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Ductless Mini-Splits and Their Kin

The Revolution in Variable-Refrigerant-Flow Air Conditioning

NEW HEATING AND COOLING technology arriving from Asian manufacturers is shaking up the world of mechanical systems, offering compelling value and efficiency in a variety of settings. The technology varies in nature and scale, making it applicable to everything from single-family to multi-unit residential buildings and from small to mid-sized commercial buildings. Buildings that require heating and cooling simultaneously in different areas stand to save significant amounts of energy by transferring heat from one area to another.

This technology is fully realized at the commercial level in *variable refrigerant flow (VRF) multi-split* systems with up to 20 tons (240,000 Btu/hour or 70 kW) of cooling each; multiple systems can be combined for more cooling. Similar to these are simpler *mini-split* systems with two tons (24,000 Btu/hour or 7.0 kW) or less of cooling capacity. Mini-splits don't have the added efficiency of VRF, but they still represent an attractive option for smaller spaces in homes or light-commercial buildings.

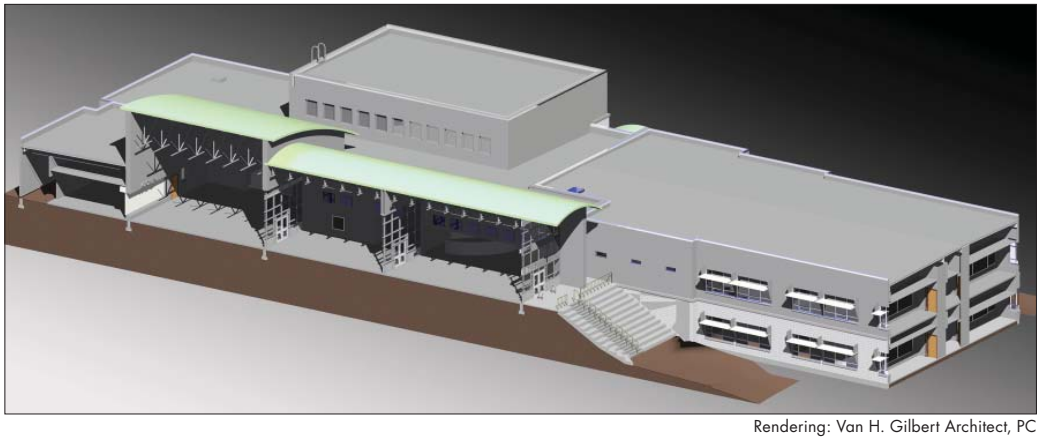
Extending the Reach of Split Systems

Both mini-splits and VRF multi-splits are types of *split systems*, a category that includes conventional central air-conditioning systems both large and small (see table, page 13). Any air-conditioning system includes two units, one in which heat is exhausted to the outdoors and one in which heat is absorbed from the indoors. Whereas packaged systems like room air-conditioners (and refrigerators) combine these into one unit, split systems separate these into indoor and outdoor functions.

In the outdoor *condenser* unit, a *compressor* pressurizes refrigerant gas, raising its temperature. The refrigerant then runs through a *condenser coil*, radiating its heat to the outdoor air. Now cooled to a liquid

(continued on p. 9)

Autodesk, Bentley Continue to Expand *(see article on page 2)*



Rendering: Van H. Gilbert Architect, PC

This rendering of a section through a prototype elementary school for Albuquerque Public Schools by Van H. Gilbert Architect was done in Autodesk Revit and analyzed in Autodesk's Green Building Studio.

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Quote of the month:

"So many municipalities were contacting us, asking whether their current code met the Challenge and, if not, how far off they were."

– Kristina Kershner of Architecture 2030 on its new guide comparing existing codes to the 2030 Challenge

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What's Happening

Autodesk, Bentley Continue to Expand, Agree to Collaborate

Fresh off a series of acquisitions early in 2008 that provide energy modeling capabilities to complement their building information modeling (see *EBN* Vol. 17, No. 3), both Autodesk and Bentley are at it again. This time, Autodesk bought Ecotect and its related tools from Square One Research, while Bentley has obtained the exclusive worldwide distribution rights to the Tas line of energy and fluid simulation tools developed by Environmental Design Solutions Limited (EDSL). As these acquisitions were being finalized, the two companies also announced a mutual commitment to ensuring interoperability between their tools for the architecture, engineering, and construction (AEC) community.

With the purchase of Ecotect, Autodesk has obtained the most visually appealing and architect-friendly of the widely used modeling packages. "Ecotect offers a more complete sustainability analysis of buildings" than Autodesk's previous acquisitions in this area, according to the company's senior product manager for sustainability, John Kennedy. Ecotect is highly regarded as a teaching tool for the visual feedback it provides on physics, solar angles, daylighting, and acoustics. Autodesk's acquisition also brings Ecotect's creator, Andrew Marsh, Ph.D., to the Autodesk team. Both the software itself and Marsh's skills should help Autodesk move towards its vision of providing instant performance feedback for designers within its design tools. Meanwhile, Autodesk's challenge, according to Kennedy, is to help designers understand how to use instantaneous feedback, such as the energy, water, and carbon predictions already available from Green Building Studio.

Bentley is pursuing a similar vision, according to Huw Roberts, a global marketing director for Bentley. "We're excited about integrating that analysis into the workflow," Roberts said. Looking into the future, he envisions a scenario in which, "as you make the window bigger in the room, the impact on your analysis could be presented to you right away—perhaps even putting limits on the edits that you can make based on that analysis." Bentley's partnership with EDSL and its Tas software is consistent with Bentley's traditional strength in especially large and complicated projects. Tas Building Designer incorporates both natural and mechanical airflows into its energy models, while a second tool,

Counting Carbon Can Be Tricky!

The image on the cover of our July issue showing cubes representing one metric ton of steel, concrete, and wood and much larger cubes showing the associated CO_2 emissions contained an error. The carbon quantity shown for concrete actually represented the carbon associated with one metric ton of cement. A ton of concrete is responsible for much less carbon—about 0.2 metric tons, instead of 1.2—because cement only represents about 12% of a typical concrete mix, and the other ingredients are much less carbon intensive.

It may also be misleading to compare these three materials in this way, because their mass does not represent their utility. A structure made of concrete will weigh much more than a structure made of steel or wood, for example. We've posted the full letters from the stakeholders on the blog at BuildingGreen.com/LIVE.

Also, in the table of "Greenhouse Gases By Energy Content of Power Plant Fuels," the labels for residual (#6) and distillate (#2) fuel oil were reversed. Residual fuel oil has higher emissions than distillate (as shown in the previous table).

Finally, in the graphic of above- and below-grade sequestered carbon, the numbers on the y-axis should all be positive (not negative below the axis, as shown).

Tas Ambiens, uses a computational fluid dynamics (CFD) program to display a cross-section of microclimate variations within a room.

While Autodesk's recently acquired Green Building Studio and now Ecotect are both especially useful for early feedback during conceptual design, Bentley's tools are more sophisticated and demanding to use. The collaboration announcement should ensure that designers using either company's BIM tools can continue to take advantage of the broad array of analysis tools. Roberts touted the agreement as a specific arrangement that will provide for low-level integration across the two companies' tools, but Autodesk's senior public relations manager for the AEC industry, Paul Sullivan, is more reserved: "This deal was announced because we want people to be aware of it, but details will emerge over the next couple of years," he said. Either way, the promise of real-time performance feedback within the design environment is challenging enough that each company will likely be most effective at delivering it within a software environment that it totally controls.

– Nadav Malin

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Mazria Publishes Code Equivalents for 2030 Challenge

Architecture 2030, the organization created by Ed Mazria, FAIA, to reduce the building sector's contribution to climate change, has published a guide that compares existing energy codes with the performance targets of the 2030 Challenge. The 2030 Challenge calls for an immediate 50% reduction in the fossil fuel consumption of new buildings, compared with a baseline drawn from the 2003 Commercial Building Energy Consumption Survey (CBECS) for commercial buildings and Residential Energy Consumption Survey (RECS) for residential buildings.

The white paper "Meeting the 2030 Challenge Through Building Codes," published in June 2008, provides a table showing the degree to which commonly referenced energy codes have to be exceeded to achieve the 50% fossil-fuel-reduction target. Selected content from this table is provided above.

The paper was written in response to demand, according to Architecture 2030 director Kristina Kershner. "We created the chart because so many municipalities were contacting us, asking whether their current code met the Challenge and, if not, how far off they were," she told *EBN*. Charles Eley, FAIA, P.E., of Architectural Energy Corporation, Harvey Bryan, FAIA, Ph.D., of Arizona State University, and Mark Frankel, of the New Buildings Institute, contributed to the project.

The brief white paper addresses only the initial 50% reduction called for in the 2030 Challenge, not deeper cuts that are called for in later years (though not much later—a 60% reduction is called for by 2010). According to Kershner, the organization will publish the 60% and subsequent equivalents in the coming months.

– Alex Wilson

For more information:

Architecture 2030
www.architecture2030.org

Improvement or Level Required to Meet the 2030 Challenge

Code or Standard	Commercial	Residential
ASHRAE 90.1-2004	30% below	N/A
ASHRAE 90-1-2007	25% below	N/A
ASHRAE 189 (in progress)	Meets target	N/A
IECC 2006	30% below	30% below
California Title 24 – 2005	N/A	15%–25% below
California Title 24 – 2008	10% below	N/A
Oregon Energy Code	25% below	30% below
Washington Energy Code	25% below	25%–30% below
RESNET HERS Index	N/A	65 or less
LEED-NC 2.2 and LEED for Homes	New construction, EA credit 1: 6 points Renovation, EA credit 1: 8 points	HERS Index 65
LEED 2009 (in progress)	New construction, EA credit 1: 7 points Renovation, EA credit 1: 9 points	N/A
GBI Standard (in progress)	Path A, 8.1.1.1: 150 points	N/A
EECC Option (prescriptive path)	N/A	EC-154
NBI Option (prescriptive path)	New construction, Core Performance with enhanced features	N/A

Adapted from *Meeting the 2030 Challenge Through Building Codes*, 2008

Solar Water Heating Required for New Homes in Hawaii

Despite the highest electric rates in the U.S., abundant sunlight, and a frost-free climate that allows the use of relatively simple open-loop designs, only about a quarter of all houses in Hawaii currently heat water with the sun. But legislation

Solar water heaters are standard equipment on houses at the Helemano Military Reservation in Wahaiwa, Hawaii. Photo courtesy of Inter-Island Solar Supply

passed in June 2008 will require that most new one-family houses be equipped with solar water heaters, starting in 2010. The law cites Hawaii's overwhelming dependence on fossil fuels and the impact on the state's economy of rising petroleum prices as reasons for the requirement. The Hawaii Public Utilities Commission will be tasked with formulating specifications for acceptable installations.

The law will rescind the current state tax credit worth 35% of the cost of a new solar heating system, starting on December 31, 2009. Utility rebates of $1,000 now available will also disappear for houses permitted after that date. The Hawaii Solar Energy Association (HSEA) estimates the cost of a solar water heater installation at $6,000; without state and utility incentives, the portion paid by the user will increase by $2,450, and if the federal tax credit, set to end in 2008, is not renewed, it would increase by another $1,800.

The Hawaii Association of Realtors, the Building Industry Association of Hawaii, and the state's gas utility opposed the law. Surprisingly, so did HSEA, which described the law as "grossly flawed," although it supported the Legislature's stated goals. HSEA's Rick Reed argued that the bill was not needed, noting that Hawaii has "the most robust and successful solar water heating market in the country." According to Reed, in 2007, about 5,500 new solar hot water systems were installed, accounting for almost half of the new residential systems in the U.S.

In a letter to Governor Linda Lingle, HSEA argued that the bill includes too many loopholes. Exemptions from the law's requirement are to be granted if any of four conditions are met: the "solar resource" is poor; a cost-benefit analysis finds the system won't pay for itself over 15 years; wind or photovoltaics are used for primary water heating; or a gas-fired, tankless water heater and at least one other gas appliance are installed in the house. The law allows any architect or engineer, even if in the employ of the builder, to certify that a dwelling meets the variance conditions. HSEA also criticized the bill for failing to guarantee that current quality standards for solar heating systems are maintained.

Hawaii is the first state in the U.S. to mandate installation of solar hot water heaters. Israel has mandated solar heating systems since 1980; today about 90% of buildings there have them. Also, Spain requires new and renovated buildings to obtain 30%–70% of their hot water needs through solar means.

– Michael Wilmeth

Jones Lang LaSalle Gives Green Globes a Boost

Property management and real estate investment firm Jones Lang LaSalle (JLL) acquired ECD Energy and Environment Canada in July 2008. Toronto-based ECD was responsible for launching Green Globes, a program that aims to compete with the U.S. Green Building Council's LEED Rating System (see *EBN* Vol. 14, No. 3). The acquisition will not affect administration of Green Globes because the rating system is controlled by other organizations—by the Green Building Initiative in the U.S. and by the Building Owners and Managers Association–Canada (BOMA Canada) in that country.

JLL bought ECD primarily to enhance the services it can offer building owners, according to Dan Probst, JLL's chairman of energy and sustainability services. "A lot of prospective tenants in the market want to include sustainability criteria in their search for leased space. Tools like this can help with that need for assessment," he said. To serve that need, JLL has acquired similar capabilities in the U.K. and Australia.

Ironically, JLL has not used Green Globes yet. It plans to use the system soon, however, both for existing buildings and for entire real estate portfolios in the U.S. and Canada, according to Probst. Whether it will use the tool just for internal assessments or through third-party certification will depend on the owner's needs and interests for each project. "Corporate clients who own and occupy their real estate may not care as much about a certified score," Probst explained, adding that "investors looking for tenants may have more desire for a certification process." Probst also expects to continue seeking LEED certification, especially for new construction and tenant fit-out, but also for some existing facilities where LEED's brand is important. "There is room for both," he says, noting that some clients cite LEED

in their requests for proposals for leased space. "LEED is gaining some currency. We're not seeing Green Globes at that level in the marketplace."

Through ECD, JLL has acquired contracts to provide technical support for the ongoing use and evolution of Green Globes. JLL is interested in building on Green Globes internationally, in markets without established rating systems, and hopes to better support specific real estate markets, such as retail and light manufacturing, in the U.S. and Canada. Both in North America and elsewhere, JLL wants to partner with organizations to develop Green Globes as an open standard, but the company will also build internal property-assessment tools based on the Green Globes framework and expertise where that makes sense, Probst says.

– Nadav Malin

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Newsbriefs

Congressional Caucus Focused on Green Building Legislation—Green building has a new voice in Washington: the High-Performance Buildings Congressional Caucus and Coalition. The caucus consists of members of Congress, led by co-chairs Russ Carnahan of Missouri and Judy Biggert of Illinois, interested in green building legislative issues; the group hosts briefings and communicates its findings to other members of Congress. The coalition is made up of several private-sector organizations that support the caucus with research and technical advice as well as event hosting. For its first order of business, the caucus attended a briefing on a report crafted by the National Institute of Building Sciences, among other organizations, in response to requirements laid out in the Energy Policy Act of 2005 (see *EBN* Vol. 14, No. 9). Among other findings, the report recommends that Congress establish metrics and verification methods for buildings' energy efficiency, occupant productivity, durability, and ability to function after a disaster. More information on the caucus, as well as the full report, is available at www.hpbccc.org.

EPA to Study Formaldehyde—In response to a petition from 25 organizations, led by the Sierra Club, and about 5,000 individuals, the U.S. Environmental Protection Agency (EPA) has announced that it plans to give "advance notice of proposed rulemaking" on formaldehyde in composite wood products in fall 2008. EPA denied the petition's request to adopt the California Air Resources Board regulations pertaining to hardwood plywood, medium-density fiberboard, and particleboard (see *EBN* Vol. 16, No. 6). The agency claimed there was insufficient data to assess the risk posed by formaldehyde or to identify the least burdensome means of protecting against that risk. Instead, EPA said it would "initiate a proceeding to investigate whether and what type of regulatory or other action might be appropriate." Becky Gillette, who heads the Sierra Club formaldehyde campaign, said that the petition was prompted by widespread complaints of nose, eye, and throat irritation among residents of emergency housing trailers used after Hurricane Katrina. No federal standard for exposure to formaldehyde currently exists, and in 2004, EPA abandoned its assessment of the chemical after seven years of research. Given that EPA has 70 ongoing chemical assessments, considers half the 480 chemicals in its IRIS database in need of review, and completed only four assessments in fiscal years 2006–2007, creating a rule to limit formaldehyde exposure could take many years. Gillette said Congress needs to set a deadline for EPA to act, and Senator Barbara Boxer has said that if the EPA assessment process doesn't improve, Congress will start banning chemicals itself.

Canadian Study Finds Regulations Can Handle Nanotechnology—In response to a request by government agency Health Canada, the nonprofit Council of Canadian Academies has released a study on the risks of nanomaterials (see *EBN* Vol. 17, No. 3 for more on nanotechnology). The group found that nanomaterials are too new and unstudied for a full risk assessment, but it believes existing regulatory mechanisms in Canada can be adjusted to account for the new risks that nanomaterials pose to human health and the environment. To adjust these mechanisms, defini-

A coalition of groups and individuals petitioned EPA on formaldehyde regulation, provoked by widespread complaints of sickness among FEMA-trailer inhabitants. Photo: Mary DeVany

Clotheslines can't be prohibited by Colorado homeowners associations, under a new state law. Photo: Anikasalsera, Dreamstime

tions of nanomaterials would need to be developed, and regulatory "triggers" (actions or materials that bring regulations into play) would need to be reworked. The report recommends a precautionary approach to nanomaterials until a full scientific risk assessment can be performed, similar to the approach Canada has taken with some other materials. The report is online at www.scienceadvice.ca/nanotechnology.html/.

Appropriate Technology Protected in Colorado—While efforts to pass legislation protecting the right to line-dry clothes failed in recent legislative sessions in Vermont, New Hampshire, and Connecticut, a similar law in Colorado passed in April 2008. The law overrides homeowners association prohibitions not only on clotheslines (provided they are retractable), but on wind turbines, shade structures, ventilation fans, evaporative coolers, and efficient outdoor lights. The law permits restrictions of such devices only if the restrictions do not unreasonably impede their use or drive up their cost. The "right to dry" has become a *cause célèbre* in many places, as those wishing to line-dry their clothes run up against homeowners association rules and, occasionally, local ordinances. Dryers account for about 6% of residential electricity use in the U.S., equivalent to the electricity generated by burning 30 million tons of coal each year.

First Canada Green Building Council Summit a Success—In June 2008, the Canada Green Building Council (CaGBC) hosted its first national green building summit, Shifting Into the Mainstream, in Toronto. Over 1,200 people attended the event, which included educational sessions and a trade show. The development of LEED Canada 2009, a major reworking of the LEED Canada Rating System, was on the agenda. The organization also announced that Canadian versions of LEED for Homes and LEED for Neighborhood Development should be available by the end of 2009. Finally, CaGBC launched the Green Building Performance Initiative, which will set baselines for energy and water use for several building types. These baselines will later be incorporated into the Green Building Performance System, which will make it easier for building owners to compare their buildings to the baselines and track performance improvement. More information is available at www.cagbc.org.

San Francisco Allocates $3 Million for PV Incentives—San Francisco officials hope to lead the nation in the installation of rooftop photovoltaic systems by having 10,000 systems in place within a decade. (About 770 systems are currently installed.) The City's Board of Supervisors has approved $3 million per year for ten years to provide taxable incentive payments to residents and businesses installing new systems on existing buildings. Residents can receive $3,000–$6,000 for systems of at least 1 kilowatt, with the greater incentives going to those who hire graduates of a City workforce development program to do the installation. Businesses are eligible to receive $1,500 per kilowatt, up to $10,000 per system. The program is intended to leverage state and federal incentives; combined with those programs, the out-of-pocket costs of a three-kilowatt system could drop from $24,000 to $11,000. For more information, visit www.sfwater.org.

Massachusetts Enacts Far-Reaching Energy Legislation—The Green Communities Act, passed by the Massachusetts Legislature and signed into law on July 2, 2008, promises to "reduce electric bills, promote the development of renewable energy, and stimulate the clean energy industry that is taking root here in the Commonwealth," according to Governor Deval Patrick. The act includes a wide range of measures to promote energy conservation and renewable energy development. Among other things, it requires utilities to increase the share of renewables in their energy portfolios by 1% annually—double the current rate—to reach 25% renewable generation by 2030. Utilities will be required to enter into 10- or 15-year contracts with renewable-energy suppliers in order to facilitate suppliers' acquisition of financing. The act also promotes conservation by tightening the state's energy code and requiring utilities to invest in cost-effective efficiency measures before meeting growing demand with more generating capacity. The law promotes distributed power generation by increasing the cap for net metering from 60 kW to 2 MW and by allowing utilities to lease photovoltaic arrays to customers.

Product News & Reviews

Energy-Efficient Water Coolers from Elkay and Halsey Taylor

For a cool drink of water that avoids the environmental costs of extracting, bottling, and distributing bottled water, the humble drinking fountain is getting a new look. Elkay, makers of drinking fountains and pressure water coolers (drinking fountains that refrigerate and store water before dispensing), is set to release a new pressure water cooler in the fall of 2008, the Elkay VRCGRN (it will also be sold by Halsey Taylor, a subsidiary of Elkay, as the HVRGRN).

Elkay hopes that the model will become a new standard-bearer for environmental responsibility. For durability and ease of cleaning Elkay is making the basins and cabinets from stainless steel and the frames from galvanized steel. But the substantive improvements will be found under the cabinet.

"We redesigned the refrigeration system to be as efficient as possible," says Rod Magnuson, marketing manager at Elkay. The company purchased energy-efficient compressors that use non-ozone-depleting R-134a refrigerant, the industry standard, but Elkay fine-tuned these compressors, balancing the charge of the refrigerant under full-load conditions (using a continuous flow of water and warm ambient air) and no-load conditions (using different air temperatures and no water flow). The company then wrapped the cooling unit in EPS foam. The result is a unit that uses 7.7% less R-134 refrigerant than the industry average, according to the company, while improving the overall energy and water efficiency of the water cooler. "We couldn't take the refrigerant level any lower without compromising [cooling] performance," said Magnuson.

Elkay reduced water consumption as well through the use of a low-flow bubbler. (Manufacturers use the term "bubbler" to describe to the nozzle that dispenses the water, not the whole drinking fountain, as in some regions.) These low-flow bubblers do not use an aerator, like some low-flow faucets, which would create a poor flow for drinking. Instead, Elkay thinned the stream. Considering that up to 60% of the water dispensed from a standard bubbler goes down the drain, according to industry estimates, a low-flow bubbler should offer considerable water savings. Collecting the water in a cup or a bottle avoids this waste altogether, and the VRCGRN is available with an optional glass or bottle filler.

An optional water filter is also available, certified to ANSI Standards 42 and 53 for water treatment units, which improves tap water by reducing chlorine, particulates, taste and odor, and many contaminants. Though drinking water is regulated by the U.S. Environmental Protection Agency, local water quality can vary and contaminants can be introduced by piping during distribution. Each filter can process 1,500 gallons (5,700 l)—the equivalent of 12,000 16-ounce plastic bottles—with little to no pressure drop and should last anywhere from six months to a year, depending on use and incoming water quality. The filters cost around $85 each, about six cents per gallon (1¢/l). (Depending on its source, bottled water—which is regulated by the Food and Drug Administration—may contain more contaminants than local tap water.)

While the U.S. does not have an energy standard for drinking-water coolers, the Canadian Standards Association (CSA) created one in 1999: C-815, Energy Performance of Drinking Water Coolers. CSA C-815 provides a table listing these standards (the "energy effective limit"), which are based on the maximum amount of energy (the "standard minimum energy factor") a cooler uses to provide a specified number of gallons. The calculation is based on 10% "loaded" conditions (a steady flow of 80°F (27°C) water in, 50°F (10°C) water out, and 90°F (32°C)

Energy Consumption of Pressure Water Coolers

Pressure Water Coolers	Measured ARI Rate Gallons/Day	kWh/Day	Gallons/ kWh	Percent of Efficiency Limit
Competitor 1	193	1.28	151	121%
Competitor 2	167	1.13	148	119%
Competitor 3	170	1.16	147	119%
Elkay Model A	201	1.19	169	136%
Halsey Taylor Model B	202	1.15	175	141%
VRCGRN / HVRGRN	197	0.81	245	197%

Air-Conditioning and Refrigeration Institute (ARI) Rate: The cooling capacity (tested to ARI 1010) based on the quantity of water cooled by a water cooler, measured using a steady flow of 80°F water going into the cooler and 50°F water out, in an ambient temp of 90°F. All listed models have a nominal rating of eight gallons per hour or 192 gallons/day.

Percent of efficiency limit: This percent is based on an 8-gallon ARI-rated product and a minimum energy factor of 124 gallons/kWh (as defined by C-815.) The higher the percent, the less energy was consumed to produce the 8-gallon rating.

Source: Tests were conducted by Elkay's UL-certified lab and not verified by a third party.

Elkay's energy- and water-efficient pressure water coolers have stainless steel basins and cabinets that are built to stand up to commercial use. Photo: Elkay Manufacturing

ambient air) and 90% no-loaded condition (the cooler cycles on and off with no water flow) that are meant to reflect water cooler use. A cooler that is rated for 8 gallons per hour would have a minimum energy factor of 124 gallons (470 l) per kWh per day. Using this standard, Elkay tested the VRCGRN along with five other models (three competitors and two of the company's other models). The VRCGRN used 55% less energy than the industry average, based on a minimum energy factor of 127 gallons (481 l) per kWh per day. The company also found that the VRCGRN used 40% less water, though water consumption is not measured by C-815.

While the price hasn't been set, Magnuson says the units will sell at a premium. If these pressure water coolers prove to be as efficient as the company claims, however, the energy savings and environmental benefits could make them an intriguing proposition, not only for institutional settings where they are more often required, but also in offices and other settings where bottled water has gained turf in recent decades.

– Brent Ehrlich

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Product Briefs

Conserval Introduces Rooftop PV and Thermal Modules—Building on the success of SolarWall's unglazed (transpired) solar collector for commercial and industrial walls (see *EBN* Vol. 5, No 1), Conserval Engineering has created SolarDuct PV/T for rooftop applications. Like SolarWall, SolarDuct has a dark, perforated metal surface that heats air inside a passage. This heated air is then drawn into the mechanical system to reduce a building's heating load. Whereas SolarWall systems need to be installed on a south-facing wall, SolarDuct panels can be placed on any flat rooftop. Angled to take advantage of maximum solar gain, these 6' x 4' (1.8m x 1.2m) modular panels are easy to install and integrate into an air handler—an eight-panel array is capable of generating 8 kilowatts of thermal energy and 2,000 cubic feet per minute of heated ventilation air, according to the company. SolarDuct PV/T can also be used as the racking system for mounting photovoltaic (PV) modules, making cogeneration possible in one rooftop footprint. SolarDuct's metal surface draws heat off the back of the PV cells, improving cell efficiency by as much as 10% and raising overall system efficiency above 50%. This is important since electrical output from PV cells is reduced by 0.4%–0.5% for every 1.8°F (1°C) above 77°F (25°C). Generating heat energy as well as electricity in one unit may provide the quick return on investment necessary to make these units a realistic option for commercial and industrial applications. For more information, visit www.solarwall.com.

Rendering: National Renewable Energy Laboratory

Serving as a racking system for mounting PV modules, SolarDuct PV/T can create both heat energy and electricity.

Alpen Acquired by Serious Materials—Alpen Energy Group, the Colorado-based manufacturer of high-performing windows (see *EBN* Vol. 16, No. 10) and recipient of a 2007 BuildingGreen Top-10 Award, was acquired in June 2008 by Serious Materials, Inc., of Sunnyvale, California. Serious Materials, previously Quiet Solution, Inc., produces acoustic drywall and plywood products (see *EBN* Vol. 14, No. 3), and the company is planning to introduce EcoRock, a greener alternative to standard drywall, later in 2008. According to Steve Weiss, vice president for marketing at Serious Materials, the company had planned to introduce its own line of high-performance windows at the end of 2008; this purchase has jumpstarted the company's entry into the windows business. Weiss told *EBN* that the company is committed to fiberglass frames and top energy performance, which Alpen achieves with such features as triple glazing, multiple low-emissivity coatings, krypton gas fill, and low-conductivity edge spacers. According to Robert Clarke, founder of Alpen, the "financial horsepower" of Serious Materials will allow it to achieve certification from the National Fenestration Rating Council "right away," while actively pursuing expansion, including manufacturing capacity in the Northeast. Financial details of the transaction were not released. For more information, visit www.seriousmaterials.com.

Ductless Mini-Splits and Their Kin *(from page 1)*

form, that refrigerant flows through an expansion valve. As it expands, the refrigerant loses pressure and evaporates, becoming a cold gas.

A pipe brings the refrigerant to the indoor unit, called a fan-*coil*, where it flows through the *evaporator coil*. A fan blows warm air across the evaporator coil, which absorbs heat, cooling the air. In the typical residential or light-commercial central air-conditioning system, that cool air is distributed throughout the building via ductwork that may also be used for heating. Closing the loop, the refrigerant flows back outside to the condenser unit to exhaust the heat it has absorbed.

Split systems benefit from use of a large outdoor unit that doesn't take up indoor space and that reduces interior noise. But as they become larger, central split systems can be cumbersome. They require larger and longer ducts, which take up more space and are likely to leak more air, wasting energy. These systems also face tight limits on the length of their refrigerant loops; refrigerant typically carries some lubrication oil away from the compressor because of unavoidable leaks, and problems compound with longer refrigerant loops. These problems are avoided by systems that distribute chilled water instead of air, and VRF multi-splits have similar advantages. To understand the benefits of these larger systems, we first examine smaller-scale mini-splits.

Mini-Split Systems

Mini-splits are like many conventional split systems: an outdoor condenser unit provides cool refrigerant to an indoor air handler. But instead of serving as a central air handler that provides conditioned air through ductwork, that air handler is typically in the room being cooled, either on the wall or in the ceiling. Although some mini-splits have the option of using small duct systems to distribute air, most are *ductless*. Numerous North American manufacturers produce mini-splits, as well as the Korean and Japanese manufacturers that are leading the way with larger multi-splits.

Ductless mini-splits do away with costly and space-hogging duct systems. Refrigerant lines also move thermal energy more efficiently than ducts, according to the U.S. Department of Energy (DOE), which estimates that ductless systems lose 1%–5% of their thermal energy through distribution, compared with 30% distribution losses for ducted systems. Ductless systems can also increase the reach of a system in a building, because of the greater thermal efficiency of moving refrigerants and because they avoid the fan power required to move larger volumes of air.

The most basic mini-splits come in one-to-one configurations, meaning that one outdoor unit connects to one indoor unit. Some systems offer up to one-to-four unit configurations (this article calls these systems mini-splits to distinguish them from larger multi-split systems, although they are sometimes also called multi-splits). With some models, temperature settings can vary among the indoor units, while with others they must be uniform. Either way, the controls are integrated.

Mini-splits often come with variable-speed compressors, improving energy efficiency. In typical air-conditioning systems, both compressors and air-handling units cycle between off and full capacity, with no settings in between. In most mini-splits, both the compressor and the fan coil are controlled by inverters, which can turn the compressor on at a low amperage and adjust the capacity as needed to meet actual loads. This improves system efficiency and durability as well as occupant comfort.

In mini- and multi-split systems, indoor, wall-hung air-handling units like this one distribute warm or cool air. Photo: Daikin

"The new electric heat"

Most mini-splits can also work as *air-source heat pumps*, in which the refrigeration cycle is reversed, and instead of exhausting heat from the inside air to the outside air, heat is extracted from the outside air and exhausted to the inside air. Operating at temperatures as low as 0°F (–18°C), or down to –13°F (–25°C) in one Mitsubishi unit designed for heating climates, and with high efficiencies, these heat pumps have made mini-splits a primary heating solution for homes in climates with mild heating needs. Mini-splits can also integrate as either a primary or an auxiliary heating source with existing forced-air heating systems or electric-resistance heating, while with hydronic heating systems, mini-splits would operate as a separate system with the option to integrate controls. (For more on fuel cost comparisons for heating, see *EBN* Vol. 17, No. 7.)

According to Jeff Pratt, an energy consultant based in Washington state, over 20 million homes in the U.S. use electric-resistance heat, usually in the form of baseboard strips. As a contractor, Pratt has installed about 50 ductless mini-splits

These outdoor condenser units, part of a residential ductless mini-split system, supply cooled or heated refrigerant to indoor air handlers. Photo courtesy of Jeff Pratt

in Washington as an alternative heat source to existing electric-resistance systems, calling them "the new electric heat." Pratt is also working with a local utility that is interested in promoting them across the region. Although Pratt hasn't been able to systematically measure energy use in houses using the units, he says that preliminary results show that they use one-third to one-fourth as much energy as electric-resistance systems. (See below for more on cost and efficiency.)

Multi-Split VRF Systems

Like larger mini-splits, multi-splits pair a single outdoor condenser unit with multiple indoor air handlers. With multi-splits, however, there can be as many as 40 indoor units for one outdoor unit. Multi-split systems also add a few features that extend the benefits of mini-splits to much larger settings.

Among these added features is *variable refrigerant flow* (VRF), also known as variable refrigerant volume (VRV). VRF systems allow different air handlers on a multi-split setup to offer a variety of comfort conditions, unlike many central systems and some mini-splits, which offer a single setting for the whole system. VRF also allows delivery of various temperatures without cooling and then reheating air, a common and inefficient practice in large commercial buildings.

VRF is made possible by sophisticated control technology and the use of inverters to modulate both indoor air handlers and the outdoor unit. Instead of the simpler controls used for mini-splits, in which a single refrigerant line usually serves a single indoor air handler, VRF multi-splits use computer-controlled valves that adjust the amount of heating or cooling delivered to individual units. That means that refrigerant can be run in more compact systems with branches for individual air handlers rather than dedicated lines from the outdoor units. VRF multi-splits are modular, so although outdoor units have size limits, they can be tied together with additional indoor *and* outdoor units, eliminating any strict size limits.

Mini-splits as well as smaller VRF multi-splits require all of the indoor air handlers to operate simultaneously in the same mode, either heating or cooling. Larger VRF multi-split systems allow individual air handlers to heat or cool as needed, simultaneously. "That's a terrific way for a heat pump to work," points out Stephen Little of Level Solutions, an Indiana distributor of Sanyo equipment. "When you're cooling in some units and heating in others, you're transferring heat from one spot to another," rather than generating it or exhausting it. That situation arises, for example, in hotels with widely varying comfort preferences or in office buildings when occupied spaces need heating but equipment rooms need cooling.

Buildings with these systems also benefit when conditioning needs change with the time of day. Kim Shinn, director of sustainable design for TLC Engineering, said that a 94,000 ft^2 (8,700 m^2) police headquarters in Tennessee with a recently installed 100-ton Mitsubishi VRF multi-split will benefit from heat transfer through the building in the spring and fall, when conditioning needs change rapidly. "We're going to have a couple of east faces of the building calling for cooling in the morning while west faces are calling for heating, and vice versa in the afternoon," he said.

Another benefit of the VRF system is its innovative management of oil migration. Refrigerant lines typically carry some lubrication oil from the compressor because of minor leaks in seals separating the fluids. Oil migration limits the length of refrigerant runs in conventional split systems, and requires them to be relatively straight to ensure that the oil is returned to the compressor eventually, preventing burnout, and doesn't settle into a trap and clog up the loop. VRF systems include a computer-controlled blowdown sequence in which all of the valves in the air-handling units are opened and refrigerant moves through the pipes at high velocity, carrying the oil with it, back to the compressor. "That alone is worth the price of admission," said Brian Lomel, P.E., of TLC Engineering. The process

prevents compressor failure and allows refrigerant loops to be longer, making layouts more flexible. According to Chris Bellshaw, a product manager for Daikin AC, Daikin's VRF systems can have 1,000–3,300 feet (300–1,000 m) of piping from one condenser unit, depending on the unit's size.

Those long loops do come at an additional cost, beyond the pipe installation and refrigerant charge. The ozone-safe refrigerant used on current mini- and multi-splits, R410a, has a relatively high global-warming potential, and systems with long refrigerant runs may not comply with LEED's credit for enhanced refrigerant management because they use a large amount of refrigerant per ton of cooling.

Applications

Asked to identify the best applications for split systems with VRF technology, Joe Bush, an applications specialist for Mitsubishi, said, "I can't think of an application where they're not effective." He noted that they would not be cost-effective in large open spaces that don't require zone control, such as warehouses and large retail stores. But, he said, "If you want to give people individual control in an office building and transfer energy around the building, the only thing that can match up to VRF is a variable-speed chiller, a boiler system with four pipes, and VAV (variable air volume) units with controls as a whole other package added on—a very costly and complex system."

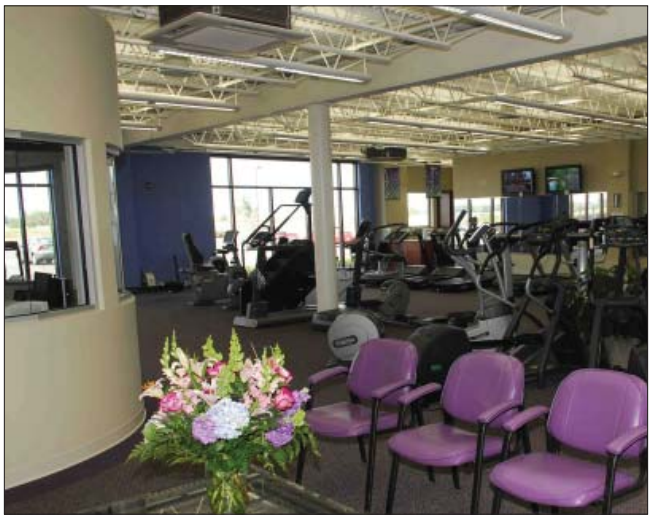
These are still air-cooled systems, however, which will never match well-designed water-cooled systems for pure efficiency, notes Peter Rumsey, P.E., of Rumsey Engineers in Oakland, California. However, in many buildings central systems have big inherent inefficiencies, such as the need to overcool and then reheat air, that these systems avoid. "I'm a real big fan of decoupling sensible cooling load from ventilation load," Rumsey says. Rumsey says that VRF multi-split systems are best suited to hotels, multifamily housing, and small office buildings with individual tenants—although in each of these settings ventilation air still must be delivered, and treated, separately.

According to Shinn, a 125-ton multi-split VRF system works well for a Nashville, Tennessee, core-and-shell renovation of a multi-tenant office building. The building has a central condensing unit and refrigerant piping with connections at tenant suites. Individual tenants will have to decide how many air handlers to install, and they will be responsible for buying them and submetering their electricity use. Shinn says that multi-splits are also attractive in multi-tenant buildings because they don't transfer air across tenant spaces, avoiding a common complaint.

Mini- and multi-splits integrate well into systems in which dehumidification and cooling are separate, an approach that is especially important in humid climates. "We learned by painful experience over the years that the equipment and control of dehumidification and ventilation need to be kept separate [from cooling]," said Shinn. Multi-splits require separate ventilation—potentially a downside, since a separate system, quite likely one requiring ducts,

Benefits and Drawbacks of Mini- and Multi-Split Systems

Installation	Ductless installation reduces indoor space requirements, benefiting retrofits in particular, and reducing costs. All of these systems are relatively lightweight and modular and offer integrated controls.
Comfort	Independent zonal control of temperature improves comfort. However, control is not as fine-grained as in some systems, such as with underfloor air distribution.
Air Quality	Low-velocity local delivery of conditioned air improves air quality. Separation of air-conditioning and ventilation that is provided is desirable in humid climates. Local air handlers may not produce enough fan pressure for high levels of filtration, including MERV-13, though that is a LEED credit requirement.
Cost	Relative cost depends on setting and alternatives: multi- and mini-splits often carry a premium over simple systems for open floorplans, and savings in more complex situations.
Efficiency	Strongest efficiencies come with ductless systems, operation at part-load capacity, and simultaneous heating and cooling. Efficiency under full-capacity conditions is good, but published efficiency numbers are difficult to apply to any specific situation.
Heating	These systems offer packaged heating with high COPs and good efficiency with simultaneous cooling and heating. They offer significantly more-efficient heating than electric resistance but can require auxiliary support in cold climates.
Energy Modeling	Energy consumption is often reduced, but benefits are difficult to model and document. VRF systems cannot be modeled in nonproprietary DOE-2 or EnergyPlus software.
Water Treatment	Mini- and multi-split systsems avoid the water-treatment problems associated with large chilled-water systems.
Reliability	While relatively new in North America, these systems have a long history in Asia and Europe. Modularity reduces the risk of a major, building-wide failure, but the many individual units could complicate maintenance and repair.
Submetering	Modularity of systems, distributed units, and local controllability support submetering.
Safety	With long refrigerant lines in occupied spaces, leaks could create hazardous conditions. However, safety can be achieved with careful system design.
Climate	These systems commonly use R410a, which is ozone-safe but has a relatively high global-warming potential. This contributes to climate change and can disqualify the project from the LEED refrigerant-management credit.



Several ceiling-mounted air handlers in a Mitsubishi VRF multi-split system serve this exercise room. Photo: Mitsubishi

must be added—reducing one of the benefits of ductless multi-splits.

Efficiency

Mini-split and VRF multi-split systems have impressive efficiency ratings—when those ratings are available and when they reflect actual performance. Efficiency numbers aren't published at all for some companies' VRF multi-splits, due to DOE waivers that recognize the lack of adequate testing procedures. However, the Air-Conditioning and Refrigeration Institute (ARI) recently published efficiency numbers for several mini-split models from Daikin, Mitsubishi, and Sanyo with less than 65,000 Btu/hour in cooling capacity. (Heating capacity varies significantly based on outside temperature; it is generally higher than cooling capacity at moderate temperatures and drops rapidly as temperatures dip below 0°F, or –18°C.) The ARI numbers vary, but most products offer a heating seasonal performance factor (HSPF) of 8–9, an energy-efficiency ratio (EER) of 9–11, and a seasonal energy-efficient ratio (SEER) of 13–17. Those numbers aren't bad, but they don't by themselves justify the excitement generated by these products. Only one model, from Sanyo, meets Consortium for Energy Efficiency (CEE) specifications for high-efficiency commercial air-conditioning.

According to company representatives, the published efficiency numbers don't reflect the actual performance of mini-splits or VRF multi-splits, mainly because most efficiency numbers, including EER and coefficient of performance (COP), are measured with the system running at full capacity, a relatively uncommon and inefficient setting for VRF multi-splits.

The compressor and fan in a conventional system will typically turn on at full capacity to meet the partial load, then turn off. This on-and-off cycle puts stress on the system and isn't efficient, so "for standard equipment your highest efficiencies are generally at full load," says Bellshaw, "[however,] if you've designed the system correctly, you're going to be at full load anywhere from 2% to 5% of the year."

By contrast, VRF systems are most efficient at partial capacity, says Bellshaw. The compressors on VRF systems can typically run as low as at 16% of capacity. That means that, while there is less power input to the compressor, the size of the condenser coil stays the same and heat is transferred more efficiently. Bellshaw noted that, while the system really shines at partial capacity, "it's still efficient" at full capacity.

Integrated-part-load values (IPLVs) published by Mitsubishi for its larger City Multi units begin to reflect the benefits because those values measure system efficiency at partial loads. For heat-pump systems, IPLVs range from 12.5 to 18.6, depending on system capacity. Even these numbers are limited, though, because they don't take into account the possibility of transferring heat from one part of a building to another, varying indoor unit capacity, and building load diversity that can allow for smaller outdoor units.

Comparing the efficiency numbers of different technologies can also be difficult, because the numbers don't necessarily include the same system components. According to Joe Bush, a multi-split application specialist for Mitsubishi, "When we give an IPLV, it includes every motor used in that system, the indoor fan motors—all of the energy consumption in that system." Bush said, however, that "chillers do it differently," leaving out pumps, indoor fan-coil motors, and other components.

Actual performance figures as well as more effective simulation—neither of which has arrived—will be needed to provide more accurate efficiency figures. William Goetzler, a Massachusetts-based consultant for VRF manufacturers, surveyed previous energy-efficiency studies in a 2007 article in *ASHRAE Journal* and found up to 40% savings for VRF cooling systems over chiller systems, although each of those studies had limitations.

From his experience with several applications in the cooling-dominated climates of Tennessee and Florida, Shinn "conservatively" estimates an energy savings of 20% for a VRF multi-split compared with a packaged rooftop VAV system. Shinn notes that it is hard to document those savings because energy modeling software such as DOE-2 cannot handle VRF multi-splits. For documentation in the LEED Rating System, Shinn said that his firm has modeled the VRF multi-split systems as water-source heat pumps. He noted, however, that, while this was accepted for LEED, the multi-splits are penalized because they don't require energy for pumping. Some manufacturers offer proprietary

Common Mechanical Air-Conditioning Systems

Duct / Ref. piping — Cool air — Warm air — Warm/hot air

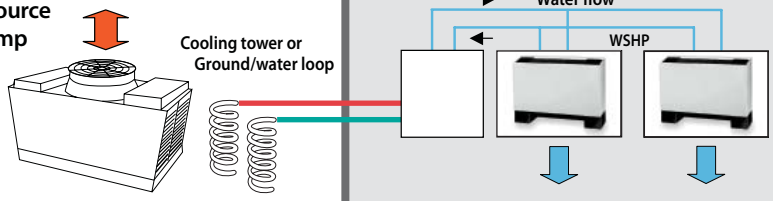
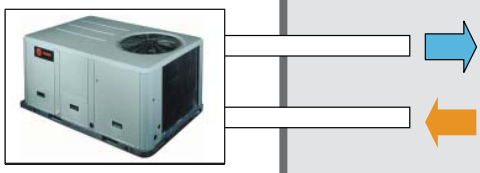
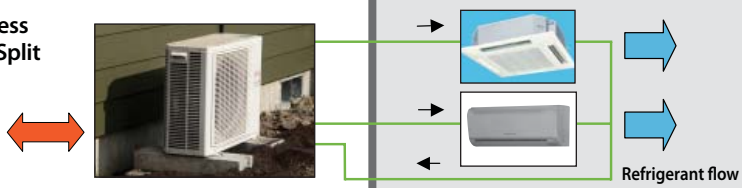
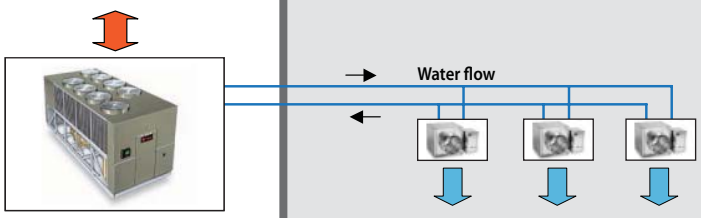
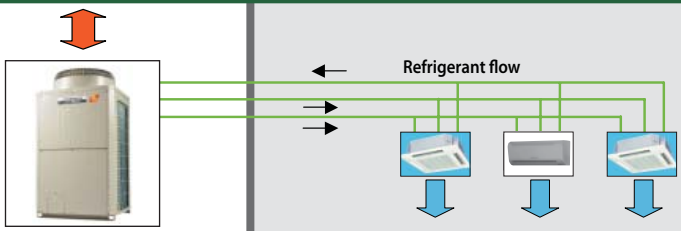
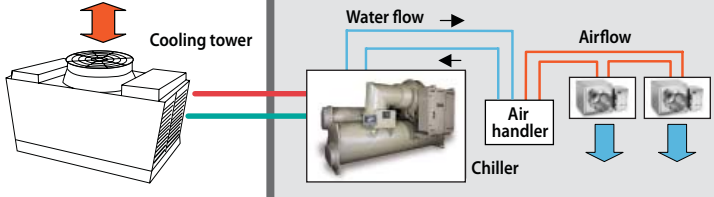
Outdoor	Roof/Exterior wall	Indoor	Description
Room Air Conditioner/ PTAC			These small packaged units offer customized cooling for individual rooms. Relatively inexpensive and installable by nonprofessionals, they also tend to be relatively inefficient and ineffective compared with integrated whole-building systems.
Water-Source Heat Pump			Water-source heat pumps use a cooling tower, pond, or groundwater to dissipate heat and can operate in either heating or cooling mode, but otherwise they work like room or packaged air-conditioners. As with all the schematics, cooling mode is illustrated.
Central Air: Packaged			Central air systems provide ducted cooling for a whole house or small commercial building. Packaged units in which the condenser and air handler are located together outside are more common in warmer climates and on commercial rooftops.
Central Air: Split			Like central packaged systems, central split systems provide ducted cooling throughout a building. An outdoor condenser unit provides refrigerant to an indoor air-handling unit, which may be the building's furnace.
Ductless Mini-Split			Ductless mini-splits combine some of the benefits of split systems with the flexibility and zonal control of room air-conditioners, for residential and light commercial applications. Use of refrigerant lines instead of ducting saves space and improves efficiency.
Air-Cooled Chiller			An exterior chiller provides chilled water to interior air handlers in mid-sized and larger facilities. Air-cooled systems don't require a cooling tower, reducing installation costs and maintenance issues, but sacrifice efficiency.
VRF Multi-Split			Variable refrigerant flow (VRF) multi-split systems offer the benefits of mini-splits for mid-sized nonresidential buildings while adding additional features, including simultaneous heating and cooling for different air-handling units on the same system.
Water-Cooled Chiller			Water-cooled chillers are typically more efficient than air-cooled chillers, although with a cooling tower they have increased installation and maintenance costs. They are most common in facilities with large cooling loads.

Image Sources: Trane, Daikin, Jeff Pratt

energy-modeling software, but that software received poor reviews from users *EBN* spoke with.

On the heating side, Joseph Kohler, Ph.D., a mechanical engineer based in Keene, New Hampshire, compared ground-source heat pumps to Daikin multi-splits for heating and cooling an athletic facility in Vermont. Through a "bin analysis" using the temperature profile of the location, Kohler found an annual COP of 3 for each system. The split systems, he said, "are equal to ground-source heat pumps without the hassle" of installing wells or burying pipe, performing complex engineering, and designing sophisticated pumping systems. Pratt's preliminary measurements of installed mini-splits in Washington state has similarly shown an annual COP of 2–3, and a preliminary analysis by Marc Rosenbaum, P.E., of Energysmiths in New Hampshire, also found similar numbers.

For cold climates, mini- and multi-splits offer a mainstream choice for projects considering low-temperature heat pumps, which are available in North America but remain relatively unproven and don't offer some of the benefits of VRF multi-splits (see *EBN* Vol. 15, No. 12). According to Jay Stein, an energy analyst at E Source, the suitability of mini- and multi-split systems for heating depends on local factors such as the relative cost of electricity and gas, and how cold it gets for how long. Fundamentally, air-source heat-pump performance drops at very cold temperatures when it is needed most, and efficiency approaches that of electric-resistance heat, which can be relatively expensive and inefficient.

Costs

The relative cost of mini-splits and VRF multi-splits depends heavily on the setting, on what alternatives are being considered, and on what, if any, existing systems are in place. According to Little, VRF multi-splits generally come at a premium, costing $1,500–$2,200 per ton of cooling capacity versus $600–$800 per ton for standard central air-conditioning, not including installation. In a large, open space with little need for zoning, a standard rooftop unit will likely be much cheaper.

According to Shinn, however, "The cost has been very competitive." Refrigerant-piping and chilled-water piping systems cost about the same amount, he says, the air-handling units themselves aren't much more expensive than conventional units, and the choice between a condens-

Efficiency Ratings for Heating and Cooling Systems

Assessing the energy efficiency of mechanical systems for heating and cooling is not straightforward. Some types of systems have standard efficiency ratings that everyone in the industry uses—and some don't. Furthermore, a number that at first glance appears to be a standard efficiency rating may not make an apples-to-apples comparison for different systems. For example, some tests take auxiliary equipment into account while others only consider the primary energy use in the system. For systems providing both heating and cooling, the number of relevant ratings increases.

For evaluating central air-conditioner performance, and heat pumps in cooling mode, the *energy efficiency ratio (EER) and seasonal energy efficiency ratio* (*SEER*) are commonly used. Both compare cooling capacity (in Btus) to energy input (in watts). EER shows the efficiency of a system running at full capacity while SEER shows the system's effectiveness over a season by dividing the amount of cooling by the power used during a representative cooling season. In the same way that cars have highway and city gas mileage ratings, SEER reflects operation in lower outdoor temperatures (82°F), and EER reflects peak operation in higher outdoor temperatures (95°F). In both cases higher numbers are better. Whether EER or SEER is more important depends on the climate and whether the local utility rebate policies for peak load reduction based on EER.

Like EER, the *coefficient of performance* (COP) measures full-load performance, but it is used for both cooling and heating equipment. COP is the ratio of cooling or heating delivered (in watts) to energy consumed (in watts). COP is used for chillers, refrigerators, and air-conditioners, as well as heat pumps and space and water heating equipment. Heat pumps tend to have COPs of two to three. To convert COP to EER, convert the cooling capacity from watts (W) to Btus per hour by multiplying by 3.413 Btu/hr/W.

Large commercial air-conditioners and heat pumps may be rated using *integrated-part-load values* (IPLVs) instead of SEER. IPLV measures the weighted average efficiency at partial loads. The units can vary, as IPLV is an accepted term for both seasonal COP (unitless) and seasonal EER (Btu/W-h). For large chillers, IPLV is measured in kW/ton (a ton is 12,000 BTU/hr).

The parallel to SEER on the heating side, *heating season performance factor* (*HSPF*) divides of the amount of heat delivered (in Btus) by the energy used (in watt-hours) during a representative heating season. This works for heat pumps but not fuel-fired furnaces and boilers, which typically measure seasonal efficiency through *annual fuel utilization efficiency* (*AFUE*). There are a variety of other measures of heating efficiency for fuel-fired systems, including combustion efficiency (Ec) and thermal efficiency (Et), but these won't be encountered in electrically powered systems.

Measures of Efficiency for Heating and Cooling Equipment

Mode of Operation	Full Capacity Operation	Average Seasonal Operation
Cooling	Coefficient of Performance (COP) Energy Efficiency Ratio (EER) Kilowatts per ton (kW/ton)	Coefficient of Performance (COP) Integrated-Part-Load Values (IPLV) Seasonal Energy Efficiency Ratio (SEER)
Heating	Coefficient of Performance (COP) Combustion Efficiency (Ec) Thermal Efficiency (Et)	Annual Fuel Utilization Efficiency (AFUE) Coefficient of Performance (COP) Heating Season Performance Factor (HSPF)

ing unit and a boiler and cooling tower "seems to be pretty close to a wash."

For homes, mini-splits are generally more expensive than room or central air-conditioning systems, but they cost less to operate. If they are being used as a primary heat source, the savings can be significant, particularly compared with other efficient but more complex systems, such as ground-source heat pumps. The installation cost for mini-splits ranges from $3,000 to $5,000, according to Pratt, who says he leaves existing electric heating systems in place as a backup and for very cold weather.

Choosing a System

The adoption of both mini- and multi-splits in North America has been hampered until recently by their lack of availability as well as the long history and support infrastructure behind ducted central-split and packaged systems. As more units are installed, as engineers and building owners gain confidence with the technology and support systems, and as better information emerges on efficiency, more project teams are likely to turn to them. They are not suitable for all building types in all climates, but they offer an innovative way to provide comfort with efficiency.

With this technology already widespread in Europe and Asia, North American consumers can benefit from overseas innovations. A number of manufacturers, including domestic companies, offer mini-splits. With VRF multi-splits, three manufacturers offer the greatest variety of products: Sanyo with its ECO-i line, Mitsubishi with its City Multi line, and Daikin with its VRV lines.

The company representatives *EBN* spoke with were hard-pressed to note any major differences between the product lines from Daikin, Mitsubishi, and Sanyo, and acknowledged that the appearance of the indoor air handlers is particularly similar. Seeing a wide-open market in North America, the companies appear more inclined to compete on distribution models and support than on technology and aesthetics.

– Tristan Korthals Altes

For more information:

Daikin AC
www.daikinac.com

Mitsubishi Electric
www.mehvac.com

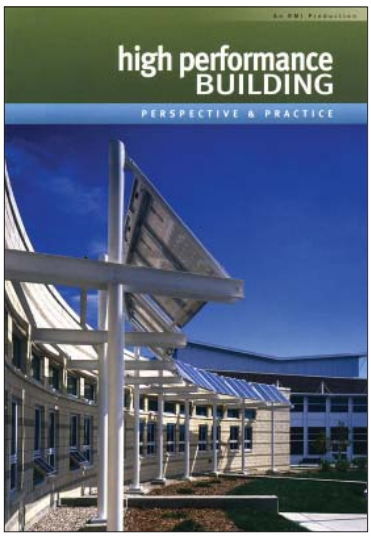
Sanyo HVAC
www.sanyohvac.com

From the Library

High-Performance Building
Perspective and Practice

Rocky Mountain Institute, 2008. 29/17 minutes, $5. Also available for viewing online at www.bet.rmi.org/video/.

Green building is increasingly synonymous with building well: healthfully, efficiently, durably, and even profitably. Yet some designers still struggle to make the business case for green practices. For them, Rocky Mountain Institute and the U.S. Green Building Council have produced a video that they can use to persuade clients to take a closer look at environmentally conscious design.



The film begins and ends with Ray Anderson, the CEO of carpeting manufacturer Interface. Anderson's conversion to sustainability has become iconic for those arguing for the convergence of business and environmentalism. The rest of the film is organized into a series of case studies, which include a wide range of building types: a school, government buildings, a Toyota distribution facility, and several large office buildings. The architects of these buildings and their clients discuss how they arrived at green building strategies and why they consider high environmental standards sound business practice.

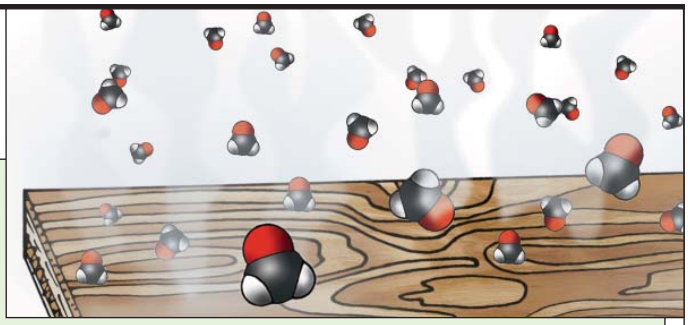
No one is likely to learn a great deal about the specifics of green building from this video, which focuses on the benefits of green building rather than on strategies. The fast pace, accompanied by voiceovers and on-screen text, provides an abundance of information about costs and paybacks in a visually engaging but somewhat distracting manner. Shots of waterless urinals and daylit rooms of cubicles show that these high-performance buildings look much like conventional buildings. Although presented without much explanatory detail, the numbers tell the real story. As one businessman in the film notes, a company that fails to take advantage of the potential savings in green building is going to be left in the dust.

Available in full-length and abbreviated versions on DVD (with an accompanying booklet of case studies) and online, this video is a very usable and well-produced piece of salesmanship. It would take a stubborn skeptic to refuse to look deeper into green building after viewing this presentation.

– Michael Wilmeth

BackPage Primer

All About Formaldehyde



When we hear "formaldehyde," a lot of us probably think of the liquid preserving frogs awaiting dissection, back in high school. That liquid, called formalin, is a solution of about 40% formaldehyde and 60% water. Formaldehyde is a simple organic compound, consisting of carbon, oxygen, and hydrogen. At atmospheric temperature and pressure it is a colorless gas with a distinctive, pungent odor. It occurs naturally, though generally at concentrations no higher than 0.03 parts per million (ppm).

Formaldehyde is also manufactured and used for a wide range of products, including adhesives, paints, fabrics, paper products, and even cosmetics. The very first plastic—bakelite, invented in 1905—was a polymerized phenol formaldehyde, and modifications of that compound are still widely used. Formaldehyde is prevalent enough that it rates its own trade association to sing its praises.

Formaldehyde is an important constituent in most manufactured wood and laminate products. Due largely to its low cost and light color, urea formaldehyde (UF) is the most common binder for interior-grade wood products, such as particleboard, medium-density fiberboard (MDF), and hardwood plywood. Unfortunately, the formaldehyde in UF binder is not very tightly locked up, so a lot of it is released into the air.

Phenol formaldehyde (PF) is used as a binder in exterior-grade wood products, such as plywood, oriented-strand board (OSB), and glulam beams. It is also a common resin in hard-surface countertop materials, such as those used in lab desks, it is the most common binder used in fiberglass insulation, and it is foamed to create some poured-in foam insulation materials. A related compound, melamine formaldehyde (MF) is used in plastic laminate and overlay materials. Formaldehyde is more tightly bound in PF and MF than it is in UF, reducing emissions.

Though useful, formaldehyde is harmful to our health. According to the U.S. Consumer Product Safety Commission, at concentrations in the air above 0.1 ppm, formaldehyde can cause irritation of the eyes, nose, and throat; nausea; chest tightness; coughing and wheezing; skin rashes; and allergic reactions. Over long periods of exposure, formaldehyde also likely causes cancer, according to the U.S. Environmental Protection Agency, and it can cause a variety of other problems.

Since 1985, the U.S. Department of Housing and Urban Development (HUD) has regulated formaldehyde emissions from wood-panel products made for use in manufactured homes, with a maximum allowable formaldehyde concentration of 0.4 ppm, when tested according to ASTM E-1333-96. The LEED Rating System awards a point for avoiding UF binders in wood products.

In 2007, the California Air Resources Board (CARB) finalized a new air quality rule regulating formaldehyde (see *EBN* Vol. 16, No. 6). This rule phases in maximum allowable formaldehyde concentrations for five types of manufactured wood panels, based on the same ASTM test standard HUD uses. Phase I, to take effect in January or July 2009, sets maximum concentrations ranging from 0.08 to 0.21 ppm; Phase II, to become effective between January 2010 and July 2012, sets limits of 0.05 to 0.13 ppm. The CARB standards will likely cause a phaseout of UF binders.

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