

Technical Barriers, Gaps, and Opportunities Related to Home Energy Upgrade Market Delivery

M. V. A. Bianchi
National Renewable Energy Laboratory

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Prepared by:

Marcus V. A. Bianchi

National Renewable Energy Laboratory

1617 Cole Boulevard

Golden, CO 80401

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Unless otherwise noted, all tables were created by NREL.

Definitions

DOE	U.S. Department of Energy
HVAC	heating, ventilation, and air-conditioning
NREL	National Renewable Energy Laboratory
EPA	U.S. Environmental Protection Agency

Executive Summary

The objective of this report is to outline the technical¹ barriers, gaps, and opportunities that arise in executing home energy upgrade market delivery approaches, as identified through research conducted by the U.S. Department of Energy’s (DOE) Building America program. This information will be used to provide guidance for new research necessary to enable the success of the approaches. Investigation for this report was conducted via publications related to home energy upgrade market delivery approaches, and a series of interviews with subject matter experts (contractors, consultants, program managers, manufacturers, trade organization representatives, and real estate agents). These experts specified technical barriers and gaps, and offered suggestions for how the technical community might address them.

The potential benefits of home energy upgrades are many and varied: reduced energy use and costs; improved comfort, durability, and safety; increased property value; and job creation. Nevertheless, home energy upgrades do not comprise a large part of the overall home improvement market. Residential energy efficiency is the most complex climate intervention option to deliver because the market failures are many and transaction costs are high (Climate Change Capital 2009). The key reasons that energy efficiency investment is not being delivered are:

- The opportunity is highly fragmented.
- The energy efficiency assets are nonstatus, low-visibility investments that are not properly valued.

There are significant barriers to mobilizing the investment in home energy upgrades, including the “hassle factor” (the time and effort required to identify and secure improvement works), access to financing, and the opportunity cost of capital and split incentives.

Current Market Delivery Approaches

To organize information on technical barriers, gaps, and opportunities in this review, we recognized four major market contractor delivery categories that most stakeholders recognize and that operate in the residential upgrade market:

- Consultant or independent assessor
- Trade contractor
- General contractor
- Whole-house energy upgrade contractor

There are also variants and hybrids of these models.

Technical Gaps, Barriers, and Opportunities

Table 1 and Table 2 present technical gaps, barriers, and opportunities that were identified from current literature and interviews with professionals involved in home energy upgrades. They affect all the recognized market delivery approaches.

¹Many nontechnical areas also present gaps and barriers for enabling market delivery approaches. These are beyond the scope of this report.

Table 1. Energy Assessment Gaps, Barriers, and Opportunities

Gap or Barrier	Opportunity
<p>Software-based energy analysis of inefficient existing homes tends to over-predict pre-upgrade energy use and resulting energy savings.</p>	<ul style="list-style-type: none"> • Address software inaccuracy issues, including the models and inputs determined by the energy assessment.. • Investigate the minimum requirements of the initial energy assessment by climate, housing type and vintage, and other characteristics. • Continue to develop certification procedures for building energy simulation tools.
<p>Building characteristics and utility billing data from actual houses have not been available in large scale for comparing software predictions with metered data.</p>	<ul style="list-style-type: none"> • Build a data-driven, actuarial-based performance standard for testing and verifying savings accuracy. • Obtain data from very well instrumented houses. • Investigate the possibility of displaying the Residential Energy Consumption Survey data by major climate zone. • Expand the Field Data Repository. • Create open data repositories where homeowners can add the characteristics and energy uses of their homes.
<p>Building energy simulation tools cannot be updated immediately when a new technology is developed.</p>	<ul style="list-style-type: none"> • Investigate alternatives to evaluate new technologies that do not involve building energy simulation tools. • Develop collaborations between industry and software developers to create software solutions in parallel with new products and technologies.
<p>Nonenergy benefits are not easily monetized.</p>	<ul style="list-style-type: none"> • Investigate ways to monetize nonenergy benefits
<p>Initial house assessment is time consuming and expensive.</p>	<ul style="list-style-type: none"> • Work with utilities to create energy-use metrics available in specific territories. • Develop simpler ways to assess homes, such as smart meter data and surveys to identify major savings opportunities. • Focus on larger neighborhoods with fewer house models.

Table 2. Upgrade Gaps, Barriers, and Opportunities

Gap or Barrier	Opportunities
Comprehensive energy efficiency upgrades require large initial capital investment.	<ul style="list-style-type: none"> • Create plans for staged energy upgrades instead of an all-or-nothing approach. • Create modules, packages, and components that can stand alone in an upgrade.
Specific housing types in certain areas are challenging for upgrade solutions.	<ul style="list-style-type: none"> • Develop technical solutions for specific housing types and issues with clear recommendations based on climate.
Mechanical equipment that is installed directly before a deep energy upgrade is often oversized. It is also often installed incompletely or poorly.	<ul style="list-style-type: none"> • Investigate the best solutions to accommodate recently installed equipment after an aggressive enclosure upgrade is executed.
Sealing existing homes effectively is challenging.	<ul style="list-style-type: none"> • Investigate solutions to air seal existing homes.
There are no common acceptable practices to install additional insulating sheathing when re-siding a house.	<ul style="list-style-type: none"> • Develop standards for adding insulation when re-siding a house.
Reducing miscellaneous electric loads is challenging.	<ul style="list-style-type: none"> • Use miscellaneous electric loads as an opportunity to address the effects of occupant behavior on energy consumption. • Develop better load monitoring and automated controls for miscellaneous electric loads, such as smart occupancy-sensing shutoffs on plug strips.
There are no common practices for homeowners to convert garage spaces into living spaces	<ul style="list-style-type: none"> • Investigate solutions and develop protocols for appropriate conversion of garage spaces to living spaces.

Next Steps and Conclusions

This report identifies technical gaps, barriers, and opportunities that are related to market delivery of home energy upgrades. These were identified through literature search and interviews with subject matter experts and they will support the DOE planning process.

Key conclusions from this work include:

- Major barriers have been identified for large-scale market delivery of home energy upgrades. This report concentrates on the technical barriers and gaps, recognizing that many barriers are nontechnical. Addressing the technical barriers identified in this report would support the goals of delivering large-scale home energy upgrades to the market. Building America will coordinate closely with other programs to ensure that all issues are addressed.
- The majority of the technical barriers and gaps occurred in two areas: energy assessment and energy upgrade. Opportunities for overcoming these barriers and gaps were identified in the literature research and during interviews, with the vast majority being the latter.
- Issues associated with energy assessment are:
 - a. Software-based energy analysis – related to the Analysis Methods and Tools Standing Technical Committee.
 - b. Access to building characteristics and utility billing data – related to the Implementation Standing Technical Committee.
 - c. Assessment needs – related to three standing technical committees: Analysis Methods and Tools, Testing Methods and Protocols, and Implementation.

- Gaps and barriers associated with upgrades are centered on specific measures, such as:
 - a. Mechanical equipment – related to Hot Water Standing Technical Committee and Space Conditioning Standing Technical Committee)
 - b. Air sealing and insulating sheathing – related to Envelope Standing Technical Committee.
 - c. Miscellaneous electric loads – related to two standing technical committees: Lighting, Appliances, Miscellaneous Electric Loads and Home Energy Management.
- Four key contractor market delivery approaches were identified, including:
 - Consultant or independent rater
 - Trade contractor
 - General contractor
 - Whole-house energy upgrade contractor.

There are variants and hybrids of these approaches and a combination of these may be necessary to deliver home energy upgrades.

- Since a home energy upgrade involves both an energy assessment and the upgrade itself, the barriers and gaps identified in this report apply to all the market delivery contractor approaches.

These findings will serve as a resource to the Building America teams conducting research in the area of home energy upgrade market delivery (see Appendix A), and provide input into the Building America Strategic Plan. Specific items that are associated with Standing Technical Committees will be communicated to them directly for further consideration.

Acknowledgments

Individuals representing the following organizations provided input to identify technical gaps, barriers, and opportunities related to home energy upgrade market delivery approaches:

Affordable Comfort Inc.	Johns Manville
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Building Performance Institute, Inc.	Navigant Consulting
Building Services & Consultant	Owens Corning
DickKornbluth, LLC	Pennsylvania State University
Dow	Performance Systems Development
EPA	RW Ventures, LLC
Ecobrokers	RESNET
Energy Trust of Oregon	Recurve
Every Watt Matters	Ridgewood Capital
Florida Solar Energy Center	SRA International, Inc.
GreenHomes America	Washington State University
IBACOS	WellHome
Innovation Network for Communities	

1 Introduction

1.1 Objective

Despite the many potential benefits, such as energy savings, greenhouse gas emission reductions, increased comfort, health, durability, and property value, home energy upgrades do not comprise a large part of the overall home improvement market. Barriers have been identified by other studies (see Section 1.2), including:

- Fragmented opportunity
- Nonstatus, low-visibility investments that are not valued by the marketplace
- Market failures
- High transaction costs
- Significant time and effort required to identify and secure improvement works
- Difficult access to capital, high opportunity cost of capital, and split incentives.

Our research objectives are to identify the technical barriers, gaps, and opportunities that arise in executing the home² energy upgrade market delivery approaches.³ This information will be used to provide guidance for new research work that can enable the success of the approaches. These barriers, gaps, and opportunities will support the DOE planning process.

1.2 Background and Context

In 2008, the United States consumed 99.5 quads of energy; the buildings sector represented 40% of that total. Residential buildings used 54% of the total energy (21.54 quads) (Building Energy Data Book 2010). This resulted in 1.2 billion metric tons of carbon dioxide emissions. The largest end uses of energy in homes are space heating, water heating, space cooling, and lighting (see Figure 1). The breakdown depends on the climate, house type, and user. The end uses that consume the most energy also result in the most carbon dioxide emissions; maximizing energy savings should reduce carbon emissions significantly.

Sweatman and Managan (2010) reported on American, British, and Spanish studies, which show that energy use in existing buildings can be cost effectively reduced by 20%–50%. These studies measure only the potential for energy efficiency improvements above and beyond what is already being done. Granade et al. (2009) show an analysis to estimate the expected costs and benefits of U.S. home energy upgrades. The authors used the Home Energy Saver software with data from the Residential Energy Consumption Survey and concluded that upgrading existing homes can produce almost 28% energy savings by 2020 at a net present value of \$41 billion.

Home energy upgrades can also improve unhealthy conditions (e.g., radon mitigation, natural gas leaks, carbon monoxide, allergens), comfort (thermal and acoustic), durability, and can increase property value. Properly trained contractors⁴ provide recommendations that reduce energy consumption and correct a broad range of nonenergy deficiencies such as poor thermal distribution, excessive equipment wear, indoor air contaminants, noise, and moisture-related dangers (Knight et al. 2006).

² Most of the work in this area focused on single-family detached homes, but the items discussed in this report may apply to multifamily dwellings.

³ Market delivery refers to the relationship between a customer (a homeowner) and a service provider. Program models that create incentives and rules for the home energy upgrade industry are out of scope.

⁴ Contractors are professionals who are involved in the home energy upgrade process of an existing house.

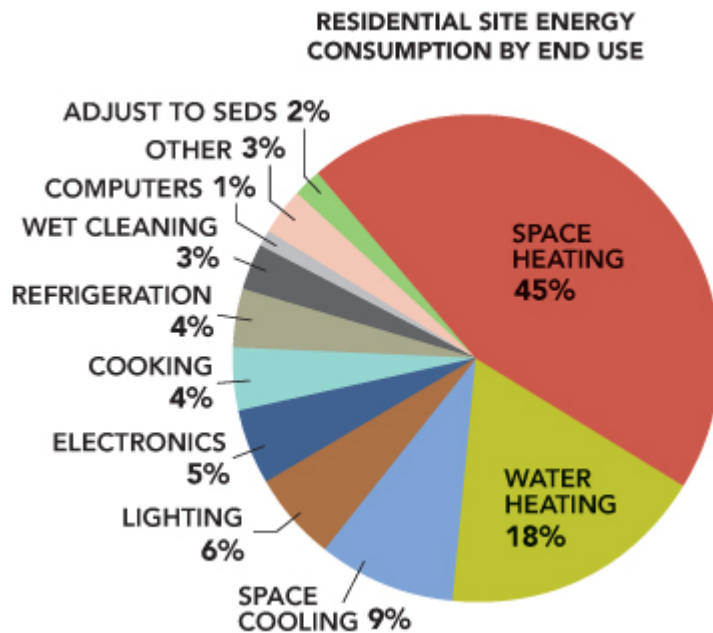


Figure 1. 2008 residential buildings primary energy use
(Building Energy Data Book 2010)

Investments in energy efficiency can also save money and create jobs. According to the Middle Class Task Force (2009), home energy upgrades can help people save money by lowering their utility bills. By encouraging nationwide weatherization of homes, workers of all skill levels will be trained, engaged, and participate in ramping up a national home energy upgrade market. Across the European Union, case studies indicate that an additional €1 million (\$1.37 million⁵) of investment creates 8–14 person-years of direct employment; indirect employment effects contribute 9–40 more person-years (Impetus Consulting 2009). Fei Liu and Emrath (2008) estimated that the impact of residential remodeling is 1.11 jobs and \$30,217 in taxes from \$100,000 spent on residential remodeling.

Despite the many potential benefits, as well as public and utility investments, home energy upgrades do not comprise a large part of the overall home improvement market. Residential energy efficiency is the most complex method to reduce greenhouse gas emission to deliver because the market failures are many and transaction costs are high (Climate Change Capital 2009). The key reasons energy efficiency investment is not being delivered are:

- The opportunity is highly fragmented.
- The energy efficiency assets are nonstatus, low-visibility investments that are not properly valued.

There are very significant barriers to mobilizing the investment in home energy upgrades, including the “hassle factor” (the time and effort required to identify and secure improvement

⁵ On September 13, 2011.

works), access to and the opportunity cost of capital and split incentives. Other reasons include lack of consumer buy-in, that green jobs and energy efficiency have become controversial, and that there is currently minimal or no increase in home value from the energy upgrades.

2 Approach

A literature review identified publications, including reports, articles, and presentations available on the Internet, which are related to existing home energy upgrade market delivery approaches.

There are many ways to classify market delivery approaches for the contractors who provide home energy upgrades. In this report, the models were characterized from the perspective of service delivery. Alternative ways to characterize them could include company ownership, original trade, or size.

Input was provided through a series of interviews and exchanges with subject matter experts (contractors, consultants, program managers, manufacturers, trade organization representatives, and real estate professionals). They identified the current approaches and technical barriers, gaps, and opportunities that need to be addressed by the technical community, including DOE's Building America program.

3 Home Energy Upgrade Market Delivery Approaches

We define a market delivery approach as “how a company makes money.”⁶ A market delivery approach makes more money through either increasing the number of jobs or streamlining operations to make more money. There is an important distinction between certain stakeholder activities, such as rebates and other incentives, and contractor/rater approaches. In the context of this report, programs⁷ that create incentives and rules for the home energy upgrade industry are not market delivery approaches, but potential enablers of the actual approaches of raters and contractors. Also, although home energy upgrades can be do-it-yourself projects, this method does not involve contractors⁸ and is thus not included in this report.

Appendix A includes information about Building America research and efforts related to home energy upgrade market delivery approaches. Appendix B describes other information related to the approaches, including supply chain and value network.

Thomas et al. (2004) reported a survey of home performance contractors with a resulting development of a comprehensive set of protocols. After a screening process, 16 contractors deemed successful were selected to provide representation across a range of company sizes, market delivery approaches, and geographic locations and were interviewed for the article. The interviewers collected information about business, marketing, and technical practices, contractor perception of consumer concerns, and sources of training information. Many were not necessarily doing “whole-house” installations and many who might aspire to do true whole-house upgrades were often trapped by limitations of their current models and habits.⁹ These contractors tended to focus on installing performance-tested improvements that were typical in their line of business, whether HVAC or envelope related. Knight and Thomas (2004) highlighted the results and wrote about strategies whole-house contracting businesses need to consider adopting to see strong growth.

Rogers (2004) pointed out that:

There are probably as many potential home performance business models¹⁰ as there are contractors. This continuum of business models is framed by two end points – the home performance consultant and the home performance contractor. The consultant provides a third-party evaluation, recommendation, and perhaps post-installation verification, but he or she doesn’t install the improvement measures. The contractor does it all.

This issue of *Home Energy* (July/August 2004) magazine offers several articles showcasing different approaches to the home performance industry.

Knight (2006) presented about the different market delivery approaches for upgrade home performance delivery in California. The author classified approaches in a spectrum from

⁶ Frantzis et al. (2008) defined business model this way when investigating photovoltaics market delivery approaches.

⁷ Utilities and local jurisdictions run programs in given territories with specific objectives. They create incentives and rules for the home energy upgrade industry.

⁸ Manufacturers and retailers are still involved.

⁹ NAHB Research Center conducted remodeler focus groups that pointed out that lack of funding for a homeowner is most often the reason for not doing a whole-house energy upgrade.

¹⁰ To avoid confusion, the term *market delivery approaches* is in use in this report instead of *business models*.

independent “home performance consultant” plus contractor allies to a comprehensive one-stop shop, called the “home performance contractor.” Between these are hybrid approaches with mixes of in-house capacity, subcontracting, trade alliances, and referral networks. The author pointed out that in reality the actual contractors are:

- Fully integrated contractors/testers
- HVAC contractor/tester with subcontractors
- Remodeler/tester with HVAC subcontractors
- Marketing/testing firm with affiliated contractors.¹¹

He also pointed out that at the time he had not been able to find any test-only consultants.

Home Energy (2006) published a special issue on “Home Performance.” The issue, sponsored by Home Performance with ENERGY STAR (HPwES), included articles discussing different aspects of home performance contracting: overview, marketing, sales, examples, business opportunities, growing a business, etc. *Home Energy* (2009) revisited market delivery approaches, publishing “Home Performance Contractor’s Business Development Guide.” Marketing, sales, business operations, and business growth were the main sections, which included multiple articles written by experts.

Four major market delivery approaches that operate in the residential upgrade market were identified:

- Consultant or independent assessor
- General contractor
- Trade contractor
- Whole-house energy upgrade contractor.

There are variants and hybrids of these models, with subtle differences in ways that many other models could be described. For example, a general contractor may operate as an aggregator of small contractors and raters or a general contractor may simply be a remodeler who does much of the work and subcontracts pieces as needed. Additionally, Booz & Company and RW Ventures (2009) identified two additional models: Non-Governmental Organization (NGO) Aggregator and Big-Box Retailer. For the most part, a NGO aggregator tends to operate under programs. A Big-Box Retailer works either as a general contractor or a trade contractor, depending on the model. Thomas et al. (2004) described a typical home energy upgrade market delivery approach as one containing the following elements:

- Marketing
- Selling the energy assessment
- Conducting the assessment
- Making savings projections
- Making estimates of installation cost
- Reporting on findings and making recommendations

¹¹ Kornbluth (2011) pointed out that in New York, participation from HVAC contractors and remodelers in the NYSERDA Home Performance with ENERGY STAR program has been much lower than from envelope contractors, and, in fact, was almost nonexistent during the first few years of the program.

- Selling the job
- Installation
- Testing out.

Technical gaps and barriers may apply to several of these elements independently on the market delivery approach taken by the contractors.

3.1 Consultant or Independent Assessor

Under this model, the contractor works directly for the homeowner (or for another contractor)¹² to market and promote the value of independent recommendations. The contractor performs a comprehensive building science-based home assessment¹³. If the homeowner is the client, the consultant also develops a work scope of measures to be conducted, provides the homeowner with a list of recommended contractors to execute the work scope, tests the house after improvements are made, and performs quality assurance for the project. James (2004) provided an overview of the services of one consultant, Keith Williams. The author highlighted the steps that the consultant takes, including the initial assessment. Table 3 lists the advantages and disadvantages of the consultant model.

Table 3. Advantages and Disadvantages of the Consultant Model

Advantages	Disadvantages
<ul style="list-style-type: none"> • Relatively low barrier to entry • Moderate capital investment • Low operating costs • Customers have more confidence in the end product • Serves as a third-party expert, overseeing the project and providing immediate independent quality assurance on the work. 	<ul style="list-style-type: none"> • A large number of customers are needed to sustain this approach. • The consultant needs to have a deep and comprehensive understanding of buildings and their systems • The product being sold is the solution to specific problems. This could create a liability¹⁴ to correctly diagnose the problems and ensure they are resolved. • The consultant has to develop a reliable network of competent and willing contractors.¹⁵ • Integrated home upgrade contractors can undercut the independent consultant's home audit price easily; the result is that this approach is rarely used.

The investment to start as a consultant involves acquiring test equipment, computer, software (business and building modeling software), training, and certifications.

¹² When programs are used, the consultant or independent assessor might work for the program manager (the utility, for example).

¹³ The terms *energy audit*, *evaluation*, and *inspection* are also used. This report uses energy assessment.

¹⁴ Bob Knight noted that in California the general contractor bears all the liability, and he never heard of a liability claim against an independent rater who advised the owner and contractor about what to do. Even so, RESNET offers professional liability insurance to raters and some integrated general contractors also use such insurance.

¹⁵ Some programs might consider this a conflict of interest and prevent any such referrals.

Many professionals operating in this model recommend specific contractors in whom they have confidence and can charge referral fees to the trade contractors that are hired to perform the upgrade. When programs are present, the practice of charging referral fees is sometimes viewed as a conflict of interest and is not allowed (e.g., in Energy Upgrade California¹⁶).

3.2 General Contractor

The general contractor¹⁷ performs a comprehensive building science-based home assessment, develops a work scope, and sells the job. Also, they subcontract all the trades involved in the upgrade. If a program is involved, the general contractor processes the paperwork involved and tests the house after the upgrade was performed. Table 4 lists the advantages and disadvantages of the general contractor model.

Table 4. Advantages and Disadvantages of the General Contractor Model

Advantages	Disadvantages
<ul style="list-style-type: none"> • Low start-up cost (similar to the consultant model) • Low overhead • Reduced liability (shared or transferred to subcontractors) • Not bound to specific installers • No employees to manage • The network of subcontractors can be a good lead source 	<ul style="list-style-type: none"> • Selecting good installers may be challenging. • Profits have to be shared with installers • Production scheduling is more complicated, because the work has to be accommodated by subcontractors' schedules. • Quality control and quality assurance are more difficult to manage. • Managing service and call-backs can be challenging • Prone to customer confusion/dissatisfaction with all the many trades and people on the job.

The investment to start is similar to that of the consultant model.

3.3 Trade Contractor

The trade contractor provides a comprehensive building science-based home assessment and develops the work scope and offers some, but not all, of the services required to perform comprehensive whole-house work. The services depend on their original trade, usually adding services to their original services. Many trades could be involved, but more typical ones are HVAC and insulation. After all the services are performed, the contractor usually tests the house to verify its performance after the upgrade. Table 5 lists the advantages and disadvantages of the trade contractor model.

¹⁶ See https://energyupgradeca.org/statewide_for_contractors

¹⁷A general contractor is usually a builder or remodeler who performs much of the work, hiring specialty contractors as needed. For our purposes, such a contractor would be accommodated by the trade contractor model.

Table 5. Advantages and Disadvantages of the Trade Contractor Model

Advantages	Disadvantages
<ul style="list-style-type: none"> • Provides a point of entry to home performance contracting that allows for a phased approach to delivering whole house services. • Services delivered in house provide greater control over quality. • There is higher profitability on in-house work. • Easier to schedule in-house jobs. • Easier to manage service on in-house jobs than in general contractor model. • Subcontractors can be a valuable lead source. 	<ul style="list-style-type: none"> • Selecting good installers may be challenging. • Profits have to be shared with installers. • Production scheduling is more complicated, because the work has to be accommodated by subcontractors' schedules. • Whole-house performance is more difficult to ensure. • Managing service and call-backs can be challenging.¹⁸

Alliances of different trades and remodelers who add energy efficiency upgrades to their offerings usually work under this model. Efforts are in place to understand how to transition HVAC and remodeling contractors to whole-house energy upgrade contractor (see Appendix A).

3.4 Whole-House Energy Upgrade Contractor

This model is the full-service, or home performance contractor. Services offered include insulation, air sealing, and HVAC services, all with installers and technicians who are employees. In some cases, the company also offers window and door installation services. Table 6 lists the advantages and disadvantages of the whole-house energy upgrade contractor model.

Table 6. Advantages and Disadvantages of the Whole-House Energy Upgrade Contractor Model

Advantages	Disadvantages
<ul style="list-style-type: none"> • It has the highest profit potential. • Most control over quality of work • Easier to schedule and coordinate multi-phase projects. • Easier to manage service and callbacks. • The diversity of services provided helps to even out the natural demand cycles. • One stop service from a customer perspective • Prone to higher satisfaction. 	<ul style="list-style-type: none"> • There is a higher overhead. • There are more employees to manage • There is less flexibility in mix of jobs. Unless the field staff is cross-trained, a backlog needs to be maintained for all services delivered.¹⁹

¹⁸ Because of multiple contractors involved, good documentation is necessary to identify who performed the work that created issues to prompt call-backs.

¹⁹ Many contractors in this field also do other work, such as simple HVAC installations or repairs, so there may be more flexibility than one might expect.

4 Technical Barriers, Gaps, and Opportunities

Our main objective is to identify technical barriers, gaps, and opportunities that are associated with the home energy upgrade market delivery approaches. Classifying them as technical and nontechnical (for example, operational) is sometimes challenging. For this report, gaps, barriers, and opportunities²⁰ are considered technical if they can be either addressed or developed by the Building America program participants (national laboratories and teams). Nontechnical barriers, gaps, and opportunities were identified and are listed in Appendix C. These also need to be addressed for the success of home energy upgrades, but are beyond the scope of this report. It is important to note that many professionals who were interviewed for this report believe the nontechnical issues are more urgent than the technical gaps and barriers.

The barriers, gaps, and opportunities listed here were identified through interviews with individuals representing organizations that work directly on home energy upgrades: contractors, assessors, manufacturers, researchers, consultants, trade organizations, etc. (see the Acknowledgements section).

The technical barriers and gaps that affect all the approaches are identified in Section 3.

Table 7 lists the technical barriers, gaps, and opportunities associated with energy assessment; Table 8 lists those elements for energy upgrades.

²⁰ In some cases, barriers and gaps may be non-technical but have associated technical opportunities, so they are included in the report. Such case include discussions.

Table 7. Energy Assessments: Technical Barriers, Gaps, and Opportunities

Technical Barrier or Gap	Opportunities	Description
<p>Software-based energy analysis of inefficient existing homes tends to over-predict pre-upgrade energy use and resulting energy savings.</p> <p>There are significant uncertainties in the energy use and energy saving predictions estimated by software tools, caused by the inputs collected at the energy assessment and the algorithms used in the tools. Particularly in inefficient existing homes, energy use predictions tend to be higher, causing the prospective energy savings from a home energy upgrade to be over-predicted (Polly et al. 2011). Investors may be reluctant to invest in the home energy upgrade industry when uncertainties are present. The estimated energy savings from a home energy upgrade are uncertain even when the simulations are calibrated using prior year’s energy use.</p>	<p>Address software inaccuracy issues</p>	<p>Develop research to identify and address software inaccuracy issues. This involves inputs and the algorithms related to analysis tools. To address input issues, investigate and improve the energy assessment process (data collection, questions asked to the homeowner, utility consumption data, etc.). Software models and solution processes can be improved by isolating specific issues and comparing them with laboratory experiments and field tests. Large-scale comparisons between predictions and actual energy use and savings in upgraded houses are necessary to continuously improve tools.²¹</p>
	<p>Investigate the minimum requirements of the initial energy assessment by climate, housing type and vintage, and other characteristics.</p>	<p>Determine the minimum requirements for the initial energy assessment to make it cost effective. It is important to determine if an initial assessment is needed. Require safety measures and create a risk management approach to face issues that are less likely to have catastrophic effects.</p>
	<p>Continue to develop certification procedures for building energy simulation tools.</p>	<p>Expand the certification procedures, particularly adding empirical base tests to build trust in software predictions. Stakeholders are more interested in large-scale comparisons with empirical data than in software-to-software comparisons.</p>

²¹ It is important to note that comparing predictions to actual energy use for asset improvements also presents issues.

Technical Barrier or Gap	Opportunities	Description
<p>Building characteristics and utility billing data from actual houses have not been available in large scale for comparing software predictions with metered data.</p> <p>Building energy simulation tool developers have limited access to energy use data from properly characterized houses to compare the predictions made using their tools with the actual energy use of the houses. This gap prevents software tool developers from improving their products based on actual houses.²²</p>	<p>Build a data-driven actuarial-based performance standard to test and verify savings accuracy.</p>	<p>A specific certification procedure could be created where an actuarial-based performance standard for savings predictions could be built. Instead of a pass/fail test, the standard would lead to accuracy uncertainties based on error propagation of all the elements of the prediction.</p>
	<p>Obtain data from very well-instrumented houses</p>	<p>To address specific issues in building energy software tools, very well-instrumented and very well-characterized laboratory houses may be necessary. Side-by-side test houses where specific issues can be tested would provide additional data for improving house diagnostics and energy saving predictions.</p>
	<p>Investigate the possibility of displaying the Residential Energy Consumption Survey data by major climate zone</p>	<p>Currently the RECS data are displayed by regions (West, Midwest, South, and Northeast) that include multiple climate zones. Displaying the data by climate zone (Building America) would make the survey results more useful, because climate is a major driver for energy use. Bars stacked side by side show distribution of use by zone and the zone-to-zone comparison of total and end use.</p>
	<p>Expand NREL's Field Data Repository</p>	<p>Continue to collect building characteristic and energy use data to feed into the Field Data Repository in development at NREL, where field data for many residential buildings are collected and stored. The information collected in the field includes the building characteristics that are relevant to energy analysis, as well as metered utility data. The range and resolution of the field data are determined according to established field data collection procedures from labeling, rating, scoring, and upgrade</p>

²² It was pointed out that, while not a technical barrier, utility data confidentiality poses difficulties to obtain data.

Technical Barrier or Gap	Opportunities	Description
		efforts. This information must cover a wide range of residential building types and occupants and span each DOE climate region. When energy improvements are made, building descriptions and utility bill data also cover pre- and post-upgrade conditions (Polly et al. 2011).
	Create open data repositories where homeowners can add the characteristics and energy use of their homes	This could be an expansion of EPA’s Home Energy Yardstick, but metrics could be more local if data are available. ²³ There may be privacy issues, but the availability of energy use per neighborhood of similar houses may indicate whether a house consumes a lot of energy. If people have an incentive to add their houses to the repository and quality control to make sure data entry errors can be corrected, professionals and homeowners can identify issues with large energy use. It is important to keep homeowner input data separate from data gathered by professionals.
<p>Building energy simulation tools cannot be updated immediately when a new technology is developed.</p> <p>Many energy ratings are based on building energy simulation tools, so new technologies that are not currently modeled by the tools are not given proper credit and the ratings do not reflect associated energy improvements. This barrier may discourage investment in and adoption of new technologies.</p>	Investigate alternatives not involving building energy simulation tools to evaluate new technologies.	An example is the use of actual energy bills before and after the installation of new technologies to justify their implementation.
	Develop collaborations between industry and software developers to create software solutions in parallel with the development of new products and technologies.	Investigate ways to foster collaboration between innovators and software developers to develop software solutions for new technologies as soon as issues related to intellectual property are no longer present. The development of simulation tools can take place in parallel with third party testing to make sure their use is safe and advantageous.

²³ Home Energy Saver Pro user input data could also be used here.

Technical Barrier or Gap	Opportunities	Description
<p>Nonenergy benefits are not easily monetized.</p> <p>Because energy benefits can be monetized, a return-on-investment calculation is usually performed and often becomes the central piece on selling upgrades. Usually, however, upgrades are driven by benefits that are not energy-related. Because they are difficult to monetize, they do not register in a return-on-investment comparison. Additionally, comprehensive energy upgrades often require investments that are not directly attributed to the energy savings technology. (i.e., roof replacement or electrical rewiring at time of insulation). When these costs get rolled into investment analysis this makes the energy improvement appear to be a poor investment if only the energy savings are considered.</p>	<p>Investigate ways to monetize nonenergy benefits</p>	<p>In commercial buildings, comfort has been associated with workers' productivity (Clements-Croome and Baizhan 2000), so comfort could be monetized. Houses may have other proxies that could be developed for measuring nonenergy benefits in dollars. Determining metrics to address other benefits of saving energy, such as environmental, health, livability, durability, etc. would be of interest. There is also some evidence in the new construction market indicating higher values for green houses, which may become a leading indicator for home energy upgrades.</p>
<p>Initial house assessment is time-consuming and expensive.</p> <p>Performing a house assessment involves a series of tests and evaluation of the utility bills to determine where energy is used and if there are safety and durability issues that need to be addressed. A big part of the assessment is the post-data collection effort to estimate the best upgrade scopes, run the model, and submit the analysis for approval. While contractors have different ways to conduct the assessment, it is usually expensive and, as expected, not every assessment results in contracts to perform upgrades.</p>	<p>Work with utilities to create energy use metrics available by specific territories</p> <p>Develop alternative means of home assessment that require less effort, such as smart meter data and surveys to identify major savings opportunities.</p>	<p>Privacy issues may limit the availability of specific house energy use, but creating overall energy use metrics by territory (ZIP codes, neighborhoods, etc.) could provide enough information for professionals and homeowners to identify larger than normal energy use. Examples are minimum, maximum, and average energy consumption by fuel per neighborhood, square footage, house type (one- or two-story), and age of a home. These metrics could be published as part of utility bills or available online.</p> <p>Conduct research to determine the useful information that can be extracted from frequent (e.g., 15-minute interval) data, such as high energy users, large energy uses, and high baselines. Determine how to couple gas metering to electricity smart meters and other technologies.</p>

Technical Barrier or Gap	Opportunities	Description
	Focus on larger neighborhoods with fewer house models	Some neighborhoods have a limited number of models that are representative of multiple houses. ²⁴ Conduct a detailed assessment on a few houses in a neighborhood, identify the specific upgrades and issues that are likely common, and approach each house type as if the issues identified are common. This would limit the number of comprehensive assessments that need to be conducted.

²⁴ Dick Kornbluth pointed out that the “larger neighborhoods with small number of house models” tend to be newer housing stock: neighborhoods with older and more varied housing stock have the most energy-inefficient houses. On the other hand, Duncan Prahel noted that in many parts of the country production builders have been operating since the early 1900’s.

Table 8. Energy Upgrades: Technical Barriers, Gaps, and Opportunities

Technical Barrier or Gap	Opportunities	Description
<p>Comprehensive energy efficiency upgrades require large initial capital investment.²⁵</p> <p>Some jobs that include air sealing, insulation, windows, and equipment replacement may cost tens of thousands of dollars. Also, the real estate transaction process as it currently exists does not typically result in increased values for houses with comprehensive home energy upgrades, possibly discouraging some homeowners from installing energy efficiency measures.</p>	<p>Create plans for staged energy upgrades instead of an all-or-nothing approach</p>	<p>Rather than offering only an all-or-nothing approach, there is an opportunity to create an upgrade plan for the house with deeper energy savings in mind. This is related to an event-driven plan: a series of events are predicted during the life of a house, including mechanical equipment failures and external siding and window replacements. Such events should be accounted for in the home energy upgrade plan. Ideally, the plan should be somehow attached to the house, not to the homeowner, so when the house changes ownership, the new owners can consider the plan. There is an opportunity to create this connection: house manual that is part of the house closing, Internet, stickers on major appliances, windows and siding, etc. HVAC contractors could benefit significantly, because they make frequent visits to the house to perform maintenance.</p>
	<p>Create module/packages/components that can stand alone</p>	<p>Related to the plan for staged energy upgrades, packages of measures could be created that would go as deep as one can afford at a given moment, keeping in mind the goal of deeper savings. This should also consider the event-driven replacements (broken air conditioner, furnace, water heater, damaged roof, siding, etc.). Wigington (2010) discussed this opportunity in detail.</p>

²⁵This is not a technical barrier per se, but some related technical opportunities are presented later. Opportunities related to financing the upgrade are not presented because they are nontechnical. For information about financing efforts, refer to Appendix A.

Technical Barrier or Gap	Opportunities	Description
<p>Specific housing types in certain areas are challenging for upgrade solutions</p> <p>Neighborhoods are typically developed in waves over time. An area may have been developed in an era when typical construction was such that upgrades may be challenging. For example, masonry walls were usually not insulated, so trying to add insulation creates dilemmas for the contractor and the homeowner (space constraints inside and appearance outside). Other examples include air sealing of split-level homes, how to deal with crawlspaces, slabs, and foundations.</p>	<p>Develop technical solutions for specific housing types and issues with clear recommendations based on climate</p>	<p>Many viable solutions have not been documented and tested in large scale. Issues considered here are the ones that, if resolved, could significantly enable some of the home energy upgrade market delivery approaches. The opportunity is to identify major issues that are barriers in specific regions and create a process to address the issues so the improvement can be included in a home energy upgrade.</p>
<p>Recently installed mechanical equipment prior to a deep energy upgrade</p> <p>When deep energy upgrades are being considered for a house that had mechanical equipment recently installed, issues may arise: with significant air sealing and insulation increase, the equipment may be oversized, atmospherically vented appliances are risky with significant air sealing jobs, systems are installed in locations that are not within the home's thermal/pressure boundary in heating climates. Replacement is usually a difficult option to discuss with the homeowner, who recently paid for the equipment installation. Contractors expressed interest in alternatives that would involve changes to the installed equipment without replacing it. This problem is less significant with variable speed²⁶, two-stage gas furnaces that can adapt to reduced load, but a problem with other equipment.</p>	<p>Investigate the best solutions to accommodate recently installed equipment after an aggressive enclosure upgrade is executed</p>	<p>Determine if there are practical ways to downsize equipment after an upgrade takes place: for example, can it be done to an air conditioner in a hot and humid climate, so it does not short-cycle after the cooling load is significantly reduced? Identify packages of measures that need to be included in an energy upgrade when the air conditioner is not replaced (for example, is a dehumidifier necessary?).</p>

²⁶ However, the ducts and register do not vary in size, which may create comfort problems

Technical Barrier or Gap	Opportunities	Description
<p>Air sealing existing homes is challenging</p> <p>There are no standard practices to air seal existing homes to very low infiltration levels (to the point that mechanical ventilation becomes necessary) when the upgrade is not a gut rehab. With no access to the cavity, comprehensive air sealing tends to be limited to the attic: it reduces infiltration in the house, but not sufficiently. Even experienced contractors using infrared, a blower door, and dense pack insulation techniques do not always get two- and three-story homes down to the level where ventilation is recommended. This is due in part to three-dimensional interstitial air leakage between interior and exterior walls and floors (Wigington 2010).</p>	<p>Investigate solutions and develop protocols for deep air sealing existing homes</p>	<p>Investigate solutions to air seal existing homes to very low infiltration levels. Document the necessary steps that need to be followed to achieve such infiltration levels.</p>
<p>There are no common acceptable practices to install additional insulating sheathing when residing a house.</p> <p>Installing external foam insulation before residing a house is a great opportunity to improve enclosure efficiency,²⁷ but it lacks common acceptable practices that have been tested and documented. For example, manufacturers of cladding systems and exterior insulation materials often limit thicknesses to 1½ in. with their warranties, which may be an issue in cold climates when ideally the levels of external insulation could be over twice that thickness. Additionally, contractors need standard practices to deal with openings (windows and doors) when installing additional siding.</p>	<p>Develop solutions to install additional board insulation prior to residing a house</p>	<p>Investigate solutions for attaching foam board externally to the framing, including protocols for installation. In developing solutions, one should consider how to attach the cladding to the insulation and how the water management of the assembly will be accomplished. Work with the siding manufactures to include specifications for external insulation that exceeds the current standards and incorporation of standard practices for windows and doors when extended insulation material thickness exceeds 1-1/2".</p>

²⁷ Insulating sheathing maintains the structural elements of the home at a warmer temperature reducing the risk of condensation and freeze thaw (masonry walls).

Technical Barrier or Gap	Opportunities	Description
<p>Reducing miscellaneous electric loads is challenging.</p>	<p>Use miscellaneous electric loads as an opportunity to address the effects of occupant behavior on energy consumption</p>	<p>Energy use from miscellaneous electric loads is directly related to home occupant behavior. High energy consumption creates an opportunity to discuss the effect of that behavior in the utility bill and ways to reduce it.</p>
	<p>Develop better load monitoring and automated controls, such as smart occupancy-sensing shutoffs on plug strips, for miscellaneous electric loads.</p>	<p>Identify commercially available plug load controls and field test them to document their benefit. Field tests of solutions are necessary to document their effectiveness.</p>
<p>There are no common practices for homeowners to convert garage spaces into living spaces. Homeowners are choosing to use their attached garage spaces as living space and often do so with little to no change in the physical structure to improve the thermal envelope. These homes rank among the highest energy users and often accommodate space heating portable with resistance electric wall heaters. Furthermore occupants have been found to be in a dangerous combustion safety environment and don't know it.</p>	<p>Investigate solutions and develop protocols for appropriate conversion of garage spaces to living space</p>	<p>Beyond homeowner education on how expensive and potentially dangerous it is to live in a garage space without proper envelope treatment; contractors need a set of common standards for how to best convert garage spaces into livable space. Recommendations for how to best seal the space as well as assure indoor air quality, health and safety are both important especially when water heaters are located in the garages.</p>

5 Conclusions and Next Steps

This report identifies technical gaps, barriers, and opportunities that are related to market delivery of home energy upgrades. These were identified through literature search and interviews with subject matter experts and they will support the DOE planning process.

Key conclusions from this work include:

- Major barriers have been identified for large-scale market delivery of home energy upgrades. This report concentrates on the technical barriers and gaps, recognizing that many barriers are nontechnical. Addressing the technical barriers identified in this report would support the goals of delivering large-scale home energy upgrades to the market. Building America will coordinate closely with other programs to ensure that all issues are addressed.
- The majority of the technical barriers and gaps occurred in two areas: energy assessment and energy upgrade. Along with these barriers and gaps, opportunities were identified in the literature or suggested by professionals during interviews, with the vast majority of them being the latter.
- Issues associated with energy assessment are on:
 - a. Software-based energy analysis – related to the Analysis Methods and Tools Standing Technical Committee.
 - b. Access to building characteristics and utility billing data – related to the Implementation Standing Technical Committee.
 - c. Assessment needs – related to three standing technical committees: Analysis Methods and Tools, Testing Methods and Protocols, and Implementation.
- Gaps and barriers associated with upgrades are centered on specific measures, such as:
 - a. Mechanical equipment – related to Hot Water Standing Technical Committee and Space Conditioning Standing Technical Committee.
 - b. Air sealing and insulating sheathing – related to Envelope Standing Technical Committee.
 - c. Miscellaneous electric loads – related to two standing technical committees: Lighting, Appliances, Miscellaneous Electric Loads and Home Energy Management.
- Four key contractor market delivery approaches were identified:
 - Consultant or independent rater
 - Trade contractor
 - General contractor
 - Whole-house energy upgrade contractor.

There are variants and hybrids of these approaches and a combination of approaches may be necessary to deliver home energy upgrades.

- Since a home energy upgrade involves both an energy assessment and the upgrade itself, the barriers and gaps identified in this report apply to all the market delivery contractor approaches.

These findings will serve as a resource to the Building America teams conducting research in the area of home energy upgrade market delivery (see Appendix A). It will also provide input into the Building America Strategic Plan. Specific items that are associated with Standing Technical Committees will be communicated to them directly for further consideration.

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Appendix A – Current Status of Research and Related Efforts

This appendix provides an overview of the research performed by Building America teams on home energy upgrade market delivery and the many efforts conducted by others in related areas.

A.1 Building America Teams

Building America²⁸ is part of the DOE, Office of Energy Efficiency and Renewable Energy, Building Technologies Program. The Building America program focuses on conducting the systems research required to improve the efficiency of the 500,000–2,000,000 new homes built each year, as well as the approximately 116 million existing homes.

Research from this program accelerates the development of reliable and effective whole-house packages of measures for highly energy efficient new and existing homes that are tailored for each major U.S. climate region. This research can be broadly implemented to reduce risks, increase durability, and provide a reasonable return on investment. These improvements are accomplished through multiscale research, systems development, systems integration, large-scale field implementation and evaluation, and effective communication of key research results and system-based strategies. Recently, the near- and long-term performance targets for Building America have been updated to help guide the energy efficiency of homes past updated code requirements and current standard practices.

Since July 2010, Building America research teams have begun projects that help dramatically improve the energy efficiency of American homes. These highly qualified, multidisciplinary teams work to deliver innovative energy efficiency strategies to the residential market and address barriers to bringing high-efficiency homes within reach for all Americans.

A number of Building America projects are directly related to the technical gaps highlighted in this report:

- **IBACOS – Transitioning HVAC Contractors to Home Performance Contractors:** The team is conducting a research effort to understand business impacts and change management strategies for HVAC companies. IBACOS researchers believe that HVAC companies can implement these strategies to quickly transition from a “traditional” heating and cooling contractor to a service provider for whole-house energy upgrade contracting. Because they have service contracts, which create opportunities for frequent interaction with homeowners, IBACOS researchers believe that HVAC companies are ideally positioned in the marketplace to resolve homeowner comfort issues through whole-house energy upgrades. (Burdick 2011).
- **NAHBRC - Evaluation of Retrofit Delivery Practices:** The NAHB Research Center Industry Team’s strategic approach is to identify business models for the remodeling industry that foster remodelers’ adoption of energy efficiency services. Remodeling contractors often need additional technical, marketing, and other resources to successfully provide energy upgrades to their customers. The goal is to develop and assemble a set of operating and marketing guidelines and resources for remodelers, similar to the business startup kit, to increase their

²⁸ Visit the Building America website for more information about Building America teams, projects, partners and tools: www.buildingamerica.gov

likelihood for success in expanding their current services to include a comprehensive menu of energy upgrade options. An awareness program is recommended for the future deployment of these resources to hasten the development of this emerging energy upgrade business. During 2011, the NAHB Research Center conducted market research with remodelers to determine the gaps and ways to add energy efficiency upgrades into remodeling projects.

- NELC – Audit Processes and Upgrade Delivery Systems: The National Energy Leadership Corps (NELC), lead by the Pennsylvania State University, researches new approaches to home and homeowner energy audits and assessments that facilitate multiple levels of energy efficiency measures for existing homes including modest and low-cost improvements, extensive energy retrofits, occupant interactions, and the introduction of advanced energy controls and renewable energy technologies. Nontraditional audits types, such as the self and assisted audit, may help mitigate the cost of whole house evaluations.

A.2 Related Efforts

This report focuses on the technical gaps, barriers, and opportunities. Many other efforts are being made to identify market delivery approaches and aspects related to them that are not necessarily technical. They relate to programs, policy, and funding mechanisms for large-scale home energy upgrades.

The contracting industry can thrive only when program, business, and customer goals align. Table 10 shows the potential drivers for actions in upgrades from the perspective of the homeowner, contractor, and program. The Home Performance Resource Center published a report (Home Performance Resource Center 2010) highlighting ways for programs to support private business in home performance. There, it is stated that

“Programs that can best facilitate industry growth will give the industry maximum flexibility to innovate and develop efficient business models; provide consistency and flexibility so businesses (which often work within, outside of, and across programs) are not constantly forced to adapt their business practices to disparate program environments; and include provisions to help companies launch and reduce unneeded barriers to entry.”

Table 9. Potential Drivers for Actions in Upgrades

Homeowner	Contractor	Program
<ul style="list-style-type: none"> • Healthy house • Comfortable house • Money savings • Equipment reliability • Durable house • Energy use reduction • Smaller carbon footprint • Increased appraisal value 	<ul style="list-style-type: none"> • Business growth • Diversification • Mining of client base and marketing capabilities • Callback reduction on all jobs • Green 	<ul style="list-style-type: none"> • Energy savings • Reduced greenhouse gas emissions • Jobs • Minority employment • Reduced peak demand • Healthy houses • Improved neighborhood

Many efforts related to programs in the literature are underway. DOE invited 75 energy efficiency experts from across the country to participate at the National Residential Energy Efficiency Business Model Summit on May 27–28, 2009, in Washington, D.C. (DOE 2009). The summit provided an overview of how the established program models address known obstacles

to residential energy efficiency, what is or is not working, and whether these models are scalable. Fuller et al. (2010) wrote an overview on what works and does not work in program models. They focused on the program side, but also identified several aspects of home energy upgrades that apply to market delivery approaches, such as:

- Comfort
- Practical investment
- Self-reliance
- Social norm
- Health
- Community engagement
- Contractors (and programs) should target prospective customers carefully.
- Avoid meaningless or negatively-associated words such as *retrofit* and *audit*.²⁹
- Demands on homeowners, particularly around time and effort, must be minimized. Consolidate the number of steps required. Participants drop out with each step and with each time delay.

Hinkle and Schiller (2009) highlighted the need for aggregation to unlock the potential of energy efficiency. These include financial aggregation of projects to improve investor returns, technological aggregation to address multiple upgrade opportunities simultaneously, and geographic aggregation to access the broadest possible range of buildings, engage local support to drive upgrades aggressively, and develop the workforce to make upgrades possible at the scale contemplated by the authors.

The Climate Change Capital (2009) published a briefing note on delivering energy efficiency to the residential sector, making policy proposals in the United Kingdom to upgrade the existing housing stock using a whole-house approach. They proposed the creation of a National Energy Efficiency Program to provide funding, reduce waste in the energy system, and put more money into consumer pockets. It would also lower the cost of meeting 2020 renewable energy targets and insulate the United Kingdom against volatile energy prices to meet energy security concerns.

Sweatman and Managan (2010) wrote about financing energy efficiency building upgrades. They proposed an aggregated investments model with four key design features: the creation of a standardized energy efficiency asset, multi-channel origination, on-bill repayment, and the potential for securitization with (or without) government credit enhancement. Although the report concentrates on ideas and regulatory pathways for Spain, many findings may be applicable to the United States.

Milken Institute (2010) is dedicated to financing practices in home energy updates. The report suggests that a public-private collaboration and market acceptance by homeowners must be in place, along with an integrated program and financing design to effectively upgrade America's homes.

Home Performance with ENERGY STAR (HPwES) is a program jointly managed by DOE and EPA to significantly increase energy efficiency in existing homes (Plympton et al. 2008). It promotes whole-house improvements via home performance contracting, including

²⁹ This report uses the terms *home energy upgrade* and *energy assessment* instead of *retrofit* and *audit*.

comprehensive assessments and building-science based improvements where homeowners and the ENERGY STAR brand are protected by a robust quality assurance program. Additional information on HPwES can be found at

http://www.energystar.gov/index.cfm?fuseaction=hpwes_profiles.showSplash.

Launched in July 2010, BetterBuildings is an initiative to create a self-sustaining market for building energy efficiency upgrades. Forty-one local and state governments, reaching more than 50 communities, received 3-year awards ranging from \$1.5 million to \$40 million, totaling \$508 million. The awardees are investigating innovative models for single/multifamily building upgrades, as well as low income, small business, commercial, farms, and historic buildings.

Information about the program can be found at

<http://www1.eere.energy.gov/buildings/betterbuildings/>.

On May 20, 2011, the BetterBuildings Program held the “What’s Working in Residential Energy Efficiency Upgrade Programs Conference” in Washington, D.C. Details about the conference, including the presentations, can be found at

www1.eere.energy.gov/buildings/betterbuildings/whats_working_conference.html.

In addition to driving demand, financing, and workforce development initiatives, BetterBuildings is collecting data and performing evaluation of the different programs. Related to technical gaps, barriers, and opportunities that is the core of this report, BetterBuildings is:

- Collecting critical data to identify what works—and why—in the programs being conducted by the awardees.
- Evaluating estimated and actual energy savings.
- Identifying cost-effective packages.

The Better Buildings Operational Models Best Practices Guide combines the lessons-learned from Better Buildings grant recipients, data from research studies, and insights from private sources into operational models that pave the way to a sustainable energy efficiency market. These operational models can help inform Better Buildings grant recipients, program administrators, contractors, and retail companies seeking to expand their services in the home performance market.

Another initiative being conducted by DOE and EPA is the State and Local Energy Efficiency Action Network, a state and local effort facilitated by the federal government. It helps states, utilities, and other local stakeholders take energy efficiency to scale and achieve all cost-effective energy efficiency by 2020. This initiative has engaged diverse stakeholders in the development and implementation of eight energy efficiency roadmaps, one of which is on “Residential Building Retrofits.” Information about this working group can be found at www1.eere.energy.gov/seeaction/residential_retrofits.htm.

Efforts are also being made to mobilize a well-trained national energy upgrade workforce. DOE is working on Workforce Guidelines for Home Energy Upgrades to foster the growth of a high-quality residential upgrade industry and a skilled and credentialed workforce. Details about this effort can be found at www1.eere.energy.gov/wip/retrofit_guidelines.html.

Appendix B – Supporting Material

This appendix provides information related to the market delivery approaches and may be useful for individuals conducting research related to the approaches. The supply and value chains and the elements of the approaches are included here.

B.1 Home Energy Upgrade Supply Chain and Value Network

Booz & Company and RW Ventures (2009) developed a value chain under a Chicago Retrofit Strategy, which was presented on June 25, 2009. Their objectives were to determine whether potential supply constraints were market barriers and to identify opportunities. They found that instead of supply constraints, there were demand-related challenges. The authors identified an upgrade value chain that they used to inform their approach.

Figure 2 shows the actions associated with a home energy upgrade from both demand and supply perspectives.

Figure 3 identifies the key players in each step. Many players are involved in the process, particularly from the demand perspective, and depending on the approach, the auditor (energy assessor), the contractor, and the subcontractors may be independent or part of the same entity..

The NELC team (Penn State) developed a home energy upgrade information map and value chain (see Figure 4).

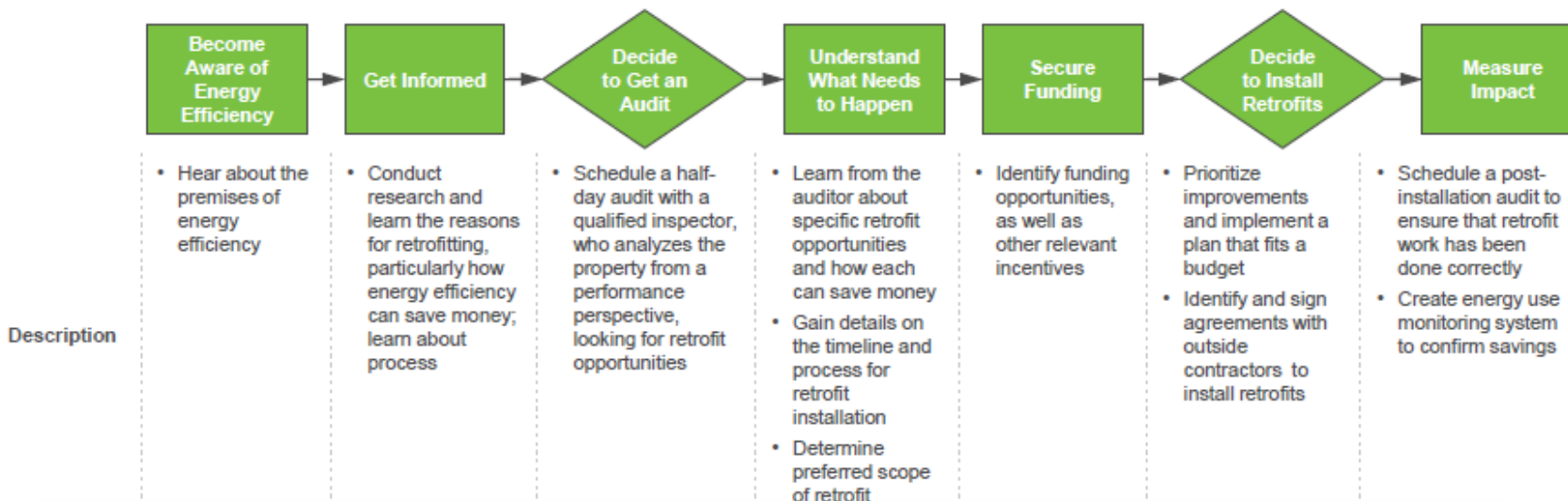
B.2 Elements of Home Energy Upgrade Market Delivery Approaches

The necessary elements of home energy upgrade market delivery approaches vary depending on how the business is structured. Here is a small compilation of the information that was made available in the literature or through interviews.

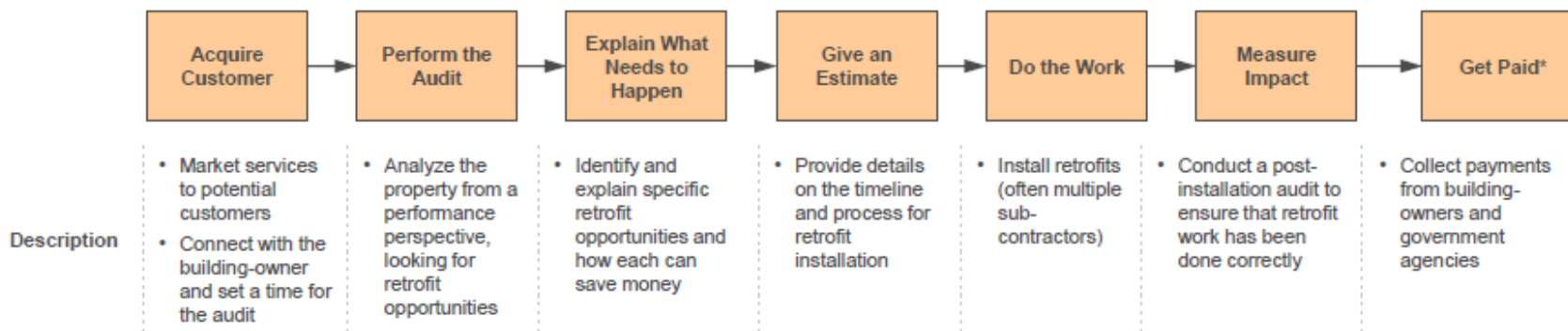
Thomas et al. (2004) described a typical home energy upgrade market delivery approach as one containing the following elements:

- Marketing
- Selling the inspection
- Conducting the inspection
- Making savings projections
- Making estimates of installation cost
- Reporting on findings and making recommendations
- Selling the job
- Installation
- Testing out.

Retrofit Installation from a *Demand* Perspective



Retrofit Installation from a *Supply* Perspective (includes auditors and contractors)



Source: Katzenbach analysis

* Payment may happen at other points during the process, not necessarily as the last action in the sequence.

Figure 2. Actions associated with a home energy upgrade
(Courtesy of: Booz & Company and RW Ventures 2009)

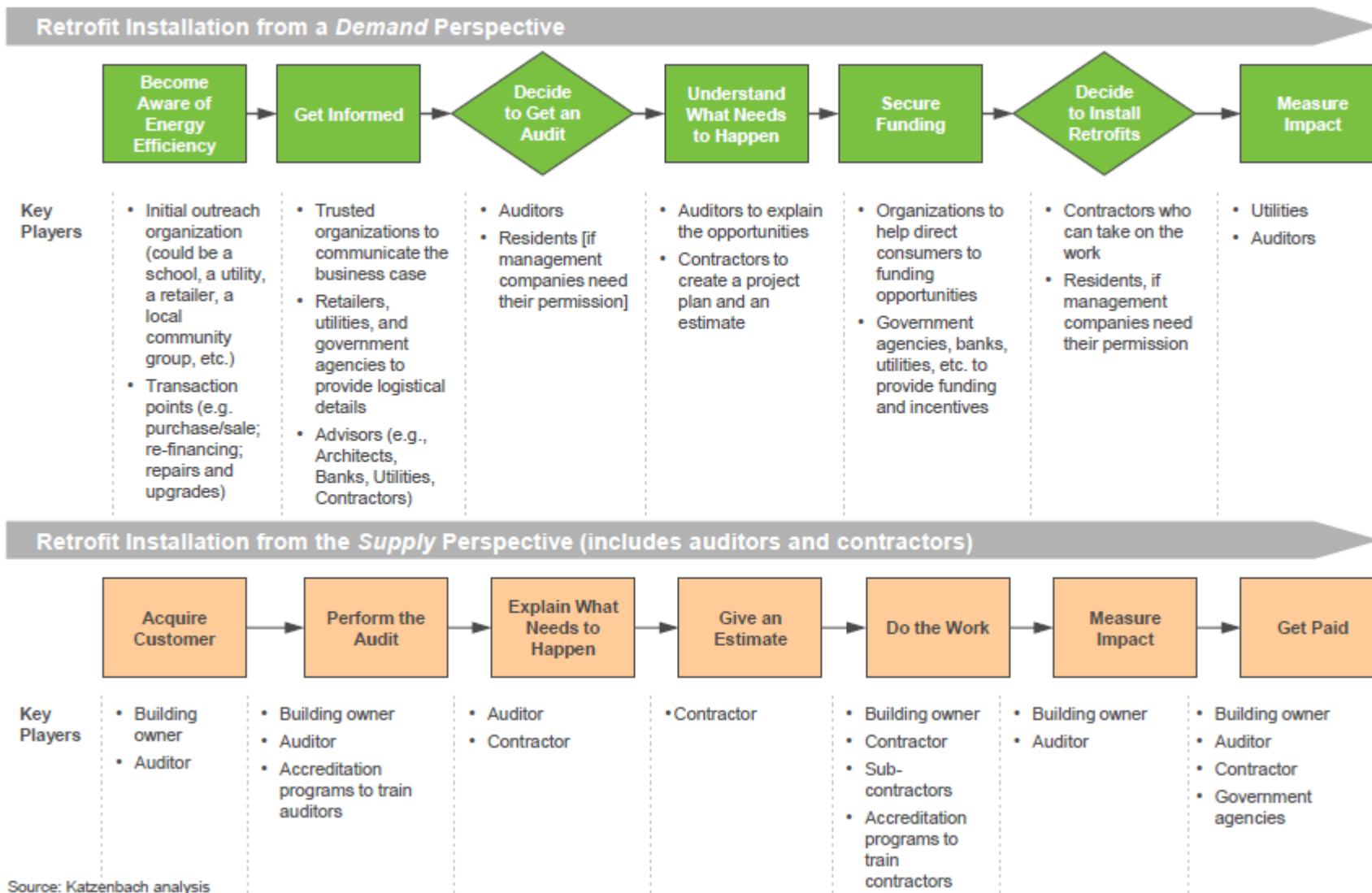


Figure 3. Key players associated with each action during a home energy upgrade
(Courtesy of: Booz & Company and RW Ventures 2009)

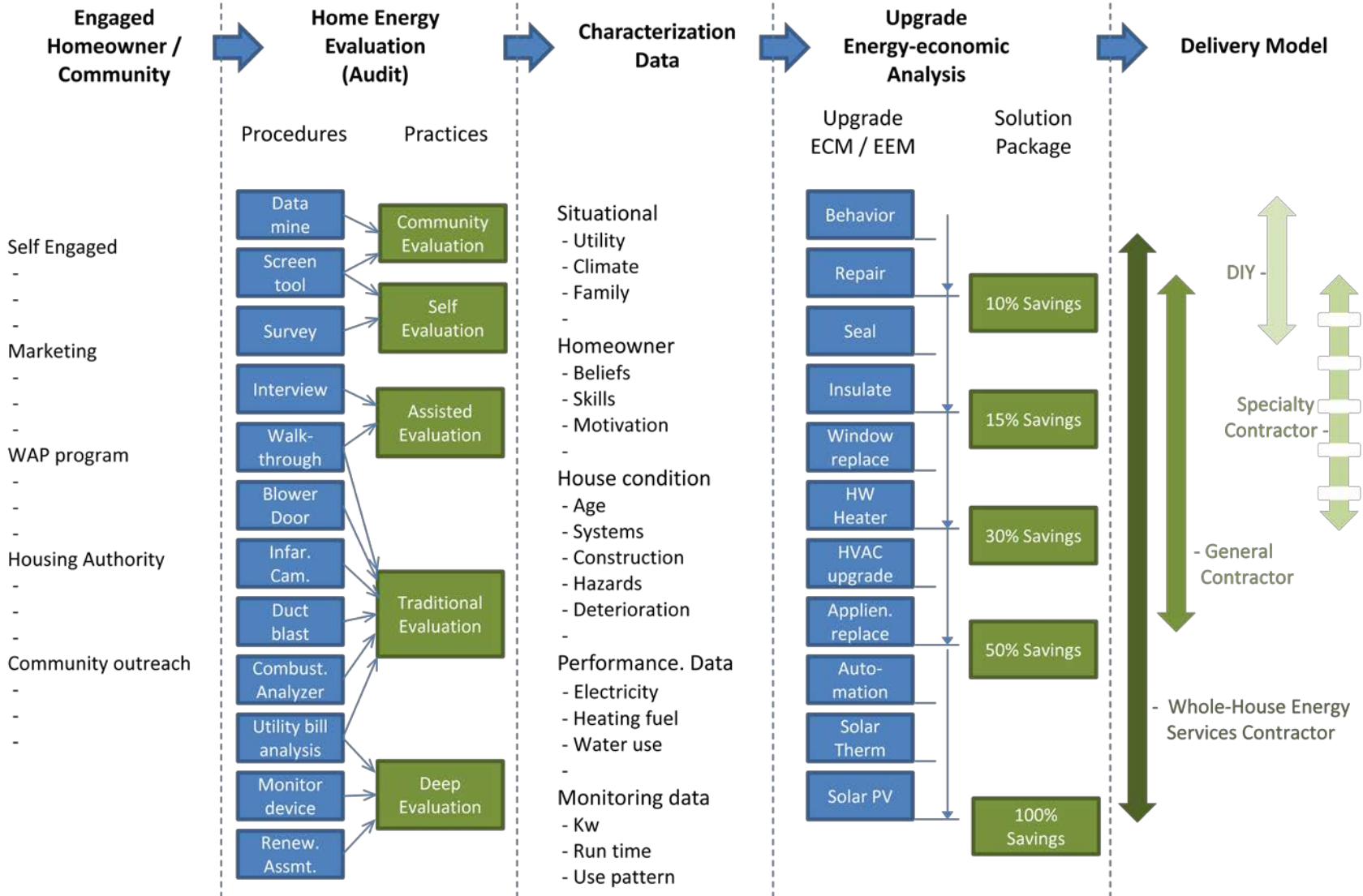


Figure 4. Home energy upgrade information map and value chain (Courtesy of: Riley 2011)

Barbour (2011) identified six required elements of market delivery approaches for a successful endeavor in the residential upgrade market:

- Marketing/consumer education – creates demand using government and private resources to reach consumers.
- Financing – enables consumers to pay for improvements (where applicable), including using “pipes and wires” charges to fund a revolving fund.
- Financial incentives – for consumers and contractors to encourage upgrades, where programs are available.
- Products – manufacturers supplying ample quantity to meet demand.
- Sales and installations – companies installing energy efficiency technologies in homes.
- Ownership – identifies who benefits from the market delivery approach and therefore will continue to invest long-term and be responsible for the continued success.

Burdick (2011) cites the following operational areas within a Whole House Energy Upgrade Contractor’s business:

- Business planning/processes
- Marketing/customer contact
- Assessment
- Sales
- Contract administration
- Production
- Customer service

The National Energy Retrofit Institute (NERI 2011) highlighted the energy improvement design-build process that is involved in a home energy upgrade. The process has four integrated phases:

1. Client Pre-Qualification Phase – Inform homeowner about the home energy upgrade process and help secure funds for project
2. Design Phase – Create a comprehensive plan of energy improvement measures from data collected from the homeowner and the energy audit.
3. Build Phase – Implement energy improvement measures identified in design phase.
4. Project Closeout Phase – Ensure quality and safety of work is completed.

Finally, Knight and Thomas (2000)³⁰ created a diagram (Figure 5) that represents the steps contractors must take to successfully evolve into whole-house contractors. The steps are based on analysis of successful whole-house contractors identified across the United States. The model dramatically demonstrates the broad scope of new requirements faced by contractors interested in transforming their businesses to building performance contracting.

³⁰ In August 2011 Bob Knight pointed out that the steps fail to acknowledge all the work and costs the contractor incurs in dealing with the sponsor’s incentives and rules.

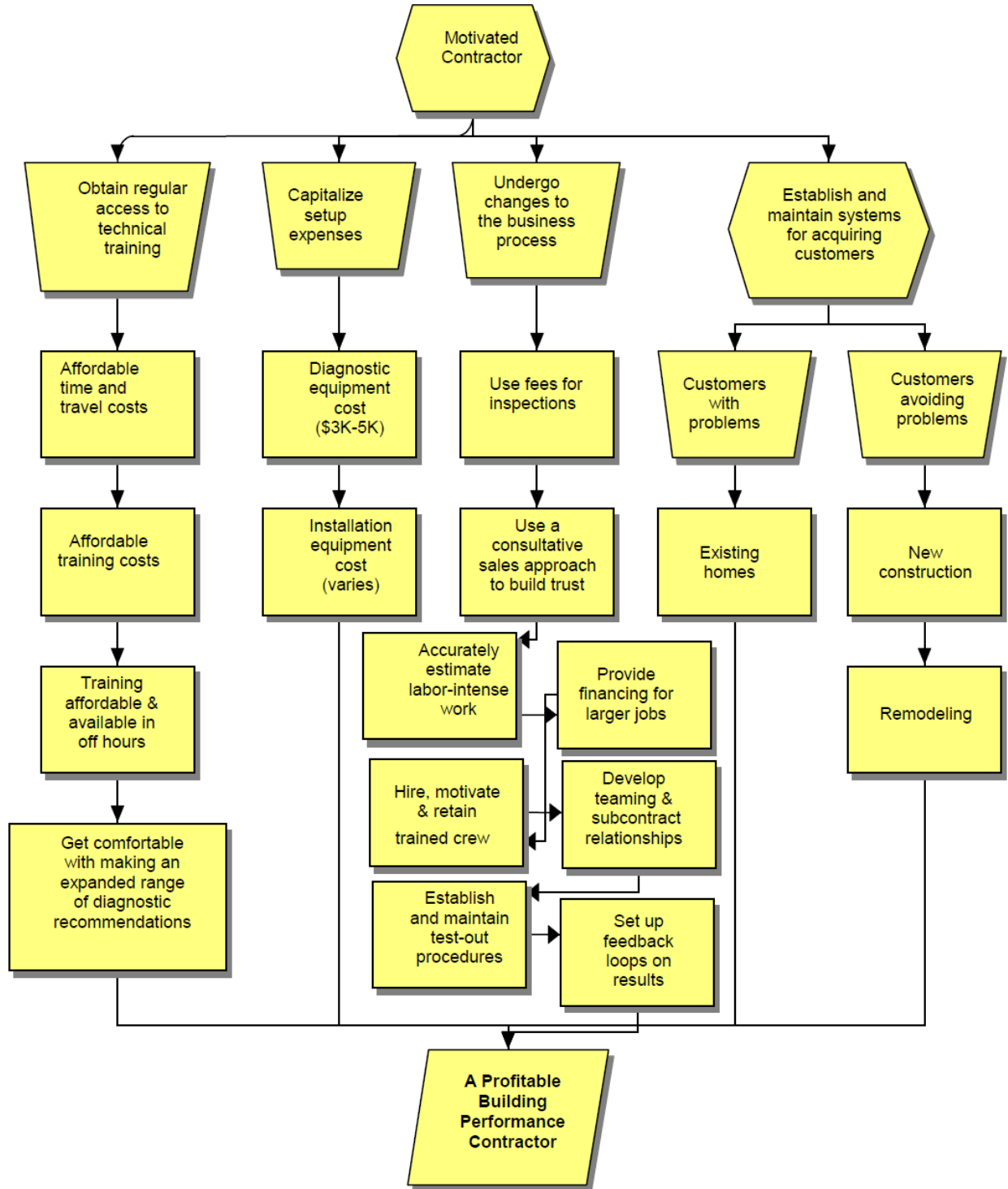


Figure 5. Steps to whole-house performance contracting
(Courtesy of Knight and Thomas 2000)

Appendix C – Nontechnical Gaps, Barriers, and Opportunities

As we investigated the literature, we identified some nontechnical gaps, barriers, and opportunities. In fact, many professionals pointed out that the main barriers and gaps they face are not technical. Commonly cited are the lack of demand for home energy upgrades and the difficulty of obtaining financing.

This appendix captures some of the gaps, barriers, and opportunities mentioned by professionals. Table 10 lists operational gaps, barriers, and opportunities; Table 10, educational; and Table 12, program..

Table 10. Operational Gaps, Barriers, and Opportunities

Gap or Barrier	Opportunity	Description
<p>Lack of demand for home energy upgrades</p> <p>Many individuals expressed this as the greatest barrier for their businesses.</p>	Not identified.	
<p>Difficulty obtaining financing for homeowners to pay for home energy upgrades</p> <p>Lack of financing mechanisms to perform upgrades was mentioned as a significant barrier.</p>	Not identified.	
<p>Information transfer from initial house assessment to the staff performing the work is difficult³¹</p> <p>Usually the initial house assessment takes place many days before any improvement is implemented and often the two are performed by different individuals. The hand-off process between assessment and execution is not clearly understood. When the work is performed by an individual who did not conduct the initial assessment, ensuring the work scope is properly communicated is a challenge.</p>	<p>Create a hand-off process from the assessment to the implementation of energy upgrades</p>	<p>Use multiple tools to communicate and document the work scope in such a way that the workers implementing the solutions can follow them independently. Technology can be used to manage the process.</p>
	<p>Make a “Good to Great” effort</p>	<p>Collins (2011) examined the performance of 1,435 good companies over 40 years and identified 11 that became great, and compared these with good ones to identify the differences. Even with fewer home energy upgrade contractors and programs, a similar effort might be done on the business side of such contractors to identify common best practices.</p>
<p>Contractors do not see utilities as potential customers.</p> <p>Utilities might be interested in purchasing energy efficiency and demand response assets, but there is no developed market where such assets can be traded regularly.</p>	<p>Develop metrics of energy savings and demand response generated by home energy upgrades that can be sold to utilities</p>	<p>Metrics for energy savings and demand response can be created to address the needs of utilities. Establishment of a cap and trade market would provide the platform for home energy upgrades to be monetized and used in a white tag market.</p>

³¹ This is often technical information, related to specific measures, so some consider it a technical barrier.

Table 11. Educational Gaps, Barriers, and Opportunities

Gap or Barrier	Opportunity	Description
<p>Whole-house building science is complex.</p> <p>This complexity affects contractors primarily, but is also a problem for homeowners struggling to understand the value of what the contractors is selling. Homeowners do not know how to proceed with all the information they may receive after an assessment is conducted. Contractors may lack full understanding of whole-house building science to identify issues with a house and act to address them. An example would be combustion safety testing, because there is so much variation in what people perceive as a worst-case depression among homes.</p>	<p>Develop simple and clear educational campaigns targeting homeowners</p>	<p>Some argue that providing access to factual building science information, demand for home energy upgrades would increase. There are challenges in striking the proper balance in this opportunity; homeowners are not interested in technical details, but in solutions to real problems, such as comfort deficiencies. The education needed is on the problems that can be solved with a home energy upgrade, because most homeowners do not realize that anything can be done other than reducing energy use. Individuals are notoriously high discounters of future benefits in justifying an immediate expense or commitments to make fixed payments. More public awareness could create a demand for financing options, which will spur entrepreneurship. Employ DOE, EPA, and Homeland Security resources to educate public on advantages of home energy upgrades</p>
	<p>Create public education videos, audio talks, and permanent or itinerant science museum exhibits showcasing the different aspects of building science</p>	<p>Although related to the previous opportunity, this is a very specific one that can leverage resources from the Building America program. Some team members have videos and demos that could be a starting point to create material and museum exhibits. Social media and YouTube should also be considered as potential distribution venues.</p>
	<p>Contractors should prioritize offering services to early technology adopters, who tend to be more educated and have more resources</p>	<p>Early technology adopters tend to be more open to performing home energy upgrades. Creating mechanisms to identify them, particularly if associated with large energy use, could be prioritized.</p>
	<p>Make the customer engagement process simple and trustworthy</p>	<p>Presenting home energy upgrades as thermal comfort solutions in as simple one stop shop manner by a trustworthy source, with options for how to finance and credentials behind the individuals performing the work, helps enable customers to take next step actions. Third party community based organizations that have the</p>

Gap or Barrier	Opportunity	Description
		trust of the homeowners are a good collaborative source to disseminate and promote market based solutions.
<p>Specialization in the contractor community results in unfamiliarity with the full potential of energy efficiency technologies.</p> <p>Because whole-house building science is complex, traditional contractors are specialized in their trade. When facing a particular problem, they may rely on their specialization to try to solve it, when in many cases the best solution may be related to some other trade. Most do not understand the whole-house approach.</p>	<p>Expand trade contractor tasks instead of only trying to transform them into a whole-house energy upgrade contractor</p>	<p>Investigate the tasks conducted by the different trades (insulation, HVAC, window, siding, etc.) and identify home energy upgrade tasks that can improve energy efficiency and can be performed by that specific trade. Some professionals expressed concerns about this approach because it can break from a whole-house view of energy use, but others expressed the advantage of transforming the industry slowly and having results right away. So, when remodeling a kitchen, for example, identify home energy upgrade improvements that can be added to the job. Encourage contractor networking and referral among the contractor community for specialty services not provided by the contractor who owns the work scope.</p>
	<p>Develop continuous learning opportunities for contractors</p>	<p>In addition to traditional CEUs in conferences (e.g., ACI and EEBA), continuous learning opportunities could involve website-base mentoring and discussion forums on home energy upgrades. For example, upload accredited training and refresher videos on YouTube.</p>
	<p>Create apprenticeships for contractors</p>	<p>Instead of basing the training of contractors solely on one-week training classes, add an apprenticeship option where contractors can work under the supervision of experienced individuals, much as the plumbing and electrical trades do.</p>
<p>Professionals believe they know their field and do not need new information.</p> <p>Professionals involved in upgrades believe they know everything they need from their specific training and see the solutions only from this perspective. This is particularly true for seasoned installers who have not been trained in building science. There is a lack of understanding of the whole-house approach.</p>	<p>Develop continuous learning opportunities to contractors</p>	<p>In addition to traditional CEUs in conferences (e.g., ACI and EEBA), continuous learning opportunities could involve website-base mentoring and discussion forums on home energy upgrades. For example, upload accredited training and refresher videos on YouTube.</p>
	<p>Create apprenticeships for contractors</p>	<p>Instead of basing the training of contractors solely on one-week training classes, add an apprenticeship option where contractors can work under the supervision of experienced individuals, much as the plumbing and electrical trades do.</p>

Gap or Barrier	Opportunity	Description
	Develop learning opportunities for contractors through the associations they belong to	Work with the local plumbers union, home builders association, carpenters union, window installers association, or local HVAC professional organizations like ACCA, or other trade organizations to bring whole house building science education and awareness to the contractor community. Present the opportunity of cross referral or incorporation of new skills to meet the needs of this market and the value for them to promote their specialty to the weatherization trade contractors.
<p>After a minimum amount of training, individuals start a whole-house energy upgrade contracting business with absolutely no experience.</p> <p>A short training provides an overview of the building science related to the home energy upgrades, but it is a complex topic and houses are different, so the training cannot provide all the possible issues that a contractor will face when assessing problems in a house. Because homes are so different, experience is needed to diagnose atypical issues in homes. A basic training in building science (one week at the most) is not sufficient to provide the tools to diagnose and address problems. There is currently no continuous feedback mechanism for new contractors to have their questions answered.</p> <p>In many cases a contractor may have some trained and certified employees, but some field crews performing the work may not be trained.</p>	Develop continuous learning opportunities to contractors	In addition to traditional CEUs in conferences (e.g., ACI and EEBA), continuous learning opportunities could involve website-base mentoring and discussion forums on home energy upgrades. For example, upload accredited training and refresher videos on YouTube.
	Create apprenticeships for contractors	Instead of basing the training of contractors solely on one-week training classes, add an apprenticeship option where contractors can work under the supervision of experienced individuals, much as the plumbing and electrical trades do.
	Create mentoring opportunities for contractors	Establish market mechanisms or find and establish a method for local professionals that do whole house work to mentor and assist those getting started. Fund appropriate organizations to support new contractors and or conduct on-site installation mentoring and quality control.

Gap or Barrier	Opportunity	Description
<p>Trained and qualified contractors often compete against those who perform poor work.</p> <p>Most homeowners are not qualified to evaluate the quality of contractors. Multiple certifications create confusion and low bidders that perform substandard work may be successful.</p>	<p>Identify and inform homeowners and other stakeholders about good certifications for contractors</p>	<p>The value of certifications is not clear to the homeowner making decisions about whom to hire. There is an opportunity to communicate with homeowners and other stakeholders the differences between the available certifications.</p>
	<p>Establish homeowner guides or best practices in selecting a contractor</p>	<p>Include information on what credentials to look for, what happens when cheapest bid is the only goal, encourage homeowners to seek references and ensure the contractor has adequate insurance and appropriate licensing for the work being performed.</p>

Table 12. Program Gaps, Barriers, and Opportunities

Gap or Barrier	Opportunity	Description
<p>Contractors face significant challenges to comply with programs.</p> <p>For the most part, programs create incentives for home energy upgrades, but some have elements that impose difficulties to contractors. Intense documentation is usually cited as a common problem, but others include incentives on initial house assessment for contractors who offer them for free as part of their approach.</p>	<p>Identify areas where programs (government or utility) are in place and create materials that have synergy with the program objectives</p>	<p>Individual contractors already explore this option, but there is an opportunity to create literature that identifies different objectives of typical programs that can be addressed by home energy upgrades. This could provide much better and more detailed information transfer (and analysis, data, recommendations, and standards) for programs around the country.</p>
<p>Contractors have to work with multiple programs with diverse requirements in a given territory.</p> <p>Programs that take place in adjacent territories covered by a single contractor may have very different requirements. Contractors have to create mechanisms to comply with all the programs in the territory they serve, including using multiple software tools and producing specific documentation for each program.</p>	<p>Work with program developers in a territory to coordinate common requirements</p>	<p>When new programs are considered in a territory, work with the program managers of the territory to create common requirements in documentation, software, etc., as much as possible. Martel (2011) highlighted that utility collaboration enables customers and contractors to receive higher incentive amounts. It can also facilitate deeper home energy upgrade projects that involve both gas and electric building systems. She also noted that in the case where utilities implement a joint program (as opposed to separate but coordinated efforts), utilities can benefit from sharing administrative and marketing costs.</p>
	<p>Programs targeted at whole-house improvements need to design requirements in a manner that encourage contractor interaction</p>	<p>No program will be successful if contractors and or customers find its requirements too hard, confusing or timely to comply with. In order for a program to be of value it must consider the contractors who would be driving business under it and their needs.</p>

Gap or Barrier	Opportunity	Description
	<p>Programs operating in a market of multiple funding sources for home improvement or multiple utilities need to be mindful of the fit with the offers already available in the market</p>	<p>Programs best serve synergy when the installation specifications and data requirements are consistent. To maximize homeowner participation all efforts should aim to have participation rules consistent with those already in existence, and minimize a contractor's duplication of services. Contractors who find a program's requirements too cumbersome will not utilize the programs services in the course of improving a customers home.</p>

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