

Home Improvement Catalyst Plan

Residential Buildings Integration Program

October 2017

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List of Abbreviations and Acronyms

AEO	Annual Energy Outlook
ASHP	Air-source heat pump
BBR	Better Buildings Residential
BTO	Building Technologies Office
CBI	Commercial Building Integration
CCHP	Cold climate air-source heat pump
DOE	U.S. Department of Energy
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EE	Energy efficiency
EUI	Energy use intensity
GHG	Greenhouse gasses
HI Cat	Home Improvement Catalyst
HPwES	Home Performance with ENERGY STAR
HP	Heat pump
HUD	Department of Housing and Urban Development
HVAC	Heating, ventilation, and air conditioning
NREL	National Renewable Energy Laboratory
NEEA	Northwest Energy Efficiency Alliance
NEEP	Northeast Energy Efficiency Partnerships
P-Tool	BTO Prioritization Tool
PNNL	Pacific Northwest National Laboratory
PV	Photovoltaic Systems
RBI	Residential Building Integration
RECS	Residential Energy Consumption Survey
REEO	Regional energy efficiency organizations
SEER	Seasonal energy efficiency ratio
TBtu	Trillion British thermal units

Executive Summary

The Home Improvement Catalyst (HI Cat) is an initiative within the Residential Buildings Integration (RBI) program of the U.S. Department of Energy’s (DOE) Building Technologies Office (BTO), which reduces energy use intensity (EUI) of existing, single-family U.S. homes on a broad scale. With ongoing input and feedback from industry stakeholders, RBI addresses market barriers to accelerate the speed and scale of adoption of advanced technologies and practices that offer households opportunities to achieve better performing homes at a lower cost. RBI’s technical and market-focused resources also enable industry and consumer investment in advanced technologies and support job creation and economic development opportunities within the home improvement market, including remodeling and energy efficiency service businesses and trades.

RBI works with a diverse range of stakeholders involved in the home improvement market and energy efficiency programs to develop informational resources and innovative strategies that inform and support trade practices and homeowner decisions at the time of typical home improvement transactions. Common homeowner transactions include equipment repair and replacements, remodeling, exterior or interior replacements, and installation of rooftop photovoltaic (PV) systems. RBI targets these resources toward specific technologies and practices that can be implemented at key transactional opportunities to lead to national energy savings through moderate energy use intensity (EUI) reductions across a large number of homes. Figure 1 shows an overview of the HI Cat effort.



Figure 1. RBI HI Cat Overview

Typical home improvement transactions provide a critical opportunity to encourage homeowners to improve energy efficiency in their homes through advanced technologies and practices. Homeowner spending on home improvement and maintenance is on the rise, with an increasing share of households’ income being directed toward investments in home improvement projects. The Joint Center for Housing Studies of Harvard University estimates that U.S. homeowners in aggregate spent \$192 billion on all home improvements, almost half of which include opportunity areas to affect home energy performance, and homeowners spent \$52 billion on home maintenance activities alone in 2013¹. More than \$150 billion of all home improvement spending involved building professionals for installation. Additionally, the U.S. Census American Housing Survey reports that about 18 million homeowners undertake some type of home improvement activity every year, which is about 16 percent of all single- and multi-family homes today². According to the survey, only 20 percent of homeowners³ who completed home upgrades in 2013 and 2014 self-reported that at least one of these projects was performed specifically for energy efficiency purposes. Therefore, significant opportunity exists to increase awareness and education around the value of energy efficiency in typical home upgrades.

¹ Joint Center for Housing Studies of Harvard University, “Emerging Trends in the Remodeling Market,” *Improving America’s Housing 2015* (Harvard Graduate School of Design and Harvard Kennedy School, 2015). Figure 1. www.jchs.harvard.edu/sites/jchs.harvard.edu/files/jchs_improving_americas_housing_2015_final.pdf.

² Home Improvement Characteristics, Owner-Occupied Units. Table C-15-OO. American Housing Survey. U.S. Census. 2013. <https://www.census.gov/programs-surveys/ahs/data.html>.

³ Ibid.

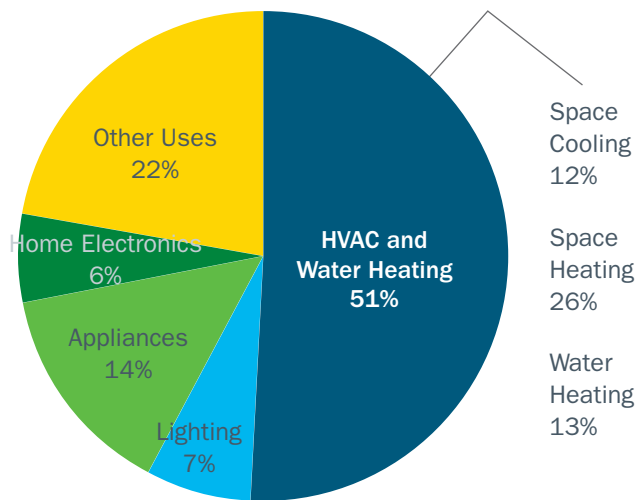


Figure 2. Heating, cooling and water heating represent more than half of residential building energy consumption.

Source: EIA AEO, 2016

Energy use in a home can be reduced through a variety of existing energy efficient technologies and installation techniques, while enhancing the comfort and services of occupants. The greatest opportunities are in heating, cooling, and water heating, as these end uses contribute more than 50 percent of total energy use of U.S. homes, as shown in Figure 2. Improvements in these areas can include building envelope upgrades involving windows and insulation, replacement of heating and cooling systems, water heaters, as well as the addition of sensor or control-based integrated systems. These end uses represent a significant portion of economic activities in the residential market. For example, of all U.S. homeowner expenditures on home improvements in 2013, about 35 percent or over \$65 million, was spent on replacements specifically in HVAC and water heating systems, windows, roofing, and insulation.⁴ Further, about 6 million central air conditioning and air-source heat pump units⁵ and 8 million water heaters are sold every year⁶ across the country, offering a significant opportunity to influence homeowner decisions at the time of home remodeling or equipment repair or replacement.

Through the HI Cat, RBI builds on opportunities that support the residential energy efficiency market, leverages existing initiatives and resources, and fosters greater coordination among public and private stakeholders. RBI engages the following stakeholders in the home improvement supply and delivery chain whom have similar interests and objectives to reach a broad portion of the national market:

- utilities and energy efficiency program providers;
- regional energy efficiency organizations (REEOs);
- trade and professional associations;
- manufacturers, distributors, retailers;
- trade contractors.

⁴ Ibid. Table A-1.

⁵ Central Air Conditioners and Air-Source Heat Pumps Historical Shipment Data. AHRI. <http://www.ahrinet.org/Resources/Statistics/Historical-Data/Central-Air-Conditioners-and-Air-Source-Heat-Pumps.aspx>.

⁶ Residential Automatic Storage Water Heaters Historical data. AHRI. <http://www.ahrinet.org/Resources/Statistics/Historical-Data/Residential-Storage-Water-Heaters-Historical-Data.aspx>.

RBI focuses on the needs of these stakeholders to provide targeted resources and deployment pathways that they can then leverage to overcome market barriers and cost-effectively increase investment in advanced technologies and practices.

As part of this HI Cat plan, RBI developed a multi-year planning strategic framework to identify and prioritize home improvement measures and ripe market opportunities, where DOE can have the greatest impact to accelerate investment in energy efficient technologies and improve installation practices at the time of key home improvement transactions. This plan outlines the systematic approach, shown in Figure 3, that RBI uses to plan and execute cohesive HI Cat activities to reach RBI goals. See Section 2 for a summary of the analysis and initial stakeholder feedback.

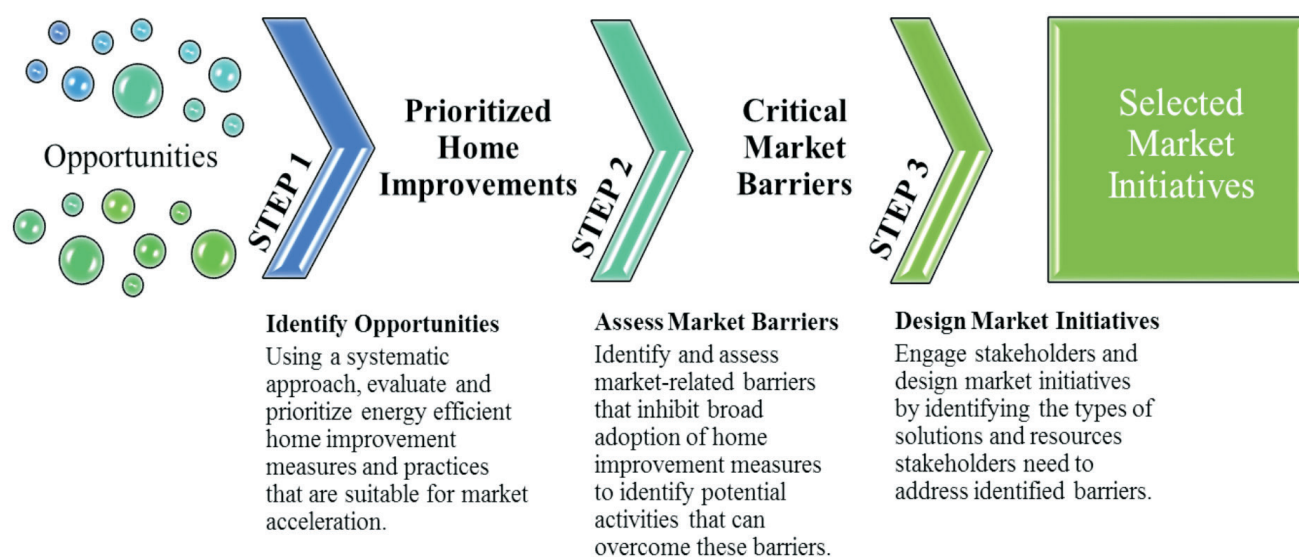


Figure 3. Overview of the HI Cat Planning Process

From this analysis, RBI identified specific focus areas to target near term, market barriers and the types of market activities that RBI will pursue with specific stakeholders, which are outlined in Table 1. RBI ultimately implements initiatives that support the market, resulting in the demonstration, documentation and dissemination of readily usable solutions and resources for stakeholders.

Table 1. Initial Results of the HI Cat Planning Process: Near-Term Focus Areas

Prioritized Home Improvements	Market Barriers	Selected Activity Types	Target Stakeholders	Technical Potential Savings (quads/year)
Heating, Ventilation and Air Conditioning				
Inverter-driven heating and cooling equipment	Limited product availability; lack of consistent field performance information; lack of awareness; high product cost, few technical resources; unclear payback or savings information	Industry outreach Technical installation resources	HVAC contractors; REEOs; Energy efficiency programs	0.4 – 1.1

Table 1. Continued

Prioritized Home Improvements	Market Barriers	Selected Activity Types	Target Stakeholders	Technical Potential Savings (quads/year)
Quality installation of forced air heating and cooling equipment (including duct sealing)	Limited product or service availability; lack of verified field performance information; lack of awareness; few technical resources; unclear payback or savings information	Industry outreach Technical installation resources Energy and cost savings Business model and sales resources	Manufacturers and distributors; HVAC contractors; Energy efficiency programs	0.5 – 0.9
Water Heating				
Heat pump water heaters	Lack of awareness; high product cost inhibits sales, unclear payback or savings information	Industry outreach	Plumbing and HVAC contractors; Energy efficiency programs	0.6 – 1.0

This document provides an overview of the HI Cat multi-year planning approach to target its activities. RBI has received stakeholder input on the approach and near-term initiatives and will continue to engage stakeholders as part of HI Cat annual planning and implementation. This feedback will help RBI continue to plan the near- and mid-term HI Cat activity portfolio. Ultimately, RBI expects that achieving HI Cat objectives can not only help BTO reach its goals but also contribute to a multitude of national benefits including:

- significant cost and energy savings across the country;
- support for infrastructure modernization and the growth of domestic jobs, especially in small businesses (e.g., HVAC, plumbing, siding and roofing contractors), residential remodeling, equipment servicing and repair, and residential energy efficiency services (e.g., energy assessments);
- increases in domestic manufacturing of products used in residential energy efficiency projects.

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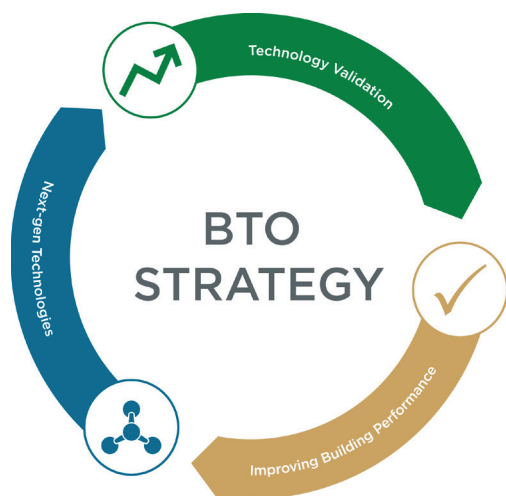
1. Introduction

1.1. Background

The Department of Energy (DOE) Building Technologies Office (BTO) envisions a strong and prosperous America in which all homes and buildings operate at peak energy performance, are affordable, and provide optimal health and comfort. The Office's Programs lead a network of national laboratory, university, small business, and industry experts toward this vision. BTO functions through five interdependent programs: Emerging Technologies, Residential Building Integration (RBI), Commercial Building Integration, Building Energy Codes and Appliance and Equipment Standards. Together, the programs develop innovative, cost-effective energy saving solutions for U.S. buildings, which are the single largest energy-consuming sector in the nation. BTO's overarching long-term goal is to reduce energy use per square foot of homes and commercial buildings by 50 percent or more through the application of cost-effective efficiency technologies that yield substantial net economic benefits. Reducing building energy use per square foot, or energy use intensity (EUI), helps conserve valuable natural resources and strengthens the U.S. economy by creating jobs, improving the productivity of businesses, and helping families save money. In addition to saving energy, certain BTO technologies and activities also benefit the United States by improving indoor air quality and enabling the integration of buildings with demand response systems implemented by operators of the nation's power grid. To meet this long-term goal, and carry out its mission, BTO implements a multi-pronged strategy.

BTO's Mission

To support the research and development, validation, and integration of affordable, energy-saving technologies, techniques, tools, and services, to enable industry and others to develop and deploy technologies that can improve the efficiency and reduce the energy costs of the nation's new and existing commercial and residential buildings.



- **Research and development** for innovative, pre-commercial, energy-efficiency building technologies, as well as their effective integration into efficient, resilient, grid-connected, and secure building systems.
- **Validation and verification** of energy-saving solutions that help building owners and homeowners reduce energy waste by improving understanding of efficient building operational practices and technologies, as well as their costs and benefits.
- **Collaboration with industry and other stakeholders** to test and implement statutorily-mandated appliance and equipment efficiency standards, and evaluation of changes to model building energy codes to support state and local building code processes.

Figure 4. BTO Strategy

1.2. Residential Buildings Integration Approach

Activities pursued in the RBI program accelerate energy performance in existing and new homes by integrating energy-efficient technologies and practices to optimize energy performance in homes; providing data, design, and decision support tools; and partnering with building professionals, energy service providers, and other stakeholders on a national scale. These activities focus on issues that most affect the performance and energy efficient operation of homes today including issues related to water heating, space heating and cooling loads, durability, comfort, indoor air quality, and moisture control, and ultimately prepares homes for renewable energy options. RBI focuses on both the new and existing homes market, and activities in each sector are largely interrelated and supportive of each other.

To accelerate improved building performance, RBI's strategies including the Home Improvement Catalyst (HI Cat) focus on identifying building integration technology areas and technical solutions that offer the potential for large energy savings, and then conducting research to resolve major technology and system integration challenges. This research creates the basis for private sector entities to voluntarily test new and improved energy-saving technologies, providing a theoretical foundation for building system design and generating field-based data that can inform the prioritization of future R&D. In addition to energy efficiency, the RBI Program also addresses other technology integration and installation issues that can affect total home performance, focusing especially on issues related to water heating and heating and cooling loads, durability, comfort, and indoor air quality and moisture control. RBI engages with stakeholders to address targeted market barriers and equip them with resources to help further embed energy efficient technologies and practices in common practice, which should ultimately result in enough market penetration to become incorporated into industry standards and building energy codes.

Relationship to RBI Existing Home Activities

RBI's research, technology demonstration and program and industry partnership efforts work closely together to accelerate energy savings in existing homes through leadership, innovation, outreach activities, and dissemination of best practices with residential energy efficiency programs and other stakeholders. HI Cat initiatives will coordinate with the following activities to support RBI goals:

Primary Existing Home RBI Activities

Building America	Demonstrates and validates new technologies and practices in homes
Building America Solution Center	Provides technical solutions to contractors and builders on a web-based platform
Residential Program Solution Center	Provides tools, resources and guidance for energy efficiency program administrators
Home Energy Score	Low-cost, reliable method for homeowners and home buyers to understand their homes' energy efficiency
Home Performance with ENERGY STAR	Connects homeowners to qualified contractors trained to evaluate the entire home and offer solutions to improve efficiency and comfort via over 50 energy efficiency program sponsors across the nation
Home Improvement Catalyst	Encourages incremental energy efficiency improvements in typical home improvement transactions
Better Buildings Residential Network	Connects a national network of over 200 energy efficiency programs and partners to share best practices

1.3. HI Cat Supports RBI Program Goals

To support achievement of BTO’s 2030 goal in the existing homes market, RBI focuses on an interim, market-focused goal to reduce the EUI of existing single-family homes by 35 percent in heating, cooling, and water heating by 2025. RBI focuses specifically on these end uses because together they account for more than half of all energy use in the residential sector. To support BTO and RBI market goals, the program implements several activities aligned with its strategies, which focus on reducing EUI in existing homes, as outlined in Figure 5. RBI is responsible for working toward these program performance targets to achieve them by 2020.

The HI Cat is one of several activities initiated by RBI that is targeted to help achieve these performance targets and market outcomes goals in existing homes. The HI Cat specifically focuses on establishing solutions to address market barriers and increase investment in individual home improvement measures across climate zones in the United States. The HI Cat effort is a primary contributor to the following RBI performance goal:

By 2020, develop and deploy effective technical and market-focused resources that address barriers to the adoption of a portfolio of individual home improvements that together have the technical potential to reduce annual energy use by at least 2.5 quads in single-family homes across a variety of climate zones.

HI Cat activities aim to accomplish this by working with stakeholders, including specific construction trades, to demonstrate and establish solutions and thereby develop and disseminate effective resources for a broader audience industry stakeholders. RBI’s expected outcome in meeting its target is the major stakeholders, across the supply and delivery chain, are equipped with objective, consistent resources and deployment pathways to facilitate adoption of energy efficient home improvements at the time of key transaction points with homeowners. As a result, homeowners are also more likely to invest in energy efficient solutions when engaging with building professionals on home improvements.

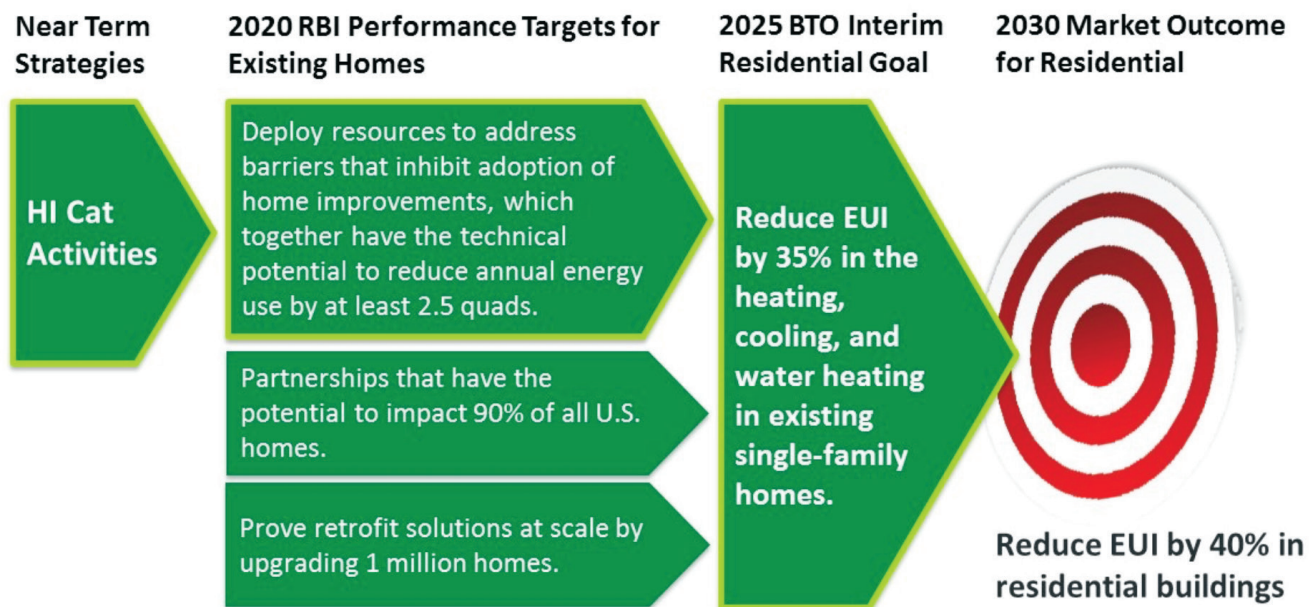


Figure 5. HI Cat Activities Contribute to RBI and BTO Market Outcome Goals

1.4. Home Improvement Catalyst Overview

1.4.1. Purpose

RBI initiated the HI Cat with a mission to accelerate adoption of underutilized energy efficient technology measures and solutions that reduce heating, cooling and water heating energy use in owner-occupied, single-family households. The HI Cat focuses on supporting stakeholders, especially building construction professional trades, by providing informational resources and innovative strategies to influence homeowner decisions at the time of typical home improvement transactions in existing homes. The intent is to create valuable resources for stakeholder use that can accelerate adoption of advanced technologies and solutions in the existing homes market on a broad scale and in a variety of climate zones. Through the HI Cat activities, RBI plans to work with diverse stakeholders including utilities and energy efficiency programs, regional energy efficiency organizations, trade and professional associations, manufacturers, distributors, retailers, and contractors to address prevalent market barriers that hinder consumer investment in energy efficient products and services. This plan outlines the process and implementation approach RBI uses to strategically identify and prioritize the types of single-family home improvements and market opportunities, where DOE can have the greatest impact in achieving RBI and BTO goals and best support private sector businesses that supply, service, and install residential energy efficiency products and improvements.

1.4.2. Technology and Market Scope

Activities in the HI Cat address home improvement measures within categories of home improvement trades (*e.g.*, HVAC, building envelope, water heating, and system controls) which affect heating, cooling, and water heating energy use in existing homes. These measures are widely commercially available and fall into one of four categories:

- high-performance HVAC equipment
- building envelope improvements
- high-performance water heating equipment
- home energy management systems

Activities primarily focus on solutions that promote technology performance levels at or above ENERGY STAR specification levels, but not at the maximum technology level available on the market. The HI Cat builds on the ENERGY STAR program efforts, particularly in areas with lower rates of market penetration for ENERGY STAR products, such as heating and cooling and water heating. HI Cat activities do not typically focus on the most efficient products available because these are often cost prohibitive for an average consumer home improvement project. Although there are large opportunities for energy savings in other end uses outside of the HI Cat scope, such as appliances and lighting, these areas are already comprehensively addressed by other DOE or EPA programs.

HI Cat Objectives

- Accelerate adoption of measures to reduce space heating, cooling, and water heating energy use intensity in single-family homes.
- Improve homeowner decision-making as it relates to energy efficiency during typical home improvement transactions.
- Identify and reduce barriers to market adoption of the most promising energy efficient measures.
- Increase available information for stakeholders, including manufacturers, distributors, construction trades, and other stakeholders.
- Disseminate solutions on a national scale in the residential sector (moderate savings per home but on a wider scale).

Furthermore, HI Cat activities center on opportunities to affect homeowner decisions at the time of *common* home improvement transactions (*e.g.*, equipment repair and replacement, remodeling, envelope replacements, installation of rooftop photovoltaic (PV) systems) and in broad scale consumer adoption. Therefore, some measures are excluded if they require major construction or disruptions for installation in an existing home. For example, ground-source heat pumps are excluded because the ground loop heat exchanger cannot be easily installed in most homes as it requires a significant amount of outdoor ground space for drilling bore holes or surface trenches, which can vary based on climate. This can be difficult to accommodate for most homes, especially those in urban areas.

Similar to all RBI activities, the HI Cat first and foremost promotes building system efficiency in addition to equipment efficiency. HI Cat activities and resulting resources address individual energy efficient measure investments at key transaction points that consider whole-house system efficiency opportunities through more informed stakeholders and homeowners. This plan provides a strategic framework for selecting underutilized energy efficiency measures, addressing the most critical barriers, and targeting opportunities to work with stakeholders to improve decision making at the time of common home improvement transactions.

1.4.3. Coordination

To enable broader market reach and impact, HI Cat activities will coordinate with a variety of public and private entities that focus on a similar mission and have a broad reach. Such organizations include other BTO programs and existing RBI activities, other DOE offices, regional energy efficiency organizations, trade organizations, utilities, energy efficiency program providers, wholesale and retail home improvement suppliers, and major equipment and product manufacturers. DOE will leverage HI Cat investments by working alongside stakeholders to connect them with objective, targeted solutions that meet specific needs. This includes building on resources already available in the market and leveraging stakeholders to widely disseminate solutions.

Within BTO, HI Cat activities serve as a bridge among various BTO's programs, including Emerging Technologies research and development (R&D), RBI's Building America demonstration efforts, Appliance and Equipment Standards, and Building Energy Codes Programs. HI Cat activities help pave the way for proven commercialized technology measures that are offered by multiple manufacturers and distributors to become more widely adopted in the market. As these technologies and practices become more common, their inclusion in energy conservation standards or model building energy codes becomes more accepted.

Within RBI, HI Cat activities target opportunities in the market that complement other existing home-focused efforts, such as Home Performance with ENERGY STAR (HPwES) and the Home Energy Score. The resources produced as part of the HI Cat focus on increasing investment in individual technology measures and installation practices at certain transaction points, which contribute to national energy savings through moderate EUI reductions across a large number of homes. These resources can be shared across all RBI existing home activities to increase information availability and dissemination. For example, HI Cat resources can provide additional guidance to HPwES program sponsors, which will help consumers and building contractors to install individual technologies as part of multi-measure energy efficiency projects.

RBI also plans to coordinate with EERE's Weatherization Assistance Program as well as the EPA and other organizations to share resources and build on the market visibility for each of the programs. For example, HI Cat activities focuses on tools and resources to improve contractor installation of HVAC equipment aligns with the ENERGY STAR Verified HVAC Installation effort, and RBI and EPA are working together to address the most critical barriers in the market. Regional energy efficiency organizations (REEOs) and energy efficiency programs also have many objectives and initiatives aligned with HI Cat focus areas, and can help develop and disseminate regionally focused resources and engage additional regional allies.

In the private sector, RBI will engage leading stakeholders in the market across the value chain that supply or deliver energy efficient products or services to demonstrate potential solutions areas and document needed resources. RBI may also leverage existing information, such as best practices or case studies, to better package as readily usable solutions.

1.5. Residential Buildings Market Landscape

The U.S. residential housing market is comprised of more than 115 million housing units, which account for more than 20 percent of total U.S. energy consumption.⁷ Among these, more than 80 million are single-family homes, which is approximately 70 percent of all housing units built to date.⁸ An additional 1 million residential units are built on average every year.⁹ Each of these households spends approximately \$1,500 – \$2,700 annually on energy bills.¹⁰ This represents a significant energy expenditure in a home: an annual household energy bill of \$2,000 amounts to about 3 percent of the median annual income of owner-occupied households. Energy use in a home can be reduced through a variety of existing energy efficient technologies and installation techniques, while enhancing the comfort and services of occupants. With the advent of ‘smart home’ technologies, homeowners are also increasingly interested in the ability to integrate, manage and control systems and appliances within their homes, enabling greater customer choice and options for improving comfort and having greater control over the energy use of their homes. The U.S. market has seen substantial year-over-year growth, or a rate of approximately 30 percent compound annual growth, in the number of smart, connected homes, and this trend is expected to continue in future years.¹¹

RBI's Engagement with NEEP Accelerates Adoption of Cold Climate Air-Source Heat Pumps (CCHP)

- RBI sponsored a collaborative industry partnership with the Northeast Energy Efficiency Partnerships (NEEP) to implement HI Cat activities focused on developing CCHP technical installation practice resources to help contractors confidently select and install these technologies across the northeast. NEEP has already implemented several initiatives focused on driving adoption of CCHP technologies in the market. Therefore, RBI is leveraging those existing efforts and has already engaged stakeholders to focus on technical resources and contractor field support needs. With RBI, NEEP is working on developing and disseminating best practice field guides and trainings to aid HVAC contractors and expand their technical knowledge. Additional near-term HI Cat ASHP-focused activities include: Accelerate adoption of measures to reduce space heating, cooling, and water heating energy use intensity in single-family homes.
- Business model, sales resources, and targeted messaging to engage consumers to displace oil heat, propane or electric resistance heating
- Development of contractor guidance and checklists for CCHP applications, selection, sizing, design, and installation
- Disseminate guidance to utility programs and contractor trades in the northeast and midwest regions.

⁷ EIA *Annual Energy Outlook*, 2016. Residential Sector Key Indicators and Consumption. www.eia.gov/outlooks/aeo/data/browser/#/?id=4-AEO2016®ion=0-0&cases=ref2016&start=2013&end=2040&f=A&sourcekey=0.

⁸ Ibid.

⁹ Ibid.

¹⁰ State fact sheets on households energy use. RECS 2009. U.S. EIA. Release date: August 13, 2013. Accessed December 20, 2016. www.eia.gov/consumption/residential/reports/2009/state_briefs/.

¹¹ There's No Place Like [A Connected] Home. McKinsey & Company. McKinsey methodology based on 2015-2016 survey. http://www.mckinsey.com/spContent/connected_homes/index.html.

Energy improvements in a wide variety of building components, systems, and appliances can benefit both new and existing homes. However, because existing homes are typically less energy efficient than newly constructed homes, they provide the biggest opportunity for energy use reductions. DOE estimates that if just one of every 10 U.S. homes cut its energy use by 25 percent, Americans could save a total of more than \$5 billion per year on their energy bills.¹²

EIA's recent *AEO* reference case projections forecast an overall decrease in residential energy use intensity. However, due to growth in the number of new housing units and a trend for larger homes, overall residential energy consumption is projected to decrease by only 4 percent.¹³ RBI is working to ensure and accelerate the decline in residential energy use intensity by further improving the efficiency of existing homes. RBI seeks to maximize its impact by focusing on end uses with the greatest potential for energy savings, such HVAC and water heating.

1.6. Market Barriers to Energy Efficiency in the Existing Homes

A significant number of barriers in the U.S. market inhibit investment in advanced energy efficient technologies, systems and practices in homes. Barriers can differ based on the stakeholder. For instance, homeowners are primarily concerned about cost and return on investment. Building professionals are focused on barriers related to running a profitable business including handling administrative burdens, finding qualified employees and generating homeowner interest in energy efficiency. Both stakeholders can have skewed perceptions about incremental costs and a lack of confidence in new or advanced technologies and installation practices. These barriers primarily stem from two key issues that uniquely characterize the existing homes market. First, many homeowners and building professionals often do not understand or recognize the value of energy efficiency, and they have several competing priorities. Second, the residential market is tremendously fragmented and includes a large number of diverse market players as well as often inconsistent programs.

Top 5 Barriers Identified by Building Professionals

A recent survey completed by qualified contractors found the top five market barriers to include:

- Homeowner awareness
- Need for incentives & financing for homeowners
- High cost of energy-efficient measures
- Return on investment concerns
- Red tape involved with energy efficiency programs

Source: Building Performance Institute survey completed by GoldStar contractors and certified professionals.

The value of energy efficiency in homes is not completely recognized or understood by many stakeholders and often not prioritized.

The lack of awareness and education of both consumers and the workforce hinders growth of the residential energy efficiency market. There is a general lack of information regarding proven energy and cost savings, particularly related to projects with long payback periods. For example, implementation of energy efficiency upgrades that require a large upfront investment can appear risky due to uncertainty of return on investment, making it very

¹² "About Residential." (2014). U.S. Department of Energy Office of Energy Efficiency and Renewable Energy. Accessed: July 18, 2014: energy.gov/eere/buildings/about-residential.

¹³ EIA AEO 2016. Residential Sector Key Indicators and Consumption. www.eia.gov/outlooks/aeo/data/browser/#/?id=4-AEO2016®ion=0-0&cases=ref2016&start=2013&end=2040&f=A&sourcekey=0.

difficult for building professionals to sell advanced technologies or solutions to consumers. Lack of information on expected savings or common industry standards for measuring and verifying energy and cost savings, estimating financial risk, and tracking performance of efficiency projects makes it difficult to convince consumers to prioritize or to pay the price differential for these types of investments. Although the higher cost of energy efficient systems can often be offset by various utility and government incentives, homeowners are frequently not aware of these incentives or are put off by the complexity and requirements of these programs. In addition, consumers often do not have the proper understanding of home energy performance or enough information on potential solutions to effectively address high utility bills. Lastly, homeowners do not easily make the connection between energy efficiency and comfort. In many cases, comfort problems within a home are due to poor energy performance.

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The fragmented nature and lack of consistency within the residential energy efficiency market also leads to several market barriers.

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For example, an owner and tenant split-incentive barrier exists, in which the interests of each party, with respect to energy use and building investment, are often not aligned. Another example is the diverse number of construction trades that install technologies in the home, many of whom do not interact with each other. Furthermore, the market lacks the framework to identify knowledgeable home energy performance contractors. Some building professionals lack knowledge of how to profitably deliver cost-effective, high-quality energy efficiency services or find it difficult to participate in energy efficiency programs due to overlapping or inconsistent requirements. Additionally, an aging energy efficiency workforce and limited initiatives to engage and train younger workers is likely to soon have an impact on the industry. Standardization of workforce training and credentialing focused on energy efficiency in buildings is only beginning, and the complex and siloed nature of the trades involved in the buildings workforce hinders a recognizable or unified marketplace of residential energy efficiency professionals. This leads to consumer uncertainty and makes it difficult for builders or contractors to differentiate their business based on building science expertise.

Primary Barriers in the Residential Market

A number of pervasive market barriers make the residential market unique and especially difficult to reach. Overall, the value of energy efficiency is not well recognized in the residential market largely due to a lack of available information and awareness:

- High cost of measures with uncertain ROI
- Lack of consistent and reliable information on expected energy and cost savings
- Lack of common standard for measuring and verifying energy and cost savings
- Homeowners are unaware of available program incentives and financing options
- Homeowners and building professionals often find incentive programs complex or a procedural burden
- Limited consumer understanding of home energy performance or potential solutions

The market is also characterized by a large number of fragmented market players facing additional barriers:

- Split incentive between owners and tenants
- Lack of standardization of workforce training and credentialing
- Lack of framework to identify knowledgeable and qualified home energy performance contractors

1.7. Opportunities to Influence Home Improvements

HI Cat activities are strategically designed to address the most prominent market barriers in the challenging existing homes market and pursue opportunities that can most affect the market, thereby reaching program goals. As a new RBI effort, the HI Cat framework and approach was specifically created to influence typical home improvement transactions in the growing home improvement market across the country. These opportunities are described in detail in this section.

Opportunity 1: Existing single-family homes consume a significant share of total U.S. energy consumption, and space heating, cooling, and water heating end-uses represent the largest opportunity for EUI reductions.

More than 115 million households annually consume approximately 20 quads of primary energy, or approximately 20 percent of total annual U.S. energy consumption.¹⁴ Single-family homes represent the largest proportion of all U.S. households—approximately 80 million units consume 80 percent of total residential energy consumption.¹⁵ Newly constructed homes, which are typically significantly more energy efficient than those constructed pre-2010, are projected to represent less than 30 percent of all U.S. homes by 2030.¹⁶ Hence, single-family homes constructed prior to 2010 will continue to be the largest energy consumer in the residential sector and will continue to represent the largest opportunity for energy efficiency gains via home improvements for the foreseeable future.

Space heating, cooling, and water heating end-uses are especially attractive opportunities to improve efficiency because of recent technological advances in HVAC and water heating equipment and building envelope solutions. New homes that use advanced technologies consume almost as much energy as older homes despite being 30 percent larger.¹⁷

Opportunity 2: Typical home improvement transactions are a critical opening to influence homeowners' decisions to invest in energy efficient upgrades and to increase sales for building professionals.

Common home improvement transactions (*e.g.*, equipment repair and replacement, remodeling, envelope replacements, installation of rooftop PV systems) represent a chance to increase homeowner awareness, influence investments in more energy efficient technologies or practices, and to reduce overall energy consumption in the home. According to American Housing Survey, approximately 50 percent of owner-occupied households report that they conducted home improvement activities in the last 2 years, and 20 percent report they performed at least one improvement for energy efficiency purposes.¹⁸

These common transactions are an opportunity for HI Cat activities to support residential market stakeholders, such as manufacturers, distributors, retailers, energy efficiency program providers, contractors, and others. These stakeholders have the ability to influence homeowner decisions to purchase energy efficient measures while promoting high-quality and integrated installation of equipment. The HI Cat focus on typical transactions also provides an opportunity for building professionals to sell (and homeowners to invest in) complementary energy savings solutions, such as air sealing, duct sealing, or home energy management devices. The typical homeownership lifecycle and

¹⁴ U.S. Energy Information Administration, *AEO* 2016. www.eia.gov/forecasts/aeo/index.cfm.

¹⁵ U.S. Energy Information Administration, "2009 Residential Energy Consumption Survey Data" (U.S. Department of Energy, 2009), www.eia.gov/consumption/residential/data/2009/.

¹⁶ U.S. Energy Information Administration, *AEO* 2014. <https://www.eia.gov/forecasts/aeo/index.cfm>.

¹⁷ U.S. Energy Information Administration, "Today In Energy: Newer U.S. Homes Are 30% Larger but Consume About as Much Energy as Older Homes," February 12, 2013, [www.eia.gov/todayinenergy/detail.cfm?id=9951&src=E2%80%B9%20Consumption%20%20%20%20%20Residential%20Energy%20Consumption%20Survey%20\(RECS\)-b3#](http://www.eia.gov/todayinenergy/detail.cfm?id=9951&src=E2%80%B9%20Consumption%20%20%20%20%20Residential%20Energy%20Consumption%20Survey%20(RECS)-b3#).

¹⁸ Only single- and multi-family homes were considered in this calculation. American Housing Survey (2013), sponsored by the Department of Housing and Urban Development (HUD) and conducted by U.S. Census Bureau. www.census.gov/programs-surveys/ahs.html.

opportunities for energy efficiency improvements are summarized in Figure 6.

Home improvement professionals and tradespeople play a significant role in improving home energy efficiency, have much to gain in selling energy efficiency improvements. Recent surveys conducted by the Joint Center for Housing Studies of Harvard University and the Farnsworth Group found that sustainable home improvement projects generate about 30 percent of revenue at full-service remodeling firms. Additionally, four out of five contractors report that sustainable projects account for at least 10 percent of their revenue.¹⁹

Homeowners invested some \$192 billion in home improvement projects in 2013. Of these consumer investments, almost half included opportunities to affect energy efficiency as shown in Figure 7. These expenditures typically include exterior replacements (roofing, siding, windows, and exterior doors), interior replacements (insulation, flooring, wall coverings, ceilings), and systems and equipment upgrades (e.g., HVAC, major equipment/appliances, plumbing, piping, electrical systems). Regular equipment repair, maintenance, or seasonal tune-ups provides another type of transactional opportunity for building professionals to improve equipment operation with duct or pipe sealing or to identify other needed energy efficient improvements.

Other categories of home improvements including remodeling of kitchens, baths, and other room additions and renovations could provide additional opportunities for building professionals to recommend improvement to a home’s energy performance. While a homeowner is already investing in improvements to these rooms, they might consider adding insulation, upgrading appliances, or installing low-flow faucets and showerheads. All of these transactions provide opportunities for building professionals to promote and readily sell energy efficient measures while working with the homeowner, and for HI Cat activities to provide effective resources to help them make the sale and properly apply solutions.

HOME OWNERSHIP LIFE CYCLE

The home ownership lifecycle offers multiple touch points involving purchasing decisions with opportunities to achieve greater comfort, incremental energy savings and value.

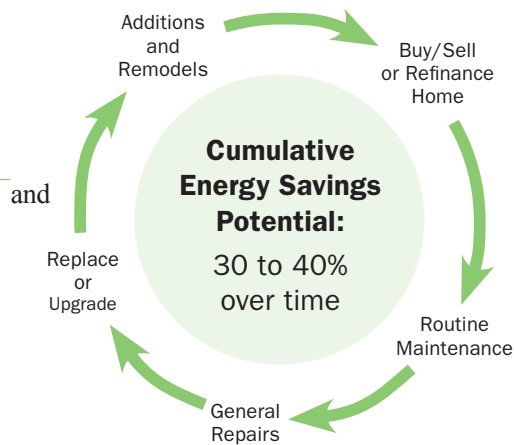


Figure 6. Home Improvement Transaction Opportunities for Improving Energy Efficiency in the Home Ownership Life Cycle

Homeowners are improving their homes.

Approximately 50% of owner-occupied households conducted home improvements in the last 2 years, and two in ten performed at least one upgrade for energy efficiency purposes. Of all types of remodeling in a home, the most frequent activities include interior additions and replacements (40%), exterior additions and replacements (38%), and system and equipment upgrades (35%).

Source: American Housing Survey, 2013.

Opportunity 3: Home improvement spending is on the rise, including areas that can benefit from increased energy efficiency.

¹⁹ Joint Center for Housing Studies of Harvard University, “Emerging Trends in the Remodeling Market,” Improving America’s Housing 2015 (Harvard Graduate School of Design and Harvard Kennedy School, 2015). Figure 1. www.jchs.harvard.edu/sites/jchs.harvard.edu/files/jchs_improving_americas_housing_2015_final.pdf.

Consumer spending on home improvement projects has been on the rise for more than a decade. In 2013, homeowners in the United States spent approximately \$192 billion on home improvement projects, which is 45 percent higher than estimates of their spending in 2001 of \$132 billion.²⁰ Further, \$150 billion of overall home improvement spending included installation by building professionals rather than do-it-yourself. In 2013, owner outlays on home improvements, on an inflation-adjusted basis, averaged about \$2,500 per year, or 8 percent increase over the annual average spent between 1995 and 2005.²¹

Historically, homeowners annually spend more than 1 percent of the share of the home value on home improvements, and this share has been consistent with the rise and fall in the housing prices. So as housing prices continue to increase, as has been happening since 2011,²² homeowners' expenditure on home improvements is also projected to continue to increase.

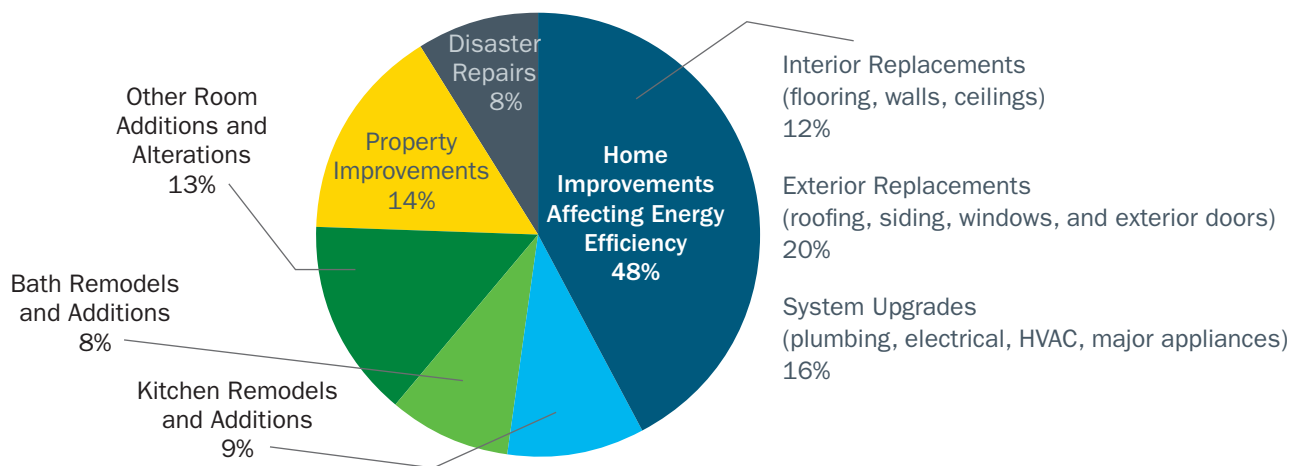


Figure 7. Share of Home Improvement Market with an Opportunity to Directly Affect Home Energy Performance

Opportunity 4: Owner-occupied, non-low income homes tend to make significantly larger investments on incremental home improvement projects.

In general, the higher the household's income, the more homeowners can afford and will consider to spend on improving their home. Of all owner-occupied single-family homes, 70 percent are considered non-low-income individuals.²³ According to the Joint Center for Housing Studies of Harvard University, households with a total income above \$40,000 spent on average \$10,500 on professional home improvement projects.²⁴ So, if these annual expenditure estimates continue to hold over a 15-year period, this spending amounts to \$160,000 on average per home. Additionally, owner-occupied households tend to spend more on their home and invest in projects or equipment with a longer payback period. The Joint Center for Housing Studies estimates that in 2013, average outlays for improvements to renter-occupied units was 70 percent lower than those to owner-occupied single-family homes.²⁵ Hence, HI Cat activities will first focus on reaching the owner-occupied market sectors that are not already addressed by low-income focused programs and have discretionary income to invest in incremental upgrades or improvements to their home, including highly energy efficient equipment and solutions that provide cost savings on energy bills over time.

²⁰ Ibid.

²¹ Ibid.

²² America's Housing Market in Five Interactive Charts. 2016. www.economist.com/blogs/graphicdetail/2016/08/daily-chart-20.

²³ EIA Residential Energy Consumption Survey, 2009. Table HC9.2 Household Demographics of U.S. Homes, by Owner/Renter Status, 2009. 60% of all single-family homes are occupied by owners with annual household income of \$40,000+; 70% of all homes that are occupied by owners, have household income greater than \$40,000+.

²⁴ Joint Center for Housing Studies of Harvard University. Emerging Trends in the Remodeling Market. Improving America's Housing 2015. Table A-4 p. 30. www.jchs.harvard.edu/sites/jchs.harvard.edu/files/jchs_improving_americas_housing_2015_final.pdf.

²⁵ Ibid. p. 9.

2. Home Improvement Catalyst Process and Approach

2.1. Process Framework

The HI Cat employs a strategic framework to target efforts for each fiscal year, which includes selection of focus areas, identification of critical market barriers, and the planning of market activities. Through this annual process, RBI is able to systematically evaluate and prioritize home improvement measures and transactions and to develop deployment strategies for those technologies and services that address barriers in the residential market. This three-step approach is outlined in Figure 8. RBI first assesses energy efficiency measures and solutions based on key technical, economic, and market criteria, as well as potential transactional opportunities (e.g., equipment replacement, remodeling, rooftop PV installations), to generate a list of the top ten home improvement measure opportunities. Next, RBI analyzes the most critical market barriers to increasing market acceptance and adoption to which DOE can provide support. Successively, RBI identifies the types of market activities and resources that the HI Cat can develop or deploy to effectively address barriers and best support industry stakeholders. The RBI Program initiated this process in fall 2016 and intends to revisit the framework on an annual basis to evaluate progress from the prior year, gain from stakeholder feedback, and plan new activities.

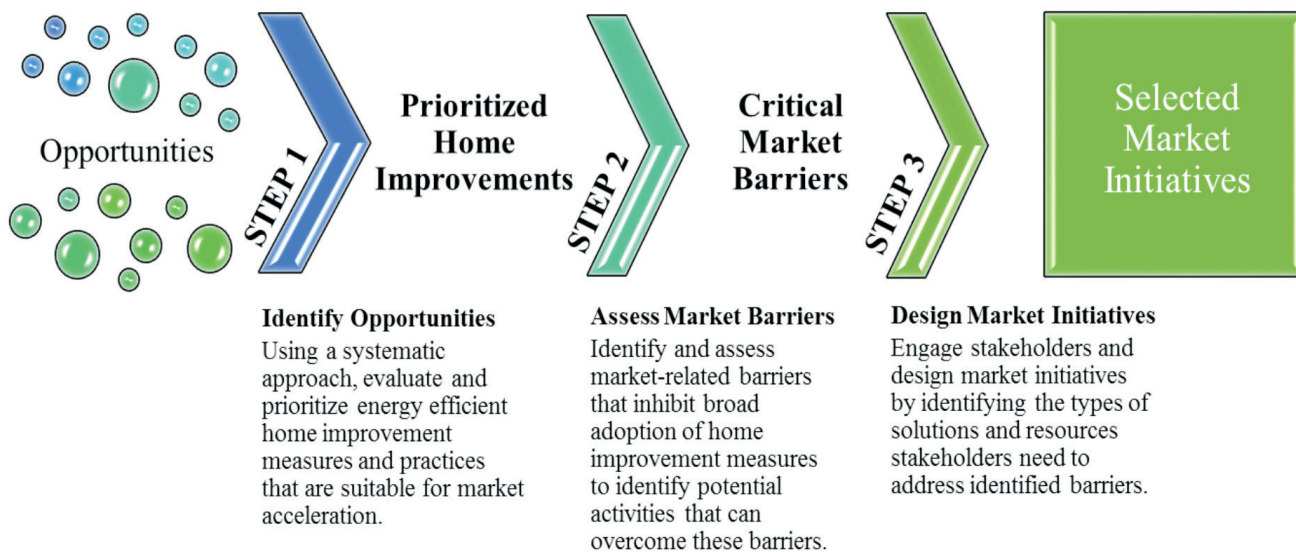


Figure 8. Overview of the HI Cat Planning Process



Step 1. Evaluate and prioritize energy efficiency home improvement opportunities that are suitable for market acceleration using a systematic evaluation process.

2.2. Research and Collection of Data

To initially analyze and prioritize home improvement measures available today, RBI created a comprehensive database of more than 50 promising energy efficiency measures and solutions, which RBI further assessed based on applicability to HI Cat's purpose and scope as well fit with the HI Cat objectives. RBI assembled this measure list from a variety of sources including the BTO Prioritization Tool (P-Tool),²⁶ Building America case studies, REEO initiatives, National Renewable Energy Laboratory (NREL) ResStock model,²⁷ and commercialized technologies from BTO Emerging Technologies activities.

²⁶ Building Technologies Office, Prioritization Tool. energy.gov/eere/buildings/downloads/prioritization-tool.

²⁷ Residential model of the existing housing stock using OpenStudio and EnergyPlus. github.com/NREL/OpenStudio-ResStock.

For each of the measures identified in the analysis, RBI first populated the database with descriptive information that distinguishes the home improvements. This data includes consistent measure characteristics, relevant home improvement transactions (*e.g.*, equipment repair or replacement, exterior replacements, interior replacement, remodeling, rooftop PV installation), installation contractor types, applicable climate zones, energy efficiency performance level, deployment readiness, as well as relevant market data, such as number of potentially affected homes, and energy efficiency organizations that already promote adoption of such measures.

2.3. Screening and Scoring of Measures

Next, RBI collected and analyzed additional data based on three key sets of evaluation criteria: an impact screen, an economic screen, and a stakeholder screen, summarized in Figure 9, to score and further evaluate the home improvement measures. Each of the three criteria serves as a consistent and consecutive screening and includes several sub-criteria as well as a score for each of the three criteria areas. To create each score, RBI used its best judgments based on the reviewed available data sources and RBI's extensive interactions with Better Buildings Residential stakeholders.

Impact screen: RBI considered the number of homes that could implement each improvement and scored the magnitude of each measure's energy savings potential using technical potential and maximum adoption potential. Technical potential is the annual energy savings potential achieved by instant replacement of all technically suitable existing stock. Maximum adoption potential, which is the key driver in evaluation of this screen, is the annual energy savings potential that can be achieved by the measure's replacement of technically-suitable installed baseline stock at the end of its expected lifetime.

Economic screen: RBI evaluated each measure based on three scores: manufacturer capability, current level of cost-effectiveness, and cost reduction potential. The first score captures existing manufacturers' supply chain infrastructure; manufacturer capabilities to support large-scale adoption of a measure; and quality of testing procedures to assess product performance. The second relies on estimates of current simple payback period, and the third qualitatively reflects the potential for future decreases in product and/or installation costs.

Stakeholder screen: RBI used this screen to evaluate how current progress in the market can be leveraged and to identify any gaps that indicate specific areas of need to address certain market barriers. RBI assessed current market status and initiatives based on the perspectives and attitudes of building professionals, REEOs, utilities' energy efficiency programs, and consumers to score each measure. The building professionals score reflects their expertise in quality installations and their ability to sell the measure to consumers. The REEO score reflects the extent of organizations' involvement with each measure and any existing initiatives or working groups. The utility or energy efficiency program score reflects the existence and level of incentives that programs offer in key regions, which plays an important role in alleviating the cost burden of energy efficiency home improvement upgrades and acceleration of market adoption. Lastly, the consumers score indicates consumers' general perception of non-energy benefits of a measure (*e.g.* enhanced comfort, ease of use), which often have a significant impact on their decision to invest in a measure, often more so than considerations of energy or cost savings.

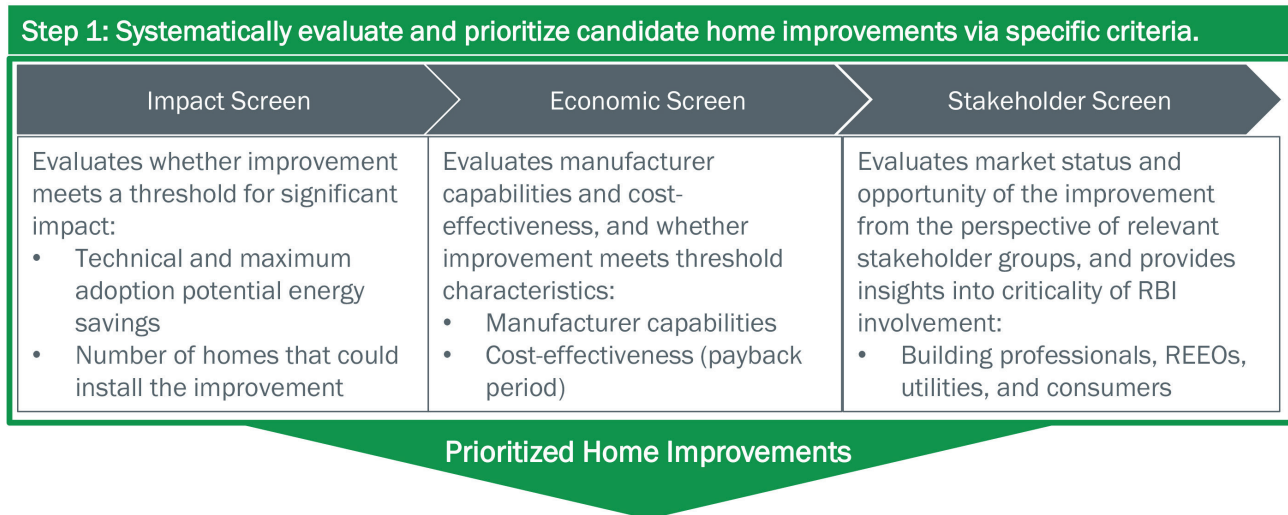


Figure 9. Key Criteria Used to Evaluate Potential Home Improvement Opportunities

RBI then applied a weight factor to each of the three screens, so that RBI can prioritize based on its preference for each of the evaluation screens to generate a final score for each measure. For more details on the energy efficiency measures database tool that RBI uses to evaluate home improvement opportunities, including more information on the scoring criteria, as well as the scoring results refer to Appendix A.

2.4. Methodology for Estimating Energy Savings Potential of Measures

As part of the HI Cat process, RBI implements various forms of market and energy efficiency measure analysis to target and prioritize potential focus areas where HI Cat activities can have an impact. The Prioritization Tool (P-Tool) and the NREL ResStock models were the primary tools used to calculate and verify energy savings potential estimates for these scenarios. Since this analysis, BTO has developed and released a new tool, Scout, that replaced the P-Tool and provides enhanced analytical capabilities. These tools relied, for the most part, on the same reports and data sources, but utilize different methodologies to calculate energy savings potential of individual energy efficiency measures in the residential sector. ResStock relies on EIA's Residential Energy Consumption Survey (RECS) 2009 for baseline energy stock and consumption data, and uses a more precise granular assessment of the residential stock, adjusting for variability in energy and cost savings depending on housing characteristics (region, performance, vintage, etc.). The P-Tool used the AEO 2014 stock and energy consumption projections to derive national or regional energy savings estimates, typically utilizing national and climate-zone based averages for measure performance and home characteristics data.

BTO's Analytical Tool - Scout

Scout replaced BTO's P-Tool in 2017 as an analytical tool that estimates the energy and carbon impacts of various energy conservation measures (ECMs) in the U.S. residential and commercial building sectors. RBI will use Scout going forward in HI Cat analysis. This tool:

- Utilizes a baseline building stock defined by EIA's Annual Energy Outlook at the granularity of building type, building vintage, climate zone, end use, and fuel type and to project growth and stock turnover in each baseline market segment.
- Characterizes ECMs using their relative or absolute performance, installed cost, service lifetime, and year of introduction into the market. Probability distributions can be placed on ECM performance, cost, and lifetime inputs, which then propagate through to final energy and carbon impacts.
- Can calculate ECM energy performance using whole-building energy simulation with EnergyPlus on prototype building models. This approach compares ECMs on a level playing field using identical assumptions, avoiding the need for normalization. It also produces savings estimates disaggregated by end use, which facilitates the evaluation of ECM packages.
- Can evaluate a portfolio of ECMs competitively, ensuring that ECM savings impacts are not double-counted.

More information can be found on DOE's website at <https://energy.gov/eere/buildings/scout>.

Both tools (now Scout instead of the P-Tool) enable RBI to verify consistency of measure data, assumptions, and calculations used to derive the energy savings estimates for typical energy efficiency measures. Through a series of national heat maps that identify areas and magnitude of energy savings potential per measure or packages of measures, the NREL ResStock analysis also allows RBI to pinpoint the specific regions of the country that can most benefit from installations of certain energy efficiency measures. This information helps RBI to further prioritize home improvement opportunities and to identify leading stakeholders in specific regions with whom they can partner.

2.5. Usage of the Energy Efficiency Measures Database Tool

RBI will use the energy efficiency measures database to plan HI Cat activities on an ongoing basis over multiple years and to coordinate with other RBI activities and BTO Programs. This central database of energy efficiency measures helps consistently guide and prioritize focus areas for the HI Cat and has several advantages:

- **The database is an active document that RBI can easily and frequently update for uses across the RBI Program.** RBI plans to update the information in the measures database annually to include new commercialized measures or provide updates on market progress. For example, as BTO Emerging Technologies R&D projects are commercialized or Building America innovations are demonstrated in the field, these measures will be added to the database and analyzed using the screening criteria. That database will also include additional informational fields for RBI's purposes such as estimated cost and market penetration. RBI anticipates this database will help with quick identification and consistent analysis of energy saving opportunities based on current data.
- **Data sources, methodologies, and scoring criteria are simple and transparent.** RBI can potentially share the database with relevant stakeholders for peer review and to obtain relevant and useful feedback. It also allows for easy communication of opportunities areas and justification of activities for program planning and evaluation purposes.
- **The database allows for quick screening and easy modifications to adjust prioritization.** As RBI's priorities shift or as RBI wants to explore new priorities, it can sort measures into various categories or assign different weights to the screening criteria. For example, if RBI wants to identify energy efficiency measures and practices that are relevant to certain transactional opportunities, RBI can sort the database by the transaction type to filter and identify all such measures.

RBI uses the energy efficiency measure database as a tool to help identify, prioritize, and track home improvements and transactional opportunities that are most ripe for HI Cat activities. As a result, RBI identifies a list of the top energy efficient home improvement opportunities that will undergo further review by existing partners and other industry stakeholders to ultimately select a portfolio of three to five near-term focus areas. Going forward, RBI updates the existing information in the energy efficiency measures database on an annual basis, as needed, to adjust the list of ten home improvement measures and determine new near-term focus areas for activity planning.

ResStock Model: Approach for Energy Analysis of the U.S. Residential Building Stock

ResStock is an energy analysis model built by NREL on the OpenStudio platform that can model the residential building stock for national, regional, or local analysis of energy conservation measures. NREL created this model in support of DOE's Office of Energy Policy and Systems Analysis update of its Quadrennial Energy Review report, which studies the U.S. electricity system. RBI plans to leverage this model and use it as a key tool to evaluate and target home improvement opportunities on a regional basis for purposes of planning the HI Cat and other RBI activities.

Key elements of the energy analysis model include:

- Multiple data sources for residential building characteristics are combined into conditional probability distributions for national and regional analyses based on location, vintage, fuel, equipment types, efficiency levels, home characteristics, envelope insulation levels, occupancy and usage data, etc. (e.g., RECS, Northwest Energy Efficiency Alliance (NEEA), Residential Building Stock Assessment, National Association of Home Builders, U.S. Census, American Community Survey).
- A statistical sampling technique is used to generate thousands of OpenStudio building models and measures through DOE's EnergyPlus simulation engine via Amazon cloud or other computing resources.
- Home improvement measures or packages are applied to user-specified subsets of the housing stock (e.g., evaluate energy savings potential of cold climate heat pumps specifically in cold climates or in homes that use electric baseboard heating in cold climates).
- Detailed market segmentation, sub-hourly simulations, and high-performance computing allows the model to account for diversity in climates and housing stock characteristics to generate more precise energy savings and conduct economic evaluation of measures on a granular level.

The results can be aggregated and visualized as a series of heat maps displaying the U.S. The Figure 10 shows an example output visualization generated by the ResStock model. (TBtu = trillion British thermal units).

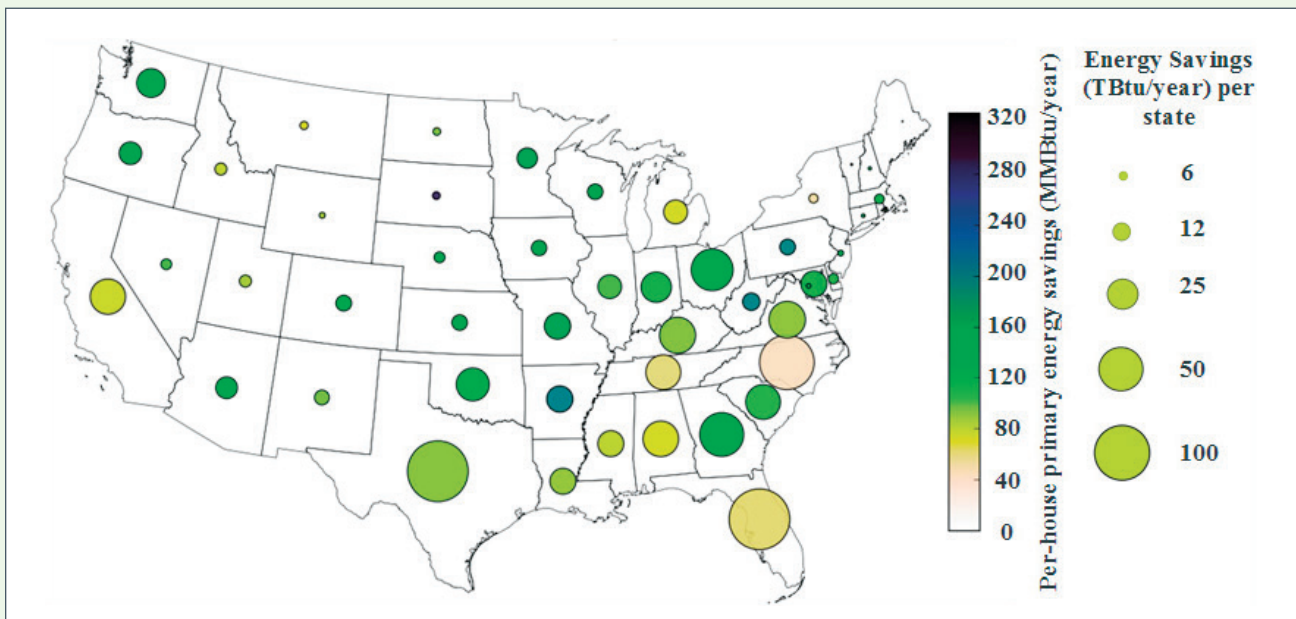


Figure 10. Example of a heatmap generated using ResStock model with estimates of cost-effective (net present value>0) energy savings potential on a per-state and per-house basis of VSHPs replacing electric resistance furnaces in residential homes



Step 2. Identify and assess market barriers that inhibit broad adoption of home improvement measures to identify potential activities that can overcome these barriers.

After identifying and prioritizing the most promising energy efficient home improvement measures for existing single-family homes, RBI next identifies and systematically reviews various technical, economic, and market barriers that impede the adoption of those measures. RBI developed a HI Cat Activity Decision Map, shown in Figure 11, to help indicate the barriers that exist for each measure opportunity. It serves as a visual representation of the structure and logic that guides how RBI identifies the most persistent barriers and how those barriers are manifested in the market.

The yes or no pathways in the decision map ultimately lead to potential HI Cat activity types that can overcome the barrier, which are further outlined in Step 3. If the pathway leads to emerging market activities, then the measure might require additional technical support before it can be accelerated to wide-scale market adoption. In this case, RBI would work with Building America or potentially the BTO Emerging Technologies Program to identify specific technical needs necessary for further commercialization. If the pathway leads to market activities, RBI takes additional steps to characterize and prioritize the most critical barriers.

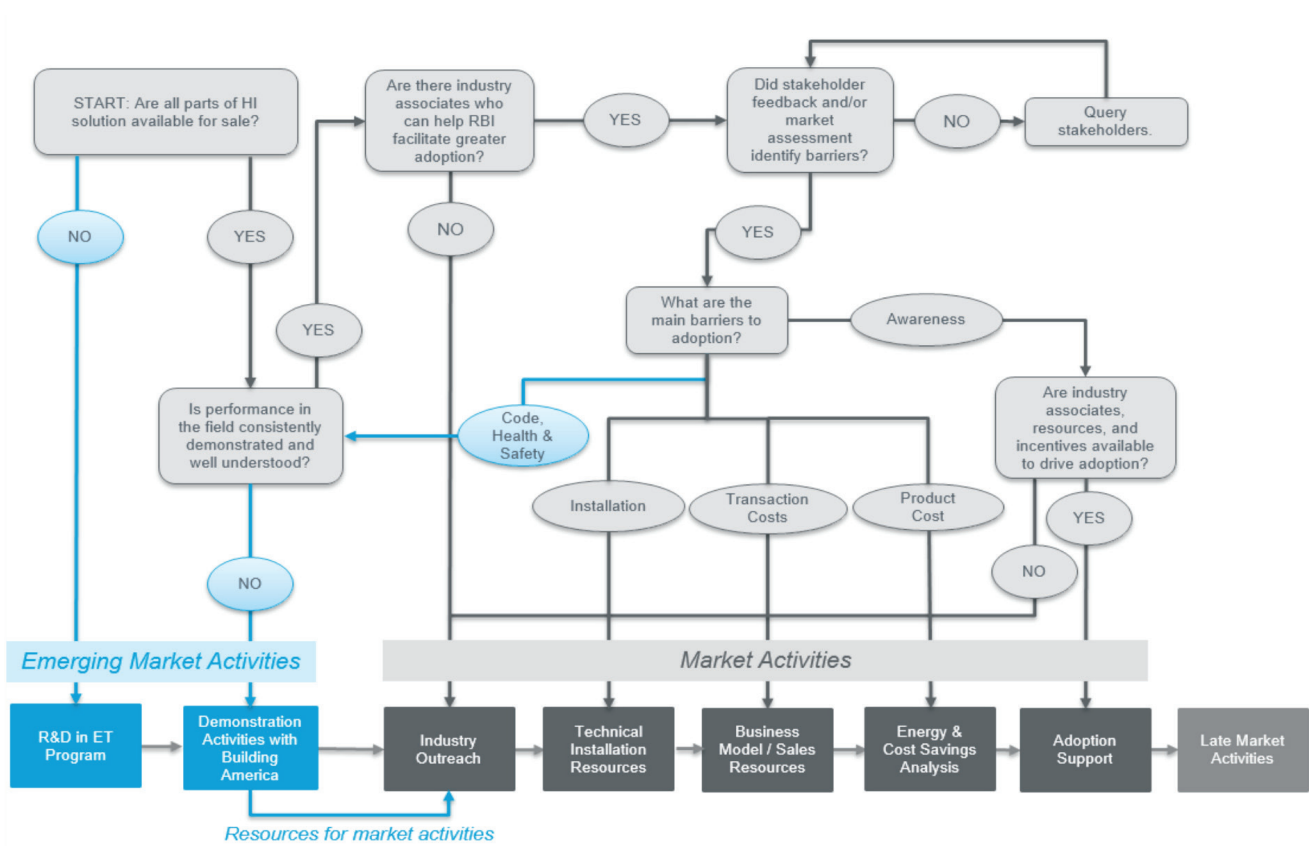


Figure 11. HI Cat Activity Decision Map

Using a value proposition design process, RBI next crosswalks the barriers with the top prioritized home improvement opportunities and stakeholder needs. The value proposition design process is an approach to outline and understand customer needs while also building a plan of activities to fill gaps, address barriers, and enhance market opportunities. Focusing initially on the HVAC market, RBI worked with stakeholders to map the profiles related to each supply chain actor. RBI then categorized and appropriately prioritized barriers according to stakeholders' most critical issues and the potential gains achieved by overcoming barriers. Figure 12 presents an example profile for an HVAC trade contractor, focused on prioritization of technical issues and opportunities. See Appendix B for more value proposition profiles. Each of the profiles are organized by functional areas that are associated with the HI Cat uniform barrier categories:

Profile Functional Area	HI Cat Uniform Barrier
Brand and Reputation	Lack of product availability or consistent product information
Technical Capabilities	Lack of consistent field performance information
Business Processes	Difficult to install and few technical resources
Financial Impact	Unclear payback or consistent savings information
	High product cost and inhibits sales
Marketing and Sales	Lack of awareness/market fragmentation

Over the next several years, RBI will employ the value proposition design process to obtain stakeholder input on each of prioritized home improvement opportunities – seeking to characterize current barriers, and identify where DOE can support activities directed at those specific challenges.

HVAC Contractor Value Proposition Functional Area: Technical Capabilities (training, tools, workforce; also quality & compliance)	
GAINS	
High Priority	Access to technical solutions, solving homeowner's problems
	Technical know-how to be a quality installer with a quality product
Med Priority	Access to DOE programs and tools
	Training
	Being on top of my game
PAINS	
High Priority	Being "expert" enough in a variety of areas to seem knowledgeable
	Staying current with best practices and new products
	Regulatory and code compliance
	Finding, training, and retaining a skilled labor force
	Dealing with inspectors
	Lengthy modeling or load calculations
	Getting the credentials (indirect costs)
	Adhering to program standards in imperfect retrofit conditions
Med Priority	Having the right tools
	Lack of building science knowledge/technical know-how
	Lack of availability of verified performance data
	Accessing hard to reach spaces (physical barriers)
	Houses are complicated and tough to solve problems
	More chemicals and hazardous materials

Figure 12. Value Proposition Map Example to Characterize and Prioritize Barriers



Step 3: Engage stakeholders and design market initiatives by identifying the types of solutions and resources that stakeholders need to address identified barriers to national-scale adoption of energy efficient home improvement measures.

At this step, RBI selects three to five near-term focus areas for the coming year from the prioritized home improvement measures list—either continued from the prior year or new home improvement areas. RBI then engages with stakeholders to obtain feedback on selected focus areas and critical market barriers to identify the types of market activities and resources that are most effective for meeting stakeholder needs and maximizing outreach. RBI either leverages RBI partners or other existing stakeholder groups within organizations (such as the Consortium for Energy Efficiency or REEOs). RBI may also create new informal stakeholder groups that are interested in accelerating adoption of particular home improvement measures. These groups might include representatives from a variety of public-private sector groups including utilities and energy efficiency programs, REEOs, trade and professional associations, manufacturers, distributors, retailers, and building professionals.

There are three main benefits of stakeholder involvement in the HI Cat process:

- 1) stakeholder input informs RBI’s program planning and prioritization;
- 2) stakeholder engagement facilitates deployment of resources on a wide scale;
- 3) stakeholder feedback reveals effectiveness or areas in need of further evaluation.

RBI then utilizes the HI Cat activity framework below to select activity types and design the market initiatives that RBI will implement, which address barriers and fit within DOE’s role. Drawing on information from Steps 1 and 2 and stakeholder feedback, RBI considers the stakeholders across the supply and delivery chain, including current construction trade practices and typical transaction opportunities, to determine which market activity types are most appropriate to support the market. The activity types are listed in a progressive order, related to the needs of construction trades and other stakeholders to drive investment in more energy efficient home improvements. Once the necessary activity types are identified, RBI uses gathered barrier information and matches market initiatives and resource products back to barriers faced by each stakeholder group along the supply chain. RBI can then plan the specific program activities within available budgets and appropriate performers that will make up the market initiatives.

The following are HI Cat activity types including descriptions and examples:



Industry Outreach

Assembles or recognizes diverse stakeholder groups (e.g., manufacturers, distributors, retailers, contractors, energy efficiency programs, REEOs, trade associations), to improve communication and determine solutions to targeted barriers. Emphasis will be on reaching broad audiences and opportunities to innovate solutions for accelerated adoption of prioritized home improvements at key transactions through more consistent information or specifications where needed. The home improvement industry is exceptionally fragmented, hence up- and downstream stakeholder outreach is critical to identify the most important market barriers and multi-faceted solutions across the value chain.



Technical Installation Resources

Provides guidance on home improvement selection and proper installation to address key issues that inhibit contractors from encouraging energy efficient options at the time of typical home improvement transactions. An example resource is a Sequencing Guide tool that helps contractors understand the appropriate steps to making energy efficiency improvements, utilizing various existing RBI resources.

Annual Stakeholder Feedback

RBI engages with stakeholders at least once a year to discuss each HI Cat near term focus area as well as activities and resources that are either planned or already underway. Feedback is also informally documented throughout the year through webinars, conferences, the BTO annual Peer Review and existing activities. RBI uses this information to inform activity planning; to track evidence that stakeholders value and use HI Cat resources; and to indicate progress in addressing market barriers.

BTO will also work with stakeholders to develop installation best practices and case studies to equip distributors, contractors, and energy efficiency programs with the information needed to create momentum and accelerate adoption of energy efficient home improvements.



Business Model and Sales Resources

Addresses stakeholder business models to more effectively sell or incent purchase of high- performance home improvement options. BTO will compile information from industry outreach and installation resources to increase available strategies and best practices for retailers, distributors, energy efficiency programs, and contractors to promote targeted home improvements at the point of typical transactions.

These strategies might include technology profiles that can be accompanied with specifications and performance data; incentive structures or point-of-sale discount options; bulk purchasing programs; and warranty/service agreement discounting to address equipment failure and upgrades.



Energy and Cost Savings Analysis

Implemented to address the lack of objective and consistent cost and savings estimates that inhibit contractor sales and consumer investment for some home improvements. BTO will compile existing information and facilitate discussions with Building America and other stakeholders to communicate home improvement(s) savings estimates on a regional basis to the public via case studies, summary reports, and home improvement profiles.



Adoption Support

This activity is the culmination of the other HI Cat activities and incorporates supporting resources and targeted solutions to verify widespread adoption of home improvements. It particularly addresses identified barriers to industry or energy conservation standards and building energy codes. BTO will work with stakeholders to identify focus areas and determine appropriate priorities. This may include information exchange or handoffs between stakeholders and standards organizations, verification of installation techniques, or other related activities. As an example, BTO identified installation issues such as space constraints, air supply requirements, and space cooling effects as one of the market barriers for heat pump water heaters. Hence, BTO may conduct studies to determine frequency and magnitude of these issues by tracking experiences of rebate program participants.

2.6. Implementation Approach

The HI Cat process described above allows RBI to systematically identify specific opportunity areas and collaboratively target efforts on an annual basis. Once activity types are identified in Step 3 for each near-term home improvement focus area, RBI outlines the market initiatives or actual program activities to be implemented with stakeholders and in initial target markets. This entails establishing the barriers addressed, components for execution such as the performers or partners, coordination needed, geographic market, existing resources and practices, and output resources. Market initiatives are focused on leveraging major stakeholders and first addressing target markets where there is high energy and cost savings potential at the time of typical home improvement transactions with consumers. RBI's approach to implementing market initiatives is summarized in Figure 13. As shown, individual initiatives successively build on each other to break down identified barriers.

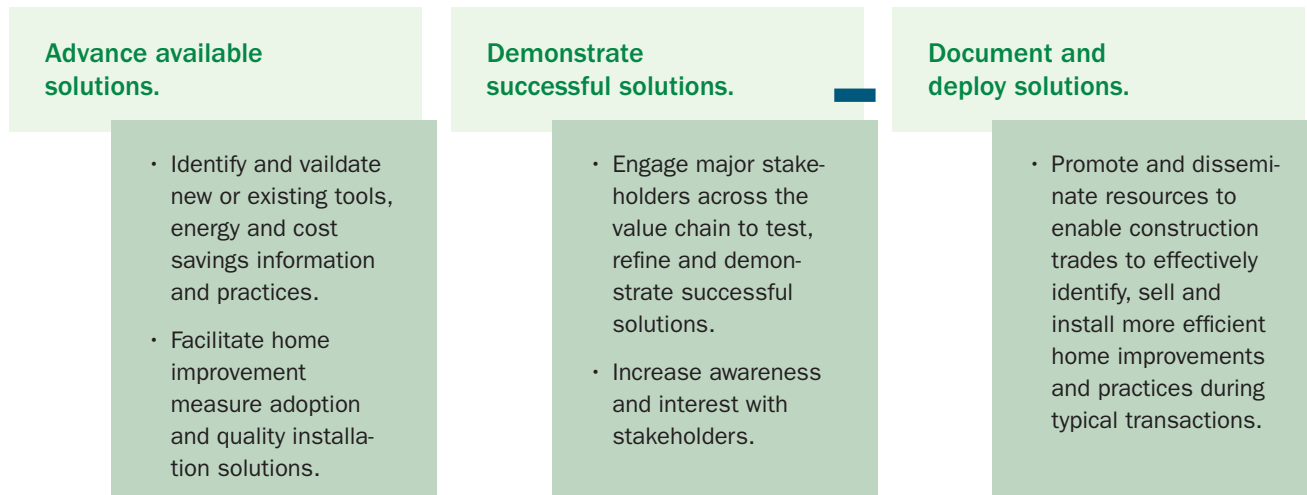


Figure 13. HI Cat Implementation Approach

RBI will publish resources resulting from each initiative. These resources will document objective information, successful examples, and deployment pathways to ultimately aid construction trades to increase investment in specific home improvement opportunities at the time of typical, key transaction points. RBI aims to create resources that have demonstrated value for targeted stakeholders, who will, in turn, further disseminate the published resources within their service area, membership base, or region. Examples of typical resources include: case studies, technical installation guidance and best practices, technology profiles and comparative analyses, energy and cost savings fact sheets, sales and messaging resources, and program design best practices.

RBI leverages DOE's analytical capabilities and existing RBI resources, such as the information in the Building America and Better Buildings Solution Centers, for its activities. The RBI Program also leans on experiences and resources from industry experts and existing partners and their networks to greatly increase the overall impact on the market per federal dollar spent. RBI aims to ultimately deploy actionable solutions on a national scale so that more energy efficient technologies and trade practices progressively gain widespread market penetration, and are incorporated into energy conservation or industry standards and building energy codes.

3. HI Cat Prioritized Measures, Market Barriers and Initiatives

This section provides the initial results of the HI Cat strategic three-step process described in Section 2.1. Though RBI already has initiated some activities under the HI Cat, these findings mark the first time RBI has utilized the process approach to target efforts, and will serve as a beginning point for future annual analysis.

The RBI internal team and existing partners reviewed and commented on the HI Cat process framework, the top ten prioritized measures, and the categorization of market barriers in late 2016. RBI is interested in additional stakeholder feedback on this plan, the initial results, and potential focus areas.

RBI will track the various outputs against its program goals and evaluate outcomes of the HI Cat initiatives over the long term through the steps discussed in Section 2.

3.1. Prioritized Home Improvement Measures

Based on the methodology discussed in Step 1 of Section 2.1, RBI identified a preliminary list of ten energy efficiency home improvement measures that can be implemented in typical home improvement transactions to reduce heating, cooling or water heating EUI in single-family homes. These ten home improvements, shown in Table 2 were prioritized as the top opportunities, and will serve as the list from which RBI determine its initial three to five near-term focus areas. Subsequently, RBI will evaluate and, if needed, revise the top prioritized home improvement measures list on an annual basis. This includes both adding new opportunities based on market or technology development, or removing measures that either have gained sufficient market traction or have been adequately addressed by RBI to the extent necessary.

The list of home improvement measures represent the following opportunity areas:

- high-performance HVAC (including inverter driven heating and cooling equipment)
- building envelope improvement strategies
- smart home systems
- high-performance water heating

The energy savings estimates are per the BTO P-Tool (and will be assessed using Scout in the same manner going forward). These estimates include a range of values that reflect a lower and an upper bound of potential savings available in the residential sector from 2016 to 2030. The estimates are annual primary energy savings that represent technical savings potential (*i.e.*, savings can be achieved through instantaneous replacement of installed base technologies in existing, single-family U.S. homes). These savings ranges are intended only to provide a sense of magnitude of the impact if homeowners were to invest in the identified home improvement measures, which are higher efficiency than conventional options.

Table 2. Top Ten Preliminary Home Improvement Measures for HI Cat Focus

Home Improvement Measures	General Market Opportunity	Technical Potential Savings* (Quads/year)
Heating, Ventilation, and Air Conditioning		
Variable speed heat pump, including cold climate heat pumps	Demonstrate and deploy highly efficient cold climate heat pumps that enable efficient operation at cold temperatures (IECC climate zone 4-6) to serve as a replacement for electric resistance furnaces and standard ASHPs. Configurations include central ducted systems only.	0.4 – 1.1
Ductless heat pump	Deploy ductless heat pumps as a high efficiency alternative to electric resistance heating at time of replacements or renovations, which also includes potential energy savings benefits in cooling.	0.1 – 0.3
Quality installation of central AC & central heat pumps	Demonstrate savings benefits and deploy quality installation practices that can ensure equipment is properly sized, selected & installed to deliver intended rated performance. This includes properly sealed ducts and proper refrigerant charging.	0.5 – 0.9
High-efficiency central AC	Increase standard equipment replacements or upgrades to central AC with seasonal energy efficiency ratio (SEER) levels at least greater than ENERGY STAR.	0.2 – 1.0
Windows/Building Envelope Improvement Strategies		
Attic insulation / Air sealing	Deploy attic insulation as a high priority for finishing a previously unconditioned space (vented attic) or for weatherization purposes. Increase air sealing application throughout the home when insulating to prevent uncontrolled air flow.	0.7 – 1.1
Wall insulation (“drill & fill”)	Deploy wall insulation for home improvements related to siding replacements and renovations. “Drill & fill” refers to using cellulose or fiberglass cavity insulation to fill uninsulated wood frame walls in older homes.	0.1 – 0.2
Highly insulating windows	Deploy highly insulating windows focused on ENERGY STAR most efficient levels as replacement windows or in renovations, specifically in cold climates.	0.5 – 1.2

Table 2. Continued

Home Improvement Measures	General Market Opportunity	Technical Potential Savings* (Quads/year)
Windows/Building Envelope Improvement Strategies		
Home energy management systems (HEMS)	Deploy and optimize HEMS or smart thermostats when installing HVAC equipment, which can monitor and provide feedback about a home’s energy usage, and automate or enable control of energy-using systems and devices in the home via Internet-connected devices.	0.7 – 1.2
Water Heating		
Heat Pump Water Heaters	Deploy high efficiency heat pump water heaters that meet or exceed ENERGY STAR minimum performance requirements as a replacement for electric resistance water heaters.	0.6 – 1.0
Condensing Water Heaters	Deploy high efficiency gas storage water heaters that meet or exceed ENERGY STAR minimum performance requirements as a replacement for storage gas water heaters.	0.1 – 0.3





































*Estimates derived via the BTO P- Tool and include a range of values that reflect a lower and an upper bound of technical potential savings available in existing homes over the 2016 – 2030 period. Where applicable, the lower bound reflects energy savings potential of technologies that meet the ENERGY STAR specification. The upper bound reflects technologies on the market that are high performance, but not the max-tech. Both estimates consider +/-10% uncertainty over 2016-2030 period.

3.2. Critical Market Barriers


Using the process outlined in Step 2 and the information collected in Step 1, RBI performed a high-level assessment of market barriers to each of the top ten prioritized home improvement measure opportunities. Table 3 summarizes the barriers according to uniform categories, identifying the most prevalent barriers that currently inhibit widespread market adoption.

For purposes of the initial review, RBI classified existing barriers into two groups, as indicated by red and yellow icons. The red icon signifies that the barrier is critical and significantly prevents widespread market adoption; the other yellow icon indicates that the barrier inhibits but does not widely prevent widespread adoption. The RBI internal team and existing partners reviewed the categorization of barriers and provided comments in late 2016.

Table 3. Identified Market Barriers for Top Prioritized Home Improvement Measures

Home Improvement	Targeted Transactions	Limited Product Availability /Consistent Info	Lack of Consistent Field Performance Info	Lack of Awareness / Market Fragmentation	High Product Cost that Inhibits Sales	Difficult to Install / Few Technical Resource	Unclear Payback or Consistent Savings Info
Variable speed heat pump / Cold climate heat pump	Upgrade, Replacement						
Ductless heat pump	Upgrade, Replacement, Renovation						
Quality Installation of central AC & heat pump	Upgrade, Replacement, Maintenance						
High-efficiency central AC	Upgrade, Replacement						
Attic insulation / Air sealing	Exterior Replacement, Room Remodeling						
Wall insulation (“drill & fill”)	Exterior Replacement, Room Remodeling						
Highly insulating windows	Exterior Replacement, Room Remodeling						
Home energy management systems	Non-Specific						
Heat pump water heaters	Upgrade, Replacement						
Condensing water heaters	Upgrade, Replacement						

 Barrier exists but does not significantly prevent widespread adoption.

 Barrier is significant and can prevent widespread adoption.

Using information collected during facilitated value proposition design exercises conducted with a range of stakeholders along the supply chain, RBI used detailed supply chain actor value proposition profiles to document how each of the barriers are manifested in the market along the supply and delivery chain (*i.e.*, the stakeholders that produce, sell or install the home improvement measures). RBI then used the value proposition profiles and stakeholder feedback to prioritize areas of need to alleviate “pains” or for potential “gains” that are most critical to stakeholders. For example, RBI identified that several barriers to quality installation of central air conditioning and heat pumps involve high program implementation costs and procedures that contractors find overly burdensome. Figure 14 provides an example of how these tools benefit several stakeholders in various ways according to the value proposition maps.

Recent stakeholder feedback and the analysis of barriers then led RBI to identify the most important challenges to overcome as unverified energy savings, lack of cost-effective installation practices, little consumer awareness and complex technical implementation issues (*e.g.*, proper sizing, refrigerant charge, system control settings, ducts and airflow capacity and distribution, effect of building envelope). Understanding these barriers then allows RBI to determine activities to pursue and that follow manufacturer recommendations and industry standards for quality installation practices.

Barriers	Need	Pain Relievers	Gain Enhancers
Lack of consistent field performance info; Lack of awareness; Unclear payback or savings; Few technical resources	HVAC Quality installation automated verification systems and tools	(M) Reduces callbacks and poor installs (D) Reduces call backs and poor installs (T) Reduces complexity and callbacks	(M) Ensures product works to manufacturer specs (D) Ensures product works to manufacturer specs; increases product sales (T) Offers technical support; access to third party verification of work; enables enhanced warranties

Legend:

(M) = Manufacturer

(D) = Distributor

(T) = Trade or Contractor

Figure 14. Value Proposition Example for Quality Installation

For future annual reviews, RBI will assess criticality of barriers using the value proposition maps and ongoing stakeholder feedback to result in a list of prioritized barriers to be addressed by HI Cat market initiatives. When new home improvement measures are added to the top ten list, RBI will perform a new review of barriers.

Heat Pump Water Heaters Market Transformation: RBI works with Pacific Northwest National Laboratory and other BTO Programs to Identify Market Barriers

Instead of generating heat, heat pump water heaters (HPWHs) use electricity to move heat via liquid refrigerant from surrounding air, and transferring it to water in an enclosed tank. HPWHs have demonstrated significant potential of up to 50 percent reduction in energy cost savings compared to conventional electric water heaters across various climate zones. They also help cool and dehumidify the home during the non-heating season and are especially advantageous in the southern and humid regions of the U.S. Manufacturers are continuing to innovate to introduce new HPWH technologies to the market, such as HPWHs that use CO₂-based refrigerants. However, there are currently several challenges preventing greater adoption of HPWHs in the U.S. market:

- High upfront cost: consumers may have to pay up to twice the installed first cost of a typical electric resistance water heater. To help decrease the upfront cost, state governments and utilities established over 70 programs, with incentives averaging about \$400 per unit.²⁸
- Lack of consumer awareness: more than 80 percent of residential water heater purchases are emergency replacements, with customers expecting a replacement within a few days. However, most purchases of HPWHs are planned replacements, hence consumer education in advance of equipment breakdown is important
- Unengaged installer base: plumbers are not properly trained in heat pump technologies
- Installation issues: space cooling effects; space constraints and air supply requirements must be met allowing for sufficient air supply to the HPWH
- Varying energy savings benefits: differences in field efficiency may be observed across various climate zones and by location of installations within a home (basement, closet, etc.)
- Unclear peak demand savings: utilities that use electric storage water heaters for demand-response programs state that HPWHs can't effectively serve this function.

RBI is working alongside other BTO programs as well as PNNL to address these widespread market barriers and increase adoption of HPWHs paving the way for higher energy savings across the country. They are gathering information and aggregating existing data and resources to plan for future activities that would aid in overcoming of these barriers. These activities include consolidating results and materials from field testing, and synthesizing the data in existing reports to generate educational materials to distribute to the public:

- Aggregated case studies of HPWH benefits, including energy, cost, and peak demand savings across various climate zones
- Research on significance and frequency of installation issues and technical solutions to quantify and lower encountered installation costs

HPWHs entered the mainstream U.S. market in the late 1970s, but due to operational problems, inadequate market and product support infrastructure, sales have fluctuated between 2,000 and 10,000 units per year. As technology, marketplace, policy, and business environment converged to offer more reliable and affordable HPWH technologies, sales increased significantly. It is estimated that in 2015 about 55,000 HPWH units were sold; however, this is still only about 1 percent of the electric water heating market.

Source: U.S. EPA. ENERGY STAR Unit Shipment and Market Penetration Report: Calendar Year 2015 Summary.



Heat pump water heater example brands

²⁸ Heat Pump Water Heaters and the Northwest Market. Hot Water Solutions. ACEEE Hot Water Forum. February 22, 2016. http://aceee.org/sites/default/files/files/pdf/conferences/hwf/2016/Reynolds_Lebrasseur_Naleway_Session2C_HWF16_2.22.16.pdf.

3.3. Market Initiatives

As described in Step 3, RBI identified three home improvement measures for its near-term activity portfolio. These were selected based on Steps 1 and 2 of the HI Cat process and determined to be areas where RBI can help inhibit barriers through market initiatives that produce valuable stakeholder resources. The near-term focus areas are shown in Figure 15.

Market initiatives are focused on equipping HVAC and plumbing contractors, distributors and manufacturers with resources necessary to increase adoption of these home improvements at the time of equipment repair and replacement. With over homeowners reporting about 3 million heating and cooling replacements as installed annually by building professionals, there is a significant opportunity to influence these home improvement transactions so that consumers invest in incrementally more energy efficient technologies and practices.²⁹

RBI identified several types of market activities that are important to address identified barriers. Once these were determined, RBI selected those activity areas to target first for each home improvement measure according to prioritized barriers and current market needs.

Inverter-driven heating and cooling equipment	Quality installation of forced air heating and cooling equipment (including duct sealing and repairs)	Heat pump water heaters
<ul style="list-style-type: none">• Industry outreach• Technical installation resources	<ul style="list-style-type: none">• Industry outreach• Technical installation resources• Energy and cost savings• Business model and sales resources	<ul style="list-style-type: none">• Industry outreach• Technical installation resources• Business model and sales resources

Figure 15. Near-Term Focus Areas and Activity Types

From these market activity types, RBI designed HI Cat market initiatives for implementation with stakeholders and identified the types of resulting resources for each initiative. For example, RBI recently performed industry outreach on the topic of quality installation and gathered 40 participants from several existing stakeholder working groups including manufacturers, trade associations, universities and federal agencies. This workshop resulted in a report that summarizes feedback on identified market barriers and possible solutions or resources that stakeholders believe can improve the quality of installations.³⁰

Concurrently, RBI is working with the National Renewable Energy Laboratory (NREL) and the ENERGY STAR Program to research automatic verification system tools to complete a comparative analysis of available tools to help validate potential solutions. RBI is also observing existing program models that promote quality installation to document as case studies and to demonstrate with other energy efficiency programs. As an example, Table 4 outlines all currently planned market initiatives that RBI will implement in the near term to address barriers and advance quality installation.

²⁹ Joint Center for Housing Studies of Harvard University. Emerging Trends in the Remodeling Market. Improving America's Housing 2015. Table A-2 p. 29. www.jchs.harvard.edu/sites/jchs.harvard.edu/files/jchs_improving_americas_housing_2015_final.pdf.

³⁰ The Residential Central Air Conditioning and Heat Pump Quality Installation Workshop Outcomes Report can be found on BTO's website, <https://energy.gov/eere/buildings/downloads/residential-central-air-conditioning-and-heat-pump-installation-workshop>.

RBI will build upon market initiative progress each year as resources are deployed and more widely used to address additional activity areas. See Appendix C: Planned FY17 HI Cat Activities for a summary of planned RBI HI Cat activities for the current fiscal year. At least once a year, RBI will obtain stakeholder feedback– related to identification of focus areas, new market initiatives or existing program activities and their effectiveness.

Table 4. Near Term Initiatives to Advance HVAC Quality Installation

Initiatives	Market Barriers for HVAC QI practices			
	Lack of consistent field performance information	Lack of awareness/ market fragmentation	High product cost & inhibits sales	Unclear payback or consistent savings info
Promote Quality Installation of HVAC Systems.				
Meta- Analysis of Existing Market Data on the Benefits (Energy & Cost Savings Analysis)	✓	✓	✓	✓
Root Cause Analysis of QI Program Cost-effectiveness Issues (Energy & Cost Savings Analysis)		✓	✓	
Engage Stakeholders (Industry Outreach)		✓		
Summary Reports, Best Practices, Factoids, and Messaging (Adoption Support)	✓	✓	✓	✓
Advance Tools, Technologies & Services for Quality Installation Practices.				
Automated Verification Systems (AVS) Taxonomy (Technical Installation Resources)		✓		✓
Engage Stakeholders (Industry Outreach)		✓		
Define Criteria to Validate AVS Tools (Energy & Cost Savings Analysis)	✓			✓
Develop Key Performance Indicators for AVS Tools (Technical Installation Resources)	✓		✓	

Table 4. Continued

Initiatives	Market Barriers for HVAC QI practices			
	Lack of consistent field performance information	Lack of awareness/ market fragmentation	High product cost & inhibits sales	Unclear payback or consistent savings info
Design and Demonstrate Field Implementation Tools to Support Performance.				
Home Improvement Sequencing Tool – Facts on Impact, Differentiation Services, Contract Language (Business Model and Sales Resources)			✓	✓
Home Improvement Sequencing Tool – Product Specifications, Future Planning, Whole-building and Systems Considerations (Technical Installation Resources)	✓			✓
Contractor Playbook (Business Model and Sales Resources and Technical Installation Resources)		✓	✓	
Sequencing Tool Demonstrations (Adoption Support)	✓	✓	✓	✓

4. Tracking Progress and Performance Metrics

RBI will track progress of HI Cat activities against its program goals, for which RBI is directly responsible. RBI also will monitor market outcomes and BTO goals, to which RBI activities and the entire market contribute. To meet RBI's program goals, the HI Cat's target requires activities between now and 2020 to focus on home improvement measures within categories of home improvement trades (*e.g.*, HVAC, envelope, water heating, and associated controls) that cumulatively have the *potential* to reduce energy use by a threshold amount of 1 quad (per year in primary energy) in single-family homes.

The primary metric for meeting the HI Cat's targets is the number of effective resources RBI makes available to increase the adoption of individual technologies and practices and that address specific barriers. The current target is at least 15 effective resources by 2020, which address key home energy efficiency opportunities related to space heating and cooling, and water heating. RBI will track the number of resources published each year as a result of individual market initiatives. See Section 1.3 for more details on RBI's goals.

To ensure these resources are effective and have value in the market, RBI will document and analyze input from stakeholders, both on an informal basis and from those who are directly involved in developing resources. The feedback help indicates if the HI Cat market initiatives and resulting resources are useful and are directed at the most prevalent market barriers. This information is important because the HI Cat activities are not intended to spur development of as many resources as possible, but to focus development of *targeted* resources that are aimed at specific barriers, ultimately aiding industry stakeholders to accelerate adoption of high-efficiency home improvement measures.

In addition to the metrics associated with RBI's HI Cat targets, RBI will also track other key indicators to help determine the collective impact in the market to increase adoption and the quality installation of certain home improvements. These data points are documented in the same measures database that is used in the HI Cat process to identify prioritized measures including:

- estimated market penetration/equipment shipments;
- market cost;
- payback period
- stakeholder initiatives in the market (*e.g.*, energy efficiency program models and incentives, REEO initiatives, manufacturer or retailer promotions.);
- changes in barriers to building energy codes or industry standards;
- other anecdotal evidence of market adoption.

RBI will utilize all collected information to regularly evaluate its current strategies, stakeholder engagement practices, and program activities to determine if changes in direction are needed; if there is still a role for DOE; and when particular home improvement measure opportunities are sufficiently addressed.

5. Appendix A: Detailed Description of Screening Criteria

5.1. Impact Screen

RBI uses the impact screen to evaluate energy savings potential of each measure across the U.S. residential sector. The criteria used to score each measure are listed in Table 5. RBI estimates each measure’s annual energy savings potential to gauge the magnitude of available savings. These estimates are based on the measure’s unit energy savings and its applicable installed base annual energy consumption using the following methods, or “lenses:”

- Technical potential—annual energy savings potential in 2025 achieved by instant replacement of all technically suitable existing stock.
- Maximum adoption potential—annual energy savings potential in 2025 achieved by replacement of technically suitable existing stock that has reached the end of its expected lifetime. This potential accounts for installed baseline stock’s turnover rate.

RBI evaluates each measure’s potential energy savings through both lenses to help inform potential energy use intensity reductions in 2025 relative to its interim market goals, discussed in Section 1.3. However, RBI primarily considers the maximum adoption potential as the key impact value that drives the final impact screen evaluation score for each measure. This is because *maximum adoption potential* represents a more realistic upper bound to potential energy savings than the *technical* potential because it considers maximum adoption rates within the market. Maximum adoption potential considers *maximum adoption rate* of a measure where consumers are more likely to replace an installed baseline unit with a new measure at the end of its expected lifetime. Some consumers may implement a measure prior to failure of the baseline unit, while others may not replace the baseline unit for significantly longer than expected because some technologies may stay operational longer than their expected lifetime.

This lens assumes that these consumer decisions even out and on average, in a best-case-scenario, a new measure is likely to replace an installed baseline unit around its expected expiration date. The actual market adoption rate of a new measure will be significantly lower than the maximum adoption potential because many technologies compete for consumer purchase. However, the maximum adoption potential lens provides a simple and more realistic estimate of potential energy savings than the technical potential.

Table 5. Impact Screen Overall Score Criteria

Criteria		Screening Score Description
Impact Screen Overall Score	1	Measure’s national maximum adoption potential annual savings are less than 250 TBtus/year
	2	Measure’s national maximum adoption potential annual savings are greater than 250 TBtus/year but less than 500 TBtus/year
	3	Measure’s national maximum adoption potential annual savings are greater than 500 TBtus/year, but less than 800 TBtus/year

5.2. Economic Screen

For the economic screen, RBI analyzes measures using a set of scoring criteria in three categories. The first category is manufacturer capability, which captures manufacturers' supply chain infrastructure and existing capabilities to support large-scale adoption of a home improvement measure. It also captures whether manufacturers consistently test their products' performance, and if these tests reflect field performance. The second category is level of current cost-effectiveness evaluated through estimates of simple payback period for each measure. The third category is cost reduction potential, which reflects estimates of potential for future decreases in product and/or installation costs based on a variety of factors. The criteria and factors affecting the scores within each of the three categories are listed in Table 6.

These three scores are combined using a set of assumptions also detailed in Table 6 to yield an overall economic screen score. Measures with the highest score have attractive payback periods, and/or high potential for cost reduction, as well as extensive manufacturer capabilities and infrastructure to meet a growing demand for a home improvement measure. Measures with the lowest score have long simple payback periods, limited potential for cost reduction, and few manufacturers producing the measure.

Table 6. Economic Screen Score Criteria

Criteria		Screening Score Description
Manufacturer Capability	1	Only one manufacturer can produce this measure at the specified efficiency level and/or few manufacturers are in a position to introduce the measure. Patented technologies with intellectual property issues would fall into this category. Insufficient supply chain to meet an increase in consumer demand.
	2	At least three to five established manufacturers sell the home improvement measure with a functional supply chain, but product performance has not been consistently tested and verified.
	3	Multiple manufacturers can produce and sell the measure at scale, and product performance has been consistently tested and verified.
Current Cost-Effectiveness	1	Current estimated simple payback period is greater than 10 years, and upfront costs are prohibitive without incentives.
	2	Current estimated simple payback period is 5-10 years, and upfront costs are not prohibitive with current incentives.
	3	Current estimated simple payback period is less than 5 years, and upfront costs are not prohibitive with current incentives.
Cost Reduction Potential	1	Limited potential for significant decreases in installation or first costs (less than 10% in the next 3+ years).
	2	First and/or installation cost reduction is likely or possible primarily due to economies of scale and production/purchase volumes as technology matures, and/or due to improvements to the installation process. (10% – 50% cost reduction potential in the next 3+ years).
	3	Potential for significant first and/or installation cost reductions due to transformative market changes, technological breakthroughs, and/or installation method improvements. (More than 50% cost reduction potential in the next 3+ years).

Table 6. Continued

Criteria	Screening Score Description	
Economic Overall Score	1	The sum of all economic criteria scores is less than 6.
	2	The sum of all economic criteria scores is at least 6.
	3	Manufacturer capability score of 3, current cost-effectiveness and cost reduction potential scores, are at least 2 each.
	4	Manufacturer capability score of 3 and current cost-effectiveness score of 3.

5.3. Stakeholder Screen

RBI uses the stakeholder screen to evaluate status of a measure from the perspective of key stakeholders interested in promoting energy efficiency opportunities throughout the U.S. residential sector. This screen informs RBI where it can leverage current progress in the market, and identify any gaps that may require further work with stakeholders to overcome technical, economic, or other market-related barriers of select home improvement measures.

In this screen, RBI evaluates each measure from the perspective of building professionals, REEOs, utilities’ energy efficiency programs, and consumers. First, scoring criteria for building professionals reflects their expertise in quality installations and their ability to sell the measure to consumers. Second, the REEOs category reflects organizations’ involvement with a measure. REEOs can have extensive regional influence, and their technology initiatives can help accelerate market adoption. Third, scoring criteria for utilities’ energy efficiency programs reflects the level of incentives they offer in key regions, which plays an important role in accelerating market adoption by decreasing measures’ first costs. Finally, scoring criteria for consumers reflects perception of non-energy benefits of a measure. Non-energy benefits, such as enhanced home comfort or ease of maintenance, can play a critical role in influencing a consumer’s decision to implement a measure; such non-energy benefits may have even more impact than considerations of energy or cost savings. Table 7 details the scoring criteria for each stakeholder and the overall stakeholder screen score.

Table 7. Stakeholder Screen Score Criteria

Criteria	Screening Score Description	
Building Professionals	1	Building professionals are unaware of the improvement, do not have the expertise to install the improvement, and have never attempted selling the improvement.
	2	Building professionals are aware of the improvement, perceive a risk that their installation will not result in intended performance, and/or have trouble selling it to consumers.
	3	Building professionals are aware of the improvement, confident that their installation will result in intended performance, and are able to sell it to consumers.

Table 7. Continued

Criteria		Screening Score Description
Regional Energy Efficiency Organizations (REEOs)	1	REEOs have no existing initiatives and/or working groups.
	2	REEOs are pursuing the measure through some existing initiatives, but have not performed any studies to date, created dedicated working groups, or are engaged with stakeholders.
	3	REEOs are actively pursuing the measure through existing initiatives and/or working groups, have performed studies and published reports about the measure, and are engaged with stakeholders.
Utilities	1	Utilities generally do not offer incentives for the measure.
	2	Some utilities offer incentives for the measure.
	3	Many utilities offer incentives for the measure, and/or offer guidance/information on the measure with or without incentives.
Consumer Non-Energy Benefits	1	There are no non-energy benefits of this improvement.
	2	There are some non-energy benefits of this improvement, but consumers are not largely unaware of them.
	3	There are well-documented non-energy benefits that are valued by consumers.
Stakeholder Screen Overall Score	1	The sum of all stakeholder criteria scores is less than 6.
	2	The sum of all stakeholder criteria scores is less than 8.
	3	The sum of all stakeholder criteria scores is less than 10.
	4	The sum of all stakeholder criteria scores is greater than or equal to 10.

5.4. Screening Results

This section provides the scoring results for the impact screen, economic screen, and the stakeholder screen discussed in sections above for the prioritized energy efficiency measures.³¹ Table 8 displays a heat map that indicates the scoring result for each screen and the overall rank score. Red cells indicate the lowest tier screening score. Yellow cells represent the next tier, followed by light green coloring for the next highest tier score. Dark green cells indicate the highest scores. After assigning weights to these scores, the rank order of the home improvement measures indicates the final outcome score.

RBI used these screening results as the starting point to determine the top prioritized measures. Stakeholder feedback was also used to corroborate results and make adjustments. For example, condensing furnaces scored higher than other selected measures but were not included in the final prioritized list because their market share has grown significantly over the last few years, and they now make up a substantial share of the market.³² Additionally, other BTO programs already have activities that address technical and cost challenges, such as issues related to proper venting of condensing units.

RBI also combined several measures such as air sealing and attic insulation, home energy management systems and smart thermostats, and cold climate heat pumps with all variable speed heat pumps to better group individual technologies with appropriate market opportunities.

³¹ Other measures analyzed but not included in the initial selected prioritized list: low-e storm windows, condensing furnaces, tankless gas water heaters, condensing boilers, basement insulation (add R-11), exterior wall insulation, roof air sealing and insulation with external thermal moisture management system (ETMMS), roof radiant barrier, insulated siding. Other energy savings measures are not listed because the energy savings impact was insignificant or the measure types was too specific for the purposes of the HI Cat activities.

³² EPA estimates 2015 market share of condensing furnaces is 26% based on ENERGY STAR shipment data. Condensing furnaces market share has grown from 9% in 2013, which is the year EPA introduced its new ENERGY STAR specification. U.S. EPA. ENERGY STAR Unit Shipment and Market Penetration Report. Calendar Year 2013, 2014, and 2015 Summary. https://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2015_USD_Summary_Report.pdf?i301-6816.

Table 8. Screening Results for Prioritized Energy Efficiency Measures

Home Improvement	Impact Screen Score	Economic Screen Score	Stakeholder Screen Score
Home Energy Management Systems	Green	Yellow	Light Green
Heat Pump Water Heaters (Replace Electric Resistance Water Heaters)	Green	Yellow	Light Green
Smart Thermostats	Light Green	Yellow	Green
Air sealing	Light Green	Light Green	Light Green
High Efficiency Central AC	Light Green	Light Green	Yellow
Quality Installation of Air Conditioning Systems	Yellow	Green	Yellow
Attic Insulation	Yellow	Green	Yellow
Ductless Heat Pump	Red	Light Green	Green
Highly Insulating Windows	Light Green	Yellow	Yellow
Cold Climate Heat Pump (Replace Electric Resistance Heat)	Red	Yellow	Green
Cold Climate Heat Pump (Replace Fuel Oil/Propane)	Red	Yellow	Green
Condensing Gas Water Heater	Yellow	Red	Yellow
Interior wall insulation with High R-Value/inch material: Spray Foam Polyurethane	Red	Red	Red

The screening scores for the selected top prioritized measures are also presented below in Figure 16, represented by a visual radar chart. The chart shows the range of scores for each screen across the various measures to easily identify which measures had similar scores and which scored especially high or low in a certain area.

Each measure is on an axis that starts from the center of the chart and has equal scale between all axes. Each screen has its own color code and each measure's screening score is represented along the line moving toward the center of the circle. The highest screening score of 4 is represented by the point in the outermost edge of the circle, and the lowest score of 1 is represented by the point in the center of the circle. For example, home energy management systems received a score of 4 for the impact screen, a score of 2 in the economic screen, and a score of 3 in the stakeholder screen.

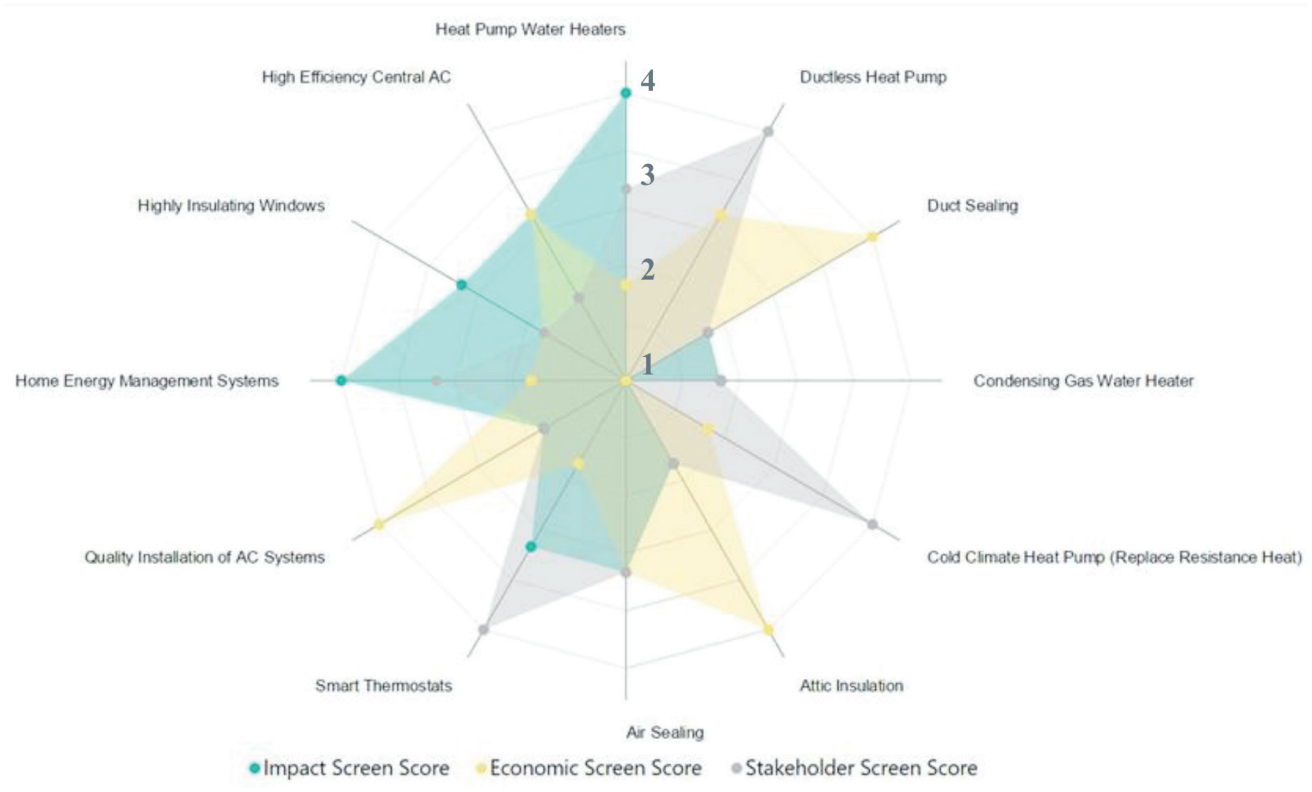


Figure 16. Impact, economic and stakeholder scores for prioritized energy efficiency measures

6. Appendix B: Value Proposition Profile for the HVAC Supply Chain Actors

6.1. Value Map: Contractor Perspective

Functional Area: Brand & Reputation	
GAINS	
High Priority	Access to federally supported brand
	Differentiation from other contractors
	Program branding and credibility
	Improved credibility with the customer
	Customer satisfaction (short and long term); improved customer experience
Med Priority	Certifications are a differentiator
	Recognition from manufacturer
	Recognition from DOE/EPA
	Leader in energy efficiency measures
	Be viewed as expert by peers
	Expert in green
PAINS	
High Priority	Need for differentiation
	Competing with utility programs (i.e. box swap rebates)
Med Priority	Unclear which credentials are most meaningful/impactful
	Customers are unsympathetic to additional (program) requirements
	Customers can become impatient or difficult

Functional Area: Technical Capabilities (training, tools, workforce; also quality & compliance)

GAINS

High Priority	Access to technical solutions, solving homeowner’s problems
	Technical know-how to be a quality installer with a quality product
Med Priority	Access to DOE programs and tools
	Training
	Being on top of my game

PAINS

High Priority	Being “expert” enough in a variety of areas to seem knowledgeable
	Staying current with best practices and new products
	Regulatory and code compliance
	Finding, training, and retaining a skilled labor force
	Dealing with Inspectors
	Lengthy modeling or load calculations
	Getting the credentials (indirect costs)
	Adhering to program standards in imperfect retrofit conditions
Med Priority	Having the right tools
	Lack of building science knowledge/technical know how
	Lack of availability of verified performance data
	Accessing hard to reach spaces (physical barriers)
	“kids” telling me how to do my job
	Houses are complicated and tough to solve problems
	More chemicals and hazardous materials

Functional Area: Business Processes (general abilities, business processes, demand smoothing)	
GAINS	
High Priority	Constant work cycle (fewer layoffs and seasonal swings)
	Program helps train and grow business
Med Priority	More diversified business
PAINS	
High Priority	Extra steps in HP process costs time and money
	Longer project cycle times
	More paperwork to fill out
	Tracking and reporting data/information
	Complex scheduling
	Coordination with other businesses/trades to solve whole house problems
	Larger scope of business
	Finding articulate techs and sales people
Med Priority	Inventory of other products
	More manufacturers to deal with
	More employees
	Maintaining focus on retrofit market when housing starts increase
	Forging relationships with trade partners, maintaining networks

Functional Area: Financial Impact (Profit & Loss)

GAINS

High Priority

- Increased profit
- Higher ticket sales
- Better margins
- Fewer callbacks
- Fewer warranty claims
- Opportunity to create customer for life
- Access to government and utility rebates
- Long-term financing offers at low cost
- No/low employee turnover
- Preferred access to incentives
- Ability to upsell beyond the project the customer called for (higher project value)

Med Priority

- Access to financing and other resources
- Inflation

PAINS

High Priority

- More training and time away from selling
- Labor costs are high for unqualified workers (i.e. cost of poor quality)
- Callbacks
- Hard to make money when programs are too prescriptive (e.g. fixed pricing)
- Liability

Med Priority

- More trucks (and maintenance costs)
- Financing (I am not a bank)
- Recouping the cost of a retrofit lead

Functional Area: Marketing & Sales	
GAINS	
High Priority	New business
	Qualified lead generation
	Increased word of mouth referrals
	Minimal to no marketing expense
	Preferential access to leads
Med Priority	Simple way to explain benefits
PAINS	
High Priority	Generating demand
	Conducting marketing, home shows, canvassing
	Selling intangible benefits: selling something the customer can't see
	Selling perceived value of insulation as opposed to other home improvements
	Generating qualified leads
	Learning to sell vs. quote projects
	Longer sales cycle
	More work selling up front
	Competing for consumer dollars vs. other trades and investments
	Lack of customer awareness
	Putting primary sale at risk with add on work (program requirements)
	Program gets between me and my customer
Med Priority	Training sales people to sell to the homeowner vs. selling B2B (e.g. working with builders)
	Translating work to customized value proposition for each customer
	Limited customer knowledge
	Properly estimating/pricing a retrofit project
	Losing to the low bidder

6.2. Value Map: Distributor Perspective

Functional Area: Brand & Reputation	
GAINS	
High Priority	Differentiate with a green supplier
	Offer great service
Med Priority	Recognition for Distributor with manufacturer
	Potential for national recognition by DOE, EPA
PAINS	
High Priority	Building and growing brand recognition
	Competing brands

Functional Area: Technical Capabilities (training, tools, workforce; also quality & compliance)	
GAINS	
High Priority	Becoming a full service provider
Med Priority	Adding new services
PAINS	
High Priority	Addressing more quality issues; conducting verifications
	Complex processes to require of dealers
Med Priority	Learning the role of an HP expert
	Dealing with codes

Functional Area: Business Processes (general abilities, business processes, demand smoothing)	
GAINS	
High Priority	Can supply to a broader group of dealers (could supply more than one manufacturer's product)
	Easier to recruit dealers with parts and supplies businesses
Med Priority	Brings more dealers into distributor's network
	New business line opportunities
	Seasonal sales opportunities with "shoulder season" sales
PAINS	
High Priority	More inventory space needs; and costs too
	More infrastructure/warehouses to maintain
	Different/more inventory to stock and manage
	Different salesperson structure (parts and supplies TM's, equipment TM's)
	Slow movement of product in shoulder months
	Involves many more contractors/dealers, small firms, higher transaction costs
Med Priority	Larger network of businesses to coordinate with/builders)
	More suppliers to deal with
	More counter people
	Too many dealers/contractors to keep track of
	More manufacturer and utility programs to deal with
	Finding labor
	Being a consultant

Functional Area: Financial Impact (Profit & Loss)

GAINS

High Priority	Increased profit/margin/sales
	Access to financing and other resources

PAINS

High Priority	Being a bank for dealers/contractors
Med Priority	Inflation

Functional Area: Marketing & Sales

GAINS

High Priority	Differentiation of services to offer
	Improved word of mouth
Med Priority	Being known as the expert

PAINS

High Priority	Possible distributor role in finding and qualifying dealers/contractors to participate
	Pitching benefits to dealers/contractors
Med Priority	The many programs compete with the distributor's brand
	Accessing local marketing monies

6.3. Value Map: Manufacturer Perspective

Functional Area: Brand & Reputation	
GAINS	
High Priority	Positive customer experience
	Improving people’s lives (homeowners and dealers)
	Being seen as a lead generator
	Improving opportunities for contractors/dealers
	Healthier financials for contractors/dealers
Med Priority	Improving customer perception of brand
	Brand awareness
	Being seen as an industry leader
	Improving national credibility of the manufacturer’s business among the building science community
	Good public perception of company’s dedication to the environment
PAINS	
High Priority	Bad or poor installers of product may give a bad reflection on manufacturer brand
Med Priority	Looking undifferentiated

Functional Area: Technical Capabilities (training, tools, workforce; also quality & compliance)	
GAINS	
High Priority	Confidence that products are installed well; ensuring proper installation
	Developing & maintaining highly trained contractor workforce/dealers to deliver product
Med Priority	Access to technical assistance and training resources (including for quality assurance)
PAINS	
High Priority	Improving a home’s performance is complex
	Gathering data about the home

Functional Area: Business Processes (general abilities, business processes, demand smoothing)

GAINS

High Priority	Making money; improving profits
	Selling more product (all product lines)
	Gaining greater insight into customer needs
	Building a customer for life
Med Priority	Reducing call backs
	Strengthening partnerships with contractors/dealers
	Growth in the number of branded contractors/dealers

PAINS

High Priority	Processing/monitoring workforce credentials
	Designing a new approach or offering for contractors/dealers
	Designing approach for providing leads to contractors/dealers
	Home performance can involve trades beyond the mechanical systems
Med Priority	Administrative oversight burdens (when working with programs)
	Infrequent/indirect contact with homeowners (contractors/dealers are the front lines)
	Data collection/reporting requirements for programs

Functional Area: Financial Impact (Profit & Loss)	
GAINS	
High Priority	Reduced warranty claims
Med Priority	Potential strategic alliances with other businesses/organizations
	Better contact with utilities/programs
PAINS	
High Priority	Manufacturer and manufacturer sales reps do not make money on HP jobs
Med Priority	Addressing any warranty claims
	Addressing any warranty claims

Functional Area: Marketing & Sales	
GAINS	
High Priority	Access to more precise and detailed information about customers
	Access to aggregated data describing market (housing, home improvements, etc.)
Med Priority	Branded equipment specified in more utility programs
	Additional connections to ENERGY STAR brand
PAINS	
High Priority	Steep learning curve for manufacturer sales people
Med Priority	Large number of regional programs that overlap with distributor territories
	Customer confusion about quality of so many different brands/products

7. Appendix C: Planned FY17 HI Cat Activities

RBI has planned HI Cat activities for fiscal year 2017. The below Figure 17 shows a summary of activities related to planning efforts such as the finalization of this plan, advanced HVAC and quality installation and foundational resources to address home improvement transaction points and properly sequence energy efficiency measures.

RBI will update the summary of planned activities each year on the BTO HI Cat webpage, <https://www.energy.gov/eere/buildings/home-improvement-catalyst-hi-cat>.

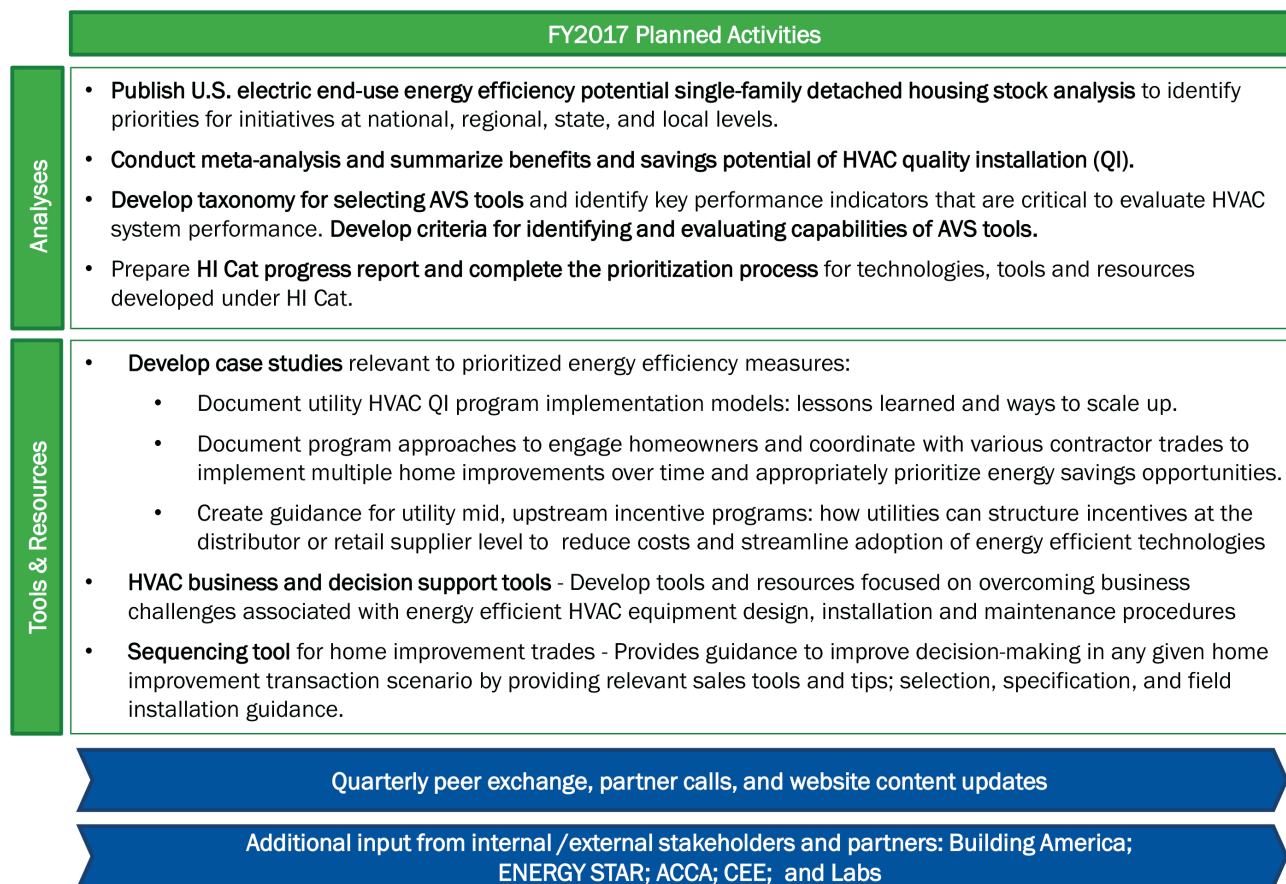


Figure 17. FY17 Planned HI Cat Activities

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For more information, visit: energy.gov/eere/buildings

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