



Final 2016 UDRH Inputs: Addendum to 2015-16 Massachusetts Single- Family Code Compliance/Baseline Study

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SUBMITTED TO:
The Electric and Gas Program Administrators of
Massachusetts

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Final UDRH Inputs

The evaluation team conducted four conference calls to review the preliminary, estimated User Defined Reference Home (UDRH) inputs provided in the Massachusetts 2015-2016 Single-Family Code Compliance/Baseline Study: Volume 3 report.¹ The group participating in this review included Program administrators (PAs), Energy Efficiency Advisory Council (EEAC) Consultants, representatives from the program implementation contractor (ICF International), and a representative of the Home Energy Rating System (HERS) raters rating program homes. Together, this group reviewed and developed a final set of UDRH inputs that incorporates baseline study findings along with additional information based on experience administering the low-rise Residential New Construction (RNC) program as well as information on specific measures that were found in either none or very few of the audited baseline homes. This addendum documents the UDRH inputs or specifications that will be used when calculating savings for all 2016 and 2017 program homes and will be used by HERS raters starting July 1, 2017 for all active projects not completed as of July 1, 2017, as well as all new recruited projects. Below is a summary table of the new UDRH inputs. Following the table is documentation on how each new input was calculated.

Table 1: UDRH Inputs

UDRH Specification	Current Specification	New Specification
Above Grade Wall (Conditioned/Ambient)	Uo=.072	Uo=.062
Frame Floor over Unconditioned Basement	Uo=.048	Uo=.047
Ceiling – Flat	Uo=.041	Uo=.030
Ceiling -- Vaulted	Uo=.043	Uo=.038
Windows U-Factor	U=.34	U=.30
Windows SHGC	SHGC=.346	SHGC=.30
Duct Leakage to the Outside	11.9 CFM per 100 sq. ft. @25Pa	3.8 CFM per 100 sq. ft. @25Pa
Air Infiltration	4.48 ACH50	3.57 ACH50
Foundation Walls - Conditioned Basement	8" solid concrete or stone walls with R-10.4	Without Air Film & Concrete Effective

¹ 2015-16 Massachusetts Single-Family Code Compliance/Baseline Study: Volume 3, Final Report, Submitted to The Electric and Gas Program Administrators of Massachusetts by NMR Group, Inc. and Dorothy Conant. February 13, 2017.

UDRH Specification	Current Specification	New Specification
	continuous insulation, grade 1, no studs	R-10.40 (U-0.096)
Foundation Walls - Unconditioned Basement	10" thick concrete or stone walls with R-3.1 cavity insulation, grade 3, 2x4 studs at 16" O.C.	Without Air Film & Concrete Effective R-0
Unheated Slab Below Grade	R-10 under slab (2ft), no perimeter insulation	No Insulation R-0
Unheated Slab on or Above Grade	R-10 under slab (2ft), no perimeter insulation	R-5 Perimeter, No Under-Slab Insulation
Heated Slab Above or Below Grade	R-15 under slab (2ft), no perimeter insulation	R-10 Perimeter R-15 Under Slab (24 ft.)
Duct Insulation - Unconditioned Attic (supply only)	R-6.5	R-5.6
Duct Insulation – All other Unconditioned Spaces	R-5.5	R-4.4
Cooling – Air Conditioner	13.7 SEER	13.9 SEER
Cooling – Air Source Heat Pump	13.7 SEER	13.9 SEER
Cooling - Ground Source Heat Pump	13.7 EER	13.9 SEER Converted to Equivalent EER 11.7
Heating Efficiencies	Various	AFUE 93.8 or Equivalent HSPF 10.05
Water Heater Energy Factors	Various	EF 0.69 fossil fuel water heaters EF 2.18 electric conventional and heat pump water heaters

1.1 ABOVE GRADE WALLS

UDRH Specification	Current Specification	New Specification
Above Grade Wall (Conditioned/Ambient)	Uo=.072	Uo=.062

This is the average Uo from the 2016 baseline study based on observations of conditioned/ambient walls at 96 homes—46 stretch code and 50 2012 IECC homes.

1.2 FRAME FLOOR OVER UNCONDITIONED BASEMENT

UDRH Specification	Current Specification	New Specification
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UDRH Specification	Current Specification	New Specification
Frame Floor over Unconditioned Basement	Uo=.048	Uo=.047

This is the average Uo from the baseline study based on observations of floors over unconditioned basements at 79 homes—35 stretch code and 44 2012 IECC homes.

1.3 CEILINGS

1.3.1 Flat Ceilings

UDRH Specification	Current Specification	New Specification
Ceiling – Flat	Uo=.041	Uo=.030

This is the average Uo from the baseline study based on observations of flat attic ceilings at 89 homes—41 stretch code and 48 2012 IECC homes.

1.3.2 Vaulted Ceilings

UDRH Specification	Current Specification	New Specification
Ceiling -- Vaulted	Uo=.043	Uo=.038

This is the average Uo from the baseline study based on observations of vaulted ceilings at 60 homes—29 stretch code and 31 2012 IECC homes.

1.4 WINDOWS--U-FACTOR AND SHGC

UDRH Specification	Current Specification	New Specification
Windows U-Factor	U=.34	U=.30
Windows SHGC	SHGC=.346	SHGC=.30

These are the average U-Factor and SHGC values from the baseline study based on documented U-Factor and SHGC information based on visible NFRC (National Fenestration Rating Council) stickers or building department documentation for 33 homes—20 stretch code and 13 2012 IECC homes.

1.5 DUCT LEAKAGE TO THE OUTSIDE

UDRH Specification	Current Specification	New Specification
Duct Leakage to the Outside	11.9 CFM per 100 sq. ft. @25Pa	3.8 CFM per 100 sq. ft. @25Pa

This is the average duct leakage from the baseline study based on duct leakage testing at 141 homes with ducts—43 stretch code homes and 98 2012 IECC homes—and one stretch code home with only ductless mini-splits, which was treated as having zero duct leakage to the outside. Duct systems in conditioned space were also treated as having zero duct leakage to the outside: Under both stretch code and 2012 IECC, duct tightness testing is not required if the air handler and all ducts are located within conditioned space.

1.6 AIR INFILTRATION

UDRH Specification	Current Specification	New Specification
Air Infiltration	4.48 ACH50	3.57 ACH50

This is the average air infiltration (ACH50) from the baseline study based on blower door testing at 144 homes—46 stretch code and 98 2012 IECC homes.

1.7 FOUNDATION WALLS

1.7.1 Foundation Walls—Conditioned Basement

UDRH Specification	Current Specification	New Specification
Foundation Walls - Conditioned Basement	8" solid concrete or stone walls with R-10.4 continuous insulation, grade 1, no studs	Without Air Film & Concrete Effective R-10.40 (U-0.096)

These are the average R-value and U-value from the baseline study. The U-value was calculated without accounting for air film or concrete, which are addressed in REM/Rate. The averages are based on observations at 32 homes—18 stretch code and 14 2012 IECC homes.

1.7.2 Foundation Walls —Unconditioned Basement

UDRH Specification	Current Specification	New Specification
Foundation Walls - Unconditioned Basement	10" thick concrete or stone walls with R-3.1 cavity insulation, grade 3, 2x4 studs at 16" O.C.	Without Air Film & Concrete Effective R-0

Building code does not require insulation on foundation walls in unconditioned basements and the standard practice of builders in the RNC program is to not insulate these walls. Not insulating these foundation walls was also standard practice in baseline homes. Only four of 58 baseline homes with unconditioned basements had insulated foundation walls. Therefore, the new UDRH specification reflects the standard practice of no insulation on foundation walls in unconditioned basements.

1.8 SLABS

1.8.1 Unheated Slab Below Grade

UDRH Specification	Current Specification	New Specification
Unheated Slab Below Grade	R-10 under slab (2ft), no perimeter insulation	No Insulation R-0

It is difficult to verify slab insulation in completed homes and all baseline homes were completed before being inspected. Overall, slab insulation could be verified through confirmed HERS reports, code compliance certificates, or homeowner knowledge for only five baseline homes--three stretch code and two 2012 IECC baseline homes. Standard practice in program homes is to not insulate unheated below grade slabs. The new UDRH specification of no insulation reflects standard practice.

1.8.2 Unheated Slab on or Above Grade

UDRH Specification	Current Specification	New Specification
Unheated Slab on or Above Grade	R-10 under slab (2ft), no perimeter insulation	R-5 Perimeter, No Under-Slab Insulation

Again, unfortunately, slab insulation details were unavailable for most baseline homes and are impractical to ascertain once a slab is poured. Unheated above grade slabs in program homes are typically either uninsulated or have R-10 perimeter only insulation. The group reviewing new UDRH input specifications agreed on R-5 perimeter insulation and no under-slab insulation.

1.8.3 Heated Slab Above or Below Grade

UDRH Specification	Current Specification	New Specification
Heated Slab Above or Below Grade	R-15 under slab (2ft), no perimeter insulation	R-10 Perimeter R-15 Under Slab (24 ft.)

Only one baseline home had a heated slab and very few program homes have heated slabs. Based on available information from the baseline and program homes the new UDRH specification is R-10 perimeter and R-15 under slab insulation.

1.9 DUCT INSULATION

1.9.1 Duct Insulation - Unconditioned Attic (supply only)

UDRH Specification	Current Specification	New Specification
Duct Insulation - Unconditioned Attic (supply only)	R-6.5	R-5.6

This is the average R-value of insulation on supply ducts in unconditioned attics from the baseline study with one revision. The group discussed the results of studies² that found the actual R-value of installed bubble wrap is R-1, not the manufacturer's stated R-value, unless the insulation is installed with an air barrier. Based on these discussions, the group agreed on treating bubble wrap as R-2 when calculating the average R-value to account for at least some insulation being properly installed with an air barrier. The result is an average R-value of R-5.6 based 60 baseline homes--31 stretch code and 29 2012 IECC homes.

1.9.2 Duct Insulation – All other Unconditioned Spaces

UDRH Specification	Current Specification	New Specification
Duct Insulation – All other Unconditioned Spaces	R-5.5	R-4.4

This is the average R-value of insulation on all ducts in other (non-attic) unconditional spaces. As with attic supply duct insulation, the R-value of bubble wrap was assumed to be

² Some facts about bubble wrap duct insulation, its R value and usage. Source: <http://www.energy-experts.net/home/articles/the-truth-about-foil-faced-bubble-wrap/>

The Foil-Faced Bubble Wrap Sham - Understanding Radiant Barriers: Source: <http://www.energyvanguard.com/blog/29497/The-Foil-Faced-Bubble-Wrap-Sham-Understanding-Radiant-Barriers>

R-2 when calculating the average R-value. The result is an average R-value of R-4.4 based on 80 baseline homes—35 stretch code and 45 2012 IECC homes.

1.10 COOLING

UDRH Specification	Current Specification	New Specification
Cooling – Air Conditioner	13.7 SEER	13.9 SEER
Cooling – Air Source Heat Pump	13.7 SEER	13.9 SEER
Cooling - Ground Source Heat Pump	13.7 EER	13.9 SEER Converted to EER 11.7
ALL TYPES, SIZES, AUXILARY POWER AND LOCATIONS ARE THE SAME AS THE RATED HOME		

The specification for all cooling systems is the average SEER of all air conditioning and air source heat pump (ASHP) cooling systems observed at baseline homes. The average 13.9 SEER is based on 139 cooling systems observed in baseline homes—61 air conditioners and 8 ASHPs in stretch code homes and 64 air conditioners and 6 ASHPs in 2012 IECC homes.

1.11 HEATING EFFICIENCIES

UDRH Specification	Current Specification	New Specification
Heating Efficiencies	Various	AFUE 93.8 or Equivalent HSPF 10.05
AUXILARY POWER AND LOCATIONS ARE THE SAME AS THE RATED HOME		

Previous UDRH specifications included different UDRH specifications for different types of heating systems and fuels. After discussion, the PAs, EEAC consultant, and representatives of the implementation contractor and HERS raters agreed to take a different approach this year, using one efficiency for all heating systems. The new UDRH specification for all heating systems is AFUE 93.8 or its equivalent, HSPF 10.05, for heat pumps. These specifications will apply to all fossil fuel furnaces, boilers, combi-appliances, electric heat pumps and electric resistive heat.

The average AFUE of 93.8 for all heating systems was calculated based on 136 heating systems observed in baseline homes—68 heating systems in stretch code homes and 68 in 2012 IECC homes. The 136 heating systems do not include one ground source heat pump or two heating systems (one boiler and one furnace) that were incentivized through the

GasNetworks program. To get all heating systems, regardless of fuel, on the same playing field ENERGY STAR’s Portfolio Manager Source-Site conversion factor of 3.14 for electricity was applied to all electric heating system efficiencies.³ (Site-to-Source conversion factors, are the multipliers to convert site energy into source energy) The 93.8 AFUE equivalent HSPF for electric heating systems was calculated as follows: The 93.8 AFUE equivalent HSPF for electric heating systems was calculated as follows: 0.938 (AFUE) x 3.14 (Portfolio Manager Source Site conversion factor for electricity) x 3.412 (BTU/Watt-Hour) = 10.05 HSPF.

1.12 WATER HEATER ENERGY FACTORS

UDRH Specification	Current Specification	New Specification
Water Heater Energy Factors	Various	EF 0.69 fossil fuel water heaters EF 2.18 electric conventional and heat pump water heaters
Water Heater Recovery Efficiency		Recovery Efficiency 0.77

Previous UDRH specifications included different UDRH specifications for different types of water heaters and fuels. Just as with heating systems, after discussion the PAs, EEAC consultant, and representatives of the implementation contractor and HERS raters agreed to take a different approach this year, using one base efficiency for all water heating systems. The new UDRH specification for all fossil fuel conventional stand-alone, integrated (with a boiler heating system), and on-demand/instantaneous (including combi-appliances) water heaters is an Energy Factor of 0.69. The new UDRH specification for all electric water heating systems, both conventional and heat pump water heaters, is an Energy Factor of 2.18.

The average Energy Factor for water heaters was calculated based on 96 water heaters observed in baseline homes—47 water heaters in stretch code homes and 49 in 2012 IECC homes. The 96 heating systems do not include two water heaters (one instantaneous and heat pump water heater) that were incentivized through the GasNetworks program. When calculating the average Energy Factor, the Energy Factors for integrated water heaters were calculated as 92% of the boiler AUFE. Also, the manufacturer reported Energy Factors for on-demand/instantaneous water heaters were multiplied by 92% to account for the fact that on-demand water heaters are not as efficient as their ratings when used for short draws of hot water. The overall average Energy Factor of all 96 water heaters was 0.69. Finally, to get all water heaters, regardless of fuel, on the same playing field the ENERGY STAR’s Portfolio Manager Source-Site conversion factor of 3.14 for electricity

³ To evaluate energy performance of buildings, we have to express all different energy types in a single common unit. Source energy is the most equitable unit of evaluation, because it includes the energy “losses” associated with generating and delivering the fuel.
Source: <https://portfoliomanager.zendesk.com/hc/en-us/articles/216670148-What-are-the-Site-to-Source-Conversion-Factors->

was applied to the average 0.69 Energy Factor to get the UDRH input specification Energy Factor for electric conventional and heat pump water heaters ($0.69 \times 3.14 = 2.18$).

When calculating the average recovery efficiency, the recorded recovery efficiencies for conventional electric water heaters were divided by the ENERGY STAR's Portfolio Manager Source-Site conversion factor of 3.14 for electricity to convert to source energy. Also, recovery efficiencies for heat pump water heaters were excluded from the average recovery efficiency calculation because REMRate does not use recovery efficiencies with heat pump water heaters.

1.13 SKYLIGHTS

UDRH Specification	Current Specification	New Specification
Skylights	U=0.48, SHGC=0.30	Same: U=0.48, SHGC=0.30
Only seven of the baseline homes had skylights and auditors could confirm U-values for only two homes. Given the lack of verified field data it was decided to continue to use the 2011 Hybrid U-0.48 and SHGC 0.30. <i>(Current ENERGY STAR criteria are U-≤0.50, SHGC Any.)</i>		

1.14 DOORS

UDRH Specification	Current Specification	New Specification
Doors	U=0.35	Same: U=0.35
Auditors were not able to document U-values for doors in baseline homes. It was decided to continue to use the 2011 Hybrid U-0.35, which is the REM/Rate default. <i>(Current ENERGY STAR U-value criteria are U-≤0.17 for opaque, -≤0.25 for ≤1/2 light and 0.30 for >1/2 light doors.)</i>		

1.15 OTHER INPUTS

UDRH Specification	New Specification
Climate Location	Same as Rated Home
Photovoltaics Eliminated	No Change
Sunspaces Eliminated	No Change
Thermostats	No Change Manual Thermostats – Set-points: 72 and 75
Mechanical Ventilation	Same as Rated Home
Lights and Appliances	Same as Rated Home