

Residential Heat Pump Efficiency Rating Representativeness Project Phase 1 & Phase 2 Executive Summary



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Acknowledgements

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About NEEP

NEEP was founded in 1996 as a non-profit whose mission is to serve the Northeast and Mid-Atlantic to accelerate regional collaboration to promote advanced energy efficiency and related solutions in homes, buildings, industry, and communities. Our vision is that the region's homes, buildings, and communities are transformed into efficient, affordable, low-carbon resilient places to live, work, and play.

Disclaimer: NEEP verified the data used for this report to the best of our ability. This paper reflects the opinion and judgments of the NEEP staff and does not necessarily reflect those of NEEP Board members, NEEP Sponsors, or project participants and funders.

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PHASE 1 EXECUTIVE SUMMARY

This report details the first phase of a residential heat pump efficiency rating representativeness study conducted by DNV for Northeast Energy Efficiency Partnership.



DNV performed field experiments and conducted preliminary data analysis to assess the representativeness of two heat pump testing and rating procedures:

- Air-conditioning, Heating and Refrigeration Institute (AHRI) 210/240-2023 (hereafter AHRI 210/240), used for regulation in Canada and the USA
- Canadian Standards Association (CSA) SPE-07:23¹ (hereafter SPE-07), which is being considered for regulatory adoption in Canada

DNV, working with the University of Nebraska-Lincoln (UNL), conducted experiments in Lincoln, NE, using three mobile homes and six heat pumps. The first phase (the “field” phase) of the study was conducted from March 2022 through February 2023.

The first phase report documents the field experiments, preliminary analysis of field-collected data, stakeholder access to data dashboards, and descriptions of second phase lab testing and analysis tasks. Lab testing and analysis comparing field-to-lab measurements will be performed in the second phase of the representativeness project managed by NEEP.

¹ The first edition of *Load-based and climate-specific testing and rating procedures for heat pumps and air conditioners*. It supersedes the document CSA EXP-07:19 of the same name

Methodology

For Phase 1, this study has two primary aims:

- Build a robust set of rigorous and well-controlled in-field measurement data to enable in-depth comparisons of the field data to the ratings produced by two major laboratory test procedures (SPE-07 and AHRI 210/240) for a set of ducted and ductless heat pumps².
- Determine the shortcomings or differences that diminish the relevance or representativeness of the lab test results compared with measured field performance.

DNV commissioned three identical, new mobile homes in Lincoln, Nebraska, for the duration of the mobile home calibration and both the cooling and heating measurement periods. The cooling measurement period was delayed and spanned from August to October 2022. The heating measurement period spanned from October 2022 to February 2023.

Each mobile home had two air-source heat pumps installed: one ducted and one ductless. The mobile homes were also modified (to the extent possible) to mimic the thermal properties prescribed by CSA SPE-07, typical of building load profiles for single-family residences based on the rated heat pump size. All three mobile homes were similarly oriented, weatherized, and commissioned, with similar exterior shading and wind exposure conditions. Infiltration, conduction, and capacitance calibration tests were conducted to (1) measure the existing condition of the mobile homes and to (2) guide thermal alterations to more closely match CSA SPE-07 properties. Building load profiles and capacitance were also estimated from data collected during the heat pump measurement period. These parameters are critical to reasonably compare the field data with results from the subsequent laboratory tests.

² Note that the Department of Energy (DOE) “Appendix M1” is the governing document that the study will be testing to in the lab. Appendix M1 is harmonized generally with AHRI 210/240 as explained further below. Technically, field test conditions include (or are at least very close to) conditions set by Appendix M1, and there will be attention focused on adjusting or normalizing for different operating conditions, both indoors and outdoors.

PHASE 2 EXECUTIVE SUMMARY

In this second phase, lab-based performance ratings provide critical information to the market for the development, sales and selection of heat pump systems, so it is essential that they are representative of real-world performance. With the emergence of variable-speed heat pumps that rely on proprietary controls to manage the systems' operation and efficiency, the representativeness of existing test procedures that determine performance under fixed-speed conditions has come under increased scrutiny. Energy efficiency programs also have a keen interest in representative performance ratings to ensure incentive investments achieve the expected savings. Representative test procedures and ratings enable the adoption of high efficiency heat pumps across North America, commonly identified as an essential step toward decarbonizing homes and businesses.

The results of the analysis comparing the laboratory data to the field data are detailed in this report.

Methodology

For Phase 2, this study has three primary aims:

1. Build a robust set of rigorous and well-controlled in-the-field measurement data to enable in-depth comparisons of the field data to the ratings produced by the two major laboratory test procedures specified above (SPE-07 and M1) for a set of ducted and ductless heat pumps. The Department of Energy (DOE) "Appendix M1" is the governing document that the study follows in the lab. As noted above, it is harmonized generally with AHRI 210/240 with field test conditions the same or very close to conditions set by Appendix M1.
2. Use the data to inform policy on the value of load-based testing¹ (SPE-07) relative to static testing² (M1).
3. Determine the shortcomings or differences that diminish the relevance or representativeness of the lab test results compared with measured field performance.

The research team carefully packed and sent the six heat pumps used in the first phase field testing to Underwriters Laboratory (UL) in Plano, Texas for laboratory testing according to the two procedures:

1. Department of Energy (DOE) Code of Federal Regulations Title 10, Chapter II, Subchapter D, Part 430, Subpart B, Appendix M1 to Subpart B of Part 4303: Uniform Test Method for Measuring the Energy Consumption of Central Air Conditioners and Heat Pumps (January 2017) (hereafter M1). This standard is harmonized generally with Air-conditioning, Heating and Refrigeration Institute (AHRI) 210/240-2023, used for regulation in Canada and the USA.

2. Canadian Standards Association (CSA) SPE-07:234 (hereafter SPE-07), which is being considered for regulatory adoption in Canada.

The results of the analysis comparing the laboratory data to the field data are detailed in this report.

Upon completion of Phase 2 testing, DNV produced a file that compares published nameplate ratings, laboratory-produced Appendix M2 SEER2 and HSPF2 ratings, field-tested FSCOPC and FSCOPH, and laboratory-produced CSA SPE-07 SCOPC and SCOPH ratings. The comparisons include measurement uncertainty propagated in accordance with established principles.