



Final 2017 UDRH Inputs for the Rhode Island Residential New Construction Program

July 24, 2017

SUBMITTED TO:
National Grid Rhode Island

SUBMITTED BY:
NMR Group, Inc.

NMR
Group, Inc.

Table of Contents

| | |
|---|-------------------------------------|
| FINAL UDRH INPUTS | 1 |
| 1.1 ABOVE GRADE WALLS | 1 |
| 1.2 FRAME FLOORS..... | 1 |
| 1.3 CEILINGS | 2 |
| 1.3.1 Flat Ceilings | Error! Bookmark not defined. |
| 1.3.2 Vaulted Ceilings | Error! Bookmark not defined. |
| 1.4 FOUNDATION WALLS..... | 3 |
| 1.4.1 Foundation Walls—Conditioned Basement | Error! Bookmark not defined. |
| 1.4.2 Foundation Walls —Unconditioned Basement... | Error! Bookmark not defined. |
| 1.5 SLABS..... | 3 |
| 1.5.1 Unheated Slab Below Grade | 4 |
| 1.5.2 Unheated Slab on or Above Grade..... | 4 |
| 1.5.3 Heated Slab on or Above Grade..... | 4 |
| 1.5.4 Heated Slab Below Grade | 4 |
| 1.6 WINDOWS--U-FACTOR AND SHGC | 5 |
| 1.7 SKYLIGHTS..... | 5 |
| 1.8 DOORS | 5 |
| 1.9 AIR INFILTRATION | 6 |
| 1.10 DUCT LEAKAGE TO THE OUTSIDE..... | 6 |
| 1.11 DUCT INSULATION – UNCONDITIONED SPACES..... | 6 |
| 1.12 HEATING EFFICIENCIES | 8 |
| 1.13 COOLING..... | 9 |
| 1.14 WATER HEATER ENERGY FACTORS | 10 |
| 1.15 LIGHTING | 11 |
| 1.16 THERMOSTAT SET POINTS | 11 |
| 1.17 OTHER INPUTS | 12 |

UDRH

Final UDRH Inputs

The following document provides final UDRH results for the Rhode Island Residential New Construction (RNC) program. The UDRH was developed based on 40 on-site inspections of non-program single-family homes and an analysis of the single-family home that participated in the 2015 RNC program.

This document provides a summary of the following items:

- The current UDRH specification used by the RNC program
- The non-program average from the RNC baseline study
- The program average from single-family homes that participated in the 2015 RNC program
- The final agreed upon value for the new UDRH

All non-program averages are weighted based on custom/spec home designations to represent the custom/spec splits identified in the RNC program. All program averages are unweighted. Average Uo values for non-program and program homes are derived from REM/rate and account for insulation type, R-value, framing factor, insulation installation grade, etc.

1.1 ABOVE GRADE WALLS

| UDRH Specification | Current Specification | Non-Program Average | Program YR 2015 Average | New Specification |
|--|-----------------------|---------------------|-------------------------|-------------------|
| Above Grade Wall-Uo (Conditioned/Ambient) | 0.073 | 0.064 (n-40) | 0.062 (n-171) | 0.064 |
| Above Grade Wall-Uo (Conditioned/Garage) | 0.077 | 0.067 (n-32) | 0.064 (n-113) | 0.067 |
| Above Grade Wall-Uo (Conditioned/Attic) | 0.081 | 0.081 (n-21) | 0.067 (n=74) | 0.081 |
| Above Grade Wall-Uo (Conditioned/Unconditioned Basement) | 0.73 | 0.097 (n-22) | 0.083 (n-113) | 0.097 |

The new UDRH specification for all above grade wall categories reflect the non-program averages observed during the baseline study.

Currently walls to unconditioned basements receive the same specification as walls to ambient. Conditioned to unconditioned walls has been added to the new UDRH.

1.2 FRAME FLOORS

| UDRH Specification | Current Specification | Non-Program Average | Program YR 2015 Average | New Specification |
|--------------------|-----------------------|---------------------|-------------------------|-------------------|
|--------------------|-----------------------|---------------------|-------------------------|-------------------|

| UDRH Specification | Current Specification | Non-Program Average | Program YR 2015 Average | New Specification |
|--|-----------------------|---------------------|-------------------------|-------------------|
| Frame Floor over Unconditioned Basement-Uo | 0.119 | 0.131 (n-22) | 0.041 (n-122) | 0.131 |
| Frame Floor over Garage-Uo | 0.054 | 0.072 (n-21) | 0.038 (n-47) | 0.072 |
| Frame Floor over Ambient-Uo | 0.085 | 0.059 (n-11) | 0.038 (n-23) | 0.059 |

The new UDRH specification for all framed floor categories reflect the non-program averages observed during the baseline study.

The Uo value for frame floors over unconditioned basements in non-program homes (0.131) seems high due to six homes that had no insulation¹, one home that had just R-19 batts², and another that had an average R-value of 14.5 due to an uninsulated portion. Additionally, of the floors over basements that did have insulation, 65% were installed at Grade II and 35% were installed at Grade III further raising the Uo value.

1.3 CEILINGS

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|--------------------|-----------------------|---------------------|-------------------------|-------------------|
| Flat Ceiling-Uo | 0.051 | 0.054 (n-32) | 0.032 (n-144) | 0.051 |
| Vaulted ceiling-Uo | 0.044 | 0.062 (n-22) | 0.030 (n-116) | 0.044 |

The new specification remained the same as the current specification for both flat and vaulted ceiling Uo values. This decision was due to high variability, divergence from Massachusetts, poor quality insulation installation, and some ceilings with little to no insulation present in the non-program home average. The results for program and non-program ceilings are discussed in more detail below.

The seemingly high non-program average for flat ceilings is the result of one home having a bonus room with no insulation on its ceiling, another home having only 7 inches of blown-in fiberglass, and other homes having R-38 fiberglass batts installed at a Grade III insulation installation level, which translates into a U-value of .0608. The average per-home R-value of flat ceilings in non-program homes of 36.1 is more than the 2011 average of 34.5.

The U-value of vaulted ceilings in non-program homes comes from Grade III fiberglass batt installations and low nominal R-values. Twelve non-program homes have vaulted ceilings

¹ In accordance with RESNET protocol, s basements that were unfinished, unheated, and had uninsulated walls were considered unconditioned regardless of the presence of frame floor insulation.

² R-19 batts are permitted by the 2012 IECC if the R-19 batt fill the entire cavity. Otherwise, R-30 is required.

with nominal R-values less than R-38. Of those twelve, one has no insulation, four have Grade II installations, three have Grade III installations, and only four have Grade I installations. The average per-home R-value of vaulted ceilings in non-program homes of 29.3 is less than the 2011 average of 33.0.

1.4 FOUNDATION WALLS

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|--|-----------------------|---------------------|-------------------------|-------------------|
| Foundation Wall R-value: Conditioned Basement | 13.4 | 7.9 (n-13) | 18.37 (n-18) | 10.65 |
| Foundation Wall R-value: Unconditioned Basement | 0.3 | 0.8 (n-22) | 0.3 (n-117) | 0.8 |

Conditioned basement foundation walls have a new UDRH specification of R-10.65. This value is the average of the current UDRH specification and the non-program average. An average between the two values was used for the new specification to account for high variability and divergence from Massachusetts results. Unconditioned basement walls will use the non-program average for the new UDRH specification.

The average non-program R-value for conditioned basements is brought down by three homes that did not have insulation and five that only had partial insulation. Of the 13 sites, only four had R-values at or above the current specification of 13.4.

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. Just three of twenty-two non-program homes with unconditioned basement space had insulation on unconditioned foundation walls, and none were fully insulated. This pushed the average R-value in 22 non-program homes up slightly to .8, while the average in 117 program homes matches the current UDRH .3 R-value.

1.5 SLABS

The new UDRH specification was derived using the same approach that was used to determine the Massachusetts UDRH. Standard practice for program homes are to leave below grade slabs uninsulated. This standard, coupled with the difficulties in verifying on-site slab insulation, resulted in adopting the MA approach for the Rhode Island UDRH. This approach was applied to all slab categories.

It is difficult to verify slab insulation in completed homes, as was the case for every non-program home inspection. To verify slab R-value, NMR auditors visited building departments to look at documentation for every non-program home, searched for visible insulation onsite, asked homeowners for any documentation or plans they had on premises, and asked homeowners if they knew anything about the slab insulation.

1.5.1 Unheated Slab Below Grade

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|---|-----------------------|---------------------|-------------------------|-------------------|
| Below Grade Slab R-value: Unheated —under insulation | 0.27 | 1.91 (n-10) | 2.81 (n-16) | 0 |
| Below Grade Slab R-value: Unheated — perimeter insulation | 0.27 | 1.91 (n-10) | 4.06 (n-16) | 0 |

1.5.2 Unheated Slab on or Above Grade

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|---|-----------------------|---------------------|-------------------------|-------------------|
| On- Grade Slab R-value: Unheated —under insulation | 0.21 | 1.73 (n-12) | 1.92 (n-39) | 0 |
| On- Grade Slab R-value: Unheated — perimeter insulation | 0.21 | 1.28 (n-12) | 9.78 (n-39) | 5 |

1.5.3 Heated Slab on or Above Grade

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|--|-----------------------|---------------------|-------------------------|-------------------|
| On- Grade Slab R-value: Heated —under insulation | 5.21 | 10.0 (n-2) | None present | 15 |
| On- Grade Slab R-value: Heated —perimeter insulation | 5.21 | 10.0 (n-2) | None present | 10 |

1.5.4 Heated Slab Below Grade

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|---|-----------------------|---------------------|-------------------------|-------------------|
| Below Grade Slab R-value: Heated —under insulation | 5.27 | 10.0 (n-2) | 15.0 (n-2) | 15 |
| Below Grade Slab R-value: Heated — perimeter insulation | 5.27 | 10.0 (n-2) | 12.5 (n-2) | 10 |

1.6 WINDOWS--U-FACTOR AND SHGC

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|---------------------|-----------------------|---------------------|-------------------------|-------------------|
| Windows-Uo | 0.34 | 0.31 (n-10) | 0.31 (n-171) | .31 |
| Windows SHGC | 0.31 | 0.29 (n-10) | 0.30 (n-171) | .29 |

The new UDRH specification for window U-factor and solar heat gain coefficient (SHGC) reflect the non-program averages observed during the baseline study.

These are the average U-Factor and SHGC values from the baseline study based on documented U-Factor and SHGC information from visible NFRC (National Fenestration Rating Council) stickers or building department documentation for ten non-program homes and REM/rate file reviews of 171 program homes.

1.7 SKYLIGHTS

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|------------------------|-----------------------|---------------------|-------------------------|---------------------------|
| Skylights—Uo | 0.48 | No verifiable data | 0.44 (n-7) | Same as rated home |
| Skylights--SHGC | 0.31 | No verifiable data | 0.38 (n-7) | Same as rated home |

The new UDRH specification for skylights will be the same as the rated home. This change from the current specification is due to no verifiable data in non-program homes and a small sample size for program homes.

Average U-value and SHGC values for program homes are derived from seven values found during analysis of REM/Rate files, no confirmed values were found during on-site visits for non-program homes.

1.8 DOORS

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|--------------------|-----------------------|---------------------|-------------------------|---------------------------|
| Doors—Uo | Same as rated home | No verifiable data | 0.302 (n-171) | Same as rated home |

The new UDRH specification will remain unchanged from the current specification for doors.

Auditors were not able to document confirmed U-values for doors at on-sites of non-program homes. The average value for program homes is derived from REM/Rate files of 171 participating homes.

1.9 AIR INFILTRATION

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|---------------------------------|------------------------------|----------------------------|--------------------------------|--------------------------|
| Air Infiltration (ACH50) | 5.96 | 5.24 (n-39) | 4.14 (n-171) | 5.24 |

The new UDRH specification for air infiltration reflects the non-program averages observed during the baseline study.

This is the average air infiltration (ACH50) from the baseline study based on blower door testing at 39 non-program homes and records of blower door testing at 171 program homes. An air leakage test was not conducted on one non-program home because the homeowner was operating a wood burning stove during the audit which would have been a fire hazard to pressurize or depressurize.

1.10 DUCT LEAKAGE TO THE OUTSIDE

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|--|------------------------------|----------------------------|--------------------------------|--------------------------|
| Duct Leakage to the Outside (CFM25/100 sq. ft. CFA) | 20 | 8.56 (n-36) | 4.65 (n-128) | 8.56 |

The new UDRH specification for duct leakage to the outside reflects the non-program average observed during the baseline study.

Duct systems in conditioned space were tested but all had 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. All homes with zero duct leakage are included in the non-program and program averages. One non-program home that had ducts was not tested due the use of a wood burning stove on the premises and is excluded from analysis.

1.11 DUCT INSULATION – UNCONDITIONED SPACES

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|---|------------------------------|----------------------------|--------------------------------|--------------------------|
| Duct Insulation - Unconditioned Attic (supply) | 7.55 | 7.34 (n-20) | 7.97 (n-76) | 7.07 |

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|---|------------------------------|----------------------------|--------------------------------|--------------------------|
| only) | | | | |
| Duct Insulation - Unconditioned Attic (return only) | 7.52 | 7.31 (n-19) | 7.97 (n-74) | 7.02 |
| Duct Insulation - Unconditioned Basement (supply only) | 6.65 | 6.06 (n-20) | 6.09 (n-103) | 5.68 |
| Duct Insulation - Unconditioned Basement (return only) | 5.18 | 5.92 (n-20) | 6.09 (n-103) | 5.68 |
| Duct Insulation – All Other Unconditioned Spaces (supply only) | 6.62 | 6.93 (n-4) | 6.40 (n-5) | 6.00 |
| Duct Insulation – All Other Unconditioned Spaces (return only) | 6.62 | 6.73 (n-3) | 6.0 (n-4) | 6.73 |

The new UDRH specification for all duct insulation measures uses the non-program average R-value, however the values for the new UDRH specification are adjusted to account for bubble wrap insulation rated R-values being artificially high. Due to studies suggesting the labeled R-values for bubble wrap insulation are over-valued³, ducts with bubble wrap had the R-value downgraded to R-2.⁴

³ Source: <http://www.energyvanguard.com/blog/29497/The-Foil-Faced-Bubble-Wrap-Sham-Understanding-Radiant-Barriers>

⁴ Source: <http://www.energy-experts.net/home/articles/the-truth-about-foil-faced-bubble-wrap/>

1.12 HEATING EFFICIENCIES

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|--|---------------------------|---------------------|-------------------------|-------------------------------------|
| NG or Propane Air Distribution (AFUE) | 92.2 | 93.0 (n-32) | 95.0 (n-126) | 93.0 |
| NG or Propane Hydronic Distribution (AFUE) | 88.7 | 90.8 (n-3) | 94.0 (n-36) | 89.5 |
| NG or Propane Unit Heater (AFUE) | 74 | N/A | N/A | Same as Rated Home |
| Oil Air Distribution (AFUE) | 81.6 | 86.2 (n-2) | 84.0 (n-1) | Same as Rated Home |
| Oil Hydronic Distribution (AFUE) | 86.0 | 85.3 (n-1) | 85.3 (n-1) | Same as Rated Home |
| Oil Unit Heater (AFUE) | 81 | Not present | Not present | Same as Rated Home |
| Kerosene Unit Heater (AFUE) | 81 | Not present | Not present | Same as Rated Home |
| ASHP & Ductless Mini-Split (HSPF) | 7.7 | 9.3 (n-7) | 10.1 (n-27) | 9.3 |
| GSHP (COP) | 2.95 | 3.9 (n-6) | 4.1 (n=5) | 3.35 (Adjusted from 3.9) |
| Dual-Fuel Heat Pump | 7.7 (HSPF) 92.6 (AFUE) | Not present | Not present | 93.0 AFUE + 9.3 HSPF |
| Location | Unconditioned space | Unconditioned space | Unconditioned space | Unconditioned Space |

Natural gas and propane air distribution will use the non-program average for the new UDRH specification, resulting in a 0.8 AFUE increase. This same adjustment was applied to natural gas/propane hydronic distribution systems, increasing the current UDRH specification by 0.8 AFUE for the new specification. This decision was due to small sample sizes in non-program homes. Oil fueled equipment and unit heaters were adjusted in the new UDRH specification to be the “Same as rated home.” Small sample sizes in non-program homes, high variability among equipment efficiencies, and reduced usage in new construction were contributing factors for the new UDRH specification.

ASHP and ductless mini-splits use the non-program average for the UDRH update. The new UDRH specification applies the default adjustment factor for pump and fan usage in GSHP closed loop systems to the non-program average COP rating of 3.9, resulting in 3.35 COP.

The location specification for heating in the UDRH does not change from current location of unconditioned space.

“Air distribution systems” includes furnaces and hydro-air boilers. “Hydronic distribution systems” include forced hot water boilers and wall mounted tank-less combined appliances.

1.13 COOLING

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|--|------------------------------|----------------------------|--------------------------------|---------------------------------------|
| Air Conditioner (SEER) | 13.1 | 13.7 (n-45) | 13.9 (n-108) | 13.7 |
| Air Source Heat Pump & Ductless Mini-Split (SEER) | 13.1 | 16.6 (n-7) | 19.1 (n-7) | 16.6 |
| Ground Source Heat Pump (EER) | NA | 19.4 (n-6) | 19.5 (n-5) | 14.65 (Adjusted from 19.4) |
| Percent of Systems in Unconditioned Space | Unconditioned Space | Unconditioned Space | Unconditioned Space | Unconditioned Space |

The new UDRH specification for air conditioners, and ASHPs and ductless mini-splits use the non-program average SEER ratings. The new UDRH specification applies the default adjustment factor for pump and fan usage in GSHP closed loop systems to the non-program average EER rating of 19.4, resulting in 14.65 EER.

The location of cooling systems does not change from the current UDRH specification of being in unconditioned

1.14 WATER HEATER ENERGY FACTORS

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|--|-----------------------|---------------------|-------------------------|----------------------------|
| NG or Propane Conventional Storage (EF, RE) | 0.63, 0.80 | 0.68, 0.81 (n-5) | 0.70, 0.82 (n-49) | 0.68, 0.81 |
| NG or Propane Integrated | 0.80 | 0.87 (n-4) | 0.93 (n-23) | 0.81 |
| NG or Propane Instantaneous | 0.84 | 0.94 (n-10) | 0.92 (n-55) | 0.92 |
| Oil Conventional Storage (EF, RE) | 0.61, 0.80 | N/A | N/A | Same as Rated Home |
| Oil Integrated | 0.78 | .79 (n-2) | .78 (n-1) | Same as Rated Home |
| Oil Instantaneous | 0.62 | 0.50 (n-1) | 0.45 (n-2) | Same as Rated Home |
| Heat Pump Water Heater | 0.90 | 3.21 (n-9) | 2.74 (n-22) | 1.76 |
| Electric Conventional Storage (EF, RE) | 0.90, 0.98 | 0.93, 0.98 (n-11) | 0.92, 0.98 (n-30) | |
| Heat Pump and Electric Conventional Storage (EF, RE) | 0.90, 0.98 | 1.76, 0.98 (n-20) | 1.69, 0.98 (n-52) | |
| GSHP with Electric Resistance | NA | NA | 1.2, 0.98 (n-1) | Same as Rated Home |
| Location | Unconditioned Space | Unconditioned Space | Unconditioned Space | Unconditioned space |

The natural gas and propane conventional water heater new UDRH specification will use the non-program home average. The new UDRH specification for natural gas and propane integrated water heaters was calculated by applying the ratio of integrated energy factor to boiler AFUE from the 2011 study to the current studies hydronic heating AFUE; this was done due to the small sample size for integrated systems. Natural gas and propane instantaneous water heaters will use the program home average for the new UDRH specification. All oil based water heaters and GSHP water heaters will be set to “same as rated home,” a change from current UDRH specification values. Small sample sizes in non-program homes, high variability among equipment efficiencies, and reduced usage in new construction were contributing factors for the new UDRH specification.

The new UDRH specification combines conventional electric water heaters and heat pump water heaters into one measure. The equipment types were combined due to same fuel

type, storage type, and to reflect the increase of HPWHs in the market. The new UDRH value is derived from calculating the weighted average of electric conventional and heat pump water heaters, for both program and non-program homes. The resulting energy factor of 1.76 will require the new UDRH to use the heat pump water heater equipment type, regardless of what the program home installed. This is due conventional water heater energy factors being limited to 1.00 or lower. The recovery efficiency is undefined, as the new UDRH specification will use a HPWH equipment type.

Wall mounted combined appliances with no tank that are used for both space and water heating are included with instantaneous systems. Systems with tanks that perform both space and water heating are included with integrated systems.

The location specification of water heaters for all groups is unconditioned space. The percent of water heaters in unconditioned space is 69% in non-program homes, and 71% in program homes. The previous baseline study had 75% of systems located in unconditioned space.

1.15 LIGHTING

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|---------------------|-----------------------|---------------------|-------------------------|-------------------|
| CFL Lighting | 16% | 64% (n-40) | 83% (n-171) | 64% |

The new UDRH specification for percentage of efficient lighting fixtures reflects the non-program average observed during the baseline study.

The CFL lighting percentages include LED and fluorescent tubes per REM/rate protocols. The name of the specification refers only to CFLs to match the input variable in REM/rate.

1.16 THERMOSTAT SET POINTS

| UDRH Specification | Current Specification | Non-program Average | Program YR 2015 Average | New Specification |
|--------------------------|-----------------------|---------------------|-------------------------|-------------------|
| Heating Set Point | 68 | 67 (n-79) | 68 (n-171) | 67 |
| Cooling Set Point | 75 | 71 (n-73) | 78 (n-171) | 71 |

The new UDRH specification for thermostat set points reflects the non-program average observed during the baseline study.

Thermostat set point data was collected from homeowners during on-site visits for non-program homes. Thermostat set points were gathered for each thermostat within the home. Program homes use a thermostat default of 68 for heating and 78 for cooling.

1.17 OTHER INPUTS

The new UDRH specification for mechanical ventilation changed from “same as rated home” to the 2010 ASHRAE 62.2 standard on air flow and fan energy. This UDRH input is set to the required code level, and allows for savings opportunities for systems that exceed code standards.

| UDRH Specification | New Specification |
|---------------------------------|---|
| Climate Location | Same as Rated Home |
| Photovoltaics Eliminated | No Change |
| Sunspaces Eliminated | No Change |
| Mechanical Ventilation | 2010 ASHRAE 62.2 – Air Flow and Fan Energy |
| Appliances | Same as Rated Home |