Yukon Heat Pump Pilot 2023 – 2025

Technical Summary Report

Introduction

RDH Building Science was commissioned by the Government of Yukon to conduct a research study on cold climate air-source heat pumps (ccASHPs) installed in existing residential homes in southern Yukon. The main objectives of this study were as follows:

- assess ccASHP performance in terms of heating energy delivered and heating coefficient of performance (COP) against outdoor temperatures;
- compare the measured seasonal COP (SCOP) of these systems to published data;
- assess potential energy and cost savings from heat pump retrofits in Northern communities;
- identify lessons learned on system operation, design, and maintenance of cold climate heat pumps in the Yukon; and
- develop general recommendations related to overall feasibility and widespread adoption of air-source heat pumps in the Yukon.

This study included various air-source heat pump system types: ductless (multi- or mini-split) air-to-air systems, central ducted air-to-air systems, and central air-to-water systems.

Two detailed technical reports containing a full description of methods and results are available for download here LINK. This technical summary contains the high level outline of results from both years.

Definitions

Efficiency of the ccASHPs was reported using two technical terms; COP and SCOP.

Cold Climate Air Source Heat Pump (ccASHP) is a specification which defines characteristics and minimum performance standards, including a minimum of COP of 1.75 at -15C and capacity at -15°C must be at least 70% of capacity at 8°C. Only the highest performing ccAHSPs are eligible for Energy Branch rebates, as identified on the list of heat pumps for Yukon and Manitoba maintained by NRCan. All ductless and centrally ducted heat pumps in the study meet the specification for ccASHPs but not all were eligible for listing on the NRCan list of heat pumps for Yukon and Manitoba.
The ccASHP specification is intended for air to air heat pumps, the air to water heat pumps in the study do not meet the ccASHP specification.

Coefficient of Performance (COP) is the ratio between the rate at which the heat pump delivers thermal energy (in kW), and the amount of electrical power required to do the pumping (in kW). For example, if a heat pump used 1kW of electrical energy to deliver 3 kW of heat, the COP would be 3. COP is unitless, instantaneous, and tends to vary with temperature. Typically, a Cold Climate Air Source Heat Pump would have a COP of about 3.5 to 4.5 at 8°C, dropping to around 2.0 to 2.5 at -15°C

The **Seasonal Coefficient of Performance (SCOP)** is a metric that measures the energy efficiency of a heat pump over an entire heating season. SCOP = total thermal energy delivered divided by the electrical energy consumed by the heat pump. Unlike the COP, which provides a snapshot of the heat pump's efficiency at a specific moment, SCOP, by its nature takes into account the varying outdoor temperatures and operating conditions throughout the season, giving a more comprehensive picture of the heat pump's overall performance. SCOP is particularly relevant in regions like the Yukon with significant temperature fluctuations throughout the heating season. By inherently considering the heat pump's efficiency over a range of temperatures, SCOP provides a representation of the system's performance and energy savings potential. SCOP is calculated using energy (in kWh), but like COP is unitless.

Methods

During the summer of 2023, equipment was installed to measure the performance of air-source heat pump systems in eighteen homes. Monitoring for this project was for two heating seasons, and spanned approximately 19 months from September 1, 2023 to March 23, 2025. Measurands included; quantity of electrical energy consumed, quantity of heat delivered to the home and outdoor temperature and humidity. Detailed description of the data collection and analysis can be viewed in the full reports.

Figure 1 - Heat pump outdoor unit. This unit has been mounted well off the ground leaving room for ice buildup underneath. It is situated away from walkways so ice removal is not needed. Outdoor units for ductless or central ducted systems are similar

Results

Overall, the ductless and central ducted heat pumps in this study operated at efficiencies reasonably close to published data and delivered substantial operating cost savings to the homeowners as well as reduced GHG emissions. Although the primary focus of the study was quantitative assessment of ccASHP performance, participant satisfaction was also gauged through interviews.

Quantitative results

On average, the correctly commissioned ductless ccASHPs (i.e. mini-splits and multi-splits) achieved COPs of approximately 2.3 at an outdoor ambient temperature of -25ºC, 2.6 at -15ºC, and 3.6 at outdoor ambient temperature of 0ºC. These systems also tended to have SCOPs within the range of the manufacturer rated SCOPs; an average measured SCOP of 3.05 for ductless systems was observed.

On average, correctly commissioned the central ducted ccASHPs achieved COPs of approximately 1.15 at -25ºC, 1.6 at -15ºC, and 2.55 at 0ºC. An average measured SCOP of 1.85 was observed for ducted systems.

Manufacturers claimed COP profiles for ductless ccASHPs are generally slightly better than for equivalent central ducted heat pumps. The COP profiles observed in this study and the long term SCOP results showed a much greater difference in performance, the reasons for this difference are not known.

COP of the single air-to-water heat pump system was 1.0 at -15ºC and approximately 2.15 at 0ºC. The measured SCOP for this system was determined to be 1.15.

COP profiles

The COPs achieved for each ccASHP across the range of operating temperatures are plotted in the graphs below. These results are broadly in line with expectations and close to published performance data. Exceptions included heat pumps with known performance issues due to poor installation and commissioning. Some of the commissioning issues identified have been rectified by the homeowner and their contractors, the Energy Branch is providing support to assist homeowners and contractors to rectify the remaining issues.

When interpreting the COP / temperature graphs it is important to note that ccASHPs which achieve the best COPs in the middle range of between -20°C and -5°C are the ones which also deliver the greatest overall improvements for the homeowner – a high portion of annual heating energy is typically delivered in this temperature range. The performance at the extreme ends of the plots below -25°C and above 0°C is less impactful on annual heating costs and SCOP.

Figure 2 - A ductless ccASHP indoor unit mounted close to the ceiling. This unit heats and circulates air within the space. Ductless heat pumps can be mini-splits which have a single indoor head, or multi-splits which have multiple indoor heads heating multiple zones.

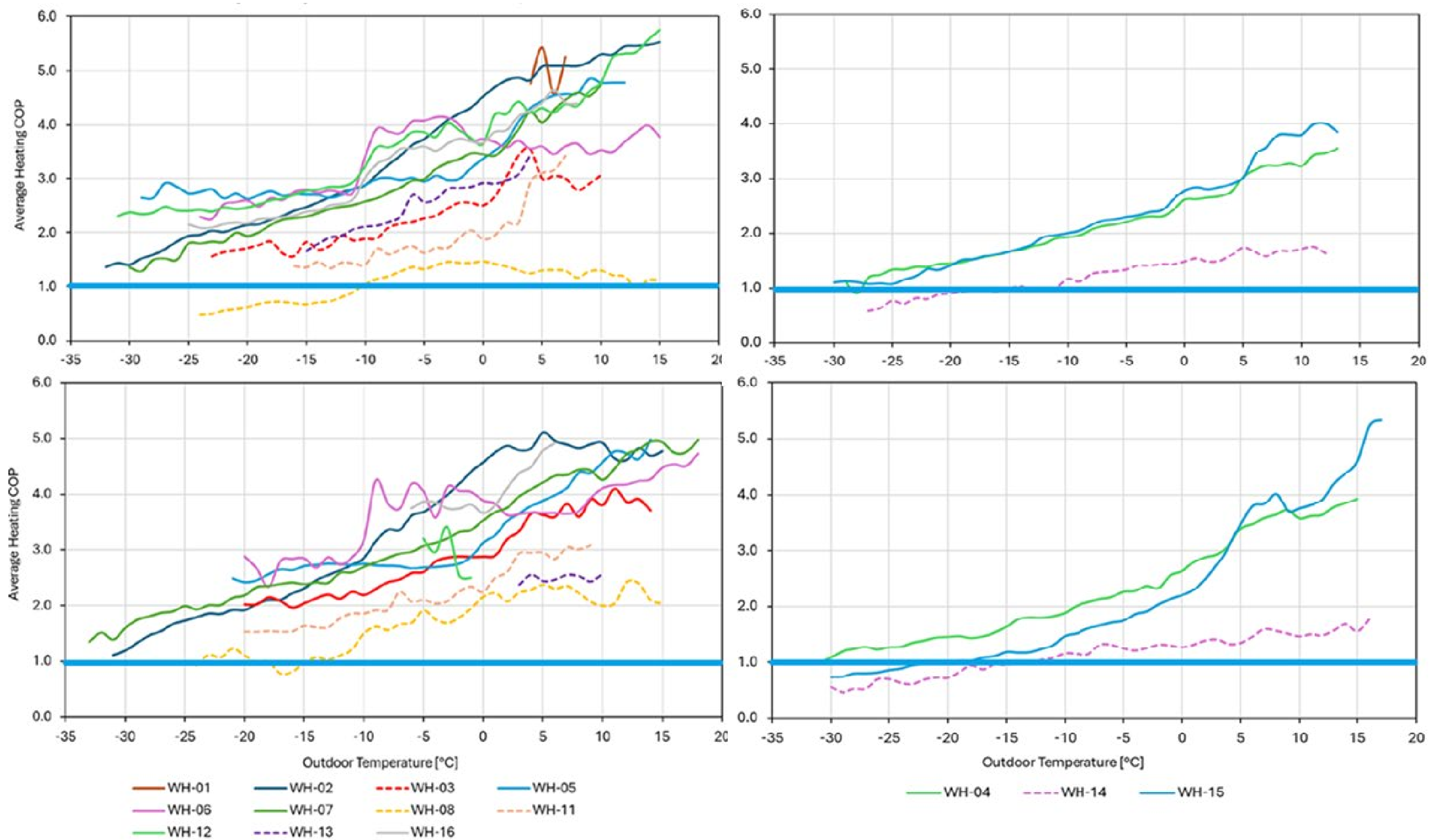

Figure 3 Average COPs for ductless and central ducted heat pumps. Ductless heat pumps are shown on the left graphs, Central Ducted heat pumps are shown on the right. The winter of 2023/24 is shown in the upper graphs and the winter of 2024/25 is shown in the lower graphs. The horizontal blue line at COP = 1 represents an efficiency of 100% equivalent to traditional resistive electric heat. The dashed lines represent heat pumps which were not operating properly for various reasons during the pilot. See the technical reports for info on the faults in these heat pumps.

SCOP comparison

SCOP results were compared to published performance data and to 100% efficient resistive electrical heat in the charts and table below. Generally, both the central ducted and ductless ccASHPs in the study substantially outperformed resistive electrical heat. The ductless ccASHPs were reasonably close to published performance data. Central ducted ccASHPs fell short of published performance data but generally achieved SCOPs high enough to deliver substantial savings for the homeowners.

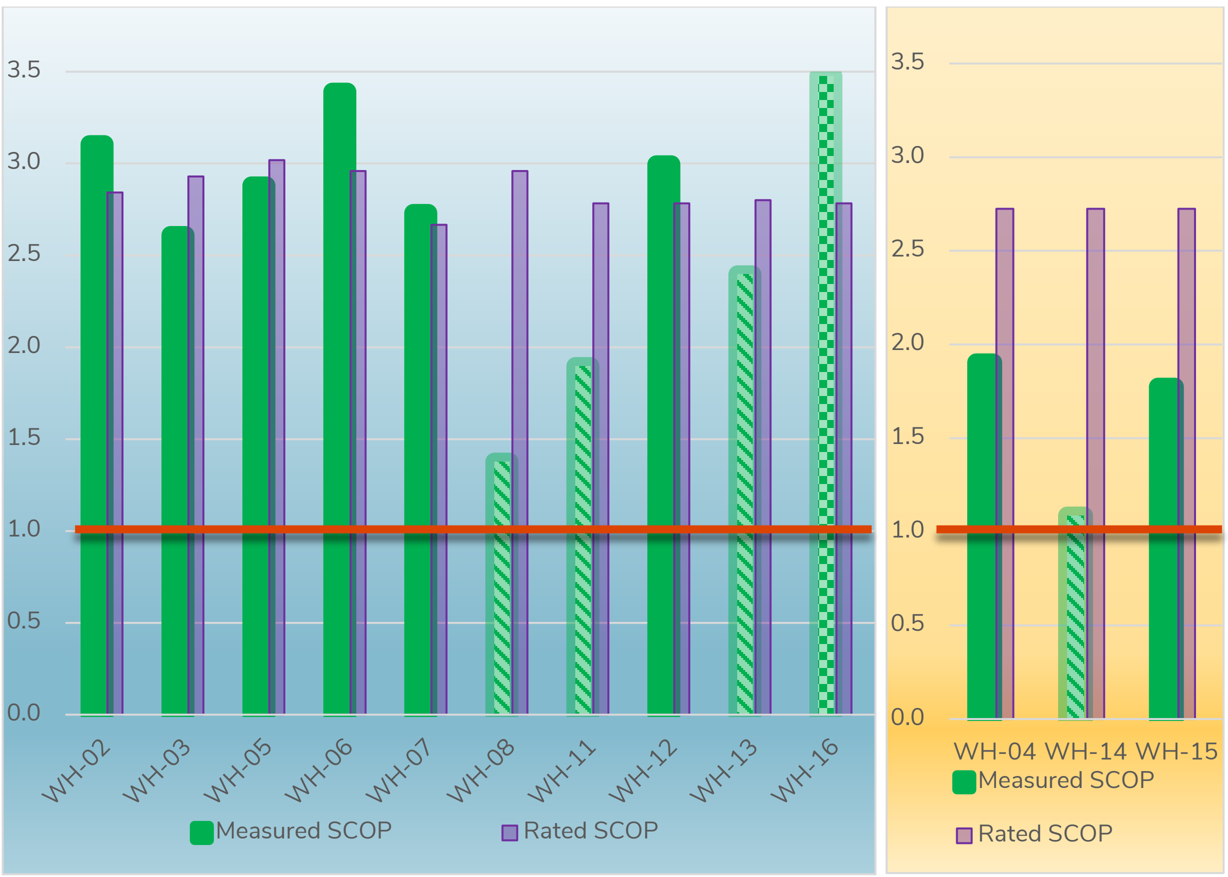

Figure 4 - Measured vs Rated SCOP. Ductless heat pumps shown on the left. Ducted Central heat pumps shown on the right. The blue line at 1.0 is equivalent to the efficiency of traditional resistive electrical heat. WH-08, 11, 13, and 14 are shown as hatched as their performance was reduced by suspected installation and commissioning errors. WH-08, 11, and 13 have been repaired, WH-14 is still under investigation. WH-16 is shown as hatched as it was mainly operated at a higher ambient temperature, so the resulting SCOP is not a true representation of normal operation for a full heating season.

Table 1 SCOP average as measured for Ductless, Central Ducted and Air to Water systems. The "Correctly Commissioned" group excludes WH-08, 11, 13, and 14 which had their performance reduced by suspected installation and commissioning errors.

	All	Correctly Commissioned
Ductless	2.70	3.05
Central Ducted	1.60	1.85

Operating savings

Heat pumps in the study achieved operating cost savings when compared to the baseline heating systems being displaced. The amount of savings a homeowner can expect will be affected by many factors, including;

- Proper sizing of the heat pump capacity in relation to the design heating load of the home, savings will be greatest for heat pumps that are neither oversized nor undersized.
- type of heating system being displaced, savings are greatest when displacing resistive electric heat.
- type of backup heating system used and control settings for when and how the backup takes over, settings which allow the heat pump to displace the greatest quantity of baseline heating energy will enable greater cost savings
- heat pump model and performance characteristics
- quality of installation and commissioning – this may be particularly important for central ducted systems.

The savings experienced by participants in this study varied widely, the tables below summarise the cost savings observed in the participating sites alongside the energy consumption and GHG reductions. The *Correctly Commissioned* group is expected to be most indicative for prospective heat pump installations – provided a high quality, modern ccASHP is specified and installed by a competent contractor.

Table 2 - Average savings as calculated for Ductless, Central Ducted and Air to Water systems. The "Correctly Commissioned" group excludes WH-08, 11, 13, and 14 which had their performance reduced by suspected installation and commissioning errors. GHG reductions are calculated based on average annual GHG intensity of electricity, results would be different if marginal GHG intensity or seasonal average GHG intensity were used.

All systems with data

	Energy Savings		GHG reduction		Cost savings	
	kWhr	**%**	**KgCo2e**	**%**	**$**	**%**
Ductless	15,569	39%	4,261	48%	$ 2,361	32%
Central Ducted	21,738	43%	6,675	63%	$ 2,083	24%
Air to water	2,338	5%	164	5%	$ 566	5%

Correctly Commissioned

	Energy Savings		GHG reduction		Cost savings	
	kWhr	**%**	**KgCo2e**	**%**	**$**	**%**
Ductless	15,569	39%	4,261	48%	$ 2,361	32%
Central Ducted	27,620	54%	6,586	69%	$ 3,226	38%
Air to water	2,338	5%	164	5%	$ 566	5%

Table 3 Average annual savings as calculated for heat pumps displacing various baseline heating systems; Oil, Propane, and Resistive Electric. All of the Oil systems were retained as backup. Of the Propane systems, one was retained as backup and the other was replaced by Resistive Electric backup. All of the homes with Resistive Electric baseline systems also used Resistive Electric as backup. The "Correctly Commissioned" group excludes WH-08, 11, 13, and 14 which had their performance reduced by suspected installation and commissioning errors. GHG reductions are calculated based on average annual GHG intensity of electricity, results would be different if marginal GHG intensity or seasonal average GHG intensity were used instead.

All systems with data

	Energy Savings		GHG reduction		Cost savings	
	kWhr	**%**	**KgCo2e**	**%**	**$**	**%**
Oil	18,588	39%	7,293	57%	$ 1,950	26%
Propane	20,162	36%	6,723	56%	$ 1,172	13%
Resistive Electric	14,652	45%	991	47%	$ 3,424	45%

Correctly Commissioned

	Energy Savings		GHG reduction		Cost savings	
	kWhr	**%**	**KgCo2e**	**%**	**$**	**%**
Oil	22,782	46%	7,735	57%	$ 2,902	38%
Propane	37,083	59%	12,006	87%	$ 2,422	28%
Resistive Electric	14,652	45%	991	47%	$ 3,424	45%

Participant satisfaction

On average, participants reported positive experiences, particularly regarding comfort, energy savings and reduced reliance on supplemental heating (e.g. wood stove). Knowledge gaps exist among homeowners regarding the operation and maintenance of their systems. Several participants were unaware of the need to clean filters regularly and expressed uncertainty about how to operate or adjust system settings. Despite this, many homeowners demonstrated a strong willingness to learn. This presents an opportunity for industry stakeholders or government bodies to provide targeted homeowner education, such as workshops, webinars, or user-friendly guides, to improve confidence and system performance through better-informed usage.

Multiple participants reported challenges in finding qualified service providers. In more than one case, a homeowner contacted several companies before finding one willing to inspect their system. There is a clear opportunity to support homeowners post-installation by offering access to a directory of qualified service providers (and by providing contractor training to provide this service), and/or by encouraging contractors to offer follow-up service visits. Including this kind of support as part of rebate or incentive programs could improve long-term satisfaction and system upkeep.

Sizing Commentary

Properly sizing heat pumps for their intended operating range is critical for ensuring optimal performance. If a heat pump's capacity is too low, the system will likely rely excessively on supplementary heating systems during colder weather, increasing overall operating costs (where supplementary heating is electric, propane, wood or oil based). The additional running costs associated with an undersized air-source heat pump typically outweigh the higher upfront cost of installing a larger unit. Conversely, oversized systems can also present issues, such as excessive cycling and reduced performance (i.e. lower COPs) at milder temperatures.

Conducting an energy assessment to determine the design heating load for the home and then sizing the heat pump accordingly is the preferred approach. Sizing a ccASHP based on square footage of the home can lead to reduced performance and higher running costs.

The heat pumps included in this study were among the first installed in the Yukon, the sizing chosen varied quite considerably. Expressed as a percentage of the design heating load, their capacities at -15°C range from 30% to 160%, resulting in theoretical balance points ranging from -7°C to -33°C.
The heat pumps supported through Energy Branch rebates in recent years have been more consistent, usually falling within the much narrower range of around 75% to 95%, achieving a theoretical balance point in the range of -18°C to -25°C.

Observations on Advancing Heat Pump Technology

The heat pumps studied in this pilot were among the first to installed in the territory. Some of the heat pumps studied are now obsolete, have lower performance, and/or would not now be eligible for Yukon rebates. Heat pumps installed in 2025 are on average more efficient than the heat pumps in this study. The number of contractors installing heat pumps in the Yukon has increased substantially, accompanied by greater experience and expertise. As a result, the quality of installations and commissioning is expected to be significantly higher now than what was available during this study period.

Figure 5 - Central Ducted ccASHPs appear similar to an oil furnace and use similar ducting to circulate hot air around the home

Conclusion

In all, these very positive results suggest that cold climate air-source heat pumps have the potential to serve as the primary heating technology for heating in the Yukon and other subarctic regions, provided the equipment is properly sized, installed and commissioned and some form of supplemental heating can be provided during periods below the heat pump's rated outdoor operating conditions.

For further information please access the full reports here LINK, or contact the Energy Branch at electrify@yukon.ca