Heating Optimization with Distributed Smart Controls

White Paper
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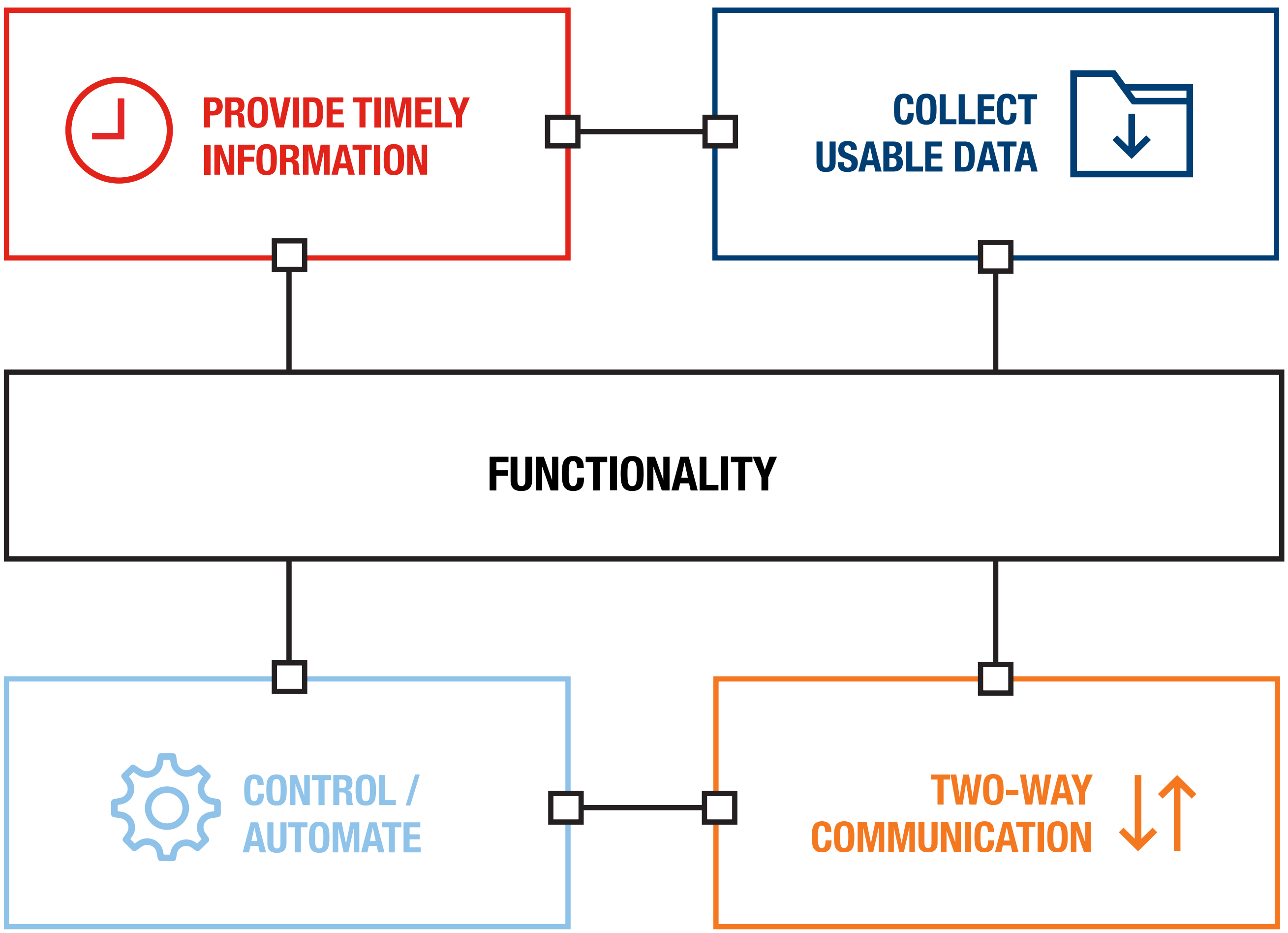
Introduction

For the purpose of this white paper, we will define heating optimization as the process of achieving and maintaining the optimal balance of heating sources needed for comfort, cost control and energy efficiency. Heating sources include heat pumps which run on electricity and supplemental heating sources which run on oil or gas.

We will consider a device or system "smart" if it performs the four key functionalities described below as defined by Northeast Energy Efficiency Partnerships, Inc. (NEEP).[1]



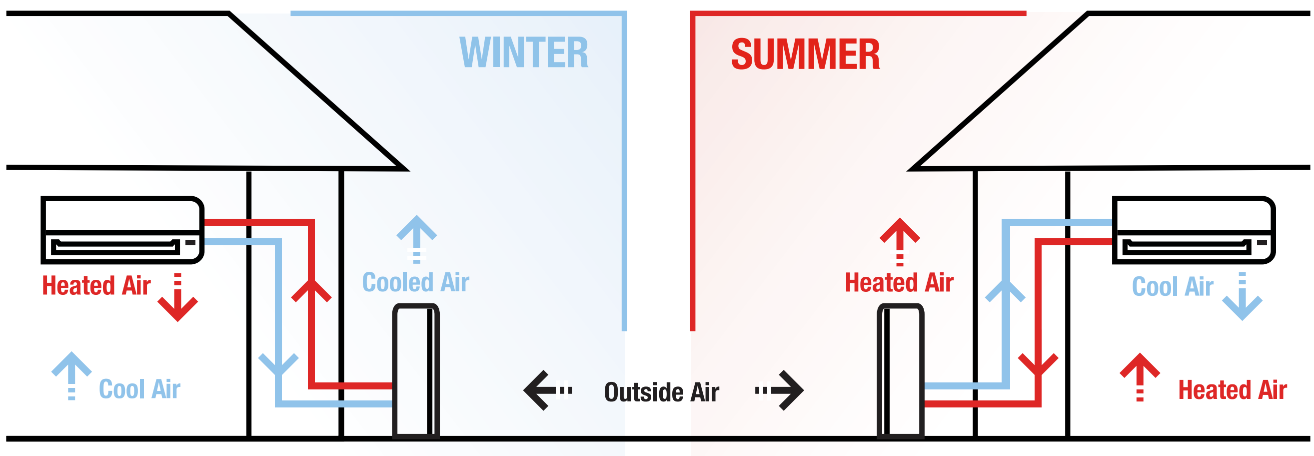
Distributed smart controls simplify the programming and operation of residential cooling and heating systems. HVAC contractors and homeowners use simple, intuitive interfaces to program systems and gain insight into home environments. Smart controllers and sensors distributed throughout the user's home communicate across a network and perform actions informed by homeowner requirements and environmental conditions.

While the distributed smart control technology described in this white paper is appropriate for light commercial applications, such as small offices or restaurants, we will concentrate on residential applications. Specifically, our discussion will center on homes in areas where extreme cold temperatures require homeowners to maintain supplemental heating sources in addition to their heat pump system. Distributed smart controls help homeowners and contractors in those regions move toward heating optimization by intelligently managing heating sources to satisfy comfort requirements and automatically performing complex tasks that open new opportunities for energy efficiency and cost savings.

Heating Sources: An Overview

Heat pumps transfer thermal energy from one location to another. In warm weather, heat pumps cool homes by drawing heat from the inside of a home and transferring that heat to the outdoors. In cold weather, heat pumps warm homes by drawing heat from the outdoors and transferring that heat to the inside of a home.

Homeowners opt for ductless heat pumps because they offer higher efficiency ratings than boiler-based systems. By maximizing the amount of heat generated from the energy consumed, ductless heat pumps can cost less to operate.



Today's advanced heat pumps are able to operate at 100 percent heating capacity even at ambient outdoor temperatures as low as 5 degrees Fahrenheit. Some manufacturers offer heat pumps that can operate at up to 76 percent heating capacity at temperatures as low as negative 13 degrees Fahrenheit. In some regions, advanced heat pumps eliminate the need for supplemental heating sources.

At extremely low outdoor ambient temperatures, heat pumps will be unable to effectively draw heat from the outdoors and homeowners will want to turn on supplemental heating sources, such as a boiler or furnace. While heat pumps cool and heat homes by transferring thermal energy, supplemental heating sources are fossil fuel systems that generate heat through combustion.

Traditionally, the changeover between heat pumps and supplemental fossil fuel heating systems has been a manual process. To get the best results, HVAC contractors and homeowners needed to have the knowledge and experience to decide when to switch heating sources. Instead of an intuitive user interface, there might have been a DIP switch or a need to enter cryptic codes. Often users and HVAC contractors would have little input into when a heating source would turn on.

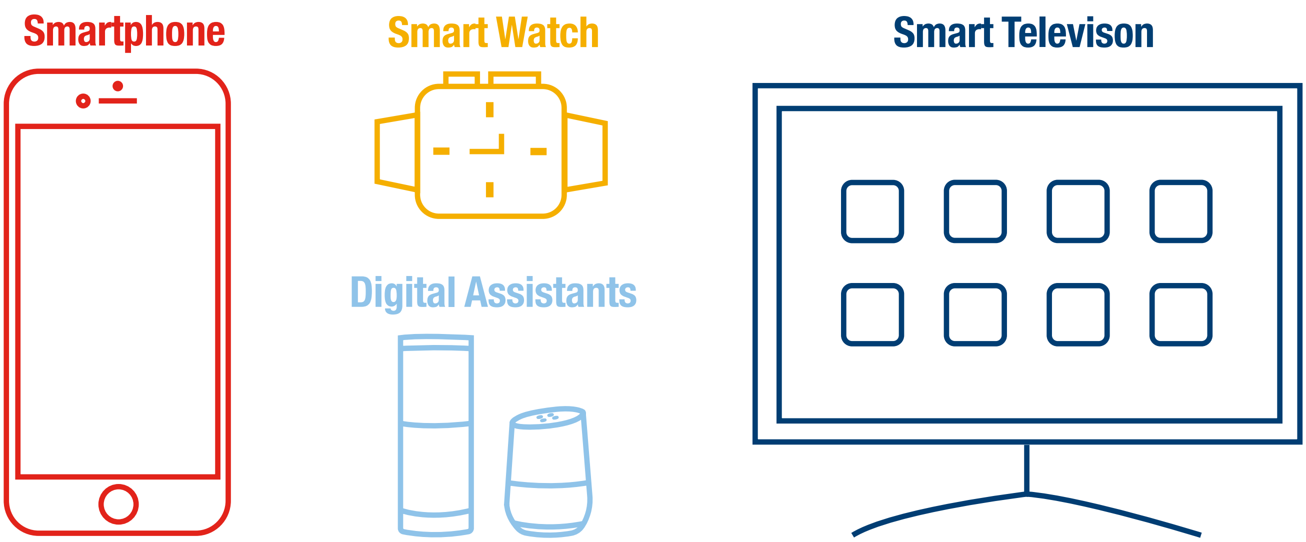
Additional complexities emerge for homeowners and contractors when zoned systems are implemented to increase comfort and energy efficiency. A zoned system allows a homeowner to assign an area or room of their house to a zone. Each zone is heated and cooled according to its individual requirements. While this approach allows for efficient use of energy, HVAC contractors and homeowners need to understand when use of the boiler or the furnace in one or more zones would affect temperatures in other zones and also understand the impact on the total cost of heating.

As we will see later in this white paper, distributed smart controls allow HVAC contractors and homeowners to offload to a system the work of switching heating sources and managing the complexities of zoning. In addition, distributed smart controls open new opportunities for homeowners to take advantage of complex billing schemes offered by utility companies.

Market and Historical Trends: Access, Automation and Abstraction

Distributed smart controls for heating and cooling systems have emerged as part of an overall increase in the availability and popularity of smart devices. The proliferation of consumer-focused smart devices over the last two decades — starting with smart phones and now including smart wearables, smart speakers and smart versions of common objects — has significantly changed how we engage with information, objects and other people. Smart phones have conditioned many of us to expect near-instant access to information and people as well as always available options for entertainment, commerce and management of personal and business interests. Smart objects that are not necessarily mobile create expectations for intelligent environments that respond to our wants and needs.

Connectivity via wireless protocols and standards such as Wi-Fi, 3G, 4G, 5G, NFC and Bluetooth is a common feature of smart devices. Smart devices are nodes distributed across a network that collect, create, transmit and store usable data. The intelligence of smart devices is a function of their ability to communicate with other devices and provide users with information, services, access and control culled from each pertinent node on a network.



The technological underpinnings of the smart device user experience are relatively new, but aspects of how smart devices help us manage information reflect an ancient part of the human experience. The extended mind hypothesis[2] suggests we have long engaged in "distributed cognition" where we outsource parts of our cognition to our tools[3]. For example, across human cultures we use symbols such as pictures and written language to acquire, retain, process and share information. Rather than doing certain math problems in our heads, we might work through a solution on a piece of paper. A person's tools augment their brain's memory and knowledge of past events, myths, instructions, formulas, commercial transactions, decrees, declarations, admonitions, songs and human thoughts of any kind. And, beyond access, all of these tools — from cave paintings to printed books and calculators to computational search engines — enhance our capacity to process and use information.

Abstraction is one of the techniques through which our modern tools, including smart devices, enhance our capacity to process and use information. With abstraction, details and complexities involved in producing the user's intended result are made abstract to the user and hidden from their direct view. Streamlined two-way communication between users and tools is achieved through user interfaces such as graphic-user interfaces (GUI), voice-user interfaces (VUI), and interfaces based on gesture and motion recognition. User interfaces simplify the user's interaction with and control of complex tools and processes. For example, rather than coding and relying on their programming expertise, individuals can use drag-and-drop interfaces to create websites, applications and augmented reality experiences.

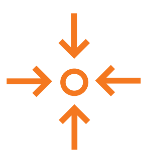
Where their predecessors relied on two-dimensional technical drawings and physical models, today's architects might use building information modeling (BIM) software to more clearly visualize and assess the likely outcomes of design plans and decisions. VUI is an increasingly popular model as consumers have integrated digital assistants (e.g. Alexa, Google Assistant, Siri®) into their daily lives. Automation operates in concert with abstraction. At layers hidden from the user, systems automatically perform work once done directly by the user. More significantly, systems automatically perform work that had never been performed by users or had only been done with great expenditures of time and effort.

Homeowners will want to consider how the expectations and experiences associated with these smart technologies may impact the value and marketability of their properties.

According to the sixth annual Houzz and Home survey, 28 percent of homeowners renovating their homes considered the integration of smart technologies to be important. Thirty-five percent of first-time home buyers among survey respondents said they were likely to prioritize integrating smart technology during renovation projects.[4] In a survey conducted by Wakefield Research, this affinity for smart homes is shown to extend into rentals and across generations. Sixty-five percent of respondents from the baby boomer generation were willing to pay more to rent a smart home while 86 percent of millennial respondents were willing to do so.[5]

NEEP has established a regional goal for the Northeast and Mid-Atlantic regions of the United States where by 2030 greater than 50 percent of homes — including 75 percent of new construction — have "energy-smart" HVAC systems.[6] In addition to satisfying the key functionalities of smart devices and systems mentioned earlier in this paper, NEEP suggests energy smart systems have the following characteristics:

Optimize major system energy savings



Can optimize distributed energy resources

Can optimize devices for the grid (through time-of-use pricing, load shifting, demand response)

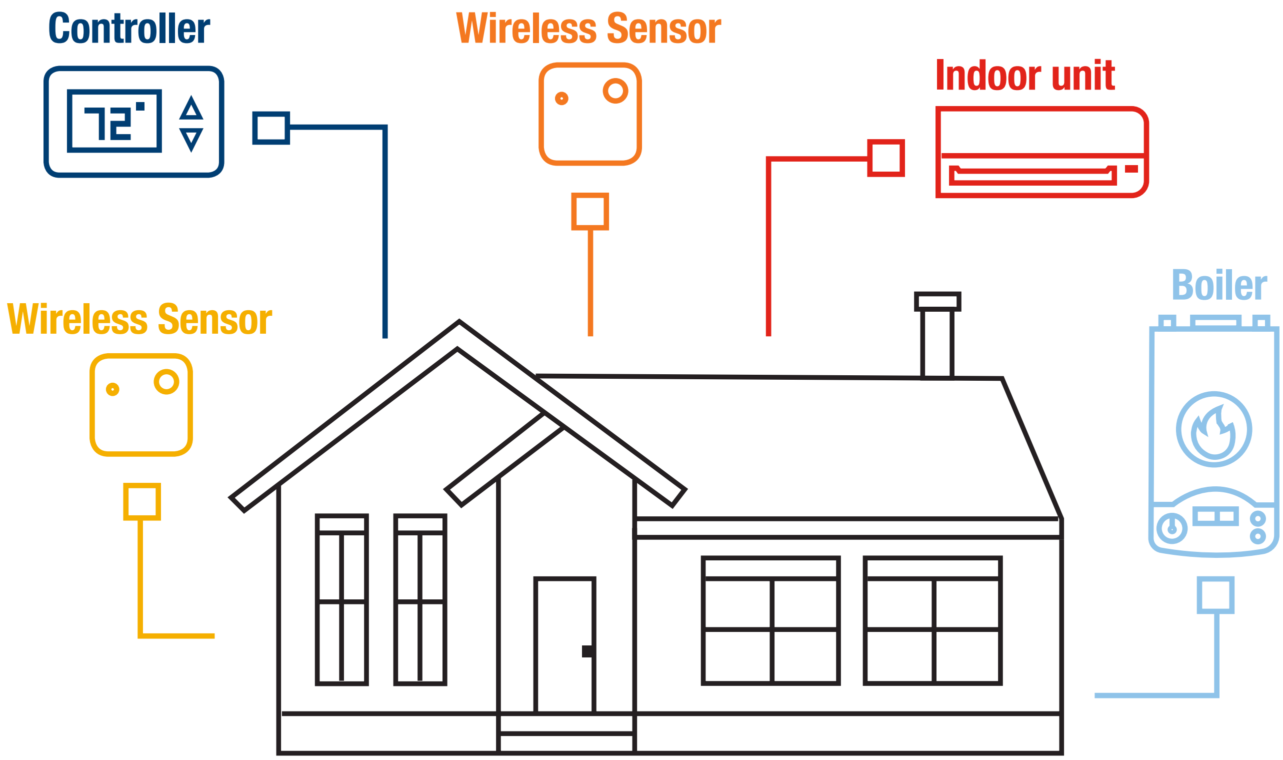
Can drive other improvements through a feedback mechanism

Heating Optimization with Distributed Smart Controls

Through distributed smart controls, control of an HVAC system is distributed throughout the home across a network setup within the home. While an internet connection may be needed to setup certain features of a distributed smart controls system, the network on which it operates will not be reliant upon an internet connection during normal operation. Instead the various nodes of a distributed smart controls system communicate across a Bluetooth-enabled wireless network. Distributed smart controls must work offline. No homeowner wants to make frantic calls to their internet service provider when it is negative 23 degrees Fahrenheit outside and no manufacturer wants to introduce internet connectivity as a potential point of failure for its HVAC system.

Smart controllers in each room of the home communicate across the network to share information about set points and room temperatures and then, based upon data captured by wireless sensors, the units collectively decide when it is more beneficial to use the heat pump, add auxiliary heat or switch over to auxiliary heat entirely.

When the cost of electricity compared to fossil fuel and the efficiency of a modern heat pump makes running the heat pump the most cost-effective way to satisfy comfort requirements, the distributed smart controls activate the heat pump. When temperatures reach extreme lows — negative 15 degrees Fahrenheit, for example — the distributed smart controls can lock out the heat pump and perform the changeover to a boiler or furnace. If there are moderate temperatures where allowing both heat sources to work together is energy-efficient and achieves the best comfort strategy, the distributed smart controls will coordinate the heating equipment. In each scenario, the distributed smart controls perform the work of equipment changeover and coordination without requiring homeowner involvement or contractor expertise.



Distributed smart controls may utilize sophisticated algorithms to precisely coordinate equipment and their operational modes based upon environmental conditions and requirements programmed by the homeowner and HVAC contractor. With these algorithms, distributed smart controls can make decisions based on variables such as the cost of energy and comfort requirements per zone.

For example, distributed smart controls can automatically coordinate equipment to save money and energy by making decisions informed by utility company programs such as time-of-use pricing. They can also facilitate compliance with energy-related building standards like California's Title 24, which encourages homeowners to use their lowest cost energy source first. Distributed smart controls enable prioritization schemes for rooms. They support weighted averages based upon variables including the importance of a room and the amount of heating required given a room's size. For example, the kitchen could be given more weight than the basement when determining when equipment changeover should occur.

Distributed smart controls also manage complexities related to zoning. Let's say a home has five zones. All five of the zones are served by a heat pump, but three of the zones are also served by a boiler or furnace. Instead of HVAC contractors and homeowners calculating when use of the boiler or the furnace in one or more zones would affect temperatures in other zones — while considering the impact on the total cost of heating — distributed smart controls manage all of the variables and priorities to discern when to fire up the furnace in an individual zone, run the heat pump or take another action.

In addition to optimizing use of heating sources, manufacturers may offer distributed smart controls that can extend intelligent management to other types of equipment. For example, some distributed smart controls can coordinate humidity control and ventilation along with regular heating and supplemental heating. For high-performance buildings with tight envelopes — such as passive houses or zero-net energy buildings —smart ventilation with distributed smart controls is of particular benefit.

Benefits for HVAC Contractors

With distributed smart controls, HVAC contractors are able to configure HVAC systems through an app and a streamlined user interface. In systems without distributed smart controls, HVAC contractors have access to fewer configuration points and must manually enter a cluster of codes to program systems. Instead of setting modes 18 and 12 to values one and six to have a heating system switch on at a certain temperature, HVAC contractors, and ultimately homeowners, can choose the temperature at which that heating system would switch on through a user interface that describes options in plain language.

With a streamlined user interface, HVAC contractors can more easily customize a system to meet the needs of the homeowner and give the homeowner the benefits of their expertise. During the install, an HVAC contractor could program instructions for equipment and operational modes. Perhaps at outdoor temperatures of 45 degrees Fahrenheit or warmer, the distributed smart controls never activate the auxiliary heat because the HVAC contractor knows the heat pump is more than capable of heating a home at temperatures between 45 and 0 degrees Fahrenheit. The auxiliary heat would only come on at super-low temperatures when the heat pump is challenged to handle the heating requirements of the building.

Benefits for Homeowners

Due to the proliferation of smart devices, homeowners are likely to have expectations of connectivity and visibility into their home environments that distributed smart controls are designed to satisfy. Smart phone apps with intuitive user interfaces provide information and control to the homeowners wherever they might be. Homeowners can also expect integrations with third party smart products that may provide new ways to interact with their system such as through digital assistants. Manufacturers design distributed smart controls for continued expansion and homeowners can expect to receive access to new features and improvements through updates and integrations.

In addition to meeting the expectations of a connected world, distributed smart controls should delight homeowners with otherwise inaccessible opportunities to save money and offload the labor associated with changeover. Homeowners could take advantage of complex time-of-use billing schemes from electric utility companies to reduce the energy costs beyond what they have already achieved through smart connected control.

In the following section, we present the experience of a homeowner who adopted a distributed smart controls system for his home in Dover-Foxcroft, Maine.

Case Study

As one of the owners of Dave's World – a supplier of modern energy-efficient equipment based in Dover-Foxcroft, Maine – Matt Scott has a long-standing relationship with ductless heat pumps. He encountered his first one while taking a refrigeration course after school and promptly fell in love. Dave's World, his proudly Maine-made and family-owned business, has been serving customers in the ductless market since 2006 and has been a Mitsubishi Electric Cooling & Heating (Mitsubishi Electric) Diamond Contractor since 2013.

After Matt purchased his dream home in November 2015, he experienced an extremely cold winter during which he ran a system on fossil fuels alone. The house, which was built in 1989, sits on a lake and has a lot of southern exposure.

Matt's home served as a beta test for hyper-heating technology supported by Mitsubishi Electric's distributed smart controls platform that includes kumo cloud® and kumo station™, a four-channel equipment controller that enables intelligent control of third party equipment.

In describing the technology, Rodney Olson, senior director of controls and engineering at Mitsubishi Electric, took care to explain that it was not a centralized control system.

"It's actually distributed control that's done by Wireless Interfaces communicating to Wireless Interfaces without dependence upon the internet. This allows kumo station to control both the heat pump and the supplemental heating in a very efficient manner. The Wireless Interfaces are what make the decisions."

The Wireless Interfaces in Matt's home receive information from Wireless Temperature and

Humidity Sensors in each room and an outdoor air temperature sensor outside of the home. As smart controllers, the wireless interfaces communicate with each other, and, using the data provided by the sensors, collectively calculate the most efficient and cost-effective heating source to use. In addition to sensor data, the calculations are informed by variables including the efficiency of the heat pump, the efficiency of the fossil fuel system, the cost of electricity and the cost of fossil fuel.

In addition to seeing his heating costs reduced significantly from what he paid the previous winter, Matt was pleased with how the system automates changeover and coordinates cooling, heating, humidification and ventilation based on his preferences and ambient conditions. He said, "One of the coolest parts about the product is that it does it on its own. You set the settings and it knows. It does the work for you. You don't have to worry, say, when you're out of town and have to worry about what the temperatures are outside. It just does it on its own."

As an HVAC contractor and a homeowner, Matt can speak from first-hand experience about the benefits of kumo cloud. "One of the nicest parts of being a part of this is to be able to sell it. I see this product and its ability to use both stages, two heating sources, as being of huge benefit to homeowners, especially here in Maine. That's what we're doing at our house right now, because it can get 20 below here. It's really nice to have a device that you can control from your pocket, right from your phone and be able to know that your house is safe and that you are not going to have a heat pump failure and you have a backup. We're really looking forward to going to market with this product. I think it's going to really tie together that typical Mainer that needs two different sources of heat to have peace of mind."

Conclusion

As consumers continue to integrate smart technologies into their daily lives, homeowners are likely to become increasingly receptive to the benefits of distributed smart controls. HVAC contractors who provide services to these homeowners will not recommend distributed smart controls to merely satisfy the trend, but will give serious consideration to how such systems can lower energy bills and deliver great customer experiences. Distributed smart controls automatically perform work toward achieving and maintaining the optimal balance of heating sources needed for comfort, energy efficiency and cost control. They are here, and as they evolve and improve, expect to see distributed smart controls become an integral part of how heating sources are coordinated and managed.

References

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[4] 2017 U.S. Houzz & Home Study: Annual Renovation Trends, September 2017

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