Alaska Emissions Reduction Quantification(s)

Detailed process descriptions for the analysis of energy savings and emissions reduction from efficiency and electrification strategies across the State of Alaska.

Date: 03/15/2024

Technical Appendix

AHFC Weatherization Assistance Program and Energy Rebate Program

MEASURE 1: WEATHERIZE 3,200 RESIDENTIAL HOMES

Reference Case

The building stock data was taken from the ARIS dataset, containing approximately 188,000 building records. From this dataset, the following fields were used to construct a baseline model of each building:

- CeilingHeight
- DryerFuel
- FloorAreaTotal
- HomeZip
- HouseType
- Occupants
- OvenFuel
- RangeFuel
- YearBuilt
- HtgSysEffic
- NaturalACH
- CoolingSystem_IsPresent
- Ventilation_VentType
- Appliances (Cost)
- DHW (cost)
- Space (cost)

The last three fields (the cost fields) are used to calibrate each building model, while the other fields set physical aspects of the model.

The 188,000 models are constructed in EnergyPlus, the industry standard building energy simulation tool, using the automatic generation capability of the Constellation Navigator software. All building data not contained in ARIS (not in the fields stated above) is applied by using the most applicable of the approximately 1,000 representative building energy models developed by NREL, PNNL, and DoE. The most applicable data source for each building was determined by comparing the year of construction, zip code, building type, and heating fuel (as assumed from other fuels in the building). Information taken from this set includes footprint aspect ratio, lighting types, and other fields not included in the ARIS set.

It is planned to calibrate the reference case to measured historical utility fuel delivery quantities at the state level. This is accomplished by joining the ARIS buildings with the AK PARCEL AND LOT set to ensure all residential buildings in the state are represented. This step ensures that models at the building level are not over- or under-estimating any fuel usage, and it also helps us refine the assumptions made for heating fuel at the building level.

Measure-specific implementation assumptions

Weatherization is taken to mean upgrades to the envelope of the building to reduce energy consumption. Included in this is window, wall, and roof insulation levels and leakage. The levels of insulation and other attributes of the upgrade-scenario are described in the next section.

In the implementation of this measure, it's assumed that the space exists to install the levels of insulation modelled, which in some cases requires the extension of the depth of the walls. For the roof insulation, the assumption of an existing unheated attic was also used.

The upgrade-scenario was modelled for each of the 188,000 buildings in ARIS using the EnergyPlus models created for the baseline case. The energy usage of the reference case scenario and the upgrade-scenario were compared, determining energy savings resulting from the upgrade. Absolute (non-normalized) savings was then sorted and the highest saving buildings were selected to produce the final set of 3,200 homes. It is planned to sort based on a more holistic metric in the next round of results, a metric such as the yearly cost of emissions reduction "$/tonCO2e", calculated over the lifetime of the unit and normalized per year.

Measure-specific activity data

The following weatherization models were run on the residential home categories. Envelope air tightness is reduced to 0.25 cfm/sf as specified by ASHRAE 198 2020 p88, section 10.6, as well as insulation and window upgrades.

For the latter, external post insulation on the walls and roof is added to reach the U-value specified by ASHRAE 90.2 (Table 7-1, p11) for the climate zone. Windows and glass doors are replaced with windows having U-values and SHGCs taken from ASHRAE 90.2 (Table 7.1, p11) envelope tables. Infiltration is reduced to 0.01 cfm/ft2 for the window portion of the walls (ref: Alpen TR-11 PH+ sales material). DoE Cost-Effective Levels were used, instead of ASHRAE 189, with Attic / Ceiling: R60, Wall: R27 and Floor: R30.

No changes in Window U-value: (no change) but window SHGC: 0.6-0.65 (Alaska Housing Finance Corp)

Source : https ://www.insulate.org/Insulation-By-Climate-Zone.pdf

Models/Tools used

- Constellation Navigator automatic energy model processing: used to create reference case models, upgrade-scenario models, and compare them using the below datasets and models on baseline energy and emissions based on building parameters from parcel data as well as PNNL prototype models, augmented by ARIS datasets before applying factors from AKWarm.
- AK PARCEL AND LOT dataset: used to attain high-level building characteristics for all buildings in Alaska (the residential set was used for this analysis). Square footage, year built and building types were gathered for all boroughs and census areas in the State for 2022 tax year.
- PNNL Residential Prototype Models: used as a source of data for building characteristics that do not exist in the building-specific datasets, including EnergyPlus model input files (.idf) and corresponding output files (.htm) across all climate locations, as well as ANSI/ASHRAE/IES Standard 90.1 Prototype Building Models, IECC Prototype Building Models as well as TMY3 Weather Files
- AKWarm: AkWarm is a tool with a wide range of Alaska-specific pre-loaded databases for weather, fuel, utility, and material costs in more than 200 locations. The application enables the creation of house data files, analyze energy use and calculate design heat load and make changes to the description of any energy component. This tool helps to compare energy performance and energy costs as well as compute the savings of individual energy-conservation measures. It also enables to illustrate compliance with Alaska Housing's Building Energy Efficiency Standard and others. Energy cost data is used to convert the cost fields in ARIS to energy usage.
- ARIS dataset: This platform used for building-level details as described in the reference case section. The Alaska Retrofit Information System (ARIS) is an internet-based platform developed by the Alaska Housing Finance Corporation (AHFC) to meet the requirement outlined in Alaska Sustainable Energy Act (SB220 Chapter 83 SLA10) requiring Office of Management and Budget (OMB) to "work with state agencies to develop a standardized methodology to collect and store energy consumption and expense data" (AS 37.07.040 (12)).
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GHG Reduction Estimate Method:

The difference between the reference (base) case and the modeled changes in energy due to the modeled adoption of measures discussed above, is the activity data being used to estimate the reduction in GHG. For example, after buildings are simulated using the tools and assumptions above, the estimated reduction or increase in different types of fuels, such as natural gas, coal, liquid fuels or electricity, is converted from MMBTU or its energy equivalents, into MT CO2e using the corresponding emission factors for that fuel type, across the constituent CO2, CH4 and N2O. Next, EPA's 2022 GWP values are used to convert to each MT per GHG type into aggregated annual MT CO2e – using 1 for CO2, 298 for N2O and 25 for CH4. Whenever appropriate, the emission factors of electricity, is matched using the community the buildings are in, and either the PCE based emission factors, or the grid-rates for the sub-region.

Source: https://www.epa.gov/system/files/documents/2022-04/ghg_emission_factors_hub.pdf

GHG Reduction Estimate Assumptions: The quantification does not assume any impacts of "joint strategies" – that is, the simultaneous impact of multiple projects at a single location. In other words, if a project analyzes the reduction of grid emissions based on upstream integration of renewable energy, the new emission factors of electricity are not being used to measure the impact of electrification or efficiency of end-use equipment, as stated above. Instead, the reference emission factors will be used. Similarly, if competing efficiency projects are modeled such that they are not additive, but are substitutes of each other, the extent of overlap is not being modeled or predicted. Additionally, the baseline models assume annualized load profiles – and actual building performance may differ, such as from partial usage or occupancy, etc. Lastly, there are no weather normalizations done on either the activity of the reference scenario or modeled measures.

GHG Emissions Reduced:

Measure 1 Using the figures of 400 homes receiving additional weatherization in 2025, 500 in 2026, 700 in 2027, 800 in 2028, 800 in 2029 for a cumulative total of 3,200 homes throughout the state receiving weatherization retrofits, the annual CO2e reduction will be 21,488 Metric tons, with a cumulative reduction of 78,5656 in metric tons between 2025 and 2030.

AHFC Measure 1: 3200 Homes Weatherized					
Annual Homes	Cumulative homes	Goal	Percent Implemented	CO2e Reduction (Annual Metric Ton)	CO2e Reduction Cumulative reduction
400	400	3200	13%	2,686.00	2,686.00
500	900	3200	28%	6,043.50	8,729.50
700	1600	3200	50%	10,744.00	19,473.50
800	2400	3200	75%	16,116.00	35,589.50
800	3200	3200	100%	21,488.00	57,077.50
				21,488.00	**78,565.50**

Measure 1: Extrapolating the data through 2050, with the annual reduction across 3,200 homes through the following 25 years would be 508,326 metric tons of C02E reduced.

GHG Emission Reduction Calculations: See attached technical appendix with linked Spreadsheet.

MEASURE 2 & 3: DEEP RETROFIT FOR 1,800 HOMES

Reference Case

The building stock data was taken from the ARIS dataset, containing approximately 188,000 building records. From this dataset, the following fields were used to construct a baseline model of each building:

- CeilingHeight
- DryerFuel
- FloorAreaTotal
- HomeZip
- HouseType
- Occupants
- OvenFuel
- RangeFuel
- YearBuilt
- HtgSysEffic
- NaturalACH
- CoolingSystem_IsPresent
- Ventilation_VentType
- Appliances (Cost)
- DHW (cost)
- Space (cost)

The last three fields (the cost fields) are used to calibrate each building model, while the other fields set physical aspects of the model.

The 188,000 models are constructed in EnergyPlus, the industry standard building energy simulation tool, using the automatic generation capability of the Constellation Navigator software. All building data not contained in ARIS (not in the fields stated above) is applied by using the most applicable of the approximately 1,000 representative building energy models developed by NREL, PNNL, and DoE. The most applicable data source for each building was determined by comparing the year of construction, zip code, building type, and heating fuel (as assumed from other fuels in the building). Information taken from this set includes footprint aspect ratio, lighting types, and other fields not included in the ARIS set.

It is planned to calibrate the reference case to measured historical utility fuel delivery quantities at the state level. This will be accomplished by joining the ARIS buildings with the AK PARCEL AND LOT set to ensure all residential buildings in the state are represented. This step will ensure that models at the building level are not over- or under-estimating any fuel usage, and it will also help us refine the assumptions made for heating fuel at the building level.

Measure-specific implementation assumptions

For envelope assumptions, we considered weatherization, which is taken to mean upgrades to the envelope of the building to reduce energy consumption. Included in this is window, wall, and roof insulation levels and leakage. The levels of insulation and other attributes of the upgrade-scenario are described in the next section.

In the implementation of this measure, it’s assumed that the space exists to install the levels of insulation modelled, which in some cases requires the extension of the depth of the walls. For the roof insulation, the assumption of an existing unheated attic was also used.

The upgrade-scenario was modelled for each of the 188,000 buildings in ARIS using the EnergyPlus models created for the baseline case. The energy usage of the reference case scenario and the upgrade-scenario were compared, determining energy savings resulting from the upgrade. Absolute (non-normalized) savings was then sorted and the highest saving buildings were selected to produce the final set of 3,650 homes. It is planned to sort based on a more holistic metric in the next round of results, a metric such as the yearly cost of emissions reduction “$/tonCO2e”, calculated over the lifetime of the unit and normalized per year.

For heat pump installation assumptions, particularly in terms of the replacement of a warm-air furnace with an air-source heat pump, it is assumed that the building has a suitable location for an outdoor condensing unit. With the unit, a suitable control system will need to be installed. No changing of the warm air distribution system is modelled.

In the replacement of a boiler with a ground-source heat pump, it is assumed that the property on which the building is located is conducive to the installation of enough bores to cover the heating load of the building. This assumption will need to be verified on a case-by-case basis. For the replacement of the boiler with an air-to-water heat pump, the assumption is made that the building has a suitable location for an outdoor condensing unit. For both cases, a suitable control system will need to be installed. These installations are assumed to not change the water distribution system in the building, so these heat pumps provide water at a high enough temperature to not require any radiator replacements. A separate measure has also been modelled in which floor-heating systems are installed, but it does not contribute to this analysis.

To filter 2833 out from the whole set, absolute (non-normalized) savings was sorted and the highest saving buildings were selected to produce the final set of 3,650 homes. It is planned to sort based on a more holistic metric in the next round of results, a metric such as the yearly cost of emissions reduction “$/tonCO2e”, calculated over the lifetime of the unit and normalized per year.

For the heat pump water heater installation, the assumption is also made that a suitable location exists on the property for an outdoor condensing unit, and that loads are intermittent enough to allow a reasonably sized tank-style water heater. For the heat pump dryer installation, it is assumed that the house has a large enough electrical distribution to handle the extra electric load.

Measure-specific activity data

1,800 residential homes throughout the state will receive equipment and appliance upgrades. The following weatherization models were run on the residential home categories. Envelope air tightness is reduced to 0.25 cfm/sf as specified by ASHRAE 198 2020 p88, section 10.6, as well as insulation and window upgrades.

For the latter, external post insulation on the walls and roof is added to reach the U-value specified by ASHRAE 90.2 (Table 7-1, p11) for the climate zone. Windows and glass doors are replaced with windows having U-values and SHGCs taken from ASHRAE 90.2 (Table 7.1, p11) envelope tables. Infiltration is reduced to 0.01 cfm/ft2 for the window portion of the walls (ref: Alpen TR-11 PH+ sales material). DoE Cost-Effective Levels were used, instead of ASHRAE 189, with Attic / Ceiling: R60, Wall: R27 and Floor: R30.

No changes in Window U-value: (no change) but window SHGC: 0.6-0.65 (Alaska Housing Finance Corp)

Source : https ://www.insulate.org/Insulation-By-Climate-Zone.pdf

The kitchen stove and oven are replaced by an electric unit with induction stoves. Dryers are replaced by heat pump dryers such as the Bosch Series 8. Existing fossil-fuel or electric water heaters are replaced with heat pump water heaters. Changes supply temperatures to 120F. Energy factor for the water heater and performance curves have been taken from the heat pump water heater line specifically designed for optimal operation in cold climates: the SANCO2 Gen 4 product line.

The current HVAC system is retrofit to replace heat generation equipment with heat pumps of efficiency of than that specified in Table 5-1 of ASHRAE 90.2 (p9). Cooling equipment is also replaced with equipment of efficiency equal to that of the same table. Boilers are replaced with either ground-source heat pumps or air-to-water heat pumps, central furnaces are replaced with air-to-air heat pumps.

Heat pump performance is modelled using performance specifications of real cold-climate heat pump models. Specifications and performance curves for the air-to-air heat pumped used the cold-climate **Fujitsu ASU line**. The **Midea M Thermal Arctic Series** is used to model specifications and performance curves of air-to-water heat pumps. Performance metrics for the ground source heat pump model are taken from the **WaterFurnace 7** series. While direct fuel reductions will result from these measures, there will be an increase in electricity consumption, the carbon content of which is dependent on the local grid.

Models/Tools used

- Constellation Navigator automatic energy model processing: used to create reference case models, upgrade-scenario models, and compare them

- AK PARCEL AND LOT dataset: used to attain high-level building characteristics for all buildings in Alaska (the residential set was used for this analysis)
- PNNL Residential Prototype Models: used as a source of data for building characteristics that do not exist in the building-specific datasets
- AKWarm: energy cost data (will be) used to convert the cost fields in ARIS to energy usage
- ARIS dataset: used for building-level details as described in the reference case section

GHG Reduction Estimate Method:

The difference between the reference (base) case and the modeled changes in energy due to the modeled adoption of measures discussed above, is the activity data being used to estimate the reduction in GHG. For example, after buildings are simulated using the tools and assumptions above, the estimated reduction or increase in different types of fuels, such as natural gas, coal, liquid fuels or electricity, is converted from MMBTU or its energy equivalents, into MT CO2e using the corresponding emission factors for that fuel type, across the constituent CO2, CH4 and N2O. Next, EPA's 2022 GWP values are used to convert to each MT per GHG type into aggregated annual MT CO2e – using 1 for CO2, 298 for N2O and 25 for CH4. Whenever appropriate, the emission factors of electricity, is matched using the community the buildings are in, and either the PCE based emission factors, or the grid-rates for the sub-region.

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GHG Reduction Estimate Assumptions: The quantification does not assume any impacts of "joint strategies" – that is, the simultaneous impact of multiple projects at a single location. In other words, if a project analyzes the reduction of grid emissions based on upstream integration of renewable energy, the new emission factors of electricity are not being used to measure the impact of electrification or efficiency of end-use equipment, as stated above. Instead, the reference emission factors will be used. Similarly, if competing efficiency projects are modeled such that they are not additive, but are substitutes of each other, the extent of overlap is not being modeled or predicted. Additionally, the baseline models assume annualized load profiles – and actual building performance may differ, such as from partial usage or occupancy, etc. Lastly, there are no weather normalizations done on either the activity of the reference scenario or modeled measures.

GHG Emissions Reduced:

Measure 2 and 3 Using the figures of 200 homes receiving deeper retrofits in 2025, 500 in 2026, and 400 for the following four years for a cumulative total of 1,800 homes throughout the state receiving subsidized audits and deeper retrofits, the annual CO2e reduction will be 38,580 Metric tons, with a cumulative reduction of 145,747 in metric tons between 2025 and 2030.

AHFC Measure 2 and3: 1800 Homes Retrofitted					
Annual Homes	Cumulative homes	Goal	Percent Implemented	CO2e Reduction (Annual Metric Ton)	CO2e Reduction Cumulative reduction
200	200	1800	13%	4,286.67	4,286.67
400	600	1800	28%	12,860.00	17,146.67
400	1000	1800	50%	21,433.33	38,580.00
400	1400	1800	75%	30,006.67	68,586.67
400	1800	1800	100%	38,580.00	107,166.67
				38,580.00	145,746.67

Measure 1: Extrapolating the data through 2050, with the annual reduction across 1,800 homes through the following 25 years would be 917,347 metric tons of C02E reduced.

GHG Emission Reduction Calculations: See attached technical appendix with linked Spreadsheet.