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Building America System Research Plan for Reduction of Miscellaneous Electrical Loads in Zero Energy Homes

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Technical Report
NREL/TP-550-43718
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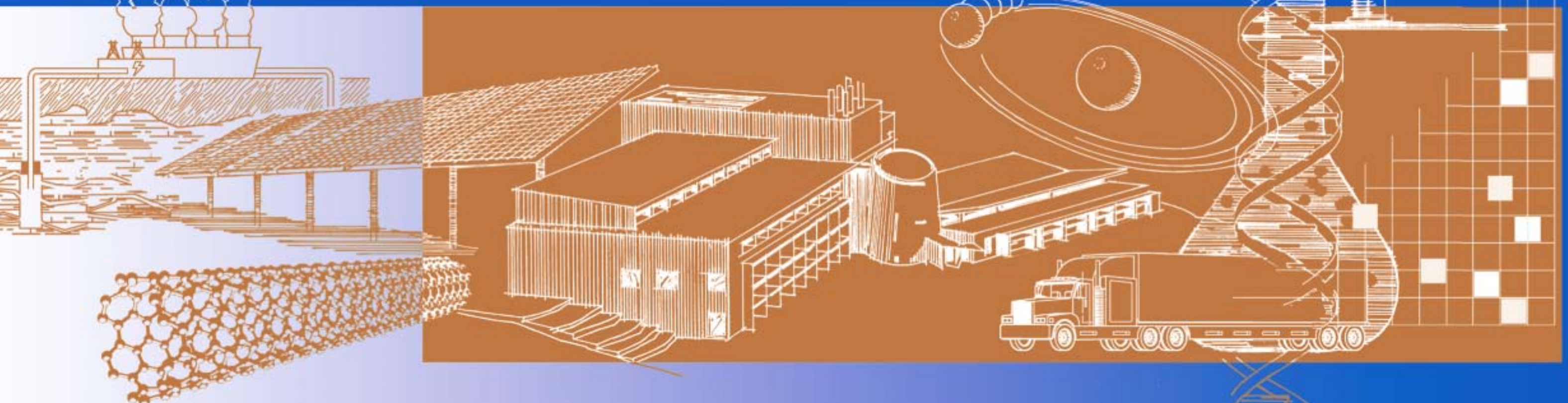

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Executive Summary

This research plan describes the overall scope of system research that is needed to reduce miscellaneous electrical loads (MEL) in future net zero energy homes. The original research plan was developed in 2006 in collaboration with a Working Group of Building America (BA) team members. In addition, an Advisory Board was also established at that time to provide current updates on related activities by other groups, including TIAX, Lawrence Berkeley National Laboratory (LBNL), the Environmental Protection Agency ENERGY STAR® program, and the Consumer Electronics Association (CEA). This update to the plan expands the discussion to include residential whole-building energy management systems due to the rapid growth in this area in recent years and the corresponding reductions in costs.

MELs in homes include components that are selected by the occupants such as televisions, computers, coffee makers, microwave ovens, vacuum cleaners, and irons, as well as some hard-wired components provided by the builder such as doorbells, alarm systems, control systems, and garage door openers. The MEL category includes all the loads that remain after accounting for heating, cooling, ventilation, domestic hot water (DHW), lighting, and large appliance loads. MELs are more difficult to address from a systems engineering standpoint because many are not under the control of the builder. As a result, energy savings in MELs has lagged behind energy savings in other residential end uses in BA homes. However, the urgency of addressing these loads increases with the increasing whole-house energy savings targeted by the BA program. MELs constitute about 17% of the BA Benchmark whole-house energy usage in a climate with large heating or cooling loads (such as Chicago or Phoenix) and about 25% of the load in a mild climate (such as San Francisco or San Diego). At the 50% energy savings target with no measures implemented to reduce MELs, they constitute about 34% of whole house energy usage in climates with large heating or cooling loads and about 50% of whole house usage in a mild climate. Future trends for MELs energy use are difficult to predict, potentially increasing the risk and difficulty of achieving 50%, 70%, and net zero energy milestones for the BA Program. Because of these factors, technologies, systems, and control strategies that directly reduce MEL energy use are a critical research gap that must be filled for the BA Program to meet its net zero energy performance goals.

The most economical design strategy for progressing toward zero energy homes is to implement aggressive energy conservation measures to reduce the loads up to the point where the incremental cost of further energy conservation measures exceeds the incremental cost of photovoltaics (PV); the remainder of the load is met with PV production. In order to include MEL reduction strategies in this progression, research is needed to ascertain the costs and the energy savings potential of various approaches, relative to the alternatives of further incremental efficiency savings in the other load categories and relative to PV production.

The present focus of this research effort is on builder-implementable whole-house energy management systems. As these strategies have the potential to also reduce non-MEL energy usage, cost-benefit analyses will include the overall impact on whole house energy usage.

Opportunities to reduce MELs fall into three general categories:

Individual component efficiency improvements. Many improvements in the efficiency of individual products and components are expected to occur as a result of ongoing investments by product manufacturers; utilities; public interest organizations; and federal, state, and local governments. Examples include recent progress by ENERGY STAR such as an updated specification for ENERGY STAR televisions that addresses standby and active power consumption and a new specification for ENERGY STAR digital-to-analog converter boxes, which are currently being introduced to the market in preparation for the transition to digital broadcasting.

Recommended technical approaches for this category include:

- Tracking product performance trends to ensure use of best available products in BA projects
- Providing recommendations for improvements in product performance based on experience in BA projects
- Acting as technical advisors on research efforts funded by other organizations
- Conducting targeted tests of new products when performance data is not otherwise available to verify benefits relative to BA performance goals.

Residential Whole House Energy Management Systems. Approaches in this category include programmable timers, occupancy detectors, whole house control switches, and adaptive controls. These systems may be implemented through a dedicated household wiring strategy, existing electrical wiring, wireless switching, and tie-ins with other control hardware in the home such as insulating blinds, lighting systems, space conditioning systems, building security systems, and utility load-management/demand-response controls.

Recommended technical approaches for this category include:

- Tracking product performance trends to ensure use of "best available" products in BA projects
- Providing recommendations for improvements in product performance based on experience in BA projects
- Using lighting systems, space conditioning systems, switchable power outlets, and other devices that allow for occupancy-based control
- Using control systems, receptacles, or other devices that control one or more outlets based on the power used by the main (master) outlet
- Using manual whole-house switches that provide occupants a tool to disable selected plug loads and lighting and change thermostat settings indefinitely or for prescribed time periods (e.g., 2 hours, 4 hours, 8 hours, extended vacation, etc.)
- Developing standardized energy-use modes for implementation in home automation and control system software and user displays.

The following figure summarizes average source energy savings relative to the Building America performance goals for a whole house energy management system that captures savings from MELs; lighting; and heating, ventilation, and air conditioning (HVAC). It is currently estimated that an average 6% whole-house source energy savings relative to the BA Benchmark will result from this integrated approach.

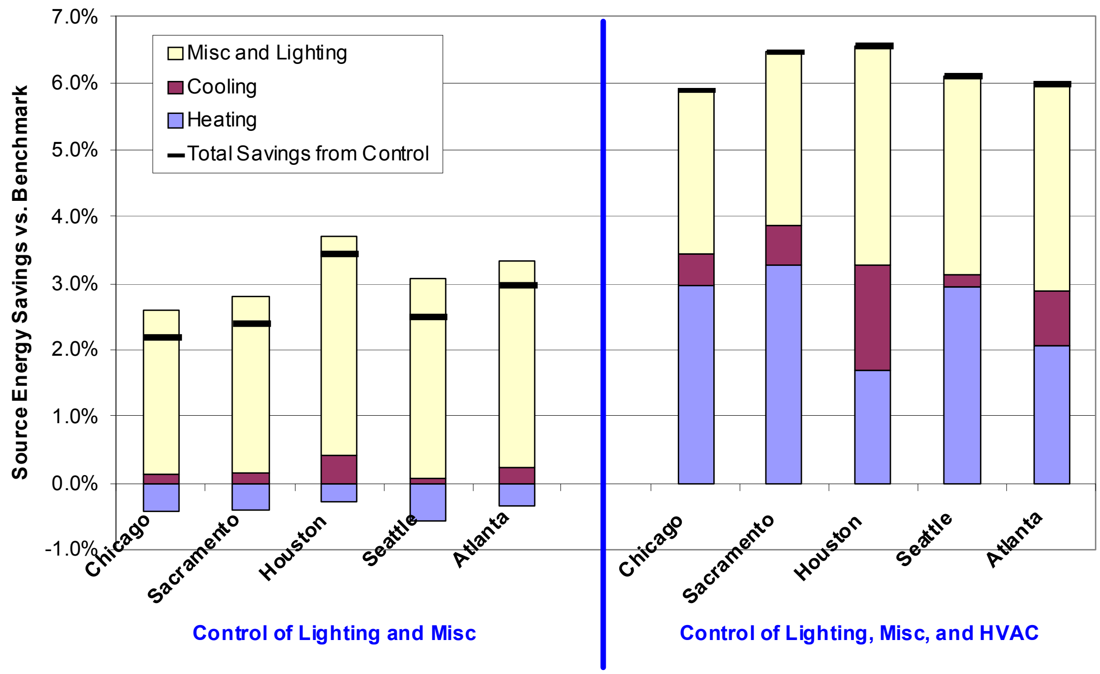


Figure 1. Estimated average source energy savings for a whole-house control systems in cities in each of the major climate zones

<u>Occupant behavior changes</u>. Approaches in this category include occupant education in household energy usage and product selection, and real-time feedback to occupants regarding energy usage. *While it is important to provide consumers with the information required to reduce energy end-uses, occupant behavior changes are considered to be largely outside the scope of the system research and technology development tasks of the BA Program.*

Opportunities with respect to this category include:

- Including information about energy-efficient home operation and product selection with homeowners manuals and operating guides
- Including energy feedback displays in BA homes.

The proposed research effort consists of six tasks and incorporates the BA Stage Gate decision process (Appendix A):

Task 1. Identify existing MEL-reduction strategies, review related work being done by other groups, and define requirements for development of advanced MEL reduction solutions beyond existing offerings.

Task 2. Stage Gate 1A (SG1A) evaluation of MEL reduction strategies: Within a whole building context and technology package, estimate the system’s contribution to BA energy performance and neutral cost targets using energy simulations and currently available performance data. Results from SG1A will be used to prioritize MEL reduction strategies for research efforts.

Task 3. Stage Gate 1B evaluation of MEL-reduction strategies: Test performance benefits of whole-house energy control systems.

Task 4. Stage Gate 2 evaluation of MEL reduction strategies: Test ability to integrate advanced systems with production building practices.

Task 5. Stage Gate 3 evaluation of MEL reduction strategies: Test performance of final production building designs and evaluate performance of occupied BA communities.

Task 6. Coordinate and track progress toward meeting program goals across the U.S Department of Energy's (DOE)-funded research in this area by all participating teams. Track product performance trends to ensure use of “best available” products in BA projects

A research schedule is outlined in Figure 2 for FY2008 through FY2010. The blue-shaded regions in the figure represent the expected duration of current control system evaluations; the red-lined tasks represent control system evaluations planned by BA team members as of June 2008; an additional breakdown of control system concepts and key research questions for Tasks 3 and 4 is included in Figure 3.

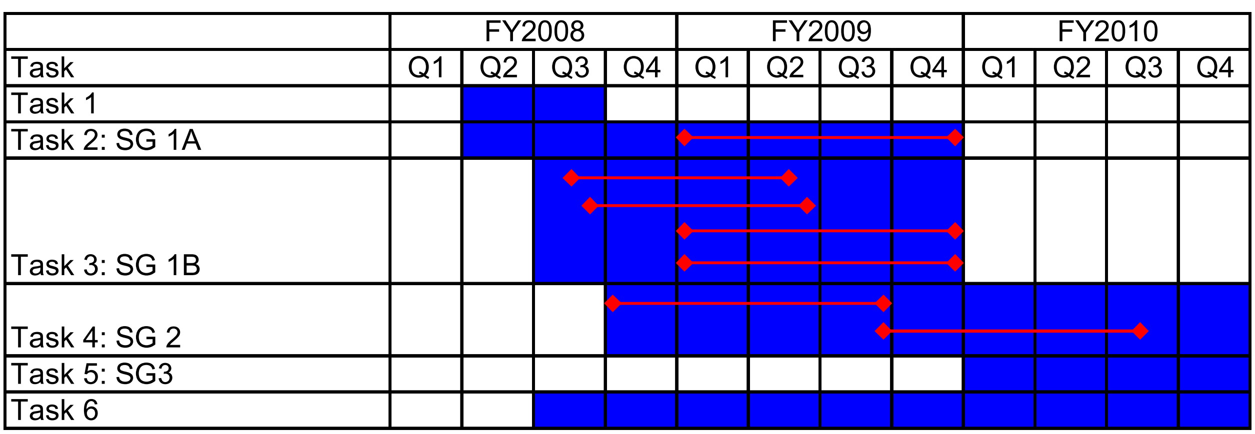
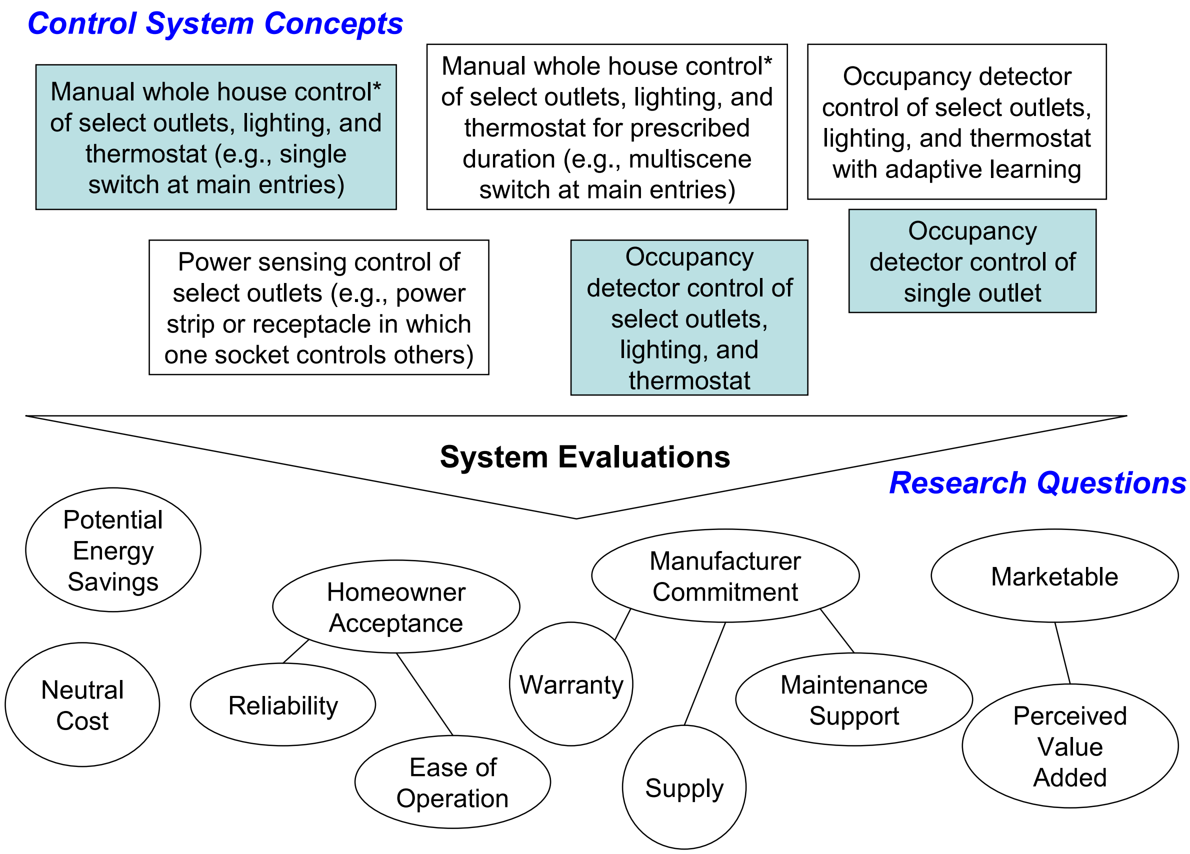


Figure 2. Research schedule for whole-house control system evaluations; blue-shaded regions represent expected task duration; red-lined tasks represent projects planned by BA team members as of June 2008



* Manual switch evaluations are recommended in conjunction with energy use feedback devices

Figure 3. Control system concepts and key research questions for MEL control system evaluations; concepts highlighted in light blue indicate work planned by BA teams as of January 2009; the listed research questions represent a subset of those included as part of the more comprehensive stage gate evaluation process

Table of Contents

I. Purpose

The purpose of this document is to:

1. Describe the overall scope of system research that is needed to reduce miscellaneous electrical load (MEL) energy use in the Building America (BA) program

2. Provide a framework for coordinating research efforts in this area by the various teams funded by the U.S. Department of Energy (DOE).

II. Collaborative Planning Group

This research plan has been developed in collaboration with the following BA MEL Working Group:

Bruce Baccei, ConSol

Dennis Barley, National Renewable Energy Laboratory (NREL)

Jeff Christian, Oak Ridge National Laboratory (ORNL)

Dianne Griffiths, California Air Resources Board (CARB)

Ryan Kerr, Building Industry Research Alliance (BIRA)

Brad Oberg, Integrated Building and Construction Solutions (IBACOS)

Danny Parker, Florida Solar Energy Center (FSEC)

Joe Wiehagen, National Association of Home Builders Research Center (NAHB-RC)

Kurt Roth, TIAX

Lew Pratsch, DOE

Also, based on a recommendation received at the BA Quarterly Meeting at DOE Headquarters on March 1, 2007, the following crosscutting Advisory Board has been established to provide current updates on related activities by other groups:

Rich Brown, LBNL

Andrew Fanara, Environmental Protection Agency ENERGY STAR® program

Brian Markwalter, Consumer Electronics Association (CEA)

III. Background

In the BA program, progress on energy efficiency in homes is measured relative to a fixed Benchmark that is based on standard construction practices and products circa the mid to late 1990s; approximately the time the program began [1]. A schedule of progressive goals over time, or Joule milestones, is defined in terms of percent whole-house source energy savings, as shown in Table 1. Reductions in miscellaneous electric energy use by way of effective residential whole-house energy management systems has been identified as on of one of the key energy-saving opportunities on the path to net zero energy homes. [2]

Table 1. Residential System Research Milestone Schedule

Performance Target[1]	Marine	Hot Humid	Hot/Mixed Dry	Mixed Humid	Cold
40%	Done	2010	Done	2009	2009
50%	2012	2012	2011	2013	2014
70%	2017	2016	2015	2017	2018
ZEH	2020	2020	2019	2020	2020

The long-term goal is to achieve net zero energy homes by the year 2020; it is expected that about 70% energy savings will be achieved through energy-efficiency measures and the remaining 30% through photovoltaic (PV) generation at the home site. In addition to economic concerns, which are discussed below, the goal of 70% energy conservation savings is considered necessary due to the constraint on the amount of PV that can be installed on the roof area typically available on a home, along with various roof orientations and the solar resource available in various climates.

As of FY 2009, progress in the program has led to well-defined, field-tested, builder-implemented approaches to meeting the 30%-40% savings goal in five climate regions. These energy savings have been achieved through:

- Building envelope improvements such as increased insulation and low-emissivity windows
- Heating and cooling system improvements such as efficient heat pumps, air conditioners, and duct systems
- Domestic water heating (DHW) system improvements such as well insulated tanks and tankless water heaters
- Installed lighting improvements such as compact fluorescent lamp fixtures

[1] Performance target is based on % energy efficiency savings relative to the Building America Benchmark.

- Improvements to large appliances installed by the builder such as range, refrigerator, dishwasher, and clothes washer and dryer.

The portion of the load that remains after accounting for heating, cooling, ventilation, DHW, lighting, and large appliances is referred to as miscellaneous electrical loads, or MELs. MELs include components that are selected by the occupants, such as televisions, computers, coffee makers, microwave ovens, vacuum cleaners, and irons. MEL may also include plug-in lighting provided by the occupants[2] and some hard-wired components provided by the builder, such as doorbells, alarm systems, and garage door openers. MELs are more difficult to address from a systems engineering standpoint, because many are not under the control of the builder. As a result, energy savings in MELs has lagged behind energy savings in other residential end uses in BA homes. However, the urgency of addressing these loads increases with the increasing energy savings targeted by the BA program. Figures 4 and 5 illustrate the increasing significance of MELs as energy savings are achieved in the other load categories, assuming that the MEL energy usage remains constant. Figure 4 is based on Benchmark cases where MEL is about 17% of the total load, as may occur in Chicago with a large heating load or Phoenix with a large cooling load. Figure 5 is based on a MEL of about 25% of the total, as may occur in mild climates such as San Diego and San Francisco. At the 50% energy savings target with no measures implemented to reduce MELs, the MEL contribution to the whole-house energy usage increases to about 34% in climates with large heating or cooling loads and to about 50% in mild climates. It would be very difficult and expensive to reach the 70% savings milestone without reducing MEL energy consumption, especially in mild climates.

Future trends for MELs energy use are difficult to predict, potentially increasing the risk and difficulty of achieving 50%, 70%, and net zero energy milestones for the BA Program. Recent projections suggest that MEL usage in 2020 may be 17% lower to 27% higher than MEL usage in 2006 [3]. Other projections suggest that MELs could double of the next 20 years. Figure 6 illustrates a scenario where MELs grow by 3.5% per year[3] in mild climates. Clearly, uncontrolled MELs are on a collision course with the performance goals of the DOE residential research program, and bringing these loads under control is critical to the Building America mission.

[2] In the BA Benchmark, plug-in lighting is included in the Lighting category rather than the MEL category. However, we mention it here because the same energy conservation strategies proposed for other plug loads may apply equally to plug-in lighting. The control of MELs thought the use of whole-house energy management systems also enables savings form control of hard-wired lighting, space conditioning systems, and appliances.

[3] 3.5% per year corresponds to a doubling in 20 years, as cited in Ref. [4] based on Ref. [5].

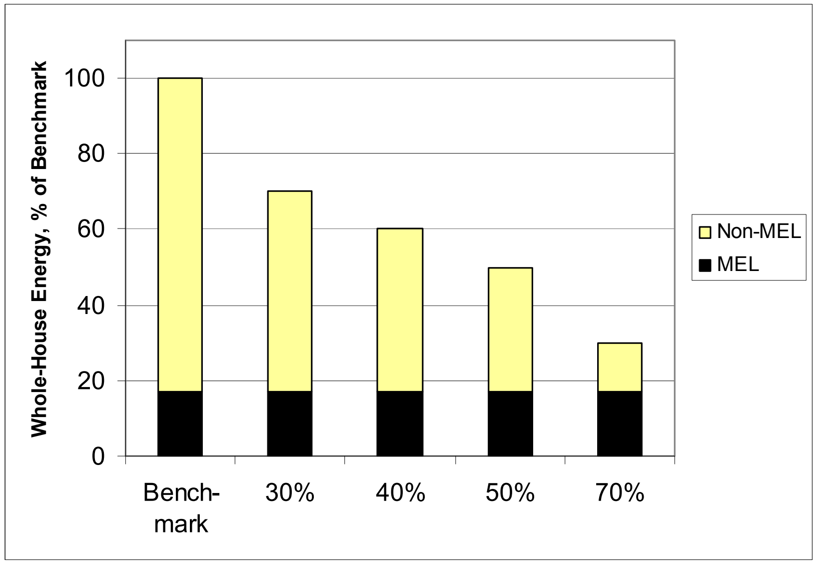


Figure 4 Increasing significance of MELs as energy savings targets increase, based on MELs = 17% of Benchmark total, typical of Chicago or Phoenix (MELs constant)

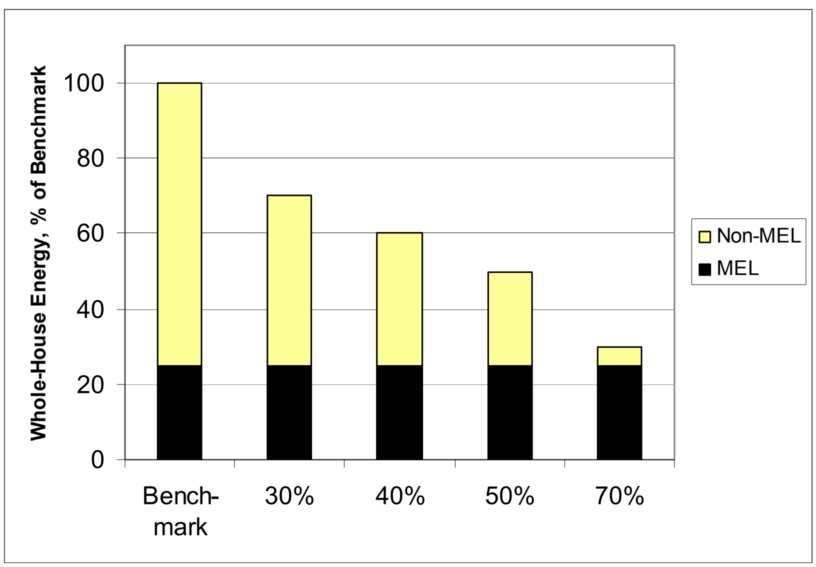


Figure 5 Increasing significance of MELs as energy savings targets increase, based on MELs = 25% of Benchmark total, typical of San Francisco or San Diego (MELs constant)

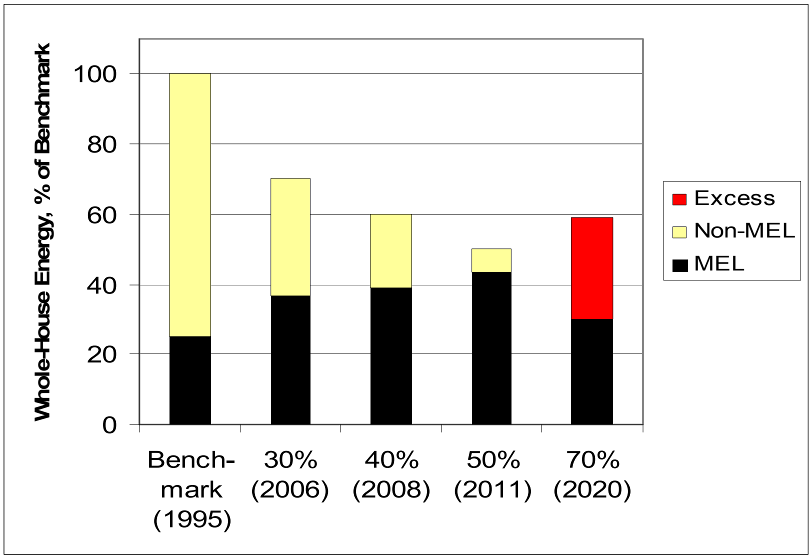


Figure 6 Increasing significance of MELs as energy savings targets increase, based on MEL = 25% of Benchmark total, typical of San Francisco or San Diego (MEL growth = 3.5%/year)

The most economical design strategy for progressing toward zero energy homes is to implement energy conservation measures to reduce the loads up to the point where the incremental cost of further energy conservation measures exceeds the cost of PV; the remainder of the load is met with PV [6]. The scenarios shown in Figures 4 and 5 are unbalanced because they require energy conservation measures in heating, cooling, DHW, lighting, and large appliances while doing nothing to reduce MELs. Thus, a compelling goal for BA's MEL research is to evaluate the cost-effectiveness of various MEL reduction strategies, relative to further incremental efficiency savings in the other load categories and relative to PV production. In the near term, existing "off-the-shelf" technologies can help meet milestones cost-effectively. More research is needed to evaluate the role of emerging technologies in achieving future milestones.

Another important consideration is the secondary effect of MELs on heating and cooling loads. In most cases, energy consumed by MELs is destined to show up as internal heat gains in the conditioned space. In any given hour, these gains may offset a portion of the heating load, may add to the cooling load, or may occur at a time when neither load is affected. Over the course of a year, the net effect of a MEL reduction on whole-house energy consumption depends on the timing of the MELs relative to the heating and cooling loads and on the efficiencies of the heating and cooling systems at those times. In addition, MEL reduction strategies such as whole-house control systems may also be employed to gain savings in lighting and space conditioning control. Thus, whole-house simulation analysis is needed to determine the net contribution MEL reduction strategies can make toward meeting the Joule milestones in the various climates.

Significant prior work on MEL usage in homes has been completed, which serves to describe MEL uses in homes and to quantify the amount of energy typically consumed for the various end uses. Hendron and Eastment [7] have reviewed data from numerous sources, including the DOE

Energy Information Administration (EIA), LBNL, Arthur D. Little, Inc., Pacific Gas & Electric Company, and KEMA Xenergy (Netherlands), and have consolidated the available data into a MEL Analysis Spreadsheet [8]. This analysis tool enables the itemized calculation of MELs characteristics (energy use in different operating modes, sensible and latent heat gains) based on numerous variables and should prove useful in estimating the effectiveness of various strategies for reducing MEL energy usage. An example calculation using the MEL Analysis Spreadsheet is included in Appendix B.

IV. Technical Approach: Strategies for Reducing MELs

Specific strategies for reducing MELs in homes based on discussions with the MEL Collaborative Planning Group and literature searches completed to date are outlined in this section. This list will be updated as additional approaches come to light. The approaches fall into three general categories:

- Individual component efficiency improvements
- Residential whole-house energy management systems
- Occupant behavior changes.

The present focus of this research effort is on builder-implementable strategies for MELs reductions, primarily through the use of integrated whole-house energy management systems. Appendix C includes lists of the top-25 benchmark MELs in terms of total power use and standby power losses as they existed in the late 1990s. These lists are intended to serve as a quick guide for assessing the primary contributors to total MEL usage and for planning MEL reduction strategies.

Individual Component Efficiency Improvements

MEL energy consumption can be decreased by improving the energy efficiency of the array of home electrical components in the home. This may occur in several ways

- General improvement in a class of components: For example, energy use by displays may be reduced by new screen technologies, implementation of low-power standby modes, or built-in occupancy sensors
- Premium components or "best in class": Such options enable MEL energy reductions through builder selection of more efficient hard-wired MELs (e.g., home security systems, ceiling fans, garage door openers) or via the occupant behavior of selecting efficient components (see Section IV C)
- Consolidation of component functions: For example, a combined printer/fax/copy machine may have lower energy consumption than three individual units. A single set-top box serving multiple televisions may have lower energy consumption than multiple set-top boxes
- Direct current (DC) components: Many components operate on DC power internally, but include AC-to-DC power converters for compatibility with AC power systems. Each of these internal AC-to-DC power converters incurs conversion losses as well as stand-by losses. The marketing of components that are compatible with an external DC power supply enables the systems approach of providing a household DC power supply that may incur smaller losses than the collection of individual power converters internal to numerous components. Furthermore, in homes where DC power is already available from a PV system or other source, this approach also eliminates losses in the conversion of DC power to AC for these components [9, 10]

- Codes and standards: Federal and state regulations require components to meet specified energy efficiency criteria. "Raising the bar" on these criteria could reduce MEL energy consumption
- Certification programs such as ENERGY STAR encourage the selection of more energy efficient components, along with any associated incentive programs
- BA may provide feedback to industry regarding the highest priorities for component efficiency improvements based on specific impacts on whole-house energy usage

Many improvements in the efficiency of individual products and components are expected to occur as a result of ongoing investments by product manufacturers, utilities, public interest organizations, and federal, state and local governments.

Recommended technical approaches for the BA Program for this category include:

- Tracking product performance trends to ensure use of "best available" products in BA projects
- Providing recommendations for improvements in product performance based on experience in BA projects
- Acting as technical advisors on research efforts funded by other organizations
- Conducting targeted tests of new products when performance data is not otherwise available to verify benefits relative to BA performance goals.

Residential Whole House Energy Management Systems

Because of cost reductions, increased availability, and increased market demand builders are including an increasing array of automated control systems in new homes. A number of control strategies are now available:

- Programmable timers that switch component circuits on a daily or weekly schedule or provide occupants with a means to temporarily activate or deactivate a device
- Smart receptacles or power strips that automatically turn on or off slave devices based on a master outlet (e.g., automatically turn on or off slave home-office accessories when a master personal computer (PC) is turned on or off)
- Occupancy detectors (infrared or ultrasonic) that turn off components when occupants are absent
- Artificial intelligence/pattern-recognition/adaptive control strategies that collect data on occupant behavior and adapt the control strategy to fit the behaviors. Such technology is currently applied to programmable thermostats and water heaters.

In conjunction with these basic control strategies, a number of enabling technologies such as household wiring, wireless controls, self powered sensors and switches, and tie-ins with existing or additional controllers may facilitate implementation. For example, household wiring may provide dedicated circuits that may be switched by various strategies (always on, timer control, occupancy control, etc.). Wireless technology is an alternative to the household wiring strategy, enabling the switching of individual components from a centralized controller. Wireless whole-house control systems are becoming increasingly attractive with the significant growth in the home automation market and recent availability of numerous off-the-shelf products for residential applications. Additionally, the cost of implementing MEL control strategies may be decreased by consolidating these control functions with other control hardware in the home such as peak-load limiting controls, building security systems, or utility load management switching.

Recommended technical approaches for the BA Program for this category include:

- Tracking product performance trends to ensure use of "best available" products in BA projects
- Providing recommendations for improvements in product performance based on experience in BA projects
- Using lighting systems, space conditioning systems, switchable power outlets, and devices that allow occupancy-based or timer-based control
- Using control systems, receptacles, or other devices that control one or more outlets based on the power used by the main (master) outlet
- Using manual whole-house switches that provide occupants a tool to enable or disable selected plug loads and lighting and change thermostat settings indefinitely or for prescribed time periods (e.g., 2 hours, 4 hours, 8 hours, extended vacation, etc.)
- Developing standardized energy-use modes for implementation in home automation and control system software and user displays.
- User-friendly controls that enable energy savings: Turning off a television with a remote control does not eliminate the standby loss; Unplugging the unit or switching off a power block on the floor behind the unit does eliminate the standby loss—however, the inconvenience of these methods may deter most occupants from using them. Providing a wall switch for this function may facilitate more frugal occupant behavior. Another example of this approach is a manual timer switch that would enable occupants to switch circuits on or off for a designated time period (semi-automatic control).

Evaluation of manual controls are encouraged in terms of homeowner acceptance and energy savings or cost benefit compared to automated whole-house controls. Recommendations for user-friendly manual controls are included in Section IV C. Evaluations of manual controls are recommended in conjunction with providing energy feedback displays in houses, as the two technologies are expected to complement each other.

Occupant Behavior Changes

Occupant influences on whole-house energy consumption arise in occupant selection and control of systems and components. Consumer product selection can have a significant influence on MEL energy use. For example, a recent study by CNET on the power consumption of high definition television sets revealed that annual operating costs, and thus annual energy usage, varied by more than a factor of 8 for 104 televisions [11]. Television energy-use is a function of TV size, but even with a fixed television size and type (e.g., 40 – 42 inch LCD screens), standby power had a range of 0.5 to 16.3 W and operating power had a range of 91 to 244 W. Maximum standby power use in the group of 104 televisions was 76 W.

Manual control of components and systems by occupants also influences whole house energy consumption. For example, switching off components or using a wall switch or power strip eliminates the components' standby losses. Changing thermostat settings when occupants are away or sleeping can reduce space conditioning loads. Savings from past efforts at occupant behavior changes, e.g. by providing a tool such as a programmable thermostat to help reduce space conditioning loads, have not been widely realized [12]. Lessons learned from past efforts should be considered when evaluating or introducing technologies that may enable future occupant behavior changes.

Approaches that have been suggested by the MEL Collaborative Planning Group for influencing occupant behavior in the direction of lowering MEL energy consumption include the following:

- Occupant education. This approach may involve providing a handbook to occupants, or any other means of making occupants generally more aware of the energy consequences of their actions. An energy-efficient home operation handbook is another option to help occupants decide how to operate their home to realize its net zero energy potential
- Occupant feedback. Instrumentation installed in the home measures MEL (and other) energy usage and reports the usage to the occupants in real time. One common analogy is that operation of a home without a feedback device is like shopping in a grocery store that lists no prices for its products [13]. In both cases, the consumer receives a bill for the aggregate price of the energy or food consumption but has no idea how, when, or by which item/appliance costs were incurred. With an occupant feedback system, the occupant is informed whether the consumption is relatively high or low (which could stimulate a search for reasons) and whether it has increased or decreased in response to any actions by the occupant. Research shows that occupants are more frugal in their energy consumption when they receive such direct feedback regarding the energy consequences of their actions [14,15,16].

While it is important to provide consumers with the information required to reduce energy end-uses, occupant behavior changes are considered to be largely outside the scope of the system research and technology development tasks of the BA Program.

Education is recommended as an implementation strategy in BA projects. Recommended approaches for the BA Program for this category include:

- Including information about energy-efficient home operation and product selection with homeowner's manuals and operating guides
- Inclusion of energy feedback displays in BA homes.

V. Research Activities

Based on the program goals and systems engineering concerns described above, the specific tasks proposed for this research area are as follows. Full details regarding the minimum and recommended criteria for BA stage gates are included in Appendix A.

Task 1. Identify existing and emerging MEL reduction strategies; review related work being done by other groups; define requirements for development of advanced MEL reduction solutions beyond existing offerings.

Residential load control and reduction technologies are currently available to address a number of the proposed strategies in Section IV. As new devices are identified, basic information for the device including cost, warranty, power use, and manufacturer will be added to a MEL equipment database for use by all BA team members. Needs for advanced MEL reduction solutions beyond existing offerings will be identified as the research program progresses and is developed with the MEL Collaborative Planning Group.

Task 2. Stage Gate 1A evaluation of MEL reduction strategies.

Within a whole building context and technology package, estimate the system's contribution to BA energy performance and neutral cost targets using energy simulations and currently available performance data. Results from SG1A will be used to prioritize MEL reduction strategies for research efforts. A strategy must meet source energy saving and neutral cost targets before further evaluation in Task 3.

Task 3. Stage Gate 1B evaluation of MEL reduction strategies.

Field test the performance benefits of automated and manual whole-house control systems to measure the effectiveness of each reduction strategy. MEL reduction strategies must meet source energy savings and whole building benefits as well as requirements of rating systems and codes and standards prior to evaluation in Task 4.

Task 4. Stage Gate 2 evaluation of MEL reduction strategies.

Test ability to integrate MEL reduction strategy with production building practices. Whole-house performance analysis for this task, based on the measured performance of the various strategies (Task 3), should take into account the secondary effects of reduced electrical loads on heating and cooling loads. MEL reduction strategies must meet source energy savings, prescriptive-based code approvals, and quality control requirements prior to evaluation in Task 5.

Task 5. Stage Gate 3 evaluation of MEL reduction strategies.

Test performance of final production building designs and evaluate performance of occupied BA communities.

Task 6. Track progress.

Monitor the DOE-funded research in this area by all participating teams, and track progress toward meeting program goals. Track product performance trends to ensure use of best available products in BA projects

A progress report on Task 2 was presented at the second quarter 2008 BA Team Meeting [17] for whole-house control systems. Figure 7 summarizes an estimate of the average source energy savings relative to the BA performance goals for a whole-house energy management system that captures savings from MELs, lighting, and HVAC. It is currently estimated that an average 6% source energy savings relative to BA performance goals will result from this approach.

Figure 8 summarizes control systems that will be evaluated as part of this research plan with potential inputs and outputs. An overview of the system capabilities currently in planning for Tasks 3 and 4 is provided in Figure 9. Recommended control system classification and tracking is included in Appendix D.

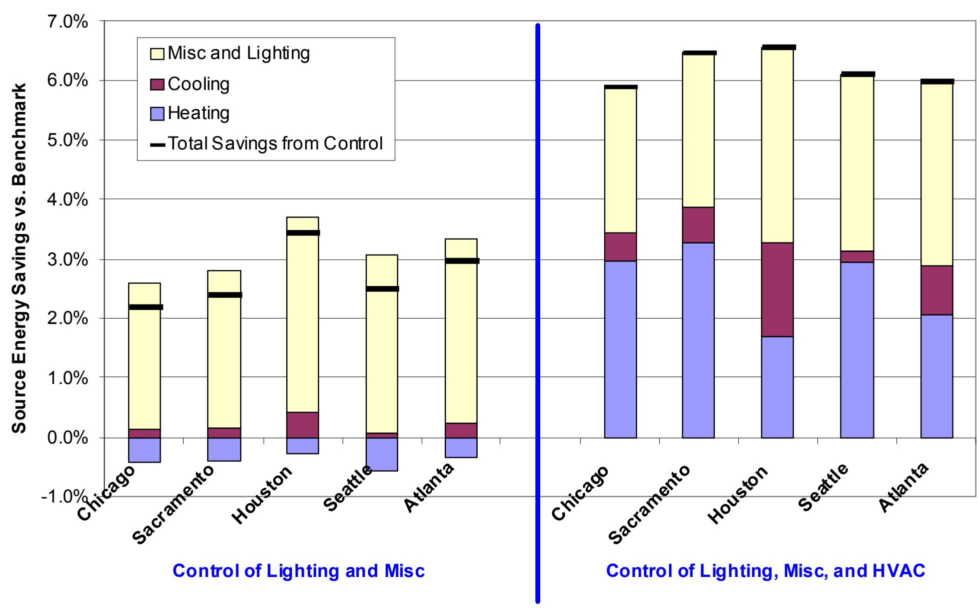


Figure 7. Estimated average source energy savings for a whole-house control system in cities in each of the major climate zones

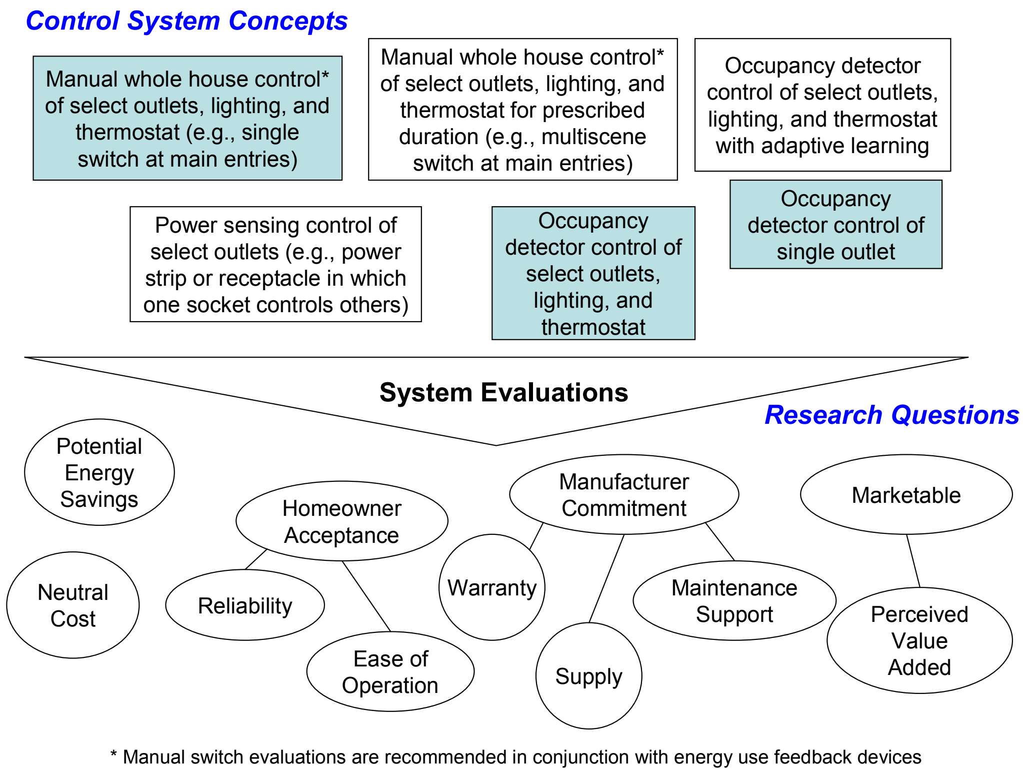


Figure 8. Control system concepts and key research questions for MEL control system evaluations; concepts highlighted in light blue are in planning by BA teams as of June 2008; the listed research questions represent a subset of those included as part of the more comprehensive stage gate evaluation

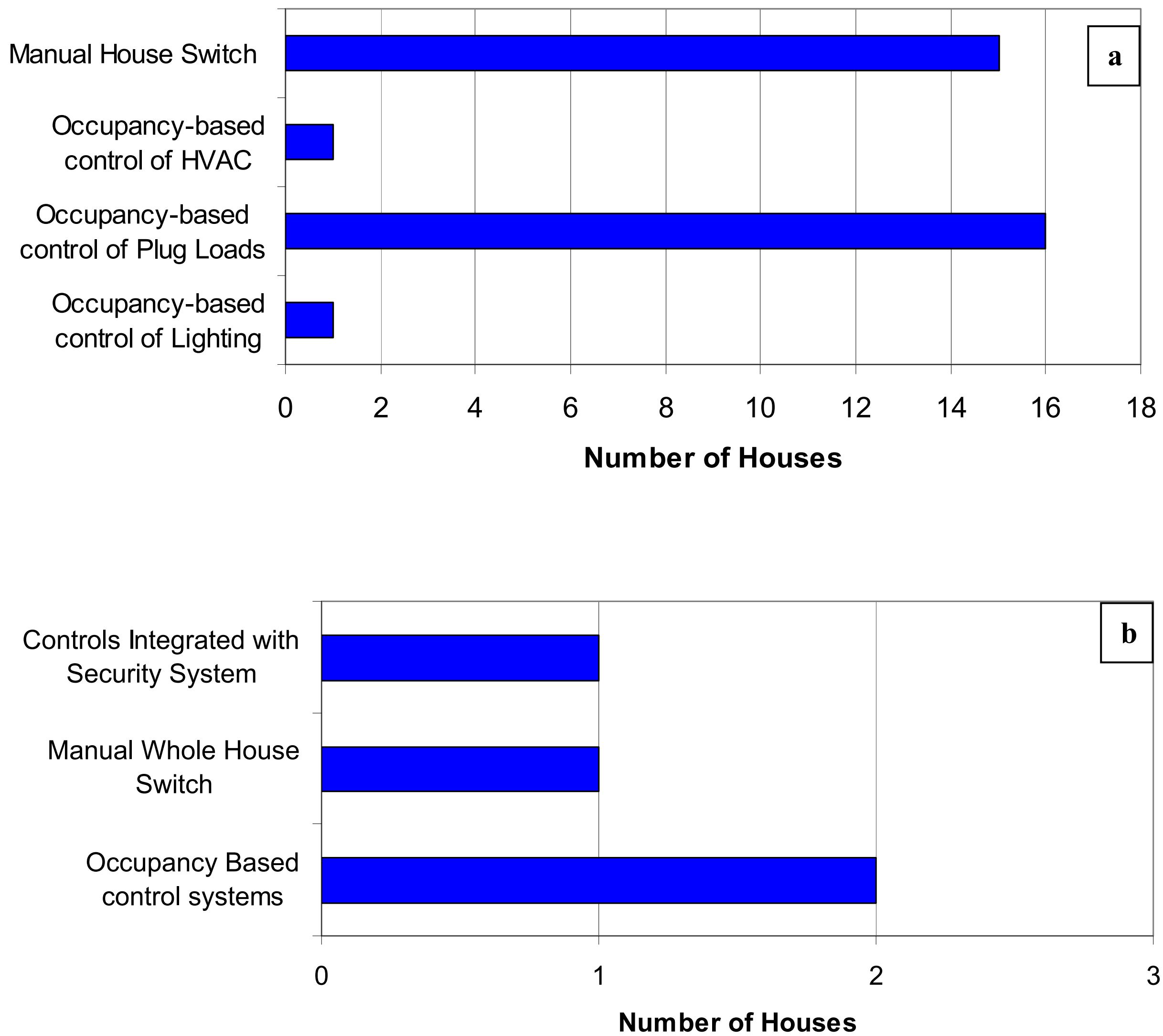


Figure 9. Summary of evaluations planned in 2009 for (a) Task 2 and (b) Task 3

VI. Research Schedule

The supporting research schedule for this plan is presented in Figure 10 for FY2008 through FY2010. The blue-shaded regions in the figure represent the expected duration of current control system evaluations. The red-lined tasks represent control system evaluations planned by BA team members as of June 2008.

This schedule illustrates MEL strategy evaluations for whole-house control systems through the stage gate process. Although tasks are identified with start and stop dates in this schedule, it is recognized that this will be an on-going effort for BA as new technologies are developed and evaluated.

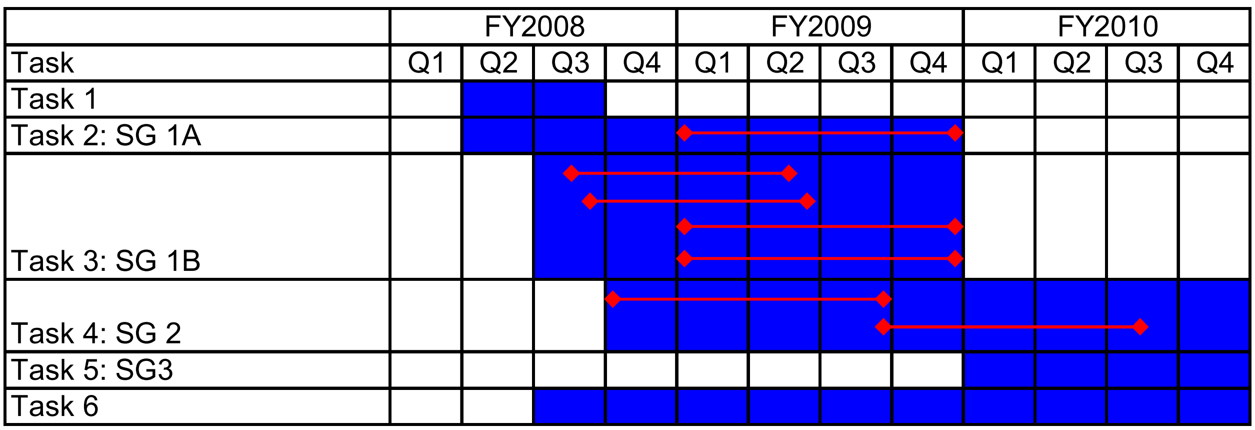


Figure 10. Research schedule for whole-house control system evaluations; blue-shaded regions represent expected task duration; red-lined tasks represent projects planned by BA team members as of January, 2009.

VII. References

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Appendix A. Building America Stage Gate Process

The BA stage gate process provides the means by which MEL reduction strategies will be evaluated for this research plan. The stage gate process is a methodical approach to ensure strategies pass a relatively low-cost gate such as analysis prior to evaluation in a higher-cost gate such as a field test. The gate process also provides a basis for evaluation of savings as measured results are compared to analysis and best-case savings projections. Table A1 summarizes the "must meet" and "should meet" criteria for each gate evaluation. Also included are supporting details and documentation required to verify gate fulfillment.

Table A1 Building America Stage Gate Process

Gate	Title	Must Meet	Should Meet	Details	Documentation
1A	**Expected Whole House Energy Saving and Cost Targets**			Within a whole building context and technology package, estimate system's contribution to BA energy performance and neutral cost targets using energy simulations and currently available performance data.	
		Source Energy Savings Target		Expected source energy savings from recommended technology package including the advanced system must meet BA program performance goal.	Analysis. Calculated based on definitions in BA Performance Analysis Procedures. Specifications for target source energy savings based on BEOpt analysis.
		Neutral Cost Target		The incremental mature market cost of energy improvements, when financed as part of a 30 year mortgage, should be less than or equal to the annual reduction in utility bill costs relative to the BA benchmark house.	BEOpt savings vs. source cost summary.
			Least Cost	Mature market incremental cost of technology package including advanced system should be less than or equal to currently available "least cost"alternatives based on sum of utility bill and energy-related increases in mortgage costs.	Evaluation of cost tradeoffs.
			Marketability	System should contribute market value and performance benefits, including utility peak demand reduction benefits, relative to climate region best practices.	Evaluation of market value/market incentives.
			Gaps Analysis	Should include initial evaluation of major technical and market barriers to achieving the targeted system performance levels.	Initial evaluation of barriers and risks.
1B	**System Evaluations**			Test performance benefits of new systems.	
		Source Energy Savings and Whole Building Benefits		New whole house system solutions must provide demonstrated source energy and whole building performance benefits, including labor and material cost tradeoffs, comfort,durability, reliability, health, …, relative to current system solutions based on BA test and analysis results.	Test and analysis (Also see 1A Source Energy Savings comment). What performance testing has been completed? What additional testing is required?
		Performance-Based Code Approval		Must meet performance-based safety, health, and building code requirements for use in new homes.	Summary of code and standards issues based on performance.
			Prescriptive-Based Code Approval	Should meet prescriptive safety, health and building code requirements for use in new homes.	Summary of prescriptive code and standards issues.
			Cost Advantage	Should provide strong potential for cost benefits relative to current systems within a whole building context.	Summary of cost benefits.
			Reliability Advantage	Should meet reliability, durability, ease of operation, and net added value requirements for use in new homes.	Summary of overall benefits.
			Manufacturer/Supplier/ Builder Commitment	Should have sufficient logistical support (warranty, supply, installation, maintenance support) to be used in prototype homes.	Summary of market availability.
			Gaps Analysis	Should include system's gaps analysis, lessons learned, and evaluation of major technical and market barriers to achieving the targeted performance level.	Summary of remaining gaps based on test results.
2	**Prototype House Evaluations**			Test ability to integrate advanced systems with production building practices.	
		Source Energy Savings		Prototype homes must provide targeted whole house source energy savings based on BA performance analysis procedures and energy performance measurements.	Test and analysis (Also see 1A Source Energy Savings comment).
		Prescriptive-Based Code Approval		Must meet prescriptive or performance safety, health and building code requirements for new homes.	Summary of code issues.
		Quality Control Requirements		Must define critical design details, construction practices, training, quality assurance, and quality control practices required to successfully implement new systems with production builders and contractors.	Quality design checklist.
			Neutral Cost Target	The incremental annual cost (evaluated relative to builder standard practice, based on estimated mature market cost) of energy improvements, when financed as part of a 30 year mortgage, should be less than or equal to the annual reduction in utility bill costs relative to the BA Benchmark.	BEOpt cost summary.
			Quality Control Integration	Health, Safety, Durability, Comfort, and Energy related QA, QC, training, and commissioning requirements should be integrated within construction documents, contracts and subcontractor scopes of work.	Simple quality implementation checklist.
			Gaps Analysis	Should include prototype house gaps analysis, lessons learned, and evaluation of major technical and market barriers to achieving the targeted performance level.	Summary of remaining gaps.

Table A1 Building America Stage Gate Process - Continued

minimum code

3	**Initial Community Scale Evaluation**			Test performance of final production building designs.	
		Source Energy Savings		Final production home designs must provide targeted whole house source energy efficiency savings based on BA performance analysis procedures and prior stage energy performance measurements.	Summary of performance specs and updated hourly simulations based on data from previous tests.
		Market Coverage (Includes projects from all teams)		Must have a minimum of 5 builders with (1) a minimum of 10 homes per project and (2) a minimum of 5 homes completed by March/April.	Summary of project status.
		Neutral Cost Target		The incremental annual cost* of energy improvements, when financed as part of a 30 year mortgage, must be less than or equal to the annual reduction in utility bill costs relative to the BA benchmark house.	BEOpt cost summary.
			Marketability	Based on initial response from model homes, should be marketable relative to the value-added benefit seen by consumers at increased or neutral cost.	Summary of market value.
			Market Coverage	Project case studies should cover a representative range of weather conditions and construction practices in major metropolitan areas in the targeted climate region.	Summary of project case study locations.
			Builder Commitment	Should demonstrate strong builder commitment to continued construction at current or future BA performance targets.	Summary of builder business model.
			Gaps Analysis	Should include a summary of builder technical support requirements, gaps analysis, lessons learned, optimal builder business practices, what not to do, documentation of failures, recommendations for policy improvements, and remaining technical and market barriers to achieving current and future performance	Summary of remaining gaps.
			Quality Assurance	Should provide documentation of builder's energy related QA and QC processes.	Summary of builder QA and QC processes.
	Final Project Close Out Evaluations			Evaluate lessons learned from occupied BA communities.	
		Source Energy Savings		Final production homes must provide targeted whole house source energy savings based on BA performance analysis procedures and energy performance measurements in unoccupied homes.	Summary of final performance specs and analysis.
		Neutral Cost Target		The final incremental annual cost of energy improvements, when financed as part of a 30 year mortgage, should be less than or equal to the annual reduction in utility bill costs relative to the BA benchmark house.	BEOpt cost summary.
		Quality Control Integration		Health, Safety, Durability, Comfort, and Energy related QA, QC, training,and commissioning requirements must be integrated within construction documents, contracts, and subcontractor scopes of work and builder quality procedures.	Final quality implementation checklist.
			Marketability	Based on sales data, should be marketable relative to the value-added benefit, including utility peak demand reduction benefits, seen by consumers at increased or neutral cost.	Summary of market value.
			Builder Commitment	Should demonstrate strong builder commitment to continued construction at current or future BA performance targets.	Summary of builder/developer business model.
			Homeowner Satisfaction	Should demonstrate high levels of homeowner satisfaction.	Homeowner survey.
			Gaps Analysis	Should include a summary of builder technical support requirements, gap analysis, lessons learned, optimal builder business practices, what not to do, documentation of failures, recommendations for policy improvements, and major technical and market barriers to achieving the next performance levels.	Summary of remaining gaps.

Appendix B. Building America MEL Analysis Spreadsheet

An MEL Analysis Spreadsheet was developed by Hendron and Eastment [i]. It is based on data from numerous sources, including EIA, LBNL, Arthur D. Little, Inc., Pacific Gas & Electric Company, and KEMA Xenergy (Netherlands), which describe MEL uses in homes and quantifies the amount of energy typically consumed for the various end uses. This analysis tool, which is available on the Internet at no cost to the user [ii], enables the itemized calculation of MELs energy savings based on numerous variables. The excerpts shown on the following pages serve to illustrate an approach for estimation of MEL savings resulting from elimination of "off mode" power losses for a home office control device.

References

[i] Hendron, R.; Eastment, M. *Development of an Energy-Savings Calculation Methodology for Residential Miscellaneous Electric Loads.* NREL/CP-550-39551. Golden, CO: National Renewable Energy Laboratory, 2006.

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The savings strategy example in Table B1 considers the total savings potential for a device that eliminates all off-mode power use for a home office. As the quantity and type of home-office accessories for the prototype are unknown, it is assumed for this example that the prototype will have the same quantity and type of home office equipment as the benchmark. This results in the prototype having less than one printer and computer monitor, which is not realistic for an individual prototype. The total savings are instead representative of the average savings possible for a large sample of occupants. As shown in the table, the calculated miscellaneous savings for this approach are 0.7%.

Table B1 MEL Analysis Spreadsheet Example Savings Strategy

	Prototype Characteristics	
4	Finished Floor Area (ft2)	1800
5	Number of Bedrooms	3
6	State Multiplier*	1.00
7	Total MEL/MGL Energy (kWh/yr)	3047
8	% MEL/MGL Savings vs Benchmark	0.7%
9	Total MEL Energy (kWh/yr)	2714
10	Total MGL Energy (therms/yr)	11.4
11	Fixed MEL/MGL Energy (kWh/yr)	698
12	Unspecified MEL/MGL Energy (kWh/yr)	2968
13	Total MEL/MGL Standby Energy (kWh/yr)	745
14	Total MEL/MGL Operating Energy (kWh/yr)	2302
15	% MEL/MGL Sensible Load	67.3%
16	% MEL/MGL Latent Load	7.1%

	Benchmark Characteristics	
19	Total MEL Energy (kWh/yr)	2735
20	Total MGL Energy (therms/yr)	11.4
21	Fixed MEL/MGL Energy (kWh/yr)	698
22	Unspecified MEL/MGL Energy (kWh/yr)	2968
23	Total MEL/MGL Standby Energy (kWh/yr)	766
24	Total MEL/MGL Operating Energy (kWh/yr)	2302
25	% MEL/MGL Sensible Load	67.6%
26	% MEL/MGL Latent Load	7.1%

Instructions

(1) Enter prototype house physical characteristics under the "Prototype Inputs" tab.
(2) For MELs that are installed or provided by the builder, enter the quantity in the white boxes in the table below.
(3) For all other MELs, enter zero for the number of units.
(4) For all MELs with a non-zero quantity, enter the average power draw in each operating mode in the white boxes below. Use the Benchmark value if power draws are unknown (column AB, AF, and
(5) ***Do not change the data in gray cells.*** These are calculated values, operating conditions, and fixed MELs that should remain constant.
(6) Total MEL energy for the Prototype and Benchmark are calculated and highlighted in red at left.
(7) Each MEL category has a user-defined end-use available for new technology. The user is responsible for entering realistic Benchmark energy use and operating conditions that allow comparison to

* State Multipliers: New York = 0.82
California = 0.77
Florida = 0.94
Texas = 1.11
All Others = 1.00

		Units KNOWN to be Present in Prototype	Prototype Characteristics: Off / Standby Power (W)	Idle Power (W)	Operating Power (W)	Prototype Energy (kWh/yr)	Benchmark Energy (kWh/yr)	Prototype Stdby/Idle Energy (kWh/yr)	Prototype Operating Energy (kWh/yr)	Benchmark Stdby/Idle Energy (kWh/yr)	Benchmark Operating Energy (kWh/yr)	Prototype Sensible Load (kWh/yr)	Prototype Latent Load (kWh/yr)	Benchmark Sensible Load (kWh/yr)	Benchmark Latent Load (kWh/yr)	Prototype Stdby/Idle Energy Savings (kWh/yr)	Prototype Operating Energy Savings (kWh/yr)	Total % Savings
91	New Technology / Other	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
92	***Home Office***																	
93	Laptop PC (Plugged In)	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
94	Desktop PC w/ Speakers	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
95	PC Monitor	0.592	0	5	65.0	67.2	70.9	2.2	65.0	5.9	65.0	67.2	0.0	70.9	0.0	3.8	0.0	5.3%
96	Printer (Laser)	0.049	0	80	250.0	2.8	4.5	2.2	0.5	4.0	0.5	2.8	0.0	4.5	0.0	1.8	0.0	39.2%
97	Printer (Inkjet)	0.118	0	15	45.0	1.2	4.6	1.0	0.2	4.4	0.2	1.2	0.0	4.6	0.0	3.4	0.0	73.2%
98	Dot Matrix Printer	0.030	0	0	875.2	3.5	3.5	0.0	3.5	0.0	3.5	3.5	0.0	3.5	0.0	0.0	0.0	0.0%
99	DSL/Cable Modem	0.200	0	0	5.4	1.4	3.5	0.0	1.4	2.1	1.4	1.4	0.0	3.5	0.0	2.1	0.0	59.0%
100	Scanner	0.050	0	0	14.0	0.1	2.4	0.0	0.1	2.4	0.1	0.1	0.0	2.4	0.0	2.4	0.0	97.4%
101	Copy Machine	0.020	0	0	39.3	0.3	0.5	0.0	0.3	0.2	0.3	0.3	0.0	0.5	0.0	0.2	0.0	49.0%
102	Fax Machine	0.030	0	0	175.0	2.3	9.8	0.0	2.3	7.5	2.3	2.3	0.0	9.8	0.0	7.5	0.0	76.5%
103	New Technology / Other	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
104	***Bathroom***																	
105	Hair Dryer	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
106	Curling Iron	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
107	Electric Shaver	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
108	Electric Toothbrush Charger	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
109	New Technology / Other	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
110	***Garage & Workshop***																	
111	Auto Block Heater	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
112	Lawn Mower (Electric)	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
113	Heat Tape	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%

Prototype Outputs / Locations / **Detailed MEL Analysis** / MEL Graphs / MEL References

Appendix C. Top MELs

The top-25 MELs were extracted from the MEL Analysis Spreadsheet to aid in understanding the primary contributors to MEL usage in the late 1990s time frame. Tables C1 summarizes the top-25 MELs in terms of total power use, and Table C2 summarizes the top-25 MELs in terms of standby power losses. The top-25 MELs in terms of total power use constitute almost 78% of the total MEL usage.

Table C1. Top 25 MELs in terms of total power use and their contribution to total MEL usage

Top 25 MELs (in terms of total power use)	Fractional Units per Household	Benchmark Total Energy (kWh/yr)	Contribution to Total MEL Usage
Freezer	0.323	297.3	9.7%
First Color TV	0.986	209.2	6.8%
Extra Refrigerator	0.179	193.8	6.3%
Pool Heater (Gas)	0.024	156.3	5.1%
Pool Pump (Electric)	0.066	144.8	4.7%
Microwave	0.933	126.1	4.1%
Component / Rack Stereo	0.730	109.9	3.6%
Cable Box, DVR, or TIVO	0.637	97.3	3.2%
Hot Tub / Spa Heater (Electric)	0.056	93.9	3.1%
Hot Tub / Spa Heater (Gas)	0.038	88.8	2.9%
Desktop PC w/ Speakers	0.592	83.8	2.7%
Second Color TV	0.669	74.2	2.4%
PC Monitor	0.592	69.8	2.3%
Water Bed	0.066	69.4	2.3%
Coffee Maker (Drip)	0.685	68.0	2.2%
Fan (Ceiling)	1.400	67.8	2.2%

First VCR	0.876	61.5	2.0%
Gas Fireplace	0.035	59.9	2.0%
Compact Stereo	0.460	50.8	1.7%
Well Pump (Electric)	0.129	50.8	1.7%
Air Handler Standby Losses	0.800	50.4	1.6%
Iron	0.847	44.9	1.5%
Hot Tub / Spa Pump (Electric)	0.094	42.6	1.4%
Toaster	0.837	36.6	1.2%
Home Security System	0.187	35.4	1.2%

Standby energy use for the top-25 standby MELs constitutes nearly 22% of the total MEL usage. While some of this usage may be difficult to reduce with a builder implementable strategy (e.g., standby losses due to answering machines or clock radios), a number of the top 25 standby users are builder-controlled items such as air handler standby losses, doorbells, ground fault circuit interrupters (GFCIs), HVAC controls, garage door openers, and home security systems. Standby losses from these hard wired devices make up 4.6% of total MEL usage. A several percent savings in MEL usage is likely through identification of best-in-class components for these items.

Table C2. Top 25 MELs in terms of standby losses and the contribution to total MEL usage

Top 25 MELs (in terms of standby losses)	Fractional Units per Household	Benchmark Standby Energy (kWh/yr)	Standby Contribution to total MEL Usage
Cable Box, DVR, or TIVO	0.637	80.0	2.6%
First VCR	0.876	56.7	1.8%
Component / Rack Stereo	0.730	55.5	1.8%
Air Handler Standby Losses	0.800	50.4	1.6%
Compact Stereo	0.460	42.4	1.4%

Cell Phone Charger	0.450	32.0	1.0%
First Color TV	0.986	29.8	1.0%
Doorbell	0.670	29.5	1.0%
Microwave	0.933	25.5	0.8%
Second Color TV	0.669	23.7	0.8%
Ground Fault Circuit Interrupter (GFCI)	3.850	23.1	0.8%
Coffee Maker (Drip)	0.685	22.1	0.7%
Second VCR	0.320	21.4	0.7%
Satellite Dish Box	0.202	20.6	0.7%
Answering Machine	0.650	20.6	0.7%
DVD Player	0.472	20.5	0.7%
HVAC Controls	1.000	20.3	0.7%
Clock Radio	1.260	18.2	0.6%
Desktop PC w/ Speakers	0.592	14.9	0.5%
Cordless Phone	0.601	12.9	0.4%
Video Gaming System	0.631	10.4	0.3%
Garage Door Opener	0.266	9.3	0.3%
Third Color TV	0.296	9.0	0.3%
Boombox / Portable Stereo	0.670	9.0	0.3%
Home Security System	0.187	8.2	0.3%

Appendix D. Control System Classification

The following table was developed to provide a consistent reporting format for whole-house control systems evaluated as part of this research plan. The table is designed as a form with drop down options for all categories except Builder and City.

Builder			
City			
Climate Region			
Communication Type Internal (in-house)			
Communication Type External (to utility)			
Control Options			
Integrated with home security system		Energy Usage Feedback	
Automated control of:		Manual Timer-based control of:	
Appliances	If Yes, specify	Appliances	If Yes, specify
Lighting		Lighting	
Home Office MELs		Home Office MELs	
Home Entertainment MELs		Home Entertainment MELs	
Other MELs		Other MELs	
Pool		Pool	
Shading system		Shading system	
Thermostat		Thermostat	
Ventilation		Ventilation	

Whole house "sleep" mode		Whole house "sleep" mode	
Manual whole house switch control of:		Utility Control of:	
Appliances	If Yes, specify	Appliances	If Yes, specify
Lighting		Lighting	
Home Office MELs		Home Office MELs	
Home Entertainment MELs		Home Entertainment MELs	
Other MELs		Other MELs	
Pool		Pool	
Shading system			
Thermostat		Thermostat	
Ventilation			

Appendix E. Building America MEL's Working Group Web site

BA MEL's Online Discussion Group

Sign up for the MEL's group site via the following link:

http://tech.groups.yahoo.com/group/BA-MELs/join?

This site includes presentations from BA MEL Expert meetings and links to online papers and feedback and control vendors.

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This research plan describes the overall scope of system research that is needed to reduce miscellaneous electrical loads (MEL) in future net zero energy homes. The original research plan was developed in 2006 in collaboration with a Working Group of Building America (BA) team members. In addition, an Advisory Board was also established at that time to provide current updates on related activities by other groups, including TIAX, Lawrence Berkeley National Laboratory (LBNL), the Environmental Protection Agency ENERGY STAR® program, and the Consumer Electronics Association (CEA). This update to the plan expands the discussion to include residential whole-building energy management systems due to the rapid growth in this area in recent years and the corresponding reductions in costs.

15. SUBJECT TERMS
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