Alaska's Rural Building Stock: a Validation Study Using ResStock and Field Data

Patricia Guillante,[1,2] Katelyn Stenger,[1] Rajendra Adhikari,[1] Anthony Fontanini,[1] Nathan Wiltse,[1] Lixi Liu,[1] and Kristen Cetin[2]

1 National Renewable Energy Laboratory
2 Michigan State University

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated under Contract No. DE-AC36-08GO28308

This report is available at no cost from NREL at www.nrel.gov/publications.

Technical Report
NREL/TP-5500-91194
July 2025

Alaska's Rural Building Stock: a Validation Study Using ResStock and Field Data

Patricia Guillante,[1,2] Katelyn Stenger,[1] Rajendra Adhikari,[1] Anthony Fontanini,[1] Nathan Wiltse,[1] Lixi Liu,[1] and Kristen Cetin[2]

1 National Renewable Energy Laboratory

2 Michigan State University

Suggested Citation

Guillante, Patricia, Katelyn Stenger, Rajendra Adhikari, Anthony Fontanini, Nathan Wiltse, Lixi Liu, and Kristen Cetin. 2025. *Alaska's Rural Building Stock: a Validation Study Using ResStock and Field Data*. Golden,Colorado: National Renewable Energy Laboratory. NREL/TP-5500-91194. https://www.nrel.gov/docs/fy25osti/91194.pdf.

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated under Contract No. DE-AC36-08GO28308

This report is available at no cost from NREL at www.nrel.gov/publications.

Technical Report
NREL/TP-5500-91194
July 2025

15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

NOTICE

This work was authored in part by NREL for the U.S. Department of Energy (DOE), operated under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Building Technologies Office. The views expressed herein do not necessarily represent the views of the DOE or the U.S. Government.

This report is available at no cost from NREL at www.nrel.gov/publications.

U.S. Department of Energy (DOE) reports produced after 1991 and a growing number of pre-1991 documents are available free via www.OSTI.gov.

Cover photos (clockwise from left): Josh Bauer, NREL 61725; Visualization from the NREL Insight Center; Getty-181828180; Agata Bogucka, NREL 91683; Dennis Schroeder, NREL 51331; Werner Slocum, NREL 67842.

NREL prints on paper that contains recycled content.

Acknowledgments

This study was funded by the National Science Foundation through supplemental funding granted under Award Number 2144468 and the National Renewable Energy Laboratory's 2024 Strategic Investments provided through the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Building Technology Office's Residential Building Integration team. Data collection was funded through the National Science Foundation Navigating the New Arctic, under Award Number 2220236. The findings of this study do not reflect the views of the National Science Foundation. The authors would like to extend their heartfelt gratitude to the following individuals for their valuable time and review on the manuscript: Janet Reyna, Stacey Rothe, and Achilles Karagiozis.

This report is available at no cost from NREL at www.nrel.gov/publications.

List of Acronyms

A3DDC	aerial and 3D-view data collection
ACH50	air changes per hour at 50 pascals pressure difference
ARIS	Alaska Retrofit Information System

This report is available at no cost from NREL at www.nrel.gov/publications.

Executive Summary

The availability of accurate national data on demographics, building stock, and energy use is vital for modeling residential buildings and evaluating energy affordability and resilience strategies. However, rural and Indigenous populations, including those in rural Alaska, are typically underrepresented in these datasets. ResStock primarily gathers data from national surveys and energy audits that tend to focus on more populated areas, resulting in limited coverage and accuracy for remote and underserved communities. These rural Alaskan communities face unique challenges because of their remote locations, severe weather conditions, and limited access to resources, which result in high energy burden. This report examines how rural Alaskan communities are underrepresented in the ResStock™ housing characteristics and energy model and highlights the need for improved data to address their unique housing and energy challenges.

We conducted a validation study considering ResStock, field data, and aerial and 3D-view data collection (A3DDC) datasets. The validation process started by using the filter based down-selecting approach on the ResStock building stock dataset. We selected rural Alaska boroughs and census areas located in American Society of Heating, Refrigerating, and Air-Conditioning Engineers International Energy Conservation Code Climate Zone 8 to ensure a more accurate and fair comparison with field data, which was collected in Nome census area, a rural area located in Climate Zone 8.

While ResStock may accurately represent several characteristics of the building stock for rural Alaska, we identified some differences among modeled, field data, and A3DDC datasets. The following building characteristics have a high impact on modeled energy consumption and demonstrated large differences. We summarize these differences and list possible actions to resolve differences for future iterations of ResStock results:

- **Heating setpoints.** The average heating setpoint in ResStock is lower than the average observed in the field data. Revisit distributions and consider higher setpoints, which could potentially address missing loads if found to be the case.
- **Toyo heating**. Toyo heating is currently missing from ResStock, but prevalent in field data collected. Develop and include Toyo heating in future modeling for ResStock and EnergyPlus.
- **Natural gas**. Natural gas is not readily available in rural Alaska apart from the North Slope. Remove natural gas as a water heater fuel type outside of North Slope County.
- **Foundation type**. Field and A3DDC data show that 80% of dwellings have crawlspaces in rural Alaska, while ResStock shows only 28.7% of dwellings have crawlspaces and 40% of dwellings have basements. Revisit distributions and consider more crawlspaces than basements.
- **Infiltration rates**. The average infiltration rate is 5.06 ACH50 in ResStock, approximately 30% lower than the average field data, 7.35 ACH50. Reevaluate the distribution to consider higher infiltration rates.
- **Exterior wall type**. Field data has revealed the predominancy of wood and vinyl light colored walls, while ResStock shows a predominancy of wood and brick medium/dark colored walls. Include more vinyl and less brick, and revise wall color for greater proportion of light than dark.
- **Roof material**. Field and A3DDC data show that 93% of dwellings have metal roofs in rural Alaska, while approximately 75% of dwellings in ResStock have shingles. Revise from majority shingles to majority metal roofing material.
- **Occupant count**. Occupancy rates in field data are 2.85 persons/dwelling, compared to 2.20 persons/dwelling in ResStock. Update to higher occupant count.

This report is available at no cost from NREL at www.nrel.gov/publications.

- **Building orientation**. Field and A3DDC shows approximately 35% of dwellings are south facing, while ResStock follows a normal distribution. Update to represent a higher proportion of south-facing than relatively equal south- and north-facing.

The findings suggest that updating ResStock's input data could better represent rural Alaskan buildings and their energy consumption. ResStock can be used to identify the residential building energy consumption and energy efficient building improvements.

This report is available at no cost from NREL at www.nrel.gov/publications.

Table of Contents

Motivation **1**
Background **1**
Objectives 2
Methodology **2**
Data Sources 2
ResStock 3
Field Data 3
Aerial and 3D-View Data Collection (A3DDC) 5
Validation Process 6
Results and Analysis **7**
Building Type 8
Building Orientation 8
Water Heater Fuel Type 9
Heating Fuel and System Type 10
Window Types 11
Exterior Walls Type and Color 11
Foundation Type 12
Roof Material 13
Vacancy Status 13
Floor Area 14
Number of Stories 14
Vintage 15
Infiltration Rates 15
Heating Setpoint and Indoor Temperature 16
Number of Occupants 17
Conclusions **18**
Next Steps and Implication for Revisions 19
References **21**

This report is available at no cost from NREL at www.nrel.gov/publications.

List of Figures

Figure 1. Location of the communities where field data was collected 4
Figure 2. Location of the communities where aerial and 3D-view data was collected 5
Figure 3. Boroughs and census areas selected from ResStock for the validation study 7
Figure 4. Comparison of building types: ResStock versus the field data 8
Figure 5. Comparison of building orientation: ResStock versus the field data and A3DDC 9
Figure 6. Comparison of water heater fuel type: ResStock versus the field data 10
Figure 7. Comparison of heating systems (a) and fuel type (b): ResStock versus the field data 11
Figure 8. Comparison of window types: ResStock versus the field data 11
Figure 9. Comparison of (a) Exterior wall finish type, and (b) Color: ResStock versus the field data 12
Figure 10. Comparison of foundation type: ResStock versus the field data and A3DDC 13
Figure 11. Comparison of roof material: ResStock versus the field data and A3DDC 13
Figure 12. Comparison of floor area: ResStock versus the field data and A3DDC 14
Figure 13. Comparison of number of stories: ResStock versus the field data 14
Figure 14. Comparison of vintage: ResStock versus the field data 15
Figure 15. Comparison of infiltration rates: ResStock versus the field data 16
Figure 16. Comparison of heating setpoints and indoor temperature: ResStock versus the field data 17
Figure 17. Comparison of number of occupants: ResStock versus the field data 18

List of Tables

Table 1. Summary of Data Sources and Information 3
Table 2. Summary of Population, Housing Units, and Field Assessments 4
Table 3. Summary of Population, Housing Units, Field Assessments, and A3DDC 5
Table 4. Summary of Housing Units in Each Census Area Considered in the Validation Study 6
Table 5. Descriptive Statistics for Infiltration Rates 16
Table 6. Descriptive Statistics for Heating Setpoints and Indoor Temperature 17
Table 7. Descriptive Statistics for Number of Occupants 18

This report is available at no cost from NREL at www.nrel.gov/publications.

Motivation

Understanding the building stock in a specific community or region can help develop more accurate energy models to set targets for specific energy efficiency measures. By analyzing housing characteristics such as construction materials, heating systems, and insulation levels, researchers and policymakers can estimate home energy use and identify opportunities for housing improvements. As energy affordability efforts rise in the United States, researchers can identify energy efficiency measures. Tailoring these measures can reduce energy consumption and lower energy bills.

Accurate, updated, and detailed nationwide data on demographics, building stock, and energy data provide foundational information needed to model viable energy efficient technologies in residential buildings. However, this data is not always available with the same level of quality and detail for all populations. Rural and Indigenous populations, including American Indian and Alaska Native communities, are often underrepresented in publicly available datasets (Evans-Romaysa et al. 2022). Rural communities —like rural Alaskan communities—face several housing-related challenges because of their remote locations, extreme weather conditions, and limited access to construction materials and skilled labor for repairs, maintenance, and new home construction (Robinson 2021, Hossain 2016). Additional challenges include high costs of heating fuels and electricity, resulting in a significant energy burden for households in these communities (Robinson 2021, Hossain 2016, U.S. Department of Agriculture 2017). In this report, we focus on the representation of residential building characteristics in rural Alaskan communities within the national housing stock model, ResStock.

Background

Publicly available datasets contain partial information on residential buildings in Alaska. These datasets include the Residential Energy Consumption Survey public-use microdata (U.S. Energy Information Administration, 2023), the American Community Survey public-use microdata (U.S. Census Bureau, 2023), and the American Housing Survey (U.S. Census Bureau, 2021). These household surveys collect data from a nationally representative sample of housing units and include household demographics, energy use patterns, and housing unit characteristics, among others. Other surveys dedicated to collecting housing data specific to Alaska include the Anchorage Housing Survey (NeighborWorks Alaska Organization, 2022), surveys conducted by Tribal Organizations, and several others. Additionally, the Alaska Retrofit Information System (ARIS), an online database platform developed by the Alaska Housing Finance Corporation, also contains housing data from Alaskan households and is based on energy ratings and building assessments conducted during evaluations of energy performance (Alaska Housing Finance Corporation, 2018, Alaska Housing Finance Corporation 2022).

The ARIS data contains information on fuel use, heating equipment type and efficiency, infiltration rates measured by air changes per hour at 50 pascals pressure difference (ACH50), construction and insulation materials, and several other housing characteristics. This detailed dataset can be used as a benchmark tool because it provides a thorough understanding of the building stock in Alaska, which can help to support informed decision-making for energy policies (Alaska Housing Finance Corporation 2022, Alaska Housing Finance Corporation 2015). However, several challenges can arise when using ARIS data, which include an uneven regional representation and a high representation of households that have participated in energy efficiency programs or assessments. These structural data collection challenges limit the representation of housing conditions across the state, which can vary greatly. ARIS

This report is available at no cost from NREL at www.nrel.gov/publications.

data has informed Alaska-specific housing characteristics, including the model ResStock 3.3.0 (National Renewable Energy Laboratory, 2024).

ResStock is a residential buildings characteristic and energy analysis tool that combines extensive public and private data sources, statistical sampling, and detailed sub-hourly building simulations, among other modeling outputs. The model generates high granularity and accuracy in representing the varied housing stock and the effects of building technologies across different communities (National Renewable Energy Laboratory, 2021). Integrating ARIS data into ResStock supported an Alaska-specific building stock analysis, but how revised ResStock building characteristics compares to field and remotely-sense data remains unclear.

To address this gap, we conducted a validation study to assess the representation of rural Alaska housing stock in the ResStock database using field data. While collecting field data can be expensive and resource-intensive—requiring field surveys, measurements, and inspections—it also provides a direct benchmark against which model predictions or survey data can be compared, which increases confidence in the results. We compared field data collected in two rural communities on housing characteristics to ResStock housing stock for rural Alaska. This validation study also provides an opportunity to ensure that rural and Indigenous populations are more accurately represented in ResStock. Ultimately, this method promotes greater trust in data-driven decisions, leading to improved strategies for energy security and affordability in the residential sector.

Objectives

Primary Objective: Validate the accuracy and reliability of a set of input distributions into the ResStock building stock models for rural Alaska using field and aerial and 3D-view data collection (A3DDC) from small Alaskan rural communities.

Secondary Objectives: Suggest improvements to the ResStock building stock models based on validation results.

Methodology

The methodology section is divided into two main subsections: (1) The datasets and sources used in this study, and (2) information on the validation process used.

Data Sources

This study relies on two primary data sources for housing characteristics, supplemented by an additional dataset obtained through A3DDC. Table 1 provides a summary of the three data sources: ResStock, Field data, and A3DDC.

This report is available at no cost from NREL at www.nrel.gov/publications.

Table 1. Summary of Data Sources and Information

	ResStock	Field Data	A3DDC
Source data	ARIS data used to update other national sources used by ResStock	Surveys and energy audits	Aerial and 3D views
Samples	1,269 out of 326,200 housing units[1]	91 out of 1,696 housing units	855 out of 1,955 housing units
Geographies	Alaska-wide	Unalakleet and Nome	Unalakleet, Nome, and Quinhagak
Data collection approach	Public and private data sources, surveys, program administration (ARIS)	Field data	Remote data (aerial and 3D-view)
Year of data collection	ResStock updated with ARIS data after 2008	2021, 2023, and 2024	2023
Collection group	Survey participants and enrolled households (ARIS)	Households randomly selected or interested	Residential buildings of the three communities
Data types	Housing characteristics, heating systems, water heater equipment, and infiltration rates, among others	Housing characteristics, heating systems, water heater equipment, and infiltration rates, among others	Floor area, building orientation, roof material, and foundation type

[1]Number of housing units in the state of Alaska (2020 Decennial Census, U.S. Census Bureau)

ResStock

ResStock is an analysis tool that helps states, municipalities, utilities, and other stakeholders identify the impact of electrification and energy efficiency upgrades. It uses a statistical sampling methodology to provide a probabilistic representation of the housing stock characteristics in the United States (National Renewable Energy Laboratory, 2016). To develop this statistical representation, it uses a variety of public and private data sources, including several nationally distributed surveys. The ARIS dataset was integrated into ResStock to improve Alaska-specific housing characteristics (National Renewable Energy Laboratory, 2024), which processed 80,000 records from the ARIS database after the year 2008. The records contain detailed building characteristics and energy use across all census areas in Alaska and informed the development of 1,269 dwelling models in ResStock.

Field Data

Field data was collected by the Michigan State University and Iowa State University teams as part of "NNA Research: Collaborative Research: Responding to Energy Insecurity in Arctic Housing Using a Community-Based Participatory Research" project (National Science Foundation 2022) in two rural communities in Alaska, Nome and Unalakleet. These two communities are located on the western coast and belong to the Nome census area. A summary of population, housing units, and number of homes assessed in each community is presented in Table 2, and Figure 1 shows a map of Alaska with the location of these two communities.

This report is available at no cost from NREL at www.nrel.gov/publications.

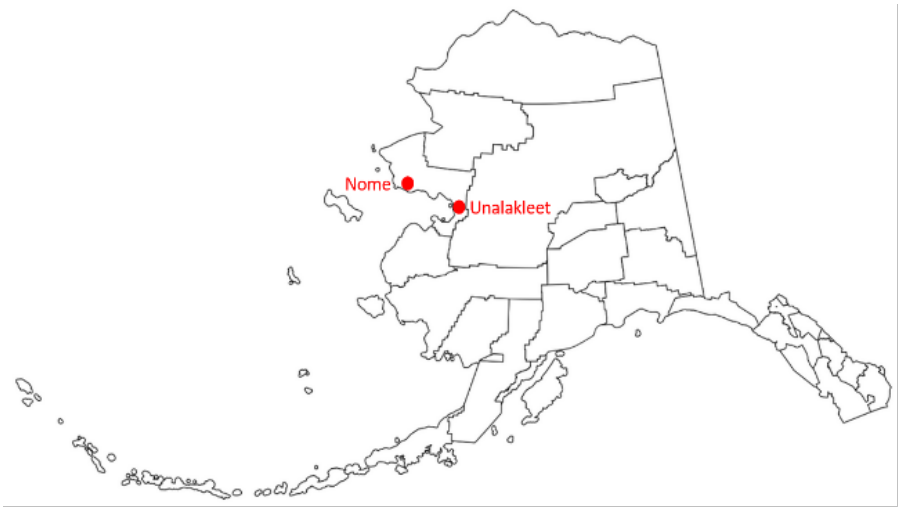

Figure 1. Location of the communities where field data was collected

Table 2. Summary of Population, Housing Units, and Field Assessments

Alaska Community	Population (Census 2020)[1]	Total Housing Units[1]	Field Data (Housing Units)
Nome	3,710	1,495	43
Unalakleet	743	201	48

[1] Census reporter (2022)

We conducted semi-structured interviews with homeowners and energy assessments over four trips. The semi-structured interviews gathered information on household size, house age, and thermostat settings for both winter and summer. Field data collection followed a Michigan State and Iowa State Universities Institutional Review Board protocols and occurred from 2021 to 2024. Energy assessments focused on gathering detailed housing characteristics, including building orientation, foundation type, materials and colors of walls and roofs, heating systems, water heater equipment, energy sources, building dimensions, and infiltration rates. A digital energy assessment guide was developed within Fastfield™ (Quickbase, 2023), a mobile data collection and analytics tool enabling direct collection of data on the site's housing characteristics, equipment specifications, and environmental conditions. Infiltration rates were measured using blower door tests performed in each assessed home. During the energy assessments, long-term indoor air quality sensors were installed. These sensors measure indoor temperature, relative humidity, and several other indoor air quality indicators.

As indicated in Table 2, 48 and 43 homes were assessed in Unalakleet and Nome, respectively. The sample of housing units assessed in Unalakleet can be considered representative of the community (Guillante et al 2024). The sample of housing units was not randomly selected, because homeowners interested in participating signed up voluntarily. Data collection took place from 2021 to 2024. We collaborated with local tribe leaders, including members from the Native Village of Unalakleet and Village of Solomon, and we also utilized radio announcements for outreach. This approach tried to ensure a broad representation across different housing types and demographics within each community,

This report is available at no cost from NREL at www.nrel.gov/publications.

while also considering homeowners' interest in learning more about their housing conditions and energy efficiency.

Aerial and 3D-View Data Collection (A3DDC)

Aerial and 3D-view data was gathered in three communities in Alaska, Unalakleet and Nome in the Nome census area and Quinhagak in the Bethel census area (Gioppo et al 2024). In general, geographic information system, assessors' data, and Google Earth were used to divide each community into sections and house coding. Aerial and street-view images were used to remotely collect information on foundation type, siding and roofing material, house dimensions, building orientation, and percentage of windows per side, among others. A summary of population, housing units, number of homes assessed, and aerial and 3D-view data collected in each community is presented in Table 3, and Figure 2 shows a map of Alaska with the location of these three communities.

Table 3. Summary of Population, Housing Units, Field Assessments, and A3DDC

Alaska Community	Population (Census 2020)[1]	Total Housing Units[1]	A3DDC (# of Buildings)
Nome	3,710	1,495	509
Unalakleet	743	201	190
Quinhagak	1,079	259	156

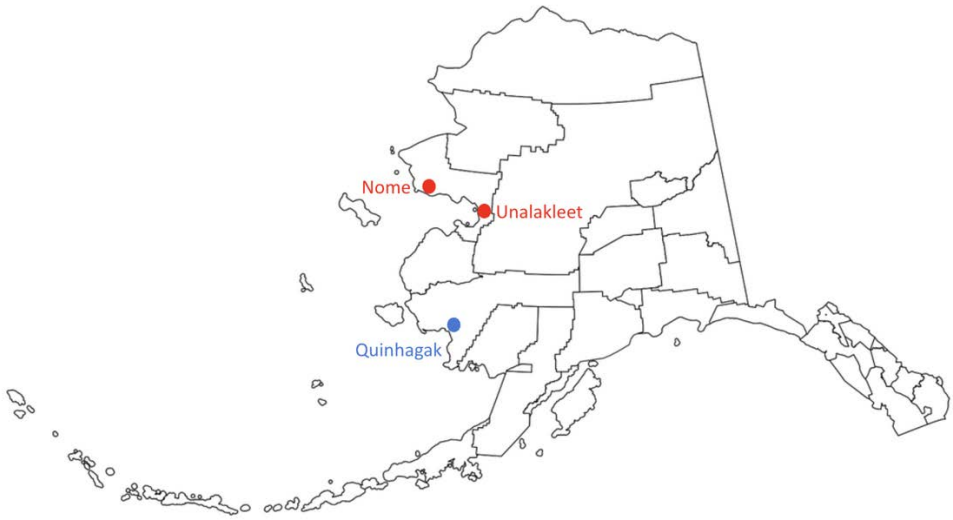

Figure 2. Locations of the communities where aerial and 3D-view data were collected

As shown in Table 3, aerial and 3D-view data was collected for 509, 190, and 156 residential buildings in Nome, Unalakleet, and Quinhagak, respectively. These numbers are lower when compared with the total number of housing units in each community. This discrepancy arises because A3DDC methods may not fully account for multifamily units and can sometimes struggle to distinguish between attached

This report is available at no cost from NREL at www.nrel.gov/publications.

single-family homes. In addition, the community of Quinhagak does not have street view images available; thus, the type of foundation, siding, and percentage of windows could not be obtained.

Validation Process

The validation process started with the filter based down-selecting approach on the ResStock building stock dataset. For this study, we considered only the rural Alaska boroughs and census areas located in ASHRAE IECC Climate Zone 8. Among the 29 boroughs and census areas and the 1,269 representative buildings from ResStock, we selected all the 115 buildings that met the down-selection approach above-mentioned to proceed with the validation study. These 115 representative buildings were located across eight different boroughs and census areas. Figure 3 shows the selected areas in orange, and Table 4 provides a summary of them, including population, total number of buildings in the region and in ResStock, and percentage of housing and land situated in rural areas.

Table 4. Summary of Housing Units in Each Census Area Considered in the Validation Study

Boroughs and Census Areas (Census 2020)[1]	Population (Census 2020)[1]	ResStock Alaska Dataset (Representative Units)	Census 2020 (Housing Count)[1]	Census 2020 % Housing in Rural Area[1]	Census 2020 % of Land in Rural Area[1]
Bethel	18,666	25	5,984	70.66%	99.96%
Dillingham	4,857	10	2,405	100.00%	100.00%
Kusilvak	8,368	9	2,342	100.00%	100.00%
Nome	10,046	17	4,095	100.00%	100.00%
North Slope	11,031	10	2,619	100.00%	100.00%
Northwest Arctic	7,793	11	2,717	100.00%	100.00%
Southeast Fairbanks	6,808	16	3,513	100.00%	100.00%
Yukon: Koyukuk	5,343	17	4,014	100.00%	100.00%

[1] U.S. Census Bureau (2023)

This report is available at no cost from NREL at www.nrel.gov/publications.

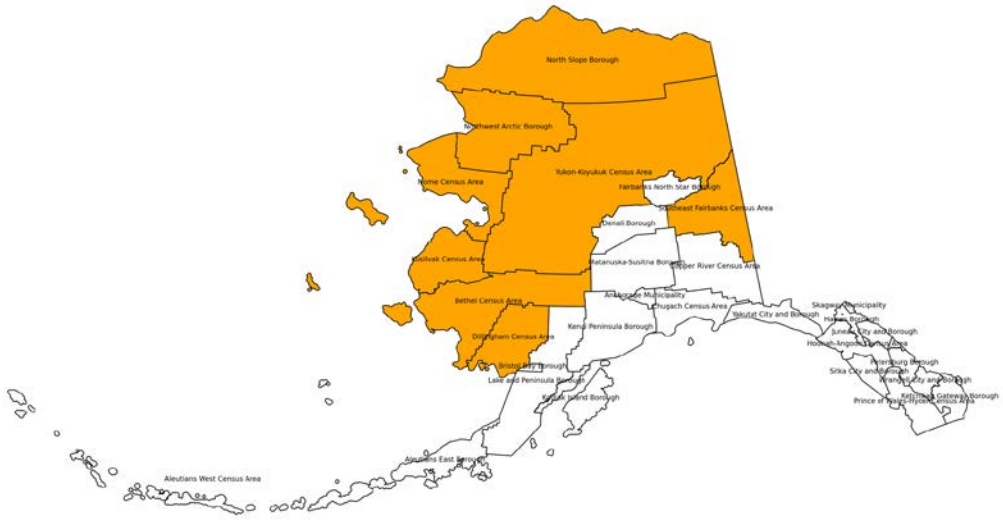

Figure 3. Boroughs and census areas selected from ResStock for the validation study

We selected these areas in ResStock to ensure a fair and accurate comparison with field data collected in rural areas within Climate Zone 8, specifically in the Nome census area. After the down-selection approach in ResStock, we cleaned and organized the datasets to ensure uniform nomenclature, with some variable options combined. For instance, for this study, under the variable "Windows," we aggregated options such as "Double Clear Metal," "Double Clear Non-Metal," and "Double, Low-E" into a single category named "Double pane." In the case of "Double, Clear, Non-metal, Storm," these were grouped with "Triple pane" windows. The same procedure was applied to "Roof material," where options such as "Wood, Asphalt, and Composition Shingles" were consolidated and named "Shingles." Similarly, for "Foundation type," "Unvented and Vented Crawlspaces" were merged into "Crawlspace," and "Unheated and Heated Basements" were combined into "Basement."

With the datasets cleaned and organized, we selected a total of 17 variables—11 categorical and 6 numerical—from ResStock and the field data for comparison. We selected these variables because of their compatibility across datasets and their potential impact on building energy simulations. For the categorical variables, we considered the following: building type, building orientation, heating fuel type, heating system type, water heater fuel type, window type, exterior wall type, exterior wall color, foundation type, roof material, and vacancy status. For the numerical variables, we selected the following: floor area, number of stories, vintage, infiltration (ACH50), heating setpoint, and number of occupants. We performed descriptive statistics (mean, median, standard deviation) to compare these quantitative characteristics. We used only four variables for the A3DDC because of its data collection limitations: building orientation, foundation type, roof material, and floor area. We visualized and compared the data using the Python packages 'matplotlib' for plotting, 'numpy' for numerical operations, and 'pandas' for data manipulation. Additionally, we employed the 'tabulate' package to present the results in a clean, readable table format.

Results and Analysis

We compared ResStock building stock data relative to the field and A3DDC data across the following building characteristics: building type, building orientation, water heater fuel type, heating fuel type, heating system type, window type, exterior wall type, exterior wall color, foundation type, roof material,

This report is available at no cost from NREL at www.nrel.gov/publications.

vacancy status, floor area, number of stories, vintage, infiltration (ACH50), heating setpoint, and number of occupants. Findings are often reported in percentages, which support comparisons across datasets, despite varying sample sizes (Dlugosz et al 2006).

Building Type

Five different building types are included in ResStock: single-family detached and attached, multifamily with 2–4 units, multifamily with 5+ units, and mobile homes. The base data for this characteristic comes from U.S. Department of Energy's Energy Information Administration (EIA)'s Residential Energy Consumption Survey at the state-level. For the field data, three different types were observed: single-family detached, single-family attached, and multifamily with 5+ units. The most common building type across both datasets is single-family detached homes (75.7% in ResStock and 84.6% in the field data), as shown in Figure 4. Overall, both datasets show alignment, indicating that ResStock effectively represents the distribution of building types within these rural communities.

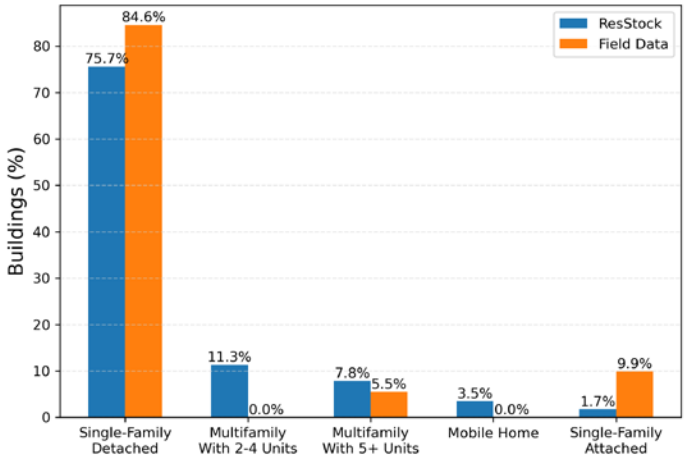

Figure 4. Comparison of building types: ResStock versus the field data

Building Orientation

Figure 5 compares building orientation across ResStock, field data, and A3DDC. Building orientation is defined as the front of the dwelling unit facing the street. The base data for this characteristic comes from the OpenStreetMap data queried by Radiant Labs at the city level. According to the field data and A3DDC, the highest number of buildings face south, followed by west. These results also indicate an underrepresentation of south-facing buildings and an overrepresentation of north-facing buildings in ResStock.

This report is available at no cost from NREL at www.nrel.gov/publications.

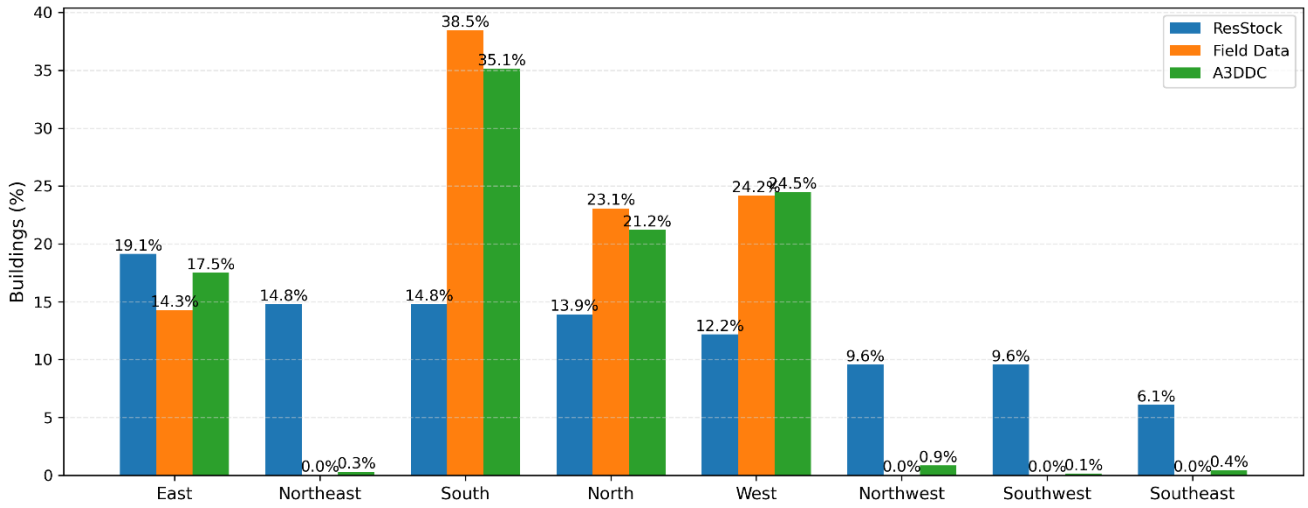

Figure 5. Comparison of building orientation: ResStock versus the field data and A3DDC

Water Heater Fuel Type

Figure 6 shows the comparison results for water heater fuel type between ResStock and the field data. The base data for this characteristic comes from the U.S. EIA 2020 Residential Energy Consumption Survey (RECS) microdata and for Alaska, the distribution is based on Alaska Retrofit Information System (2008 to 2022) maintained by Alaska Housing Finance Corporation. The main source used by water heaters in rural Alaska according to both datasets is oil. However, the field data reveals a higher percentage of households with fuel oil water heaters (82.4%) compared to ResStock (53.9%). Electricity is the second most common source of heating in both datasets, and in this case, ResStock states a higher percentage compared to the field data. ResStock also contains households that use natural gas, propane, and other fuel as an energy source for water heaters. These households are in five census areas and boroughs, including the North Slope (4 buildings), Nome (2 buildings), Yukon (2 buildings), Bethel (1 building), and Southeast Fairbanks (1 building). According to the Alaska Department of Natural Resources Division of Oil and Gas (Alaska Department of Natural Resources Division of Oil & Gas, 2023) and the National Pipeline Mapping System Public Viewer (U.S. Department of Transportation, 2003), only the North Slope borough contains natural gas pipelines. Therefore, natural gas could be the primary energy source for water heaters in this region, but this may not be the case for other regions. While ResStock includes information from an Alaskan database, it may still underrepresent households with fuel oil water heaters and overrepresent those with natural gas water heaters. This discrepancy could arise because, although rural Alaskan communities predominantly rely on fuel oil for water heating, larger cities in Alaska tend to use natural gas. As a result, the weighting of urban areas in the dataset may skew the overall representation toward natural gas systems.

This report is available at no cost from NREL at www.nrel.gov/publications.

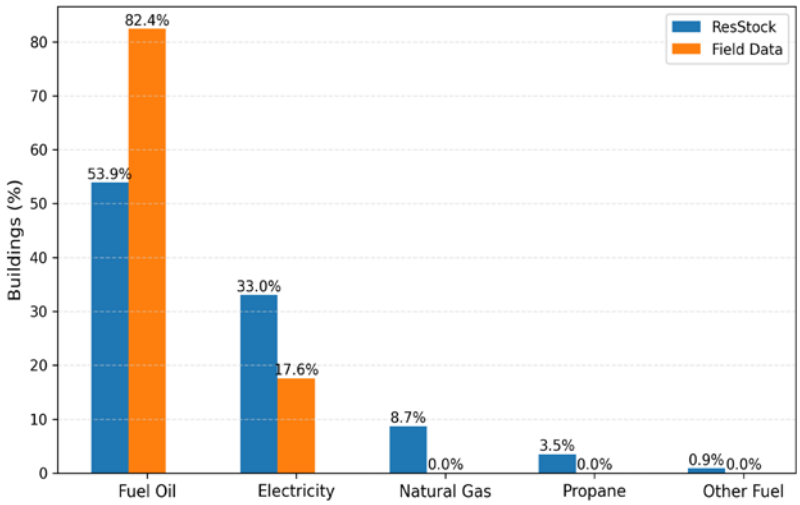

Figure 6. Comparison of water heater fuel type: ResStock versus the field data

Heating Fuel and System Type

The heating system and fuel type comparison is illustrated in Figure 7(a) and Figure 7(b), respectively. The base data for heating fuel and heating system type is derived from the U.S. EIA 2020 Residential Energy Consumption Survey (RECS) microdata. For Alaska, the distribution is based on the Alaska Retrofit Information System (2008 to 2022) maintained by Alaska Housing Finance Corporation. The field data reveals that there are two main heating system types, fuel oil boilers and direct-vent heaters (Toyostoves). When compared with ResStock, the number of fuel oil boilers aligns well with the field data (65.2% in ResStock and 60.5% in the field data) whereas Toyostoves, which account for 38.5% in the field data, are not represented in the ResStock dataset. This absence can be associated with the limited capability of current energy simulation tools used in ResStock to account for direct-vent heaters such as Toyostoves.

Regarding the heating sources used by households in rural Alaska, oil is the primary heating source observed in both datasets (84.3% in ResStock and 98.9% in the field data). While these communities rely on oil as the main source of heating, some households located in the North Slope borough also use natural gas, which is facilitated by the presence of natural gas pipelines—the only rural area in Alaska with such infrastructure. The North Slope area contains six of the 100 largest oil fields and one of the 100 largest natural gas fields in the United States (U.S. Energy Information Administration 2024).

Accurate information on heating systems and sources plays an important role because heating represents a significant cost for homes in Alaska. In Anchorage, the main source of heating is natural gas; in rural communities, oil is the primary source of heating (Kohler and Schutt 2012). Having a dataset in ResStock that accurately represents these communities allows for testing different upgrades and energy efficiency measures, as well as helping community leaders make more informed decisions based on their unique heating challenges.

This report is available at no cost from NREL at www.nrel.gov/publications.

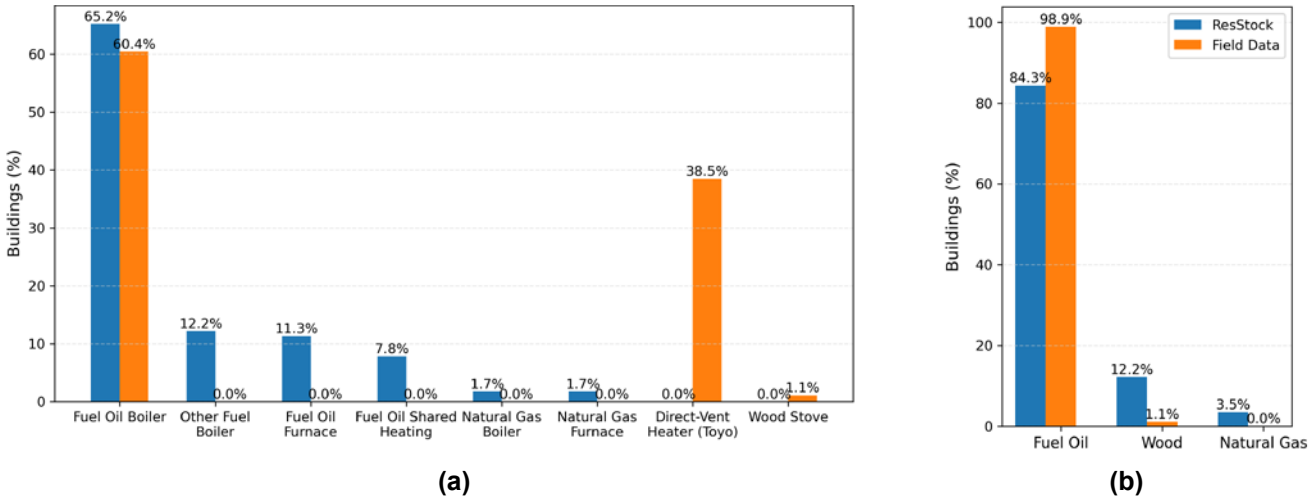

Figure 7. Comparison of heating systems (a) and fuel type (b): ResStock versus the field data

Window Types

Figure 8 presents the types of windows between datasets and their respective percentages. The base data for type of window comes from the U.S. EIA 2020 Residential Energy Consumption Survey (RECS) microdata, at the state level. The results indicate agreement between ResStock and the field data, with most observed window types being double pane. However, according to the field data, 17.6% of homes had triple-pane windows, whereas ResStock accounts for 9.6%. These findings could be associated with the fact that some of the assessed homes in the field data were retrofitted with more energy-efficient windows. Despite the differences, ResStock and the field data seem to align well in terms of window types.

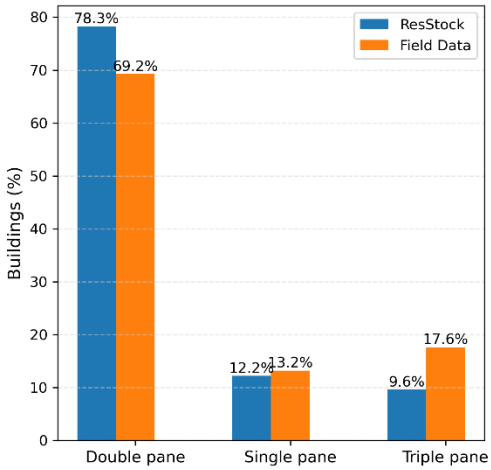

Figure 8. Comparison of window types: ResStock versus the field data

Exterior Walls Type and Color

Figure 9(a) and Figure 9(b) show the results of exterior wall finish type and color, respectively, between the two datasets. Regarding exterior wall finish type, wood is predominant in both ResStock (56.5%) and the field data (51.6%). However, the field data indicates nearly 40% of homes have vinyl as the exterior wall finish material, whereas ResStock only accounts for 4.3% using this material. These results suggest an underrepresentation of vinyl exterior wall finishes and potentially an overrepresentation of

This report is available at no cost from NREL at www.nrel.gov/publications.

brick and concrete walls without attached finish materials in ResStock. The ResStock base data for this characteristic comes from the Homeland Infrastructure Foundation-Level Data (HIFLD) database, at the individual parcel level.

We also observed a discrepancy in exterior wall colors between the two datasets. While the field data reveals more households with light-colored exterior walls, ResStock contains a higher percentage of medium- and dark-colored walls, followed by brick and concrete. Exterior wall materials and colors can affect the amount of heat absorption. In heating-dominated climates, darker-colored exteriors generally absorb more heat from the sun compared to lighter colors, and that can help increase the indoor temperatures in buildings and affect energy simulation results (Fernandez-Antolin, del-Río, and Gonzalez-Lezcano 2019).

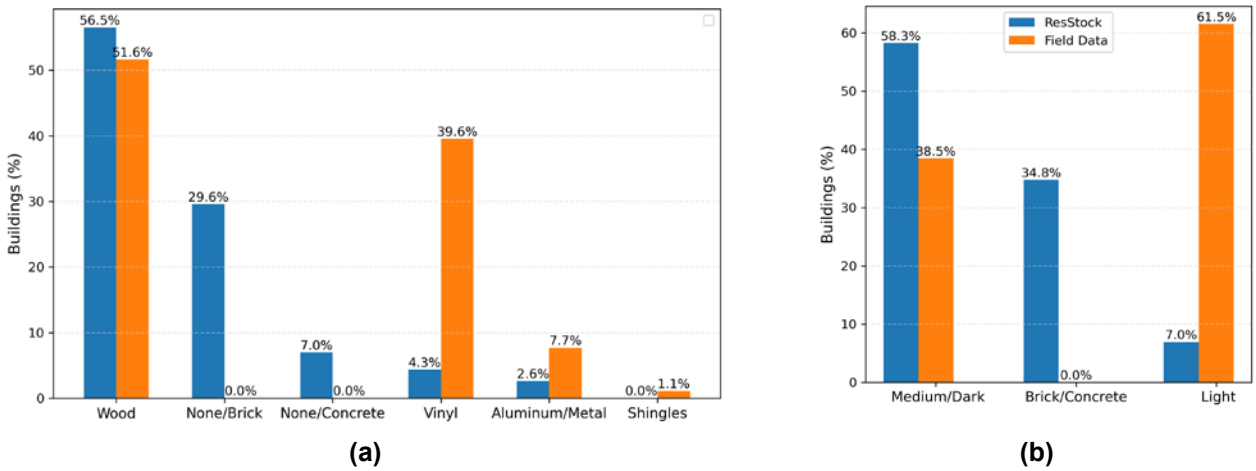

Figure 9. Comparison of (a) Exterior wall finish type, and (b) Color: ResStock versus the field data

Foundation Type

The different foundation types and their respective percentages are illustrated in Figure 10. The sample counts and sample weights from ResStock are constructed using U.S. EIA 2009 Residential Energy Consumption Survey (RECS) microdata. The results show an agreement between the field data and A3DDC, with a predominance of crawlspaces (82.4% and 80.7%, respectively), followed by slab on grade (11.0% in the field data and 18.5% in A3DDC). When comparing these results with ResStock, ResStock shows that many buildings have basements (40.0%). Considering that 80% of Alaska is underlain by permafrost, or permanently frozen ground, one of the greatest challenges is building foundations that can remain stable over time (Cold Climate Housing Research Center n.d.). Therefore, the most common foundation types observed in rural Alaska include crawlspaces, slab-on-grade, and "permafrost foundations" such as triodetic foundations or driven pilings. The results suggest that there may be an inaccurate distribution of foundation types across these communities in the ResStock dataset.

This report is available at no cost from NREL at www.nrel.gov/publications.

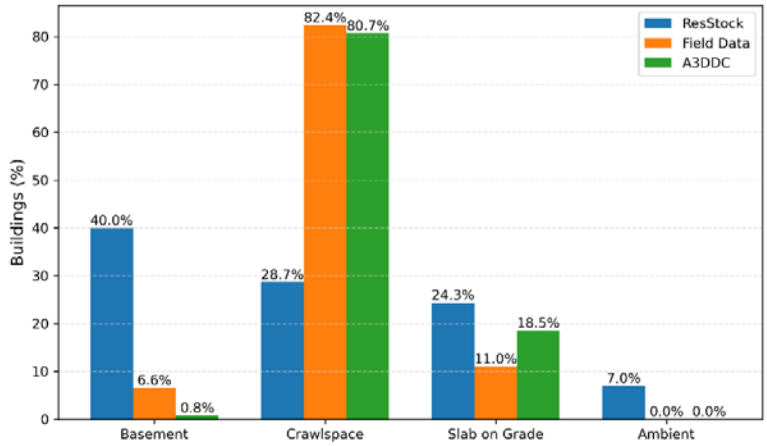

Figure 10. Comparison of foundation type: ResStock versus the field data and A3DDC

Roof Material

Figure 11 demonstrates a comparison of different roof materials across the datasets. The base data for roof material comes from the U.S. EIA 2020 Residential Energy Consumption Survey (RECS) microdata. The most common roof material observed in both the field data (95.6%) and A3DDC (93.3%) is metal, whereas in ResStock, it is shingles (74.8%). These findings suggest that metal roofs may be underrepresented in the ResStock datasets.

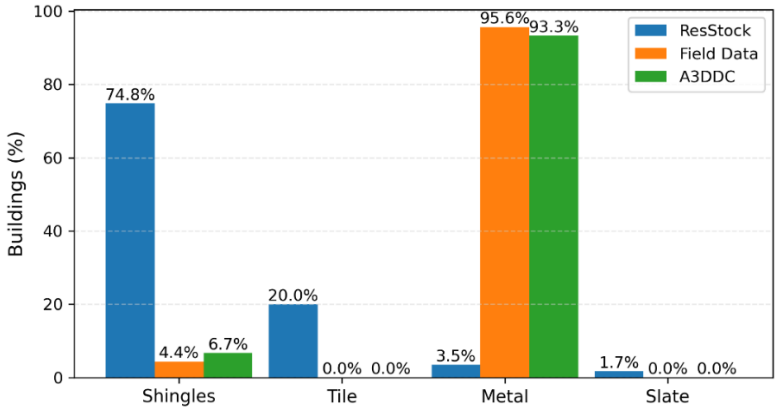

Figure 11. Comparison of roof material: ResStock versus the field data and A3DDC

Vacancy Status

Regarding vacancy status, both datasets, the field data and ResStock, show a larger number of buildings as occupied, 67.8% and 91.2%, respectively. The remaining homes, 32.2% (ResStock) and 8.8% (field data) are considered unoccupied. The ResStock base data for vacancy status comes from the 2019-5yrs Public Use Microdata Samples (PUMS). This could explain the observed discrepancy, as the PUMS dataset may not account for vacancy characteristics specific to Alaska, particularly rural Alaskan communities. Additionally, in Alaska, there are significant differences in vacancy patterns between urban areas, such as Anchorage and Fairbanks, and rural regions. Rural Alaskan communities often experience higher vacancy rates due to factors such as seasonal occupancy, economic challenges, and limited housing stock turnover. However, these nuances may not be well-represented in national datasets such as PUMS, which aggregate data across broader geographic regions and lack sufficient granularity for rural and remote areas.

This report is available at no cost from NREL at www.nrel.gov/publications.

Floor Area

Floor area is one of the most common modeling parameters considered in building energy simulation (Alrasheed and Mourshed 2024, Shen and Wang 2024). The base data for this characteristic comes from the 2017 and 2019 American Housing Survey (AHS) microdata. Figure 12 shows the distribution of floor area ranges in ResStock, the field data, and A3DDC. The most common building size range was 1000–1499 square feet across all datasets. Overall, results show alignment in floor area sizes among the datasets.

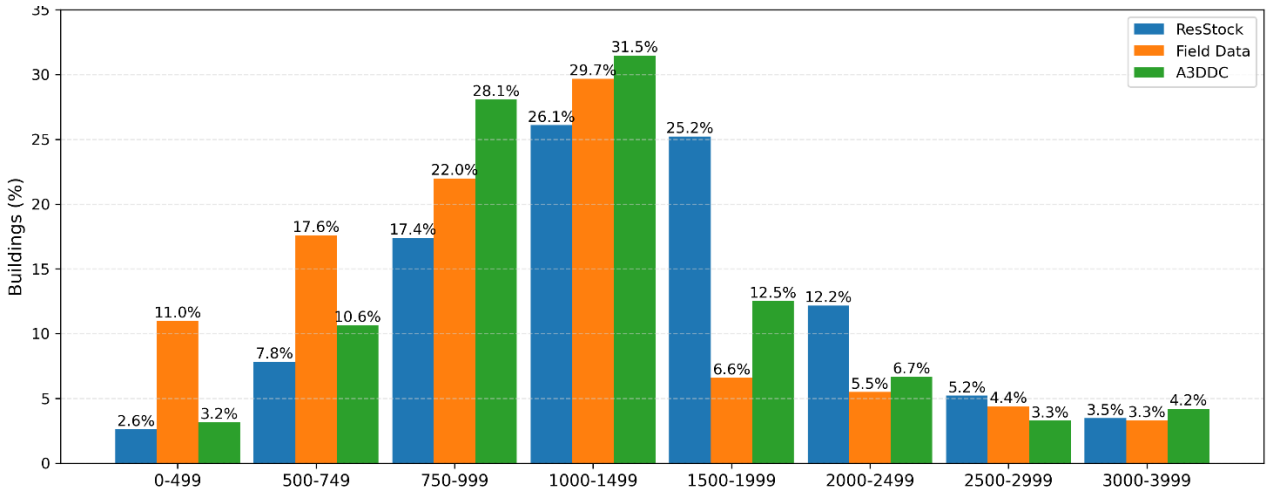

Figure 12. Comparison of floor area: ResStock versus the field data and A3DDC

Number of Stories

Figure 13 represent both multifamily and single-family homes. The base data for number of stories comes from the U.S. EIA 2009 Residential Energy Consumption Survey (RECS) microdata. One-story buildings are the most observed across datasets, accounting for 57.4% in ResStock and 73.6% in the field data. The 0.9% for a 21-story building (multifamily with 326 units) represented in ResStock, located in the Nome census area, may not accurately reflect the reality of that location.

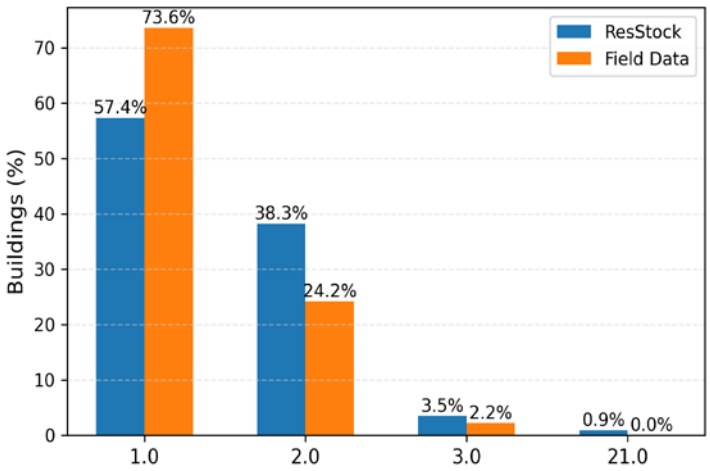

Figure 13. Comparison of number of stories: ResStock versus the field data

This report is available at no cost from NREL at www.nrel.gov/publications.

Vintage

Vintage represents the period in which the building was constructed. Figure 14 presents the results of vintage by decades between the two datasets. While the field data appears to identify more newer buildings (constructed after the 2010s) compared to the ResStock dataset, overall, there is alignment in terms of vintage. The highest number of homes were built in the 1980s, followed by the 1970s.

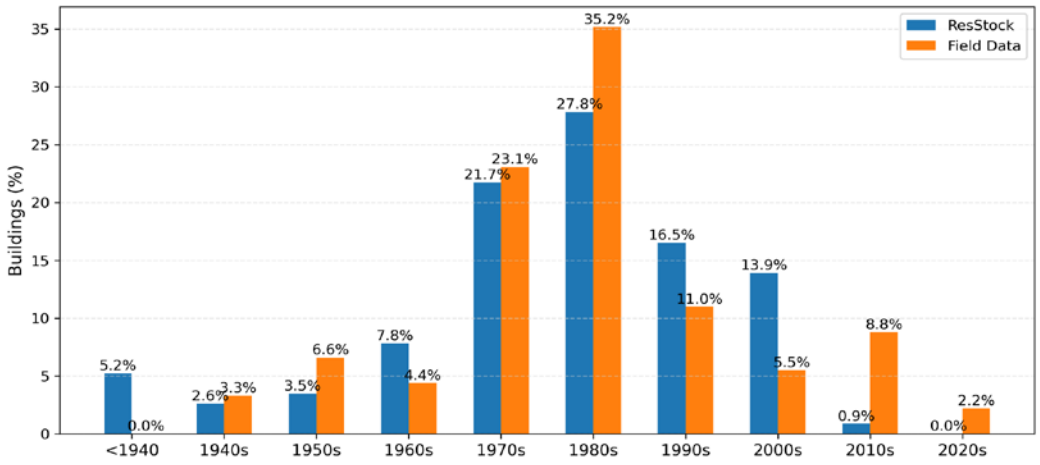

Figure 14. Comparison of vintage: ResStock versus the field data

Infiltration Rates

Infiltration rates from ResStock and the field data, represented by ACH50, are summarized in Table 5. The base data for infiltration rates in ResStock are based on the cumulative distribution functions from the Residential Diagnostics Database (ResDB) and Alaska specific distribution is based on Alaska Retrofit Information System (2008 to 2022) maintained by Alaska Housing Finance Corporation. Additionally, Figure 15 provides a graphical illustration of these rates, offering a visual comparison to enhance the descriptive statistics presented. According to the field data, most homes (62.7%) had infiltration rates of 6 ACH50 or higher, while in ResStock, most homes (70.4%) are reported to have infiltration rates of 5 ACH50 or lower. The ResStock dataset primarily derives its infiltration rates from ARIS at census tract level, which also includes data on homes participating in weatherization programs. This data may also include administrative records of homes that have not undergone retrofitting, where a few higher ACH50 values might be observed. The average ACH50 for buildings in ResStock is 5.06 ACH50 and in the field data the average is 7.35 ACH50. Overall, ResStock may be biased toward lower ACH50 values.

This report is available at no cost from NREL at www.nrel.gov/publications.

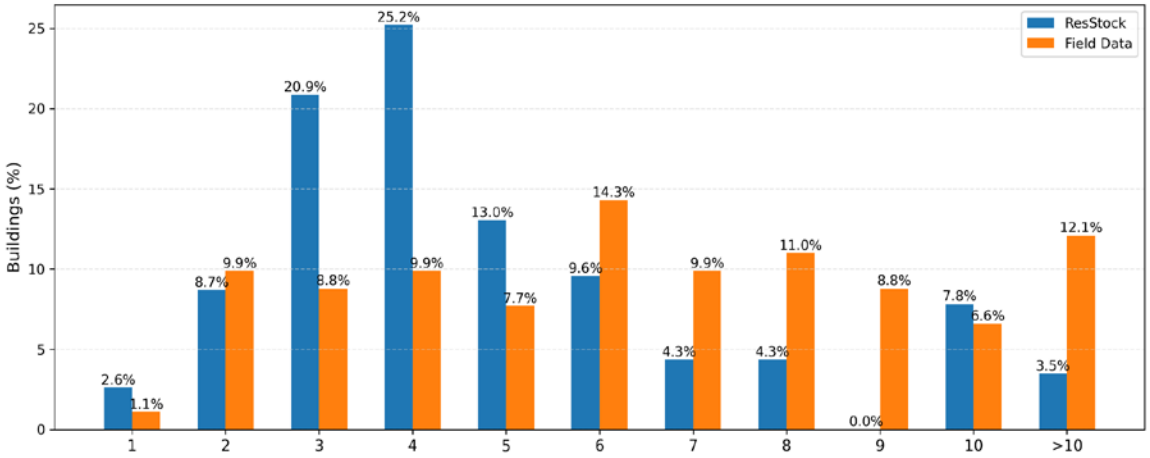

Figure 15. Comparison of infiltration rates: ResStock versus the field data

Table 5. Descriptive Statistics for Infiltration Rates

Descriptive Statistics	ResStock[1]	Field Data
	Value (ACH50)	Value (ACH50)
Mean	5.06	7.35
Standard deviation	3.09	4.45
Median	4.00	6.00
Min	1.00	1.00
Max	20.00	31.80

[1] Data sourced from rural Alaskan communities as represented in the ResStock, following the down selecting approach described in the Methodology section

Heating Setpoint and Indoor Temperature

Figure 16 shows the comparison between heating setpoints (ResStock) and the average indoor temperature measured by long-term sensors installed inside 47 homes in Alaska (field data). The duration of indoor temperature collection depended on the sensor installation date, ranging from 6 months to 1 year of data and therefore accounting for different seasons throughout the year. Indoor temperatures were used to compare heating setpoints because temperature is usually regulated by the heating system. Results from the field data reveal a tendency toward higher temperatures inside homes in rural Alaska. Most homes (40.4%) had average indoor temperatures in the range of 70–74°F. In contrast, the ResStock dataset reports many homes with heating setpoints around 55–59°F. The base data for heating setpoint in ResStock comes from the U.S. EIA 2020 Residential Energy Consumption Survey (RECS) microdata. All homes reported with temperatures ranging from 55 to 59°F in ResStock are unoccupied (vacancy status = vacant). When these vacant homes are removed from the dataset, the resulting distribution of temperatures for the remaining occupied homes becomes more representative of typical residential heating patterns, but still the field data shows higher heating temperatures being set by households in rural Alaskan communities compared to ResStock. The average heating setpoint for

This report is available at no cost from NREL at www.nrel.gov/publications.

ResStock is then 70.3°F, closer to the one observed in the field data collected. Adjusting the vacancy status in ResStock to more accurately reflect occupancy patterns may be an alternative approach to better align the heating setpoints with the observed behaviors in these communities.

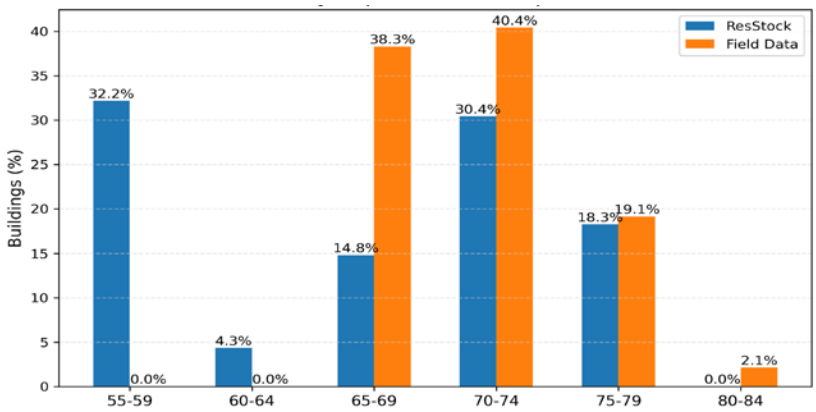

Figure 16. Comparison of heating setpoints and indoor temperature: ResStock versus the field data

Table 6 reports the descriptive statistics for heating setpoint and indoor temperature between the two datasets. The average indoor temperature (field data) observed is 71.15°F, and the average heating setpoint (ResStock) is 65.38°F. The minimum values vary from 55°F in ResStock to 65°F in the field data. Although the field data is based on a yearly or 6-month average, summer daytime temperatures in Alaska typically range from 55 to 70°F, which are unlikely to significantly impact the results of this comparison that uses heating setpoints as the metric.

Table 6. Descriptive Statistics for Heating Setpoints and Indoor Temperature

Descriptive Statistics	ResStock[1]	Field Data
	Heating setpoint (°F)	Avg. indoor temperature (°F)
Mean	65.38	71.15
Standard deviation	7.84	3.61
Median	68.00	71.00
Min	55.00	65.00
Max	76.00	80.00

[1] Data sourced from rural Alaskan communities as represented in the ResStock, following the down selecting approach described in the Methodology section

Number of Occupants

Figure 17 illustrates the results of the number of occupants per household between datasets. The field data reveals that over 75% of households have two or more occupants, while ResStock reports 32.2% of unoccupied homes and 33.0% two-person households. The base data for number of occupants in ResStock comes from the 2019-5yrs Public Use Microdata Samples (PUMS). Like heating setpoints, when removing vacant dwellings, the distribution becomes more representative of typical residential

This report is available at no cost from NREL at www.nrel.gov/publications.

heating patterns, but ResStock has an average number of occupants of 2.20, with 70.5% of homes with 1 or 2 occupants.

Rural Alaska homes face several housing and behavioral challenges, including overcrowding. The rates of overcrowding in every region of Alaska are higher than the rest of the United States (Association of Alaska Housing Authorities n.d.). According to the 2018 Alaska Housing Assessment conducted by Cold Climate Housing Research Center, 37% of homes in the Bering Straits region are overcrowded (Alaska Housing Finance Corporation 2018). Considering this and the comparison results, ResStock may be underestimating the number of occupants in residential buildings.

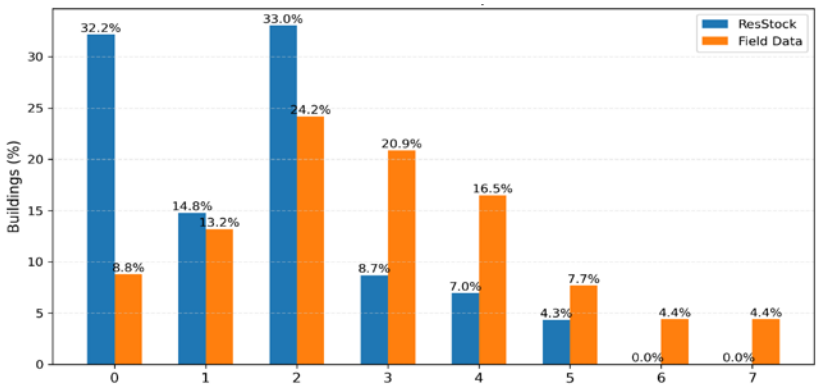

Figure 17. Comparison of number of occupants: ResStock versus the field data

Table 7 presents the descriptive statistics for occupancy between the two datasets. The average number of occupants identified in the field data is 2.85, whereas in ResStock, this number is 1.56. Additionally, the maximum number of occupants differs by 2, because the field data findings include homes with up to 7 people living in them.

Table 7. Descriptive Statistics for Number of Occupants

Descriptive Statistics	ResStock[1]	Field Data
	Number of occupants	Number of occupants
Mean	1.56	2.85
Standard deviation	1.42	1.77
Median	2.00	3.00
Min	0.00	0.00
Max	5.00	7.00

[1] Data sourced from rural Alaskan communities as represented in the ResStock, following the down selecting approach described in the Methodology section

Conclusions

Data on rural areas and Indigenous populations has been limited, leading to their underrepresentation in nationwide datasets. Access to this information is important for accurately modeling residential

This report is available at no cost from NREL at www.nrel.gov/publications.

buildings and identifying energy-efficient solutions across diverse populations and building types throughout the United States, including those in typically underrepresented areas. Based on that, this validation study aimed to identify similarities and differences across ResStock, the field data, and A3DDC datasets in rural areas in Alaska. ResStock is an excellent tool for modeling stock and testing energy efficiency upgrades, and it has significantly improved since the integration of ARIS data for the state of Alaska. A summary of the findings is reported below, along with possible next steps and implications for revisions described in the following section.

Among the categorical variables we analyzed, our findings suggest that ResStock may be underrepresenting south-facing buildings and overrepresenting north-facing buildings. Regarding heating equipment, Toyostoves account for 38.5% in the field data but are not represented in the ResStock dataset, possibly because of the limited capability of current energy simulation tools used in ResStock to account for direct-vent heaters such as Toyostoves. The field data also revealed a higher prevalence of vinyl exterior wall finish materials and lighter-colored walls compared to the ResStock dataset. Additionally, the field data shows a higher percentage of crawlspaces as the foundation type, whereas ResStock contains more buildings with basements. Because 80% of Alaska is underlain by permafrost, the presence of basements in homes is unlikely. Roof material is another characteristic that differs between datasets, with ResStock indicating more shingled roofs and the field data showing more metal roofs.

Among the numerical variables, infiltration rates are shown to be lower in ResStock compared to the field data. This could be attributed to the fact that ARIS data, integrated into ResStock, includes mostly data on homes that participated in weatherization programs, potentially resulting in more energy-efficient features being represented. Heating setpoints also report lower values in ResStock compared to the field data. A similar trend is observed for the number of occupants, where ResStock reports lower averages of persons per household.

Next Steps and Implication for Revisions

Based on this validation study, we identified some differences between modeled, field data, and A3DDC datasets. The following building characteristics have a high impact on modeled energy consumption and demonstrated large differences:

- **Heating setpoints.** The average heating setpoint in ResStock is lower than the average observed in the field data. Revisit distributions and consider higher setpoints, which could potentially address missing loads if found to be the case.
- **Toyo heating**. Toyo heating is currently missing from ResStock, but prevalent in field data collected. Develop and include Toyo heating in future modeling for ResStock and EnergyPlus.
- **Natural gas**. Natural gas is not readily available in rural Alaska apart from the North Slope. Remove natural gas as a water heater fuel type outside of North Slope County.
- **Foundation type**. Field and A3DDC data show that 80% of dwellings have crawlspaces in rural Alaska, while ResStock shows only 28.7% of dwellings have crawlspaces and 40% of dwellings have basements. Revisit distributions and consider more crawlspaces than basements.
- **Infiltration rates**. The average infiltration rate is 5.06 ACH50 in ResStock, approximately 30% lower than the average field data, 7.35 ACH50. Reevaluate the distribution to consider higher infiltration rates.

This report is available at no cost from NREL at www.nrel.gov/publications.

- **Exterior wall type**. Field data has revealed the predominancy of wood and vinyl light colored walls, while ResStock shows a predominancy of wood and brick medium/dark colored walls. Include more vinyl and less brick, and revise wall color for greater proportion of light than dark.
- **Roof material**. Field and A3DDC data show that 93% of dwellings have metal roofs in rural Alaska, while approximately 75% of dwellings in ResStock have shingles. Revise from majority shingles to majority metal roofing material.
- **Occupant count**. Occupancy rates in field data are 2.85 persons/dwelling, compared to 2.20 persons/dwelling in ResStock. Update to higher occupant count.
- **Building orientation**. Field and A3DDC shows approximately 35% of dwellings are south facing, while ResStock follows a normal distribution. Update to represent a higher proportion of south-facing than relatively equal south- and north-facing.

The findings suggest that the probability logic in ResStock could be revised to better represent the building stock in rural areas in Alaska. ResStock can be used to identify effective upgrades or energy efficiency improvements to address specific challenges faced by these communities. Additionally, it will help community leaders make more informed decisions regarding investments and solutions.

This report is available at no cost from NREL at www.nrel.gov/publications.

References

Alaska Department of Natural Resources Division of Oil & Gas. https://dog.dnr.alaska.gov/Services/Pipelines/Filter

Alaska Housing Finance Corporation. "Alaska Housing Assessments." https://www.ahfc.us/pros/energy/alaska-housing-assessment

Alaska Housing Finance Corporation. 2015. "Energy Efficiency Programs and Resources Overview." https://www.energy.gov/sites/default/files/2015/12/f27/Session1-Ord-AHFC overview.pdf

Alaska Housing Finance Corporation. 2018. "Rural overcrowding: A different view of homelessness."

Alaska Housing Finance Corporation. 2022. "Empowering Alaska Borrowers with Information to Save Money." https://www.ahfc.us/blog/posts/empowering-alaska-borrowers-information-save-money

Alrasheed, M., and M. Mourshed. 2024. "Building stock modeling using k-prototype: A framework for representative archetype development." *Energy and Buildings* Volume 311, 114111.

American Council for an Energy Efficiency Economy. "Residential Codes: Alaska." https://database.aceee.org/state/residential-codes

Association of Alaska Housing Authorities. "An Overview of Alaska's Housing Shortage."

Census Reporter. 2022. "Alaska: Unalakleet, Nome, and Quinhagak." Based on 2022 American Community Survey 5-year data. https://censusreporter.org/

Cold Climate Housing Research Center. "Foundations. Crawlspace Foundation, On-grade Foundations, Permafrost Foundations."

Dlugosz, J., R. Fahlenbrach, P. Gompers, and A. Metrick. 2006. "Large blocks of stock: Prevalence, size, and measurement." *Journal of Corporate Finance* Volume 12, 3: 594–618.

Evans-Lomayesva, Gwynne, Jae June Lee, and Cara Brumfield. 2022. "Advancing American Indian & Alaska Native Data Equity: Representation in Federal Data Collections." Georgetown Center on Poverty and Inequality. https://www.georgetownpoverty.org/issues/advancing-american-indian-alaska-native-data-equity/

Fernandez-Antolin, Maria-Mar, José-Manuel del-Río, and Roberto-Alonso Gonzalez-Lezcano. 2019. "Influence of Solar Reflectance and Renewable Energies on Residential Heating and Cooling Demand in Sustainable Architecture: A Case Study in Different Climate Zones in Spain Considering Their Urban Contexts." *Sustainability* 11(23): 1–31. https://doi.org/10.3390/su11236782

Gioppo, Z., J. Cooper, C. M. Kiesling, P. Guillante, and K. Cetin. 2024. "Remote Data Collection Methods to Determine Housing Characteristics in Rural Alaskan Communities." In Proceedings of the 7th Residential Building Design & Construction Conference, State College, Pennsylvania.

This report is available at no cost from NREL at www.nrel.gov/publications.

Guillante, P., C. M. Kiesling, J. Cooper, Z. Gioppo, K. Cetin, and C. Poleacovschi. 2024. "Development of a Prototype Energy Modeling Framework for Residential Buildings in Rural Alaska." In Proceedings of the Eleventh National Conference of IBPSA-USA, Denver, Colorado.

Hossain, Y., P. A. Loring, and T. Marsik. 2016. "Defining energy security in the rural North—Historical and contemporary perspectives from Alaska." *Energy Research and Social Science* 16, 89–97.

Hunter, J. D. 2007. "Matplotlib: A 2D Graphics Environment," *Computing in Science & Engineering* Volume 9, no. 3: 90–95.

Kluyver, Thomas, Benjain Ragan-Kelley, Fernando Pérez, Brian Granger, Matthias Bussonnier, Jonathan Frederic, Jessica Hamrick, et al. 2016. Jupyter Notebooks—a publishing format for reproducible computational workflows. In F. Loizides and B. Schmidt (Eds.), *Positioning and Power in Academic Publishing: Players, Agents and Agendas*: 87–90.

Kohler, M., and E. Schutt. 2012. "Energy for a Sustainable Alaska: The Rural Conundrum. A Commonwealth North Study Report."

McKinney, Wes, and others. 2010. "Data structures for statistical computing in python." In Proceedings of the 9th Python in Science Conference Volume 445: 51–56.

National Renewable Energy Laboratory. "Public Datasets: ResStock Dataset 2024.2." https://resstock.nrel.gov/datasets

National Renewable Energy Laboratory. "ResStock Analysis Tool." https://www.nrel.gov/buildings/resstock.html

National Renewable Energy Laboratory. 2024. "Integrate ARIS data." GitHub. https://github.com/NREL/resstock/pull/1214

National Science Foundation. 2022. "NNA Research: Collaborative Research: Responding to Energy Insecurity in Arctic Housing Using a Community-Based Participatory Research." https://www.nsf.gov/awardsearch/showAward?AWD_ID=2220236&HistoricalAwards=false

NeighborWorks Alaska Organization. "Anchorage Housing Survey." https://nwalaska.org/programs-events/community-engagement/anchorage-housing-survey

Robinson, D., E. Hunsinger, E. Sandberg, and L. Brooks. 2021. "Alaska Population 2021 Estimates." Alaska Department of Labor and Workforce Development. https://live.laborstats.alaska.gov/pop/

Shen, P., and H. Wang. 2024. "Archetype building energy modeling approaches and applications: A review." *Renewable and Sustainable Energy Reviews* Volume 199, 114478.

U.S. Census Bureau. "American Community Survey (ACS)." https://www.census.gov/programs-surveys/acs

U.S. Census Bureau. "American Housing Survey (AHS)." https://www.census.gov/programs-surveys/ahs.html

This report is available at no cost from NREL at www.nrel.gov/publications.

U.S. Census Bureau. 2023. “Urban and Rural: County-level Urban and Rural information for the 2020 Census.” https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural.html

U.S. Department of Agriculture. 2017. “Alaska Rural Homeownership Resource Guide.” https://www.frbsf.org/community-development/files/alaska-rural-homeownership-guide.pdf

U.S. Department of Transportation. National Pipeline Mapping System (NPMS) Public Viewer. https://pvnpms.phmsa.dot.gov/PublicViewer/

U.S. Energy Information Administration. “Residential Energy Consumption Survey (RECS).” https://www.eia.gov/consumption/residential/

U.S. Energy Information Administration. 2024. Alaska State Profile and Energy Estimates.

U.S. Office of Energy Efficiency and Renewable Energy. “Building Energy Codes Program: State Energy Code Methodology: Alaska.” https://www.energycodes.gov/status/states/alaska

This report is available at no cost from NREL at www.nrel.gov/publications.