

## Proper installation and maintenance of residential heating and cooling equipment reaps savings

Heating and cooling systems are major energy users in Minnesota homes, many of which have a natural gas furnace and central electric air conditioner or heat pump. If not properly installed and maintained, these systems may operate at less than their rated efficiency and cost their owners unnecessarily high energy bills.

A recently completed CARD research project awarded to [Seventhwave](#) looked at the savings and CIP opportunities from properly installing and maintaining furnaces, air conditioners, and heat pumps in Minnesota single-family homes. The market characterization and field study involved interviews with market actors, a survey of more than 700 homeowners, field testing of more than 100 systems, and year-long monitoring of the heating- and cooling-equipment operation in more than 50 homes (Figure 1).

**Figure 1. Test rig installed on furnace in the study**



The results show widespread opportunities for improving the efficiency of cooling systems and heat pumps through better installation practices and maintenance. More than 90% of systems tested in the study had at least one improvement opportunity (Table 1). Most prevalent were improper refrigerant charge and airflow (RCA), both of which need to be individually tuned for every installation—but are often neglected or not carefully done—by installers and service contractors. While most interviewed

contractors reported assessing and adjusting refrigerant charge when installing new systems, the methods used to do so vary somewhat. In contrast, few contractors measure system airflow. Improper RCA tends to persist over the life of the system, but it can also be corrected at any time.

**Table 1. Incidence of cooling-system adjustments**

		<b>New replacement system</b> (n=50)	<b>New home</b> (n=21)	<b>Older system</b> (n=38)	<b>Overall</b> (n=109)
<b>Type of adjustment</b> (in descending order of incidence)	No Adjustments	6%	14%	5%	7%
	Refrigerant charge	64%	71%	76%	70%
	Airflow	54%	48%	53%	52%
	Filter replacement	34%	33%	32%	33%
	Condenser coil clean	18%	24%	29%	23%
	Other	8%	0%	0%	4%

On average, measurements of actual operating efficiency before and after tuning the systems found an improvement in air conditioner and heat pump efficiency of about 12% (Table 2), though about one in six systems showed an improvement of more than 25%. Remarkably, these results seem to hold true for new systems in new homes, new replacement systems in older homes, as well as older systems in older homes.

**Table 2. Average savings from cooling-system adjustments.**

		<b>n</b>	<b>Average % change in efficiency</b>	<b>95% confidence interval</b>
Incremental effect of common individual adjustments	Refrigerant	72	+8.6	±3.8
	Airflow	52	+7.1	±2.5
	Filter	36	+2.9	±2.0
	Condenser coil clean	2	+7.4	±2.5
<b>Any individual adjustment</b>		<b>195</b>	<b>+6.9</b>	<b>±1.7</b>
Overall system effect of all adjustments among...	...adjusted new replacement systems	50	+14.1	±4.6
	...adjusted systems in new homes	21	+12.4	±10.7
	...adjusted older systems	358	+11.3	±4.3
	...all adjusted systems (weighted)	101	+12.8	±3.3
	<b>...all systems (weighted)</b>	<b>109</b>	<b>+12.1</b>	<b>±3.2</b>

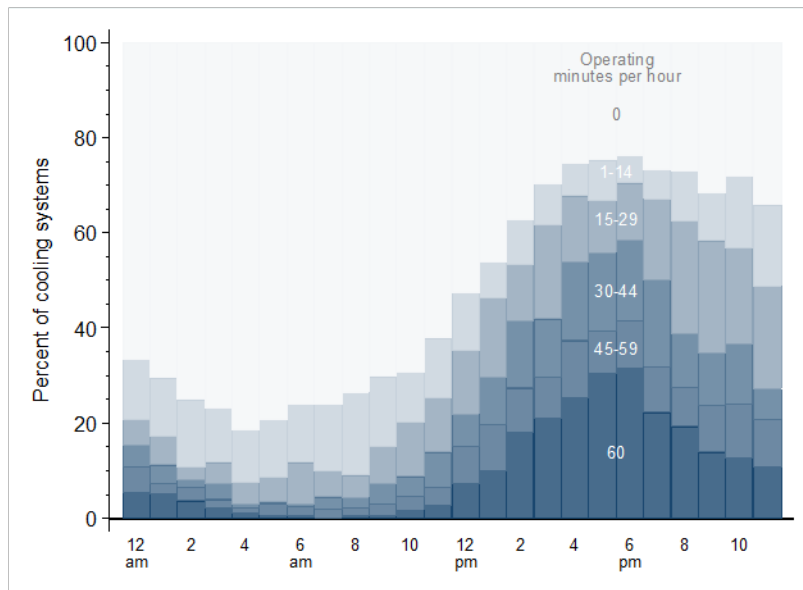
The study found limited opportunities to improve the operating efficiency of gas furnaces, though investigation of furnaces was restricted to measuring and adjusting gas manifold pressure, temperature rise (airflow), blower-off delay and air-shutter adjustment. Since most of the furnaces in the study were high-efficiency models, there was little to adjust.

How can these savings opportunities be captured? Several Minnesota utilities already run quality-installation and quality-maintenance programs. Outside of quality-installation requirements for new, high-efficiency cooling systems, the reach of these programs is limited by low program incentives and contractor awareness and interest. New approaches that reduce the hassle that contractors face in participating in these programs could help spur demand: cloud-connected diagnostic equipment could make reporting system data nearly painless, and provide valuable diagnostic information to installation and service technicians as well.

The market research conducted for the study shows that success or failure of proper-installation and tune-up programs is largely in the hands of heating and cooling contractors. Homeowners shop mainly based on price, nameplate efficiency, and installer reputation—and simply assume that whatever they purchase will be properly installed and tuned.

The project also provided some hard data on operating hours for heating and cooling systems. The longer-term monitoring data suggest that a typical cooling system in the Twin Cities region operates for  $340 \pm 70$  hours per year, and uses  $800 \pm 175$  kWh of electricity, while a natural-gas furnace operates for  $900 \pm 100$  hours per year and consumes  $670 \pm 80$  therms of gas. Because the Minnesota cooling season is short, cooling-system use is more discretionary than in other parts of the country: on average, Minnesota central air conditioners run about 20% less than they would if their owners simply left their thermostats set in cooling mode all summer long. On a hot summer afternoon, about a quarter of central air conditioners are not operating at all, half are cycling on and off to satisfy the thermostat, and a quarter are running flat out without cycling (Figure 2).

**Figure 2. Hourly cycling behavior of 54 monitored systems on 10 days where the outdoor temperature exceeded 87F.**



The final report on the project, [Improving Installation and Maintenance Practices for Minnesota Residential Furnaces, Air Conditioners and Heat Pumps](#), can be downloaded from the Commerce website. In addition, Seventhwave created three videos for the project: one for homeowners titled [“How to Get Top Performance from your Furnace, Air Conditioner or Heat Pump,”](#) one for contractors titled [“Measuring Airflow for Residential Forced-Air Systems for HVAC Professionals,”](#) and one that is an

overview of research results titled "[Research Results: Improving Installation and Maintenance Practices for Minnesota Residential Furnaces, Air Conditioners and Heat Pumps.](#)"

For more information, contact project manager and CARD program administrator [Mary Sue Lobenstein.](#)