recognized performance criteria
- Lack of access to information about new products
- Inadequate education and training on products and materials, installation techniques, and methods of operation and maintenance
- Exposure to liability

[29] For lack of a better name, this document will continue to refer to these institutional and industrial processes as "barriers to innovation." Much of the following literature review and analysis comes from PATH's Barriers to Innovation project, whose final report will be posted in FY05 Q3 on PATHNet.

- Required acceptance by the finance and insurance industries
- Limited funding for research
- Resistance to innovations from homebuyers
- Lack of clear means for moving new technology from government and university research labs to field-testing
- Poorly developed links between universities and the construction industry
- Low levels of government support for technology development
- Changes in ownership over the long service lifetimes of buildings
- Inadequate flow of information within the industry and between the industry and manufacturers
- Adversarial relations in design and construction related to fixed-price contracts
- Inadequate capital for (and a high cost of) deployment
- Lack of documented management ingenuity
- High discount rates for innovation
- Lack of financial incentives among producers (manufacturers), decision-makers (builders), and end-users (consumers) for research and adoption
- Low impact of technology on profit

Many of these barriers either have no empirical support, or cannot feasibly be evaluated. As such, they can be disqualified. Further, the National Research Council's evaluation categorized this list into three target areas for PATH to consider:

- Barriers and Policy, including regulatory barriers
- Information and Outreach
- Research and Development

Barriers and Policy

There are a few key questions regarding specific characteristics of homebuilding and home purchasing, aside from those institutionally engrained barriers to innovation specified in the R&D and Information Dissemination areas above, which have been raised and require special attention. What is perhaps most interesting about these is that many of the lessons from other industries and from innovation literature do not or cannot have the same application—that is, that they are such a part of the homebuilding

industry that their resolution must involve very strategic separations of what can be done in the short-term with regard to circumventing their influence on the innovation process, and what can be done in the long-term to reduce or eliminate them. The barriers of this magnitude that have been identified include:

- **Building codes**—and additional national, regional, or municipal regulations affecting the physical production of houses—prohibit innovation either by explicitly specifying only certain materials and methods, not providing speedy and impartial acceptance in the code where that explicit prohibition does not exist, or by being unfairly interpreted during permitting and inspections.
- The **risk and liability** involved in developing or adopting any one specific housing construction usually outweigh the returns or benefits received, respectively.
- The **financial incentives** for generating and adopting innovation are often viewed as insufficient for overcoming the initial investment, even when considering full market penetration (for manufacturers), additional potential home sales (for builders), and life-cycle costs (for homeowners). A variety of direct, external mechanisms may be considered along with the indirect financial incentives provided through other barriers' reduction. Additionally, the effect of current and potential financial incentives on returns on investment—and how those returns differ between innovators and non-innovators—appear to be unclear to all parties.
- Poor **skills and training** in every profession and vocation of the homebuilding industry prohibit innovative thinking and experimentation. This holds true for the business skills of many manufacturers and innovators, to advanced technical skills among many homebuilding professionals, and including fundamental work training for construction laborers.
- There are multiple **pre-construction parties** that intervene between innovators and adoption decision-makers that can either enable, neutralize, or actively

prevent the transfer of innovation. Vendors, suppliers, exchanges, and retailers all play a major role between the producer and consumers of innovation and, as such, can shape ultimate adoption success.

- There are also many **post-construction parties** that determine how the final consumer values the innovation that she has purchased (knowingly or unknowingly). Based on the physical qualities of either a new or existing house, appraisers, private home inspectors, financiers and lenders, and insurers all determine whether any changes in the house itself ultimately matter to the bottom line. In essence, they determine the value of the home and all of its components, including innovations.
- Homebuilding runs through **significant economic cycles** whose highs and lows are not conducive to innovation. During bust years, there are no surplus funds among innovators to invest in research and development or for innovation adopters to risk experimentation in materials and methods; essentially, there is no market for housing innovation when there are no homes being built. In boom times, there are no slack resources to investigate and decide upon innovations, nor are there any financial incentives to do so.

As described, each of these barriers are inscribed into the method of producing and selling homes in the US—in fact, they are institutionalized. Because there are few parallels between these phenomena and other industries, unique and focused strategies must be undertaken for each.

Building Codes

Numerous academic articles and legal documents have been written with regard to the process of building codes as a barrier to housing construction in general, and to housing innovation in particular.[30] Many of these studies pre-date the 2002 consolidation of the

[30] Office of Policy Planning of the Federal Trade Commission. *Building Regulatory Practices and the Courts* (Washington: Office of Policy Planning of the Federal Trade Commission, 1980); Field and Rivkin,

model building codes and, as such, need significant updating. Several of their findings are still relevant today, regardless.

Loosely, it is clear that building regulatory activities directly and indirectly affect new building technology research, development and deployment. For instance, a building technology developer may devote resources to research and development of a building technology, discovering too late in the process that the technology does not meet building regulatory criteria. As a consequence the technology must then be tested, retested, redesigned or significant documentation developed indicating it meets the intent but not the specific criteria of adopted codes. Similarly, local code officials may be reluctant to approve a technology submitted in a homebuilding permit application unless sufficient documentation showing code compliance on the basis of performance equivalency with the code is provided or there is specific guidance in their codes and regulations pertaining to the new technology to minimize the need for such documentation. Builders may also not want to assume the liability for a non-traditional technology or invest the time necessary to secure approval; consequently more traditional technology is used.

In short, it appears that the primary problems identified with contemporary building regulatory systems include:

- Innovator's ignorance or unawareness of the regulatory process
- Innovator's lack of resources to address regulations regardless of awareness
- Innovator's inability to provide correct and appropriate information to pertinent parties

---

The Building Code Burden (Lexington: Lexington Books, 1975); Cooke [ed.], *Research and Innovation in the Building Regulatory Process: Proceedings of the First NBS/NCSBCS Joint Conference* [Washington, DC: US Department of Commerce, 1977]; The Business Roundtable, *Administration and Enforcement of Building Codes and Regulations* (New York: The Business Roundtable, 1982); Ventre, op. cit., (1973); Sanderson, *Readings in Code Administration: Volume 1* (Chicago: Building Officials & Code Administrators International, 1974).

- Competitors to innovators purposeful manipulation of regulatory information or of the process itself
- The codes themselves are prescriptive in nature, or do not describe the appropriate testing and standards (conformity assessment) necessary for the given innovation
- The interpretation of the code by local jurisdictions is oftentimes ambiguous, arbitrary, or unfairly conservative
- Code organization's evaluation services, created to assist innovators with the regulatory process, are somewhat ineffective due to their internal evaluation timeframes and their lack of weight among local jurisdictions

As stated here, the difficulty in acquiring and presenting uniform information about issues related to the acceptance of innovation to all relevant parties was seen as a core problem; indeed, the issues relating to acceptance alone ranged from testing and standards, to certification, to regulatory criteria and their interpretation, processes for acceptance of new technology, etc. This complex process is compounded by the number of relevant parties through the homebuilding supply chain that shape or are shaped by the codes, including: manufacturers, builders, contractors, and code officials. Consequently, potential solutions focused on the need to develop centralized, standardized, and binding criteria associated with innovation testing and acceptance.

It seems highly unlikely that the model code creation, adoption, and implementation processes are likely to change significantly in the short or even medium terms. In an effort to grasp the scope of studies that need to be performed as well as the potential policy implications in dealing with this barrier, PATH sponsored a December, 2003 Code Barrier Roundtable in coordination with the International Code Council (ICC). The subsequent report provided initial recommendations to address each of these barriers.[31] Respectively, these include:

[31] David Conover, "Removing Building Regulatory Barriers Prepared by the International Code Council for PATH," (Unpublished monograph: January 2004) and "Getting Building Technology Accepted:

- Insuring that manufacturers, particularly small ones, are trained and skilled in the procedures of the regulatory environment. It should be noted that PATH is linking this recommendation with the R&D recommendation regarding commercialization assistance
- With this improved knowledge base, innovators will be able to predict the costs to be incurred for testing and regulatory approval and, thereby, search for additional funding as a consequence. A funding vehicle for these additional costs may also be helpful
- During the process of commercialization, innovators must learn how to communicate their regulatory status—especially when all requirements have been satisfied—more effectively to potential decision-makers. This also addresses the misuse of information by competitors, and should be part of the commercialization training
- A long-term effort to promote and promulgate performance-based standards or, at a minimum, to have new technologies be more readily incorporated into the codes development and adoption process. In addition to active support, PATH can assist in promoting collaboratively-based performance testing protocols and guidelines throughout the industry in order to allow for a variety of options that could still meet safety, health, and even "beyond-code" performance levels
- The conformity assessment system needs to become more efficient, readily recognized, and relied upon on a uniform basis by building regulators. Evaluation services should establish guidelines and other criteria that outline documentation needed to facilitate evaluation and acceptance. They should also review and accept information and issue reports in a more timely and accountable manner
- Code officials need to have clear and timely information on what products have been tested and certified to help them in uniformly reviewing and approving technology installations. Establishing weight to evaluation services—or some

---

Developing and Deploying New Building Technologies" (Unpublished monograph: November 2002). Much of this entire discussion is either directly taken from these documents, or paraphrased.

equivalent overriding authority—among local jurisdictions could streamline the approval process for innovators who all need to work in multiple jurisdictions

These are very clear recommendations, and PATH has begun appropriate activities to address them.

Risk and Liability

One of the barriers to innovation in homebuilding that does have some parallels to other industries is that of risk and liability. In homebuilding, however, that risk is compounded by multiple factors:

- Homes are not just one product, but the assembly of thousands of products, systems, and components
- All of those products and components must be assembled by a third party—namely, the builder and her subcontracting trades
- The performance of homes is related as much to the climactic, geological, and social features a specific location and its occupants as it is to the sum of the individual performance of its respective parts. So, it is difficult to gauge fault when an innovation fails technically

Indeed, the enhancement, improvement, or substitution in one of the components brings not just the risk of poor performance of that one component, but the potential failure of a variety of components, an assembly, and a system. The potential for not just one but multiple "houses of cards" to topple is enough to keep any builder from placing one more card atop.

Again, a limited amount of literature sheds some light on this barrier.[32] Generally speaking, the overall barrier is that the risk of high liability associated with failure of

[32] It is important to note that *market risk* is as substantial as legal risk and liability. We have dealt with market risk issues in the R&D and commercialization discussions before, and focus here only on the latter.

products and practices in the homebuilding industry is a barrier to innovation.[33] Specifically, risk and its assignment can be viewed differently for three key parties, each of whom may be viewed as negligent when building technologies fail to perform satisfactorily: the manufacturer, the builder, and the homebuyer.

Manufacturers are clearly responsible for the successful or failed performance to the extent that they have not performed due diligence in reaching a "standard of care" in testing and certification. The potential for negligent design and misrepresentation increase the level of risk for a technology's buyers, forcing manufacturers often to overcompensate in describing the product, its installation, and its proper maintenance. General insurance often covers the manufacturer's liability, but many firms are developing additional installation training programs for trades (and even opening up their own trade contractor organizations to insure proper installation), as well as providing added maintenance information to consumers. Larger manufacturers, while conservative regarding risk assessment due largely to their financial exposure, tend to invest heavily in liability reduction mechanisms (such as training programs) while small manufacturers often underestimate potential risk, and usually have few resources to insure limited risk down the supply chain.

First, additional insurance mechanisms for manufacturers and innovators need to be explored. Insurers oftentimes make innovation possible by protecting the innovator, but they are often too slow to respond in pulling an innovation out of the marketplace when there is failure. Improved technical monitoring resources among insurers could be a possible method of reducing this risk. Also, the standard safety and durability testing protocols that can be accepted in regulations as described previously would also be helpful. Assistance in developing limited field tests coordinated with builders and through regulatory agencies (i.e., performing due diligence) would also provide significant feedback on technical performance, and potentially reduce risk particularly to

[33] Toole, op. cit., (1998). See also: White and Nancy Holland, "Statutes of Repose: Protection for Manufacturers and Material Suppliers," *ASC Proceedings of the 32nd Annual Conference*.

small manufacturers. Lastly, improved installation and maintenance training procedures seem to be in order.

If a product or technology fails, builders are often the first to be held liable by the homeowner regardless of whether the installation, the product itself, or its maintenance was to blame.[34] Most builders rely on trades to physically install the technology and, though they might specify it, the builders are often responsible for their trades' poor quality. Similarly, they are often held accountable for defects in the manufacturer's design, particularly if there are unanticipated effects on other systems because of that one product. Where behavior in dealing with risk seems to be correlated with manufacturers' size, there seems to be no correlation between a builder's size and the risk assumed.

Apart from creating and funding an institution to guarantee builders and insure manufacturers from all liability, a variety of options can be considered by PATH. Builders could definitely benefit from improved trade training as described above. Developing improved contractual allocation of risks between themselves and their trade contractors, such as arbitration clauses, might also reduce risk for the builder, as well as improved customer service for having buyers understand obligations and limitations. Insurance mechanisms for builders also seem to be a very necessary tool. There has been some limited success in special demonstrations where builders provide evidence of reduced risk by technology to insurers, though these are limited and are not institutionalized. Additional assistance in promoting quality training programs among builders and trades, and having builders' general liability insurers acknowledge these, appear to be a significant method of dealing with builder risk.[35] Further securing such programs is an additional option.

---

[34] As a small corollary to builders' risk, many designers and specifiers have also been held liable for product defects, and "errors and omissions" insurers encourage conservatism as a consequence. Given that design professionals have limited influence on the home production process, this is a somewhat lower priority concern.

[35] NAHB Research Center, "PATH Roundtable: Making the Quality Connection: Improving the Building Industry Insurance Situation Through Quality Assurance Programs" (Unpublished monograph: 2003).

Lastly, homeowners and buyers also have potential liability based on their specifications for and purchase of the home, though consumer protection law has reduced this liability considerably. Successful claims by and settlements for homebuyers against builders, designers and materials suppliers have further complicated the picture. There is also unclear evidence, however, as to how owner and occupant negligence contributes to poor home performance.

Certainly reduced homeowner's insurance premiums would prove a clear financial incentive for adopting some kinds of technologies (especially those that are disaster-resistant and durable). In turn, increased homeowner demand would lead to great adoption and diffusion of these technologies, and would be the clearest homeowner's insurance vehicle for increasing innovation and reducing homeowner risk.[36] Additional programs, such as quality certification, could also assure the homeowner of due diligence by the production side.

Financial Incentives

The example of reduced insurance premiums for technologies with more advanced performance in natural hazards is one that demonstrates an even broader potential area for PATH's focus. While financial incentives of this sort are not a "barriers" to innovation (though their absence can be construed as such), they pose a clear opportunity to advance innovation among all links in the supply chain. So, both indirect and direct financial incentives are relevant policy issues for PATH.

In particular, manufacturers are motivated financially to innovate either because they expect increased sales or higher margins on their sales, or because their innovative activity is subsidized. The former set of more indirect incentives is addressed through performance standards, marketing and dissemination, and a host of other strategies that are discussed elsewhere in this document. The latter, however, has received

[36] PATH, "PATH Position Paper: Homeowner's Insurance as a Tool for the Adoption of Innovation" (Unpublished white paper; January 25, 2000).

attention primarily among larger manufacturers; tax credits, deductions, or other related mechanisms for R&D are largely biased against smaller innovators because only R&D activities beyond a base absolute amount qualify.[37] In addition to that discrepancy, the research and experiment tax credits that currently exist are still not at a significantly high enough offering for any sized manufacturers. Such an increase in the tax credit rates, whether they are applied to all industries or focused in the homebuilding sector, would certainly induce an increased level of independent R&D funding by manufacturers and trade associations. Such tax credits are not rare, but require significant justification and operational maintenance. PATH should explore both the projected increases in R&D activity with a variety of tax incentives, as well as the potential enactment of such policy changes.

Similarly, builders could receive both indirect and direct financial benefits from adoption innovations. If homeowners' demand for innovative homes increased, builders prepared to supply them would have a competitive advantage and, in turn, increased sales. For product innovations, this indirect benefit would also pass along to the manufacturers whereas, for process innovations, builders could reap the full rewards. The mechanisms for this are also addressed in this document through other vehicles.

There are direct financial incentives that need to be explored, however. One of these could involve reduced homebuilder insurance premiums for R&D adoption based on the assumption that such adoption improves performance and reduces builder liability. This was introduced in the previous section. A tax-based incentive, however, could also be a feasible vehicle and there are numerous examples of this; the recently passed Energy Policy Act of 2005 (EPA2005) includes homebuilder tax credits of up to $2,000 for homes that reduce heating and cooling energy use by 50%.[38] Again, the need to develop standards for compliance and creating an operational method of instituting

[37] Hassell et al. op. cit (2003), p. 89.
[38] The Act uses the 2004 IECC Supplement as the base energy performance criteria, and builders must utilize approved modeling software as well as third-party inspectors to demonstrate compliance. Such standards and standard processes are only available for energy-related technologies at this point.

these credits—along with assessing their political feasibility—should be PATH target areas.[39]

Lastly, consumers have also benefited financially from innovations. Aside from general home improvement and increased value (which are described in the *Valuation* section below), homeowners have seen decreased utility bills simply because the technologies are reducing consumption. More durable materials will save in reduced maintenance costs and time, as well. Reduced insurance premiums, such as those described in the previous section, also provide significant financial incentives. Yet, tax incentives have also been utilized for home improvements; in fact, EPA2005 contains numerous provisions for remodeling existing homes with either specific innovations or at a performance level that would require certain technologies. Analyzing the utilization of this tax credit as well as its effect on innovation adoption and diffusion is a feasible PATH role in coordination with other Federal agencies. Exploration of other R&D-focused consumer tax credits (and any other direct financial incentives, for that matter) clearly falls within PATH's mandate. It should be noted again that such direct incentives also serve as indirect incentives up the supply chain, since manufacturers would obviously benefit from the increased adoption of their innovations.

An additional area of financial analysis that can be impacted by such incentives but that requires additional study is that of returns on investment (ROI); currently, the difference between high and low innovators' ROI is unclear. Essentially, it is not clear whether the innovators and early adopters of innovation among both manufacturers and homebuilders receive benefits proportional to their investment.[40] This would need to be studied prior to investigating how any additional incentives would shape those returns.

[39] This tax credit, obviously, was part of a larger energy-focused bill and not of an R&D-focused bill. The potential for new or redefined tax credits must be viewed in light of such strategies.

[40] One study of cross-industry innovative behaviors suggests that innovators receive more than 10 times higher returns from their innovation investment than lower-innovating competitors (Arthur D. Little Co,; *Innovation Excellence Study 2005*). Of course

Skills, Training, and Labor Force

For several decades, the construction industry in general has expressed concern regarding the decreasing skill and knowledge level within its labor and professional pools available to meet current industry's needs. This trend has been noted at almost all levels of organizations and across almost all disciplines and fields in construction, but especially within homebuilding.[41] This is true from the least specialized construction site laborer to very high professional and academic sectors. It should be noted, further, that this decreasing quantity and quality of available staff is gauged on the inability to produce current norms in design and construction, not taking new, innovative, and advanced knowledge into account.

For different positions, this trend has also been marked by different measures and received different analyses. Many innovations that reduce the reliance on skill or actual labor (such as increased factory production) have developed. Other industry efforts have focused on improved training in all sectors, though most of the work in the area has focused on laborers and trades. Debates regarding the skill, composition, and authority of the construction labor force have raged within building circles since the nineteenth-century. Construction workers, arguably more than any other trade, have obstinately held onto strict definitions of tools, practices, and working conditions in American popular culture. Beginning in the 1970s, construction leaders blamed the inability to pursue and adopt new products and processes on the workforce's diminishing skills and fading determination, where earlier arguments were based on labor's overwhelming control and drive. Regardless of the polemic, the demographic base of this sector has certainly changed. The level of building trade unionization has dropped significantly from its peak in the 1960s.[42]

[41] NAHB Research Center, "Labor Shortages And Productivity In The Home Building Industry," (Unpublished monograph: August 12, 1998).
[42] Bureau of Labor Statistics (1975).

The increasing employment of non-union, low-paid, immigrant, Latino, often undocumented, male workers is noticeable throughout the United States residential construction industry; various studies suggest that 20 per cent of the national homebuilding labor force includes this demographic, with upwards of 30 and even 50 per cent in certain regions.[43] The level of classroom or on-site training available to any of these laborers from their employers, from vocational centers, or otherwise in order to meet basic quality standards is unclear. The advanced training needed to understand and adopt innovations is obviously more obscure, if existent at all.

There is simply not much literature to review on this subject. While additional research is needed, anecdotal evidence is strong enough to suggest that inadequate skills and training are a barrier to innovation, and that institutional initiatives are needed to rectify it.[44] It is clear that union apprenticeship programs do not hold since residential construction is generally open-shop, though the advent of the non-AFL-CIO affiliated Carpenters' Union training centers may counteract some of this trend. The increasing use of English as a second language on construction teams is also a barrier to transferring innovative knowledge to the actual site. Both increased support of vocational training centers in residential construction, as well as increasing the number of isolated installation guides and training programs for specific technologies in a broader, linguistically diverse context have also been suggested.

Homebuilders (owners and developers of general contracting or trade firms) and regulatory officials are two additional groups whose training varies greatly. The amount of study on homebuilders' educational level and skill base is even more limited, and is almost non-existent for those of regulatory officials, construction managers, architects, and other housing professionals. An unfortunate perception that homebuilders lack professional skills persists, often because they do not compete based on the physical

[43] Bureau of Labor Statistics and US Census Bureau (2001).
[44] Burnett and Buddenbohn, "Training and Education Needs Assessment for the Home Building and Remodeling Industry" (Unpublished monograph: Pennsylvania Housing Research Center, 1999).

performance of their homes. The advent of larger production builders has done much to rectify this perception, however.

Similarly, regulatory officials have been accused of not following the latest innovations in the industry, and rejecting them in a knee-jerk manner. While the extent of the problem is not known, it is clear that most municipalities do not provide sufficient funding for ongoing training for their code officials, though most model code and regional code official groups offer this.

Lastly, no strong college- or university-based curriculum standard exists in housing production. Of those that do exist, few incorporate either specific technological innovations or the management of innovation actively. This leads to a decreased knowledge base—as well as innovative capacity—among homebuilding professionals like construction managers, architects, and sales/marketing forces.

In addition to the skill and knowledge levels of individual in all homebuilding sectors, there is also anecdotal evidence of problems regarding individual firms skill and knowledge. Some studies of innovation across industries suggest that firms which are unable to or struggling with developing internal R&D capacity have a variety of organizational barriers to overcome.[45] While this is described more in detail later in this document, additional studies are needed to gauge

In response to this knowledge base problem in the professional trades, it is suggested that PATH:

[45] One such study (Arthur D. Little, *Innovation Excellence Study 2005*) lists a variety of factors that impede internal R&D capacity, including: lack of internal resources; lack of market intelligence; badly-defined innovation strategy; unclear responsibilities; organizational barriers; unclear evaluation criteria; lack of industrial financial incentives; poor corporate culture; and, lack of skilled personnel.

- Assist in the development of a national educational standard for homebuilding design and construction
- Sponsor ongoing university research to indirectly support graduate and undergraduate interest in homebuilding innovation
- Develop and support easily accessed training and technical reports for building code officials
- Actively promote examples of builders who adopt innovations to other builders to both educate and instigate technology-based competition (particularly those innovations that improve productivity rather than product), and market those same builders to homeowners
- Survey the industry at all professional levels to understand their innovative skills base and behaviors, as described in a previous section
- Survey firms to investigate their individual R&D capacities, to categorize the barriers to improving those capacities, and subsequently provide analysis and technical assistance (further discussed below in *Technology Transfer, Development, and Commercialization*).

Pre-Construction (Purchase) Intermediaries

There are many pre-construction parties that intervene between innovators and adoption decision-makers that can either enable, neutralize, or actively prevent the transfer of innovation. Vendors, suppliers, exchanges, and retailers all play a major role between the producer and consumers of innovation and, as such, can shape ultimate adoption success. As the “point-of-sale” contacts for both builders and homeowners, these pre-construction, or purchase, intermediaries play a key role in transmitting information on the benefits—and, oftentimes, even the mere existence of—technologies. Since they do not generally create information (the role of innovators and manufacturers) or apply it (homebuilders, remodelers, architects/specifiers, and homeowners fill this role), their role is primarily that of information *channel*. Because they are such a unique channel, however, their role as a barrier to or opportunity for

innovation deserves special attention apart from the information channel work discussed previously.

Just as importantly, as identified in the PATH "Barriers to Innovation" Roundtables, the communications from the manufacturer to the supplier/vendor/exchange/retailer must be sufficient to answer all of the technical and business related questions so that the product might be added to the list of materials sold. Further, it must be easy for these intermediaries to pass along information to the builder or customer that is sufficient to answer their technical and business questions. A breakdown in either type of communication represents a significant barrier to innovation acceptance. Because both time and money are limited at the purchase-intermediary level, it is up to the innovator or manufacturer to take a large amount of responsibility to support these communications. Failure to do so significantly increases the potential for delay or failure of the proposed innovation.[46]

Interestingly, many purchase intermediaries have always been on the lookout for new products or materials that will help builders perform better or reduce costs, primarily because it is the primary source of competitive advantage after pricing and geographic advantages. Innovations are usually not commodities and, therefore, justify an intermediary's profit margin. However, by agreeing to carry a product, the intermediary assumes some part of the credibility (or liability) for that product. Innovators must communicate the benefits of their innovations clearly and reduce concerns about liability to be more readily accepted by intermediaries. Thus it is poor or missing communications that become a barrier at this stage of the product distribution chain. This is particularly true of those purchase intermediaries that deal predominately with homebuilders: the vendors, exchanges, and suppliers.

[46] White and Holland, op. cit.

The remaining purchase intermediary, vendors who work directly with homeowners rather than builders such as “big box” retailers (though this situation is possibly changing), requires special consideration. “Big box” chains increasingly impact how mid-size and large housing product manufacturers do business and even how they innovate, including recent exclusivity requirements, manufacturing capacity and capability specifications, and even product differentiation demands. Generally speaking, only large innovators and manufactures can take on such arrangements and small ones, who produce a significant portion of homebuilding innovations if not the majority, are excluded from “big boxes.” On the final sales side, these retailers are increasingly and sometimes unintentionally providing product for small builders and remodelers, and are trying to make inroads with large builders. Larger manufacturers, however, are increasingly dealing directly with large builders themselves or through a distributor network rather than relying on large retailers. In either case, the selection in purchase intermediary can result in a “make-or-break” scenario for an innovator.

In addition to very specific needs for information content, all purchase intermediaries are concerned with the amount of time required to understand the innovation when first approached by the innovator, as well as the time required to translate and communicate that to the builder or buyer. Of course, underlying all of these issues is the intermediaries’ primary concern regarding being able to ultimately sell any product that they purchase, and do so through unique sales rather than long-term deliveries as much as possible. This requires not only a marketable innovation, but also one that can be supplied consistently.

So, for this barrier, PATH is charged with developing tools that feed into the R&D and Information Dissemination goals and activities. Specifically, PATH should:

- Help innovators assess whether purchase intermediaries add value to their sales by developing commercialization tools that: assess marketing and sales

strategies in comparison to production supply; assess whether the innovation lends itself to purchase-intermediary sales or other sales methods (like direct); and assess whether the innovator has the in-house sales capacity to meet her target market. These tools will be developed and provided in the package of Commercialization Tools described in the R&D section.

- Develop a template for innovators that will both educate the intermediaries and that intermediaries can pass on to buyers/builders to educate them. This is particularly necessary if innovators determine that purchase intermediaries add value and are needed for successful diffusion. One critical aspect of the template will be insuring that the content is appropriate, comprehensive, and sensitive to the time and resources of the intermediaries and their buyer clients. This template will also be developed and provided in the package of Commercialization Tools, but will also be included in the Information Dissemination mechanisms for builders and homeowners for innovations that are already on the market.
- Work with the larger associations of suppliers, exchanges, and vendors (like the American Supply Association and Affiliated Distributors) to develop training for their members and staff on innovative products either through workshops or newsletter announcements.
- Explore whether “big box” retailers are willing to promote innovative products both to their traditional homebuying clientele and, when appropriate, to smaller builders and remodelers—and *how* that promotion can occur. Some potential mechanisms for this include training of in-store sales staff (which promotes the retailers’ knowledge among clients), assembling similar innovations in packages and performing additional on-line and in-store promotions, training purchasing staff on technical alternatives, and ultimately insuring that the deliverables from small manufacturers’ use of the Commercialization Tools are provided to them.

Post-Construction (Valuation) Intermediaries

Just as there are numerous firms that can add supply-side value in the communications from the innovator to the ultimate builder or buyer, there are many demand-side parties that create both the need for innovation and support its value in the final purchase. Aside from the fact that their work constitutes a barrier or enable for "technology pull" in homebuilding, these parties are generally more institutional than being simply business entities. Financiers and lenders, appraisers, realtors, private home inspectors, and insurers all determine whether any changes in the house itself ultimately matter to the "bottom line," and are all in some way regulated because they deal directly with the American public and work in an area of fundamental economic value in the nation.[47]

In all cases, these parties determine the value of the home and all of its components—including innovations—based on a variety of factors; the physical qualities of either a new or existing house and the cost to construct it, in fact, are only a few of many determinants in a home's value. These groups' procedures shape whether the inclusion of any single innovation, group of innovations, or a whole systemic change in construction in a home is translated into financial value for the consumer (who may or may not know exactly what she has bought). One fundamental result of this difference is that these groups can provide incentives and disincentives for adopting technology, and not just information. Given that the new approach PATH should take involves considering feasible changes to current practices, it may be more reasonable to look at ways to remove disincentives, though there are a few incentives that have some promise.

While they are not involved in the direct sales of a home, architects play a critical role in determining in whether a technology gets designed or specified in homes. As such, they determine the value of the technology within the large home purchase. While only a minority of American homes have received direct architectural services prior to

[47] Insurers will not be dealt with here as their role was described in the previous section on Risk and Liability.

construction or remodeling, this segment of the homebuilding production team requires very clear information prior to design, including standards specifications.

Generally, appraisers and lenders are indispensable components of single-family home purchases whether they are new or existing structures, where private home inspectors are needed in purchasing existing homes. Lenders are unwilling to provide financing for structures where the value of the property is unknown in the event of foreclosure; innovation, by definition, is the creation of something unknown and is therefore difficult to prove that it will add any positive value to a home (particularly when the innovation is small and isolated, or promotes builder productivity rather than homeowner comfort and affordability).[48] This chain effect eventually forces a homebuyer to cover the cost of an innovation upfront rather than having its cost amortized throughout the mortgage.

The advent of energy-efficient mortgages (EEMs) and energy-improvement mortgages (EIMs) has been one major advance in the lending community in support of housing performance improvements generally and, in turn, housing innovation. Both EEMs and EIMs take into account the lower energy costs of an energy-efficient home, yet their utilization rates are still relatively unclear. Much of this is due to the fact that available lenders, loan insurers (including HUD's FHA Insurance), and mortgage securities (like Fannie Mae and Freddie Mac) have marketed their EEMs/EIMs vehicles at varying levels, and that the energy inspection and rating that they require might complicate the lending process for the homeowner. Additional studies and marketing opportunities need to be explored on EEMs, as well as considerations for innovations or performance attributes that are not energy-related.

In fact, a wide variety of studies regarding consumers' valuation of different kinds of technologies, holding for different financial contexts and home variations, are critically

[48] Whiddon, Hattis and Leng "Measuring and Assessing the Consequences of Technology and Innovation for Affordability of Housing: Proceedings of the NIST - PATH Workshop" (Gaithersburg: National Institute of Standards and Technology, February 2004).

needed. The assumption that consumers undervalue or devalue technology is the primary reason why valuation intermediaries have been reluctant to invest resources or time in becoming versed in different technologies. As such, a vast terrain is still left unexplored. Examples of such projects (as suggested in the PATH Appraisal Roundtable) include looking at FHA default rates on Habitat for Humanity homes that incorporated energy-efficient technology and studying marketing programs for EEMs/EIMs and their utilization rates. It should be noted that these valuation studies of innovation vary from the consumer perceptions, motives, and behaviors discussed previously as they focus on the actual pricing and willingness to pay for innovations. Much of this work can and should be coordinated with the housing finance research community, and might be necessary for justifying any of the following recommendations.

Lenders also base the valuation of innovation on an appraiser's perspective, thereby making the appraisal a key gate in interpreting and diffusing the value of innovation. It is difficult, however, to evaluate the relative advantage of some new technologies due to their complexity and lack of visibility to appraisers. Methodologies for estimating the amount of value the consumer ascribes to new technologies when buying a house are often too complex and time consuming to encompass in the appraisal process; appraisers are not necessarily housing technology experts, and will subsequently undervalue or devalue some innovations. The low valuation of new technologies by appraisers may shape consumers recognition of the value of new technology when buying a new or existing home. Alternatively, appraisers' low valuation of new technology may reflect their uncertainty about the degree to which consumers value such technologies in the marketplace. Currently, evidence of market valuation of technology in residential housing is almost wholly inferred from technologies associated with energy conservation. When we consider the variety of housing innovation whose benefits are either only partially or totally not related to energy, we know very little. Better understanding of both homeowners' actual valuations and appraisers' capacities are clearly needed, as well as reformulating appraisers' tools to accommodate innovation.

Realtors generally rely on a variety of information sources in order to promote the selling of a home, including a home inspection. They require brief, non-technical descriptions of the homes and easily translatable measures for those descriptions. Where they do not require the same level of ongoing education as appraisers, they do need accessible information to resolve any technical questions they might find—and descriptions of innovation's benefits—that they can use in promotion.

The use of private home inspectors for assessments of a home's physical qualities is common, though this is generally not mandatory and often (particularly in strong markets) not even performed. Neither profession is in the position to promote innovation. They do, however, have the potential to discourage innovation along with appraisers by adversely steering homeowners away from technologies that they are not familiar with but that may actually be a benefit or value-addition for the home. This discouragement can come about because the inspector is simply not familiar with a technology at best, or not competent, ethical, and/or certified by a national association at worst.

General training improvement on technological innovations appear to be a significant barrier for all of these groups, but this is particularly a concern for inspectors who are entrusted with the physical assessment of structures, systems, construction, and technologies of homes. Many national associations (like the American Society of Home Inspectors) are actively working to maintain strict professional standards as well as ongoing educational requirements for membership. Continued support for such professionalism and the specific training modules are clear policy options. Additional mechanisms for informing all inspectors of technological alternatives should be made available to complement generalized ongoing education, since often there are spot decisions made at which time some general information may be helpful—and may make the difference between a negative versus indifferent inspector's report.

Given the overall potential for these “housing institutions” to discourage innovation—let alone encourage them, a variety of activities are recommended. These include:

- PATH should first assist manufacturers by helping them understand the incentives, disincentives, and indifference that controls innovation adoption in homebuilding. This can helps determine how a specific technology can, or even should, be marketed and described. PATH should include this within the Commercial Tools package previously described.
- Determine the appropriate role for architects in the process of technological innovation, and help manufacturers and their trade associations develop the appropriate tools (like standards specifications) in order to be able to provide adequate information for architectural services.
- General educational support can be provided for appraisers, inspectors, and architects as a component of ongoing training and certification requirements. PATH can assist in developing workshop templates, or providing online educational workshops.
- Access to information on technology in a professionally specific manner is needed for these intermediaries at the point of having questions, such as the appraisal visit or the home inspection. Such non-commercial information can be provided though membership dues in national associations and be created through existing PATH information vehicles, like ToolBase.
- Additional ongoing relationships with key journals in the appraisal and home inspector communities (like the Appraisal Journal) on both technologies and their valuations should be pursued.
- Specific tools used by the appraisal community can be complemented with innovation-based information. Since appraisers rely on both professional evaluation standards and “comparables,” PATH and partner Federal programs like Energy Star could assist in tracking the sale values for homes using

particular technologies for dissemination in central appraisal guides, like the Appraisal Institute's Residential Database. A revision to the industry-wide standard "Appraisal Form 2055" might also be a vehicle to track, and potentially valuate, different major innovations and should be negotiated with the appraisal community. This effort could also fall out of the broader valuation research agenda discussed earlier.

- Along with providing training materials for the private home inspector community through their national professional organizations, PATH should support continued professionalism and certification in the industry. This could involve promoting only certified inspectors to homeowners who are concerned with the quality of their homes.

Housing Cycles

Some qualitative historical evidence suggests that economic fluctuations in the housing market partially determine the rate of innovation. This is somewhat supported by studies in economic theory, though actual empirical analyses seem sparse.[49] During market highs, it is assumed that the supply side has financial resources for innovation investment but there is no time for innovation information and training. During market lows, not only does the reverse hold, but there is also no demand for innovation (since there is no demand for housing). In either case, it is reasonable to assume that highs and lows in housing markets dramatically shape the ability to invest in research and development, to provide information, education and training in the industry, and bring attention to the industry's innovation rates to the point of enacting industrial or governmental policy responses. The question is the magnitude and direction of that effect. PATH should consider funding studies in this area, though this innovation barrier is both of lesser priority because PATH is limited to enacting policy in the current

[49] Briscoe, *The Economics of the Construction Industry (Construction Technology and Management)* (New York: Chrysalis Books, 1988); Morton and Brunner, *Design and the Economics of Construction* (New York: Routledge, 1995); Manseau and Seaden, *Innovation in Construction: An International Review of Public Policies* (New York: Routledge, 2001); Bon, *Building As an Economic Process: An Introduction to Building Economics* (New York: Prentice Hall, 1989).

economic context, and because it would seem impractical to enact policies to stabilize housing market cycles for the sole purpose of generating a stable innovation rate.

Information and Outreach

When it comes to the process of innovation and its diffusion in homebuilding, the literature is scarce; in fact, it is virtually silent on the communications and social networks builders and other participants use to learn about innovations or influence their adoption practices. No one has even begun to look at how the above issues regarding the quality of, access to, and predisposition towards innovation information are linked.

Despite this, numerous barriers to innovation with regard to the quality and volume of information between industry participants (including the final homeowner) have been suggested. Included among these are:

- There is often a lack of basic information about new products and innovations (including education and training on products and materials, installation techniques and costs, and methods of operation and maintenance), let alone information tailored to each industry participant. Much of the information that is provided is commercial and marketing-oriented, thereby confusing the recipient as to its authenticity and veracity. Appropriate information *content* is critical.
- When information does exist, there is no easy access to it; it is not adequately transferred between participants—i.e., there is poor communication. The *channels* by which that information is transferred are also critical.
- There is a general reluctance among homebuilding participants (particularly builders and homeowners) to adopt innovation. The *context* in which information is transferred and received determines its interpretation, use, and the overall predisposition towards or against innovation.

Information Quality

For starters, the issues surrounding *content* and quality of information is a particular concern, and one in which PATH can play an active role. These include the level of information detail that is needed for a decision-maker to be able to pass judgment, as well as the manner in which it is delivered (that is, in the form of marketing or sales information versus unbiased technical delivery). As stated in the NAS 2000 PATH Evaluation:

> "Information asymmetries result when buyers and sellers in market transactions have different information. PATH could develop impartial, credible information that rates the quality and value of new technologies. PATH could support existing product evaluation programs and ongoing efforts to develop product evaluation methods. PATH could also assist in the development of programs to increase public awareness and to make information about housing technologies available to builders and consumers."

In numerous focus groups for PATH's ToolBase information resource, builders and remodelers (as well as many architects, homeowners, and other homebuilding participants) have demonstrated that they have very specific needs and questions about innovations. Generally, smaller-scale innovators do not develop adequate materials for these decision-makers. Having unbiased, clear, and readily accessible information is not only critical but absolutely necessary for a technology to be introduced to decision-makers, to be considered, and to be decided upon. PATH has a clear role in continuing to produce, comprehensive, readily accessible, non-commercial information on technologies—including performing the necessary testing and evaluations needed to generate that information.

Information Needs and Channels

In addition to the content of the information, tracking how a decision-maker hears about information, acts on it, and then passes it on is also a needed tool—that is, the *channels* for information exchange. Several studies have tracked the actual documents and physical communications used during the homebuilding process.[50] These have been done with the hope of understanding where communication breaks down and how those channels can better accommodate new technologies and processes. Unfortunately, they only track documents during construction, and not across the entire supply chain or with sample innovations.

Much additional work is needed to understand how information is transferred across the industry, who provides it, where it fails, and, most importantly, whether a governmental intervention is needed to make up for those gaps. In an effort to provide broad brushstrokes towards this, PATH sponsored a variety of focus groups and expert interviews. The discussions focused on five key housing supply chain decision-makers: builders; remodelers; large and small manufacturers; and homeowners (of both new and existing homes). The findings, though certainly not conclusive, did suggest certain patterns in information channels.

Homebuilders, as the first core group, rely heavily on media, especially trade publications, to learn about advanced technologies and high-performance building practices. National demonstration homes, exhibits and educational sessions at trade shows, and installation training are also very important sources for this information as builders rely heavily on visual or hands-on media, and shared stories based on actual experiences.

[50] Mead, Stephen P. 2001. Developing Benchmarks for Construction Information Flows. Journal of Construction Education 6, no. No. 3: 155-66.
Wakefield et al. Center for Housing Research at Virginia Polytechnic Insititute and State University "Industrializing the Residential Construction Site Phase Two: Information Integration" Department of Housing and Urban Development, June 2001

As a special subgroup of the larger category of builders, remodelers tend to deviate more widely from the norm than the new-home builder—that is, the early adopters among remodelers tend to seek out information on new technologies at least as much as early adopter homebuilders, if not more so. Their information channels are similar (especially with regard to industry trade shows and training), but also include additional internet research. Late-adopter remodelers, however, are even less likely to seek out information than their new-home builder counterparts. They would seem to require financial incentive programs to arise any interest.

Not surprisingly, consumers rely much more heavily on major media than home producers. Consumer publications and television appear to be strong general vehicles for this group. One unique information channel, however, is the sales force of homebuilders; new homebuyers rely heavily on this group for information about all of their prospective home's characteristics, including new technologies and their benefits. For consumers that are remodeling their homes, similarly, the sales staff at large home and hardware stores are critical to informing and guiding technology decisions. For the early adopters among both kinds of consumers, exhibits and demonstrations at consumer events are likely very effective channels too.

Manufacturers, the last core homebuilding group analyzed, seek out information to develop new products and services. These can come from a variety of sources and channels and, as such, could benefit from centralizing and categorizing. Once a product is technically developed, however, manufacturers need assistance in developing a channel that remains limited and ad hoc: direct training to trades. Currently, builders are the primary channel for manufacturer-produced information to both the trades and the ultimate consumer. This channel is occasionally mediated through architects, distributors/suppliers, and retailers (who would also require expanded information content and some centralization of sources), but is critical nonetheless. For all of the above groups, it is clear that PATH must develop very clear

and targeted marketing campaigns and perform all dissemination activities through the prescribed channels.

Market Research

Lastly, a better understanding of information's context is needed; studies on information perceptions of homebuilding participants, and influences upon perceptions within the segments of those groups that are innovators and second-stage adopters, would illuminate the best course to reach this audience. Much of this focuses on behaviors, practices, and motivations of different industry groups (and segments within those groups). In other words, we need to understand the underlying context in which specific information is received and interpreted. In turn, there is much need to shed light on the many cultural assumptions made by the same homebuilding groups identified previously.

The literature in this area is generally sparse, as it is in other information areas. However, many manufacturers and builders have gleaned insights into buyers' decision processes and preferences from surveys of potential, current and past customers. From these, observers can infer a variety of behaviors, but these observations are by no means conclusive or even methodologically sound. What is more, many are entirely proprietary.[51] To begin to fill some of the knowledge gaps, PATH is currently conducting market studies to determine which segments of the homebuilding industry

[51] The most notable ongoing Federal or governmentally-sponsored surveys and studies in this area include the US Census Bureau/HUD American Housing Survey, DOE's Residential Energy Consumption Survey, and a variety of studies done under Energy Star ®, its multiple partners, and State or regional utilities and energy offices. Other related independent and academic studies include those performed by Harvard University's Joint Center for Housing on building products, scholarship at the University of Georgia and Virginia Polytechnic Institute, and the NAHB Economic Research publications; most of these are not ongoing with the exception of the NAHB. Lastly, numerous private survey instruments and data collection services exist, leading among these are products from F.W. Dodge, the NAHB Research Center's Builder Practice and Consumer Surveys, R.S. Means cost data, housing customer satisfaction studies by J. D. Powers, trade journal surveys in McGraw-Hill, Reed Publishing, Scripps, and Hanley-Wood publications, and a volume of private trade association and/or individual manufacturer market research studies.

have the greatest potential for diffusing change, and what methods are most effective in reaching them.[52]

While many sociological, economic, and architectural analyses of historical market behaviors have been performed, governmental housing innovation programs and industrial innovation advocates are still left with many questions regarding current conditions, and too few data sources. With the hope of increasing the number of data sources and improving the quality of their instruments, PATH can begin by categorizing some of our questions by either topic or actor. In particular, we are interested in the motives, behaviors, and practices of housing actors across technology types, geography, and socio-cultural indicators. "Motives" can be defined as the decision-making processes, cost-benefit analyses, institutional barriers, and perceptions of risk for innovating and for adopting innovations. The term "behaviors" describes actual adoption rates throughout the industrial supply chain, as well as the organizational individual characteristics implicated in innovation and adoption decisions. Finally, "practices" includes the various communication and information dissemination vehicles (both internally to an organization or network, and externally via media channels) used for innovation and adoption purposes.

All of these categories and questions begin to hit at what it means for an industry participant to be an early adopters or in the early majority of adopters of innovation.[53] For builders, for example, little is known about:

- how builders assess relative competitive advantage
- how they estimate consumer reaction

[52] In addition to the recently published PATH report, "Diffusion of Innovation in the Residential Building Industry," the Partnership is currently developing three survey instruments—one on the behaviors and practices of production homebuilders, another on builders who have adopted panelized, factory-built systems, and a third on consumer perceptions of factory-built housing—all of whose reports will be published in 2005.

[53] Koebel, op. cit., 2003.

- information gaps between builders and manufacturers, and intermediaries like vendors and suppliers
- their respective information brokers
- the relative weight of industry and independent information sources
- the importance of word-of-mouth among builders, and
- the time and effort that builder allot or can afford to listen to innovators or to make decisions about innovations.

If the behavioral and economic patterns of builders and remodelers are still obscure, those of the individuals who work for them (from all trade subcontractors down to the laborers on-site) are virtually invisible. While the issue of their skill level and training involves a broader set of policy issues to be discussed later, those groups' behavior in relation to innovation and technological information is clearly a component of dissemination needs in the industry, and an area for further exploration and action for PATH. Currently, innovation discussions suggest that one key barrier to adoption is that the number of subcontractors trained in and willing to work with new technologies is still small and dispersed; as such, builders cannot require or adopt technologies without adding significant additional expense and effort to their projects. With regard to construction workers, demographic studies demonstrate a nearly complete reduction in unionized laborers in residential construction nationally, with a significant number of these being immigrant workers with limited English proficiency.[54] Language barriers and poor, overall construction training have clear implications for information dissemination.

[54] Linder, *Wars of Attrition: Vietnam, the Business Roundtable, and the Decline of Construction Unions*. (Iowa City: Fanhipua Press; 2000); US Bureau of Labor Statistics & Census Bureau. *Current Population Survey* (Washington: GPO, 2001); US Bureau of Labor Statistics. *Handbook of Labor Statistics – 1975 Reference Edition* (Washington: GPO, 1975); Goodrum, "Hispanic and Non-Hispanic Wage Differentials: Implications for the U.S. Construction Industry;" *Journal of Construction Engineering and Management.* (2003).

For homeowners, the adage that consumers "are more interested in granite countertops" than in any more detailed technology or technological change has almost become an industry-wide prophesy. Because the ultimate homebuyer is at the very far end of the "old" linear model of the construction industry and because they are often described as being represented solely by the builder, consumer preferences have often been ignored by the innovation adoption literature. Similar questions regarding the trends in current and new homeowners' perceptions of technologies and, in particular, their willingness to pay for them or determined their satisfaction of builders because of them, has been the source of an interesting new field of inquiry. Most of this work has focused on energy-efficient technologies, and it is still not conclusive.[55]

Similarly, still less is known about the developers of innovation themselves. While these innovators are usually product manufacturers, they can often be builders themselves (particularly when it comes to management and production innovations) or researchers and advocacy groups (when it comes to fundamental knowledge creation and broad knowledge exchanges). Little is known about how those innovators in homebuilding-related technology behave during all phases of R&D and commercialization, including:

- how they initially conceive of their ideas
- how they test them
- how they assess the probability of commercialization and market size
- the extent of their knowledge of the homebuilding industry
- where they seek investment resources
- how they market their ideas and the subsequent innovation
- the level of business development for their individual firms

[55] Torbica and Stroh, "Customer Satisfaction in Home Building," *Journal of Construction Engineering and Management* 127:1 (2001); Sirmans, Bacheller and Mcpherson, "The Value of Housing Characteristics, National Center for Real Estate Research," (Unpublished monograph: National Association of Realtors, Washington, DC, 2003). Most of the work on consumers' perception of energy-efficiency is referenced in a later note on home valuations.

- what level of resources mark the majority of innovators and whether that leads to a bias in favor of large innovators or those that have access to large builders, and
- the “success” rate of different innovators

Clearly, for all of these homebuilding participants, there are major gaps in our knowledge of their motivations, perceptions, and ultimate behaviors and practices in relation to technological innovation and change. These gaps beg the need for more market and social science research.

But, what do we gain from knowing this? Where we have tracked the production process in homebuilding and contemplated how innovation fits into each of those stages, we have yet to understand the process of “innovation production.” Knowing how an idea comes to fruition and is perceived and acted upon by others is key to understanding not just the success or failure of any one technology, but what role any external party—like PATH—should have in changing these behaviors and perceptions. PATH should clearly redirect resources in this area both to improve its own programs and to provide the industry with a basis for innovators’ knowledge.

R&D

R&D primarily refers to the phases of innovation that include the creation or invention of an idea, through its testing and prototyping, and to its eventual commercialization. The most critical concerns regarding these phases identified in the literature include:

Regarding investment in research:

- Comparatively little funding of basic and applied research by primary research funders (including Federal government)
- Little to no funding of basic and applied research by industry

- Significant industry fragmentation restrains consolidation of research funds for large-scale studies and projects
- No priority-setting to establish critical research agendas among either funders, researchers, or the eventual recipients of research products

Regarding research transfer, development, and commercialization:

- Few and decentralized institutional channels for basic and applied research to be transferred to industrial development and testing
- Little to no funding for development and testing for smaller businesses
- Cost and complexity of commercialization is a barrier to entry for smaller businesses and innovation developers
- Lack of knowledge base of markets, standards, and regulatory environments—i.e., of the entire housing industry—among small manufacturers and innovators

Regarding regulations and performance of innovations:

- Extremely complicated, localized, and oftentimes arbitrary regulatory environment
- No clear performance test protocols for many innovation which, in turn, prohibits comparisons of innovations down the supply chain
- No baseline or threshold performance level against which decision-makers can measure innovations beyond building codes and EnergyStar product certification

The issue of fragmentation is one that cuts through many of these barriers, and is also a particularly difficult one since it affects both the pooling of research funds and political clout on an industrial scale, and the skills and knowledge base of the entire industry on at the level of production for an individual firm. As such, there are benefits (competition) and disadvantages (lack of resources and standard knowledge base) to fragmentation in relation to innovation. Significant competition is traditionally seen as an economic ideal, where similar producers of similar products compete within similar markets. On the whole, however, this does not hold for construction, which is still more of an aggregate of local markets that may or may not be very competitive. The consolidation and collaboration between and across manufacturers, vendors, and builders that has marked the last two decades have improved the possibility of industrial R&D funding;

there is much anecdotal evidence that R&D efforts have increased because of these mergers. Essentially, the verdict on fragmentation's effects on innovation is still out.[56] The trick, then, is to utilize fragmentation's advantages (increased competition) and disadvantages (lack of resources).

Both academic scholars and industrial analysts generally accepted the rest to be true since they rely more on quantitative measures than either empirical analysis or speculation. So, PATH's charge in R&D is to overcome these barriers. In practice, these findings have many implications. We can break these out into three categories.

Investment Capital and Knowledge Collaboration

PATH has a clear leadership role to play in overcoming investment barriers. PATH must increase the level and quality of housing research by convincing other institutions to develop cooperative research agenda, to perform joint research, and to create ongoing, institutionalized collaborations out of some of these—*not* to simply fund research itself. By serving as an intermediary and neutral party, PATH can help other organizations like trade associations, larger builders, and housing-related foundations pool their funds. While the financial incentives explored earlier would certainly assist in such commitments, PATH must also bring these groups' attention to the fact that R&D investment is in their best interests.

Along with the funding needed for R&D, much more collaboration regarding the potential R&D projects where appropriate and, just as importantly, regarding the supply chain and markets for their innovations is needed. Overcoming the negative aspects of fragmentation by pooling funds involves the added benefits of spreading investment risk and of sharing research findings to the extent that these are non-proprietary. PATH's coordination of "Manufacturer Summits" along with representative trade associations

[56] Blackley and Slaughter actually disagree on this point, though both measured fragmentation in very different ways.

could bring in the technical staffs of leading innovators to lay out research agendas in which Federal assistance may be needed in which other collaborations (especially cross-supply chain ones) could be brought to light. An example of such collaboration could be between a wall panel manufacturer and window manufacturer to better integrate and test their products. Such collaboration could direct practical research agendas rather than await the benefits of whatever research products come down the pike of public- and academic-sector work. PATH began this process of research agenda setting (without the contribution of investments, though) through the PATH Roadmaps effort. This Roadmap work, along with funding for some key seed research projects from the Roadmaps to spur private-sector development, must continue.

Along with encouraging industrial efforts, PATH must put the public sector's house in order. As a largely Federal effort, PATH must assist in reducing redundancies among the governmental research agencies, and look to the major civilian research funding agencies (that is, the National Science Foundation and the Department of Energy) to consolidate and collaborate on research agendas, view their funding as seed money for later additional development by the research and industrial communities, and, just as importantly, share research findings. In all of these efforts, it is also important to note that PATH itself should continue funding seed projects in those areas that are not covered by the other agencies but that researchers and industry experts view as critical and strategic areas for preliminary funding. Fortunately, PATH began the "Roadmapping" process several years ago; this initiative directly corresponds to that need, though its products must also be better integrated in industry's agendas—that is, it must be a better "seed."

The second area that requires PATH's attention comes directly from the PATH "Barriers to Innovation" roundtables and indirectly from the scholarship proving that there is a significant level of incremental innovation in the industry. This is the issue of commercialization—both the institutional problems inherent in the process of commercialization, and the lack of familiarity with that process among the smaller

innovators. The former is discussed in the "Other Policy & Barriers" section below, but the latter is startlingly obvious despite the fact that no discussion has occurred in the main literature or policy developed to address it. The "Innovation Centers" created by the Civil Engineering Research Foundation (CERF) have been close conceptually, but they have focused on the innovations themselves—their technical, cost, and regulatory performance. Programs such as Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STIR) efforts, while realizing that certain innovators have unique capacity or lack thereof, also focus only on the innovation. Certainly much work needs to be done in terms of assisting innovators of all sizes, though, in both transferring seed ideas from other industries and sectors, and from non-industrial researchers without development skills. But, this is only the tip of the iceberg.

No program has focused on the *innovators*—the seeds for their ideas, their business development, market research, methods of communication and marketing, sales and distribution, long-term production capacity, links to other technologies and innovators, and strategic alliances. This knowledge gap was expressed as an explicit recommendation in the "Barriers to Innovation" report, but was also underlying the expert panelists' reactions to each of the manufacturer presentations. General assistance in business development and innovation commercialization for innovators as opposed to just the innovations are somewhat common, including the Small Business Administration's offerings. However, relevant guidance has never been provided for housing technology innovators. As this discussion shows, there are so many idiosyncrasies in housing that tailored assistance is a marked omission in thinking and policy. PATH must clearly address this.

This assistance should delve even more deeply into innovators' processes, however. In addition to providing mechanisms for the external acquisition of R&D and subsequent market commercialization of their products, PATH should assist firms in developing short- and long-term R&D capacities. After additional studies of the primary barriers for internal R&D capacity-building in the homebuilding sector (discussed previously), it is

critical to develop additional modules that can be incorporated into commercialization and small business outreach. These will focus on training firms (particularly smaller ones) on longer-term R&D capacity building and strategies.

Technology Performance Standards

The last R&D-specific initiative that is suggested by the literature deals with the lack of performance standards for the multitude of housing innovation across an equally wide variety of performance attributes. For example, energy-efficiency is the most robustly studied home performance area partially because of the extensive standards set by the energy codes and EnergyStar certification requirements. Numerous, though still inconclusive, efforts have been made to set performance characteristics for "green," "sustainable," and environmental impact performance, as well. By definition, building codes and occupational hazard requirements define only minimum occupant life safety after construction and labor precautions during. Yet, other attributes still lack much of the performance thresholds and requirements that can be applied to specific technology and system innovations for measurement and comparison. This lack of guidance for builders, homeowners, and other decision-makers has proven particularly difficult.

PATH is committed to improving innovation rates without recommending regulations—that is, in making the act of innovation achievable through existing markets. As such, performance standards that are developed with industry, that are optional, and that are quantifiable appear to be reasonable responses to this dilemma. Indeed, numerous PATH focus groups have argued that a basic, non-enforceable method of computing performance between products (without specifying a baseline beyond that currently implied by the building code but could easily surpass it) is not only helpful in the decision to adopt a technology, but oftentimes is critical to success during that adoption. The great advances in testing protocols for product durability funded by PATH at the National Institute for Standards and Technology's Building and Fire Research Laboratory and, to date, done in conjunction with sealants and coatings manufacturer testing samples and full industry cooperation, are tremendous examples of this initiative.

According to the NAS 2000 PATH Evaluation, further, PATH "could produce public goods that might lead to a broader diffusion of innovations, such as methods of measuring product performance. Because it is in the public interest that all manufacturers producing building materials and systems subscribe to similar standards, and because private producers will be unable to recoup the costs of creating standards, it is appropriate for the government to establish the standards for building materials and systems." Affordability and durability appear to be the greatest concerns to consumers and builders in addition to energy-efficiency, though additional and oftentimes, overlapping performance attributes have been identified. As such, identifying which attributes demand the most current attention among industry participants is critical before any protocol development.

Role of Government

While the need for intervention to improve housing innovation is argued and supported by most of the literature, it is still not clear *why* government should play a role in that intervention. Just as importantly, we need to know *who* in government should play the role. Also, it is unclear *how* that should happen given both precedents for government's involvement in industrial and economic growth and the unique structure of the homebuilding industry.

Understanding whether government should have a role in industrial innovation is a fundamental concern. Historically, the Federal government has been involved in a wide variety of housing-related activities, including "making homes more affordable to build, safer to live in, and less costly to maintain and operate."[57] Part of these policies has included sponsoring research in housing design, construction, and maintenance, and in setting standards for the same. The government has also been concerned with barriers

[57] National Research Council, op. cit., 2001.

that impede further housing development and homeownership. When it comes to looking at barriers to innovation, then, PATH follows a long tradition on both fronts.

There are additional economic reasons why governmental intervention is needed. As suggested by the National Research Council:

> "Economists generally agree that some common market failures lead to deviations from the ideal of a perfectly competitive market and that correcting these failures may warrant government intervention… Arguably, [public goods, externalities, and information asymmetries] are applicable and support the need for the PATH Program."

If we assume that public goods are not diminished by any one individual's use despite being made available to all, information on housing performance and quality is one such public good. It is in the public interest that all manufacturers producing building materials and systems subscribe to similar standards, and because private producers will be unable to recoup the costs of creating standards, it is appropriate for the government to establish the standards for building materials and systems.

Similarly, governmental intervention is needed to address externalities. In many research endeavors, externalities arise when parties do not bear the full costs, or reap the full benefits, of their actions or investments. Manufacturers, builders, and homeowners all have little incentive to bear the full cost and risk of investing in new technologies. Diffusion assistance—including coordinating shared investments, educating and disseminating housing participants, and reducing local barriers such as building codes—could help overcome market failures in product diffusion resulting from externalities.

Lastly, many builders and homeowners make decisions and purchases with different levels of information. The need for non-commercial, impartial information on innovation, including evaluation-like programs, is critical to overcome these asymmetries. In

addition to developing such programs, PATH could also increase public awareness in such a way that access to the information is well-publicized and available.

The case for governmental intervention has been made in numerous historical instances in the past century. There are also numerous locations and hierarchies within government by which this has taken place. The Federal government has taken two approaches to this, either by creating separate research and development agencies and departments (the National Science Foundation, the National Institute of Health, and the National Institute of Standards and Technology, for example) and creating applied research and development divisions or programs within agencies (for housing technology, this has been done in the Departments of Energy, Agriculture, and HUD). In housing and construction research, there is also the unique opportunity to enforce innovation in Federal or Federally funded construction projects. Some scholars have argued that there should be a single agency or program charged with the comprehensive housing or construction research and development agenda. [58] Because of the uniqueness of each Federal agency's charge, however, it would appear that individual programs (though coordinated to reduce redundancy and share resources for similar efforts) would be more practical.

Each of these agencies has also developed very different activities to improve housing innovation based on the above assumptions regarding governmental roles. The most comprehensive listing of the most critical activities that should be publicly directed and supported were provided in the 2003 RAND publication "Building Better Homes."[59] These include:

- Sustained research support
- Support networking across horizontal and vertical boundaries
- Coordinate government efforts

[58] Dibner and Lemer, *The Role of Public Agencies in Fostering New Technology in Innovation Building* (Washington, DC: National Academy of Sciences Press, 1992).
[59] Hassell et al, *Building Better Homes* (Santa Monica: RAND, 2003). The following listing is quoted directly and entirely from this publication, p. xvii and detailed in pp.83-95.

- Search and disseminate information on relevant Federal R&D
- Support education and training
- Support exploratory and applied research for technology transfer
- Modify the research and experiment tax credit for small firms
- Support development and demonstration
- Explain the regulatory process to innovators
- Provide technical and standard development support
- Public procurement
- Help identify market trends and opportunities
- Support product performance monitoring and evaluation
- Reward important innovations with valuable recognition
- Create linkages among markets
- Create financial incentives for end users

So, while the previous literature suggests numerous opportunities, activities, and policies upon which PATH (both public and private sides of the partnership) should embark, these readings also specify which initiatives fall exclusively or, at least partially, on governmental shoulders.

The next issue, then, becomes how such a delineation of tasks between public and private entities can be structured. While historical examples of innovation interventions generally have taken unilateral agendas into industry, it is important to recall that PATH is a public-private partnership rather than a public or private program. Changes in thinking about the role of government in recent years have given rise to public-private partnerships as a new framework for relations between government and other entities in society.[60] In promoting innovation in housing, the government has come to recognize that success depends on working with multiple entities considering the complex structure of the housing industry and the government's limited influence (since virtually all housing is produced by and sold to the private sector).

[60] Goldsmith and Eggers, *Governing by Network:The New Shape of the Public Sector* (Washington: Brookings Institution Press, 2004).

Partnerships have been used successfully for coordinating public and private research agendas for over two decades. As stated in a National Academy of Engineering report:

> "Innovative public-private partnerships have emerged as one important form of government support for accelerating the development of new technologies. These public-private collaborations can significantly expand the breadth and depth of technical expertise available to the individual partners, reduce the costs and risks of research and development, and bring new technologies to the marketplace faster." [61]

Examples and models of such structures abound, including the Partnership for a New Generation of Vehicles (PNGV) and American Textiles Partnership (AmTex) in the Department of Energy, and the Department of Transportation's Intelligent Transportation Society of America (ITSA).[62] EnergyStar, the most relevant partnership to PATH, has also successfully integrated industry and governmental efforts, particularly with regard to divvying and leveraging marketing efforts for appliances.

Indeed, one critical, though non-operational, goal suggested by the National Academy of Science's PATH evaluation committee included improvements in how "to administer… the PATH program to achieve its mission, goals, and objectives." This included "[enhancing] its relationships with the broad spectrum of housing researchers, innovators, adaptors, and consumers." [63] It is also worthwhile to note that many of the suggestions for initiatives in promoting innovation described before (such as shared investments in R&D and coordinated marketing materials and promotion) lend themselves well to public-private partnership agreements. PATH must explore the extent to which all of the above recommended initiatives and activities can be

---

[61] National Academy of Engineering, *Engineering and Environmental Challenges: Technical Symposium on Earth Systems Engineering* (Washington: NAE, 2002) and "Science, Technology and Innovation for the 21st Century" OECD Committee for Scientific and Technological Policy at Ministerial Level Final Communique (January 2004).

[62] The National Council for Public-Private Partnerships *Critical Choices: The Debate Over Public-Private Partnerships and What it Means for America's Future* (Unpublished monograph: 2003).

[63] National Research Council, *Promoting Innovation: 2002 Assessment of the Partnership for Advancing Technology in Housing* (Washington: NRC, 2003).

coordinated under a single cooperative partnership, and how that can be developed over the longer term.

Summary

While all of the literature on innovation and innovation barriers—as well as the implications for PATH—is summarized in Table 1, it is also important to note that there is a clear need to do further studies and develop more extensive empirical analyses in technology management in construction in general, and in housing in particular. This holds true as a policy initiative itself for all the areas described, and should be understood as an implied recommendation for PATH in all of these areas.

However, as a policy-oriented program, PATH cannot suggest “more studies” as the sole activity either, nor is that desirable. As described at the beginning of this document, PATH is an experiment. As such, it must balance the need to both expand empirical and theoretical work while actually implementing extent knowledge. Basically, we can figure out what we don’t know but we need to work with what we do know.

Table 1a. Literature Summary: Defining Housing Innovation		
Background Literature	**Key Findings**	**Implications for PATH**
History of Housing Innovation	Technological change is as social as it is technical.	PATH must consider the institutional constraints on technological changes, as well as the social perceptions towards them. In effect, PATH should perform social science research as much as it does engineering and design research.
Incremental Innovations Dominate	Practical interventions must work on expediting incremental innovations. Radical innovation must be viewed as a long-term effort.	PATH should utilize its resources sparingly (and strategically) when it comes to radical innovation. Such efforts should be limited to marketing campaigns and longer-term research. Larger investments should be made in applied research, diffusion, and institutional change for incremental innovations.
Both Product and Process Orientation	R&D and commercialization approaches for different innovations must be specific to that innovation—i.e., product- and process-innovations have different target audiences and vested interests.	PATH must not exclude either product or process innovations. However, it must be aware that each one has very different builder, consumer, and institutional implications. Those programs that are targeted to a specific audience or institution must take this distinction into account: no one size fits all.
Multiple Sources of Innovation	Diffusion and communications are as important for innovation as R&D —if not more so.	PATH must accept that innovation does not necessarily follow a neat development from basic research through to market penetration. Often, innovations can come from builders, labor, and consumer feedback. PATH should institute methods for capturing innovation at all of these points of entry. More importantly, PATH should ensure diffusion methods for all of them.

Table 1b. Literature Summary: General Production and Innovation		
Background Literature	**Key Findings**	**Implications for PATH**
Measuring Innovation's Industrial Effect	- Innovation is measured based on its contribution to productivity changes in industrial practice and subsequent economic gains in industry	- A variety of measures of innovation and innovation's effects exist. PATH must clearly separate the two in order to focus its efforts. - PATH could explore how technological "exuberance" is affected within an industry in seemingly advancing sectors.
Innovative Behaviors	- An individual or firm goes through phased (informal and/or formal) decision-making processes when deciding whether to innovate or adopt innovations - Individuals and firms can be classified based on their innovation behavior	- We must classify innovative behaviors in homebuilding - Determine whether there are correlations between firm characteristics and innovative behavior - Document formal processes for decision-making and diffuse - Investigate the "success" of formal processes - Explore informal processes and their effect on decisions and ultimate "success"
Industrial Capacity for Innovation	- Industries demonstrate different innovative capacities based on the structure of their processes and products - There is no one-sized model that fits all industries. So, most models demonstrate only overarching principles.	- Document total volume of innovation in housing in comparison to other industries - Compare general characteristics of innovative firms in other industries to those in housing - Compare formal and informal processes for innovation decision-making in other industries to those in housing - Document cases of innovation "failure" to gauge level of innovative "determinants" or "barriers" specific to other industries.

Table 1c. Literature Summary: Housing Production and Innovation		
Background Literature	**Key Findings**	**Implications for PATH**
Measuring Housing Innovation	- Innovation measures used in other industries are not necessarily applicable (patent issuances, Federal research funding, etc.) - Productivity measures in construction are inconclusive, and their innovative determinants are unclear.	- PATH should focus on innovation measures rather than measures of innovation's effects (we can only assume positive significance at this time). - PATH should develop an aggregate innovation measure but also a distinct measures for different categories of innovation (process, product, incremental, radical). - Innovation measures should be marked along the research, development, and adoption process. So, the measures themselves should lend themselves to longitudinal and cross-sectional study.
Innovative Behaviors in Housing	- There's little to no analysis of behaviors. - From the few works, we know that all participants have behavioral commonalities, and that these can be segmented in traditional innovation terms (innovators, early adopters, early majority, etc.)	- PATH needs to fill the gaps in understanding of innovative behavior through survey and case study analysis, and provide these to the industry and scholars at large. - PATH must create marketing campaigns predicated on the knowledge of behaviors for market segments with a focus on the early majority.
Housing's Capacity for Innovation	- Perceptions of stagnancy are as significant as the reality - Barriers are the "culprit" for those perceptions	- PATH should identify the barriers to innovation and measure their effect. - PATH should develop policies and programs for institutional change (see exploration in Table 1d.)

Table 1d. Literature Summary: "Barriers" to Housing Innovation		
Background Literature	**Key Findings**	**Implications for PATH**
Overall	- Numerous barriers to innovation creation, adoption, and diffusion have been identified. - Causal determination between these has not been proven. - No longitudinal model has been created to measure the dynamic effect and perception of barriers.	- PATH must regularly review the status and effect of different perceived barriers to innovation. - PATH should then prioritize those barriers that have the highest effect and develop short-term strategies for helping innovators circumvent them, and long-term strategies to reduce them.
R&D	- There are barriers to funding and resource investment in R&D. - There are significant barriers to the transfer of R&D products and their subsequent development and commercialization. - There is an inability (market failure) to measure and compare housing innovations' performance that reduce R&D incentives.	- PATH must facilitate consolidation of R&D investment capital from private, non-profit, and public sectors, along with making public research agendas transparent. - PATH must actively promote initial or increased investment among larger manufacturers, builders, housing foundations, and governmental agencies. - PATH must develop comprehensive guidance for innovators in order to develop and commercial their products, as well as to acquire investors. - PATH must promote the creation of uniform protocols for testing "beyond code" performance of different housing systems. Such protocols can assist in developing performance-based standards as well as builder and consumer comparisons (which should be linked to existing comparison media, e.g., Consumer Reports).
Information	- There are few non-commercial sources of information on housing	- PATH must evaluate and provide non-commercial information on innovations to serve as a promotional resource for the innovative

	products and innovation. - There are few media by which that information can be provided. - There is little knowledge of how different participants assimilate and act upon information.	community. - PATH must develop active marketing campaigns for its initiatives, tools and services, and the technologies it promotes that accurately target the desired market segments and create a call to action among recipients. - Extensive and ongoing market surveys of different homebuilding participants perceptions, motives, and behaviors in relation to innovation should be pursed.

Policy	- There are significant regulatory impediments to innovation and experimentation. - The risk and liability of experimenting and innovating are too large. - Poor skills and training at all levels of housing production—from labor to professionals—impede innovative thinking. - Numerous parties work between manufacturers and builders that may or may not suppress, ignore, or promote innovation. - Numerous parties work between builders and homeowners that may or may not suppress, ignore, or promote innovation. - Housing's economic cycles simultaneously enable and deter innovation.	- PATH should work both with innovators (so that they understand the regulatory requirements for their innovations) and with the regulatory community (so that it might provide more opportunities for experimentation and innovation). The latter can take the form of improved code evaluation services, increased regulatory weight to evaluation reports at the municipal level, and performance code models in the longer term. - PATH must work with the insurance community to develop cost-effective compliance vehicles and testing for innovators and builders, as well as promote innovation adoption in homeowner insurance. - PATH must develop insurance planning guides, standard contractual clauses for risk sharing, and training/installation planning as part of its commercialization services to innovators. - PATH should develop training standards and curricula for the different labor professionals in the industry, as well as promote training and installation guides by innovators. - PATH can provide sales planning guides to innovators, while working with sales associations (suppliers, exchanges, and vendors) and large, direct retailers on member training or resources for innovation promotion. - PATH should perform ongoing studies on the valuation of technologies in housing prices, assist in training on and promotion of innovation among inspectors, appraisers, realtors, and lenders, and tailor existing tools among these professions to account for innovation. - PATH could perform a longitudinal, econometric study correlating innovation creation and diffusion rates with cycles in housing starts.

Table 1e. Literature Summary: Public Role in Innovation		
Background Literature	**Key Findings**	**Implications for PATH**
Need for Public Role	- There is a precedent for governmental involvement in innovation in general (and housing innovation in particular). - Regulations implicate governmental involvement. - Housing displays market failures with regard to public goods, externalities, and information asymmetries.	- PATH is justified.
Public Activities	- Government involvement should include all the activities that currently "fall through the cracks" in the R&D process. - These include activities in R&D resources, marketing and information, and policy or institutional change.	- However, PATH should take on only those activities required for housing innovation that also are appropriate and legal for governmental intervention.
Public Vehicles	- Precedents in housing innovation demonstrate that command-control (public-only) innovation programs are ineffective. - Recent experiments with public-private innovation partnerships are proving effective.	- The public half of PATH should further explore and define the partnership in ways that support the full-range of activities, and expand the private half's involvement and investment.

Performance Metrics: Background

At the same time that PATH is revisiting its fundamental policies and programs to develop a more sound set of goals and approach, it is also required to develop measures of its performance that are both appropriate to those goals and that comprehensively link all of the specific activities. With new goals and activities to implement, PATH must also develop the methods for evaluating whether the activities are successfully moving towards the goal. This is not only a requirement from Federal administrators. Even more importantly, it is a critical self-appraisal for the program. Such an evaluation, if performed accurately and with methodological soundness, could also add to the knowledge of innovation interventions.

Although performance measurement has a long history in the private sector (with productivity being the central focus), it is relatively new to the public sector. As noted in the previous section, performance measurement for public programs did not begin until Government Performance and Results Act (GPRA) was passed in 1993. The Performance Assessment Rating Tool (PART) utilized by the OMB is the current incarnation of the Federal response to GPRA as well as the President's Management Agenda. The reasons for establishing performance measures are generally obvious though worth noting:

- Performance measures promote efficiency in funding, personnel, and other governmental resources;
- They clarify roles and accountability for stakeholders;
- The support the development and maintenance of operational agendas and priorities;
- They assist in program reporting for public transparency; and, ultimately
- They demonstrate levels of success or failure of any given program.

When it comes to research and policy on research performance, however, measurement is noticeably more difficult.[64] While there is clearly a need to develop quantitative measures for all research projects and entire agendas that utilize public funds (including basic research), there is often no sensible way of predicting research outcomes given the long-term nature of these projects (especially basic research). It is often the case that we cannot predict any practical outcomes and, in turn, measures of "success" for research though investment in it certainly provides ultimate economic and social benefits. Applied research is somewhat simpler in this regard, since these projects often involve milestones and required deliverables that can be systematically measured.

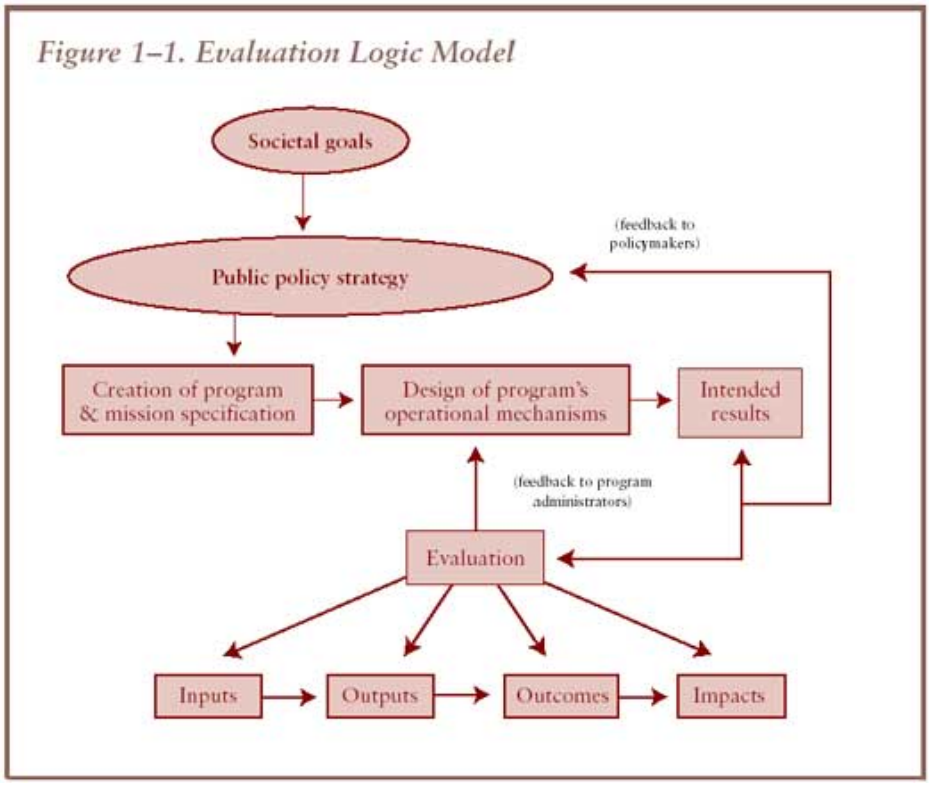
A negotiated approach has been taken by other Federal agencies responsible for research and the governmental analysts calling for tighter controls over research funds. As concluded by the National Research Council's study of GPRA implications, "Both applied research and basic research programs supported by the federal government can be evaluated meaningfully on a regular basis." The common method for undergoing this, then, is referred to as the "Evaluation Logic Model."[65] As NIST's Advanced Technology Program (ATP) spells out:

> "The logic model is intended to provide a clear diagram of the basic elements of a program, subprogram, or project, revealing what it is to do, how it is to do it, and with what intended consequences. It shows the logical linkages among mission, activities, resources (inputs), outputs, outcomes, and impacts. It is a first step in identifying critical measures of performance. The logic-model tool has been used in program evaluation more than 20 years ago and has been adapted

[64] National Research Council, *Evaluating Federal Research Programs: Research and the Government Performance and Results Act* (Washington, DC: NRCPress, 1999) and *Implementing the Government Performance and Results Act for Research: A Status Report* ((Washington, DC: NRCPress, 2001).
[65] NIST's ATP has developed several models that are useful, as well as additional references. These include: den Heyer [ed.], *A Bibliography for Program Logic Models/Logframe Analysis* (Ottawa, Canada: Evaluation Unit, International Development Research Centre, 2001); McLaughlin and Jordan, "Logic Models: A Tool for Telling your Program Performance Story," *Evaluation and Program Planning*, 22 (1999); Rossi and Freeman, *Evaluation: A Systematic Approach, 4th ed.* (Beverly Hills: Sage, 1989); Cozzens and Melkers, "Use and Usefulness of Performance Measurement in State Science and Technology Programs," *Policy Studies Journal*, 25 (1985).

to program planning where it helps ensure a correspondence among all the elements of a program."[66]

While numerous versions of this exist, the general concept can be expressed in Figure 1 from the NIST ATP assessment. Some governmental programs that follow the *innovation product* approach describe early have taken on an evaluation framework that tries to assess the "benefits" of investing, assumed to be the outcomes and inputs of the logic model.[67] Since PATH focuses on the *innovation process*, this interpretation of the logic model is not appropriate.



Indeed, in addition to its major recommendation that measures should be predicated on the latest literature and scholarly reviews, the NRC further stated that all measurements

[66] http://www.atp.nist.gov/eao/gcr03-857/chapt1.htm
[67] DOE's EERE has taken this approach. See http://www.eere.energy.gov/office_eere/pdfs/gpra_fy06/chap1.pdf

should consequently be made to “match the character of the research.” Such characteristics will shape the timescale, the unit of analysis, the appropriateness of baseline and benchmark numbers for metrics, and even the appropriate staff and mechanisms for evaluations.

We must develop metrics, then, which both respond to the new mission, goals, and activities prescribed to PATH earlier, but also think about how these metrics can be effectively implemented and sensibly understood. PATH embodies numerous qualities that complicate evaluation. Fortunately, there are methods of addressing this within the logic model. These PATH idiosyncrasies include (with respective logic model response):

- Multiple Goals

  PATH is not solely a research program. In fact, it is partially R&D, partially policy, and partially outreach and information dissemination (marketing). Each of these areas has very different kinds of evaluation and measures that do not fall neatly in GPRA or traditional R&D logic model descriptions. Consequently, PATH will retain the intent of logic model definitions while developing descriptions for each different goal. The USDA Extension School model’s template logic model is, therefore, most appropriate for PATH; this is illustrated in Figure 2. Further, linking of the different logic models for each goal will be a critical component of the metrics. One example of this could be when a specific policy outcome can shape subsequent marketing activities and their later outcomes, which could later shape an R&D agenda item. This certainly complicates things, but is the only appropriate method to evaluate PATH.

- Time Frame

  Since PATH has existed for five years already before the change in goals and strategic approach, it will be difficult to determine when to start the years under evaluation. Indeed, it may not even be relevant. Such a decision will have to come from Federal managerial authorities.

• Unit of Analysis

Other Federal housing innovation programs have looked at the number of US households that include their respective technologies, including Energy Star's product and home certification programs. Still others measure the total aggregate performance effect of their research on the market, like DOE's EERE measure of energy consumption in households. Both of these still demonstrate an innovation product focus that are either too difficult to link to their actual contributions or require very distant time frames for adequate analysis. Since PATH is concerned with the innovation process and is particularly looking at both short- and long-term policy solutions, a more appropriate evaluative benchmark would be three separate "through-put" measures (one for each separate goal) than one overall output measure.

• Effects of External Activities

Despite this level of detailed matching between activities and outcomes, there still exists the real possibility for non-PATH activities to influence the outcomes. In response, PATH will document all other known activities in the logic models as contributing variables (but not as PATH activities) so that evaluation experts can determine the extent to which those influences outweigh, complement, or are insignificant to the link between the PATH activity and outcome in question.

• Partnerships

Unlike other R&D programs, PATH and its sibling programs are often partnerships—with all of the shared risk, accountability, and potential for bottlenecks and failures associated with doing work across discrete organizations. Since PATH is a public-private partnership rather than a strictly public or private one, there are reasons to query whether GPRA-associated performance measurement is appropriate for PATH. There is also the shared emphasis on outcomes over inputs. Do the measurements provide useful indicators to private sector partners that may be more concerned about

productivity gains? Also, do these measurements say anything about how relationships among PATH participants might be leveraged to produce the desired outcomes?

Since there are no widely accepted performance measurements for public-private partnerships, developing a set of performance metrics for PATH becomes an experiment with trials and errors and lessons to be learned. For now, PATH will document all activities that are performed explicitly by either side of the partnership and annotate them accordingly. As opposed to the non-PATH activities described above, these will be fully measured and documented to allow evaluation teams to determine: 1) how PATH as a whole has performed; and 2) how each separate partner has contributed to that performance.

- Complexity

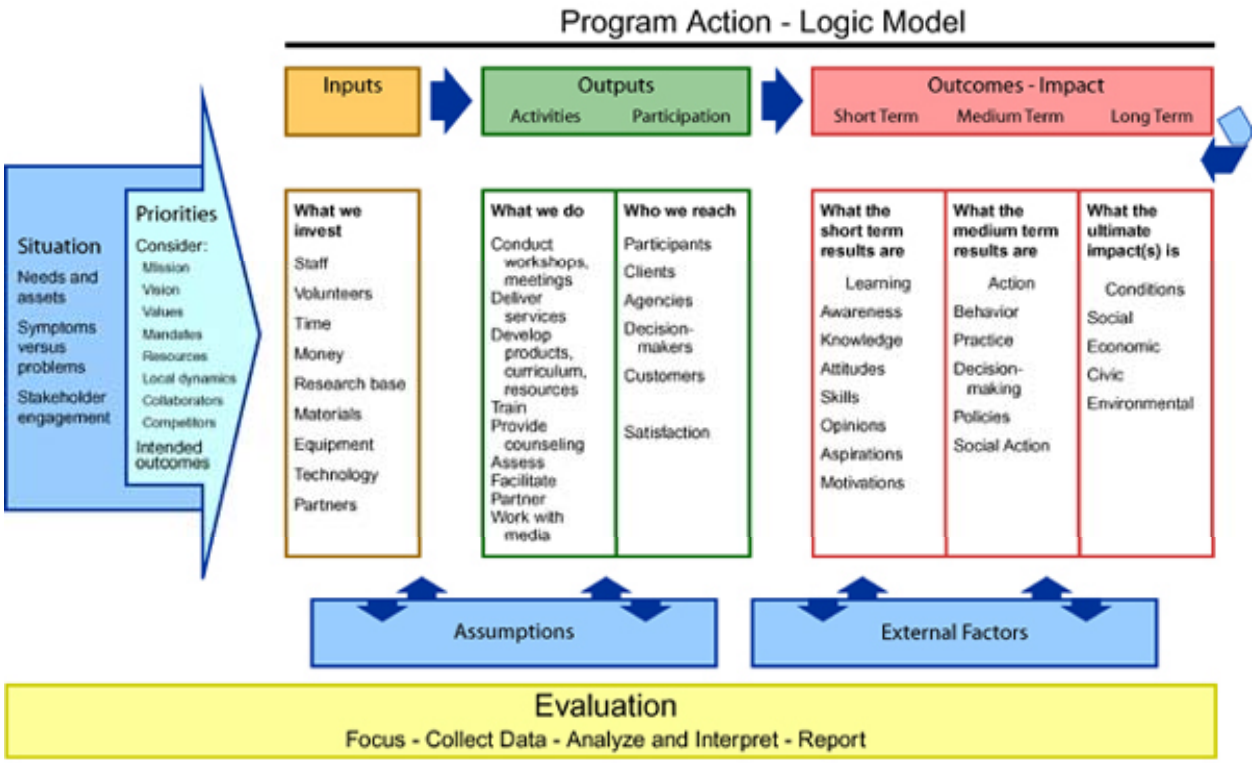
Given the detail involved in creating and describing logic models for each activity as shown in the template logic model in Figure 2, and given the number of activities suggested by the literature review, and the number of interaction between these and each others' outcomes, the PATH Metrics can easily become an incomprehensible stew. This would make evaluation a formidable chore, as well as take up sizable resources that the program could use for direct activities instead. What is more, many of the data that are necessary are currently not being collected—thereby, requiring entirely new surveys or qualitative sampling mechanisms in order to develop baseline measures for the metrics, continuously measure them, and determine appropriate levels of progress.

Perhaps of more dire consequence, such bureaucratic detail would also prove impossible to communicate to the many stakeholders involved with PATH—many of whom are vested or even interested in only the portion of the PATH's activities that effect their individual markets, industries, or circles of work. The level of complexity inherent in PATH's work, therefore, cannot be transferred onto the explanations of how that work will be measured. So, to the greatest extent

possible, PATH will develop simplified versions of these metrics for public and private partners.

With all of these disclaimers made and justified, it now time to translate the conceptual review described before into actual research, outreach, and policy activities—and diagram how these work collectively while being measured individually.

Figure 2. Logic Model Template



Operations & Management: Background

The NRC provided a fourth PATH goal in its significant evaluation: “To administer the PATH program to achieve its mission, goals, and objectives.” The issues related to PATH’s past administration, operations, and overall management have been noted, though PATH’s ability to fully integrate suggestions to overcome them has been hampered by the fact that it is administered within a Federal agency and, therefore, can only respond administratively to Federal operational mandates. This includes all Federal budgetary, contracting, personnel and partnering restrictions.

Budgets for all Federal programs, of course, are appropriated by Congress annually; in addition to prohibiting many multi-year agreements with partners, this prohibits fully planning past immediate resource allocations. For example, the future activities described in the attached operating plans are only hypothetical. Should funding be below the estimated appropriation, all activities will be seriously curtailed and progress towards the PATH goals and objectives will be delayed at best, or reversed at worst.

Similarly, HUD contracting requirements designate eligibility for the different parties who can receive and use Federal funds (including research agreements). This eliminates certain partnerships from PATH’s reach, as well as forces PATH (and potential partners) to follow limited and oftentimes restrictive contracting schedules and procedures.

As a Federal office, PATH is incapable of expanding activities without an appropriate growth in PATH staff and skills; insufficient staffing has been noted by the NRC as a serious problem in administering the careful planning and execution of partnerships. Currently, only six HUD staff members of varying levels of obligation, skill, and relevant background administer all PATH activities, including both research contract oversight and programmatic administration.

In addition to battling these present constraints, PATH will explore other models of partnering that are Federally permitted and allow for greater flexibility from the traditional Federal restrictions posed above. In particular, several model public-private research partnerships have developed in other agencies that shed some light on potential organizational restructuring for PATH. The Intelligent Transportation Society of America (ITSA) is one such example. Established in 1991 as a non-profit entity to coordinate the private industry partners of a collaboration with the US Department of Transportation's Federal Highway Administration, ITSA coordinates the development and deployment of intelligent transportation systems based on Federally funded research. It also provides numerous membership services and programs to assist members with individual deployment and business objectives. Originally formed as a utilized Federal advisory committee, ITSA works closely with the Department of Transportation on projects and programs in support of the National ITS Program.

The Department of Energy's American Textile Alliance (AmTex) was a short-term public-private research partnership created in the early 1990s between textile manufacturers and DOE's national laboratories to spark innovation in an industry that was being undercut by foreign imports. This very successful initiative was administered jointly by a DOE program office and the AmTex Industry Program through a well-crafted cooperative research and development agreement (CRADA) that allowed industry members first access to Federal research provided they supply matching development funds.

Other programs in the Federal agenda focus either the governmental or industrial roles. NIST's Advanced Technology Program forges individual agreements between Federal funding and small businesses needing applied research investment. The NSF's Partnerships for Innovation (PFI) provides seed monies for new partnerships between academe, state/local/federal government and the private sector that will explore new approaches to support and sustain innovation. Its ultimate goals, subsequently, are to stimulate knowledge transfer by broadening the participation of research entities, and to

foster and sustain innovation in the long-term. PATH should certainly focus on models like these that provide operational efficiencies with research focuses.

All of this withstanding, OMB's request for performance assessment suggests both an opportunity to incorporate many of the NRC managerial recommendations, and to build upon them. In particular, PATH will pay significant attention to preliminary baseline measures for these metrics and to their ongoing evaluation despite the fact that many of these measures do not currently exist and either require extensive resources to measure or methodologically difficult.

Partnership for Advancing Technology in Housing

We will create…

An innovation pipeline

An innovation resource

An innovation infrastructure

We will be successful when…

The cost & time to innovate is reduced.

Innovations are readily adopted.

Innovation funding increases.

Performance Metrics

Goals & Objectives

Mission:

To facilitate the development of new technology and advance the adoption of new and existing technologies to improve US housing

Metric:
The Level of Homebuilding Production "Innovativeness"
This is a composite indicator of Barrier Reduction; Technology Adoption, and R&D Investment

	An innovation pipeline	*An innovation resource*	*An innovation infrastructure*
GOALS	**I** Remove barriers and facilitate technology development and adoption	**II** Improve technology transfer, development, and adoption through information dissemination	**III** Advance housing technologies' research and foster development of new technology
OBJECTIVES	I•A Identify current and potential barriers and measure their impacts	II•A Establish and maintain non-commercial information sources on innovation	III•A Establish sustained public and private R&D investment & resources
	I•B Develop practical methods to overcome current barriers	II•B Understand behaviors, attitudes, and needs regarding innovation information	III•B Clarify and assist innovators with processes from technology transfer to market penetration
	I•C Develop alternative future industrial processes that eliminate barriers	II•C Have relevant information materials on innovation and innovators for different parties	III•C Have comparative standards for innovation performance, cost, and benefits & agendas

An innovation pipeline

GOAL

I — Remove barriers and facilitate technology development and adoption

Metric: Average Total Cost & Time from Conception to Market Penetration for PATH Identified Research

Baseline: ***Goal:***

OBJECTIVES

I•A	I•B	I•C
Identify current & potential barriers to measure their impact *Metric: Number of Expert-Identified "Barriers" Studied*	**Develop practical methods to overcome current barriers** *Metric: PATH Effect on Impact (cost & time) of Barriers*	**Develop alternative future processes to eliminate barriers** *Metric: PATH Effect on Impact (cost & time) of Barriers*

OUTCOMES

I•A•1 Regular assessment of previously identified barriers' impact on innovation	I•B•1 Practical mechanisms for addressing newly identified barriers (from I•A•2)	I•C•1 Strategies in response to newly identified barriers (from I•A•2)
I•A•2 Regular identification of new or potential barriers to innovation	I•B•2 ***Codes:*** ICC-ES Reports Improvement & Institutionalizing	I•C•2 ***Codes:*** Performance-Based Regulations
I•A•3 Establishment of a sustained expert forum for barrier analysis	I•B•3 ***Risk:*** Individual Programs with Manufacturers' & Builders' Insurers	I•C•3 ***Risk:*** Innovation Insurance Programs
	I•B•4 ***Incentives***: Consumer Programs with Utilities & Insurers; R&D Tax Credits for Manufacturers	I•C•4 ***Incentives***: Consumer Utility Subsidies & Insurance Reductions & Multiple Tax Credits
	I•B•5 ***Labor Skills***: Specific Site Training Tools & Professional Education Innovation Modules	I•C•5 ***Labor Skills***: General Labor Training & Professional Curricular Standards
	I•B•6 ***Purchase***: Retail Sales Initiatives; Architects' Spec Sheets	I•C•6 ***Purchase***: Suppliers' Promotional Materials
	I•B•7 ***Valuation:*** Appraiser/Inspector Professional Standards (e.g., comparables)	I•C•7 ***Valuation:*** Appraiser/Inspector Training Requirements
	I•B•8 ***Housing Cycles:*** TBD	I•C•8 ***Housing Cycles:*** TBD

An innovation pipeline

OBJECTIVE

I•A Identify current & potential barriers to measure their impact

Inputs	Activity	Output	Outcome (Short-Term)	Outcome (Long-Term)
Staff Time; $; Research Planning and Methods	Barriers Impact Studies	Quantitative, Longitudinal Studies on Specific Barriers' Impacts	Implementation Plans for Studies for Long-Term Policy (I-C)	I•A•1 *No. of Measures for Determining Policy Effects on Barriers*
Staff Time; $; Industry Expert Time; Meeting Forums	Barriers Identification Forums	Qualitative Agenda-Setting & Prioritization for Barriers Studies	Implementation Plans for Studies for Short-Term Policy (I-B)	I•A•2 *Reduced or Eliminated No. of Barriers Identified*
Staff & Industry Time & Interest; Public-Private $	Barriers Reduction Collaboration Forums	Plans for Periodic Innovation Barrier Meeting	Public-Private Commitments to Participate	I•A•3 *% of Event Commitments Completed Annually*

OUTCOMES

An innovation pipeline

OBJECTIVE

I•B Develop practical methods to overcome current barriers

Inputs	Activity	Output	Outcome (Short-Term)	Outcome (Long-Term)
Staff Time; $; Barriers Identification Forum; Add'l Expert Insight	Practical Policy Activity *[Holder for Future Barriers]*	TBD	TBD	I•B•1 *TBD*
Staff Time; $; Barriers Identification Forum; Add'l Expert Insight; ES Commitment	Study ES Process; Outreach to ICC Jurisdictions to Enforce ES Reports	ES Recommendations for Improvements; ES Guidelines & Training for Local Jurisdictions	ES Expedited Services; Prelim Reliance on ES Reports by Local Jurisdictions	I•B•2 *No. Manufacturers Using ICC-ES*
Staff Time; $; Barriers Identification Forum; Add'l Expert Insight; Commitments	Prototype Insurance Initiative (Same insurer for manufacturer & builder)	Outcome of insurance on innovation rate and party satisfaction	Increased prototype initiatives	I•B•3 *Number of Innovation Insurance Programs*
Staff Time; $; Barriers Identification Forum; Add'l Expert Insight; Commitments	Consumer Utility & Insurance Programs; Analysis of R&D Tax Incentives	Clearinghouse of consumer programs; Policy options for expanding R&D tax credits	Expansion of consumer programs; Policy Implementation of R&D Credits	I•B•4 *Consumer Utilization Rate of Incentives; Tax Credit Studies*
Staff Time; $; Barriers Identification Forum; Add'l Expert Insight; Training Media	Innovators' Training Assistance On-Site; Prof'l Curriculum Review	On-Site Training Packages for Trades; Curricular Standards Recommendations	Site Training Monitoring; Dissemination of Curricula Standards	I•B•5 *% of Trained Labor/Innovation; No. of University Programs*
Staff Time; $; Barriers Identification Forum; Retail Sellers' Commitments	Prototype Innovation Marketing with Retailers	Documented Sales Changes and In-Store Program Adjustments	Retailers' & Architects' Long-Term Commitments to Marketing/Spec'ing Innovation	I•B•6 *No, of Innovations Marketed by Two Largest Retailers; No. of Spec Sheets*
Staff Time; $; Barriers Identification Forum; Add'l Expert Insight	Add'l Valuation Studies; Development of Comparable & Installation Listings; Architect Spec Sheets	Comparable Database; Quality Installation Database; Spec Sheets & Documented Design Spec Growth	Appraisers' & Inspectors' Use of Database; Appraiser, Inspector, Architect Outreach	I•B•7 *% of Innovations Included in Various Databases (if applicable)*
Staff Time; $; Barriers Identification Forum; Add'l Expert Insight	Macroeconomic Analysis of Building Activity and Innovation Rates	Studies Suggesting Optimal Strategies during Different Phases of Cycle	Planning for Cyclical Changes Past PATH	I•B•8 *NA*

OUTCOMES

An innovation pipeline

OBJECTIVE

I•C Develop alternative future processes to eliminate barriers

Inputs	Activity	Output	Outcome (Short-Term)	Outcome (Long-Term)
Staff Time; Practical Policy Feedback; External Commitments	Long-Term Policy Activity *[Holder for Future Barriers]*	TBD	TBD	I•C•1 *TBD*
Staff Time; Practical Policy Feedback; Code Group Commitment	Performance-Based Codes Prototypes & Advocacy	Prototype Performance-Based Codes	Monitoring and Evaluation of Prototype Programs	I•C•2 *% Code Provisions Drafted in Performance Basis*
Staff Time; Practical Policy Feedback; Insurance or Gov't Commitments	Prototype Innovation Insurance Initiative	Insurance-Firm Lead or Federal Insurance Program for Innovations: Prototype Cases	Monitoring and Evaluation of Prototype Programs	I•C•3 *No. of Innovation Insured Under Program*
Staff Time; Practical Policy Feedback; Insurance & Gov't Commitments	Consumer Programs Advocacy; Innovation Adoption Tax Credit Studies	Consumer awareness; Innovation Tax Credits Recommendations	Expansion of consumer programs; Implementation of all R&D Credits	I•C•4 *No. of Consumer Programs; No. of Tax Credit Programs*
Staff Time; Practical Policy Feedback; Trade & University Commitments	Full Labor Training Programs & Certifications; Curriculum Standards Advocacy	Program Agreements; Curricular Standards Adoption	On-Site Training Programs for Trades; Curricular Standards Requirements	I•C•5 *% of Trained Labor; No. of Accredited University Programs*
Staff Time; Practical Policy Feedback; Suppliers' Commitments	Prototype Innovation Marketing with Suppliers	Documented Sales Changes and Program Adjustments	Suppliers' Long-Term Commitments to Marketing Innovations	I•C•6 *No. of Innovations Marketed by 50 Largest Suppliers*
Staff Time; Practical Policy Feedback; Appraisers', Inspectors', & Architects' Commitments	Professional Training Requirements on Innovation	Standards for Certification	Increased Innovation Certification	I•C•7 *% of Certified Professionals In 3 Fields*
Staff Time; Practical Policy Feedback	TBD	TBD	TBD	I•C•8 *NA*

OUTCOMES

Goal II • Objectives & Long-Term Outcomes

An innovation resource

GOAL

II — **Improve technology transfer, development, and adoption through information dissemination**

Metric: ***Avg. Cost & Time from Market Introduction to Proportional Market Share Penetration for PATH Identified Technologies***

Baseline: ***Goal:***

OBJECTIVES

OUTCOMES

II›A	Establish & maintain sources of non-commercial innovation info *Metric: % of Users Relying on Peer-Determined Non Commercial Sources*	II›B	Understand behaviors, attitudes, and needs regarding innovation info *Metric: % of manufacturers & builders with access to market research*	II›C	Change behavior through relevant information materials on innovation and innovators *Metric: Proportion of "Innovator," "Early Adopter," & "Early Majority"*
II›A›1	Centralized, credible sources of innovation information	II›B›1	Perform & disseminate studies of homebuilding participants' "innovativeness"	II›C›1	Homebuyers' selection of builders based on innovation information
II›A›2	Industry training on information quality and credibility	II›B›2	Sustained public-private funding of homebuilding participants' "innovativeness" studies.	II›C›2	Homeowners' selection of remodelers based on innovation information
II›A›3	Industry-generated relevant, credible information	II›B›3	Innovators' awareness of market segments in order to target "innovativeness."	II›C›3	Homebuilders' design & construction of innovative homes
				II›C›4	Homebuilders' marketing of innovative homes based on innovativeness
				II›C›5	Remodelers' design & construction of innovative remodels
				II›C›6	Remodelers' marketing of innovative services
				II›C›7	Manufacturers promotion of innovative products

An innovation resource

OBJECTIVE

II•A Establish & maintain sources of non-commercial innovation info

Inputs	Activity	Output	Outcome (Short-Term)	Outcome (Long-Term)
Staff time; $; Unbiased Research Skills & Staff	Tool Base ® & PATH Generated Info	Technology Inventory New Content (Website and Materials)	ToolBase @ PATHNet Utilization (Tech Inventory)	II•A•1 *ToolBase Utilization Rates*
Staff time; $; Outreach Staff & Training	Manufacturer Information & Market Training	Manufacturer Commercialization Tools (Marketing Assistance)	Marketing Assistance Program Utilization	II•A•2 *No. of Non-Commercial Information Sources*
Staff time; $; Monitoring Staff	Tool Base ® & PATH Collected Info	Technology Inventory Content Management (Website and Materials)	ToolBase Utilization (Tech Inventory)	II•A•3 *Utilization Rates of Non-Commercial Information Sources (non-PATH)*

OUTCOMES

An innovation resource

OBJECTIVE

II•B Understand behaviors, attitudes, and needs regarding innovation info

Inputs	Activity	Output	Outcome (Short-Term)	Outcome (Long-Term)
Staff time; $; Market Research Firm Commitments; Federal Agency Commitments	Market Research Agenda Forum; Research Project Scoping and Funding	Preliminary Research Data and Analysis	Coordination of Non-Commercial Research Data with Commercial; Utilization of Non-Commercial Data	II•B•1 *Proportion Completed of Market Research Agenda*
Staff time; $; Market Research Firm Commitments; Federal Agency Commitments	Advanced Research Project Scoping and Funding; Prelim Data	Research Funding and Commitments for Execution	Short-Term Funding Increases For Market Research	II•B•2 *Total Research Funding Proportion to Sales Consistency*
Staff time; $; Market Research Results; Dissemination Vehicles	Market Research Dissemination & Monitoring	Public or Targeted Access to Research Results	Preliminary Utilization by Innovators without Market Research Resources	II•B•3 *Utilization of Market Research Data*

OUTCOMES

Goal II • Objective II.C Metrics Map

An innovation resource

OBJECTIVE

II•C **Change behavior through relevant information materials on innovation & innovators**

Inputs	Activity	Output	Outcome (Short-Term)	Outcome (Long-Term)
Staff Time; $; Media Access & Commitments; Technical Information (Tech Inventory, Tech Sets, Concept Home)	Homebuyer Outreach	Journals, TV (PSA), Events, Incentives, Builder Mat's, PATHNet, Mfctr. Ads/Links, Realtor/Appraiser/HOA Mat'ls	Homebuyer assimilation and action (home purchase)	II•C•1 *Proportion of Homebuyers Purchasing Homes w/ 5 + PATH Tech's*
Staff Time; $; Media Access & Commitments; Technical Information (Tech Inventory, Tech Sets, Concept Home)	Homeowner Outreach	Journals, TV (PSA), Events, Incentives, Retail Outreach, Remodeler Mat's PATHNet, Mfctr. Ads/Links; HOA Mat'ls	Homeowner assimilation and action (home remodel)	II•C•2 *Proportion of Homeowners Remodeling Homes w/ 5 + PATH Tech's*
Staff Time; $; Trade Media Access & Commitments; Builder Commitments (Tech Inventory, Tech Sets, C Home)	Homebuilder Technical Outreach	Trade Journals, Events, Training/Demos; Trade/Supplier/ Code Outreach, Mfctr. Links; PATHNet; Architect Mat'ls	Homebuilder assimilation and action (home design & build)	II•C•3 *Proportion of Homebuilders Building Homes w/ 5 + PATH Tech's*
Staff Time; $; Trade Media Access & Commitments; Builder Commitments (Tech Inventory, Tech Sets, C Home)	Homebuilder Marketing & Sales Outreach	Trade Journals, Events, Incentives; Sales/Realtor Training; Mfctr. Ads; PATHNet	Homebuilder assimilation and action (home sales based on special marketing)	II•C•4 *Proportion of Homebuilders Marketing Homes w/ 5 + PATH Tech's*
Staff Time; $; Trade Media Access & Commitments; Remodeler Commitments (Tech Inventory, Tech Sets, C Home)	Remodeler Technical Outreach	Trade Journals, Events, Incentives; Training/Demos; Trade/Appraiser/Architect Outreach, Mfctr. Links; PATHNet	Remodeler assimilation and action (home design & remodel)	II•C•5 *Proportion of Remodelers Remodeling Homes w/ 5 + PATH Tech's*
Staff Time; $; Trade Media Access & Commitments; Remodeler Commitments (Tech Inventory, Tech Sets, C Home)	Remodeler Marketing & Sales Outreach	Trade Journals, Events, Incentives; Sales/Realtor Training; Mfctr. Ads; PATHNet	Remodeler assimilation and action (remodel services based on special marketing)	II•C•6 *Proportion of Remodelers Marketing Svcs. w/ 5 + PATH Tech's*
Staff Time; $; Manufacturer Commitments & Resources, Tech Inventory	Manufacturer Outreach	Mnfctr. Training & Assistance; Ads/Links; Commercialization Tools; Distributor/Supplier/Trade/ Builder Outreach Assitance	Manufacturer assimilation and action (product sales)	II•C•7 *Market Shares for all PATH Identified Technologies OR Avg share of firm sales by innovative products launched in the last 10 years*

OUTCOMES

An innovation infrastructure

GOAL

OBJECTIVES

OUTCOMES

III — Advance housing technology research & foster development of new technology

Metric: Total R&D Investment as a Percentage of Industry Sales

Baseline: ***Goal:***

III•A — Establish sustained public and private R&D funding & agendas

Metric: Total R&D Investment as Percentage of Industry Sales

- III•A•1 — Sustained Federal basic research funding for research institutions
- III•A•2 — Sustained Federal applied research funding for institutions & industry
- III•A•3 — Ongoing collaboration with international research agencies and programs
- III•A•4 — Sustained state and local funding of applied research & development
- III•A•5 — Sustained non-profit & private foundation funding of research
- III•A•6 — Sustained trade association & industry collaborative funding of applied research & development
- III•A•7 — Sustained venture capital funding for development, prototype, and commercialization
- III•A•8 — Sustained internal R&D funding among manufacturers and builders
- III•A•9 — Public-private seed research projects based on priorities (III•C•4) and using above funding

III•B — Clarify and assist innovators with processes from technology transfer to market penetration

Metric: Average Cost & Time from Conception to Market Introduction

- III•B•1 — Sustained Federal technology transfer programs (Federal and university research to industry)
- III•B•2 — Sustained & coordinated state and local technology transfer programs (e.g., MTDC, VA CIT, DC VIP, etc.)
- III•B•3 — Networks of research technology transfer programs in housing (from institutions to industry)
- III•B•4 — Channels for technology transfer from non-housing to housing industries
- III•B•5 — Relevant development planning, commercialization, and market assessment tools for innovation
- III•B•6 — Sustained business planning technical assistance programs for small innovators
- III•B•7 — Sustained technical assistance for evaluating individual firms' R&D capacity & needs
- III•B•8 — Sustained public-private support of testing facilities

III•C — Develop comparative standards to assess innovation performance, cost, benefits, & agendas

Metric: Indirect (Planning) R&D Investment as % of Industry Sales

- III•C•1 — Industry collaborations for performance criteria development
- III•C•2 — Industry acceptance of performance criteria
- III•C•3 — Sustained public-private funding for performance criteria testing
- III•C•4 — Public-private research agenda forums and priority-setting ("Roadmaps")

An innovation infrastructure

OBJECTIVE

III•A Establish sustained public and private R&D funding & agendas

Inputs	Activity	Output	Outcome (Short-Term)	Outcome (Long-Term)
Seed $, Staff Time, University Proposals, NSF Agreement	NSF-PATH Program	University Research Projects; Current & Future Academic Interest; Potential Academic Research Centers	Sustained Academic Interest; Combined Federal Academic Research Funding	III•A•1 *Tot Fed $ to Academic Research*
Seed $, Staff Time, Agency Cooperation	Joint Research Agendas; Fed'l Applied Research Funds	Applied Research & Development Project Results;	Sustained Federal Interest; Combined Federal Applied Research Funding	III•A•2 *Tot Fed $ to Applied Research*
Staff Time; Int'l Agency & Research Org. Cooperation	Current Research Findings Sharing Events ; Joint Research Agendas	Int'l Research Collaborations On Agendas and Projects	Sustained Int'l Research Interest; Combined Int'l Applied Research Agendas	III•A•3 *Annl Int'l Exchange Events*
Staff Time; Seed $, State Agency & EPSCOR Agreement	Collaborative Fed/State Research Funds	Collaborative Fed/State Research Projects	State Interest In Housing Research	III•A•4 *Tot State/Local Appd Research $ (Proportional to Sales)*
Staff Time; Seed $, Foundation Interest & Agreements	Identify Foundations; Convene Events for Agendas; Develop Prelim Projects	Foundation Agreements; Prelim Results of Agendas And Projects	Foundation Independent Funding of Research Projects; Intra-Foundation Collaboration	III•A•5 *Tot Foundation Appd Research $ (Proportional to Sales)*
Staff Time; Seed $, Assoc. Interest & Agreements	Identify Trade Associations (w Research), Model Research Programs; Prelim Collaboration	Association Research Efforts (Mktng or Projects); Collab. Project Results	Association Independent Funding of Research Projects; Intra-Association Collaboration	III•A•6 *Tot Association Research # & $*
Staff Time; VC Assoc. & Agency Interest & Agreements	Identify & Access VC Funds for Industrial Collaborations For Large & Small Manftrs.	Prelim Venture Capital Investments & Collaborations	Ongoing Venture Capital Investments & Collaborations	III•A•7 *Tot Private Investment $; Avg $/Tech (Proportional to Sales)*
Staff Time; Seed $; Trade Association Assistance; Company Interest	Prelim Research Projects w/ Individual Firms or Collaborations	Prelim Project Results & Documentation; "Next Step" Discussions	Sustained Internal Research Interest & Agenda Setting (Firm & Collaboration-Level)	III•A•8 *Avg. Firm Investment $ (Proportional to Sales)*
Staff Time; Seed $; Roadmaps	Roadmap Research Projects w/ Individual Firms or Collaborations	Research Results; Updating Of Roadmaps	Progress towards Roadmaps; Commitments For Above Activities	III•A•9 *Tot Roadmap Research Matching $*

OUTCOMES

Goal III • Objective III.B Metrics Map

An innovation infrastructure

OBJECTIVE

III•B **Clarify & assist innovators with processes from technology transfer to market penetration**

Inputs	Activity	Output	Outcome (Short-Term)	Outcome (Long-Term)
Staff Time; Seed $; Tech Scanning; University & Industry Commitments	PATH-Related Tech Transfer Efforts (Basic to Applied)	Tech Transfer Results (Successes & Lessons Learned); Federal Sharing	Independent Tech Transfer by Basic Researchers & Industry; Federal Collaborations	III•B•1 *Federal TT $ & Programs*
Staff Time; Tech Scanning; State TT Program Interest & Commitments	State/Local TT Outreach	State TT Interest in Housing	State TT Commitments to Housing	III•B•2 *No. of State TT Housing Programs*
Staff Time; PATH TT; Institutions Interest & Commitments	Network-Building of Independent Tech Transfer Efforts (Basic to Applied)	Best Practices in Housing TT; Clearinghouse of TT Programs	Increased Usage of & Reliance on Independent TT Programs	III•B•3 *Total Independent TT Programs*
Staff Time; Seed $; Thorough Industry Knowledge	PATH Tech Scanning	Tech Scan Reports for TT Use	Non-Housing Interest in Housing Markets; Material for PATH & Non-PATH TT	III•B•4 *No. of Housing Product Sales Efforts by Non-Housing Firms*
Staff Time; Seed $; Industry Needs Assessments	PATH Commercialization Tools	Tools for Manufacturers (esp. Small)	Use by Manufacturers; Dissemination by Commercialization Centers	III•B•5 *No. of Manufacturers Using Tools*
Staff Time; Seed $; Commercialization Center/SB Interest	Commercialization Center/SB Outreach	Commercialization Center/SB Use of PATH Tools	Commercialization Center/SB Development of Add'l Tools Focus on Housing Innovators	III•B•6 *% of Manufacturers Using R&D Assistance Services*
Staff Time; Seed $; PATH Barriers Studies; Cooperative Commercialization Outreach	R&D Capacity Evaluation & Assistance	Tools & Guidebooks for Increasing Internal R&D Capacity	Use and Assimilation of Knowledge from Tools & Guidebooks	III•B•7 *Percentage of Firms Ranked as Mid- to High-Innovators*
Staff Time; Seed $; Active & Certified Testing Facilities	Testing Facility Clearinghouse & Outreach to Innovators; PATH Field Evaluations	Clearinghouse & Innovators Guide to Testing Facilities	Increased & Appropriately Timed Use of Testing Facilities& 3rd Parties	III•B•8 *Percentage of Fully Tested Innovations at Market Introduction*

OUTCOMES

Goal III • Objective III.C Metrics Map

An innovation infrastructure

OBJECTIVE

III•C **Develop comparative standards to assess innovation performance, cost, benefits, & agendas**

Inputs	Activity	Output	Outcome (Short-Term)	Outcome (Long-Term)
Staff Time; Seed $; Industry Time & Interest; Legal Counsel	PATH Beyond-Code Performance Testing Protocols (e.g., Durability)	Performance Testing Protocol for Different Performance Areas	Industry Commitment to Produce and Test Products with Testing Protocol	III•C•1 *No. of Performance Testing Protocols*
Staff Time; Industry Time & Above Commitments	Testing Protocol Outreach	Implementation of Testing Protocols for Beyond Code Performance.	Monitoring of Industry's Use of Testing Protocol in Product Development & Marketing	III•C•2 *Percentage of Maintained Commitments*
Staff Time; Industry Time; Results of Outreach Monitoring; Prelim Assessment of Impact	Testing Protocol Expansion	Plan & Execution for Add'l Systems' Testing Protocols for Beyond Code Performance	Implementation and Monitoring 0f New Testing Protocols for Beyond Code Performance	III•C•3 *No. of Non-PATH Testing Protocols*
Staff Time; Seed $; Industry Time; Researchers' Time	PATH Roadmaps	Roadmap Reports; Public-Private Commitments For Follow-Up Research	Roadmap-Based Research Projects; Commitments for Other Public-Private Agendas	III•C•4 *Percentage of Executed Research Projects; No of Roadmaps*

OUTCOMES

Operating Plans: Past

Note that the following analysis of past PATH activities only includes those that are relevant to the new PATH goals and objectives. Activities relevant to the previous PATH goals are not included here. As such, the total of individual activities' budgets will not equal the full PATH appropriations listed.

Past Activities Relevant to New Goals

	1999	2000	2001	2002	2003	2004
I		R&D Funding Study	Appraisal Forum; Commercialization Study	Quality Forum; Study of Government Role	Code Forum	Barriers Forum
				Regulatory Streamlining	Regulatory Streamlining	
II	ToolBase	ToolBase	ToolBase	ToolBase	ToolBase	ToolBase
					Builder Diffusion Study	Consumer Study; Production Bldrs; Panel Decisions
	Pilots/Demos; Marketing	Pilots/Demos; Marketing	Demos; Marketing	Demos; Marketing	Demos; Marketing	Demos; CAD; Marketing; Concept Home
III	PATH-NSF; Coop Federal & Industry Field Evaluations	PATH-NSF; Coop Federal & Industry Field Evaluations	PATH-NSF; Coop Federal & Industry Field Evaluations	PATH-NSF; Coop Federal & Industry Field Evaluations	Coop Industry; Field Evaluations	PATH-NSF; Coop Industry; Field Evals; Concept Home
				TechScanning	TechScanning; Panel Prescriptive Methods	
	Roadmapping; NIST Testing	Roadmapping; NIST Testing	Roadmapping; NIST Testing	Roadmapping; NIST Testing	NIST Testing	NIST Testing

Past Activities Relevant to New Goals • Associated Budget

	1999	2000	2001	2002	2003	2004
Total Budget ($1000s):	*$10,000*	*$10,000*	*$10,000*	*$8,500*	*$7,500*	*$7,000*
I		$200	$75	$300	$0	$100
				$100	$100	
II	$525	$750	$750	$1,000	$905	$1,000
					$150	$550
	$1,350	$790	$1,100	$1,188	$1,100	$1,650
III	$4,240	$6,024	$4,971	$5,366	$6,420	$3.425
				$150	$350	
	$1,450	$1,350	$1,750	$1,000	$600	$600

Past Activities Relevant to New Goals • Outputs

	1999	2000	2001	2002	2003	2004
I		Federal Funding Level Study	Appraisal Strategy Commercialization Case Studies	Insurance Strategy; Government Role	Code Strategy	Prelim Barriers Overview Strategy
				Regulatory Case Studies	Regulatory Case Studies	
II	Non-Commercial Information Source	Non-Commercial Information Source	Non-Commercial Information Source	Non-Commercial Information Source	Non-Commercial Information Source	Non-Commercial Information Source
					Builder Behavior Knowledge	Consumer, Panel Builder, Prod Builder Behavior Knowledge
	Technical Assistance; PATH Awareness	Technical Assistance; PATH Awareness	Technical Assistance; PATH Awareness	Technical Assistance; Tech Awareness	Technical Assistance; Tech Awareness	Technical Assistance; Tech Awareness
III	Basic & Applied Research Results; Product Eval.	Basic & Applied Research Results; Product Eval	Basic & Applied Research Results; Product Eval	Basic & Applied Research Results; Product Eval	Basic & Applied Research Results; Product Eval	Applied Research Results; Product Eval
				Source Info for Tech Transfer	Source Info for Tech Transfer	
	Research Agenda; Performance Criteria (1 System)	Research Agenda; Performance Criteria (1 System)	Research Agenda; Performance Criteria (1 System)	Research Agenda; Performance Criteria (1 System)	Performance Criteria (1 System	Performance Criteria (1 System)

Relevant Past Effect on New Objectives & Goals

	1999	2000	2001	2002	2003	2004
I		Federal Coop Strategy	Commercialization Strategy	NA; New Goals	New Code Strategy Projects	New Barriers Strategy Projects
				NA	NA	
II	Non-Commercial Info	Non-Commercial Info	Non-Commercial Info	Non-Commercial Info	Non-Commercial Info	Non-Commercial Info
					New Marketing Strategy	New Marketing Strategy; Mnfctr Assistance
	PATH Awareness Increase	PATH Awareness Increase	PATH Awareness Increase	Tech Diffusion Increase	Tech Diffusion Increase	Tech Diffusion Increase
III	Research Partnerships; Tech Diffusion Increase	Research Partnerships; Tech Diffusion Increase	Research Partnerships; Tech Diffusion Increase	Basic Research Interest; Research Partnerships	Basic Research Interest; Research Partnerships	Basic Research Interest; Research Partnerships
				Tech Transfer	Tech Transfer	
	Research Partnerships	Research Partnerships; Criteria Partnership	Research Partnerships; Criteria Partnership	Research Partnerships; Criteria Partnership	Criteria Partnership	Criteria Partnership

Operating Plans: Current

FY05 Activities

Programmatic Activities:

- Planning Innovations for Disasters
- Evaluation of PATH Metrics

I

- **I•A**
  - Overcoming Barriers Modification
  - Architects' Role in Innovation
- **I•B**
  - Innovation & Code Evaluation Service
- **I•C**

II

- **II•A**
  - ToolBase
- **II•B**
  - Consumer Study Modification
  - Manufacturers Survey
  - Builders' Use of IT
- **II•C**
  - PATH Marketing Activities
  - Military Demos
  - PATH Builder Tech Practices
  - Builder Friendly Tech Reports

III

- **III•A**
  - PATH-NSF Grants
  - PATH NOPI Coop Research
  - Concept Home (Design+Build+ Codes)
  - Whole House Calculator
  - Utilities & Panels
  - IT Streamlining
- **III•B**
  - Tech Transfer +
  - Commercialization Tools
  - International Factory-Built Study
  - SIPS Prescriptive Methods
  - PATH Field Evaluations
- **III•C**
  - NIST Durability Research
  - Energy Efficient Protocol

FY05 Expected Outputs

I	I•A	"Barriers to Innovation" Report	Architects' Role: White Paper				
	I•B	ICC-ES Process Recommendations					
	I•C						
II	II•A	Non-Commercial Information (PATH Tech Inventory)					
	II•B	Report on Consumer Perceptions	Report on Manufacturers Behaviors	Report on Builders' Use of IT			
	II•C	Journals, Events, PATHNet, Outreach Mat'ls, Training Assistance	Technical Assistance Reports	Builder Case Studies & Outreach	Technical Assistance Reports		
III	III•A	Basic Research Projects; Researcher Interest; Training	Research Projects Research Partnerships	Concept Home Specs & Manufacturer/ Builder Partners	Research Partnerships; Seed Concepts	Research Partnerships; Seed Concepts	Research Partnerships; Seed Concepts
	III•B	Tech Transfer Case Studies	Commercialization Tools	International Tech Transfer Analysis	Commercialization Assistance	Tech Evaluations; Mnftr. Development Assistance	
	III•C	Performance Criteria (1 performance)	Performance Protocol (1 category)				

FY05 Effect on New Objectives & Goals

I	I•A	Barriers ID & Prelim Strategies For I.B & I.C	Specific Barrier Strategy For I.B & I.C			
	I•B	Implementation Of I.A Strategy Codes & Innovation				
	I•C					
II	II•A	Non-Commercial Information (Public-Private)				
	II•B	Strategies for Factory-Built Marketing	Strategies for Commercialization Assistance	Strategies for IT Roadmap Implementation		
	II•C	Participant Behavioral Changes	TBD	Builder Behavioral Change	TBD	
III	III•A	Sustained Basic Research	Sustained Applied Research	Increased Firm Research	Increased Research Partnerships	Increased Research Partnerships	Increased Research Partnerships
	III•B	Preliminary Tech Transfer Organizations	Preliminary Commercialization Organizations	Preliminary Int'l Tech Transfer Organizations	Preliminary Commercialization Assistance	Preliminary Commercialization Assistance	
	III•C	Comprehensive Performance Criteria Partnerships	TBD				

Operating Plans: Future

Note that the following analysis of future PATH activities describes expected projects and estimated budgets for them only. As articulated in "Operations & Management: Background" (page 87), exact budgets and work scopes are subject to Congressional and Federal constraints.

Future Activities

		2006	2007	2008	2009	2010
I	I•A	Measuring Barriers Study 1; Valuation Study	Measuring Barriers Study 2	Barriers ID Forum; Coop Barriers Forum	Measuring Barriers Study 3	Measuring Barriers Study 4; Coop Barriers Forum
	I•B	Incentives Forums & Clearinghouse; Tax Credit Analysis; Training Modules	ES Implementation; Incentive Expansion; Curricular & Retail Modules; Arch Specs	Insurance Prototypes; Tax Credit Expansion; Appraisal Database; Training Modules	ES Monitoring; Incentive Monitoring; Inspection Standards	Insurance Monitoring; Training Monitoring; Appraisal Monitoring
	I•C	NA	NA	Supplier Marketing Prototypes	Labor Training; Curricular Standards;	Performance Code Forum; Tax Credit Expansion; Appraiser/ Inspector Req's
II	II•A	ToolBase-Sponsorship Growth	ToolBase-Sponsorship Growth; Info Expansion	ToolBase-Sponsorship Growth; Info/Mnftr Expansion	ToolBase-Sponsorship Growth; Info/Mnftr Expansion	ToolBase (Min. Federal $)
	II•B	Innovation Studies Forum I	Joint Studies; Prelim Dissemination	Joint Studies; Dissemination; Use Monitoring	Assignments Forum; Dissemination; Use Monitoring	Innovation Studies Forum II; Studies (No Federal $); Use Monitoring
	II•C	Outreach Activities	Expanded Outreach Activities; Monitoring	Outreach Activities; Monitoring; Revised Planning	Coop Outreach Activities; Monitoring;	Outreach Activities (Reduced Federal $); Monitoring
III	III•A	PATH-NSF; Federal Agendas; Int'l Event; Research Outreach (TA); Roadmap Seeds	PATH-NSF; Federal Agendas; State & Firm Funds Analysis; Outreach (Fnds); Roadmap Seeds	Fed-NSF; Federal Agendas; Int'l Event; Research Outreach (State/ Firm); Roadmap Seeds	Fed-NSF; Federal Agendas; Outreach Monitoring; VC Analysis; Roadmap Monitoring	Fed-NSF; Federal Agendas; Int'l Event; VC Outreach; Roadmap Monitoring
	III•B	Tech Transfer; Tech Transfer Forum; Comm. Tools	Tech Transfer; Tech Transfer Clearinghouse; Comm. Tools Outreach	Tech Transfer; Comm. Tools; Testing Clearinghouse	Tech Transfer; Tech Transfer Monitoring; Comm. Tools Monitoring	Tech Transfer Monitoring; Comm. Tools Monitoring; Testing Monitoring
	III•C	Protocol/Criteria Research; Outreach	Protocol/Criteria Research; Expansion; Outreach	Protocol/Criteria Research; Expansion; Outreach; Roadmaps	Protocol/Criteria Research; Expansion; Outreach	Protocol/Criteria Research; Expansion; Monitoring ; Roadmaps

Expected Future Outputs

		2006	2007	2008	2009	2010
I	I•A	Studies	Studies	Studies; Forum Proceedings	Studies	Studies; Forum Proceedings; Recommended Strategies
	I•B	ncentives Clearinghouse Tax Credit Strategy; Training Modules	ES Changes; Incentive Strategy; Curricular & Retail Modules; Arch Specs	Insurance Prototypes; Tax Credit Studies; Appraisal Database; Training Modules	Monitoring Studies; Inspection Standards	Monitoring Studies
	I•C	NA	NA	Prototypes	Labor Strategies; Curricular Standards	Performance Code Forum; Tax Credit Changes; Appraiser/ Inspector Req's
II	II•A	ToolBase	ToolBase	ToolBase	ToolBase	ToolBase
	II•B	Forum	Studies	Studies; Monitoring Studies	Forum; Monitoring Studies	Forum; Monitoring Studies
	II•C	Outreach Materials & Services	Outreach Materials & Services; Monitoring Studies	Outreach Materials & Services; Monitoring Studies; Plan	Outreach Materials & Services; Monitoring Studies	Outreach Materials & Services; Monitoring Studies
III	III•A	Research Projects; Agendas; Event Proceedings; Outreach Materials	Research Projects; Agendas; Study; Outreach Materials	Research Projects; Agendas; Event Proceedings; Outreach Materials	Research Projects; Agendas; Studies; Outreach Materials; Monitoring Studies	Agendas; Event Proceedings; Outreach Materials; Monitoring Studies
	III•B	Transfer Services; Forum Proceedings; Comm. Tools	Transfer Services & Tools; Outreach Materials	Transfer Services & Tools; Comm. Tools; Testing Clearinghouse	Transfer Services & Tools; Transfer & Comm. Monitoring Studies	Monitoring Studies
	III•C	New Protocol/Criteria; Outreach Materials	New Protocol/Criteria; Outreach Materials	New Protocol/Criteria; Outreach Materials; New Roadmaps	New Protocol/Criteria; Outreach Materials	New Protocol/Criteria; Outreach Materials; Protocol & Roadmap Monitoring Studies

Expected Future Effect on Objectives & Goals

		2006	2007	2008	2009	2010
I	I•A			Preliminary Completion		Partial Completion
	I•B	Commencement		Preliminary Completion		Partial Completion
	I•C			Commencement		Preliminary Completion
II	II•A	Preliminary Completion		Partial Completion		Significant Completion
	II•B	Commencement		Preliminary Completion	Partial Completion	Significant Completion
	II•C	Preliminary Completion				Partial Completion
III	III•A			Preliminary Completion		Partial Completion
	III•B	Commencement		Preliminary Completion		Partial Completion
	III•C					Preliminary Completion