Ductless Mini-Splits—What’s All the Excitement About?
By Mark Pierce

Ductless mini-splits, a type of air-source heat pump, are generating a lot of excitement and interest in the energy efficiency community across the United States. While the technology is not new—ductless mini-splits have been in use for years in Asia and Europe—they have only recently been introduced to the U.S. Mini-split systems also offer something to be excited about for the many homeowners who use hot-water, steam or electric baseboard for their space heating needs. Designers and builders of net-zero energy homes are excited about the ability of some mini-split systems to pull a significant amount of heat from frigid winter air and deliver that heat indoors for space heating purposes. The technology of mini-split systems also makes it possible to provide whole-house air-conditioning at a very affordable price to homes heated with boilers or electric baseboard heating systems. This article explores the advantages of ductless mini-split systems for building professionals and for individual homeowners.

Most of us are familiar with heat-pumps. They do not create heat, but instead move heat from one space and transfer it to another space. In a sense this is what air conditioners do. They remove heat from indoor spaces and dump that heat to even hotter outdoor air during summer months. But a heat pump can be reversed to pull heat from colder outdoor air and move that heat to help warm indoor spaces during colder months. But conventional air source heat pumps that have traditionally dominated U.S. markets are not extremely effective at moving warmth from cold outdoor air. This is fine in areas of the country that have relatively mild winters, and helps a bit with heating during the spring/fall shoulder seasons in colder areas. Conventional air source heat pumps can be effective at pulling heat from outdoor air in the 40°F range, but their efficiency and effectiveness drop off to negligible levels when outdoor temperatures get much lower than that. Contrast this with the ability of some mini split heat pumps to pull a significant amount of heat from air as cold as 5°F and you begin to see what the excitement is all about.

There are three significant differences between conventional and mini-split air source heat pumps. The first is that, as the name implies, ductless mini-split units do not need to be connected to an (Continued on page 4)
Conventional air-source heat pump systems are relatively easy to install in homes with hot-air furnaces. An indoor heat exchanger located within the furnace air plenum is attached to a compressor located in the outdoor portion of the heat-pump (see Figure 3) via refrigerant lines. The compressor cools the refrigerant which is then pumped to the indoor heat exchanger. The furnace fan then blows air through the heat exchanger and this cooled air is channeled to each room of the house via a system of air ducts (Figure 2).
Figure 4 - **Mini split system:** As you can see from this graphic, no duct-work is required; just relatively small diameter supply and return refrigerant lines are needed to connect the outdoor compressor to the indoor heads (heat exchangers). Each head can be individually controlled, allowing occupants to cool only the spaces they desire. So during daytime hours the living areas of the home could be cooled and not bedroom areas. During sleeping hours bedrooms can be cooled without also cooling living areas. This is another attractive factor with mini-split systems that is not easily available with conventional heat-pump systems. It also adds to the overall efficiency of a mini-split system.

![Diagram of mini-split system](image)

Each head requires a condensate drain to outside

Indoor heat exchangers called heads can be placed to cool individual rooms, or zones within the house. Up to 8 heads can be attached to each outdoor compressor.

Refrigerant lines from outdoor compressor connected to each head

Figure 5: **Outdoor compressor**
This portion of the system is hooked to each indoor unit (Head) via small diameter refrigerant lines.

![Outdoor compressor](image)

Figure 6: **Head**
Indoor portion of a mini-split system is called a head. The heads deliver cooled air from the outdoor unit during summer months and can also deliver a significant amount of heat from outdoor air during winter months.

![Head](image)
indoor system of air ducts that distribute the conditioned air to each room of the house as conventional heat-pumps do. Similar to mini-splits, conventional heat pumps have an outdoor compressor and heat exchanger tied to an indoor heat exchanger via refrigerant lines. But the similarity ends there. With traditional heat pumps the indoor heat exchanger is located within a portion of the furnace air handling system which in turn is tied to a whole house system of duct work. While the refrigerant is responsible for removing the heat from the house, air forced through the duct system via a powerful fan is the method used to distribute the cooled air throughout the house. (see Figures 1-3 on page 2 for graphics & pictures that illustrate a conventional heat-pump system). With a mini-split system there are no ducts, only relatively small diameter refrigerant lines connecting the exterior compressor to a series of indoor heat exchanger “heads.” A typical exterior mini-split unit can handle up to 8 interior heads (see Figures 4 - 6 on pg. 3 for Illustrations of a typical mini-split system).

Eliminating the need for duct work means that it becomes possible to cool existing homes that do not have a furnace and the accompanying whole house system of duct work, homes heated with a hot-water boiler for example. Prior to the introduction of ductless mini-splits, owners of houses without furnaces that wanted the efficiency and comfort of central air needed to be retrofitted with an air handler and duct work running to each room of the home. This is difficult and also extremely expensive to do. The other option was to use several window AC units to cool the home. Window units are much noisier than heat pumps and also much less efficient.

The second significant difference between mini-split and conventional systems is that mini-splits make use of a technology called variant refrigerant flow. When conventional heat pumps are on, it runs at full speed, regardless of the load on the system. When the heating or cooling load is satisfied, the unit switches off. The ability of mini-splits to run at variable speeds, from very low to very high, with the speed being set automatically based on the cooling or heating load on the system, is another factor that makes mini-splits significantly more efficient than conventional heat pumps.

Not your average air source heat pump

The third, and for designers and builders of net-zero energy homes, most exciting difference of mini-split heat pumps is the ability of some brands to pull heat from very cold air. As mentioned, some brands of mini-splits on the market can pull heat from very cold outdoor air. Just how much heat can such a mini-split system deliver to a house from very cold outdoor air? Marc Rosenbaum, owner of South-Face Energy in New England, recently built a very well insulated and carefully air-sealed home for himself on Martha’s Vineyard. Rosenbaum reports that during this recent winter the outdoor temperature dropped to 5° F, yet his ¾ ton mini-split heat pump system kept his 2,400 square feet house at a comfortable 70°F. (Source: Guest Blogs, Green Building Advisor accessed at: http://www.greenbuildingadvisor.com/blogs/dept/guest-blogs/minisplit-heat-pumps-and-zero-net-energy-homes).

What do mini-splits have to do with net-zero energy homes?

A net zero-energy home balances the annual amount of energy it consumes for space heating, water heating, powering lights and electrical appliances with the amount of energy created on-site with a renewable energy system – solar PV panels or wind turbines for example. Most homes in the northeast install a fossil fuel fired space heating system. However, it can be difficult to obtain a net-zero energy home when burning fossil fuels on-site. But by combining the attributes of the low heat load of a super insulated house, with an air source mini-split unit capable of pulling heat from very cold winter air coupled with a correctly sized on-site renewable energy system allows houses, even in cold areas of the country, to achieve net-zero energy consumption. Part of the beauty of this method is that by spending some extra money to super insulate the house, R-40 walls, R-60 ceiling, an expensive central heating and distribution system is not needed. Ductless mini-split systems are much less expensive than typical fossil fuel fired central heating systems and a fraction of the cost of ground-source heat pump systems. Ductless mini-split systems, coupled with a super insulated house are making the construction of a net-zero energy home cost competitive with a typically constructed home.
The term green building has been prominent in discussions about sustainability for about a decade or so (Laquatra et al., 2008). Homeowners, home buyers, builders, and remodeling contractors have become more aware of green building issues through information available from the U.S. Green Building Council, Green Builder College, Green Builder magazine, and many other resources. A green building, whether it is a residence, a commercial structure, or an institutional building, is energy and resource efficient and has healthy indoor air. However, other issues are critical as well, such as choices made regarding building materials and heating systems (Laquatra et al., 2008).

An important feature to consider when building green is siting, which reflects the use of sunlight for daylighting and energy. Damage to plants and vegetation is minimized at this stage. Another consideration is to build a small house that optimizes the use of building materials (Wilson, 2010).

Green building also focuses on materials, specifying re-used or salvaged materials to those with the highest recycled content and finally to sustainably harvested or mined materials. Another issue to consider is the use of alternative construction techniques that use less building materials and provide higher levels of energy efficiency than conventional techniques. Examples of this are Advanced Framing, which is also referred to as Optimum Value Engineering; and the use of Structural Insulated Panels (SIPs). Embodied energy, the energy used in producing and transporting materials to the construction site, is another consideration, as is waste minimization during construction.

Products are chosen for their durability and contributions to energy efficiency. Water use is also a factor. For example, a house without a lawn is considered to be greener than one that features native plants that are watered with recycled water (Vick & Tufts, 2006). Paints that do not emit volatile organic compounds (VOCs) are natural choices for green construction, because they do not contribute to indoor air quality problems (Laquatra et al., 2008).

Green building may include green certification from one of various organizations that provide this service, including EarthCraft House, the U.S. Green Building Council’s Leadership in Energy and Environmental Design (LEED) program, and the National Green Building Standard of the International Code Council.

Green homes are not difficult to build, but before they are constructed as a matter of routine, training and education of general contractors and subcontractors, as well as homebuyers, would be necessary. Green homes make contributions to energy independence and human health. As educational resources become increasingly available to help people understand issues related to green building, so do chances that building green homes will become routine.

Sustainable Communities

When the concept of sustainability is applied to communities, the term refers broadly to various community attributes, including the built environment; transportation, including reduced or eliminated automobile dependency; water systems; local economies; health and safety; education; the arts; and more. The Sustainable Tools for Assessing and Rating (STAR) Communities is a national certification system that recognizes sustainable communities (STAR Communities, 2014a). This system assigns scores to community features so that municipalities can assess their progress toward sustainability goals. For example, 100 points can be earned in each of these areas: Built Environment; Climate and Energy; Economy and Jobs; Energy and Empowerment; Health and Safety; and Natural Systems. The category of Education, Arts, and Community can achieve up to 70 points because it has fewer STAR objectives than the other categories.

Community Sustainability Rankings under STAR are 600 or more for a 5-STAR Community; 400 – 599 for a 4-STAR Community; 200 – 399 for a 3-STAR Community; and under 200 for a Reporting STAR Community. This rating system is used by many cities and counties throughout the U.S. and Canada, for example Albany, New York; Northampton, Massachusetts; Cleveland, Ohio; Wichita, Kansas; Vancouver,
British Columbia; among others (STAR Communities, 2014b). As students in academic planning programs and practicing planning professionals, including city, village, town, and county planning board members and personnel of planning departments become familiar principles of sustainability, the implementation of these principles will eventually become routine.

Conclusion

Housing is considered to be sustainable when efficiencies across various aspects are considered and deployed. These include efficiencies in the use of materials, energy, water, and other resources. Communities are considered sustainable when numerous attributes are planned and developed in ways that viably meet present and future needs. Much education of builders, subcontractors, planners, and other community officials is necessary before sustainability will be considered as a matter of routine when homes are built and communities are planned. For that to occur, policy makers need to understand the importance of this issue and advance the agenda through public discussions and, ultimately, legislation.

References


What is Causing the Black Streaks On My Roof, and How Do I Get Rid of Them?

Carole Fisher

Those black streaks that look like mold are usually the result of harmless, but pervasive, algae that grow on asphalt roofing shingles. Often first appearing on a shady or north-facing side of the roof, the algae require moisture and feed on the limestone filler in asphalt roof shingles. However unsightly, neither algae nor mold on a roof is harmful, but may reduce the lifespan of your roof. Fortunately the stains are not difficult to remove, and the algae growth can be controlled.

Power/pressure washing of asphalt roofing is not recommended as it may damage the integrity of the roof and will most likely void your roofing warranty. Instead, if you are willing to get up on the roof, you can clean the shingles with a non-metallic scrub brush using a solution of 1 gallon household bleach, 2½ gallons of water, and 1 cup of detergent (ammonia-free). For safety, consider wearing a harness for fall protection.

Choose a cloudy day to clean your roof so the solution doesn’t evaporate so quickly. Starting at the top, work your way down the roof. Make sure to always stand on a dry section of roofing, as the cleaning solution will make the roof slippery. Scrub gently, being careful not to damage the shingles, then rinse with a garden hose. Or spray a section of roof with the solution using a garden pump sprayer. Let the bleach solution sit for about 15 minutes, then rinse off with the hose. Rinse the roof thoroughly and make sure the cleaning solution is rinsed from gutters and downspouts also.

Before cleaning your roof, you may want to spray all plants growing near the house with water to help protect them from damage caused by the chlorine bleach solution. You may also want to cover your plantings with plastic to avoid potential spotting of leaves. To keep the algae from coming back, you can purchase and install strips of either zinc or copper under the top row of shingles just below the ridge. Whenever it rains or the snow melts, some of the zinc or cop-
per molecules will wash down the roof and create an environment that prevents the future growth of algae, mold, or moss.

Another option is to use a spray-on commercial product to block the growth of algae or mold, and which usually needs to be applied annually. Also available are asphalt roofing shingles that contain a copper additive to prevent mold and algae growth.

Back to Table of Contents

**Laptop Computers and Thermal Comfort of Users**

Han Zhang, a PhD student here at the Department of Design and Environmental Analysis at Cornell University is completing his dissertation research. Working with Professor Alan Hedge, Han conducted both survey and experimental studies that examined user comfort and burn-risk related to heat generated by laptop computers. Han has provided HHE-News with a brief description of his research and some of his findings.

*Survey of laptops*

The heat from some laptop computers has resulted in reports of toasted skin syndrome and even skin burns. Although standards exist to limit the maximum temperature of electronic devices to prevent skin burns, few studies have been conducted on the thermal discomfort associated with laptop heat production. Consequently, I conducted a survey and temperature measurement with 100 laptop computer users. The study surveyed the normal working temperatures of laptops and asked users how they felt about the heat coming from both keyboard side and bottom side.

I found that newer laptop computers, and the ones with larger screens tend to have lower surface temperatures, and when the computers run video playing software, the bottom temperature can increase. As the surface temperature on keyboard and bottom increased, users tended to report more discomfort. We also found that the use of covers or stands with the laptops can improve user thermal comfort.

*Experimental studies of how people feel about the heat from a simulated tablet computer*

A tablet computer’s surface temperature can reach levels that can lead to user discomfort, especially in a warm environment. The ambient environments in which tablet computers are used can also vary. To understand how users perceive the heat from tablet computers, we conducted a laboratory study where surface temperatures and ambient temperatures were controlled. The room temperature ranged from 55°F to 92°F.

In the tablet computers surface temperature range of 93°F to 111°F, we found that as the surface temperature of the device increased, the participants’ thermal comfort was decreased. Participants’ thermal responses to the surface heat of a simulated tablet were moderated by the indoor temperature. Higher tablet surface temperature (111°F) was rated less warm in a cool environment than a hot environment, while lower tablet surface temperatures (93-100°F) were rated warmer in cool than hot environment. The thermal responses corresponding to the tablet surface temperatures and ambient temperatures will be helpful for setting future tablet computer heat dissipation design limits.

Toasted Skin Syndrome is a term used within the medical community to describe a type of skin rash. The rash is associated with exposure to heat not hot enough to cause burns, but warm enough to increase local skin temperatures and create a rash. Laptop computers and video games are cited as frequent causes of toasted skin syndrome. There is some concern within the medical community that toasted skin syndrome may increase the risk of skin cancer and infertility. However, to date, none of those concerns have been proven.

Back to Table of Contents
**Uncontrolled air leakage (infiltration/exfiltration) across the building enclosure of a house, is the primary source of heat loss in most homes during the winter heating season. Air leakage into wall, ceiling and floor cavities also carries moisture laden air into those cavities where it will condense on colder surfaces eventually causing mold growth and rot on structural components. Mold growth often leads to indoor air quality problems. To overcome this problem a house needs to be constructed with a building enclosure that is as air tight as possible. Yes, the occupants of a home need fresh air, and this is easily be provided with various types of mechanical ventilation systems specifically manufactured for residential structures. Build tight, but ventilate right is the saying among building scientists.**

A good quality building enclosure will have a thermal (insulation) boundary that completely surrounds the heated portions of the home. It ALSO will have a dedicated air boundary made from a durable material that is air-impermeable. The air boundary material should be in continual contact with the thermal boundary of the home and any penetrations in the air-boundary need to be sealed with caulk or gaskets to block air leaks. The majority of insulation products used in houses are designed to reduce conductive heat loss by trapping air within the fibers of the insulation. This means there is a double energy penalty for not installing an air-boundary. Without an air-boundary heated air from inside the house quickly flows through the insulation and to the outdoors (convective heat loss). In addition the movement of that air through the insulation material significantly decreases its ability to lower conductive heat loss.

In a coming issue of *Housing and Home Environment News* air-boundary materials and their installation will be discussed.

**Contributors to this issue of HHE News**

Carole Fisher: (crf11@cornell.edu)
Consumer & Food Safety Educator
Cornell Cooperative Extension of Tompkins County
Carole is coordinator of the CCE Consumer HelpLine, which helps consumers explore their options and provides unbiased, research-based information.

Han Zhang (hz262@cornell.edu)
Ph. D. Human Behavior & Design
Department of Design & Environmental Analysis
College of Human Ecology
Cornell University

Joseph Laquatra (jl27@cornell.edu)
Professor
College of Human Ecology
Department of Design and Environmental Analysis
Cornell University
3423 Martha Van Rensselaer Hall
Ithaca, NY 14853

Mark Pierce (mrp6@cornell.edu)
Extension Associate
College of Human Ecology
Department of Design and Environmental Analysis
Cornell University
4233 Martha Van Rensselaer Hall
Ithaca, NY 14853

HHE News is also posted on the web: