Water Heating Standing Technical Committee

Strategic Plan, v2012a

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Committee Chair:

2011, 2012	Marc Hoeschele mhoesch@davisenergy.com 530-753-1100 x23	ARBI

Background on Residential Water Heating

According to the U.S. Energy Information Administration's 2005 Residential Energy Consumption Survey (RECS), annual residential water heating totals 2.11 quads of energy annually, or 20% of the energy delivered to residential buildings[1]. Over the past 70 years, gas and electric storage water heaters have been the predominant water heater type in the United States[2]. Recently, gas tankless water heaters have made inroads in market share with current industry projected gas tankless sales estimated at 400,000+ annually, and an expected higher growth rate than storage water heaters in the years ahead[3]. Additionally, heat pump water heaters (HPWHs) are starting to gain a presence as they offer potential savings of 50% or more relative to electric resistance storage water heaters. In addition to efficiency opportunities at the heating plant, future improvements in water heating system efficiency must also consider appliances, fixtures, and showerheads; improved hot water distribution system options; and integration of cost-effective renewable resources and/or heat recovery systems.

According to U.S. Census data[4], 85+% of the 127.7 million U.S. households live in single family homes, mobile homes, and smaller multi-family buildings where individual water heaters serving a household are the norm. The remaining population lives in multi-family buildings with ten or more units, where hot water loads are more commonly met by central systems. The size of the national average household is 2.60 persons, but nearly 58% of U.S. households are comprised of two or less people, which has significant implications in terms of hot water load and resulting equipment efficiency.

Key stakeholders in the water heating arena include manufacturers and the distribution chain, plumbers, DOE and other regulatory bodies, utilities (offering efficiency programs to the marketplace), trade groups, builders, and finally, building occupants. The nature of the residential market is such that the vast majority of water heater sales are of minimum efficiency equipment. The continued emergence and growth in sales of gas tankless units, HPWHs, and other higher efficiency products, is needed to build the production volumes of these advanced products and make them more cost competitive with the commodity storage water heaters.

Relevance of Gaps and Barriers to Building America Goals

The Building America program is focused on delivering market-acceptable energy efficiency solutions to homeowners, builders, and contractors. Near-term goals of 30%-50% source energy savings are currently targeted. In addition to the significant energy savings goals, improved health and safety, comfort, and building durability are also key goals of the program. As part of the Water Heating Strategic Plan, a set of broad strategic goals have been drafted. These goals are intended to provide a framework to address individual gaps and barriers. The current and future research efforts of the Building America teams, as well as other efforts outside of Building America, are intended to address the identified gaps.

The following "draft" water heating strategic goals will continue to be refined in future strategic plans:

1. To provide conclusive laboratory and field performance data to manufacturers, the building industry, and code bodies to enable the delivery of efficient, cost-effective (or lower cost) water heating

[1] Ranging from 17% of household consumption in the Northeast to 27% in the Western states.
[2] RECS estimates average electric water heater consumption is 2,814 kWh/yr, and gas water heater use is 230 therms/yr.
[3] http://www.aceee.org/files/pdf/conferences/hwf/2011/Plenary%20-%20Mike%20Parker.pdf
[4] http://factfinder.census.gov/servlet/ADPTable?_bm=y&-geo_id=01000US&-qr_name=ACS_2009_5YR_G00_DP5YR4&-ds_name=ACS_2009_5YR_G00_&-_lang=en&-redoLog=false&-_sse=on

solutions to the marketplace. This effort should focus both on currently available technology solutions, as well as advanced configurations promising greater savings.

2. To develop validated simulation tools to facilitate the evaluation and comparison of alternative water heating system designs for new and existing, single and multi-family buildings. The validated tools, and accurate inputs to drive the models, are needed to accurately understand the transient nature of hot water system performance.

3. To develop industry design guides that convey optimal water heating system design practice for new buildings and preferred retrofit strategies for existing buildings, taking into account loads, climate, and utility rates.

4. To identify the performance, maintenance, reliability, and customer acceptance characteristics of high efficiency water heating technologies in different applications, and to determine key factors that affect performance of these technologies relative to mainstream "conventional" technologies.

The draft goals are all interrelated in the sense that more conclusive science is needed in the development of models and the key inputs that drive the models; greater lab and field efforts are needed to develop a robust understanding of performance, reliability, and customer acceptance; and information transfer both to and from stakeholders is critical in moving the marketplace toward the implementation of preferred high efficiency solutions for a given application.

The development of the Strategic Planning process began in the summer of 2011. The ARBI team developed a list of gaps and barriers based on input from prior Building America meetings, the 2011 DOE Water Heating Roadmap Workshop (in Berkeley, CA), and input from the ARBI team. A kickoff webinar was held in July 2011 to present and review water heating gaps and barriers. As a follow-up to the presentation, webinar participants were asked to provide their input in ranking the three highest and three lowest priority gaps and barriers. Based on the group voting, gaps/barriers were identified as high, medium, or low priority. Table 1 summarizes the rankings of the gaps and barriers.

More details on the "high" and "medium" ranked gaps are found in the "2 page write-ups" that follow. The next version of the Strategic Plan (late May/early June of 2012) will recast the existing gaps presented here into more granular gaps that are more clearly actionable.

These gaps will then undergo another round of prioritization in the summer of 2012. The process will utilize the Pareto voting method, whereby:

- The number of votes that each member gets ("X") will be defined by the total number of identified gaps multiplied by 0.20. If this yields a fractional value, it will be rounded up to the next whole number.
- Voters shall select "X"gaps that they consider to be most important.
- Gap priority ranking will be reflected by the total number of votes received.

Table 1: Consensus Ranking of Priority Water Heating Gaps and Barriers

Rank	Description	Priority
1	High efficiency combined hydronic system performance and cost impacts	High
2	HPWH performance (isolate behavior impacts on performance)	High
3	Collect a broad, uniform set of hot water usage data and associated demographics	High
4	Track maintenance/reliability/customer acceptance issues on emerging technologies (gas tankless, HPWH, hybrid systems, demand recirc, etc.)	High
5	Pre and post field testing on distribution system improvements	High
6	Validate HPWH, tankless, condensing storage, hybrid models with lab/field data	High
6b	Integrate detailed modeling tools (Note: interrelated with “6”)	High
7	Develop application-specific retrofit decision tool	Medium
8	Characterize tankless and high efficiency gas water heater performance	Medium
10	Support plumbing code update (lab testing of right-sized plumbing systems)	Low
11	Develop industry friendly best practice design guides based on real-world performance	Low
12	Low-cost solar hot water system (not necessarily roof-mounted)	Low
13	Existing stock - Water quality impact on high efficiency water heating systems	Low
14	Validate distribution system models	Low

The following pages identify the “high” and “medium” priority gaps and barriers identified in the 2011 strategic plan, with minor updates based on new information from current or recently completed studies.

1. Combined Hydronics

BA Enclosures		BA Hot Water		House Type	
Walls		Test Standards	X	New	X
Roof/Ceiling		Distribution		Existing	X
Foundations		Condensing/Tankless	X	Single Family	X
Moisture		Heat Pump Water Heater		Multi Family	X
Windows		Combined Space & DHW Heating	X	**DOE Emerging Technologies**	
Other:		Other:		Walls and Windows	
BA Space Conditioning		**BA Miscellaneous Loads**		Efficient Appliances	
Heating	X	Home Energy Management		Advanced Heating & Cooling Fluids	
Cooling		Lighting		Solar Heating & Cooling	
Dehumidification		Large MELs (pools, etc.)		Geothermal Heat Pumps	
Distribution	X	Small MELs (TVs, VCRs, etc.)		Solid State Lighting	
Ventilation		Other:		Bulk Purchase	X
Other:				Onsite Renewables (Building-Integrated Photovoltaic, onsite cogen)	X
Testing Methods/Protocols		**BA Implementation**			
House Simulation Protocol	X	Quality Control/Quality Assurance	X		
Lab Test Methods		Training	X	**DOE Deployment**	
Field Test Methods	X	Documentation/Resources	X	Labeling/Rating	X
Analysis Methods/Tools		Needs Evaluation/Identification		Codes	
Analysis Tools	X	Other:		Standards	X
Strategic Analysis				Large Scale Retrofit (Better Buildings)	X

Problem Statement-

Combined hydronic systems, which provide both domestic water heating and space heating, offer potential cost and performance advantages over conventional system heating and water heating options. A better understanding of component compatibility, preferred configurations (climate/load implications on performance), component sizing, reliability, retrofit issues, and overall cost implications are needed before this strategy can be widely implemented.

Combined hydronic systems offer an elegant solution in many applications by substituting one high efficiency heat source as a replacement for a separate water heater and space heating device. These systems are not new, although in many areas of the country this design strategy is not very common. Developing the optimal design, sizing, and packaging of components is critical to understanding the overall cost and benefits. Although the industry is working to develop new products, Building America can play a valuable role by completing laboratory and field testing, resolving installation issues, and assessing reliability and customer satisfaction. Without Building America support, this effort will proceed on a much slower pace.

Background Knowledge:

Combined hydronic technology has been around for many years. Common applications include low-rise multi-family buildings where combining a standard storage water heater with a hydronic fan coil results in low first cost system installation. A common high efficiency combined hydronic system design would substitute a condensing storage or tankless gas water heater (or an efficient multi-function heat pump) for the standard storage water heater. Several Building America teams are currently working on refining and documenting the performance of combined hydronic system designs. NorthernSTAR[5] has completed extensive laboratory testing in 2011 to optimize the equipment package and identify installation issues before installing in the field. Three hundred existing homes in Minneapolis will be retrofitted with these systems, and 20 of those will be monitored. Pre-monitoring will be complete in February 2012, at which retrofits will occur and post-monitoring will ensue. The PARR team will be testing various equipment packages in the lab, under varying load scenarios. In 2011, Building Science monitored two New York homes[6] with combined systems featuring tankless water heaters. BSC hosted an Expert Meeting on Combined Systems in July 2011, exploring performance issues, reliability, and implementation issues related to these systems.

Stakeholder/Customer	Involvement/Interest
Manufacturers	Gaining field feedback; redesigning and repackaging components and controls
DOE/Regulatory	Savings potential and cost/benefit; market transformation; code issues
Utilities/Programs	Understanding savings and customer satisfaction; implementation issues
Builders	Demonstrated performance, lower cost; customer satisfaction, reliability
Plumbers	Gain familiarity and expertise with systems
Occupants	$ savings, reliability, meets comfort needs; warranties; low maintenance

Systems Considerations:

Combined systems, by their nature, must respond to both space and water heating loads. Most systems are controlled to give priority to water heating loads over space heating loads. Better understanding of these loads and their patterns in a variety of applications is needed to optimize performance and control strategies. Reduced water heating loads due to system improvements (e.g. lower flow fixtures and appliances, distribution system improvements, drain heat recovery) needs to be evaluated to assess the costs and benefits. Understanding equipment configurations in different regions and construction vintages (i.e. load scenarios) is important in assessing the feasibility and rough cost-effectiveness of the combined hydronic systems approach. Distribution system research is also beneficial in assessing delivery losses that combined systems will experience in providing hot water to fan coils, baseboards, and radiant systems.

Planned or Ongoing Research:

Ongoing field studies assessing real world performance, installation issues, reliability, and customer satisfaction are needed to characterize performance under varying conditions and loads. The NorthernSTAR team has the most ambitious project currently underway. This will last 2 years and include lab testing (to determine performance and preferred equipment packages) and detailed pre- and post- monitoring at 20 homes in the Minneapolis area. CDH Energy is monitoring three combined hydronic system installations in high efficiency

[5] http://www.aceee.org/files/pdf/conferences/hwf/2011/8A%20-%20Sam%20Greene.pdf
[6] http://www.aceee.org/files/pdf/conferences/hwf/2011/8A%20-%20Armin%20Rudd.pdf

homes[7] in New York State. BSC is also monitoring two New York homes with combined hydronic installations and GTI (under BA-PIRC) is completing laboratory testing to assess performance characteristics for various system configurations under varying load patterns. BA-PIRC is also completing a multi-family combined hydronic field project.

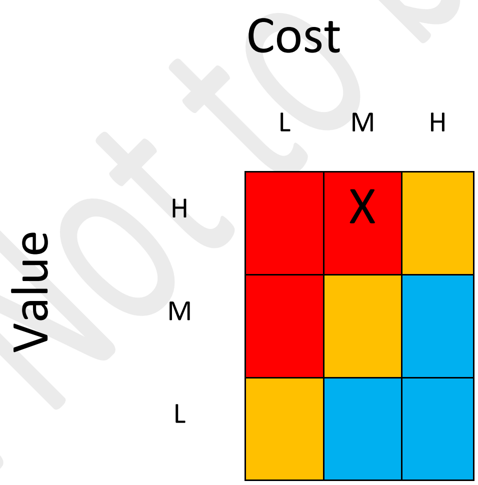
Closing the Gap:

The primary goal of this effort is to characterize the performance and savings of combined hydronic systems and develop an understanding of preferred configurations and sizing, climate influences on design, installation issues and barriers, maintenance issues, and customer satisfaction. A comprehensive design guide addressing these issues would represent a key milestone. Installation infrastructure also needs to be developed in many parts of the country to support cost-effective installations.

Timeline:

This effort should encompass 2-3 years.

Milestones: 1) Complete lab and field testing activities (2011-2013); 2) Enhance and validate detailed modeling tools to better model systems and control characteristics (2012-2013); 3) Use enhanced tools to complete a parametric study assessing performance, economics, key sensitivities, and target applications (2012-2013); 4) Develop design guide (2013).



[7] http://www.aceee.org/files/pdf/conferences/hwf/2011/8A%20-%20Hugh%20Henderson.pdf

2. Heat Pump Water Heaters

BA Enclosures		BA Hot Water		House Type	
Walls		Test Standards	X	New	X
Roof/Ceiling		Distribution		Existing	X
Foundations		Condensing/Tankless		Single Family	X
Moisture		Heat Pump Water Heater	X	Multi Family	X
Windows		Combined Space & DHW Heating		**DOE Emerging Technologies**	
Other:		Other:		Walls and Windows	
BA Space Conditioning		**BA Miscellaneous Loads**		Efficient Appliances	
Heating	X	Home Energy Management		Advanced Heating & Cooling Fluids	X
Cooling	X	Lighting		Solar Heating & Cooling	
Dehumidification	X	Large MELs (pools, etc.)		Geothermal Heat Pumps	
Distribution		Small MELs (TVs, VCRs, etc.)		Solid State Lighting	
Ventilation		Other:		Bulk Purchase	X
Other:				Onsite Renewables (Building-Integrated Photovoltaic, onsite cogen)	
Testing Methods/Protocols		**BA Implementation**			
House Simulation Protocol	X	Quality Control/Quality Assurance	X		
Lab Test Methods	X	Training	X	**DOE Deployment**	
Field Test Methods	X	Documentation/Resources	X	Labeling/Rating	
Analysis Methods/Tools		Needs Evaluation/Identification		Codes	
Analysis Tools	X	Other:		Standards	X
Strategic Analysis				Large Scale Retrofit (Better Buildings)	X

Problem Statement-

HPWH field performance needs to be better understood in terms of how climate, behavior, hot water loads, water heater location, etc., affects performance and customer satisfaction.

Although HPWHs offer the expectation of 50%+ savings relative to conventional electric storage water heaters, a better understanding of performance, customer acceptance, and longer term reliability is needed before the technology achieves widespread implementation. Variations in performance can occur due to climate, unit location, hot water usage magnitude and profile, but equally as important are the occupant interactions in terms of setpoint temperature and selected operating mode. All of these factors will impact performance, although the relative importance of each factor needs to be better disaggregated to the extent feasible. Without obtaining a better understanding of how these factors affect performance, field performance of HPWHs will not approach the levels represented in lab testing. Control modifications, homeowner education, and a systems approach towards optimizing performance are all needed.

Background Knowledge:

Lab testing of HPWHs has been completed by the Pacific Gas and Electric Company[8], Bonneville Power[9], and the Gas Technology Institute for BA-PIRC[10]. These studies show performance results are generally consistent

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[8] http://www.etcc-ca.com/component/content/article/29/2985-laboratory-evaluation-and-field-testing-of-residential-heat-pump-water-heaters

[9] http://www.bpa.gov/energy/n/pdf/BPA_HPWH-demo-project_Overview_Final.pdf

with Energy Factor ratings when tested under similar test conditions. However both studies infer that HPWH operation in an electric resistance heating only mode (no heat pump operation) results in lower efficiencies than are typical for conventional electric storage water heaters, ostensibly because of greater thermal losses due to piping connections bypassing the tank insulation. This underscores the importance of understanding how these units are operated in the field to insure that predicted savings are realized.

Field testing is currently underway in several projects. EPRI is currently monitoring ~170 units nationwide, in climates ranging from the Southeast to the Pacific Northwest. Monitoring should continue through March 2012 although preliminary results have been presented at the ACEEE Hot Water Forum[11]. The CARB BA team is testing fourteen units in the Northeast[12] with monitoring continuing through 2011. Both of these datasets should better inform researchers on how the units operate and what factors contribute to the observed performance variations. The CARB team has drafted a measure guideline on HPWHs. The Northwest Energy Efficiency Alliance is monitoring 30 units in the Pacific Northwest.

Stakeholder/Customer	**Involvement/Interest**
Manufacturers	Gaining field feedback; redesigning components and controls to optimize performance; achieving high volume markets to reduce cost
DOE/Regulatory	Understanding savings potential; assisting market transformation
Utilities/Programs	Understanding savings and customer satisfaction; promoting the technology to help transform the market
Builders	Demonstrated performance, customer satisfaction, reliability; recognition in energy codes
Occupants	Finding a cost-effective solution for all-electric customers; evaluating customer acceptance; warranty and reliability; low maintenance

Systems Considerations:

The performance of HPWHs, possibly more so than any other residential water heater technology, is strongly affected by climate, hot water usage pattern, selected operating mode, and the specified temperature setpoint. Understanding these interactions is critical in assessing field performance and determining how to best optimize the performance of these systems and how to achieve the best performance in more challenging environments.

This effort would benefit from other water heating field studies that are focusing on hot water usage patterns, since load patterns and load magnitude have a strong influence on performance. Other demographic data and housing stock studies would be useful for better targeting preferred applications for HPWH implementation.

[10] Glanville, P., and D. Kosar, 2011. *Building America Industrialized Housing Partnership II- Subtask 2.2.3: Efficient Hot Water and Distribution Systems Research*. Gas Technology Institute project number 20970.
[11] http://www.aceee.org/files/pdf/conferences/hwf/2011/2B%20-%20Ammi%20Amarnath.pdf
[12] http://2011.acinational.org/sites/default/files/session/81137/aci11h2o5puttaguntasrikanth.pdf

Planned or Ongoing Research:

Ongoing field studies assessing real world performance are critical in refining savings estimates and better understanding performance under highly variable conditions. It has become increasingly clear over the past few years that the Energy Factor ratings and other laboratory performance data do not accurately represent field performance. Preliminary field results indicate that projected annual performance will likely be below the nominal equipment rating. NREL is currently working on implementing into BEopt a more detailed HPWH model that recognizes the short-term transient performance effects. Developing high-resolution hot water draw profiles to drive the simulation is an important need.

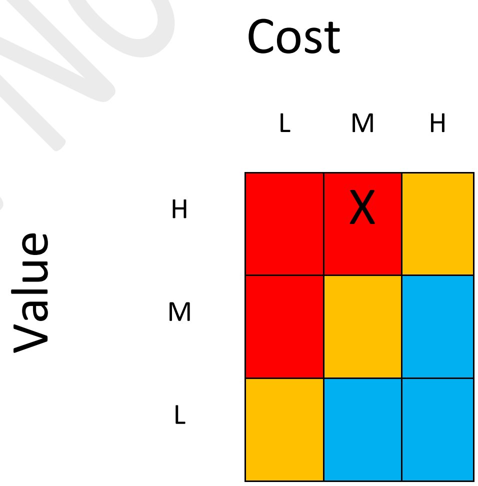
Closing the Gap:

The primary goal of this effort is to gain an understanding of HPWH field performance and to isolate (to the extent possible) the factors that affect performance. Feeding this data back to manufacturers would support design and control enhancements aimed at boosting performance. A key desired outcome would be developing a statistically valid understanding of how the various factors affect performance for implementation into simulation models.

Timeline:

This effort should encompass 2-3 years.

Milestones: 1) Collect field data and isolate performance factors (2011-2013); 2) Enhance and validate detailed modeling tools to better model key parameters (2011-2013); 3) Use enhanced tools to complete a parametric study assessing performance, key sensitivities, and target applications (2012-2013); 4) Develop design guide (2013); 5) Assess hybrid HPWH systems that integrate solar and/or gas heating (2012-2013).



3. Detailed Hot Water Usage Data

BA Enclosures		BA Hot Water		House Type	
Walls		Test Standards	X	New	X
Roof/Ceiling		Distribution	X	Existing	X
Foundations		Condensing/Tankless	X	Single Family	X
Moisture		Heat Pump Water Heater	X	Multi Family	X
Windows		Combined Space & DHW Heating	X	**DOE Emerging Technologies**	
Other:		Other:		Walls and Windows	
BA Space Conditioning		**BA Miscellaneous Loads**		Efficient Appliances	X
Heating		Home Energy Management		Advanced Heating & Cooling Fluids	
Cooling		Lighting		Solar Heating & Cooling	
Dehumidification		Large MELs (pools, etc.)		Geothermal Heat Pumps	
Distribution		Small MELs (TVs, VCRs, etc.)		Solid State Lighting	
Ventilation		Other:		Bulk Purchase	
Other:				Onsite Renewables (Building-Integrated Photovoltaic, onsite cogen)	
Testing Methods/Protocols		**BA Implementation**			
House Simulation Protocol	X	Quality Control/Quality Assurance			
Lab Test Methods	X	Training		**DOE Deployment**	
Field Test Methods	X	Documentation/Resources		Labeling/Rating	X
Analysis Methods/Tools		Needs Evaluation/Identification		Codes	X
Analysis Tools	X	Other:		Standards	X
Strategic Analysis				Large Scale Retrofit (Better Buildings)	X

Problem Statement-

Obtaining a broad sample of standardized hot water usage data is critical in better understanding hot water system performance since the pattern and magnitude of loads affect both distribution system efficiency and the water heater efficiency.

Hot water usage data collection efforts have increased in recent years, but additional high resolution data is needed to better understand regional performance effects, demographic effects, occupant behavior, and the impact of improved fixtures and appliances on loads[13]. Older datasets have some value, although many of the datasets are not granular enough to properly characterize draw events and end uses. Collecting short time step data (5 seconds or less) during flow events is needed to properly characterize hot water draws. These data are needed to feed into simulation tools to better evaluate system performance. A key step in the process involves statistically evaluating the data to define representative use profiles. Current understanding of hot water distribution losses is fairly limited and this effort is needed to advance the state-of-the-art.

Background Knowledge:

The DOE Energy Factor test procedure prescribes a daily hot water load of 64.3 gallons per day at a 77°F hot-to-cold water temperature difference. The resulting recovery load of ~ 41,000 Btu/day has implications on the expected performance of different water heater types. Recent research by Thomas[14] and Lutz[15] and others

[13] Very little data has been collected in new homes where all the appliances, showerheads, and faucets are likely to be representative of the low use devices common in today's market.
[14] http://www.aceee.org/files/pdf/conferences/hwf/2010/3D_Martin_Thomas.pdf

indicate that actual hot water loads are lower, with Lutz data indicating average per capita hot water loads of 19.6 gallons per day. Other research recently completed at eighteen California homes[16] suggests that the measured temperature rise through the water heater is considerably lower than the 77°F rise prescribed in the Energy Factor test. Clearly gathering additional data on hot water loads and patterns would be beneficial for developing water heater test procedures, as well as for informing simulation tools. New lower cost sensing technologies and wireless technologies are emerging and should reduce data acquisition costs. University of Washington researchers have developed the HydroSense[17] system, which records and deciphers water system pressure fluctuations to determine where the water is flowing.

Stakeholder/Customer	Involvement/Interest
Manufacturers	Manufacturers interested in better understanding hot water loads/patterns and how it affects performance. Distribution system performance.
DOE/Regulatory	Improved data could feed into the DOE WH test procedure; Energy codes would also benefit from better loads data.
Utilities/Programs	All E/G/ water utilities could better assess savings and design programs
EnergyStar/WaterSense	Better data to understand impacts of distribution systems and efficient end uses.
Occupants	Improved data would lead to recommendations on cost-effective strategies.

Systems Considerations:

The pattern and magnitude of hot water usage in a building is interrelated with the occupant, the distribution system, and the water heating appliance. A recent ACEEE paper (Springer, 2008) indicates that the pattern of hot water usage could have greater savings impact than whether the piping is insulated or not. Developing a better sense of hot water usage characteristics around the country would provide valuable input to models that could then better predict overall system performance. Gathering demographic data on the monitored homes and the characteristics of the hot water use points is also important.

Planned or Ongoing Research:

ASHRAE 118.2 is currently working on identifying up to five 24-hour draw patterns for use in both simulation models and in driving new water heating test procedures. This work will rely on existing data collected to date. Jim Lutz, who heads 118.2, has presented a methodology at the 2012 Winter ASHRAE meeting to develop representative draw profiles. Several recently completed studies (Shoenbauer et al, 2011; Pigg et al, 2010; Davis Energy Group 2011) have collected detailed usage data from a minimum of ten homes each. Current Building America water heating activities include the CARB HPWH testing at fourteen sites, the ARIES distribution system monitoring at five homes (underway in early 2012), and NAHBRC HPWH monitoring slated for start in the fall of 2012. LBNL recently received CEC PIER funding to develop and demonstrate new lower

[15] http://www.energy.ca.gov/2008publications/CEC-500-2008-082/CEC-500-2008-082-APA.PDF (Appendix H)
[16] http://www.aceee.org/files/pdf/conferences/hwf/2011/3D%20-%20Marc%20Hoeschele.pdf
[17] http://www.aceee.org/files/pdf/conferences/hwf/2010/4D_Eric_Larson.pdf

cost sensing technologies for water and gas use. Ongoing data collection activities, especially at multi-family sites (which appear to be under-represented in terms of usage data), should be pursued.

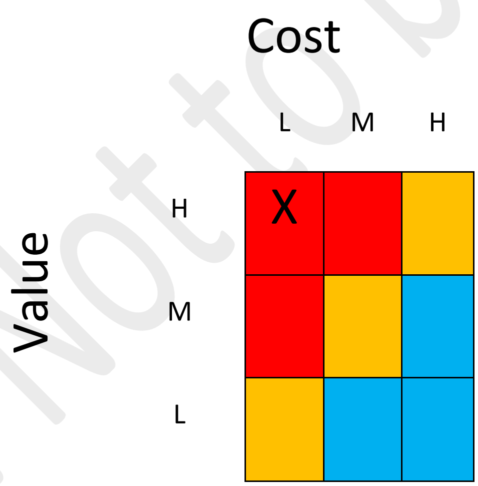
Closing the Gap:

The primary goal of this effort is to collect and process high resolution hot water usage data, as well as household and building demographic data from the monitored sites. Compiling data from identified projects, and other earlier projects that have high quality data, would advance the state of water heating knowledge. Data from one to two hundred households, with a mix of housing types, vintages, and climates should satisfy the data needs.

Timeline:

This effort should encompass 2-3 years.

Milestones: 1) Develop specifications for minimum DHW data requirements with Testing Methods and Protocols STC (2012); 2) Collect high quality field data from existing projects; screen and evaluate. (2012-2013); 3) Continue hot water field monitoring data collection efforts (2012-2013); 4) Develop hot water usage pattern report (2012-2013).



4. Advanced Water Heater Customer Acceptance

BA Enclosures		BA Hot Water		House Type	
Walls		Test Standards		New	X
Roof/Ceiling		Distribution		Existing	X
Foundations		Condensing/Tankless	X	Single Family	X
Moisture		Heat Pump Water Heater	X	Multi Family	X
Windows		Combined Space & DHW Heating	X	**DOE Emerging Technologies**	
Other:		Other: Behavior	X	Walls and Windows	
BA Space Conditioning		**BA Miscellaneous Loads**		Efficient Appliances	
Heating		Home Energy Management		Advanced Heating & Cooling Fluids	
Cooling		Lighting		Solar Heating & Cooling	
Dehumidification		Large MELs (pools, etc.)		Geothermal Heat Pumps	
Distribution		Small MELs (TVs, VCRs, etc.)		Solid State Lighting	
Ventilation		Other:		Bulk Purchase	
Other:				Onsite Renewables (Building-Integrated Photovoltaic, onsite cogen)	
Testing Methods/Protocols		**BA Implementation**			
House Simulation Protocol		Quality Control/Quality Assurance	X		
Lab Test Methods		Training	X	**DOE Deployment**	
Field Test Methods		Documentation/Resources	X	Labeling/Rating	
Analysis Methods/Tools		Needs Evaluation/Identification		Codes	
Analysis Tools		Other: Market Issues	X	Standards	
Strategic Analysis	X			Large Scale Retrofit (Better Buildings)	X

Problem Statement-

Advanced water heating technologies that are starting to replace existing stock of gas and electric storage water heaters have different performance attributes, delivery capabilities, and maintenance requirements. Assessing these factors is important in identifying and overcoming customer acceptance issues.

New water heater types (tankless, HPWH, solar, hybrid units, etc.) and distribution/delivery technologies (e.g. demand recirculation, drain heat recovery) provide a change in the hot water experience that customers are used to. As well as understanding the energy impacts of these technologies, we need to understand and assess the frequency of any customer satisfaction issues. For example, gas tankless water heaters are known to increase hot water waiting times and not adequately satisfy very low flow rate draws. How big an issue is this for customers and what technical fixes could be implemented to improve performance? Are some of these problems more pronounced in different climates or with different load patterns? Addressing these issues is important in moving towards energy-saving, market-acceptable solutions.

Background Knowledge:

Many new technology early adopters want to try the latest and greatest widget and will accept some level of behavior modification as part of the process. Looking at the mass market, some fraction of the population will fall into this category, but most will not. Understanding customer acceptance of emerging technologies is critical in addressing shortcomings and moving the technology forward. The current EPRI HPWH project (with 170 monitored sites nationwide) is an example of a project that could provide valuable customer feedback to both the equipment vendors and the utility and energy efficiency industry. Other technologies, such as gas tankless water heaters, offer great potential, although there is concern over longevity in areas with hard water. It is currently not well understood what level of maintenance tankless units are receiving in the field and what level of performance degradation occurs if not properly maintained.

Stakeholder/Customer	Involvement/Interest
Manufacturers	Manufacturers are very interested in customer feedback and hard data from the field.
Utilities/Programs/ EnergyStar/WaterSense	Programs like to promote products that have high customer satisfaction and good reliability and maintenance records.
Plumbers	Plumbers need to understand the limitations/installation issues related to new products; The easier to install, the more receptive the plumber will be.
Builders	Finding cost-effective solutions that consumers desire; better usage data and understanding of performance issues would inform the industry.
Occupants	"Quality" DHW experience with minimal maintenance needs and costs.

Systems Considerations:

From a systems viewpoint, occupant use patterns and expectations factor heavily into customer satisfaction. Expectations vary widely, especially when homeowners have spent money to obtain a "better" product. Applicability of the installation relative to the rest of the system (distribution system, installed fixture characteristics, usage patterns, etc.) all factor into the customer's perceived level of satisfaction. Reliability and maintenance issues are longer term factors that also need to be assessed on a broad sample size.

Planned or Ongoing Research:

Field monitoring studies of advanced systems provides small customer samples on satisfaction issues. Maintenance issues and customer perception of reliability requires longer term involvement with individual installations. Unfortunately this rarely, if ever, occurs. Utilities are the obvious partner to gather customer acceptance and maintenance/reliability data since they generally have the best connection to the marketplace, and a desire to obtain the market feedback in support of their programs. In 2012, BA-PIRC will undertake a survey with a Florida multi-family developer to assess their experiences related to the installation and maintenance of 750 HPWHs in various projects.

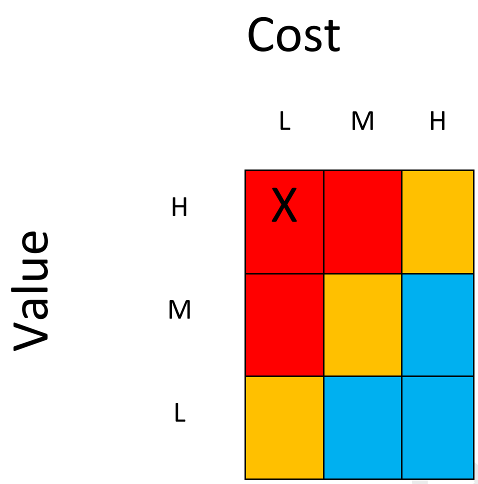
Closing the Gap:

This effort involves a collaborative effort among BA teams, utilities, and manufacturers. It is not clear to the extent that Building America can play a central role in this effort, other than gathering data from the relatively small number of customers involved in individual BA projects. Feedback from larger community-scale projects would be helpful in assessing these emerging technologies. BA teams could work with local utilities to develop a survey tool that could assess customer acceptance issues. Survey results from different regions could then be compiled into a broad assessment.

Timeline:

This effort should encompass 3+ years.

Milestones: 1) Develop standardized technology customer acceptance survey (2011-2012); 2) Collect ongoing customer satisfaction and high quality field data from existing BA projects; 3) Work with utilities and industry to gather data (2011-2014); 4) Compile and update findings (2011-2014).



5. Distribution System Performance

BA Enclosures		**BA Hot Water**		**House Type**	
Walls		Test Standards		New	X
Roof/Ceiling		Distribution	X	Existing	X
Foundations		Condensing/Tankless	X	Single Family	X
Moisture		Heat Pump Water Heater	X	Multi Family	X
Windows		Combined Space & DHW Heating	X	**DOE Emerging Technologies**	
Other:		Other:		Walls and Windows	
BA Space Conditioning		**BA Miscellaneous Loads**		Efficient Appliances	X
Heating		Home Energy Management		Advanced Heating & Cooling Fluids	
Cooling		Lighting		Solar Heating & Cooling	
Dehumidification		Large MELs (pools, etc.)		Geothermal Heat Pumps	
Distribution		Small MELs (TVs, VCRs, etc.)		Solid State Lighting	
Ventilation		Other:		Bulk Purchase	
Other:				Onsite Renewables (Building-Integrated Photovoltaic, onsite cogen)	
Testing Methods/Protocols		**BA Implementation**			
House Simulation Protocol	X	Quality Control/Quality Assurance	X		
Lab Test Methods		Training	X	**DOE Deployment**	
Field Test Methods	X	Documentation/Resources	X	Labeling/Rating	X
Analysis Methods/Tools		Needs Evaluation/Identification		Codes	X
Analysis Tools	X	Other:		Standards	X
Strategic Analysis				Large Scale Retrofit (Better Buildings)	X

Problem Statement-

Distribution systems are likely the least understood component of a domestic hot water system, especially in single family homes where plumbing designs are rarely completed. Changes in house architectural design and plumbing practice over the years and changes in end use characteristics (showers, appliances, etc) have led to the perception that distribution losses are becoming an increasingly larger fraction of total hot water usage.

Significant data collection needs to be completed to better assess distribution system performance and understand how climate, building layout and vintage, distribution system design, user behavior, and household patterns affect performance. Simulation tools exist and/or are being developed to better assess distribution losses, but these tools need to be driven by realistic and representative hot water usage patterns and an accurate characterization of the distribution system piping layout. Understanding and documenting the characteristics of distribution systems in new buildings, as well as what was installed in existing buildings, is the first step in defining an accurate baseline.

Background Knowledge:

The level of existing knowledge on distribution system performance is fairly limited. Performance monitoring in the field is challenging to implement since temperature sensing devices (typically thermocouples) need to be installed on piping close to individual use points. This is often difficult except on new homes where access can be made available during construction. Future advancements in wireless technologies (Lutz et al, 2011) and pressure sensing technologies (Froehlich et al, 2011) will offer lower cost alternatives relative to running thermocouple wire through a building.

Prior distribution system modeling efforts include Building America's support for the HWSIM distribution model (Springer et al, 2008). The HWSIM tool allows the user to lay out a distribution system, define pipe characteristics, specify use points on the distribution system, and impose a detailed schedule of hot water draws. Extensive lab testing of piping systems and configurations can be used to validate models such as HWSIM or TRNSYS. In 2011, the ARBI team completed HWSIM enhancements (to incorporate pipe radiant heat transfer) and validation against laboratory test data. This information is presented in a technical report still undergoing Building America peer review. A similar development and validation effort was completed by NREL and the University of Colorado at Boulder using the TRNSYS model (Maguire et al, 2011). Davis Energy Group has been involved in two field surveys (detailed measurement of piping length, diameter, and pipe location) to document new California home plumbing practice. Similar studies in other parts of the country are needed to better characterize both existing and new housing.

Distribution system retrofits that occur commonly involve pipe insulation (varying level of benefits), addition of recirculation systems (demand recirc preferred), and full or partial re-piping. The performance impacts of these modifications are currently not well understood.

Stakeholder/Customer	Involvement/Interest
Manufacturers	Industry as a whole is interested in seeing better "system" performance and recognizes that distribution systems are a key part of the problem.
DOE/Regulatory	Improved distribution systems reduce loads and increase system efficiency.
Utilities/Programs	Programs like to promote products that have high customer satisfaction and good reliability and maintenance records.
Plumbers	Looking for low cost solutions that provide satisfactory hot water delivery.
EnergyStar/WaterSense	Determining what constitutes water and energy efficient designs.
Builders	Looking for low cost solutions that provide satisfactory hot water delivery.
Occupants	Looking for "quality" water heating experience.

Systems Considerations:

Distribution systems are the link between the heat source and the use points. Ideally, minimizing the size (i.e. entrained volume) of the system is the preferred solution, although adding a second (low standby) water heater may also be a viable alternative. Architectural design and water heater placement are of primary importance in new buildings. Retrofit options are much more limited since modifications are generally costly to implement. How the distribution system performs also influences behavior, as users react to delivery shortcomings. A recent ACEEE paper (Springer et al, 2008) indicates that the pattern of hot water usage could have a greater impact on distribution system performance than whether the piping is insulated or not. Distribution systems can also amplify the impacts of other system modifications.

Planned or Ongoing Research:

ARIES is in the process of implementing a retrofit water heating monitoring program at five homes in New York State. Several of the homes will have distribution system improvements which could include demand recirculation installation, pipe insulation, or possibly installation of a home run system. In 2012, the project will be completed with pre- and post-retrofit monitoring to allow for quantification of the benefits. In 2012, the ARBI team will work with both the TRNSYS and HWSIM distribution models to validate performance against detailed field data.

Davis Energy Group, as part of the GTI PIER Advanced Gas Water Heating Project, is completing the integration of the TANK model and a tankless water heater model with the enhanced HWSIM distribution system model, to develop a better integrated simulation tool. LBNL has recently received PIER funding that includes research into field distribution system performance as well as developing "next generation" integrated water heating simulation models.

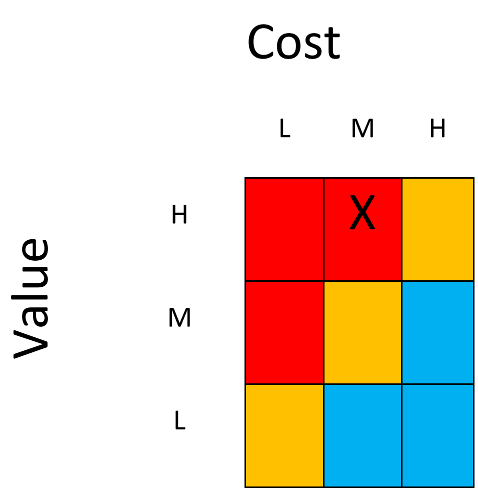
Closing the Gap:

Understanding distribution system performance involves gathering data on many fronts. We need to be able to characterize typical plumbing practice in both new and existing buildings throughout the United States. Hot water load characteristics and patterns need to be better quantified. Field data needs to be collected where existing distribution systems are pre-monitored, improvements are made, and post-monitoring occurs. This data can be used to validate and improve distribution system modeling tools. All of these efforts need to proceed to develop quantitative data characterizing distribution system performance. Reaching consensus on one or more "typical" hot water usage patterns for simulation tools is also a key goal.

Timeline:

This effort should encompass 3-4 years.

Milestones: 1) Develop specifications for minimum DHW data collection requirements with Testing Methods and Protocols STC (2011); 2) Continue hot water monitoring data collection efforts (2011-2013); 3): Complete additional pre- and post-distribution system improvement monitoring projects (2011-2013); 4) Enhance and validate distribution system models (2011 - 2013); 5) Complete hot water design guide (2012 or early 2013)



6. Validate Advanced Water Heater System Models

BA Enclosures		BA Hot Water		House Type	
Walls		Test Standards		New	X
Roof/Ceiling		Distribution	X	Existing	X
Foundations		Condensing/Tankless	X	Single Family	X
Moisture		Heat Pump Water Heater	X	Multi Family	X
Windows		Combined Space & DHW Heating	X	**DOE Emerging Technologies**	
Other:		Other:		Walls and Windows	
BA Space Conditioning		**BA Miscellaneous Loads**		Efficient Appliances	
Heating		Home Energy Management		Advanced Heating & Cooling Fluids	
Cooling		Lighting		Solar Heating & Cooling	
Dehumidification		Large MELs (pools, etc.)		Geothermal Heat Pumps	
Distribution		Small MELs (TVs, VCRs, etc.)		Solid State Lighting	
Ventilation		Other:		Bulk Purchase	
Other:				Onsite Renewables (Building-Integrated Photovoltaic, onsite cogen)	
Testing Methods/Protocols		**BA Implementation**			
House Simulation Protocol	X	Quality Control/Quality Assurance			
Lab Test Methods	X	Training		**DOE Deployment**	
Field Test Methods	X	Documentation/Resources	X	Labeling/Rating	X
Analysis Methods/Tools		Needs Evaluation/Identification	X	Codes	X
Analysis Tools	X	Other:		Standards	X
Strategic Analysis				Large Scale Retrofit (Better Buildings)	X

Problem Statement-

Current advanced water heater simulation models are not sufficiently detailed to characterize real-world performance. To properly understand overall impacts, better models need to be developed, validated, and integrated with distribution system and occupant behavior models.

Water heater and distribution/delivery/heat recovery technologies are not adequately modeled with existing tools. Historically, determinations of equipment efficiency have relied heavily on rated efficiency, such as Energy Factor. Increasingly we realize that these simplified metrics do not adequately reflect actual performance as well as the impact of effects due to changing loads, distribution system impacts, and occupant behavior. Advancing the state-of-the-art in water heating requires better tools to provide application-specific solutions rather than generic solutions. Validated tools are needed to develop design guides that will contribute to better decision-making in different applications and different climates.

Background Knowledge:

Existing simulation tools such as DOE2, EnergyPlus, BEopt, and TRNSYS have varying capabilities in modeling water heating systems. In general, the models operate on an hourly basis, which implies that the modeling of transient water heating effects is ignored. For several emerging water heater types (e.g. HPWH or tankless), these effects may have a significant performance impact, and therefore need to be accurately modeled.

Stakeholder/Customer	Involvement/Interest
Manufacturers	Understanding integrated system performance.
DOE/Regulatory	Understanding integrated system performance.
Utilities/Programs	Utility programs need improved models to evaluate and design customer programs.
Builders	Finding the most cost-effective solutions.
EnergyStar/WaterSense	Design guides to direct best practices.
Plumbers	Design guides for implementation.
Occupants	Performance, reliability, cost savings.

Systems Considerations:

Better modeling capabilities, combined with better input data to drive the models, will improve system performance projections. If the models are too crude, transient effects will be overlooked. As well as improving the modeling capability of water heaters, distribution systems, and heat recovery systems, improved inputs in terms of realistic hot water use patterns and distribution system characteristics are needed to drive the models.

Planned or Ongoing Research:

LBNL recently received PIER funding to complete work in several water heating research areas, including the development of an advanced gas water heating system simulation model. NREL is currently working on an EnergyPlus HPWH model that has been validated using both lab and field test data. Based on this work, a modified HPWH modeling algorithm will be integrated into BEopt in early 2012. Under the GTI PIER Advanced Gas Water Heating Project, Davis Energy Group is currently integrating both the 1980's TANK code (stratified center flue gas storage water heater model) and the TRNSYS single node gas tankless water heater model into the HWSIM distribution model.

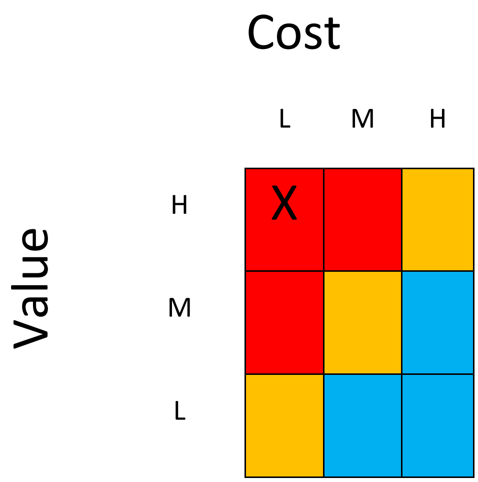
Closing the Gap:

The goal of this effort is to develop and validate models for emerging advanced water heaters that recognize the control nuances that can potentially have significant performance implications. Independent verification of model accuracy with lab or field data is needed.

Timeline:

This effort should encompass 2-3 years. Much of the effort would likely occur at national labs.

Milestones: 1) Collect detailed lab and field data for model validation efforts (2011-2013); 2) Complete model development (2011-2013); 3) Validate models and document (2012-2013).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7. Retrofit Evaluation Tool

BA Enclosures		BA Hot Water		House Type	
Walls		Test Standards		New	
Roof/Ceiling		Distribution	X	Existing	X
Foundations		Condensing/Tankless	X	Single Family	X
Moisture		Heat Pump Water Heater	X	Multi Family	X
Windows		Combined Space & DHW Heating	X	**DOE Emerging Technologies**	
Other:		Other:		Walls and Windows	
BA Space Conditioning		**BA Miscellaneous Loads**		Efficient Appliances	
Heating		Home Energy Management		Advanced Heating & Cooling Fluids	
Cooling		Lighting		Solar Heating & Cooling	
Dehumidification		Large MELs (pools, etc.)		Geothermal Heat Pumps	
Distribution		Small MELs (TVs, VCRs, etc.)		Solid State Lighting	
Ventilation		Other:		Bulk Purchase	X
Other:				Onsite Renewables (Building-Integrated Photovoltaic, onsite cogen)	
Testing Methods/Protocols		**BA Implementation**			
House Simulation Protocol		Quality Control/Quality Assurance	X		
Lab Test Methods		Training	X	**DOE Deployment**	
Field Test Methods		Documentation/Resources	X	Labeling/Rating	
Analysis Methods/Tools		Needs Evaluation/Identification	X	Codes	
Analysis Tools	X	Other:		Standards	
Strategic Analysis	X			Large Scale Retrofit (Better Buildings)	X

Problem Statement-

Intelligent implementation of efficient water heating technologies in existing homes requires a more customized strategy for apportioning limited resources. Energy efficiency implementers and plumbers need a straight forward methodology for determining the most cost-effective measures for a specific application.

Broad-scale retrofit programs typically rely on a standardized suite of measures to be applied in the field. In the world of water heating, appropriate measures that should be considered include alternative water heater types, distribution system improvements (insulation, demand recirc, re-piping), energy efficient appliances, and improved fixtures and faucets. Making the right retrofit decision involves balancing the specifics of the existing household needs and "system" characteristics, with the general perspective of implementing the best mainstream solution. The historical approach of pulling the next water heater off the truck needs to evolve as the available options and performance characteristics of new equipment becomes more varied.

Background Knowledge:

Field studies looking at the comparative performance of conventional and alternative water heater types (Schoenbauer et al 2011, Pigg et al, 2010, Hoeschele et al, 2011) are informative about assessing real energy impacts, as well as customer satisfaction (on a small scale). Ongoing studies on HPWHs (EPRI, NEEA, and CARB studies) and the GTI PIER Advanced Gas Water Heater project will provide additional information. With a systems perspective, one needs to look at end use impacts such as showerheads (Mowris et al 2010) and efficient appliances. Distribution system impacts have been modeled (Springer et al, 2008), but more field data such as the Solar Row monitoring project[18] is needed to better understand these effects.

Stakeholder/Customer	Involvement/Interest
Manufacturers	Understanding integrated system performance. Conveying preferred applications to plumbers and homeowners.
DOE/Regulatory	Understanding integrated system performance.
Utilities/Programs	Programs are generally designed around delivering cost-effective savings. Improving the decision making process should contribute to greater savings.
Plumbers	Finding the most cost-effective solution. Respond to customer desires.
Occupants	Performance, reliability, cost savings.

Systems Considerations:

Historically water heating savings have been simplistically calculated based on comparing Energy Factors of competing technologies. With more and more field data suggesting that EF ratings do not necessarily reflect real performance, a more detailed evaluation approach is needed. This approach must balance between the best solution for a "typical" household with the immediate needs and desires of the current household. Water heater selection cannot be evaluated in isolation of other factors at the site. Improved fixtures and appliances, distribution system improvements, and load reducing strategies (solar, drain heat recovery, desuperheaters) must all be considered. This effort is integrated with other research areas focused on quantifying benefits as well as understanding customer acceptance issues.

Planned or Ongoing Research:

Ongoing and near-term research efforts will improve performance and customer satisfaction data on new products that are starting to achieve significant market share. Efficiency benefits, as observed with gas tankless water heater and HPWHs, come with some potential impacts to the customer. In 2012, the ARIES team will be assessing the potential for water heater and distribution system retrofits in five existing Syracuse, NY homes. NAHB is looking at the integration of solar with POU electric water heaters with a focus of better understanding distribution loss impacts. The ARBI team has completed a draft water heater selection criteria measure guideline that will support development of a retrofit assessment tool. CARB and IBACOS have completed measure guidelines specific to HPWHs and gas tankless water heaters, respectively. Under the GTI PIER Advanced Gas Water Heater project, Davis Energy Group is developing a California-specific design guide, which will be beneficial in the development of a retrofit tool.

Closing the Gap:

The goal is to develop a tool or methodology that can inform retrofit programs on how to proceed in different climates, housing types, utility rate scenarios, etc. The customer also plays into the equation, as preferences or

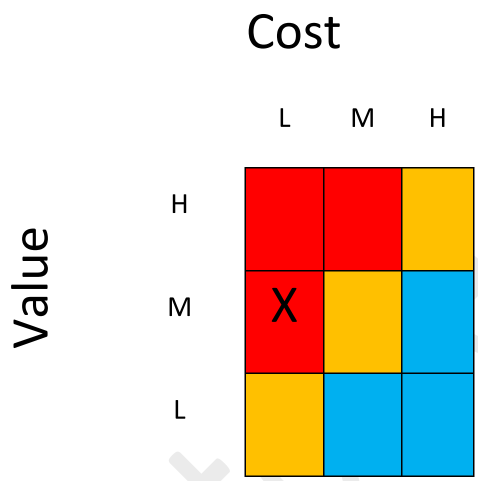
[18] http://www.aceee.org/files/pdf/conferences/hwf/2008/1c_burch.pdf

biases must be addressed. More field performance data and customer survey data are needed to inform the process.

Timeline:

This effort should encompass ~2 years.

Milestones: 1) Collect data on field performance, customer acceptance, utility programs (2011-2013); 2) Develop retrofit decision tool or methodology (2012-2013).



8. Advanced Gas Water Heater Field Assessment

BA Enclosures		BA Hot Water		House Type	
Walls		Test Standards	X	New	X
Roof/Ceiling		Distribution		Existing	X
Foundations		Condensing/Tankless	X	Single Family	X
Moisture		Heat Pump Water Heater		Multi Family	X
Windows		Combined Space & DHW Heating	X	**DOE Emerging Technologies**	
Other:		Other:		Walls and Windows	
BA Space Conditioning		**BA Miscellaneous Loads**		Efficient Appliances	
Heating		Home Energy Management		Advanced Heating & Cooling Fluids	
Cooling		Lighting		Solar Heating & Cooling	
Dehumidification		Large MELs (pools, etc.)		Geothermal Heat Pumps	
Distribution		Small MELs (TVs, VCRs, etc.)		Solid State Lighting	
Ventilation		Other:		Bulk Purchase	
Other:				Onsite Renewables (Building-Integrated Photovoltaic, onsite cogen)	
Testing Methods/Protocols		**BA Implementation**			
House Simulation Protocol		Quality Control/Quality Assurance			
Lab Test Methods		Training		**DOE Deployment**	
Field Test Methods	X	Documentation/Resources	X	Labeling/Rating	X
Analysis Methods/Tools		Needs Evaluation/Identification		Codes	
Analysis Tools	X	Other:		Standards	
Strategic Analysis	X			Large Scale Retrofit (Better Buildings)	X
Other:					

Problem Statement-

The field performance of standard atmospheric and high efficiency gas water heaters are known to often be lower than their rated efficiency. Field data has been collected in several recent studies, but some feel that additional information is needed to better assess these advanced gas technologies.

Tankless, condensing storage, and emerging hybrid gas water heaters all tout high efficiencies with Energy Factors or thermal efficiencies often exceeding 90% or 95% for condensing equipment. Lab testing and recent field studies have provided limited feedback on performance, with considerably lower observed annual efficiencies[19] (Schoenbauer et al, 2011). Factors that appear to degrade field performance include climate effects, hot water use behavior, standby losses, and parasitic electrical consumption. Understanding performance and customer acceptance issues (primarily for tankless) are likely the biggest issues.

Background Knowledge:

Recent laboratory testing (Colon and Parker, 2010; PG&E, 2008; Hoeschele and Springer, 2008) has shown that advanced gas storage water heaters perform at less than rated efficiency, especially for storage systems at low recovery loads. This has been corroborated in recent field studies (Schoenbauer et al, 2011; Pigg et al, 2010; Hoeschele et al, 2011).

[19] http://www.aceee.org/files/pdf/conferences/hwf/2008/1c_hoeschele.pdf

Stakeholder/Customer	Involvement/Interest
Manufacturers	Gather field data under varying conditions to understand field performance.
DOE/Regulatory	Characterize real world performance; input to test standard procedures.
Utilities/Programs	Programs designed around delivering cost-effective savings. Re-calibrating savings estimates based on observed field effects benefits program design .
Plumbers	Finding the most cost-effective solution for their customers.
Occupants	Understanding real performance vs. rated for improved decision making.

Systems Considerations:

Conventional storage water heater efficiency varies fairly strongly with load, but delivery of hot water to the distribution system is immediate and fairly steady in temperature. Tankless water heaters have performance issues (such as cold water sandwich, time delay) that may result in significant delivery issues, depending upon the characteristics of the distribution system and the homeowner expectations. Expectations vary widely, especially when homeowners have paid more to obtain a "better" product. Characteristics of the installation (distribution system, installed fixture specifications, climate, etc.) all contribute to the level of satisfaction the occupant receives from their new water heater. Reliability and maintenance issues are longer term factors that need to be studied with a broader sample size. Ideally, utility survey data could contribute in this area.

Planned or Ongoing Research:

The recently completed GTI Advanced Gas Water Heater Project has completed field monitoring activities at 18 California field sites (Hoeschele et al, 2011). This project evaluated a range of advanced water heaters relative to the existing gas storage water heaters at the homes. Part of the effort included surveys of the 18 homeowners on pros/cons of the installed equipment. This sort of data, combined with prior field assessment work, is needed on a broader scale to better inform on customer satisfaction issues.

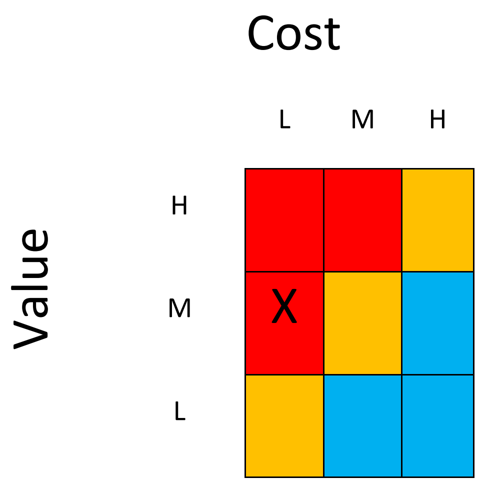
Closing the Gap:

This effort involves a collaborative effort among BA teams, utilities, and manufacturers. It is not clear to the extent that Building America can play a central role in this effort, other than gathering data from the relatively small number of customers involved in individual BA projects. Feedback from larger community scale projects would be helpful in assessing these emerging technologies. BA teams could also work with local utilities to develop a survey tool that could assess customer acceptance issues. Survey results from different regions could then be compiled into a broad assessment.

Timeline:

Assuming that this effort would rely largely on data from recent studies, this effort should encompass one year, or two at most.

Milestones: 1) Assess field findings performance from various studies (2011-2012); 2) Collect ongoing customer satisfaction data high quality field data from existing BA projects and potentially from utility partners (2011-2012); 3) Compile findings (2012-2013).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Gap/Barrier Resolution (page 3 of Gap/Barrier, to be completed after substantial completion)

***Outcome**: Description of how gap, barrier or need was resolved or modified. What role did Building America play? What are the indications that industry has benefited from the resolution of the gap/barrier? Did the resolution uncover other gaps or barrier? Include the date of resolution and the duration of research effort needed to resolve the issue.*

Appendix A:
Change Log

Record of additions and modifications to the summary sheets.

Date	Version of Plan (updated version #)	Title of Gap/Barrier/Need	Description of Change

Appendix B:
Past Research – Resolved Gaps, Barriers and Needs

When gaps or barriers are resolved a brief summary is appended to the strategic planning document as a running record of Building America achievements.

Appendix C:
Contributors