MARYLAND-NATIONAL CAPITAL BUILDING INDUSTRY ASSOCIATION
1738 Elton Road, Suite 200, Silver Spring, Maryland 20903
(301) 445-5400 / Fax (301) 445-5499
Email : communications@mncbia.org
Website : www.mncbia.org

May 17, 2012

Mayor and Council
Rockville City Government (Send by E-mail)
Rockville City Hall
111 Maryland Avenue
Rockville, MD 20850

REF: 2012 Proposed Chapter 5, Buildings and Building Regulations Amendments

Madam Mayor and Members of the Council:

The Maryland-National Capital Building Industry Association appreciates the opportunity to provide comments on the proposed 2012 Building Regulations Update by the City of Rockville, which includes adopting the 2012 International Codes. Our comments and recommended amendments are submitted for the hearing record.

In addition to the well thought out amendments proposed in the City of Rockville's draft, the Association would like to bring to your attention the following energy and other amendments for your consideration and adoption.

These are commonsense energy neutral amendments that will lead to equal or higher energy efficiency than the requirements of the 2012 IECC, cost savings for the builder and consumer, and better indoor air quality and better design of buildings.

In particular, we would like to provide comments on the real world implications of the 2012 IECC requirements that led us to propose the following two priority energy code amendments, which are attached:

A. Reinstate energy neutral equipment trade-offs in the performance section of the 2012 IECC Residential Energy Efficiency.

B. Allow for energy neutral performance trade-offs for air leakage levels exceeding the overly stringent and problematic levels specified in the 2012 IECC Residential Energy Efficiency.

Our amendments merely allow exchanging one BTU saved for another and thus result in energy neutral outcomes which do not "weaken energy conservation and efficiency provisions contained in the Standards" [2012 IECC], a requirement of Maryland law.

The purpose of ***Amendment A*** is to allow equipment trade-off provisions for the heating systems, cooling systems, and service water heating in residential construction 3 stories and below as it already is allowed for those 4 stories or above.

One of the most practical, cost effective ways to conserve energy is to utilize high efficiency equipment. The 2012 energy code does not provide any incentives for the builder to install high efficiency equipment, but rather continues the use of the minimum equipment efficiencies established by federal standards. Failure to remove the existing language concentrates solely on the building envelope by focusing on insulation and windows to meet specific energy targets.

Removal of equipment efficiency for energy code compliance, which first occurred in the 2009 edition of the IECC and remains absent from the 2012 edition, is contrary to the intent of the IECC and the legislated mandate of the DOE. Section R101.3 of the 2012 IECC states that "this code is intended to provide flexibility to permit the use of innovative approaches and techniques to achieve" "effective use and conservation of energy." Also, DOE's legislative mandate states that the department should "seek adoption of all technologically feasible and economically justified energy efficient measures" as stated in section 42 U.S.C. § 6836. There is evidence that the ICC Final Action (Charlotte, NC, October 25-30, 2010) results for the 2012 energy code were undermined and the outcome biased with respect to specific products and the placement of limits on choices [**Appendix A**].

It is clear that high performance space heating, space cooling and water heating equipment save energy and are technically feasible; therefore, it should ultimately be a market determination of whether the use of high efficiency mechanical equipment is economically justified to achieve code-required levels of overall building efficiency.

There is evidence that significant construction cost savings can be realized by the consumer when allowing energy neutral equipment trade-offs; making equipment efficiency trade-offs essential in achieving "effective use and conservation of energy."

A recent study [**Appendix B**] from the NAHB Research Center provides energy simulation results for the 2009 and 2012 IECC. The study determined cost savings of more than $1,600 for building an equally energy efficient house using the 2012 IECC when flexibility is allowed for trade-offs that included air tightness and insulation and a higher efficiency furnace.

The 2012 IECC already allows performance equipment trade-offs for achieving the required degree of energy efficiency in commercial and high-rise residential construction (above 3 stories) and further EPA's and DOE's jointly sponsored Energy Star program and DOE's Builder's Challenge acknowledge the importance of equipment efficiency in attaining required, cost-effective, energy saving results.

Eliminating the ability to use equipment efficiency as a means to achieve whole-house energy conservation will discourage the use of higher efficiency equipment. Eliminating this ability discourages the concept of the "house as a system" approach which is a cornerstone of many state energy programs and the Federal Energy Star Program. In fact, without this amendment the current practice for constructing an Energy Star home in this jurisdiction would be disallowed.

Using less efficient HVAC equipment such as a 78% naturally vented gas furnace with a B-vent (chimney) configuration will complicate and perhaps prevent the installation of higher efficiency replacement equipment at a future time.

The feedback from builders knowledgeable about energy efficiency supports the view that the 2012 IECC is pushing or exceeding practical limits in nearly every aspect of the energy code. There are concerns about liability from a house that is too tight and that has indoor air quality issues.

While the 2012 IECC is driving, in a positive way, major changes in how builders evaluate certain products and construction practices, there nonetheless are some changes that many builders, with seemingly sound justification, are reluctant to make (e.g. adding continuous exterior foam insulation and consistently achieving extremely tight envelopes). In addressing such concerns, high efficiency equipment trade-offs are necessary to provide builders the ability to manage potential liabilities since additional time and experience may end up demonstrating that liability concerns are well founded and that alternative approaches to increasing energy efficiency are warranted.

We want to prevent indoor air quality issues caused by "building too tightly" from becoming the energy equivalent of the Exterior Insulation and Finish System issues of the early 2000s or the Fire Retardant Plywood issues of the early 1990s.

This leads us to support code ***Amendment B***: Allow for energy neutral performance trade-offs for air leakage rates exceeding those specified in the 2012 IECC Residential Energy Efficiency.

Our amendment offers the ability to trade off building tightness in the performance path against other building requirements resulting in a home with equivalent energy performance.

A requirement for home air tightness of 3 Air Changes per Hour or less at a 50 Pascal pressure (3 ACH50 or less) is extremely aggressive. A 1998 study by Lawrence Berkeley National Labs (Sherman and Dickerhoff) shows that only about 7% of the homes in the U.S. are at that level of tightness or tighter.

Meeting this requirement is challenging in nearly all circumstances; however, it is even more difficult in smaller homes that are built on slabs or crawl spaces. Moreover, the test for air tightness cannot be performed until the house is at or near completion, thereby limiting the ability to correct most leaks after testing.

Achieving air tightness is not an exact science. In order to meet a target requirement for air leakage rate of either 3 ACH50 (2012 IECC) or 7 ACH50 (2009 IECC) in climate zone 4, a builder will aim for an ACH50 that is lower by 2. The builder does this to meet the requirement since the air tightness is controlled by too many variables.

We are saying that even with the current 7 ACH50 requirement, an extremely air tight house could be the result. If the code required 5 ACH50, then because of real world construction tolerances influenced by variables such as buried basement vs. slab on grade condition, house size, and architectural features such as loft conditions, the builder would still need to aim for a home with an air tightness of 3-4 ACH50 with a deviation expected of minus 1 or 2 ACH50. Again creating an extremely tight house and not eliminating the need for make-up air supplied by energy inefficient powered outdoor air ventilation. In the real world a target of 5 ACH50 does little to address the issues.

7 ACH50 is a practical effective level and any leakage in excess of 3 ACH50 would have to be offset by other energy savings for a net energy neutral home.

In summary, not receiving credit for more efficient equipment will encourage the use of less efficient naturally vented rather than direct vented equipment. This in conjunction with the overly stringent air dwelling requirement of 3 ACH at 50 Pascals is likely to increase the probability of poorer indoor air quality.

Our two amendments work in conjunction to help address potential indoor air quality issues. The Association believes that these changes, if approved, will result in sounder and more relevant code requirements.

Finally, since a BTU saved is a BTU saved we speculate that it could be deemed a constraint of free trade to deny recognition of time proven cost effective means of saving energy such as we are proposing.

MNCBIA also offers the following two energy neutral code amendments.

Prescriptive Potable Pipe Water Insulation

There are limited water savings and high costs associated with the pipe insulation required by **2012 IECC R403.4.2 and IRC N1103.4.2** as shown by information from both EPA WaterSense Program and a NAHB Research Center study. We therefore propose an exception to the code as shown [**Amendment C**] that provides the choice of using a simpler means of saving at least an equivalent amount of energy and thus will not detour builders from using the prescriptive compliance path for this code.

EPA evaluated this requirement and eliminated it from its final WaterSense program [**Appendix C**]. A December 2010 study entitled "Domestic Hot Water System Piping Analysis of Benefits and Cost" [**Appendix D**] was prepared for the National Association of Home Builders by the NAHB Research Center and supports the EPA conclusion that there are limited water savings and high costs associated with pipe insulation. "When a full hot water system is simulated in a single-family house using standard hot water use profiles with varying flow rates, time between draws, and pipe lengths from the hot water heater to the outlet, the study showed that the benefit of pipe insulation is much less significant and the cost benefit to using pipe insulation is on the order of approximately $3 to $11 per year depending on the fuel rates, resulting in simple paybacks of 60 to 100 years based on a range of installed insulation costs. In addition, it is very difficult to measure, to install or inspect such insulation and this requirement will detour builders from using the simple streamlined prescriptive compliance approach allowed by the code."

Wood Frame Wall Insulation

Revise prescriptive insulation/fenestration 2012 IECC Table R402.1.1 and IRC Table N1103.4.2 to allow low cost R-19 fiberglass batt insulation and other cost effective alternatives. Rather than replace existing prescriptive systems, additional energy neutral solutions should be added to the list. For example, builders could use R-18 insulation or a .60U factor for above grade walls when the framing factor is 19% or less as an alternative to R-20 insulation or a .57U factor when the framing factor is 25% or less. Alternatives could provide the same energy savings but at a lower cost. The attached **Amendment D** contains the Association's recommended code changes for these tables.

In addition, the Association also proposes several **amendments to the IRC, IBC and IMC** that make sense and are based on sound reasoning.

Make up Air Requirement for Domestic Kitchen Exhaust

The Building Industry is proposing amendments to **2012 IRC M1503.4 and 2012 IMC 505.2** [**Amendment E**] in order to reduce bringing in an excessive amount of unnecessary air into the home. As currently written, the code requires all the exhaust air to be replaced if the range hood exhausts in excess of the rate of 400 cubic feet per minute. The 400-cfm figure is arbitrary. It was selected in the 2009 code cycle based on the hood systems on the market as "a reasonable threshold to start at" [Ref: ICC Sept. 2006 M65-06/07]. The code section as written does not take down-draft systems, popular with homeowners, into consideration. Most of them operate at 500 to 600 cfm and therefore require makeup air.

Our amendment as proposed would require only the exhaust air in excess of the rate of 400 cubic feet per minute to be replaced. Essentially, there would be no difference between the effect a 400 cfm fan has on a house and a 600 cfm fan with 200 cfm of makeup air. This would also improve the feasibility and acceptance of this code section as well as cut down on the amount of wasted energy in heating or cooling the makeup air.

Window Sill Height

From a safety viewpoint, there is no reason not to use 18 inches above the finished floor surface of the room as the window sill height for all residential, whether below or above four stories.

Education has been determined to be the best deterrent since with higher sill heights, there is the potential for the occupant to place furniture or other objects under the window that a child could climb upon. In fact in Denver, Colorado, one of the few areas in the country that has had a minimum sill height requirement for the past decade, the number of child injuries and deaths were increasing.

Therefore we propose amendments to **IBC 1013.8** [**Amendment F**] and to **IRC R312.2.1** [**Amendment G**] to require the same window sill height for all residential.

Cripple Wall Bracing

Amendment H proposes a needed correction for **Cripple Wall Bracing 2012 IRC R602.10.11** that was inadvertently left out when the 2012 bracing wall provisions were correlated in the ICC code cycle.

With regard to **Division 4, Non-Residential and Multi-Unit Residential Green Buildings,** the Association recommends that the sections be updated to include the ICC-700 National Green Building Standard (NGBS), which is applicable to all residential whether below or above three stories. This is a nationally recognized American National Standard that is being used to construct multifamily buildings. The Rockville code already recognizes the NGBS in Division 5, One and Two Family Dwelling Requirements and in Division 3, Definitions.

The Association hopes that you will adopt the offered amendments which will lead to smarter, more flexible and safer code. Allowing choices among all the techniques and approaches available will reduce construction costs, leading to more affordable housing and better building design.

Extensive education and training is needed before the 2012 I-Codes are used and enforced. With the financial climate still in flux, there are many projects in the design pipeline that have not been finalized. Having to redesign these projects to the 2012 I-Codes could result in loss of financial backing or abandonment of the project. Therefore, MNCBIA requests that the transition or phase-in period be six months from the signing date or effective date of this regulation.

The Association hopes that you see the advantages of including our recommendations as modifications in the City of Rockville's update of its building codes. We look forward to continuing to work constructively with the City to achieve workable solutions.

Thank you for your consideration and we look forward to favorable deliberations on our proposals. If you have any questions, please contact Annette Rosenblum at 301-445-5407 or arosenblum@mncbia.org.

Sincerely yours,

Randy Melvin

Randy Melvin
Chair, Codes & Standards Committee

cc: Mr. Robert Purkey, Rockville Inspection Services Division,

Enclosures

Amendment A

Recommended State & Local Amendments to the 2012 International Energy Conservation Code (IECC)

Issue: The Elimination of Equipment Trade-offs

2012 IECC Section: Table R405.5.2(1)

Recommended Amendment:
Modify the Table as shown below (Delete text, add New Text)

TABLE R405.5.2(1)
SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Heating systems [f, g]	~~As proposed for other than electric heating without a heat pump, Where the proposed design utilizes electric heating without a heat pump the standard reference design shall be an air source heat pump meeting the requirements of Section R403 of the IECC-Commercial Provisions.~~ Fuel type: same as proposed design Efficiencies: Electric: air-source heat pump with prevailing federal minimum efficiency Nonelectric furnaces: natural gas furnace with prevailing federal minimum efficiency Nonelectric boilers: natural gas boiler with prevailing federal minimum efficiency Capacity: sized in accordance with Section R403.6	As proposed
Cooling system [f, h]	~~As proposed~~ Fuel type: Electric Efficiency: in accordance with prevailing federal minimum standards Capacity: sized in accordance with Section R403.6	As proposed
Service Water Heating [f, g, h, i]	~~As proposed~~ Fuel type: same as proposed design Efficiency: in accordance with prevailing Federal minimum standards Use: gal/day = 30 + 10 × N_{br} Tank temperature: 120°F ~~Use: same as proposed design~~	As proposed Same as standard reference ~~gal/day = 30 + (10 × N_{br})~~

(Remainder of Table remains unchanged)

Reason:
The purpose of this amendment is to retain the original equipment trade-off provisions from the 2006 International Energy Conservation Code (IECC) for the heating systems, cooling systems, and service water heating.

By retaining these, builders have an opportunity to optimize a code-compliant house design by using energy efficient equipment.

Eliminating the ability to use equipment efficiency as a means to achieve whole-house energy conservation will discourage the use of higher efficiency equipment. Quite often, the use of this high efficiency equipment provides a more cost effective solution to achieve code compliance. Eliminating this ability discourages the concept of the “house as a system” approach which is a cornerstone of many state energy programs and the Federal Energy Star Program. In fact, without this amendment the current practice for constructing an Energy Star home in this jurisdiction would be disallowed.

Without accepting this amendment will force a negative impact on the installation of state-of-the-art, more energy efficient equipment, it will increase the cost of construction by driving builders to often use less efficient equipment while dramatically increasing the cost of construction of the building envelope, namely windows and fiberglass insulation.

Significant improvements in the efficiency of HVAC and water heating equipment have been made in the last 20 years. With the increased emphasis on new and improved technologies, this trend will continue and will result in even higher energy savings in future years. Eliminating the ability to recognize the value of these technologies in the marketplace will prove detrimental to all builders and ultimately the homeowners.

One of the easiest ways to conserve energy is to utilize high efficiency equipment. The 2012 IECC code does not provide any incentives for the builder to install high efficiency equipment, but rather continues the use of the minimum equipment efficiencies established by federal standards.

The language in the 2012 IECC effectively removes the use of high efficiency HVAC equipment as a reasonable and cost-effective solution to achieve compliance. Failure to remove the existing language concentrates solely on the building envelope by focusing on insulation/windows to meet specific energy targets.

For these reasons we encourage the adoption of this amendment.

Amendment A

Recommended State & Local Amendments to the 2012 International Residential Code (IRC)

Issue: **The Elimination of Equipment Trade-offs**

2012 IRC Section: **Chapter 11, Table N1105.5.2(1)**

Recommended Amendment:
Modify the Table as shown below (Delete text, add New Text)

TABLE N1105.5.2(1)
SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Heating systems [f, g]	~~As proposed for other than electric heating without a heat pump, Where the proposed design utilizes electric heating without a heat pump the standard reference design shall be an air source heat pump meeting the requirements of Section R403 of the IECC-Commercial Provisions.~~ Fuel type: same as proposed design Efficiencies: Electric: air-source heat pump with prevailing federal minimum efficiency Nonelectric furnaces: natural gas furnace with prevailing federal minimum efficiency Nonelectric boilers: natural gas boiler with prevailing federal minimum efficiency Capacity: sized in accordance with Section N1103.6	As proposed
Cooling system [f, h]	~~As proposed~~ Fuel type: Electric Efficiency: in accordance with prevailing federal minimum standards Capacity: sized in accordance with Section N1103.6	As proposed
Service Water Heating [f, g, h, i]	~~As proposed~~ Fuel type: same as proposed design Efficiency: in accordance with prevailing Federal minimum standards Use: gal/day = 30 + 10 × *Nbr* Tank temperature: 120°F ~~Use: same as proposed design~~	As proposed Same as standard reference ~~gal/day = 30 + (10 × N_{br})~~

(Remainder of Table remains unchanged)

Reason:
The purpose of this amendment is to retain the original equipment trade-off provisions from the 2006 International Residential Code (IRC) Chapter 11 for the heating systems, cooling systems, and service water heating.

By retaining these, builders have an opportunity to optimize a code-compliant house design by using energy efficient equipment.

Eliminating the ability to use equipment efficiency as a means to achieve whole-house energy conservation will discourage the use of higher efficiency equipment. Quite often, the use of this high efficiency equipment provides a more cost effective solution to achieve code compliance. Eliminating this ability discourages the concept of the "house as a system" approach which is a cornerstone of many state energy programs and the Federal Energy Star Program. In fact, without this amendment the current practice for constructing an Energy Star home in this jurisdiction would be disallowed.

Without accepting this amendment will force a negative impact on the installation of state-of-the-art, more energy efficient equipment, it will increase the cost of construction by driving builders to often use less efficient equipment while dramatically increasing the cost of construction of the building envelope, namely windows and fiberglass insulation.

Significant improvements in the efficiency of HVAC and water heating equipment have been made in the last 20 years. With the increased emphasis on new and improved technologies, this trend will continue and will result in even higher energy savings in future years. Eliminating the ability to recognize the value of these technologies in the marketplace will prove detrimental to all builders and ultimately the homeowners.

One of the easiest ways to conserve energy is to utilize high efficiency equipment. The 2012 IRC Chapter 11 code does not provide any incentives for the builder to install high efficiency equipment, but rather continues the use of the minimum equipment efficiencies established by federal standards.

The language in the 2012 IRC Chapter 11 effectively removes the use of high efficiency HVAC equipment as a reasonable and cost-effective solution to achieve compliance. Failure to remove the existing language concentrates solely on the building envelope by focusing on insulation/windows to meet specific energy targets.

For these reasons we encourage the adoption of this amendment.

Amendment B

Recommended State & Local Amendments to the 2012 International Energy Conservation Code (IECC)

Issue: **Dwelling Unit Air Leakage**

2012 IECC Section: **R402.4.1.2**

Recommended Amendment: Add Exception

R402.4.1.2 Testing. The building or dwelling unit shall be tested and verified as having an air leakage rate of not exceeding 5 air changes per hour in Climate Zones 1 and 2, and 3 air changes per hour in Climate Zones 3 through 8. Testing shall be conducted with a blower door at a pressure of 0.2 inches w.g. (50 Pascals). Where required by the *code official*, testing shall be conducted by an approved third party. A written report of the results of the test shall be signed by the party conducting the test and provided to the *code official.* Testing shall be performed at any time after creation of all penetrations of the *building thermal envelope*.

Exception: When using the Simulated Performance Alternative (Section R405), an air leakage rate of up to a maximum of 7 air changes per hour at 50 Pascals in lieu of the mandatory 3 air changes per hour at 50 Pascals shall be allowed when equivalent or greater energy efficiency trade-offs are provided to offset the additional air leakage in excess of 5 air changes per hour at 50 Pascals in Climate Zones 1 and 2 and 3 air changes per hour at 50 Pascals in Climate Zones 3 through 8.

During testing:
1. Exterior windows and doors, fireplace and stove doors shall be closed, but not sealed, beyond the intended weatherstripping or other infiltration control measures;

Reason: A requirement for home air tightness of 3 Air Changes per Hour or less at a 50 Pascal pressure is extremely aggressive. A 1998 study by Lawrence Berkeley National Labs (Sherman and Dickerhoff) shows that only about 7% of the homes in the U.S. are at that level of tightness or tighter.

Meeting this requirement is challenging in nearly all circumstances; however, it is even more difficult in smaller homes which are built on slabs or crawl spaces. Moreover, this test cannot be performed until the house is at or near completion, thereby limiting the ability to correct most leaks after testing.

In addition, poor indoor air quality becomes a concern with a very tight house.

This proposed code change offers the ability to trade-off building tightness in the performance path against other building requirements resulting in a home with equivalent energy performance.

Amendment B

Recommended State & Local Amendments to the 2012 International Residential Code (IRC)

Issue: **Dwelling Unit Air Leakage**

2012 IRC Section: **N1102.4.1.2**

Recommended Amendment: Add Exception

NI102.4.1.2 (R402.4.1.2) Testing. The building or dwelling unit shall be tested and verified as having an air leakage rate of not exceeding 5 air changes per hour in Zones 1 and 2, and 3 air changes per hour in Zones 3 through 8. Testing shall be conducted with a blower door at a pressure of 0.2 inches w.g. (50 Pascals). Where required by the *building official,* testing shall be conducted by an *approved* third party. A written report of the results of the test shall be signed by the party conducting the test and provided to the *building official.* Testing shall be performed at any time after creation of all penetrations of the *building thermal envelope.*

Exception: When using the Simulated Performance Alternative (Section N1105), an air leakage rate of up to a maximum of 7 air changes per hour at 50 Pascals in lieu of the mandatory 3 air changes per hour at 50 Pascals shall be allowed when equivalent or greater energy efficiency trade-offs are provided to offset the additional air leakage in excess of 5 air changes per hour at 50 Pascals in Climate Zones 1 and 2, and 3 air changes per hour at 50 Pascals in Climate Zones 3 through 8.

During testing:
1. Exterior windows and doors, fireplace and stove doors shall be closed, but not sealed, beyond the intended weatherstripping or other infiltration control measures;

Reason: A requirement for home air tightness of 3 Air Changes per Hour or less at a 50 Pascal pressure is extremely aggressive. A 1998 study by Lawrence Berkeley National Labs (Sherman and Dickerhoff) shows that only about 7% of the homes in the U.S. are at that level of tightness or tighter.

Meeting this requirement is challenging in nearly all circumstances; however, it is even more difficult in smaller homes which are built on slabs or crawl spaces. Moreover, this test cannot be performed until the house is at or near completion, thereby limiting the ability to correct most leaks after testing.

In addition, poor indoor air quality becomes a concern with a very tight house.

This proposed code change offers the ability to trade-off building tightness in the performance path against other building requirements resulting in a home with equivalent energy performance.

Amendment C

Recommended State & Local Amendments to the 2012 International Energy Conservation Code (IECC)

Issue: Hot Water Pipe Insulation

2012 IECC Section Number: R403.4.2

Recommended Amendment:
Modify as shown (Add Exception):

R403.4.2 Hot water pipe insulation (Prescriptive).
Insulation for hot water pipe with a minimum thermal resistance (*R*-value) of R-3 shall be applied to the following:

1. Piping larger than $^3/_4$ inch nominal diameter.
2. Piping serving more than one dwelling unit.
3. Piping from the water heater to kitchen outlets.
4. Piping located outside the conditioned space.
5. Piping from the water heater to a distribution manifold.
6. Piping located under a floor slab.
7. Buried piping.
8. Supply and return piping in recirculation systems other than demand recirculation systems.
9. Piping with run lengths greater than the maximum run lengths for the nominal pipe diameter given in Table R403.4.2.

All remaining piping shall be insulated to at least R-3 or meet the run length requirements of Table R403.4.2.

TABLE R403.4.2 MAXIMUM RUN LENGTH (feet)[a]

Nominal Pipe Diameter of Largest Diameter Pipe in the Run (inch)	$^3/_8$	$^1/_2$	$^3/_4$	$> ^3/_4$
Maximum Run Length	30	20	10	5

For SI: 1 inch = 25.4 mm, 1 foot 304.8 mm.

a. Total length of all piping from the distribution manifold or the recirculation loop to a point of use.

Exception: Insulating hot water pipe is not required when one of the following off - setting energy savings alternatives is instituted.

Increase any one of the prescriptive; ceiling, wood frame wall, mass wall, floor, basement wall, slab, or crawlspace insulation R-value requirements, as per Table R402.1.1, by R-1.

<u>Reason</u>:
It is very difficult to measure, install and inspect hot water pipe insulation and thus this requirement will detour builders from using the simple, streamlined, prescriptive, compliance approach allowed by this code. In addition, Hot Water Pipe Insulation saves only negligible amounts of energy and is not cost effective. EPA evaluated this requirement and eliminated it from its final WaterSense program [BIA Sept 30, 2011 Testimony, Appendix E]. A December 2010 study entitled "Domestic Hot Water System Piping Analysis of Benefits and Cost" [BIA Sept 30, 2011 Testimony, Appendix F], prepared for the National Association of Home Builders by the NAHB Research Center, supports the EPA conclusion that there are limited water savings and high costs associated with pipe insulation. "When a full hot water system is simulated in a single-family house using standard hot water use profiles with varying flow rates, time between draws, and pipe lengths from the hot water heater to the outlet, the study showed that the benefit of pipe insulation is much less significant and the cost benefit to using pipe insulation is on the order of approximately $3 to $11 per year depending on the fuel rates, resulting in simple paybacks of 60 to 100 years based on a range of installed insulation costs.

The proposed exception/alternative provides the choice of using a simpler, means of saving at least an equivalent amount of energy and thus will not detour builders from using the prescriptive compliance path for this code.

Amendment C

Recommended State & Local Amendments to the 2012 International Residential Code (IRC)

Issue: Hot Water Pipe Insulation

2012 IRC Section Number: N1103.4.2 (R403.4.2)

Recommended Amendment:
Modify as shown (Add Exception):

N1103.4.2 (R403.4.2) Hot water pipe insulation (Prescriptive).
Insulation for hot water pipe with a minimum thermal resistance (*R*-value) of R-3 shall be applied to the following:

1. Piping larger than $^{3}/_{4}$ inch nominal diameter.
2. Piping serving more than one dwelling unit.
3. Piping from the water heater to kitchen outlets.
4. Piping located outside the conditioned space.
5. Piping from the water heater to a distribution manifold.
6. Piping located under a floor slab.
7. Buried piping.
8. Supply and return piping in recirculation systems other than demand recirculation systems.
9. Piping with run lengths greater than the maximum run lengths for the nominal pipe diameter given in Table R403.4.2.

All remaining piping shall be insulated to at least R-3 or meet the run length requirements of Table R403.4.2.

TABLE N1103.4.2 (R403.4.2) MAXIMUM RUN LENGTH (feet)[a]

Nominal Pipe Diameter of Largest Diameter Pipe in the Run (inch)	$^{3}/_{8}$	$^{1}/_{2}$	$^{3}/_{4}$	$> ^{3}/_{4}$
Maximum Run Length	30	20	10	5

For SI: 1 inch = 25.4 mm, 1 foot 304.8 mm.

a. Total length of all piping from the distribution manifold or the recirculation loop to a point of use.

Exception: Insulating hot water pipe is not required when one of the following off - setting energy savings alternatives is instituted.

Increase any one of the prescriptive; ceiling, wood frame wall, mass wall, floor, basement wall, slab, or crawlspace insulation R-value requirements, as per Table N1102.1.1 (R402.1.1), by R-1.

Reason:
It is very difficult to measure, install and inspect hot water pipe insulation and thus this requirement will detour builders from using the simple, streamlined, prescriptive, compliance approach allowed by this code. In addition, Hot Water Pipe Insulation saves only negligible amounts of energy and is not cost effective. EPA evaluated this requirement and eliminated it from its final WaterSense program [BIA Sept 30, 2011 Testimony, Appendix E]. A December 2010 study entitled "Domestic Hot Water System Piping Analysis of Benefits and Cost" [BIA Sept 30, 2011 Testimony, Appendix F], prepared for the National Association of Home Builders by the NAHB Research Center, supports the EPA conclusion that there are limited water savings and high costs associated with pipe insulation. "When a full hot water system is simulated in a single-family house using standard hot water use profiles with varying flow rates, time between draws, and pipe lengths from the hot water heater to the outlet, the study showed that the benefit of pipe insulation is much less significant and the cost benefit to using pipe insulation is on the order of approximately $3 to $11 per year depending on the fuel rates, resulting in simple paybacks of 60 to 100 years based on a range of installed insulation costs.

The proposed exception/alternative provides the choice of using a simpler, means of saving at least an equivalent amount of energy and thus will not detour builders from using the prescriptive compliance path for this code.

Amendment D

Recommended State and Local Amendment to the 2012 International Energy Conservation Code (IECC)

Issue: **Wood Frame Wall Insulation**

2012 IECC Section: **Table R402.1.1**

Recommended Amendment:
Modify the Table as shown below: (Add new data)

TABLE R402.1.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 18 with framing factor of 19% or less or 13 + 5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.35	0.55	0.40	49	20 or 18 with framing factor of 19% or less or 13 + 5[h]	8/13	19	10/13	10, 2ft	10/13
5 and Marine 4	0.32	0.55	NR	49	20 or 18 with framing factor of 19% or less or 13 + 5[h]	13/17	30[g]	15/19	10, 2ft	15/19
6	0.32	0.55	NR	49	20 + 5 or 18+5 with framing factor of 19% or less or 13 + 10[h]	15/20	30[g]	15/19	10, 4ft	15/19
7 and 8	0.32	0.55-	NR	49	20 + 5 or 18 + 5 with framing factor of 19% or less or 13 +10[h]	19/21	38[g]	15/19	10, 4ft	15/19

All footnotes remain unchanged

Reason:
The purpose of this amendment is to allow an additional prescriptive, commonly constructed, cost effective, energy neutral alternative under the Wood Frame Wall R-value column for climate zones 3 through 8.

The 2012 IECC does not prescriptively provide for 24" O.C., cavity insulated wood wall assemblies that are widely used in the construction industry and that have a proven track record of providing equivalent energy conservation, thus limiting market choices, making it economically unreasonable and unnecessarily creating a negative financial impact.

This amendment provides for, among others, the use of a common, cost effective compressed R-19 fiberglass batt cavity insulation in a typical 24" O.C. framed exterior wood wall assembly that has a framing factor of no more than 19% and which is at least as energy efficient as the 16" O.C. R-20 cavity insulated wall assembly provided for in the 2012 IECC, which was derived, based on, but not limited to, an assumed framing factor of 25%. This addition will retain the original requirements of the 2012 IECC, while prescriptively allowing an additional, commonly used, insulated wood frame wall assembly. The proposed amendment provides a competitive alternative that benefits the builder and home owner with lower construction costs. Prescriptive minimum R-18 cavity insulation was chosen in lieu of a R-19 cavity insulation level, because as provided for in footnote "a," the compression of a typical 6-1/2" thick fiberglass R-19 batt into a nominal 6" deep wall cavity that is actually 5-1/2" deep reduces its effective R value from R-19 to R-18.

Amendment D

Recommended State and Local Amendment to the 2012 International Residential Code (IRC)

Issue: **Wood Frame Wall Insulation**

2012 IRC Section: **Chapter 11, Table N1102.1.1 (R402.1.1)**

Recommended Amendment:
Modify the Table as shown below: (Add new data)

TABLE N1102.1.1 (R402.1.1)
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 18 with framing factor of 19% or less or 13 + 5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.35	0.55	0.40	49	20 or 18 with framing factor of 19% or less or 13 + 5[h]	8/13	19	10/13	10, 2ft	10/13
5 and Marine 4	0.32	0.55	NR	49	20 or 18 with framing factor of 19% or less or 13 + 5[h]	13/17	30[g]	15/19	10, 2ft	15/19
6	0.32	0.55	NR	49	20 + 5 or 18+5 with framing factor of 19% or less or 13 + 10[h]	15/20	30[g]	15/19	10, 4ft	15/19
7 and 8	0.32	0.55-	NR	49	20 + 5 or 18 + 5 with framing factor of 19% or less or 13 +10[h]	19/21	38[g]	15/19	10, 4ft	15/19

All footnotes remain unchanged

Reason:

The purpose of this amendment is to allow an additional prescriptive, commonly constructed, cost effective, energy neutral alternative under the Wood Frame Wall R-value column for climate zones 3 through 8.

Chapter 11 of the IRC does not prescriptively provide for 24" O.C., cavity insulated wood wall assemblies that are widely used in the construction industry and that have a proven track record of providing equivalent energy conservation, thus limiting market choices, making it economically unreasonable and unnecessarily creating a negative financial impact.

This amendment provides for, among others, the use of a common, cost effective compressed R-19 fiberglass batt cavity insulation in a typical 24" O.C. framed exterior wood wall assembly that has a framing factor of no more than 19% and which is at least as energy efficient as the 16" O.C. R-20 cavity insulated wall assembly provided for in Chapter 11 of the IRC, which was derived, based on, but not limited to, an assumed framing factor of 25%. This addition will retain the original requirements of Chapter 11 of the IRC, while prescriptively allowing an additional, commonly used, insulated wood frame wall assembly. The proposed amendment provides a competitive alternative that benefits the builder and home owner with lower construction costs. Prescriptive minimum R-18 cavity insulation was chosen in lieu of a R-19 cavity insulation level, because as provided for in footnote "a," the compression of a typical 6-1/2" thick fiberglass R-19 batt into a nominal 6" deep wall cavity that is actually 5-1/2" deep reduces its effective R value from R-19 to R-18.

Amendment E

Recommended State & Local Amendments to the 2012 Edition of the International Mechanical Code (IMC)

Issue: Domestic Kitchen Exhaust Makeup Air

2012 IMC Section Number: 505.2 Makeup Air Required

Recommended Amendment:
Modify the section as shown below:

505.2 Makeup air required. Exhaust hood systems capable of exhausting in excess of 400 cubic feet per minute (0.19 m3/s) shall be provided with makeup air at a rate approximately equal to the difference between the exhaust air rate and 400 cubic feet per minute. Such makeup air systems shall be equipped with a means of closure ~~and shall be automatically controlled to start and operate simultaneously with the exhaust system~~.

Exception: Where all appliances in the house are of sealed combustion, power-vent, unvented, or electric, the exhaust hood system shall be permitted to exhaust up to 600 cubic feet per minute (0.28 m3/s) without providing makeup air. Exhaust hood systems capable of exhausting in excess of 600 cubic feet per minute (0.28 m3/s) shall be provided with a makeup air at a rate approximately equal to the difference between the exhaust air rate and 600 cubic feet per minute.

Reason:
This section, new in the 2009 International Residential Code (IRC) and 2009 International Mechanical Code (IMC), attempts to solve an unproven backdrafting problem with range hoods. The exhaust rate of 400 cubic feet per minute (cfm) was chosen arbitrarily and without substantiation other than it being greater than the minimum exhaust rate of range hoods on the market. However, several manufacturers do not produce any range hoods below the 400 cfm threshold, effectively reducing a homeowner's choice of kitchen exhaust options without the added difficulty and expense of installing makeup air.

The reasoning that kitchen exhaust systems are available with an exhaust rate under 400 cfm does not take down-draft systems, popular with homeowners, into consideration. Most of them operate at 500 to 600 cfm and therefore require makeup air.

As written, this section allows range hoods up to 400 cfm to be installed without makeup air. It would be consistent to require makeup air equaling the amount above and beyond 400 cfm for larger fans. Essentially, there would be no difference between the effect a 400 cfm fan has on a house and a 600 cfm fan with 200 cfm of makeup air. This would also improve the feasibility and acceptance of this code section as well as cut down on the amount of wasted energy in heating or cooling the makeup air.

This section requires an automatic means of closure for the makeup air opening beyond what the code has historically required for residential construction. For example, Section G2407.6 requires no dampers whatsoever for combustion air openings to the outdoors, such as found in many homes in the northern U.S. The amended section would allow barometric dampers.

Finally, the current code section does not take into effect the fact that in many homes there is no danger of backdrafting, due to the lack of natural draft appliances. The 400 cfm threshold could be raised to 600 cfm in those cases with no added danger. This would allow for down-draft fans without dedicated makeup air.

Amendment E

Recommended State & Local Amendments to the 2012 Edition of the International Residential Code (IRC)

Issue: Range Hood Makeup Air

2012 IRC Section Number: M1503.4 Makeup Air Required

Recommended Amendment:
Modify the section as shown below:

M1503.4 Makeup air required. Exhaust hood systems capable of exhausting in excess of 400 cubic feet per minute (0.19 m3/s) shall be provided with makeup air at a rate approximately equal to the difference between the exhaust air rate and 400 cubic feet per minute. Such makeup air systems shall be equipped with a means of closure ~~and shall be automatically controlled to start and operate simultaneously with the exhaust system~~.

> **Exception:** Where all appliances in the house are of sealed combustion, power-vent, unvented, or electric, the exhaust hood system shall be permitted to exhaust up to 600 cubic feet per minute (0.28 m3/s) without providing makeup air. Exhaust hood systems capable of exhausting in excess of 600 cubic feet per minute (0.28 m3/s) shall be provided with a makeup air at a rate approximately equal to the difference between the exhaust air rate and 600 cubic feet per minute.

Reason:
This section, new in the 2009 International Residential Code (IRC) and 2009 International Mechanical Code (IMC), attempts to solve an unproven backdrafting problem with range hoods. The exhaust rate of 400 cubic feet per minute (cfm) was chosen arbitrarily and without substantiation other than it being greater than the minimum exhaust rate of range hoods on the market. However, several manufacturers do not produce any range hoods below the 400 cfm threshold, effectively reducing a homeowner's choice of kitchen exhaust options without the added difficulty and expense of installing makeup air.

The reasoning that kitchen exhaust systems are available with an exhaust rate under 400 cfm does not take down-draft systems, popular with homeowners, into consideration. Most of them operate at 500 to 600 cfm and therefore require makeup air.

As written, this section allows range hoods up to 400 cfm to be installed without makeup air. It would be consistent to require makeup air equaling the amount above and beyond 400 cfm for larger fans. Essentially, there would be no difference between the effect a 400 cfm fan has on a house and a 600 cfm fan with 200 cfm of makeup air. This would also improve the feasibility and acceptance of this code section as well as cut down on the amount of wasted energy in heating or cooling the makeup air.

This section requires an automatic means of closure for the makeup air opening beyond what the code has historically required for residential construction. For example, Section G2407.6 requires no dampers whatsoever for combustion air openings to the outdoors, such as found in many homes in the northern US. The amended section would allow barometric dampers.

Finally, the current code section does not take into effect the fact that in many homes there is no danger of backdrafting, due to the lack of natural draft appliances. The 400 cfm threshold could be raised to 600 cfm in those cases with no added danger. This would allow for down-draft fans without dedicated makeup air.

Amendment F

Recommended State & Local Amendments to the 2012 International Building Code (IBC)

Issue: Window Sill Height

2012 IBC Section Number: 1013.8

Recommended Amendment:
Delete the portion of the code and replace as shown below:

1013.8 Window sills. In Occupancy Groups R-2 and R-3, one- and two-family and multiple-family dwellings, where the opening of the sill portion of an operable window is located more than 72 inches (1829 mm) above the finished grade or other surface below, the lowest part of the clear opening of the window shall be at a height not less than 18 inches (457mm) ~~36 inches (610 mm)~~ above the finished floor surface of the room in which the window is located. Operable sections of windows shall not permit openings that allow passage of a 4-inch-diameter (102mm) sphere where such openings are located within 18 inches (457mm) ~~36 inches (915mm)~~ of the finished floor
Remainder left unchanged

Reason:
The International Building Code requires the installation of windows guards on windows with a sill height less than 36 inches off of the finished floor. During the 2009-10 code development cycle, the IRC-BE committee disapproved a similar proposal to raise the window sill height to 36 inches and the committees decision was upheld at the final action hearing. A similar public comment to raise the window sill height to 36 inches also failed to pass the final assembly.

For the many years the debate for requiring fall protection devices the most contentious issue has been the height of the window sill in which the device should be required. The Building Industry agrees with many of the concerns that were raised by the opponents of the proposal. By raising the window sill height requirement to 36 inches there is the potential for unintended consequences as it may cause children to prop items or move furniture to allow them to see over the window sill which is no longer below their field of vision.

Public education is the most effective means of reducing the number of falls by children through windows. Many of the children safety advocates focus their efforts to relay safety messages to parents regarding the prevention of falls by recommending that windows should be closed in rooms where children are playing, where children are unsupervised, avoid placing furniture near windows and if windows are going to be left open, open them from the top down.

Amendment G

Recommended State & Local Amendments to the 2012 International Residential Code (IRC)

Issue: Window Sill Height

2012 IRC Section Number: R312.2.1

Recommended Amendment:
Delete the portion of the code and replace as shown below:

In dwelling units, where the opening of an operable window is located more than 72 inches (1829 mm) above the finished grade or surface below, the lowest part of the clear opening of the window shall be a minimum of 18 inches (457mm) ~~24 inches (610 mm)~~ above the finished floor of the room in which the window is located. Operable sections of windows shall not permit openings that allow passage of a 4-inch-diameter (102 mm) sphere where such openings are located within 18 inches (457 mm) ~~24 inches (610 mm)~~ of the finished floor.

Remainder left unchanged

Reason:

For the many years the debate for requiring fall protection devices the most contentious issue has been the height of the window sill in which the device should be required. The Building Industry agrees with many of the concerns that were raised by the opponents of the proposal. By raising the window sill height requirement to 24 inches there is the potential for unintended consequences as it may cause children to prop items or move furniture to allow them to see over the window sill which is no longer below their field of vision.

Public education is the most effective means of reducing the number of falls by children through windows. Many of the children safety advocates focus their efforts to relay safety messages to parents regarding the prevention of falls by recommending that windows should be closed in rooms where children are playing, where children are unsupervised, avoid placing furniture near windows and if windows are going to be left open, open them from the top down.

Amendment H

Recommended State & Local Amendments to the 2012 International Residential Code (IRC)

Issue: Cripple Wall Bracing

2012 IRC Section Number: R602.10.11

Recommended Amendment:
Modify the section as shown below:

R602.10.11 Cripple wall bracing. Cripple walls shall be constructed in accordance with Section R602.9 and braced in accordance with this section. Cripple walls shall be braced with the length and method of bracing used for the wall above in accordance with Tables R602.10.3(1) and R602.10.3(3), and the applicable adjustment factors in Table R602.10.3(2) or R602.10.3(4), respectively, except that the length of cripple wall bracing shall be multiplied by a factor of 1.15. ~~The distance between adjacent edges of *braced wall panels* shall be reduced from 20 feet (6096 mm) to 14 feet (4267 mm).~~

Reason:
The purpose of this amendment is to correct an error made in correlating the 2012 braced wall provisions. The reduction in spacing between braced wall panels in a cripple wall originated from cripple wall failures observed in seismic events such as the 1994 Northridge Earthquake. Working through the ICC Ad-Hoc Committee on Wall Bracing, NAHB developed a proposal for the 2009/2010 Code Development Cycle that reorganized the cripple wall bracing provisions and removed the spacing reduction for low-seismic areas. The proposal was approved at the Public Hearings and ratified by the consent agenda vote at the Final Action Hearings. Unfortunately, a separate effort by the Ad-Hoc Committee to correlate their comprehensive reorganization of the wall bracing section with a modification made by the IRC-Building/Energy Committee inadvertently resulted in the spacing reduction being reinstated for low-seismic areas. This amendment corrects that oversight and restores the original intent of the cripple wall proposal.

Appendix A

Appeals of Final Action Hearing Actions in Charlotte, NC on October 25-30, 2010 by:

- BOMA International and National Multi Housing Council/National Apartment Association
- Pilkington North America, Inc. and AGC Flat Glass North America, Inc.
- Aluminum Extruders Council, International Window Film Association, National Multi Housing Council, National Apartment Association, and 3M Company, Renewable Energy Division

Appellants Joint Statement of Issues

Activities surrounding actions taken on proposed changes to the 2009 edition of the International Energy Conservation Code (IECC) during ICC Final Action Hearings in Charlotte, NC, October 25-30, 2010, represent a failure in ICC's governmental consensus process. Specifically:

1) Adequate safeguards (policies and procedures) were either not employed or were not uniformly applied during the 2010 IECC Final Action Hearings to ensure that voting was limited to designated Governmental Member Voting Representatives meeting the requirements established in the "Bylaws for the International Code Council, Inc." ("Bylaws"), revised February 2010, Article II (Section 2.1.1.1): "*...an employee or a public official actively engaged either full or part time, in the administration, formulation or enforcement of laws, ordinances, rules or regulations relating to the public health, safety and welfare*", and in CP#28 (Code Development Process), revised February 2009 (Sections 1.2.3 and 7.4): "*...officials representing code enforcement and regulatory agencies...*" and in ICC's website description of its code development process: "*The governmental consensus process leaves the final determination of code provisions in the hands of public safety officials who, with no vested financial interest, can legitimately represent the public interest.* These irregularities took place despite written notice of possible violations of ICC's voting eligibility policies provided to ICC prior to the IECC Final Action Hearings. Ineligible designated Governmental Member Voting Representatives were therefore allowed to cast votes at the 2010 Final Action Hearings in Charlotte, NC;

2) The governmental consensus process was subverted by vote stacking at the 2011 IECC Final Action Hearings in favor of outcomes sought by the Energy Efficient Codes Coalition ("EECC") and its members;

3) The governmental consensus process was violated when EECC members were allowed to vote, unfairly permitting EECC's financial and proprietary interests to influence the outcome of the IECC Final Action Hearings;

4) "Travel scholarships" funded by federal agency and others and dispensed by the National Association of State Energy Officials (NASEO) and ICLEI – Local Governments for Sustainability (ICLEI) and other organizations to voters at the IECC Final Action Hearings, violated CP #36 (Sponsorships and Contributions) and CP #37-09 (Ethics, and now included in the ICC Statement of Ethical Conduct which replaced CP #37-09 by ICC

Board of Directors action in September 2010). This allowed proprietary interests to unfairly influence the outcome of the IECC Final Action Hearings; and

5) ICC's commitment to an unbiased, fair and open code development process was undermined by the proprietary or pecuniary interests of some designated Governmental Member Voting Representatives at the 2010 Final Action Hearings in Charlotte, NC, in violation of the principles outlined in CP #37-09 (Ethics) and now included in the ICC Statement of Ethical Conduct which replaced CP #37-09 by ICC Board of Directors action in September 2010: *"ICC members and member representatives should pursue fairness and objectivity in all activities"* and *"Governmental Member Voting Representatives are further directed to avoid participating or influencing ICC activities in which the member is financially interested"* and *"Promote transparency by disclosing potential conflicts of interest, or any matter which would reasonably create the appearance of a conflict of interest"*.

151988 v_01 \ 0465.0465

Appendix A

Appeal from the Final Action Hearings ("Final Action Hearings") regarding
Proposed Changes to the 2009 International Energy Conservation Code ("IECC")

Thomas S. Zaremba, on behalf of Pilkington North America, Inc. ("PNA") and AGC Flat Glass North America, Inc. ("AGC") (collectively "Appellants") appeal the final actions taken on proposed changes to the 2009 IECC.

I. The issues:

The questions (issues) raised by this appeal are set out in a Consolidated Statement of Issues for Determination on Appeal.

II. The standard applicable to a determination of the questions raised in this appeal:

Pursuant to CP #1-03 Section 5.3.8, the standard applicable to a determination of the questions raised in this appeal is whether there was a material and significant irregularity of process or procedure in the IECC's Final Action Hearings?

III. Why these issues are being appealed:

These issues are being appealed because significant irregularities of process or procedure may have occurred at the IECC Final Action Hearings.

The Energy Efficient Codes Coalition ("EECC") has membership interests that are both proprietary and non-proprietary. EECC developed a detailed voting agenda (the "30% Solution 2012") for its members to follow at the Charlotte hearings. NASEO and ICLEI are both members of EECC and it is believed that some of their members were allowed to vote at the IECC Final Action Hearings. Did allowing members of EECC to vote allow proprietary interests of EECC members to influence the outcome of the IECC Final Action Hearings; or, did it create the appearance that the proprietary interests of EECC members influenced the outcome of the IECC Final Action Hearings? If so, did allowing EECC members to vote violate the International Code Development "Governmental Consensus" Process ("CDP") which requires Final Action Hearings to be "open, fair, objective, and allow no proprietary interests to influence their outcome"? Or, did allowing EECC members to vote undermine the requirements of the CDP by creating the appearance that they were violated?

It appears that some voters at the IECC Final Action Hearings were associated with State Energy Offices or other offices that have no responsibility for enforcing the code or public safety. This raises the question whether voters with no responsibility for enforcing the code or public safety were qualified or eligible to vote at the IECC Final Action Hearings?

Finally, it appears that some voters were recruited and provided travel reimbursements to attend and vote in favor of the 30% Solution 2012. This raises questions whether vote stacking occurred at the IECC Final Action Hearings and if so, whether it violated the CDP requirements or whether it undermined the CDP requirements by creating the appearance that they were violated?

IV. Adverse affect on Appellants:

Appellants are both primary glass manufacturers and active participants in the ICC's CDP. As such, they are interested in its integrity. Even an appearance of irregularity or impropriety in voting at Final Action Hearings can materially and significantly undermine the integrity of the CDP which will adversely affect Appellants.

PNA and AGC are directly, materially and adversely affected by the process, procedures and outcome of the ICC's Final Action Hearings and the issues being appealed. In that regard, PNA manufactures glass at six (6) float lines in four (4) different plants throughout the United States. AGC manufactures glass at four (4) float lines in four (4) different plants throughout the United States. Each float line represents a capital investment of approximately $100,000,000 (or more) and employs between 200 and 300 people. Once a float line begins operation, its furnace must remain in operation, producing glass 24 hours a day, 7 days a week, 365 days a year over its useful life of approximately 15 years.

Appellants have invested hundreds of millions of dollars in their, respective, glass manufacturing facilities and have a significant investment and interest in the architectural glass market throughout the United States. In addition to employing hundreds of people throughout the country, Appellants also invest millions of dollars annually to research and develop different types of glass products for use in diverse building envelope applications.

Both the architectural glass market in which Appellants are involved and the diversity of glass products that Appellants have developed are directly affected by the IECC's Final Action Hearings and the issues being appealed.

As stakeholders and long time participants in the ICC's CDP, Appellants were adversely affected by the irregularities of process or procedure that occurred at the IECC Final Action Hearings.

V. Interested parties:

ICC has informed Appellants that it intends to notify interested parties of appeals of the IECC Final Action Hearings by giving notice and providing links to the appeals on ICC's website.

VI. The remedial actions requested:

1. Rescind actions taken at the IECC Final Action Hearings,

– or –

2. Reverse actions taken at the IECC Final Action Hearings as to EC13-PC10, EC34, EC35, EC41, EC42, EC97, EC141, EC165-PC5, and EC174.

3. Prohibit voters that are members of organizations having proprietary interests in the outcome of Final Action hearings from voting.

Appendix A

3. Institute adequate safeguards to ensure that vote stacking is not permitted; that the CDP used at Final Action Hearings is open, fair, objective, and not influenced by propriety interests; and that only governmental officials who, in their positions of public trust, actually enforce the code and are charged with the public's safety, vote at Final Action Hearings.

Respectfully submitted,

/s/ Thomas S. Zaremba
Thomas S. Zaremba
Roetzel & Andress
1 Seagate, Suite 1700
Toledo, Ohio 43604
Ph: 419.242.7985

152267 v_01 \ 0465.0465

Appendix A

The 2012 IECC Hearings - 'Watt' just happened?

[http://www.examiner.com/green-building-in-seattle/the-2012-iecc-hearings-watt-just-happened]

By Kristyn Clayton, Examiner.com, November 1, 2010

The International Energy Conservation Code underwent revision in Charlotte, NC this past week. The voting body of government representatives passed a new energy code that significantly tightens the envelopes of buildings, raises the efficiency for mechanical equipment, and institutes testing and controls in homes and offices. The ICC will publish this in 2011/2012 for adoption. Please see www.Iccsafe.org for more information. WA State is currently set to adopt it in 2012. It apparently will raise the stringency of the 2009 IECC code by 25%. It also eliminates the old International Residential Code chapter 11 that contained prescriptive energy provisions. This would be controversial enough in the states that have adopted it and seek to enforce it. Yet the normal arguments that have plagued the WA energy code adoption may pale in comparison to the buzz that grew to a roar around the Crown Ballroom at the Charlotte Convention Center.

Rumor had it that DOE paid jurisdictions to send people to the hearings for "training" as part of the federal stimulus money allocation to assist states in energy code adoption and enforcement. Apparently, they were urged to join the ICC to become voting members, then given a sheet explaining the proposals and the recommended voting strategy to achieve their goals for a 30% increase in stringency over the 2009 code. In the past, the energy code voting process was attended by the people who write and defend the proposals and by about 100 voting members of the ICC at best. This time there were over 400 voters.

Due to the appearance of impropriety there should be an investigation of the ethics for using federal money to pay people to attend the hearings, join the ICC and then vote as they were directed.

Until then, it appears that the home-grown state energy code that is still being fought over and debated in Washington, will now take effect on January 1, 2011. Ironically and arguably, this code may or may not even meet the new IECC for stringency should it survive the slings and arrows of its enemies. In the opinion of one who was in Charlotte, the WSEC version is clearly not more stringent. http://www.energy.wsu.edu/apps/EnergyCode.aspx Imagine all of the computer energy that will be spent trying to investigate and defend that process if the outcome of those hearings results in appeals of the new codes due to ethics violations -not to mention the thousands of dollars spent to reconvene the hearing if necessary.

This is not the first time antics like these have plagued code hearings in the United States. Perhaps the bigger question is this: What has happened to the art of debate, where codes and laws are challenged in an intelligent, thoughtful and respectful way without dirty tricks interference? We should not allow this process to become what the political elections process has become – an unbearable, irrelevant, unintelligent and expensive waste of human energy and money. How did energy codes for buildings become so controversial that they are embroiled in ethics allegations? More on that later in another blog– The 2009 WA State Energy Code – Legal or Not? Until then - keep saving energy one watt at a time - it all adds up.

Kristyn Clayton is the owner of Green House Effects, a company that seeks to better the environment by offering practical sustainability consulting to interested and committed businesses and individuals. Her career work has been very diverse and includes commercial construction management, energy conservation advocacy and regulation, sustainability consulting and teaching in all of those subjects. She is a Washington State Building Code Council Member, appointed by the governor, representing commercial and industrial general contractors, responsible for oversight of the building codes and related policies of the state. As chair of the Energy Code Technical Advisory Group for the council she helps to guide the process of energy codes that have helped Washington be a leader in the world on efficient building construction. She has a B.S. in electrical engineering from the University of Virginia, and an M.S. in architecture from Washington State University.

Appendix A

INTERNATIONAL CODE COUNCIL

ICC Update for NAHB
"Building Codes –Future Strategies" Forum

The following is a summary of actions that the ICC Board of Directors have taken in our efforts to continually improve the ICC Code Development Process (CDP) and increase confidence in the results. These actions are a result of our collaboration with NAHB and our many other industry partners and reflect the input of our nearly 50,000 members.

Item	Action	Status
Tighten governmental member eligibility requirements, to assure that only those involved in the health, safety and welfare of the built environment, are authorized to vote	Based on recommendations from the ICC CDRAC Committee, the Board of Directors has submitted a bylaw amendment for the Members' consideration in November. The Board believes that the code development process will be strengthened by refining the definition of Governmental Member and Governmental Member Voting Representative to focus on the "built environment." This proposal was supported by the Code Development Review Ad-Hoc Committee; a board appointed committee of board members and industry stakeholders, which over a twelve month period thoroughly reviewed all aspects of the code development process. The Board encourages the Members to support this proposed amendment to help maintain the quality and credibility of the code development process.	✓
Modified the "Assemble Vote" at the initial action hearing	Based on recommendations from the ICC CDRAC Committee, the Board of Directors has modified CP 28 and modified the assemble vote at the initial action hearing	✓
Residential Energy Code Development Process	A code change in the 2010 code development cycle put in question what ICC committee had responsibility for the development of residential energy requirements. In order to comply with ICC rules of procedure and existing agreements, the ICC Board approved the following new committee structure: Two committees have maintenance of ICC energy efficiency provisions as follows: 1. The current IECC Committee will be assigned responsibility for all energy efficiency provisions, except for residential buildings as defined below. 2. A new Residential Energy Committee will be established and assigned responsibility for all residential energy efficiency provisions. This new committee will contain representation from home builders, other industry groups, and code officials consistent with the existing agreements.	✓
Strengthen existing funding rules	Based on recommendations from the ICC CDRAC Committee, the ICC Board directed staff to develop language to amend ICC policies to prohibit private funding to designated Governmental Member Voting Representatives and require certification from Governmental Member jurisdictions to verify	✓
Policy on Local Amendments	ICC has agreed to reaffirm and communicate to ICC staff out policy on local amendments, which is:	

(over)

Appendix A

	"The Code Council recognizes the sovereign right of some JAs to amend the ICodes. ICC respects the JAs desire to address specific geographic or climatic needs, for example. The ICC does not, as a matter of routine, take an active position in amendments to the I-Codes. During the adoption process, Code Council staff serves in a supporting role. Staff provides and assists JAs with rationale for existing code provisions, assists in identifying potential conflicts with correlation of regulations, assists with interpretations, code comparisons and supports technical committees chartered to review the I-Codes. The ICC may provide technical support on proposed amendments to the I-Codes when requested by the JA."	✓
New Cost Impact Criteria	The ICC Board has amend CP# 28, as follows: *"Sec. 3.3.5.6 Cost Impact: The proponent shall indicate one of the following regarding the cost impact of the code change proposal: 1) the code change proposal will increase the cost of construction; or 2) the code change proposal will not increase the cost of construction. The proponent should submit information that supports their claim. Any information submitted will be considered by the code development committee. This information will be included in the bibliography of the published code change proposal."*	✓
Remote Voting	Based on recommendations from the ICC CDRAC Committee, the Board of Directors set a strategic goal to provide for remote participation and tasked staff to present a work plan to the ICC Board of Directors in 2011 to implement changes to the code development process that utilize new and emerging technologies to increase member and stakeholder participation, consistent with ICC's mission. The work plan will provide for implementation of new processes by the start of the Code Development Cycle that will lead to the publication of the 2018 International Codes.	✓

2009 & 2012 IECC Energy Simulation Results for Climate Zone 5

Prepared for

Coalition for Fair Energy Codes

Prepared by

NAHB Research Center

400 Prince Georges Boulevard

Upper Marlboro, MD 20774-8731

www.nahbrc.com

201-249-4000

April 2012

NAHB RESEARCH CENTER

Disclaimer

Contents

Purpose

The purpose of this report is to 1) evaluate the 2009 and 2012 International Energy Conservation Code (IECC) and determine a percent energy savings over a 2006 IECC baseline, 2) determine construction cost reductions to the 2012 IECC when trading off expensive envelope code changes against cost-effective high efficiency equipment in climate zone 5.

Background

A strong push has been made by many advocacy groups, including the U. S. Department of Energy (DOE), to increase the stringency of the last two editions of the International Energy Conservation Code (IECC). This effort resulted in a number of major changes which impact both energy savings and construction costs for residential construction. This report will evaluate energy usage and the incremental cost of compliance for an average home constructed to the 2009 and 2012 IECC.

In addition, a change was made in the 2009 IECC which prevented equipment efficiency from being considered as an energy neutral trade-off. Consequently, the ability for builders or designers to cost optimize a building to achieve energy equivalent performance was removed. This analysis quantifies the consumer benefit for providing the option to include equipment efficiency when determining energy code compliance.

Methodology

The methodology employed in this analysis was patterned after an analysis done by DOE and the Pacific Northwest National Labs (PNNL)(Taylor (2010). Some assumptions and estimations were made to their analysis methodology when performing this analysis. Details related to the methodology employed in this analysis can be found in the *APA Simulation Background and Instructions* (Drumheller 2011) white paper.

For clarification, the resulting savings calculations are strictly a best effort to replicate the DOE/PNNL methodology. This is not an endorsement of said methodology, merely utilization of what might be considered by some to be a 3rd party unbiased approach.

Reference Home/Simulation File

A reference home, 2,400 square foot (above grade) with a conditioned basement, was developed by PNNL/DOE (Taylor 20120) which also included specific characteristics that were ultimately incorporated into a simulation file. PNNL/DOE used DOE-2 as their energy analysis program. For the purposes of this analysis, REM/Rate was used to compare the various versions of the IECC. REM/Rate was selected because of the wide availability of users (the majority of HERS raters), which will allow for many others to duplicate this process.

Representative City

The analysis was based on a house located in Columbus, OH which can be considered a representative location in climate zone 5A. Columbus is has 5,692 annual Heating Degree Days (HDD), and 7,490 Cooling Degree Hours (CDH) which is on the lower end of the climate zone 5 range (between 5,400-7,200 HDD).

Model Calibration

The PNNL/DOE analysis did not include a simulation for Columbus, Ohio. Consequently, to make a calibrated comparison between the two models, the same baseline home created in REM needed to be simulated in Chicago (the climate zone 5 city where PNNL/DOE results were available). The difference in heating, cooling and water heating energy use was only 1.1% ($21/yr). This calibration indicates that the base REM model used in this analysis is nearly identical to the PNNL/DOE model and would be expected to have similar results if there was a PNNL/DOE simulation run in Columbus.

Energy Simulation Variables

Table 1 lists the components which are changed in the simulations. Modified values (when moving left to right) are indicated with a black background.

Component	2006 IECC	2009 IECC	2012 IECC	2012 IECC w/Equipment
Fenestration U-Factor	0.35	0.35	0.32	0.30
Skylight U-Factor	0.60	0.60	0.55	0.55
Ceiling R-Value	38	38	49	38
Wood Frame Wall R-Value	19 or 13+5	20 or 13+5	20 or 13+5	19 or 13+5
Basement Wall R-Value	10/13	10/13	15/19	10/13
Crawl Space Wall R-Value	10/13	10/13	15/19	15/19
Duct Tightness (DSE)/% Adjustment	NR-(0.80)	8%	12%	12%
Building Tightness (ACH50)	NR-7	7	3	4
High Efficacy Lighting	NR-10%	50%	75%	75%
Furnace Efficiency (AFUE)	78%	78%	78%	94%
Hot Water Pipe Insulation	NR	NR	R-3	NR
Hot Water Energy Savings	0%	0%	10%	0%
Mechancial Ventilation (Y/NR)/Cost	NR	NR	Y/$80	Y/$80

NR- No Requirement
DSE- Distribution System Efficiency

Table 1: Simulation Model Variables

Results

Load	2006 IECC	Annual Energy Cost ($) 2009 IECC		2012 IECC		2012 IECC w/Equipment	
Heating	987	911		598		572	
Cooling	272	272		295		286	
Water Heating	267	267		267		267	
Light and Misc Loads	1,087	1,087		1,087		1,087	
Light and Misc Loads	1,087	1,087		1,087		1,087	
HCW Sub Total	1,526	1,450		1,160		1,125	
Total	2,613	2,537		2,247		2,212	
Sub total $/% savings over 2006 IECC code		$ 76	5.0%	$ 366	24.0%	$ 401	26.3%
Post Processing Adjustments							
Duct Tightness Savings (8, 10, 12%)		$ 95		$ 107		$ 103	
Addition of Piping Insulation (10%)[1]				$ 27			
Mechanical Ventilation (Penalty)				$ (80)		$ (80)	
Adjusted total $/% savings over 2006 IECC code		$ 171	**11.2%**	$ 420	**27.5%**	$ 424	**27.8%**

Table 2: Annual Energy Savings by Code

2012 IECC Energy Neutral Cost Savings Using High Efficiency Equipment

Item	Change	Unit Cost	Units	Cost	Source
Reductions					
Infiltration	3->4 ACH50	$ 0.15	2940	$430.92	ASHRAE 1481-RP
Hot Water Pipe Insulation[1]	Required->None	$ 829	1	$829.00	Faithful & Gould
Ceiling Insulation (Flat-70%)	R-49->R-38	$ 0.67	840	$558.78	ASHRAE 1481-RP
Ceiling Insulation (Cathedral-30%)[2]	R-49->R-38	$ 0.94	360	$336.89	ASHRAE 1481-RP
Wall Insulation	R-20->R-19	$ 0.19	2380	$456.18	ASHRAE 1481-RP
Basement Insulation	R-15->R-10	$ 0.56	1120	$631.39	ASHRAE 1481-RP
				$3,243.17	
Increases					
Furnace Efficiency	0.78->0.94 AFUE	$ 1,504	1	$1,504.07	ASHRAE 1481-RP
Window U-Factor	0.32->0.30 U	$ 0.34	357	$121.38	ASHRAE 90.1 Env
				$1,625.45	
Cost Totals					
Reduction for non cost effective changes				$3,243.17	
Increase for more cost effective changes				$1,625.45	
Net Reduction using equipment efficiency as energy neutral trade-off				**$1,617.73**	

[1] Assume 98ft of 1/2" pipe insulation and 80ft of 3/4" pipe insulation

[2] Does not include reduction for downsizing roof rafter

Note: ASHRAE 1481-RP (2008) Prices have been escilated for inflation by 12.7% (RS Means)

Table 3: Construction Savings Using Equipment Efficiency for the 2012 IECC

Discussion

Energy savings of over 11% should be realized with adoption of the 2009 IECC over the 2006 IECC (does not include high efficacy lighting energy savings)(Table 2).

The 2012 IECC is estimated to save 27.5% (Table 2); this does not include savings associated with high efficacy lighting and additionally penalizes the savings (5 percentage points) by adding ventilation to the 2012 requirements which was not included in the 2006 IECC analysis.

Table 3 is an example of the potential construction cost savings if higher efficiency equipment is considered for energy code compliance. This example results in a construction cost reduction of $1,617 in climate zone 5. An optimized solution would result in additional construction cost savings while yielding the same or less energy consumption.

References

ASHRAE 90.1 Envelope Subcommittee Cost Database

Building America (2010), Cost Database for BEopt Energy Simulations, National Renewable Energy Lab, Golden, CO.

Drumheller, C, (2011), *APA Simulation Background and Instructions*, NAHB Research Center, Upper Marlboro, MD.

Faithful & Gould (2012), *Residential Energy Efficiency Measures Prototype Estimate and Cost Data*, For Pacific Northwest National Lab, Richland, WA.

International Code Council (ICC). (2006). International Energy Conservation Code 2006. Falls Church, VA: ICC

International Code Council (ICC). (2009). International Energy Conservation Code 2009. Falls Church, VA: ICC

International Code Council (ICC). (2011). International Energy Conservation Code 2012. Falls Church, VA: ICC

Taylor, Z.T., Lucas, R.G., (2010-1) *An Estimate of Residential Energy Savings From IECC Change Proposals Recommended for Approval at the ICC's Fall, 2009, Initial Action Hearings,* PNNL-19367, Richland WA: Pacific Northwest National Laboratory.

Taylor, Z.T. (2010-2) The Evolving Relationship Between Energy Codes, Beyond-Code Programs, and Home Energy Ratings, 2010 RESNET Conference, Slide 21 of 42
http://www.hersindex.com/conference/2010/presentations/Taylor.pdf

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF WATER

May 8, 2009

Dear Interested Party:

The U.S. Environmental Protection Agency (EPA) is pleased to announce the release of a revised draft specification for water-efficient single-family new homes. The purpose of this letter is to inform you of substantial changes made to the initial draft specification released in 2008, to share the rationale for making these changes, and to ask for your feedback.

Encouraging the construction of water-efficient new homes is the latest endeavor by EPA's voluntary WaterSense® program, launched in 2006 to protect the future of our nation's water supply by promoting water efficiency and enhancing the market for water-efficient products, services, and practices. WaterSense aims to change the way the American public and businesses think about their water use.

In May 2008, WaterSense released the draft specification for water-efficient single-family new homes for public comment and received substantial feedback. In the months since then, EPA has been taking steps to address stakeholder comments and provide additional resources to interpret the new homes specification. These tools include the following:

- Water budget tool: released in November 2008, which explains how builders shall comply with the draft specification's landscape design options;
- Inspection and irrigation audit guidelines: released in December 2008, which explain how the criteria outlined in the specification shall be verified and provides sample checklists for these tests; and
- New home certification system: released in December 2008, which explains the third party certification and labeling process for water-efficient single-family new homes. (Note: The certification system is in the process of being finalized and will not be released again for public comment.)

EPA welcomes your input on the revised draft Water-Efficient Single-Family New Home Specification, revised Water Budget Tool, and revised Inspection and Irrigation Audit Guidelines. All interested parties are encouraged to review the revised materials and provide written comments by July 7, 2009. Written comments should be directed to watersense-newhomes@erg.com. All comments become a part of the public record.

Additionally, WaterSense will be conducting a public comment meeting in June 2009. Please check the WaterSense Web site (www.epa.gov/watersense/pp/new_homes.htm) for additional information as it becomes available.

For a snapshot of the next steps to finalize the specification for single-family new homes and launch the upcoming WaterSense New Homes program, see the timeline below.

- June – Release the final New Home Certification System
- June – Hold public meeting on the revised draft specification
- July and August – Review public comments on the revised draft specification
- September and October – Recruit and train new home certification providers
- November – Release final specification for water-efficient single-family new homes and a list of WaterSense licensed providers.

If you have any questions, please contact Allison Hogge at (202) 564-0627 or hogge.allison@epa.gov, or the WaterSense Helpline at (866) 987-7367 or watersense@epa.gov. We look forward to receiving your feedback on the specification.

Sincerely,

Sheila Frace
Director,
Municipal Support Division
EPA's Office of Water

Significant Changes in the Revised Draft Specification and Related Materials

In response to public comments, EPA has made both major and minor changes to all aspects of the draft specification for water-efficient single-family new homes. Significant changes to the indoor and outdoor water-efficiency criteria, homeowner education criteria, and water budget tool are listed here and described below.

The significant changes to the indoor water-efficiency criteria include:

- Eliminated the criterion that all hot water pipes be insulated;
- Revised the criterion for the performance of hot water delivery systems;
- Developed a criterion that all water-using fixtures, appliances, and equipment be checked for leaks; and
- Expanded the criterion for water softeners.

The significant changes to the outdoor water-efficiency criteria include:

- Revised the criterion that the entire yard be landscaped in all cases;
- Redefined "landscapable area;"
- Changed the water adjustment factor (Kwa) of 60 percent to an evapotranspiration adjustment factor (ETAF) of 70 percent;
- Revised the criterion for ornamental water features;
- Revised the criterion for designing, installing, and auditing irrigation systems;
- Developed a distribution uniformity criterion for irrigation systems; and
- Developed a criterion for the requirement of a rain shut-off device.

The significant changes to the homeowner education criteria include:

- Developed a criterion that builders provide homeowners with a drawing record (schematic) of the irrigation system, if installed.

The significant changes to the water budget tool include:

- Changed the timeframe from annual to peak watering month;
- Revised the landscape coefficients; and
- Revised the default irrigation system distribution uniformities.

Indoor Criteria – Insulation of Hot Water Pipes

EPA received comments in support of and against the criteria that all hot water pipes be insulated to a minimum of R4. Research indicates that there are water and energy savings associated with the delivery of hot water through insulated pipes during concurrent draws. The insulation allows less heat to dissipate from the pipes and, therefore, hot water is delivered more quickly once the pipes are warmed from previous draws. EPA does believe that insulating hot water pipes located below-grade, below-slab, and in crawlspaces may be cost-effective in some climates. However, there is limited data supporting water savings from the delivery of hot water through insulated pipes when draws are not concurrent. Household water usage patterns indicate that hot water is typically used in the mornings and evenings and that many hot water draws might not be close enough together to benefit from the water savings associated with pipe insulation. Therefore, due to the limited water savings and high costs associated with pipe insulation, EPA has eliminated the criterion that all hot water pipes be insulated from the revised draft specification.

Indoor Criteria – Hot Water Distribution Systems

EPA received many comments in favor of setting a single performance standard for hot water distribution systems instead of requiring the use of specific types of delivery systems. Although EPA believes that the three systems identified in the draft specification (demand-initiated hot water recirculating system, whole house manifold system, core plumbing system) will be used by builders in water-efficient homes, EPA agrees that developing a performance-based specification provides more flexibility to builders and accommodates more diverse floor plans.

EPA also received comments on required pipe sizes and the expected piping runs between hot water sources and the farthest plumbing fixtures. Based on these comments, EPA believes that revising its calculations to reflect increased pipe diameters and greater distances between hot water sources and fixtures will allow more builders to participate in the program while still achieving its objective that builders install water-efficient hot water delivery systems. Therefore, EPA determined that a maximum of 0.60 gallons of water stored in the piping between the hot water source and any hot water fixture would adequately accommodate the expected distances to fixtures from the hot water source (20 to 30 feet) and the combination of pipe sizes (e.g., 3/4-inch trunks, 1/2-inch branches) used to make the connections in a home. EPA also believes that specifying a performance standard of 0.60 gallons will alleviate concerns that builders will try to meet the criteria using too small a diameter of piping.

Indoor Criteria – Leaks

Many commenters stated that EPA should require inspectors to check for leaks at all visible supply connections and valves. EPA agreed that inspectors should be looking for leaks during their inspection and, therefore, included a requirement in the revised draft specification that there be no visible leaks from any water-using fixtures, appliances, or equipment. Based on comments from pilot builders and their inspectors, EPA believes that there should not be any increased cost for inspectors to look for leaks as they verify the fixtures, appliances, and other equipment installed in the home.

Indoor Criteria – Water Softeners

During the past year EPA has been conducting additional research on water-efficient water softeners and determined that water softeners are common in regions of the country where hard water is prevalent, with cation-exchange water softeners being the most common and most reliable technology.

While the volume of water consumed by these softeners has decreased significantly in recent years, water softeners still generate and discharge a significant volume of wastewater. To minimize water consumption and reduce the amount of salt discharged into septic and sewer systems, the NSF/ANSI Standard 44–Residential Water Softener Testing and the Water Quality Association's (WQA) S-100 Residential Water Softener Testing Standard include a voluntary set of requirements for efficiency-rated residential cation-exchange water softeners. All residential cation-exchange water softeners sold in the United States must be certified to the general requirements of NSF/ANSI Standard 44 (or WQA S-100). The voluntary efficiency requirements found in Section 7 of NSF/ANSI Standard 44 are for manufacturers looking to differentiate and market their products as water- and salt-efficient.

WaterSense also received comments recommending that EPA require only demand-initiated regeneration water softeners because they use auto-initiated regenerations initiated via a water meter or water hardness sensor that reduce the amount of wastewater generated. In contrast, devices using time-clock-initiated regenerations discharge regardless of the amount of water that has been treated and regardless of the amount of treatment capacity that may be remaining in the unit. WaterSense also received comments against the use of salt-based softeners. Based on the new research and these comments, EPA believes that NSF/ANSI Standard 44 voluntary requirements for efficiency-rated residential cation-exchange water softeners identifies and designates models that use water and salt efficiently and that incorporate the desirable demand-initiated regeneration technology. Therefore, EPA has incorporated the NSF/ANSI voluntary efficiency requirements into the revised draft specification.

Outdoor Criteria – Landscaping the Yard

WaterSense received comments arguing against a uniform requirement that the entire yard be landscaped. Commenters believed this requirement would greatly reduce the potential for builders to participate in WaterSense in markets where the prevailing practice is to landscape only the front yard of new homes. To research this issue further, EPA conducted telephone focus groups of various sizes with 40 builders across the country to discuss their standard landscaping and irrigating practices. Based on this research and other conversations with builders and developers, EPA determined that most builders landscape the front of the house using primarily turfgrass. Although custom homebuilders tended to landscape the entire yard more often than larger builders, there did not appear to be any geographic link to the landscaping practices. EPA also learned that many builders do install irrigation systems in their landscapes.

To encourage maximum builder participation and to work within the current landscaping practices of most builders, EPA has revised the landscape design criteria to require that every home seeking the WaterSense label must landscape the front yard to meet WaterSense criteria. However, to address builders who are landscaping the entire yard as part of their standard package or are installing pools, spas, water features, and/or irrigation systems, EPA is requiring that the entire yard be landscaped to meet WaterSense criteria in these instances.

WaterSense also received comments on setting a minimum lot size for the landscape design criteria. EPA agrees that on very small lots, such as those associated with some townhomes, it would be difficult to allow for a useable amount of turfgrass and still meet the landscape design criteria. Therefore, EPA has exempted lots with less than 1,000 square feet of landscapable area from the landscape design criteria.

Outdoor Criteria – Definition of Landscapable Area

EPA also revised the definition for "landscapable area." Since the release of the first draft of the specification, WaterSense has received numerous comments on areas of the lot that should or should not be subject to the landscape design criteria. EPA agrees that the definition should exclude areas designated as rights-of-way, drainage or utility easements, and septic drainfields. Therefore, EPA conducted research on definitions used by other green building programs to see if they had addressed these areas of concern. EPA believes that the definition included in this revised draft specification (i.e., "buildable lot area excluding area under roof"), which is based on the U.S. Green Building Council's (USGBC's) Leadership in Energy and Environmental Design (LEED) for Homes program's definition of the "designed landscape", is simple and sufficiently broad to address the long list of non-buildable areas that may be encountered at a given site.

Outdoor Criteria – Ornamental Water Features

EPA received hundreds of comments on the beneficial uses of water features commonly installed in homes and conducted several conference calls with key stakeholders representing this industry to better understand the type of water features installed in new homes. Many commenters recommended that EPA treat water features in the same manner as pools and spas. EPA has revised the criteria to allow the installation of ornamental water features that recirculate water and serve a beneficial use. EPA believes that this requirement helps differentiate closed system water features that contain and recirculate water from those features that are less efficient. The revised draft specification also requires that the water surface areas of the water features be deducted from the turfgrass allowance and included as landscapable area under the landscape design options, which is also the requirement for pools and spas.

Outdoor Criteria – Plantings on Slopes

Due to the runoff concerns associated with irrigating turfgrass installed on slopes in excess of 4 feet of horizontal run per 1 foot vertical rise (4:1), the first draft specification stated that turf shall not be planted on slopes greater than 4:1. However, as many commenters identified, EPA did not specify what, if anything, should be planted on the slopes. EPA's intent was that the slope would be planted and not left bare. Therefore, EPA has revised the criteria in the specification to state "non-irrigated plantings other than turfgrass shall be installed on slopes in excess of 4 feet of horizontal run per 1 foot vertical rise (4:1)."

Outdoor Criteria – Design, Installation, and Auditing of Irrigation Systems

EPA received many comments arguing against the use of WaterSense irrigation partners to design, install, and audit irrigation systems installed at homes seeking the WaterSense label. These commenters believe that there are other qualified individuals who can design and install water-efficient irrigation systems and some questioned the availability of WaterSense irrigation partners. EPA agrees that there are other individuals that can install water-efficient irrigation systems that meet the criteria for WaterSense labeled new homes. EPA also believes that through existing partnerships and use of local irrigation professionals, builders may be able reduce the costs associated with designing and installing irrigation systems. Therefore, EPA has eliminated the requirement that all irrigation systems be designed and installed by WaterSense irrigation partners. However, to ensure that the installed systems meet WaterSense criteria, EPA has retained the requirement that a WaterSense irrigation partner must audit each irrigation system.

Outdoor Criteria – Irrigation Systems Achieve Specified Distribution Uniformity

EPA received several comments recommending that EPA require a specific uniformity standard or efficiency percentage for the irrigation system. Suggested distribution uniformity values ranged from 60 to 75 percent. EPA agrees with the commenters and added a criterion to the revised draft specification that the irrigation system shall achieve a lower quarter distribution uniformity (DU_{LQ}) value of 70 percent to help ensure the system is operating efficiently at the time of installation.

Outdoor Criteria – Irrigation Systems Interrupted During Rainfall

EPA received numerous comments recommending that EPA require irrigation systems to be equipped with technology that inhibits or interrupts operation during rainfall. EPA agrees that equipping irrigation systems with devices to stop operation during periods of rainfall will reduce the amount of water wasted during landscape irrigation. Rain sensors can be purchased quite inexpensively, therefore, EPA does not believe this requirement will add significantly to the costs of the irrigation system.

Homeowner Education Criteria – Information on Irrigation Systems

Homes that are labeled under the WaterSense program are certified to meet water-efficiency criteria at the time of inspection. EPA understands that after homeowners move into WaterSense labeled homes, keeping the homes water-efficient will require maintenance, especially with respect to irrigation systems. To help educate homeowners on the irrigation systems installed in their homes, EPA is requiring that builders provide the homebuyer with a schematic of the system and copies of the two irrigation schedules developed for their system. The WaterSense materials on efficient indoor and outdoor water use shall also be provided to homeowners.

Water Budget Tool – Required Use

Due to concerns raised by commenters about inconsistent approaches used to calculate a water budget, EPA is requiring the use of the WaterSense water budget tool if the builder selects Option 2 to fulfill the landscape design criterion.

Water Budget Tool – Peak Watering Month

EPA received many comments recommending that the tool be based on a peak watering month instead of an annual timeframe in order to better reflect the conditions during the growing season, which is the period of time when plants need the most water and precipitation is utilized by the landscape. The annual timeframe did not discern between forms of precipitation, such as snow and rain, and allowed natural water falling outside of the growing season to be incorporated into the budget. To address these concerns, EPA revised the timeframe to the peak watering month, which is consistent with other water budget tools used around the country, including USGBC's LEED for Homes water budget tool. Users will base evapotranspiration and rainfall data on the peak month for their area.

Water Budget Tool – Water Adjustment Factor

EPA received a number of comments in support of different water adjustment factors (K_{wa}). Some stakeholders expressed concern that a 60 percent adjustment factor would limit the use of native plants in certain regions of the country and/or would not allow the landscape to survive. To address these concerns, EPA has increased this factor to 70 percent. Additionally, EPA is clarifying the use and intent of the water adjustment factor, now called the evapotranspiration adjustment factor (ETAF). The intent is not that all areas of the landscape can only be watered at 70 percent of the local reference evapotranspiration (ET_o). The intent is that the landscape should be designed so that, as a whole, it requires 70 percent of the amount of water that a similar-sized lot composed entirely of turfgrass would require. A variety of high, medium, and low water-using plants, as well as nonirrigated areas, can be used in the landscape to meet this requirement.

Water Budget Tool – Landscape Coefficients

EPA received numerous comments on the use of landscape coefficients based on California data and the lack of local data for use in the "custom" areas of the tool. In addition, multiple commenters noted that there was no option to designate low water-using plants. After conducting additional research with various stakeholders, academics, and cooperative extension services around the country, EPA determined that this body of data and/or a single source of regional landscape coefficients for common species is not available. While efforts in the landscape community are being made to produce a clearinghouse for landscape coefficient data, EPA is moving forward by adopting the species factor values used in USGBC's LEED for Homes Rating System Sustainable Sites Criteria 2.5 (2008). This table, based on the Water Use Classifications of Landscape Species published by the University of California Cooperative Extension, includes low, medium, and high water requirements for trees, shrubs, groundcover, and turfgrass. EPA is aware that these values are still based on California data, but believes this to be the best data currently available. EPA also eliminated the option of entering custom values until more landscape coefficient data is readily available for users.

Water Budget Tool – Run Time Multiplier, Irrigation Efficiency, and Distribution Uniformity Values

EPA received multiple comments noting that the denominator of the run time multiplier should be "distribution uniformity," instead of "irrigation efficiency." EPA changed the terminology in the equations and in Table 3 to reflect this recommendation.

EPA also received comments that the irrigation efficiencies (now lower quarter distribution uniformity values) were too high. EPA addressed these concerns by lowering the distribution uniformities from the "Excellent" level to the "Very Good" level as listed in Table 1-8 and Table 1-9 of the Irrigation Association's *Landscape Irrigation Scheduling and Water Management* (2005).

Inspection Guidelines

EPA received multiple comments that the inspection guidelines should be updated to reflect changes to the specification and released again for public comment. EPA agrees with these commenters and has included updated inspection and irrigation audit guidelines with the revised specification.

Domestic Hot Water System Piping Insulation: Analysis of Benefits and Cost

Prepared for:

National Association of Home Builders

Prepared by:

NAHB Research Center
400 Prince Georges Boulevard
Upper Marlboro, MD 20774-8731
www.nahbrc.com

December 2010

Report #: 5928-3_12292010

NAHB RESEARCH CENTER

Table of Contents

List of Figures

List of Tables

Domestic Hot Water System Piping Insulation: Analysis of Benefits and Cost

Background

Increasing the efficiency of water heating equipment is one means to achieve energy savings in the hot water system; however, the piping distribution system itself is now being scrutinized to determine opportunities for further hot water system savings. Often accepted approaches to energy savings in the hot water piping system are to reduce the length of piping to the outlets and to insulate the hot water pipes. Less regarded as an energy savings feature is the reduction in size of the hot water lines to outlets, which can reduce pipe losses, as other plumbing system performance issues such a pressure drop and fluid velocity must be considered. All of these approaches will result in lower piping system losses. The purpose of this study is to outline the mechanisms of energy savings in the piping distribution system and to estimate the range of energy savings resulting from pipe insulation based on simulated hot water use profiles.

This study was commissioned by the National Association of Home Builders (NAHB) with the purpose of understanding the energy savings available by insulating hot water piping in homes relative to the cost of the insulation, both in materials and installation. The study includes references to the existing body of research as well as results of new analyses of hot water distribution systems with various options for insulating hot water piping.

Background: Hot Water Piping Energy, Water Use, and Loss Mechanisms

Domestic hot water piping systems are designed to deliver hot water from a source (the water heater) to the outlet. The piping design must account for the source pressure and the design flow rate to ensure an adequate supply of hot water volume to the outlet. These design constraints directly influence the energy loss of the piping system. For example, in long plumbing runs, the pipe size may be increased to reduce flow losses leading to larger volumes of hot water in the piping and increased energy losses, both during the draw and after the draw as the volume of hot water cools. In addition to these energy losses during a water use event, occupant control characteristics will affect the total energy loss from the hot water system such as wasted warm/hot water while waiting for hot water to arrive at the outlet and the desired water temperature at the outlet (that affects the amount of cold water mixing) to reach the desired level.

Given these hot water use characteristics that directly affect the total energy use of the hot water system, an outline of the specific mechanisms contributing to energy (and water) losses is shown in Table 1.

Table 1 - Factors Affecting Hot Water System Energy Use

Property	Energy Use Mechanism	Loss Consequence
Pipe material, length and location	Heat transfer through the pipe to the surrounding based on conductivity and the environmental temperature around the pipe	• Energy loss during flow • Energy loss at the end of the flow event (cool down) • Water loss waiting for hot water at the outlet
Intention of use	Volume of hot water in the piping based on a desired temperature (i.e. shower) or fixed volume (i.e. dishwasher)	• Water waste waiting for hot water at the outlet • Increase in water heating energy based on the need for hotter water at the outlet
Flow rate	Heat transfer through the pipe to the surrounding during use	Magnitude of loss relative to total volume of use increases with a decrease in flow rates
Interval between use	Heat loss during pipe cool down after a use event	Energy and water loss dependent on the time to the subsequent use
Cold water temperature at the outlet	Volume of hot water used dependent on the desired temperature at the outlet, if set	Larger volume of hot water is used with colder incoming water temperature

As outlined, the confluence of parameters involved in the determination of hot water system losses increases the complexity of determining the affect of any one aspect leading to higher energy losses relative to the total energy use in the hot water system. This affect is clearly seen in the energy factor (EF) rating for water heaters which is highly dependent on the time frame and use pattern of the test procedure. For any actual home, the EF may be significantly different from the equipment rating, for example, in homes where there is large hot water use throughout the day, the actual EF may be much higher, where the opposite would be true for homes that use much less hot water than the test procedure.

Furthermore, the losses from the hot water system are all relative to the total energy supplied to the hot water system such that homes with low hot water use due to consumer behavior (including the choice of low-flow faucets) may reduce the total energy used in the hot water system, the ultimate benefit desired. However, in all homes, the performance of the hot water system may be improved (e.g. faster hot water delivery, lower piping losses, etc.) through the system design.

This study focuses on one aspect of the system design – insulating hot water piping as a means to reduce energy (and corresponding water) losses. It must be noted that this study did not evaluate recirculation systems which presents a different set of analysis complexities including the type of recirculation system, the actual layout of the system, the pumping energy, and the control mechanisms based on occupant behavior at a particular use point.

Published Hot Water Energy Use Research

A literature search was performed to review the current information available relating to hot water energy use in homes and specifically concerning the application of insulation for the piping. The relevant literature is annotated in Appendix A. Few studies specifically focused on pipe losses from domestic hot water systems. The most significant studies were published in 2004 [Baskin et. El. 2004] through 2006 [Hiller] that used analytical and some laboratory test methods to demonstrate the scope of losses from domestic hot water piping. These studies, while not applied to realistic hot water use profiles in homes, demonstrate the mechanisms of heat loss from piping and conclude that the largest benefit of insulating piping is with under-slab configurations[1]. Other energy savings from insulated piping were highly dependent on the use pattern, piping location, and the start of a use event (i.e., whether it is a "cold start"). Similar results from laboratory testing and analytical estimates highlighted by Hiller [Hiller, 2005] concluded that insulating hot water piping provides the greatest benefit with moderately spaced hot water use patterns.

The bulk of the literature concerning hot water system energy use, however, dealt with three major areas of research:

- Model development to simulate hot water use
- Development of hot water use patterns and volumes
- Hot water system design and layout including recirculation systems

Other hot water research including use of pre-heat or tempering systems such as solar or desuperheaters as well as research on various water heating technologies are not included in this review as these technologies serve a different function in hot water energy savings with regard to piping losses.

To date, little information is available that provides large scale testing or modeling of various system designs, including accurate hot water use profiles, to quantify the energy loss from piping systems in various climates and across seasons. However, some basic characterizations of hot water systems, including piping, have emerged from the body of research:

- Under-slab hot water piping supply to outlets generally shows a benefit from piping insulation both in energy and water savings,
- Hot water use patterns including the outlet point, intended use of the hot water draw, subsequent use from the same pipe section, and total volume of hot water used affect the total energy use of the hot water system, and
- The proximity of the hot water heater to the outlets plays a large role in energy and water use.

The limitations of the available research remain in the areas of modeling tools and methodologies for standardizing use patterns for various housing types, climates and fixtures, range of piping layouts, materials and use patterns, and plumbing system designs.

Study Methodology

The analysis of simulated energy performance of hot water piping detailed in this report, including the cost benefit of insulation, seeks to combine various aspects of previous studies with newly available modeling tools. A software tool, HWsim[2] available through the Davis Energy Group to the Building America Program[3] is used in this study. HWsim has allowed for a more detailed simulation of hot water systems. The software can accommodate different domestic hot water piping lengths, materials, and sizes. The piping can be connected to outlet use points that can be configured in various modes to

[1] Hiller's test results show a large benefit to insulating metal pipe buried in damp sandy soil, less benefit with plastic pipe. Further testing was considered for insulated pipe in saturated soil which is expected to reduce the effectiveness of the insulation. Baskin and Wendt et. Al. concluded that the use of insulation provides some benefit but the magnitude of the benefit is dependent on the use profile and the location of the pipe.

[2] HWSIM Hot Water Distribution Simulation Model Program, Version 1, Davis Energy Group, Inc. 2008. The software was developed through support from the U.S. Department of Energy and the California Energy Commission.

[3] The Building America Program (BAP) is a research program supported through the Department of Energy, whose purpose is to increase the efficiency of new and existing homes. The NAHB Research Center is a BAP partner team.

simulate, for example, a shower that uses hot water at a limited temperature versus a laundry that uses a set volume of hot water at any temperature. A significant feature of the software is the use of a "draw editor" in which flow rates and total volume can be assigned to a specific use point. The environmental temperature surrounding the pipe can also be defined for each month (or even hourly, if desired) and the cold water inlet temperature can be defined on a monthly basis.

A broad characterization study of the affect of installing pipe insulation on all domestic hot water pipes is performed through various approaches using the capabilities of the software coupled with use patterns defined specifically for homes. The approaches detailed in this report include:

Analysis 1: Characterization of individual energy use and loss mechanisms of the piping system as outlined in Table 1 above,
Analysis 2: Parametric study highlighting the interactions of various piping system loss mechanisms,
Analysis 3: Whole house hot water system analysis based on a standard hot water system design, environmental conditions and use pattern, and
Analysis 4: Cost-Benefit analysis.

The cost-benefit analysis (Item 4) is performed based on estimated installed cost of pipe insulation and current average utility rates for natural gas and electricity, to estimate the net energy cost savings from insulating the hot water piping. This analysis provides a cost and benefit comparison based on the simulation results.

This study is designed to analyze the current system designs and does not attempt to develop optimized piping layouts to specifically reduce the volume of hot water in the piping.

Analysis 1 - Characterization of the Domestic Hot Water Distribution System

The complexity of factors involved in the hot water distribution system design and use range from the layout of the system and number of outlets, which can be unique in even similar house models, to the daily variation in occupant use of the system. The use of hot water outlets, whether a sink faucet or washing machine, can change on a daily, weekly, and even seasonal basis throughout the year. These factors coupled with changing conditions of the house and cold water temperatures as well as the interval between hot water uses will change the system losses, including losses from the piping system.

To understand the relationship between these factors, an initial set of simulations was developed to isolate individual variables and estimate the affect of each. A simulated piping system for a single shower outlet was configured of 3/4" pipe and a length of 50 feet from the tank to the outlet. The flow rate was set at 2.5 GPM and the total flow volume was set to 50 gallons. A delivery temperature of 105°F was set at the outlet with the tank providing 120°F water. Table 2 lists the combination of variables implemented in the simulations for the shower piping system.

Table 2 - Characterization Simulation Variables

Feature or Condition	Options for Analysis		
	Option 1	*Option 2*	*Option 3*
Pipe Type[a]	Metal	Plastic	n/a
Insulation[b]	Uninsulated	1" Insulation (~R-5)	n/a
Location (Environment)	Crawlspace (50 F)	Basement (65 F)	n/a
Cold Water Temperature	45 °F	55 °F	65 °F

[a] The most commonly used residential metal pipe material is copper and CPVC for plastic
[b] Insulation R-values vary by material and thickness; 1" thick insulation is on the larger side of common insulation thicknesses used in the residential market.

A set of 24 simulations were run to evaluate the various effects of the variables on pipe loss and Figure 2 provides a graphical representation of the various system pipe loss per foot of pipe for one flow even. Associated pipe loss percentages relative to the most severe condition of uninsulated metal piping at 50°F and with a cold water temperature of 45°F are also provided for the shower piping system.

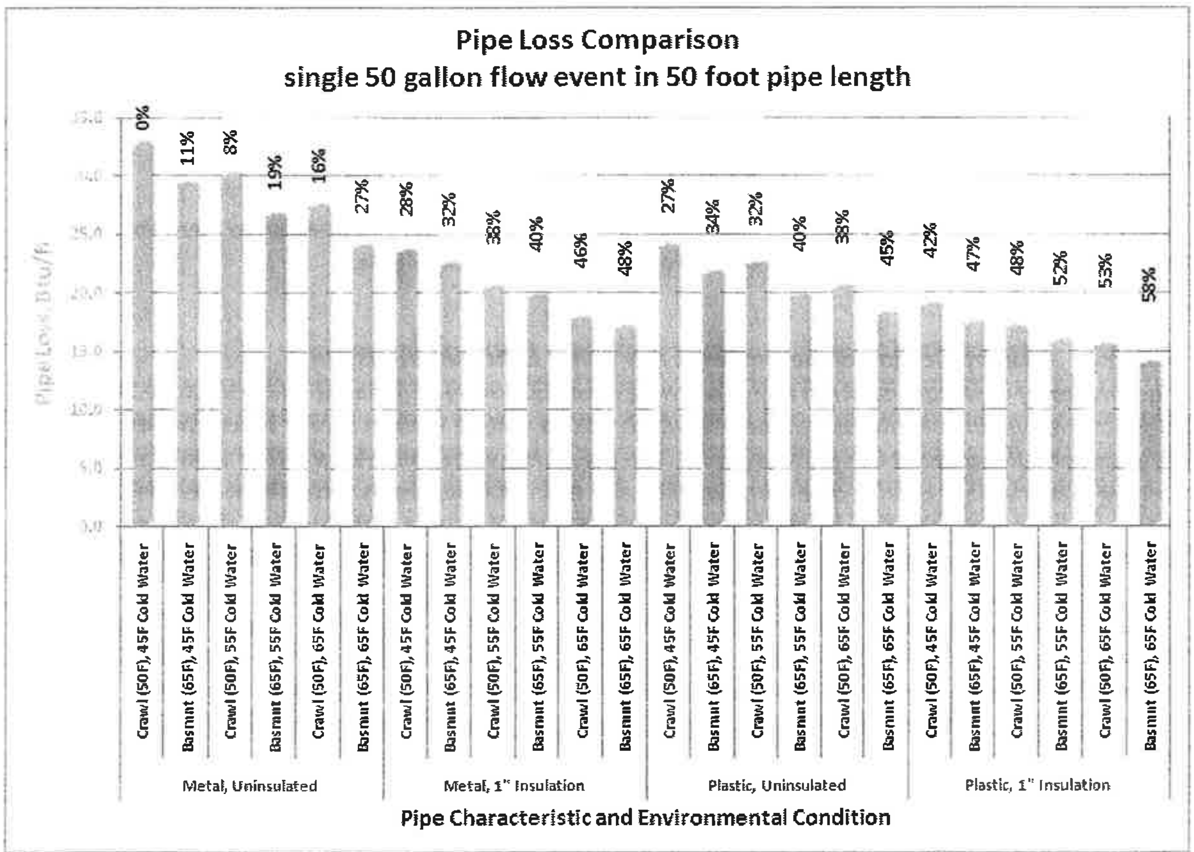

Figure 1 - Hot Water Pipe Loss Characterization

Pipe Loss Effect on Hot Water Energy Consumption

Figure 1 demonstrates the individual affect of various factors that affect the performance of a hot water piping system (Table 2 above). The energy lost from the piping system may or may not result in meaningful additional energy use at the hot water heater when evaluated both for insulated and uninsulated piping. For example, a 10% reduction in piping losses does not translate into a 10% reduction in hot water heating energy use since many of the piping losses are unrecoverable even if the piping is insulated. This is due primarily to the variation in hot water use between uses (where the pipe may cool even with insulation) and the amount of energy lost while using hot water (which is dependent on the pipe length, the temperature of the hot water, and the surrounding temperature). It is also dependent on the temperature of the hot water at the outlet (indicating the mixing of cold water) and the temperature of the cold water. Pipe energy loss can be estimated (and measured) but this estimate, while related to the energy purchased to heat water, is not represented at the same magnitude for insulated and uninsulated piping systems. The discussion in the following subsections will compare piping losses, but note that these losses are not intended to be considered energy savings at the water heater.

Volume of water in pipes

A major factor in the extent of energy loss from hot water piping is the volume of water in the piping from the water heater to the outlet. This volume of water (and the pipe itself) must be heated from its starting temperature to that of the hot water in the tank. The larger this volume, the longer it takes to deliver hot water to the outlet and the more water is left to cool in the pipes after a use. Figure 2 compares the volume of water in different pipe types and lengths.

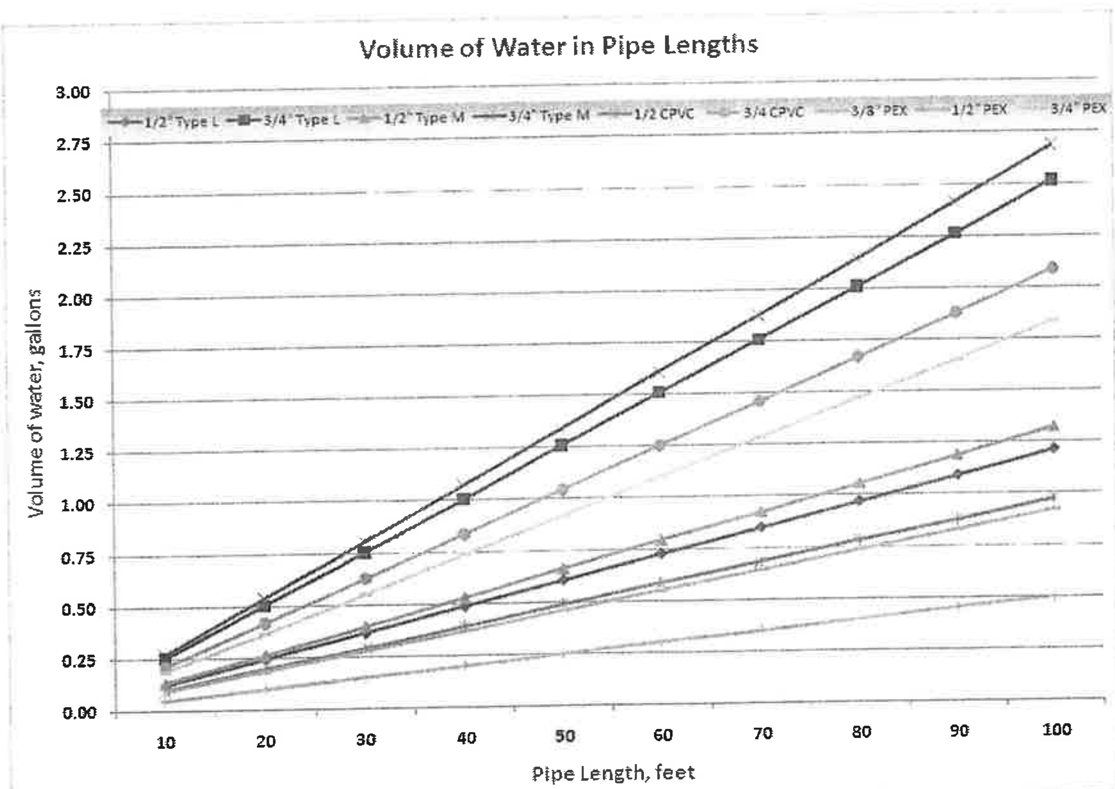

Figure 2 - Volume of water in pipe lengths by type

For example, using 20 feet of Type L copper pipe, there is a difference of over a quart of water from 1/2" to 3/4" pipe diameter. For a typical 2,200 square foot home plumbed with a combination of 3/4" and 1/2" Type L copper, there can be over 3 gallons of water in the hot water piping alone.

Environmental Temperature

Energy losses from hot water piping systems are also dependent on the environmental temperature surrounding the pipe. Previous analysis [Baskin et. Al. 2004] has indicated that hot water pipes located in the ground beneath slab foundations would benefit from insulation in all cases since the pipe losses are increased both during and after the flow event. In addition, the pipe temperature is more quickly brought to that of the surroundings (if pipe not insulated) due to the direct contact with the earth.

For above-ground pipes, pipe losses due to the temperature of the environment surrounding the pipe were analyzed for 2 conditions to highlight the affect of placing hot water pipes in either an open crawlspace (at a constant temperature of 50 °F) or in a basement (at a constant temperature of 65 °F). The pipe losses (not hot water heater energy savings) are estimated to be reduced from about 4% to as much as 13% for the given flow event (refer to Figure 1, compare the first 2 columns in each piping configuration). In most homes, the temperature surrounding the pipe could have a large range depending on the climate, the location of the pipe, and the temperature set-points in the house. It is likely that not all of the piping would see a uniform temperature and the temperature around the pipe would be expected to change through the year.

Cold Water Temperature

Another factor that influences the use of hot water and the amount of losses in the piping system is the incoming cold water temperature. The cold water temperature influences the water heating energy (colder water requires more energy to heat to a set temperature), and the amount of hot water used (for a set temperature at the outlet, more hot water must be mixed with colder water). This variable is not obvious since it would seem that the cold water temperature would not change the hot water piping losses directly. The importance of the cold water is the mixing of the hot water required to bring the water to a comfortable temperature at the outlet. The colder the incoming water, the more hot water is required to keep the outlet temperature at the desired level. Based on the characterization simulations, the effect of the cold water temperature (either 55 °F or 65 °F from a 45 °F base) reduces the resulting hot water pipe losses from 7% to 33% when the pipes are located in a colder location (50 °F environment), and from 9% to 24% when the pipes are located in a warmer location (65 °F environment). The savings (refer to Figure 1, compare the 1st and 3rd and 1st and 5th columns in each piping configuration group) are somewhat consistent and independent of the pipe being insulated indicating that the cold water temperature is a secondary effect when analyzing pipe losses[4]. Figure 1 above charts the data by characterization test.

Pipe Material

Another factor that appears to influence the pipe losses is the material used for the piping. Metal pipes have a higher heat loss coefficient than plastic pipes. The HWsim simulation software incorporates heat transfer coefficients for materials for use in heat loss calculations. The conductivity for metal piping (copper) is significantly higher than that of the plastic materials except for PEX materials with a metal sleeve. Within the plastic materials, PEX has a much lower conductivity than CPVC but the difference is much less than the relative conductivity to the metal piping, resulting in little measurable loss reduction between PEX and CPVC. Based on the characterization study, plastic piping materials result in a

---

[4] The cold water temperature is a primary effect however in the total hot water energy used at the water heater. This effect is generally independent of the piping system.

reduction of pipe losses from 27% to about 13% over metal piping with higher savings occurring when the other factors result in more losses (e.g., with colder water temperatures or a colder location for the pipe). The summary data in Figure 1 shows this trend for plastic pipe material compared with metal.

Pipe Insulation
An often suggested solution for reducing losses in the hot water system is to use insulation around the piping materials. The characterization study detailed in Figure 1, including variables such as pipe material and environmental temperature, evaluated the use of pipe insulation on the entire length of pipe from the tank to the outlet. The insulation thickness selected, one inch, was the higher of what is typically found in domestic hot water systems. The reduction in piping losses from adding insulation for metal piping is about 24% to 35% and about 20% to 25% for plastic pipe. The absolute loss reduction (Btu value) when using insulation on each of the respective pipe materials is about 40% less for plastic pipe than that of metal. Figure 3, a subset of Figure 1, graphically charts these results.

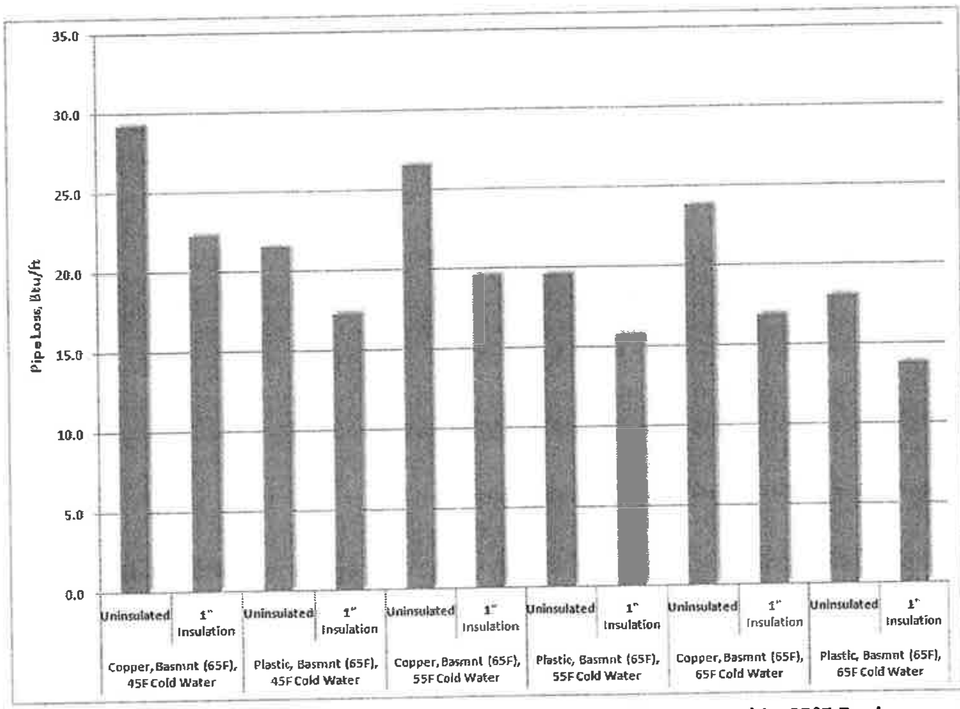

Figure 3 - Pipe Loss Reduction When Using Insulation with Pipe Located in 65°F Environment

Analysis 2 - Parametric Study of the Domestic Hot Water Distribution System

While the characterization of the hot water system summarized in Study 1 is valuable in understanding the various factors influencing pipe energy loss, this parametric study provides more detail on the interaction between performance variables such as the amount of hot water use, the interval between use events, and the length of pipe to the outlet. Based on previous studies [Hiller, 2005], these are the primary parameters of interest when evaluating the benefit of pipe insulation. Because these factors are difficult to define for a general analysis, a parametric study can help provide boundaries for the expected performance range within each factor. Table 3 outlines the parameters and the range of conditions used in the parametric study.

Table 3 - Parametric Study Parameters & Conditions

Parameter	Condition 1	Condition 2	Condition 3	Condition 4
Pipe Material	Metal (copper)	Plastic (CPVC)		
Environmental Temperature	60 °F			
Daily Hot Water Use	60 gpd			
Interval Between Draws	1 minute	10 minutes	30 minutes	60 minutes
Pipe Length to Outlets	30 feet	60 feet		
Insulation	0" thick	1/2" thick	1" thick	

The parametric study focused on evaluating the interaction of the parameters identified to contribute most to heat loss from the piping system. These parameters are based on the range of system designs (moderate and longer pipe lengths), a range of intervals between hot water use (1 to 60 minutes), a range of pipe insulation levels (none to 1" thick), and two different pipe types (metal and plastic). Other parameters such as the temperature surrounding the pipe (set as a conservative estimate of a cooler location) and the total water use (set at 60 gallons per day which is similar to average values used in various programs), are kept constant. The piping configuration was set such that there are three outlets representing a kitchen sink, a sink basin, and a shower, with all set to the same distance from the water heater tank (30' or 60'). The pipe sizes for the parametric study ranged from a nominal 3/4" for the supply lines to a nominal 1/2" to the outlets. A water use profile was developed for three common outlets in the home as shown in Table 4.

Table 4 - Parametric Study Use Points and Draw Levels

Daily Hot Water Use for Three Fixtures						
	Volume per Event		**Events**	**Daily Use**	**Flow Rate**	**Duration**
Fixture C[1]	0.5	gallon	24	12 gallons	1.50 gpm	20 sec
Fixture B[2]	1.0	gallon	12	12 gallons	1.00 gpm	60 sec
Fixture A[3]	18.0	gallons	2	36 gallons	2.25 gpm	480 sec
Outlet similar to [1]Kitchen sink, [2]lavatory sink, [3]shower						

The size of the pipe is a secondary factor as is the flow rate and duration of the use (which are dependent on the occupant use). The parametric study is focused primarily on the length of pipe and the time between hot water events. The other factors are set (e.g., the piping system design and layout) and a flow regime is specified for each outlet. The flow rate and total volume is set for the outlet providing a range of draws, albeit limited, to represent what might be expected in a typical household. *The artificial specification of the time between draws does not represent a typical household but does highlight the differences between the different draw profiles.*

Figures 4 and 5 graphically represent the interaction between pipe material (metal or plastic), pipe length to the outlets (30 or 60 feet), the interval between draws (1, 10, 30, or 60 minutes), and the amount of insulation on the pipe (none, ½", or 1"). Insulation is assumed to fully cover all hot water pipes in the system from the hot water tank to the outlets. The results are based on an annual simulation with the same daily draw profile and volume use for each day of the year.

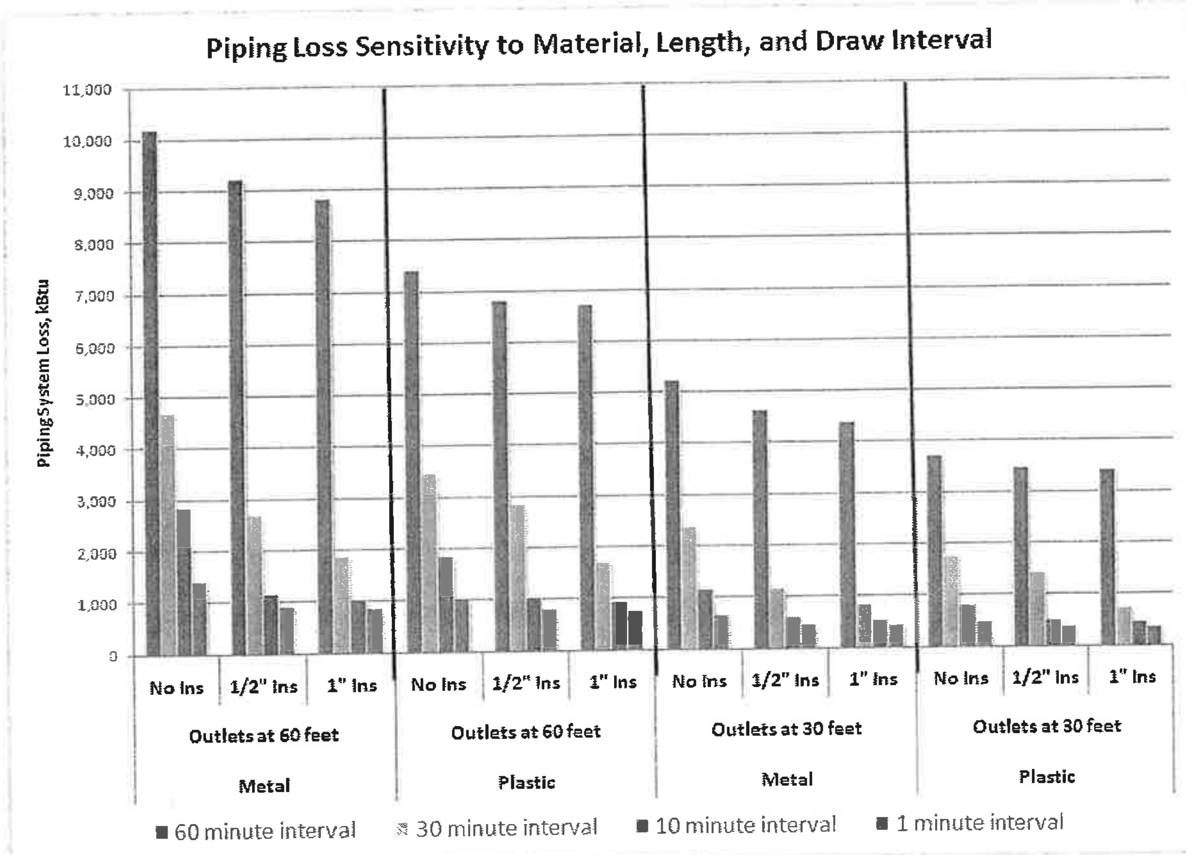

Figure 4 - Pipe Loss Comparison using Parametric Analysis

Each bar series in Figure 4 represents the time between draw events. The comparison for each bar series is shown for the other parameters. For example, looking at the 60 minute interval series, the effect of the insulation in reducing the piping loss for outlets at 60 feet and metal piping is about 1,000 kBtu for ½" thick insulation and about 1,400 kBtu for the 1" insulation relative to the configuration without insulation. In addition to the comparison between the pipe materials and outlet distance, each pipe material for the given distance to the outlets may be compared. . For example, for uninsulated pipe at 60 feet to the outlets, the plastic pipe material results in a pipe loss reduction of about 2,800 kBtu, a higher reduction than insulating the metal pipe. However, this result applies to the 60 minute interval between hot water use events only. Results from the parametric study include the following summary conclusions (also refer to Figure 5):

- When draw events are spaced over 30 minutes apart, the effectiveness of insulation diminishes significantly.
- When draw events are spaced between 10 and 30 minutes, 1" thick insulation on the pipes can reduce pipe losses by over 50%.
- Draw events spaced at 30 minutes apart show the largest benefit to insulation use.
- For draws less than 10 minutes apart, pipe insulation provides little additional benefit to reduce pipe losses.
- Plastic pipe materials reduce the pipe losses by about 25% compared with metal pipe materials.

- For metal pipes, the addition of 1/2" of insulation provides the majority of the benefit, whereas 1" insulation is more beneficial for plastic pipe.

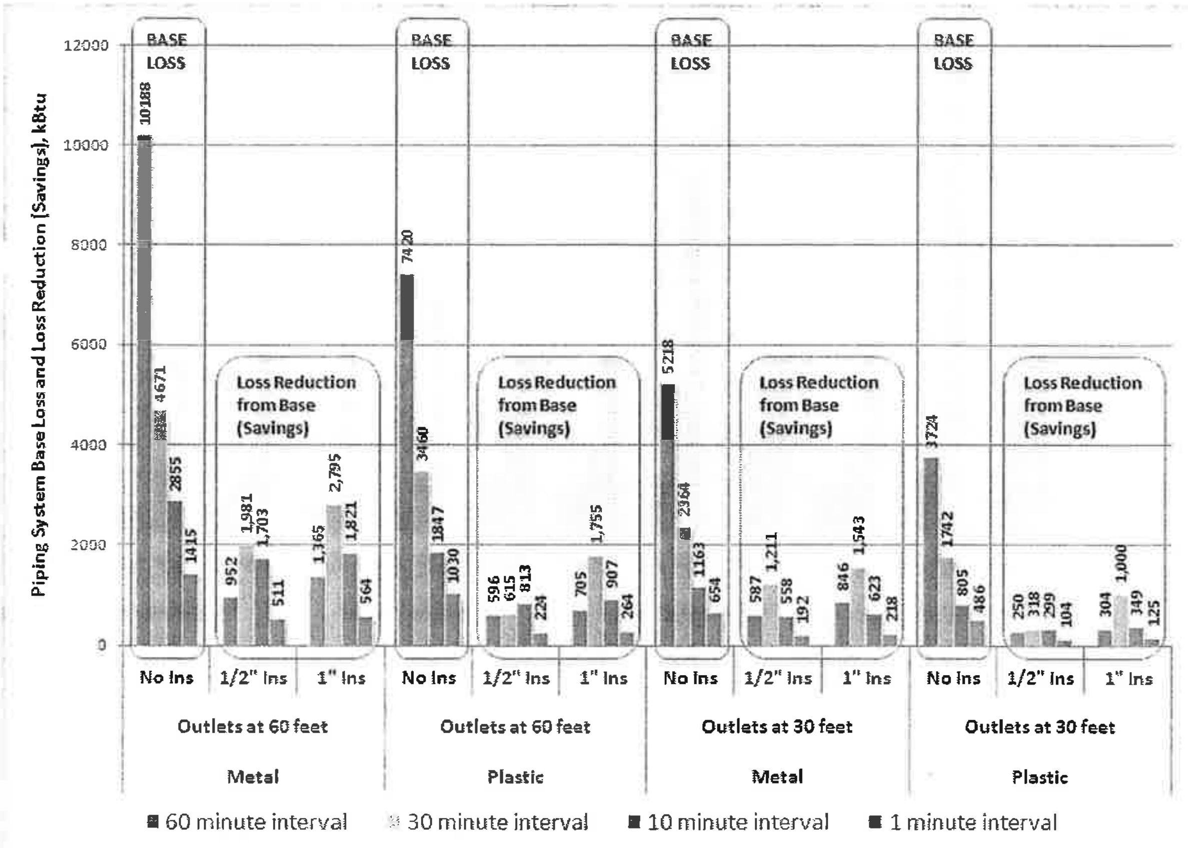

Figure 5 - Piping System Loss and Loss Reduction for Insulated Pipes

The results shown in Figures 4 and 5 are intended to demonstrate the extreme values for hot water piping system losses in any household. The extremes encompass both the length of pipe and the time between draws. In addition, an estimate of hot water use was incorporated that assumed all hot water use began once hot water arrived at the outlet. This is not the case for most dishwashers and clothes washers and may not be true for all sink uses. Typically, hot water use is much more varied throughout the day both for flow rate and the time between uses and the wait time for hot water to arrive at the fixture. Furthermore, the hot water system design generally incorporates various lengths of pipe to the outlets. Given these constraints, the energy use estimated outlines the various influencing factors in hot water energy use and compares the various factors with respect to the pipe material and the level of insulation. However, they do not represent actual losses (or savings) in a real household.

However, as Figures 4 and 5 describe the energy savings, the assignment of cost to the savings when using insulation on the entire length of hot water piping can provide additional perspective for the various systems and use profiles. Figures 6 and 7 detail the annual energy cost savings with pipe insulation for gas and electric water heaters and also compares the average annual energy cost savings over 1, 10, 30, and 60 minute intervals.

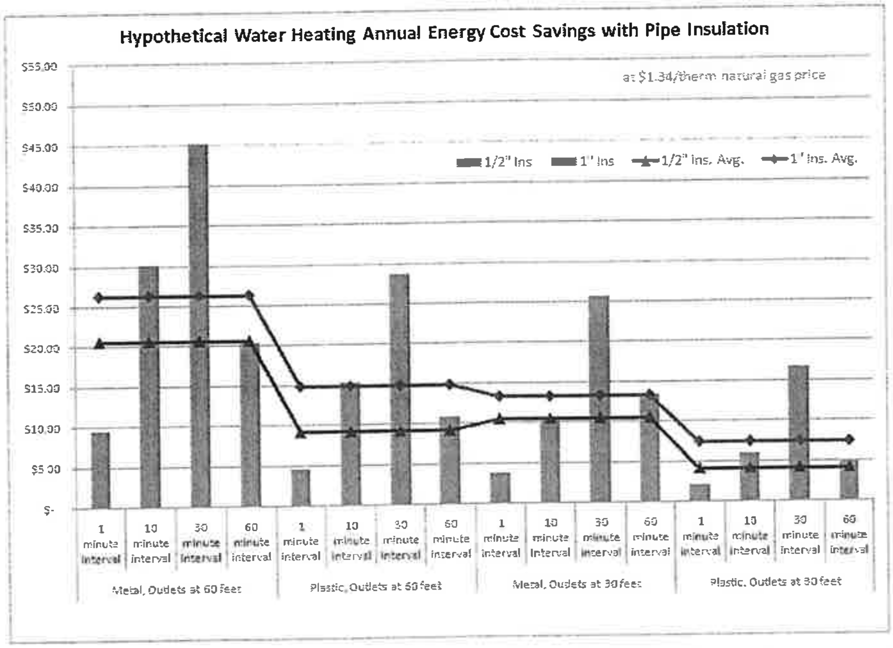

Figure 6 - Cost Value of Savings for Insulated Pipe Given the Stated Parameters - Gas Fuel

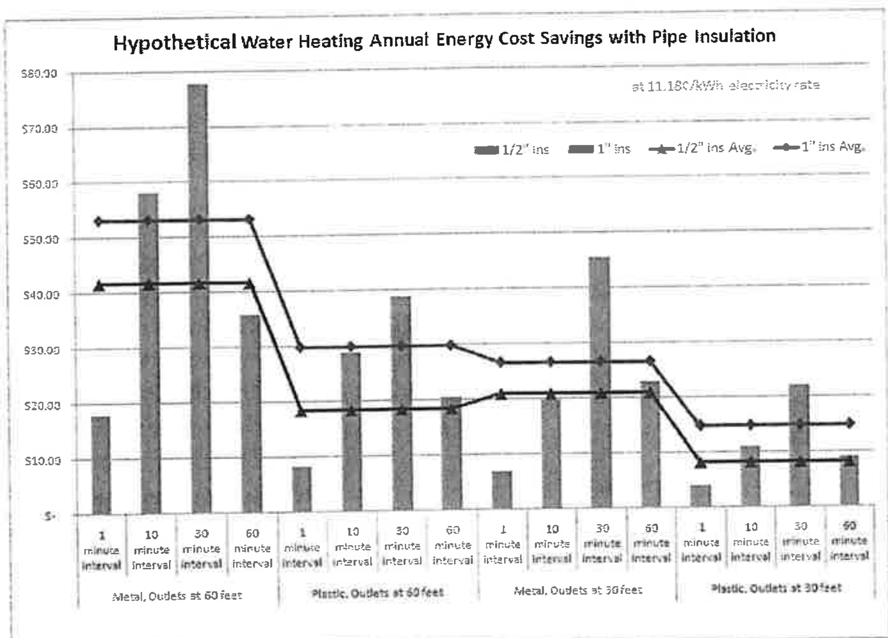

Figure 7 - Cost Value of Savings for Insulated Pipe Given the Stated Parameters - Electric Fuel

Fuel prices are taken from the Energy Information Administration data for the average annual U.S. price. Any changes in the fuel prices will be reflected directly in the savings. For example, if electric rates increase by a third to 15 cents/kWh, the savings would increase by a comparable amount. Figures 6 and 7 demonstrate the cost savings when using both 1/2" and 1" thick insulation on all hot water piping sections. The data can be summarized in the following details:

- The majority of the savings when using insulation is from the initial layer. Adding more insulation provides more limited benefit. The exception is plastic pipe when the interval between draws is 30 minutes where the benefit is equally divided between the first 1/2" of insulation and 1" thick insulation.
- Plastic pipe, due to its lower conductivity, results in average savings similar to reducing the length of metal pipe by a half.
- Reducing pipe length is of significant benefit, both in operating cost and in the cost of installation.
- The consistent 30 minute intervals between uses show the most benefit from insulation.

Although the performance issues afforded through a parametric analysis are of value in determining beneficial design details, an analysis of a "typical" home will provide an overall picture of the hot water system performance using insulated piping.

Analysis 3 - Whole House Hot Water System Simulation

A third analysis of hot water system performance using HWsim was performed using a plumbing system layout design from a typical 2-story home with a basement. The layout is considered a typical hot water piping system using both 3/4" and 1/2" pipe sizes. The outlets are representative of typical new homes with multiple baths, kitchen and lavatory sink basins, dishwasher and laundry. Figure 8 diagrams the layout modeled for the hot water system analysis.

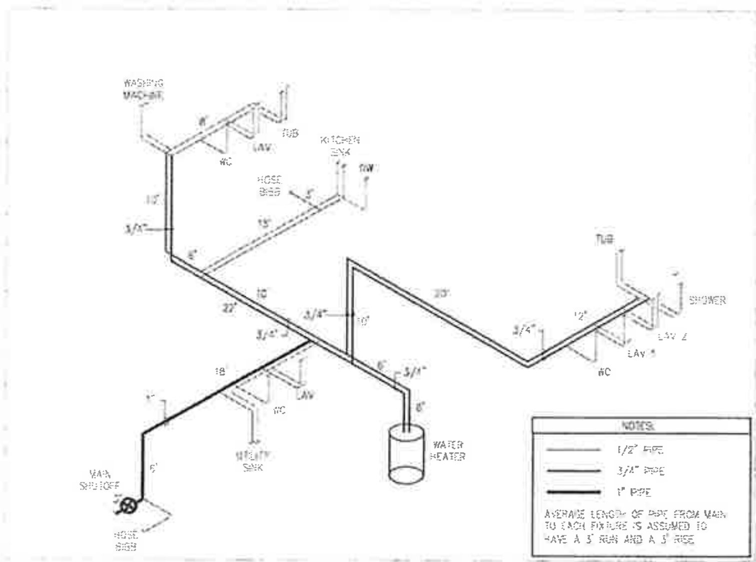

Figure 8 - Plumbing System Layout for Simulation

The simulation model incorporates various tee and branch pipe runs to the outlets. The pipe is assumed to be installed both in the basement area and in the first and second floor walls. The temperature surrounding the pipe is based on simulation runs of a house located in the Washington DC area with temperature variations modeled by month[5]. The cold water temperature is assumed to change throughout the year, by month, based on a methodology[6] developed through the Department of Energy's Building America Program (BAP).

[5] The temperature surrounding the piping would apply to a large number of homes across the US where the piping is installed indoors (either in a basement or in the walls or floors of the house). Differences in results would occur if the piping were installed under the slab or in unconditioned spaces, however the differences in the results would also vary from season to season based on the ambient air temperature.

[6] Refer to the Building America Research Benchmark Definition, Updated December 2009, NREL/TP-550-47246

With most hot water simulations, the major challenge in the simulation specification is the hot water draw profile. Numerous studies have been performed to develop hot water use profiles for equipment ratings, to estimate water use, and for energy analysis. An extensive research project was conducted at the National Renewable Energy Laboratory (NREL) that resulted in a use profiles for "typical" homes of various bedroom number [Hendron et. Al. 2008]. The profile selected for this study is the three bedroom profile. The profile is available on a six minute time interval for every day of the year except for a two-week period that represents a vacation period. The profile is based on a statistical analysis but provides a realistic estimate of the hot water use that might be expected in a home, including the variation in draw volumes and the time between draws. A significant feature of this profile is the assignment of outlets for various draw events[7], which were utilized in this analysis.

From the full year profile, a one-week period was extracted to represent the typical weekly profile of the household. The simulation software is limited to a 1-week profile that is repeated for all weeks of the year. The week selected was fairly representative of the overall daily use in a winter month (which uses more hot water than summer profiles). The data set selected sums to a hot water use of about 63 gallons per day (gpd) and a combined cold and hot water use at the fixtures of about 76 gpd. This average is close to the DOE water heater test standard[8] that uses 64.3 gpd. Figure 9 graphically displays the weekly hot water use profile set selected for simulation.

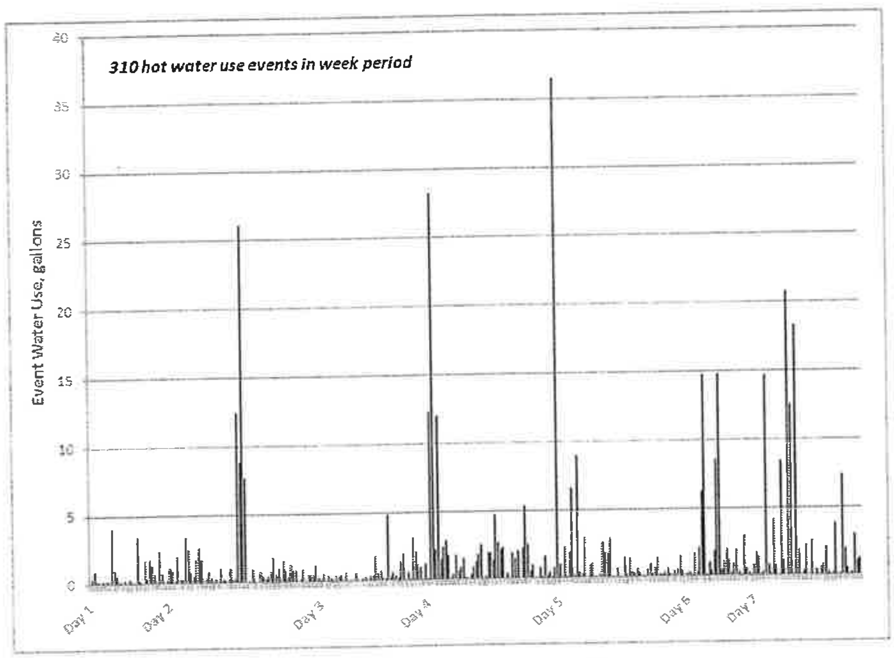

Figure 9 - Hot Water Use Profile

This weekly profile results in variations based on the outlet, the flow rate, the duration of flow, and the temperature set at the outlet, if applicable. For the whole house analysis, specific flow events are assigned to specific outlets which then are simulated with specific pipe lengths and sizes (see Figure 8).

---

[7] A common resource for residential hot water use profiles is the ASHRAE 90.2 standard, ANSI/ASHRAE Standard 90.2-2007. This standard does specify a daily profile on an hourly basis of the use factor (a percent of the total daily hot water use). The profile incorporates a diversity factor and therefore does not assign use by outlets.

[8] http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/d-2.pdf

The simulation repeats the daily profile for the week, for every month of the year. The software modifies the incoming cold water temperature and the environmental temperature around the pipes based on the time of year[9]. The software can accept a one-week profile only, however, the plumbing system layout detailed in Figure 8 with the weekly profile in Figure 9 resulted in approximately 300 flow events that were input to the software including start times, flow rates, and duration.

One other parameter defined for simulations is the outlet water temperature at specifically selected outlets that utilize a set temperature, such as a shower faucet. In this case, the software will flow hot water until the faucet is at the set temperature and then mix in cold water to keep the faucet temperature constant. This profile is applied to some sink faucets as well as the showers. Other faucets, the dishwasher, and the laundry are specified as appliances such that the hot water use is by volume only and the temperature is not a controlling factor.

The simulations were conducted for an annual period using the weekly use profile repeated for 52 weeks. The environmental conditions were varied monthly based on seasons. The simulation summary results are shown in Table 5.

Table 5 - Simulation Results for Typical Hot Water System and Use Profile

Performance Parameter	Metal Pipe, Uninsulated	Metal Pipe, Insulated, 1"	Plastic Pipe, Uninsulated	Plastic Pipe, Insulated, 1"
Annual Hot Water Use, gal	23,673	23,362	23,577	23,358
Daily Hot Water Use, gpd	64.9	64	64.6	64.0
Hot Water Waste, gal	430	221	290	174
Piping Loss, kBtu	2,416	1,226	1,860	1,108
Water Heater Energy, kBtu	21,377	21,041	21,227	21,010
Distribution Piping Efficiency	82%	91%	86%	92%
Water Heating Energy Cost, gas	$286.45	$281.95	$284.44	$281.53
Water Heating Energy Cost, electric	$525.38	$514.22	$520.31	$513.11
Annual Water Heater Energy Savings, gas (electric)		1.6% (2.1%)		1.0% (1.4%)
Total Annual Water Heater Energy Savings (Gas Fuel)	@ $1.34/therm	$4.50		$2.91
Total Annual Water Heater Energy Savings (Electric Fuel)	@ $0.1118/kWh	$11.16		$7.20

The summary data from the simulation indicates limited performance and cost benefits from the use of insulated piping based on statistical use profiles and a typical hot water piping system. Whereas the simulations are based on as complete system specifications as is available, the results are accurate in as much as an individual home mimics the simulation parameters.

[9] The values for the environmental temperature surrounding the pipe were based on house simulations in the climate.

Analysis 4 - Pipe Insulation Cost Estimates

The cost of pipe insulation products and estimated installation costs were developed as a reference point for evaluating the cost/benefit of using pipe insulation. Pipe insulation is typically sold in specific lengths and available in various thicknesses and can be foamed plastic (polyethylene), elastomeric, or fiberglass. Table 6 provides the summary of the cost estimates for installed insulation (1) developed based on retail material pricing and construction labor rates or (2) referenced directly from RS Means.

Table 6 - Installed Piping Insulation Cost Estimates

Insulation Specification		Material Cost (per foot)[1]	Installed Estimate[2,3]	Means[4] Estimate
Wall Thickness	Nominal Pipe Size			
1/2"	1/2"	$0.61 - $1.14	$510.68	$942.50
	3/4"	$0.46 - $1.29		
	1"	$0.82 - $1.55		
3/4"	1/2"	$0.91	$555.98	$1,034.60
	3/4"	$0.93 - $1.95		
	1"	$0.83 - $1.55		
1"	1/2"	$1.63	$703.34	$1,263.30
	3/4"	$1.89 - $3.22		
	1"	$2.23		

[1] *Retail material cost, no builder's O&P*
[2] *Hot water piping estimate at 80 feet of 3/4" and 98 feet of 1/2", using least cost material option*
[3] *An estimate of 1 day labor for a skilled mechanic with O&P is $392.40*
[4] *RS Means 2010 Residential Cost Data*

Using the least cost estimates for the piping insulation for 1" insulation thickness used in the simulations and the maximum estimated cost savings for an electric water heater, the payback period would be in the range of 60 to 100 years depending on the pipe material used. This estimate assumes all hot water piping is insulated completely from the hot water heater to the outlet.

Summary
Four different analyses were performed to characterize the performance of hot water piping systems and in particular to evaluate the energy and cost savings from insulating the hot water piping. The major factors that affect the energy loss from the piping systems were outlined and their affect on piping losses was demonstrated. Simulation software was used to compare the performance of different hot water system configurations, flow rates and hot water use profiles. Combining many factors together, the simulations demonstrate that the benefit of insulation is greatest when all of the hot water uses are spaced apart from 10 to 30 minutes. The benefit of insulation is diminished with shorter and longer time between uses. Individually, it was shown that pipes located in colder locations such as an unconditioned crawl space, benefit more from pipe insulation than pipes located in more conditioned spaces. Plastic pipe was shown to have less loss than metal pipe and commensurately insulation is more beneficial on metal pipe than on plastic pipe.

When a full hot water system is simulated in a single-family house using standard hot water use profiles with varying flow rates, time between draws, and pipe lengths from the hot water heater to the outlet, the benefit of pipe insulation is much less significant and the cost benefit to using pipe insulation is on the order of approximately $3 to $11 per year depending on the fuel rates, resulting in simple paybacks of 60 to 100 years based on a range of installed insulation costs.

Appendix A

Annotated Bibliography

Studies relevant to domestic hot water piping systems

Baskin, Evelyn, Robert Wendt, Roberto Lenarduzzi, and Keith A. Woodbury. 2004. "Numerical Evaluation of Alternative Residential Hot Water Distribution Systems." Report NA-04-5-3, *2004 ASHRAE Transactions: Symposia*: 671-681.

This research investigated energy and water waste in residential domestic hot water delivery systems. Four different distributions systems in three different locations of a typical house were simulated. Results showed that hot water use patterns, pipe material, pipe layout, and recirculation systems have a significant impact on the energy and water waste. Pipe insulation decreased piping heat loss slightly in attics, noticeably in crawl spaces, and significantly below slabs. Conclusions for cold start usage results included CPVC systems have less piping heat loss compared to copper systems particularly in clay under slabs, pipe insulation on pipes buried in attic insulation slightly increases heat loss, and the most efficient systems with this use pattern are demand recirculation using CPVC in the attic and parallel pipe using PEX in the attic. Conclusions for clustered hot water usage results included conventional systems have the greatest heat loss in slabs and the least in attics, pipe insulation in crawl space and slab noticeably reduces pipe heat loss, and the most efficient systems for this use pattern are demand recirculation using CPVC in the attic and conventional with a centrally located water heater using CPVC in the attic. Both use patterns showed that continuous recirculation systems significantly increase piping heat loss and total heated water energy waster.

Review comments: Development of a simulation model to estimate energy losses from piping systems. Simulation modeling temperatures of the attic, crawl space, and soil (slab) appear quite moderate; different climate zones could produce significantly different results when the pipe is located outside of the conditioned space. The use profile modeled is a limiting factor in a broad application of the results except for the location of the pipe.

Wendt, Robert, Evelyn Baskin, and David Durfee. March 2004. *Evaluation of Residential Hot Water Distribution Systems by Numeric Simulation*. Report for Davis Energy Group by Building Technology Center Oak Ridge National Laboratory.

The goal of this project was to evaluate the energy and water performance, economics, and barriers to use of various domestic hot water distribution systems in new and existing California residences. Heat loss was modeled for insulated and non-insulated hot water pipes; two draw cycles were investigated: cold start and clustered use; five new construction and two existing residences were studied; numerous changes were evaluated: alternative piping materials, centrally located water heater, additional pipe insulation, and demand and continuous recirculation systems. Model results showed consistent energy and water performance for the various scenarios however the results varied significantly (25-600%) with cold start or clustered water use patterns. The study concluded: continuous recirculation systems can reduce water waste but should not be installed due to high cost and energy waste; demand recirculation pump systems reduce water waste and energy waste but add a significant first cost; water heaters should be centrally located for new homes; parallel pipe distribution systems may be an attractive alternative but energy and water savings are sensitive to hot water use patterns. The report included numerous specific recommendations for policymakers, designers, builders, and plumbers, and new and existing homebuyers.

Review comments: A useful analysis in the comparison between types of draw patterns. Analyzes the application of circulation systems on energy use. Simulation modeling limited to one state and uses a limited piping system. The use profile modeled is a limiting factor in a broad application of the results.

Hiller, Carl. November 2005. *Hot Water Distribution System Research - Phase I.* Report CEC-500-2005-161 to the California Energy Commission Public Interest Energy Research Program.

This extensive report quantified the time, water, and energy waste characteristics of the most common hot water distribution piping systems. One notable result was that hot water pipe insulation can increase piping cool-down time by a factor of two to four.

Review comments: Detailed laboratory effort to analyze and quantify heat loss from domestic hot water piping systems. Results however are not translated into estimated energy savings for homes operating under a use profile.

Hiller, Carl C. 2005. "Comparing Water Heater vs. Hot Water Distribution System Energy Losses." Report DE-05-1 *ASHRAE Transactions*, Volume III, Part 2: 407-417.

This paper compared hot water distribution system piping heat loss to standby losses of common water heater types based on laboratory tests on a variety of piping configurations in order to evaluate when it makes sense to have more than one water heater. Various energy losses due to distribution systems were categorized, including the three components of piping energy loss: cool-down of water left standing in the pipes after a draw, energy lost to ambient during hot water flow, and heated water that is wasted down the drain. This paper addressed heat energy losses during the delivery phase and during piping cool down. Measured UA factors are given for ½" and ¾" copper pipe with 0, ½", and ¾" thick closed cell polyethylene foam insulation. Test results included the observations that even a small amount of pipe insulation provides a large reduction in heat loss, that UA value increases at a low rate as a function of water flow rate and appears to become constant at higher flow rates, and that energy lost to water cooling down in the pipes between draw events is greater than energy lost during hot water flow or wasted down the drain. Calculated results included the observation that for non-recirculation loop systems, pipe insulation is of little benefit for draws spaced far apart and also when clustered within a short period of time, but pipe insulation can significantly reduce energy and water waste when many draws are spaced moderately close together. Tables were provided for lengths of various pipes that would equal various water heater standby losses in order to decide when installing two water heaters may make sense. This paper concluded that using multiple water heaters may be desirable compared to both large recirculation loop systems and non-recirculation applications.

Review comments: The report demonstrates the heat loss mechanisms from domestic piping systems and the effect on energy loss in the hot water system. The study is not designed to estimate the heat loss from piping systems in residential buildings using standard hot water use profiles and standard plumbing system designs.

Hiller, Carl C. 2006. "Hot Water Distribution System Piping Heat Loss Factors - Phase I Test Results." *ASHRAE Transactions* Vol. 112(2):436-446.

This paper reports on the laboratory testing of piping heat loss for PEX-aluminum-PEX (PAX) hot water piping under a variety of different temperature and flow conditions, including no flow, with various insulation levels and compares the results to previous test results on rigid copper pipe. The tests resulted in calculated piping heat loss factors for several commonly used pipe sizes, and examples are provided to show how to use this information to calculate energy losses.

Stewart, William E. Jr., Charles K. Saunders, and Carol L.G. Dona. 1999. "Evaluation of Service Hot Water Distribution System Losses in Residential and Commercial Installations: Part 1 – Field / Laboratory Experiments and Simulation Model." Report 4249 (RP-696) *ASHRAE Transactions* V. 105, Pt.1:1-10.

Laboratory and field experiments were performed to determine heat loss in various piping systems and a numerical model was developed to simulate heat loss. The simulation is considered more accurate and useful and the experiments were used as a comparison to the simulation results. The simulation method included pipe insulation as an input variable. Simulation results were given in a companion paper.

Wiehagen, J., and J.L. Sikora. 2003. *Performance Comparison of Residential Hot Water Systems*. NAHB Research Center Report NREL/SR-550-32922

The goals of this research project were to conduct laboratory testing to validate hot water energy savings estimated by prior simulations, measure energy performance of tank versus demand water heater and tree-type copper piping versus PEX parallel piping, and use updated software to evaluate different hot water system designs. The simulation model was calibrated with heat-transfer coefficients determined by experimental results. Simulations showed energy savings of 14%-34% for an electric demand heater with parallel piping compared to an electric storage tank heater and standard copper piping; a parallel piping system represented a and 6%-13% energy savings when modeled with either a tank or demand heater. A point of use system consisting of multiple demand heaters modeled 28%-50% energy savings compared to a storage tank heater with tree-type distribution piping. Additionally, reductions in water use associated with improving the energy efficiency of a hot water system may be significant. This study concludes that demand water heaters with a parallel piping distribution system are the most efficient of the systems evaluated, and recommends further evaluation of actual installation

costs and field performance data for the systems that are identified in this report as energy efficient and cost effective.

Cheng, Cheng-Li, Meng-Chieh Lee, and Yen-Hsun Lin. 2006. "Empirical Prediction Method of Transmission Heat Loss in Hot Water Plumbing." Energy and Buildings 38: 1220-1229.

The purpose of this paper was to present a simplified theoretical calculation of transmission heat loss in hot water piping. The study investigated different pipe materials, with and without insulation, typically found in Taiwan. Results were verified by comparing empirical data and theoretical calculations. This paper concluded that transmission heat loss in hot water piping is an important factor when estimating hot water energy consumption and that this simplified calculation method is an accurate approach.

Lutz, James. 2005. *Estimating Energy and Water Losses in Residential Hot Water Distribution Systems.* Lawrence Berkeley National Laboratory paper LBNL-57199.

This research investigated energy and water losses in residential domestic hot water distribution systems. Three types of loss were identified: the waste of water while waiting for hot water at the point of use, waste heat as water cools down after a draw, and the energy used to reheat water that was already heated once before. Shower losses, sink losses, and dishwasher losses were estimated based on the Residential End Uses of Water Study report (Mayer 1999) and various usage assumptions. Results estimated an average of 6.35 gallons per day is wasted while waiting for hot water and 10.9 gallons per day of wasted hot water that was heated but either not used or used after it has cooled off. This paper concluded that approximately 20% of total hot water use in single-family residences appears to be wasted.

Klein, Gary. 2005. "National Impact of Hot Water Distribution System Losses in Residences." Report DE-05-1-3 *ASHRAE Transactions,* Volume III, Part 2: 423-429.

The purpose of this paper was to assess whether or not the waste of energy and water associated with the poor design and installation of residential hot water distribution systems is large enough to warrant further study and remedial actions. The research estimated the average water wasted and associated costs for showers, long faucet draws, and short faucet draws (energy loss but no water loss). The study recognized losses associated with water heater set point temperatures raised to overcome piping losses, multi-family recirculation system losses, and that there is a large variation in waste based on usage patterns and distribution design (longer or shorter runs and proximity to water heater). This paper concluded that average daily household hot water waste is at least 10 gallons per day, resulting in very large national water and energy losses that appear to be growing and therefore recommended further study of how to cost-effectively reduce this waste for new construction.

Mishustin, V.I. and Yu. A. Chistyakov. 2003. "Thermophysical Measurements: Procedure for Determining Heat Losses Through the Insulation of Hot-Water Pipes." *Measurement Techniques* vol. 46, no. 9: 880-885. (Translated from Izmeritel'naay Teknika, No. 9, pp. 47-51, September, 2003. Original article submitted April 26, 2003)

This paper described a procedure to determine steady-state heat losses through the insulation of inaccessible pipes of heating systems.

Energy Saving Potential Through Optimal Pipe Insulation. Armacell Engineered Foams

Technical article and study by the manufacturer investigated the energy savings of insulating heating and hot water pipes. The study was based on calculated piping heat losses, for heating and domestic hot water piping, of a single family house located in six different European countries. The study concluded that pipe insulation significantly reduces energy use, non-recoverable heat losses occur even on pipes in conditioned space, and the vast majority of non-recoverable heat losses are due to heat losses from domestic hot water pipes in summer.

Masiello, John A. and Danny S. Parker. "Factors Influencing Water Heating Energy Use and Peak Demand in a Large Scale Residential Monitoring Study." *Residential Buildings: Technologies, Design, Performance Analysis, and Building Industry Trends:* 1.157-1.170.

This paper evaluated various factors affecting water heating energy efficiency based on a utility research project that monitored 171 residences in Central Florida. Reported factors included hot water electric demand, day of week and seasonality variations, water heater types, element size, and tank wrap insulation, but did not include hot water pipe insulation.

Studies relevant to hot water use profiles in homes

Hendron, Robert, and Jay Burch. Draft 1/17/2007. *Development of Standardized Domestic Hot Water Event Schedules for Residential Buildings*. Report ES2007-36104, National Renewable Energy Laboratory Proceedings of Energy Sustainability 2007.

The purpose of this study was to use published data of hot water events to develop standard event schedules for the Building America Benchmark performance analysis. Drivers of domestic hot water events were identified as occupant behavior (most important), number of occupants (approximately linear), mains temperature, and magnitude of hot water distribution losses (very important); seasonality was not addressed by this study. Limitations were identified: the use of 6-minute time-steps for events (NREL planned to release another set of event schedules using 1-minute time-steps); increased energy loss using recirculation and other than standard trunk-and-branch systems; ENERGY STAR or other non-standard appliances may consume very different amounts of hot water; differences among households may not be consistent with typical family usage; conditional probability of events were not considered. NREL developed a series of residential hot water event schedules for sinks, showers, baths, clothes washer, and dishwasher.

Jordan, Ulrike and Klaus Vajen. 2005. *DHWcalc: Program to Generate Domestic Hot Water Profiles with Statistical Means for User Defined Conditions.* Proc. ISES Solar World Congress, Orlando 2005.

This report describes a program designed to generate domestic hot water profiles that are used primarily for annual system simulations. The program can be downloaded free of charge at: www.solar.uni-kassel.de.

DeOreo, William B. and Peter W. Mayer. *The End Uses of Hot Water in Single Family Homes from Flow Trace Analysis*. Aquacraft, Inc. Water Engineering and Management, Boulder, CO.

This paper explained how simultaneous flow trace data, from the main water meter and a meter installed at the feed line to the hot water tank, were used with specialized software to characterize hot water demand according to end use and presented results from ten homes tested in Seattle over 14 days. Results showed hot water end use statistics for baths, dishwashers, showers, faucets, and clothes washers, as well as household and per capita hot water use. This paper concluded that this method is an accurate and efficient method to collect data without the need for thermocouples or other devices, in order to provide detailed information on demand patterns useful to accurately design advanced hot water systems.

"Home and Outdoor Living Water Requirements, Plumbing Fixture and Appliance Water Flow Rates." *USDA Water Systems Handbook*. February 14, 2007 http://www.inspect-ny.com/septic/wateruse.htm

Table of usage requirements and typical fixture flow rates for U.S. homes and outdoor living.

Other related research

Aquilar, C., D.J. White, and David L. Ryan. April 2005. *Domestic Water Heating and Water Heater Energy Consumption in Canada*. Canadian Building Energy End-Use Data and Analysis Centre report CBEEDAC 2005-RP0, available at: http://www.ualberta.ca/~cbeedac/publications/documents/domwater_000.pdf

The purpose of this study was to review literature and technology for domestic water heating energy consumption that was estimated to be approximately 22% of total household energy consumption in Canada. Areas investigated included water heater types and efficiencies, factors influencing hot water usage and energy consumption, and energy modeling.

Mayer, Peter W., William B. DeOreo, Erin Towler, and David M. Lewis. July 2003. *Residential Indoor Water Conservation Study: Evaluation of High Efficiency Indoor Plumbing Fixture Retrofits in Single-Family Homes in the East Bay Municipal Utility District Service Area.* Aquacraft, Inc. Water Engineering and Management, Boulder, CO.

This study measured the impact of a variety of indoor water conservation measures for the EBMUD publicly owned utility in California. The methodology used was to collect two weeks of baseline water use data from 33 homes, retrofitting these homes with high efficiency toilets, clothes washers, showerheads, and faucets; next two weeks of flow trace data were collected on two different occasions. Results included a 35% reduction in total water usage; 88% of this savings was the result of three end uses: toilets, clothes washers, and leaks. Ten of the 33 homes had water meters installed on the water heaters and showed in the post-retrofit period that 30% of all water used indoors was hot water and that on a daily basis 83% of that hot water was used for faucets, showers, and baths. This study concluded that significant indoor water savings can be achieved by the installation of high efficiency fixtures and appliances and that these products pay for themselves within the expected life spans.

"Sizing of Water Piping System" *2003 International Plumbing Code* 2003: 118-119.

Wiehagen, J. March 2007. *Domestic Hot Water System Research System Design for Efficiency and Performance.* NAHB Research Center report prepared for National Renewable Energy Laboratory.

This study was a preliminary investigation of a high performance (high energy and water efficiency while delivering a satisfactory amount of hot water) hybrid water heating system design. Previous research of hot water equipment and distribution systems including various piping layout and materials, piping energy loss, and effects of piping insulation were reviewed. A systems approach was identified to examine all aspects of a high performance design that considers preheating, efficiency, delivering hot water quickly, providing sufficient capacity, and minimizing the amount of wasted water and energy. The hybrid solution is a centrally located storage water heater combined with multiple, small capacity distributed water heaters. Simulated results lead to the conclusion that such a hybrid system has the potential to deliver more hot water, more quickly, and more efficiently that a tank-only system. Additional simulations and field studies to continue the evaluation of hybrid hot water systems were recommended.

Davis Energy Group. March 21, 2006. *Field Survey Report: Documentation of Hot Water Distribution Systems in Sixty New California Production Homes.* Report for Lawrence Berkeley National Laboratory.

This field survey was completed to better understand how hot water distribution systems (HWDS) are being installed in California production homes. The methodology investigated 60 single family houses statewide and four HWDS types (conventional trunk and branch using copper or PEX, PEX parallel-manifold, hybrid, and recirculation systems). Results quantified site characteristics, pipe characteristics, plumbing layout, type of water heater, fixture characteristics, industry trends, installation practices, and gathered anecdotal feedback. Specific conclusions and recommendations were made for the four HWDS types, notably with respect to excessive pipe length.