U.S. Department of Energy Building Technologies Office
Residential Buildings Integration

Building America Program Draft Technology-to-Market Roadmaps

Date: April 3, 2015
Version: Public Comment Period Draft

Table of Contents

Table of Figures

Introduction

This report has been prepared by the U.S. Department of Energy's (DOE's) Building America program, the research, development, and demonstration (RD&D) arm of the Residential Buildings Integration (RBI) Program, within the DOE Office of Energy Efficiency and Renewable Energy's (EERE's) Building Technologies Office (BTO). For more information on any of these programs, please visit the website links provided above.

This report introduces the integrated *Building America Technology-to-Market Roadmaps* that will serve as a guide for Building America's RD&D activities over the coming years and result in an integrated *Building America Research-to-Market Plan* in 2015. This report includes salient background information about the initial draft roadmaps, an explanation of the process employed to develop the roadmaps, and details for stakeholder review and comment.

Background

The long-term goal of BTO is to develop and deploy technologies and systems to save the nation $2.2 trillion in energy-related costs through a 50% reduction in building energy consumption. To deliver on this goal, BTO employs a three-pronged strategy for advancing building technologies and practices, referred to as the BTO Ecosystem: (1) Research & Development (R&D) of advanced technologies, primarily through the Emerging Technologies (ET) Program; (2) Market Stimulation of Innovations through the Residential Building Integration (RBI) and Commercial Building Integration (CBI) Programs; and (3) Codes and Standards development and implementation through the Building Energy Codes and Appliance and Equipment Standards Programs to raise minimum industry standards once higher-performance technologies are proven cost effective at scale.

The ET Program is BTO's primary R&D program, leading up to commercialization of advanced building technologies. However, commercially available equipment and materials are often underutilized in the field because of building integration issues and market barriers. BTO addresses these challenges for residential buildings through its RBI Program, which works within the BTO Ecosystem to stimulate market adoption of whole-house energy-saving innovations.

The goals of BTO's RBI Program include the following:

1. Demonstrate at scale market-relevant strategies for new homes offering savings of 50% or more by 2025.
2. Demonstrate at scale market-relevant strategies for existing homes offering savings of 20% or more by 2020, 25% or more by 2025, and 40% or more by 2030.

RBI's Building America program conducts applied RD&D in residential buildings, in many cases linking technologies from the ET Program to the Codes and Standards Programs through demonstration projects that cost-effectively integrate these emerging technologies into residential building systems. Building America projects are led by DOE national laboratories and expert building science teams, in partnership with leading industry players (i.e., builders, contractors, manufacturers, and others).

DOE selects strategic Building America projects that can simultaneously develop and demonstrate better technologies and practices while overcoming critical market barriers to adoption, such as real and perceived technical and business risks, and codes and standards limitations. DOE also prioritizes projects that can leverage influential early adopters in order to stimulate market adoption. Building America industry partnership teams then demonstrate that the high-performance technical solutions and best practices featured in the projects are low risk and can lead to added business benefits.

Voluntary above-code programs (e.g., ENERGY STAR for New Homes and Home Performance with ENERGY STAR [HPwES]) and participating early adopters follow Building America's lead. This results in greater market penetration and adoption of energy-saving technologies and practices in new high-performance homes and existing home improvements, ultimately paving the way for better industry standards and advanced building codes.

Results from Building America projects, including proven innovations and lessons learned from RD&D projects, as well as best practice guidance culled from the Building America project portfolio, are made available through technical reports and the Building America Solution Center (BASC). The BASC (basc.energy.gov) captures Building America's best practices to help builders, contractors, installers, raters, and others in the building industry apply the latest results from Building America teams and national laboratories.

Building America "Version 2.0" – A New Program Strategy

Problem Statement

Despite significant advancement of energy efficient home technologies and best practices, including voluntary market advances and adoption of advanced codes such as International Energy Conservation Code (IECC) 2012, large technology and information gaps remain. These gaps prevent further advancement and mainstream adoption of the high-performance home technologies and systems for both new and existing homes that are needed to achieve DOE's energy-savings goals at scale.

The same market barriers that have discouraged the industry from investing in research have also led to gaps in market adoption. Increased energy performance brings new technical challenges and can increase risk to builders and contractors. Real and perceived risks associated with adopting new technologies, combined with a general lack of understanding by housing industry stakeholders of business models that can create profit from improved home performance, prevent quick uptake of new energy-saving technologies and design approaches. Without proof that these new technologies and business models are safe, effective, and provide real business benefits, the market will not move forward with energy efficiency at the rate required to meet DOE's long-term energy-savings goals.

Furthermore, the housing industry is at a critical juncture in its ability to deliver homes that safely and effectively meet increasingly demanding performance requirements in building energy codes. With the 20th-century inventions of labor-saving building materials, such as gypsum board and oriented strand board (OSB) sheathing, as well as market introduction of new materials that reduce infiltration and vapor diffusion, such as house wraps and adhesives, building envelope assemblies are less tolerant of design and installation flaws. Modern building envelopes do not dry out as easily as old, inefficient structures, which inherently increases the risks of moisture accumulation within building assemblies. Before any further advancement of building energy codes (e.g., additional insulation or air-sealing requirements) is possible, these envelope moisture risks must be better managed. The housing industry is at a "building science tipping point," where quick technological advances are needed to ensure that high-performance homes do not incur additional risk of building failures.

Program Strategy Overview

To solve these problems and help the housing industry and building codes improve home performance and reach aggressive efficiency goals, Building America has developed a new program strategy that builds on the program's historical successes and lessons learned and addresses current market needs. Leveraging past Building America successes and lessons learned, DOE has identified critical research and information gaps for three key housing technology areas: (1) high-performance building envelopes, (2) optimal comfort (i.e., heating, ventilation, and air conditioning [HVAC]) systems, and (3) optimal ventilation and indoor air quality (IAQ) solutions.

Figure 1 shows the evolution of energy use in homes over time and provides context for the *Building America Research-to-Market Plan* and the three *Building America Technology-to-Market Roadmaps* described in this report.

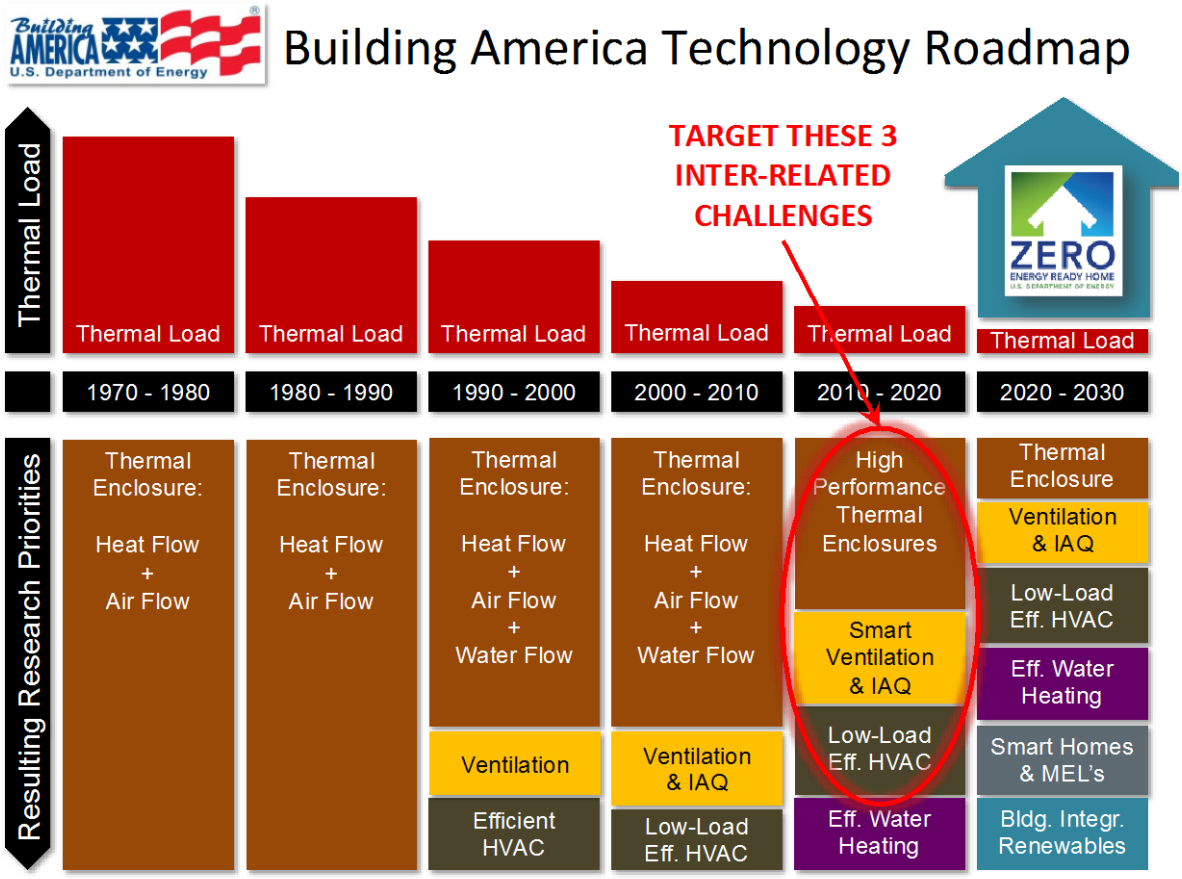

Figure 1. Building America Technology Roadmap Overview

Filling the research and information gaps for these three housing technology areas will be the focus of the program's new *Building America Research-to-Market Plan*. The plan will set specific program objectives for the next 5 years with three integrated and strategic *Building America Technology-to-Market Roadmaps*, corresponding to the critical technical challenges highlighted in Figure 1. Meeting the strategic objectives of these roadmaps will accelerate adoption of high-performance homes and home improvements throughout the U.S. housing industry.

The *Building America Technology-to-Market Roadmaps* will be developed and refined with periodic inputs from stakeholders and building science experts to ensure continued market relevance and value. The roadmaps are integrated to ensure strong links between Building America's RD&D results, RBI deployment programs (i.e., Zero Energy Ready Homes [ZERH], Better Buildings, and HPwES), and BTO codes and standards initiatives.

Feedback solicited from this Request for Information (RFI) will be used in part to plan and develop the Building America fiscal year (FY) 2016 Funding Opportunity Announcement (FOA), and possible future FOAs, as the Building America program works to meet RBI's long term program goals.

Program Objectives

The new Building America program strategy will enable market adoption of high-performance home technologies and best practices at scale (i.e., throughout the new home construction and home improvement markets) so that the housing industry and future energy codes can better promote energy efficiency. The strategy focuses on developing and demonstrating the following critical innovations, as well as improving market infrastructure to promote adoption of these innovations:

- **Water-Managed High-Performance Enclosures.** The tighter the building enclosure, the less it can dry when needed. Building America will provide high-performance construction and retrofit solutions that manage moisture risks, reduce mold potential, and improve building durability and IAQ. Moisture-managed, high-performance building assemblies will have increased insulation, reduced infiltration, reduced risk of condensation, and adequate drying potential year-round.
- **Optimal Comfort Systems for High-Performance Homes.** High-performance homes have dramatically lower heating and cooling requirements. Building America will provide efficient HVAC equipment and distribution system solutions for high-performance homes with low thermal loads, including optimal efficiency, managed air flow, and relative humidity (RH) control at all part-load conditions. Optimal comfort systems will effectively mitigate humidity and comfort risks due to reduced air flow and longer swing seasons that result from lower thermal loads in high-performance homes.
- **Comprehensive IAQ Systems.** Tight building enclosures lead to less infiltration of fresh outside air. Building America will provide smart ventilation systems and non-ventilation (e.g., source control) solutions for improved IAQ, with little or no energy penalty.

Why These Objectives Matter for New Home Construction

Because modern building envelopes do not dry out as easily as old, inefficient structures, the risk of moisture accumulation is higher within modern building assemblies. In addition, tighter building envelopes need controlled fresh air ventilation to ensure acceptable IAQ. The laws of physics have not changed; air, moisture, and heat still flow in and out of buildings according to the laws of thermodynamics. However, building materials, equipment, and construction practices have changed substantially over the last century.

Innovation in building materials and equipment and changing consumer expectations about comfort (e.g., mass market adoption of central air conditioning) have transformed the way modern buildings perform. However, the housing industry's understanding of how these changes affect building performance has evolved slowly because "tried and true" builder know-how has traditionally developed over centuries of trial-and-error experience. Today, the old design "rules of thumb" no longer apply. Modern building envelope assemblies are less tolerant of design and installation flaws. They must be better designed and constructed to control thermal, air, and moisture flows in and out of the structure. Three primary factors have led to this "building science tipping point":

- Innovative labor-saving building materials, such as gypsum board and OSB sheathing, have changed the way building envelopes behave. In addition, market introduction of

new materials that reduce uncomfortable "drafts" (i.e., house wraps and adhesives) have also contributed to the reduced drying potential of building assemblies. Even new homes not considered energy efficient by today's standards are naturally tighter and less forgiving to moisture intrusion than older homes.

- The dramatic increase in central air conditioning, even in colder climates, has significantly changed the thermal conditions inside homes throughout the United States during much of the year. These relatively new operating conditions have fundamentally changed thermal, air, and moisture dynamics in homes.
- The latest building energy codes (i.e., IECC 2009, IECC 2012, and IECC 2015) require significantly increased airtightness and insulation levels. When designed and installed properly, these new requirements cost-effectively improve comfort and energy efficiency. However, design and installation problems persist throughout the industry, leading to increased risk of failing to meet higher-performance home requirements.

The new home construction industry has not completely caught up with the new "building science imperative" and faces challenges in delivering homes that safely and effectively provide higher levels of performance. If these performance issues are not solved, energy efficient homes will have comfort and durability problems, builders will not exceed current code requirements, and energy codes will not promote increased energy efficiency.

Why These Objectives Matter for the Existing Home Improvement Market

The existing home retrofit industry faces the same risks as the new construction industry, with the following additional challenges:

- Air-sealing is often the most cost-effective measure for improving the energy and comfort performance of homes. However, air-sealing changes the building's thermal, air, and moisture flows. Consequently, air-sealing must be accompanied with actions to ensure both combustion safety of existing combustion appliances and fresh air ventilation for acceptable IAQ. These additional requirements can be more difficult to address in existing homes because of costs and potential problems accessing hidden pipes, ducts, wiring, and equipment.
- The costs of retrofitting an existing home to the same performance level as new construction can be cost prohibitive, with additional pre-retrofit testing needed and extra costs for removing old materials and equipment. Uncertainty about these additional costs prior to beginning a job increases the business risk.
- Retrofit measures occasionally exacerbate HVAC system design or installation flaws that were not noticeable prior to the retrofit. This also increases risk and/or costs associated with improving the building, which is another significant entry barrier for home energy retrofit businesses.

In addition to the solutions needed for new construction, the home performance retrofit industry needs the following:

- Envelope air-sealing solutions that effectively (1) manage moisture risks and (2) reduce the costs of testing and of removing old materials.

- Low-cost HVAC upgrade solutions that can effectively manage reduced loads without short-cycling or loss of humidity control.
- Low-cost ventilation systems that are suitable for retrofitting and compatible with existing construction and HVAC distribution systems.

Building America Research-to-Market Plan

Plan Development

Building America is developing a 5-year *Building America Research-to-Market Plan* in 2015 that is tightly focused on developing effective solutions for the aforementioned technical challenges. To date, this planning process has resulted in a set of three integrated *Building America Technology-to-Market Roadmaps* that will enable rapid market adoption of high-performance home technologies and best practices by filling critical research and information gaps.

The roadmaps are designed to achieve the following:

- Provide clear program objectives for each critical challenge.
- Develop solutions that are practical and profitable for builders and home improvement contractors.
- Link RD&D efforts with market deployment programs and codes and standards initiatives.
- Develop best practices and lessons learned to be shared in the BASC and through other deployment tools and websites.
- Engage key industry and market stakeholders in the Building America RD&D process.
- Use codes and standards improvements as endpoints for the greatest long-term market impact.
- Manage technical and business risks to minimize problems of adoption.
- Achieve optimal performance and cost effectiveness.

Providing clear program objectives will focus program resources on the highest-priority activities and provide concrete, measurable results. Linking research activities with market deployment activities and codes and standards initiatives will help break down silos and ensure BTO residential program activities are coordinated efficiently and collectively impact the market. The process of developing and refining the *Building America Research-to-Market Plan* and roadmaps over time will ensure accountability and responsiveness to changing market conditions and stakeholder value.

2015 Planning Schedule

The process for developing, vetting, and finalizing the *Building America Technology-to-Market Roadmaps* and the *Building America Research-to-Market Plan* is as follows:

- Public review and comment period on the *Building America Technology-to-Market Roadmaps*, planned April 1–30, 2015.
- RFI Informational Webinar, Tuesday, April 7, 3–4:30 pm (ET). Register here: https://attendee.gotowebinar.com/register/8686201597923361282.
- Revisions to the draft *Building America Technology-to-Market Roadmaps* addressing public comments and input from building science experts, as follows:
    - Envelope Systems Roadmap Expert Meeting, Oak Ridge National Laboratory, May 18, 2015.

    - Comfort Systems Roadmap Expert Meeting, ASHRAE Summer Meeting, June 28, 2015.
    - Indoor Air Quality Systems Roadmap Expert Meeting, ASHRAE Summer Meeting, June 28, 2015.
- Publication of revised *Building America Technology-to-Market Roadmaps* and *Building America Research-to-Market Plan* by September 2015.

Draft Building America Technology-to-Market Roadmaps

The following roadmaps are presented for public review and comment. Responses to Building America's RFI must be submitted electronically to BuildingAmericaRFI@ee.doe.gov no later than 5:00 pm (ET) on April 30, 2015. Responses must be provided to the email address above as Microsoft Word document attachments. A separate Word document should be sent for responses to each category and should be limited to two pages each. In addition, one supporting technical document (e.g., PDF technical report or Excel analysis sheet) is permitted for each response. It is recommended that attachments with file sizes exceeding 25 MB be compressed (i.e., zipped) to ensure message delivery. Only electronic responses will be accepted.

Please identify your answers by responding to a specific question or topic if possible. Respondents may answer as many or as few questions as they wish.

EERE will not respond to individual submissions or publish publicly a compendium of responses. A response to this RFI will not be viewed as a binding commitment to develop or pursue the project or ideas discussed.

Narratives and details of roadmap activities and timelines are provided in the following sections. As previously noted, a webinar will be conducted to provide full context and additional details for these roadmaps during the public review and comment period.

The following key (Figure 2) is presented for use in interpreting the roadmaps:

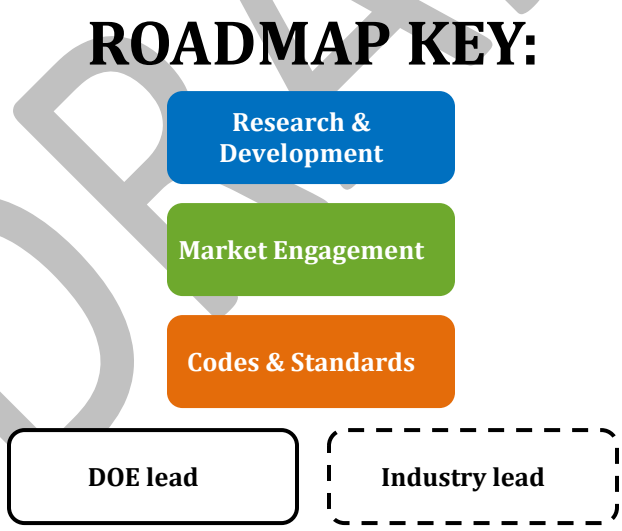

Figure 2. Roadmap Key

1. High-Performance Moisture-Managed Envelope Solutions Roadmap

Problem: Risk of moisture problems prevents adoption of high-performance building envelope assemblies

High-R-value (high-R) building envelope assemblies (i.e., foundation, walls, and roof) are the biggest potential home energy-saving measures—heating and cooling loads account for nearly 50% of home energy use. Based on a prioritized building technologies assessment, high-R building envelope assemblies in homes can decrease energy use by about 2.75 quads per year, which is nearly 3% of the energy consumed in the United States. However, the combination of recent code-mandated increases in building envelope system R-values and the anticipated improvements in airtightness has created concern among builders regarding the durability of next-generation wall, roof, and attic systems because they may have lower moisture tolerance due to their reduced drying potential. Current solutions are expensive and/or unfamiliar to many builders, contractors, and code officials, and some solutions are limited by International Residential Code (IRC) code barriers (e.g., fire and structural).

Evidence that the risk of moisture problems prevents adoption of high-performance building envelope assemblies includes the following:

- BTO Codes Group input, based on EERE discussions with key IECC stakeholders regarding the major perceived risk of increased R-values in IECC.
- Building America Envelope Standing Technical Committee and Expert Meeting reports identify moisture risk in high-R walls as the highest technical priority.
- A Building America team test hut study (Home Innovation Research Labs, 2013) of nine IECC 2012 compliant assemblies showed a risk of high moisture content in OSB exterior wall sheathing (Zone 4).
- An Oak Ridge National Laboratory (ORNL) test hut study (2013) of eight airtight assemblies with IECC 2012 insulation indicated a risk of mold on sheathing (Zone 5).
- A Building America team hygrothermal simulation study (Building Science Corporation, 2013) of eight high-R wall assemblies with defects indicated a risk of high moisture content in sheathing (Zones 2–7).
- Numerous building science experts on Building America teams have observed patterns of failure.

Needed Solutions

Many steps must be taken to address this problem, including the following:

- Develop high-R envelope solutions for new and/or existing houses that are cost effective, low risk, and durable.
- Demonstrate the solutions in real-world houses.
- Measure performance.
- Develop guidance and risk assessment tools.
- Develop optimal sequencing strategies for staged retrofits.
- Solve code barriers, as appropriate.

Solutions for both new and existing homes will include resolution of perceived cost and risk barriers to market acceptance of optimized building envelope systems; guidance, tools, and/or standards for assessing and managing related technical risk; development of design guidance and details for the BASC; development of model specifications; data collection and analysis to validate solutions; and solutions to code barriers such as restrictive fire code or structural requirements for high-R walls, as appropriate.

Roadmap Overview

Solutions to the problem of moisture risk in modern buildings have not gained significant traction in the building industry. RBI seeks to overcome this adoption barrier with moisture risk assessments that demonstrate that high-performance envelopes can be both energy efficient and durable.

This roadmap seeks to conduct R&D to evaluate the hygrothermal performance of high-R building envelope assemblies for new and retrofit construction that have high deployment potential. These R&D efforts will rely on results from field tests and laboratory evaluations to calibrate and validate simulation tools. The improved models will be used to conduct probabilistic risk analyses that will identify designs that are least likely to encounter moisture problems in each climate zone. The concurrent implementation of field tests, laboratory evaluations, and improved simulations that supplement each other will ensure trustworthy conclusions.

Further roadmap efforts will focus on improving existing moisture-related standards that are currently perceived by the construction industry as useful but too conservative, such as ASHRAE 160. Moreover, specifications for high-performance envelope systems that incorporate results from the R&D moisture-related assessments will be generated for voluntary programs. Lastly, market stimulation will be advanced by issuing construction guidelines and tools that aim to prevent moisture problems, and by promoting the developed specifications in order to prime the market for high-performance envelope systems.

The end objective of this roadmap is that its efforts on R&D, standards, and market stimulation will provide a comprehensive and compelling basis for building codes to adopt developed high-performance building envelope assemblies that are both energy efficient and moisture durable.

The roadmap focuses on two main areas:

1. ***Moisture risk management***, identifying high-R designs that are least likely to encounter moisture problems in each climate zone.
2. ***High-performance envelope systems***, developing best practice guidance and specifications for envelope systems with high thermal performance and minimal moisture risk based on validated performance.

Figure 3 presents the detailed roadmap:

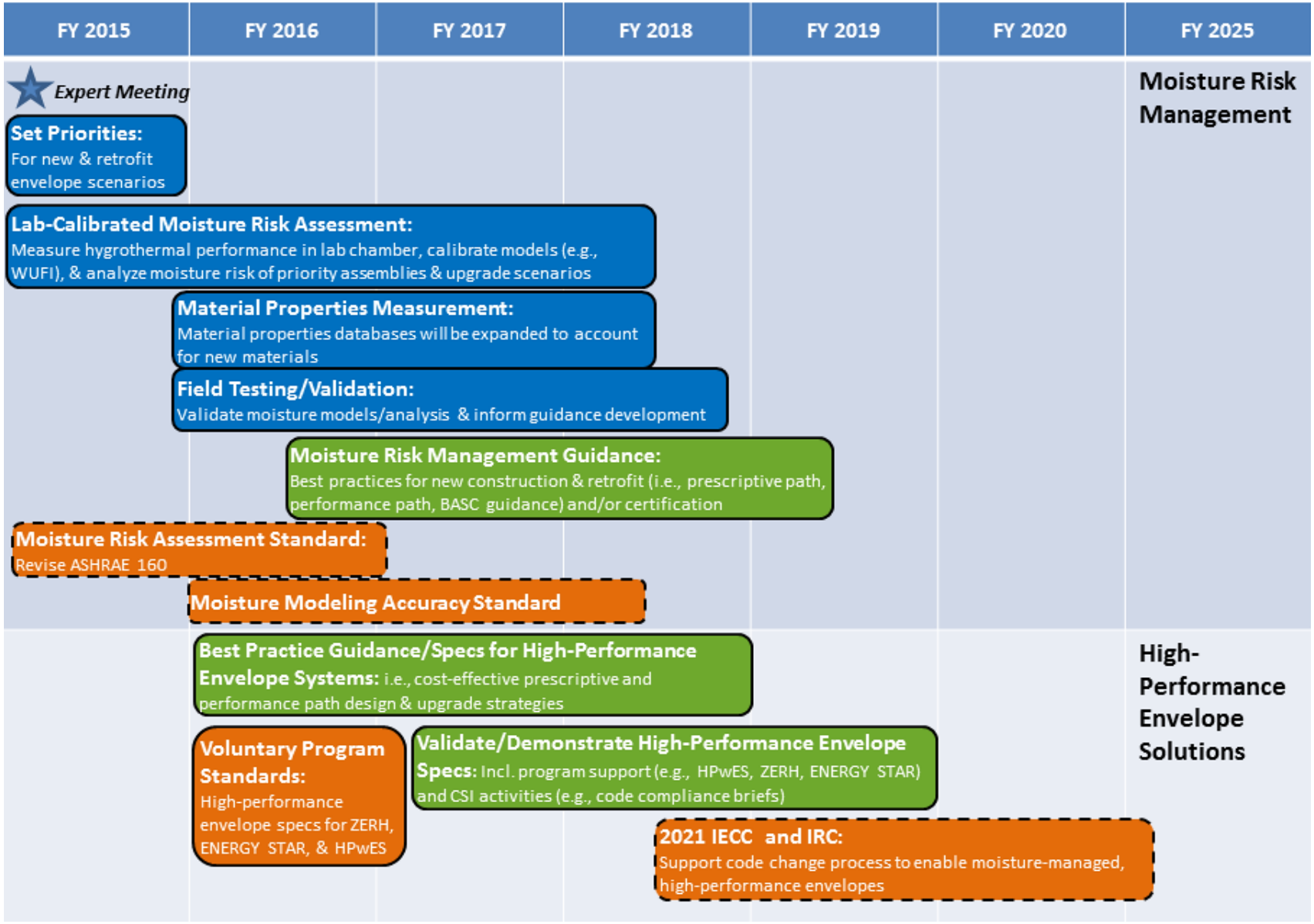

Figure 3. High-Performance Moisture-Managed Envelope Solutions Roadmap

Draft Roadmap Description: Moisture Risk Management

R&D efforts will be based on probabilistic risk analyses that will identify the high-R designs that are least likely to encounter moisture problems in each climate zone. The assemblies evaluated will include designs for new and existing homes that have high deployment potential. To this end, simulation tools will be improved to take into account airflow effects, and the models will be calibrated and validated with laboratory experiments and field tests. Material properties of new materials entering the marketplace will be measured and added to existing databases. This activity will enhance the ability of hygrothermal models to accurately reflect the moisture performance of envelope systems. The performance of materials that have been previously wetted or have been in service for extended periods of time will also be evaluated. In addition to including these material properties in hygrothermal model databases to enable a greater understanding of system-level performance, laboratory chamber and field tests will be used to further validate durability. R&D findings will be used to generate best practice guidelines on moisture risk management that will stimulate the adoption of the evaluated high-R assemblies.

Moisture-related codes and standards will be addressed in parallel to the R&D work. Tasks include improving ASHRAE SSPC 160 (Criteria for Moisture-Control Design Analysis in Buildings). Although this standard is used by building scientists, its adoption by building codes and key stakeholders in the building industry is hindered by factors such as complexity, limited validation, and over-conservative results. Moreover, efforts will be dedicated to increasing confidence in the results of moisture models by generating a standard that can be used to calibrate simulation results against actual measurements. This new standard will be guided by ASHRAE Guideline 14 (Measurement of Energy and Demand Savings).

Set Priorities

To prioritize research, DOE will host a meeting to bring together key building envelope experts to identify high-impact, high-R envelope measures whose market adoption is hindered by moisture risks. These measures could include high-R walls for new construction with unproven moisture durability, high-R roof and attic assemblies, and wall retrofit measures for existing construction that have a lower risk tolerance for moisture.

Conduct Laboratory-Calibrated Moisture Risk Assessment

Because high-R wall assemblies with increased airtightness can compromise the moisture durability and long-term performance of wall assemblies, the design of energy efficient walls should be accompanied by moisture risk assessments. This would help ensure a decrease in energy use, accelerate the adoption rate of energy efficient walls, and build confidence within the construction industry. The proposed protocol will leverage laboratory envelope environmental chambers and hygrothermal models (e.g., WUFI) to accomplish the following:

- Examine the effects of moisture sources in walls through a combination of simulations, laboratory experiments, and field tests.
- Calibrate a hygrothermal simulation tool so it can adequately model the effects of air leakage in wall assemblies.
- Validate the calibrated model with laboratory and field tests.
- Be applicable to both retrofits and new construction.

- Be based on a probabilistic approach that utilizes stochastically varying input parameters to expand the credibility and applicability of the results.

Conduct Field Testing/Validation

Field tests will be conducted by Building America teams to provide a basis for guidance documents, while also enabling the validation of hygrothermal modeling and the ground truth for the laboratory chamber results. High-risk climates and assemblies will be identified and tested.

Develop Moisture Risk Management Guidance

Specifications for high-performance envelope systems that incorporate results from the R&D moisture-related assessments will be generated for use by key stakeholders such as builders, retrofit contractors, and voluntary programs. This guidance will include construction guidelines and tools that aim to prevent moisture problems. The BASC will be the primary public interface for communicating guidance, which is consistent with the Building America approach to disseminating best practices.

Support Moisture Risk Assessment Standard Development

The current standard for moisture risk assessment is ASHRAE SSPC 160 (Criteria for Moisture-Control Design Analysis in Buildings). However, its adoption in building codes and by key stakeholders in the building industry is hindered by factors such as limited validation, false positive results (i.e., a wall known to be moisture durable is predicted to fail), and lack of agreement on the proper environmental conditions to model. Building America will support research and validation that will result in a risk assessment standard with widespread market acceptance and broad adoption.

Develop Moisture Modeling Accuracy Standard

Unfortunately, there is no current moisture modeling standard, which results in a "judgment call" by hygrothermal modelers regarding the validity of the chosen model. As high-R enclosures become broadly adopted and the need for hygrothermal modeling becomes more paramount, an accuracy standard that can be referenced is needed. Building America will work with key organizations such as ASHRAE to develop moisture modeling accuracy standards similar to those utilized for energy modeling.

Draft Roadmap Description: High-Performance Envelope Solutions

Best Practice Guidance/Specs for High-Performance Envelope Systems

This part of the roadmap will develop best practice guidance and specifications for envelope systems with high thermal performance and minimal moisture risk based on validated performance. These guidance documents will be used to provide cost-effective prescriptive and performance path strategies for inclusion in voluntary programs such as HPwES. As emerging technologies such as R-10 windows, window attachments for improved thermal performance, and smart windows are developed and made commercially available, Building America will validate their performance through field demonstrations, upon which best practices can be developed. Validate/Demonstrate High-Performance Envelope Specs

To support best practice guidance and specifications for envelope systems with high thermal performance and minimal moisture risk, Building America will validate performance in demonstrations to achieve greater market penetration.

Voluntary Program Standards

After high-performance envelope solutions are demonstrated, validated, and documented, Building America will work to include them in voluntary standards.

2021 IECC and IRC

The final step in this strategy will be to "lock in" energy savings through implementation and adoption in relevant codes (e.g., IECC and IRC). Building America will support the code change process as required to achieve this desired outcome.

2. Optimal Comfort Systems for Low-Load Homes Roadmap

Problem: Comfort (HVAC) system performance risks can be significant and may prevent adoption of high-performance home technologies and systems

Installed performance of HVAC systems, especially distribution system effects and latent performance, is typically suboptimal, which is a critical risk in low-load homes. Duct system and RH optimization are not often considered by manufacturers or required by codes or standards, and current solutions are labor intensive and/or expensive.

Evidence that comfort (HVAC) system performance risks can be significant and may prevent adoption of high-performance home technologies and systems includes the following:

- Codes Group input, based on EERE discussions with key IECC stakeholders regarding the major perceived risk of comfort problems in tighter homes (IECC 2012/2015).
- Building America Space Conditioning Standing Technical Committee and Expert Meeting reports identify air distribution issues, high RH, and equipment sizing problems affecting comfort in low-load homes as the highest technical priority.
- A Building America team study (IBACOS, 2012) investigated the most promising efficient HVAC solutions for low-load houses and found significant comfort risks related to latent performance and distribution effectiveness.
- Numerous studies and surveys have concluded that typically installed residential HVAC systems can operate inefficiently and waste considerable energy because of different installation errors (faults)—see the NIST report below for a relevant literature review.
- A recent NIST study (*Sensitivity Analysis of Installation Faults on Heat Pump Performance*) assessed the impacts of single and simultaneous HVAC system installation faults on annual energy consumption. The report found that the faults with the most potential for causing increased annual energy consumption include duct leakage, incorrect duct sizing or system airflow, and incorrect refrigerant charge. The report also found that the impact of multiple faults can be additive, and that excessive indoor humidity levels due to installation faults can also lead to significant increases in annual energy use.

Needed Solutions

Many steps must be taken to address this problem, including the following:

- Develop optimal HVAC selection and distribution system design/installation solutions.
- Demonstrate the solutions in real-world houses.
- Measure performance.
- Develop guidance.
- Solve codes and standards barriers.
- For both new construction and HVAC repair/replacement applications, validate/demonstrate optimum comfort system design and installed performance—energy use, thermal and RH control, air-leakage control, pressure management and air distribution/mixing effects, etc.—for any residential HVAC systems with high impact potential.

Solutions will include optimal comfort system details for inclusion in the BASC; improved and/or lower-cost sizing methods/guidance; simplified tools with minimal inputs that provide comparable/improved results relative to traditional methods; low-cost and reliable commissioning strategies; data collection/analysis to validate solution(s); and addressing how all of these efforts can be incorporated into codes and standards, as appropriate.

Roadmap Overview

High-performance, low-load homes face unique space conditioning challenges that are not adequately addressed by current HVAC design practices and equipment offerings. Low-load home comfort systems must address (1) year-round temperature and humidity control, and (2) air distribution and temperature uniformity throughout the home. RBI's goal is to ensure HVAC designers and builders have the tools necessary to design and install optimal comfort system solutions that address the needs of high-performance, low-load homes.

This roadmap seeks to conduct R&D to ensure residential equipment selection procedures adequately address year-round comfort control and temperature uniformity throughout the home. Previous Building America research, coupled with simulation studies and field test experiments, will be used to supplement existing comfort system design approaches to meet the needs of low-load homes. The improved comfort system design process will be validated using field demonstrations, and necessary revisions will be made.

Additional roadmap efforts will focus on meeting the equipment needs of low-load homes. By collaborating with manufacturers and conducting field demonstrations, RBI will help to ensure the spacing conditioning requirements of low-load homes can be satisfied with off-the-shelf equipment. RBI will develop best practice guidelines to ensure practitioners optimally select equipment and that installations achieve the expected efficiency.

The end objective of this roadmap is that its efforts on R&D, standards, and market stimulation will reduce the barriers to designing and installing high-performance space conditioning systems in low-load homes and are ultimately adopted by building codes to ensure homes meet occupant comfort expectations.

The roadmap focuses on two main areas:

1. ***System design*** ensuring occupant comfort is maintained uniformly throughout the home for the entire year.
2. ***Equipment*** capable of efficiently and consistently conditioning low-load homes is available on the market.

Figure 4 presents the detailed roadmap:

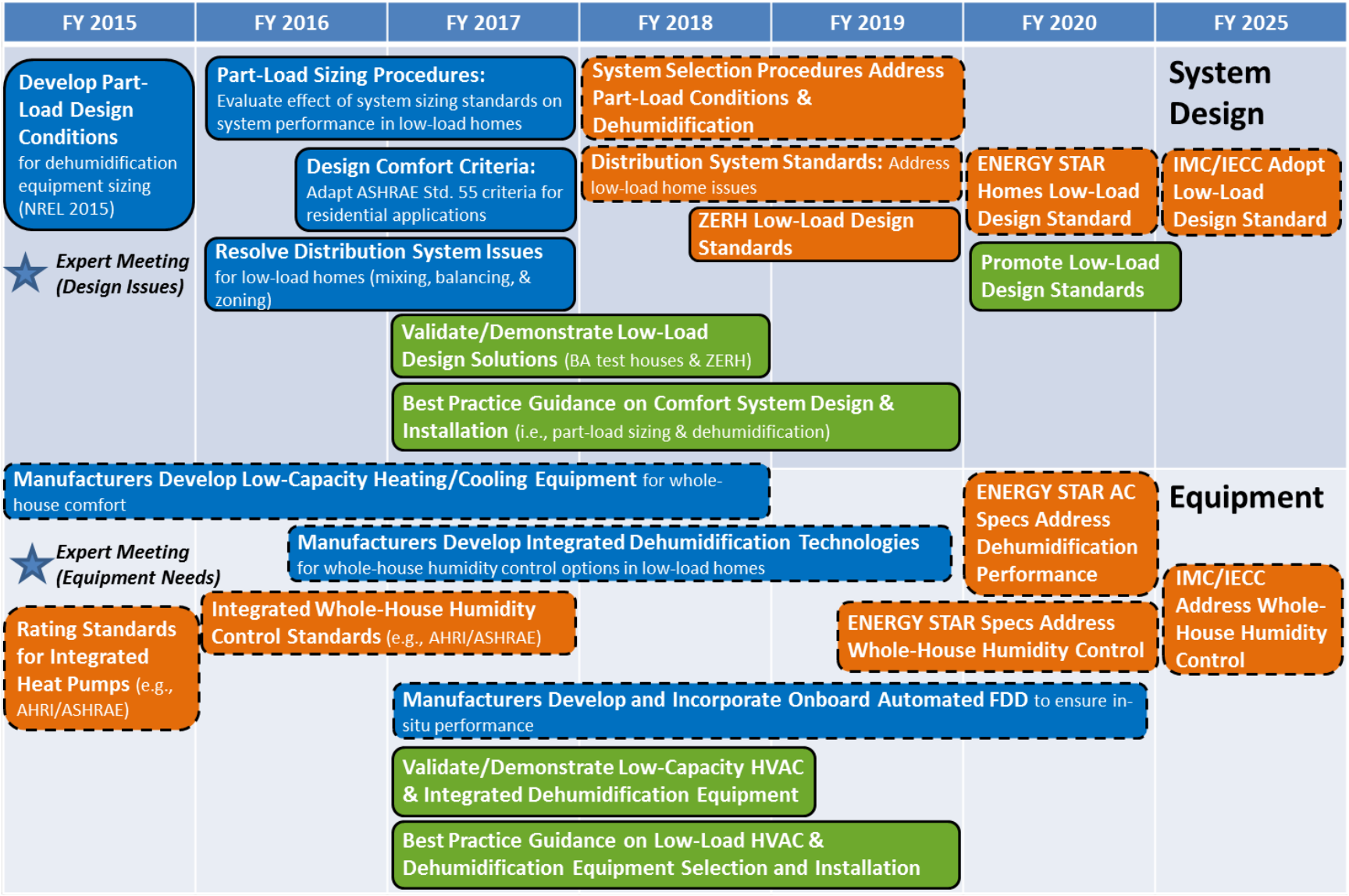

Figure 4. Optimal Comfort Systems for Low-Load Homes Roadmap

Draft Roadmap Description: Optimal Comfort System Design

Develop Part-Load Design Conditions

The first step in guaranteeing that low-load, high-performance homes can meet occupant comfort expectations is to ensure that system sizing and design standards appropriately address space conditioning issues unique to low-load homes. As a home's envelope improves, the peak and seasonal sensible cooling loads are reduced, which leads to smaller air conditioners and shorter cooling seasons. However, due to internal gains and fresh air ventilation, latent loads are not reduced as much as sensible loads, making indoor humidity control at part-load cooling conditions a critical need. Current equipment sizing procedures do not explicitly address the selection of residential dehumidification equipment that could be needed to ensure year-long comfort. Sizing HVAC equipment starts with using representative design conditions to calculate loads. In FY 2015, the National Renewable Energy Laboratory will research the first step in developing a method to select residential dehumidification equipment—determining the part-load cooling design conditions suitable for calculating residential dehumidification equipment needs.

Part-Load Sizing Procedures

The part-load design conditions developed in FY 2015 will be used in FYs 2016–2017 to evaluate the effectiveness of existing cooling equipment sizing procedures in calculating shoulder season latent loads, and necessary improvements will be researched to make existing methods work for sizing dehumidification equipment in low-load homes. Additionally, current cooling and heating equipment sizing methods will be verified for low-load homes.

Design Comfort Criteria

ASHRAE Standard 55 (Thermal Environmental Conditions for Human Occupancy) comfort criteria will also be evaluated for use in residential applications in FY 2016. Historically, Building America has set RH targets at 60%; however, ASHRAE Standard 55 allows for RH to exceed 60% at certain operating temperatures and clothing levels. Comfort criteria applicable to residential buildings need to be established to systematically evaluate potential comfort system solutions.

Resolve Distribution System Issues

Air distribution in low-load homes is challenging because low air flow rates and insufficient air mixing can lead to poor temperature distribution and reduced comfort. Building on previous Building America research, air distribution system issues will be resolved for low-load homes by FY 2018. Best practice distribution system design approaches and methods will be developed to provide uniform comfort in low-load homes.

Validate/Demonstrate Low-Load Design Solutions

To accelerate market acceptance of low-load home designs, successful space conditioning system designs need to be demonstrated. Starting in FY 2017, low-load home space conditioning design solutions will be demonstrated and validated using Building America unoccupied test houses and DOE ZERHs.

Best Practice Guidance on Comfort System Design and Installation

Using previously developed equipment selection and distribution system design methods unique to low-load homes, learning from field installations, and measured field results, best practice guidelines on system design and installation will be developed during FYs 2017–2019.

System Sizing Standards Address Part-Load Conditions and Dehumidification

Starting in FY 2018, previously developed methods to select space conditioning equipment for year-round comfort will be incorporated into existing standards. Ideally, existing system sizing standards would be revised to include the part-load design calculations necessary to select dehumidification equipment. If appropriate, new design standards specific to low-load homes could be developed.

Distribution System Standards

A parallel effort will address developing a new standard or revising existing standards to resolve distribution system needs unique to low-load homes. Similar to system sizing standards, this effort would ideally involve the revision of existing standards but could involve the development of a new standard specific to low-load homes. By the end of FY 2019, part-load equipment sizing standards will ensure year-round comfort is maintained, and air distribution standards will ensure uniform comfort is achieved throughout the home.

Low-Load Design Standards Adopted by Voluntary Programs and Codes

DOE's ZERH program requirements will be updated to require the documented use of the equipment sizing and air distribution design standards for low-load homes by the end of FY 2019. Starting in FY 2020, the ENERGY STAR homes program will also rely on the low-load home space conditioning design standards, as will International Mechanical Code (IMC) and IECC codes as standard construction practices trend toward low-load designs. Throughout FYs 2019–2020, ZERH and ENERGY STAR homes will promote and demonstrate the low-load home equipment design standards.

Draft Roadmap Description: Optimal Comfort Systems Equipment

Expert Meeting

A Building America expert meeting is being planned for June 2015 involving Building America teams, national laboratories, DOE, and residential space conditioning equipment manufacturers to discuss space conditioning equipment needs for low-load homes. Equipment manufacturers will learn where residential buildings are headed and where gaps exist in current equipment offerings. Over the following 4 years, manufacturers will be called upon to develop low-capacity heating and cooling equipment with integrated whole-house humidity control options for low-load homes.

Develop Low-Capacity Heating/Cooling Equipment for Low-Load Homes

A majority of the space conditioning equipment currently available on the market is oversized compared to the cooling, dehumidification, and heating loads that exist in high-performance, low-load homes. Available low-capacity equipment is challenging to interface with a distribution system.

Develop Integrated Dehumidification Technologies

There is a need for manufacturers to offer central equipment in lower capacities with integrated (built-in) humidity control suitable for low-load, high-performance homes. Given the nature of this issue, a majority of the efforts in this area will be led by industry. However, Building America will play a supporting role to help steer industry toward manufacturing/offering lower-capacity equipment.

Standards for Integrated Heat Pumps and Integrated Whole-House Humidity Control

In addition to improving low-capacity equipment availability, there is a need for additional performance data to allow system designers to optimally select equipment for a given home. In FY 2015, ORNL is working with the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) to develop a rating standard based on ASHRAE Standard 206 (Method of Test [MOT] for Rating of Multi-Purpose Heat Pumps for Residential Space Conditioning and Water Heating). ASHRAE Standard 206 covers a method to test residential air conditioners and heat pumps with integrated humidity control. Air conditioner and heat pump manufacturers provide expanded performance tables to system designers for properly selecting equipment. However, expanded performance data for dehumidification equipment (integrated or stand-alone) is lacking, and there is need for an AHRI or ASHRAE standard that increases the availability of humidity control equipment performance data for system design.

Develop Onboard Automated Fault Detection and Diagnostics

It is critical that installed equipment meets performance expectations and achieves optimal efficiency. Onboard fault detection and diagnostics will enable installers and owners to determine whether the equipment is underperforming and identify steps to remedy potential installation issues.

Validate/Demonstrate Low-Capacity HVAC and Integrated Dehumidification Equipment

Starting in FYs 2017–2018, Building America will demonstrate and validate the ability of new low-capacity equipment with integrated humidity control to consistently and uniformly condition a home.

Best Practice Guidance for Low-Load HVAC and Integrated Dehumidification Equipment

Best practice guidance on equipment selection, application, and installation will be developed during FYs 2017–2019.

Whole-House Dehumidification Standards Adopted by Voluntary Programs and Codes

In FY 2020, ENERGY STAR requirements for space conditioning equipment will account for dehumidification performance. The existing air conditioner and air-source heat pump specifications will be revised to account for latent performance, and ENERGY STAR will address the need for a specification on integrated, whole-house humidity control equipment. Further in the future, as standard construction practices trend toward low-load house designs, the IMC/IECC will address the need for whole-house humidity control.

3. Optimal Ventilation and IAQ Solutions Roadmap

Problem: IAQ risks prevent adoption of high-performance home technologies and systems

Basic home ventilation has become standard in some homes, building codes, and home performance programs. However, current applications and standards do little to optimize either IAQ or energy performance, and current ventilation solutions are limited by climate, controls, pollutant sources, and costs. In addition, significant IAQ risks remain, especially in low-load new homes and highly energy efficient home retrofits because envelope tightening reduces natural infiltration to levels that are too low for good IAQ.

Evidence that IAQ risks prevent adoption of high-performance home technologies and systems includes the following:

- Codes Group input, based on EERE discussions with key IECC stakeholders regarding the major perceived risk of IAQ problems in airtight houses (IECC 2012/2015).
- Building America Space Conditioning Standing Technical Committee and Expert Meeting reports identify IAQ in efficient airtight houses as a high technical priority.
- U.S. Environmental Protection Agency (EPA) (Indoor Environments Division) documents identify increased (2–5 times) health risks due to indoor pollutant exposures associated with airtight homes and homes without adequate ventilation and/or pollutant source control measures.
- ASHRAE Standard 62.2, Guideline 24, and other documents identify IAQ risks and best practices for acceptable IAQ; these practices are not widely or fully adopted/enforced in codes because of cost, education, and standards limitations.
- There is significant evidence that IAQ issues increase financial risk because of construction defect litigation; experts estimate this risk to be at least $1 billion industry wide, but accurate estimates are not available, because of confidentiality issues.

Needed Solutions

Many steps must be taken to address this problem, including the following:

- Develop low-cost, optimized ventilation and IAQ source control solutions.
- Demonstrate the solutions in real-world houses.
- Measure IAQ and energy performance.
- Develop guidance.
- Support inclusion in codes and standards.
- Address effective, low-cost ventilation solutions for new construction or existing home retrofits and their applicability (e.g., climate zone/building type).
- Demonstrate and assess energy savings and performance of “smart” ventilation controls/systems, including component integration, IAQ effectiveness, and reliability.
- May also address optimum distribution systems for ventilation systems, ventilation systems with integrated dehumidification, low-cost balanced ventilation systems, onboard diagnostic capabilities for ventilation systems, and field measurement supporting characterization of indoor pollution exposure risks.

- For retrofit applications, evaluate IAQ effects of staged retrofits, including effects of sequencing with other trades.

Solutions will include ventilation system and IAQ strategy details for inclusion in the BASC; optimum system specifications and requirements to minimize energy consumption while maintaining adequate IAQ in low-load homes; feasible low-cost IAQ and ventilation system field verification methods for program or code compliance; support for development of ASHRAE Standard 62.2 changes that allow more flexible, equivalent IAQ/ventilation approaches (e.g., source control – ventilation rate trade-offs); and data collection and analysis to validate ventilation and IAQ standard and code requirements for very tight homes, as appropriate.

Roadmap Overview

A primary challenge for the housing industry is meeting ventilation requirements while minimizing the energy impacts. RBI seeks to overcome this barrier by promoting (1) the development of high-performance homes with considerations for better IAQ, and (2) optimization for the trade-off between IAQ and energy performance.

This roadmap seeks to guide R&D to ensure that the development of high-performance homes accounts for the health of the occupants and the durability of the building. Reducing the energy impact of providing good IAQ requires technologies to be developed that optimize the balance between IAQ and energy. This includes developing solutions for pollutant control that reduce the air flow needed for dilution, developing smart ventilation technologies that are more sophisticated than simply running a continuous mechanical ventilation system, and expanding ventilation system capabilities to address some outdoor pollutants (e.g., ozone and particles).

The high-performance home industry has several options for providing energy scores to compare homes; this roadmap will facilitate development of a similar system for IAQ scores. This system will encourage better-informed choices about IAQ and provide a way to reward those in the building industry who put more effort into providing healthier, more durable homes.

The end objective of this roadmap is that its efforts on R&D, standards development, and collaboration with industry will lead to high-performance homes with great IAQ and minimized energy use. This will ease adoption of good IAQ by the high-performance home industry and increase the attractiveness of high-performance homes to the public.The roadmap focuses on three main areas:

1. ***Targeted pollutants/non-dilution solutions*** (including humidity)
2. ***Smart ventilation technology solutions***
3. ***IAQ valuation and equivalence in standards***

Figure 5 and Figure 6 present the detailed roadmap:

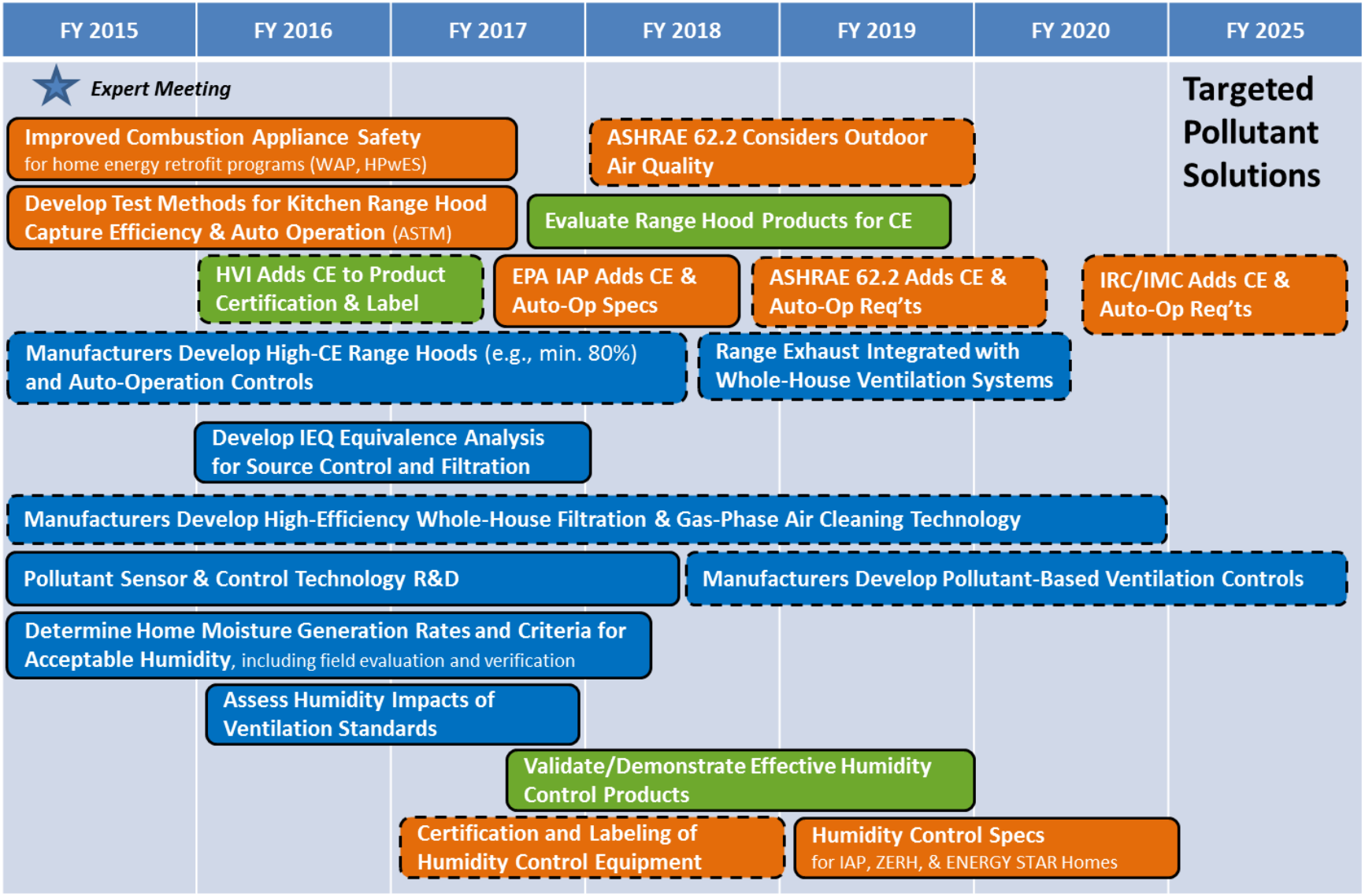

Figure 5. Optimal Ventilation and IAQ Solutions Roadmap (Part 1)

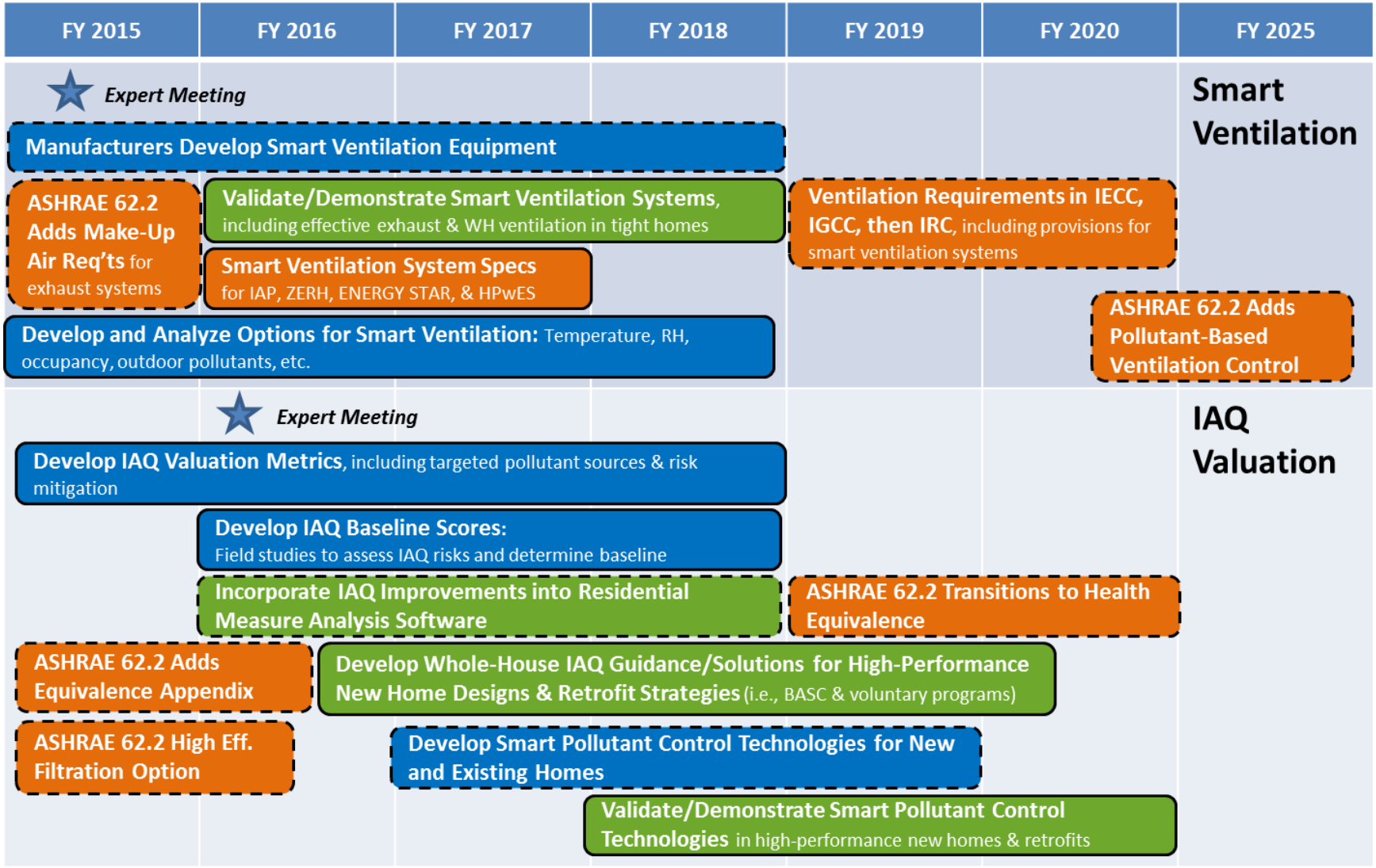

Figure 6. Optimal Ventilation and IAQ Solutions Roadmap (Part 2)

Draft Roadmap Description: Targeted Pollutants/Non-Dilution Solutions

A first step to ensuring good IAQ—and one that can be combined with other strategies—is to reduce the entry of contaminants to the occupied space. This can be accomplished through various methods, including the use of materials and products with lower chemical emission profiles, the use of effective kitchen exhaust ventilation to remove cooking-related contaminants, and the use of filtration and air cleaning to remove contaminants that are emitted or enter from outdoors.

Revised Combustion Safety Testing

Unvented or improperly vented combustion appliances can be a major source of moisture or air pollutant emissions into homes. Energy retrofits may create unsafe conditions in which existing exhaust fans depressurize spaces containing natural draft appliances, resulting in exhaust spillage. Many variations of combustion appliance safety (CAS) procedures exist, yet none explicitly identify their safety objectives. Complicated procedures and variability in results across procedures adds to the confusion. Among other efforts, this roadmap will work with multiple entities (e.g., the Building Performance Institute, the Residential Energy Services Network, state and federal weatherization programs, and utility programs) to adopt a core set of uniform procedures to improve consistency and clarity in the market. Through FY 2017, work will proceed on development and field testing of improved procedures, and Building America will work with industry stakeholders to increase harmonization of CAS objectives and methods.

Develop Test Method for Kitchen Range Hood Capture Efficiency

Cooking emits pollutants from gas combustion and electric heating elements, as well as from the cooking process itself. These pollutants need to be captured and removed (e.g., by using a range). Research indicates that many existing homes lack any kitchen ventilation, kitchen ventilation is not routinely used even when it is available, and range hoods vary widely in their ability to efficiently capture cooking pollutants even when they meet ASHRAE 62.2 minimum airflow requirements. Because range hoods are not currently rated for their effectiveness in capturing pollutants, users have no means to differentiate products based on performance and standard bodies cannot specify a requirement for IAQ performance. Efforts are underway to develop an ASTM consensus standard method of test for range hood performance, along with the associated laboratory testing. Development of the test method should be completed in FY 2016 for wall mount and under-cabinet range hoods. The test method will be expanded in future fiscal years to include island and downdraft systems.

Capture Efficiency Added to Product Certification and Labeling

Collaboration with equipment manufacturers and the Home Ventilating Institute will ensure that range hoods are tested and labeled as soon as the ASTM test method is completed. Quantifying the capture efficiency of range hoods will enable quantitative assessment of general kitchen ventilation requirements for equivalent IAQ protection.

Manufacturers Develop High-Capture-Efficiency Range Hoods with Auto-Operation

Automatic operation is a potentially important performance advancement for range hoods, because even the best hoods are ineffective when they are not used. This effort is envisioned to

include product R&D led by industry and development and demonstration of a consensus test method to assess performance. The development of products with better capture efficiency, quieter operation, automation, and other features will be an ongoing industry-led effort. The Building America program must play the key role in defining performance metrics, developing standard tests, working with codes and standards groups to set performance requirements, and conducting validation and verification testing as needed. In addition, increasing public and building industry awareness of the need for kitchen ventilation, and changing codes so that it is required nationwide, will require an ongoing collaborative effort between industry and DOE.

High Capture Efficiency and Auto-Operation Added to Voluntary Program Specs and Codes

The availability of capture efficiency and automatic operation performance test results will enable the specification of minimum performance requirements, first in high-performance home programs, then in codes and standards. It is anticipated that EPA's Indoor airPLUS (IAP) specification will be an early adopter and that ASHRAE 62.2 will be the first standard to require improved range hood performance, with later adoption by IRC/IMC.

Manufacturers Develop Improved Filtration and Air-Cleaning Equipment

Manufacturers are already developing effective, low-energy filtration products and working on efficient air cleaners for gaseous pollutants. Particle filtration is a particularly important strategy because particulate matter causes the most aggregate health damage of any indoor chemical air pollutant. Particles are emitted from various indoor activities such as cooking and cleaning, but they may also come from outdoors.

Encourage High-Efficiency Filtration in IAQ Standard

There is a current R&D effort to analyze the benefits of various filtration system designs and qualities, and to develop guidance on the best designs by home and household characteristics. A filtration credit to ASHRAE 62.2 based on the equivalence of various filtration approaches to the benefits of whole-house ventilation as an indoor source particle reduction strategy has recently been approved for public review by the ASHRAE Standard 62.2 Committee. Filtration is a more robust particle exposure reduction measure than ventilation because it addresses particles from both indoor and outdoor sources and addresses the single most important indoor contaminant, but it does not address all of the indoor contaminants that are addressed by ventilation.

Develop Pollutant-Based Ventilation Controls and Address Them in Standards

The particle and gaseous filtration products being developed by manufacturers must be independently tested to confirm performance. While standard tests and metrics are available for distinct products (e.g., a filter minimum efficiency reporting value [MERV] rating), system-level performance assessment may require new R&D products that will necessitate laboratory and field evaluation before standards can specify or give credits for their use. A longer-term goal is to have products on the market with sufficient effectiveness and energy-consumption needs for ASHRAE 62.2 to add pollutant-based ventilation controls as an option to the current whole-house dilution techniques (see "Add IAQ Equivalence Approach to IAQ Standards," below). Reliable, low-cost pollutant sensors are an important enabling technology for very

efficient filtration and air cleaning, and potentially for smart IAQ systems. As these sensors become available, there will be opportunities to develop IAQ-sensor-based ventilation control systems.

Address Humidity Control in Ventilation Products

The impact of ventilation on indoor moisture in homes is not clearly understood, and there is resistance to applying minimum ventilation standards in humid climates because of a fear of introducing humidity problems. The current lack of basic data on internal generation rates will be addressed by studies focused on measuring this specific parameter. In addition, work is ongoing to develop criteria for acceptable indoor humidity that can be used to evaluate different ventilation and moisture control strategies. In FY 2016, studies will be performed on the impact of ventilation strategies and standards that will answer questions regarding the necessity for regional variation in ventilation and humidity controls, as well as explore opportunities for using ventilation controls to control humidity in homes. Additional work focusing on acceptability will be necessary in FY 2017.

Address Humidity Control in IAQ Standards

There is a need for improved humidity control products in homes—particularly in high-performance homes that cannot rely on the incidental dehumidification provided by sensible cooling systems. The performance of new products needs to be evaluated and demonstrated in high-performance homes. In addition, new products need to be designed and controlled to ensure minimal energy use. As with range hoods, there is a lack of certification and labeling that would allow the selection or specification of effective household humidity control systems. These certification and labeling processes will be developed in FYs 2017–2018 in collaboration with equipment manufacturers, rating agencies, and potential users such as ASHRAE 62.2 and the EPA ENERGY STAR and IAP programs.

Draft Roadmap Description: Smart Ventilation Technology Solutions

Manufacturers Develop Smart Ventilation Products

Smart ventilation is intended to significantly reduce the energy needed to provide ventilation primarily used for conditioning air to meet IAQ requirements. Prior research efforts (and developed ventilation controls) have shown that smarter ventilation controls can theoretically achieve equivalency to ASHRAE 62.2 whole-house ventilation requirements while allowing for time shifting of ventilation to save energy and power or to reduce indoor concentration of outdoor contaminants. Opportunities exist to minimize ventilation-related energy and/or improve IAQ by (1) accounting for ventilation provided by other systems (e.g., kitchen/bathroom exhaust, clothes dryers, economizers, and natural draft appliances in the living space); (2) modulating ventilation with occupancy; (3) integrating with filtration; and (4) using other control strategies. In FY 2015, Lawrence Berkeley National Laboratory is working with Building America teams on the use of outdoor temperature as a control parameter. Several ventilation equipment manufacturers and HVAC companies are interested in developing smart ventilation equipment based on this technology. Field demonstrations and evaluations will be performed in FYs 2016–2018 to confirm the potential performance of these systems and to investigate applications for the aforementioned strategies.

Address Smart Ventilation in Voluntary Programs and Standards, and Then in Codes

Simulation-based analysis backed by field demonstrations will enable the development of smart ventilation options or requirements for IAP, ZERH, ENERGY STAR, HPwES, and Passive House. This effort will be linked to the equivalence approach being developed for ASHRAE 62.2. In the future (FY 2019 and beyond), smart ventilation systems will be adopted by the model codes so that smart ventilation is available in all homes.

Address Make-Up Air Requirements in IAQ Standards

As high-performance envelopes are tightened beyond traditional values, even moderate amounts of exhaust ventilation can produce undesirable levels of depressurization. There is a current effort to address this issue proactively by expanding ASHRAE 62.2 make-up air requirements to address all substantial exhaust systems in very tight homes. This effort is linked to combustion safety, kitchen ventilation, and the use of equivalency in IAQ valuation approaches.

Draft Roadmap Description: IAQ Evaluation and Equivalence in Standards

Develop IAQ Valuation Metrics

Rating methods exist for energy efficiency, but there is no useful method of rating IAQ. This effort will allow an eventual transition from *smart ventilation* to *smart IAQ*. The Disability-Adjusted Life Year (DALY) approach is a base methodology, but it is insufficient by itself. Creation of an IAQ metric will enable builders, contractors, and programs to market and receive credit for homes based on the robustness of IAQ controls. Current efforts will work with industry to develop a set of IAQ valuation metrics that factor in pollutant sources and mitigation strategies. Once an IAQ metric has been developed it should be applied in field studies so that baselines can be developed, and then the process should be refined and validated. This IAQ score will show the benefits of going beyond minimum requirements (e.g., those in ASHRAE 62.2) and will be a valuable tool for high-performance home programs (e.g., EPA ENERGY STAR homes and the IAP program).

Add IAQ Equivalence Approach to IAQ Standards

Using the ventilation equivalence approach allows comparison of different ventilation control strategies. This effort will start in FYs 2015–2016 by adding to ASHRAE 62.2 the formal calculation procedures needed to calculate equivalence for ventilation equipment and controllers.

Develop and Validate Smart Pollutant Control Technologies

Development of IAQ and valuation metrics will allow advancement from smart ventilation to smart IAQ. For this approach, smart pollutant control technologies need to be developed that go beyond the current source exhaust and dilution methods. This effort will start in FY 2017 and continue in FY 2018 and beyond through field validation and demonstration of smart pollutant controls.