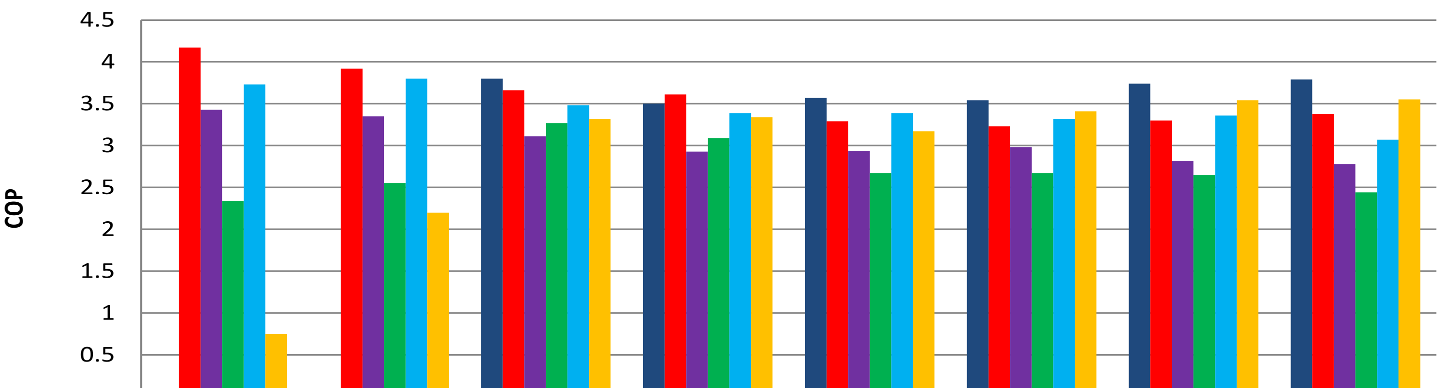
Ground Source Heat Pumps
in Cold Climates: *6-Year Update*

While ground source heat pumps are gaining popularity in cold climates, there are still questions about how they perform in cold soils. To help answer these questions, the Cold Climate Housing Research Center installed a ground source heat pump at its facility in Fairbanks, Alaska in November 2013 (*see Figure 1*). The demonstration ground source heat pump replaced an oil-fired boiler to heat office space in the CCHRC facility. Researchers are monitoring the heat pump for a 10-year period to study how the efficiency changes over time and how extracting heat from the ground affects the long-term ground temperature.

After six winters of data collection, researchers have gained valuable insight into the heat pump's performance in a cold climate. The efficiency of a heat pump is measured as the Coefficient of Performance, or COP–the ratio of how much heat is produced for each unit of electricity used. For example, a COP of 3 means the heat pump produces 3 units of heat for every 1 unit of electricity it consumes. COP is affected by many variables, with soil temperature and air temperature being the greatest drivers. Over time, harvesting heat from the ground can deplete the ground temperature, leading to lower COP. Following

Figure 1. *The ground loop is buried nine feet in the ground at a depth between deep permafrost and seasonal frost.*



	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr
2013-14			3.8	3.5	3.57	3.54	3.74	3.79
2014-15	4.17	3.92	3.66	3.61	3.29	3.23	3.3	3.38
2015-16	3.43	3.35	3.11	2.93	2.94	2.98	2.82	2.78
2016-17	2.34	2.55	3.27	3.09	2.67	2.67	2.65	2.44
2017-18	3.73	3.8	3.48	3.39	3.39	3.32	3.36	3.07
2018-19	0.75	2.2	3.32	3.34	3.17	3.41	3.54	3.55

Figure 2. *The efficiency of the heat pump, measured by COP, has fallen year after year. After averaging 3.65 in its first season 2013-2014, in its 6th seson it averaged 3.2 (excluding September 2018, which had a mechanical failure).*

What did it cost?

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
COP (annual avg)	3.66	3.57	3.04	2.71	3.44	3.22*
Annual cost *(electricity)*	$890*	$1,445	$1,666	$2,360	$1,830	$1,756
Annual savings *(compared to fuel oil)*	$603*	$639	-$207	-$328	-$18	-$88
Annual maintenance costs	-	-	-	-	$125	$1,072

**partial year*

this trend, *Figure 2* shows that the efficiency of the heat pump has decreased over 6 years (with the exception of years 3 and 4, which are lower than 5 and 6 due to mechanical failures). There is also a seasonal variability to the COP. April, for example, has higher efficiency than January because colder air air temperatures require the heat pump to deliver higher-temperature fluid to the building.

Maintenance

The heat pump required two maintenance calls in the first four years; both were electrical in nature and covered under warranty. The two post-warranty calls are listed in the costs table. In September 2017, researchers discovered that one of the ground loop pumps was not functioning at full power. For the second, in October 2018, we had to replace the heat pump thermal expansion valve and flush the refrigerant system. The low COPs in year 4 may be related to degradation in this valve, which put metal bits into the refrigerant that the heat pump was able to filter out itself. The very low COP in September 2018 required a complete valve replacement. While this service was expensive, it is not required very often. Thus, compared to the service fee of maintaining a boiler (roughly $300-600 per year), the heat pump has been relatively low-maintenance.

Figure 3. *Thin tubes of water are pulled out of the ground loop once a month and the length and depth of ice in the tubes is recorded.*

Frozen Soils

One of the initial questions about the ground loop was whether or not constant heat extraction in the winter with no thermal recharge would create permafrost (defined as soil that has been below freezing temperatures for two years). While the temperature in the center of the ground loop dropped below freezing on Dec. 12, 2016, it bounced back by Oct. 1, 2018–not quite 2 years. Changes in the groundwater on site are affecting the ground loop and may be responsible for the above-freezing temperatures around the ground loop after six years. Figure 3 demonstrates how researchers check for frozen soil underground, in addition to looking at temperature data.

Cost & Savings

The economics of the heat pump are complex. The amount of savings versus using an efficient oil-fired boiler is dependent not only on the efficiency of the heat pump but also on the cost of oil. Oil prices have been variable since the start of the project, ranging from approximately $4 gallon to $2 a gallon. Higher oil prices mean more savings. While the heat pump saved over $1,000 in fuel costs the first two years, when oil prices slipped below $2.45 per gallon in 2015 the heat pump actually became more expensive to run than an oil boiler, as seen in the table above. As with any heating appliance, the economics must be viewed not on an annual basis but over the life of the system.

Read more at:
cchrc.org/ground-source-heat-pump-demonstration-cchrc