Streamlining Electrification

In the project in August's "Streamlining Electrification in Support of Decarbonization," by Nathan Ho, P.E., Member ASHRAE, the domestic hot water load is significantly smaller than other loads. Would the proposed system still be more energy efficient with higher COP than the baseline during the California summer with limited hot water demand for heating?

What heating loads are being served in these buildings during summer?

Shahid Naeem, Member ASHRAE, Milton, ON, Canada

The Author Responds

The limiting factor on efficiency of the overall proposed process is the relatively low heating hot water temperature produced by the HVAC heat recovery chillers; the low heating hot water temperature necessitates the use of auxiliary electric heat to meet the 140°F domestic water storage requirements in the application covered, which lowers the aggregate COP of the process, even during summer conditions.

We anticipate summer heating loads would be minimal and primarily driven by HVAC reheat demands.

Nathan Ho, P.E., Member ASHRAE, Irvine, Calif.

Building Decarbonization And HVAC

In our opinion, the article "How Building Decarbonization Can Transform HVAC" in the September 2021 issue by Peter Rumsey, P.E., Fellow ASHRAE; Jorlyn Le Garrec, Associate Member ASHRAE; and Avril Levasseur, P.E., Associate Member ASHRAE presents an unrealistic picture of the ability of electric heat pumps to replace natural gas fired appliances in space heating applications, particularly where gas fired boilers are currently used in cold climates.

The authors acknowledge the drawbacks of electric resistance heating as a means of decarbonization, noting that it can consume several times the energy used by a heat pump. While not stated, it follows that when source to site losses are considered, electric resistance heating may well consume more energy, and produce more greenhouse gas (GHG) emissions, than a natural gas boiler located on-site. This, of course, is due to the far greater losses associated with electrical generation and transmission.

Consider Scenario B in Figure 1 of the article if 100% resistance heating is substituted for the heat pump. Using the authors' own assumptions for transmission losses and power plant efficiency, one finds that it takes 224 units of energy to produce 100 units of heating energy on-site, a 45% source to site efficiency. This is compared to the 80% source to site efficiency for the 84.7% efficiency gas boiler in Scenario A (the Figure 1 note indicating this to be a 90% boiler also appears to be incorrect).

Of course, the authors are not advocating widespread use of electric resistance heating. Nevertheless, existing heat pump technology is not going to replace gas boilers in cold climates without significant amounts of backup heat (i.e., electric resistance) in most existing buildings. It will also not do so at the COP levels assumed by the authors. Air-to-water heat pumps are generally designed to supply water at temperatures below 140°F, whereas many hydronic systems require 180°F supply water under design conditions. While such heat pumps may indeed be able to operate at, or close to, outdoor design temperatures in northern parts of the U.S., they are likely to operate at a COP below 2.0 under these conditions when supplying 140°F water (if they can do so at all). If one assumes a COP of 1.8 in Scenario B, rather than 3.0 as the authors do, the source to site efficiency of the heat pump is no higher than that of the gas boiler in Scenario A.


TECHNICAL FEATURE

How Building Decarbonization Can Transform HVAC

BY PETER RUMSEY, P.E., FELLOW ASHRAE; JORLYN LE GARREC, ASSOCIATE MEMBER ASHRAE; AVRIL LEVASSEUR, P.E., ASSOCIATE MEMBER ASHRAE

By the end of 2050, 12 states and 160 cities have official goals to get 100% of their electricity from clean sources.[1] California cities are leading the nation in building electrification legislation, with 28 cities having adopted all-electric requirements for new construction; 50 additional cities and counties have pending electrification legislation as of this writing.[2] Much of the southeast U.S., where heating loads are light, already uses electric sources of heating. And, in moderate and cold climates a surge of interest exists in heat pump systems, which provide an efficient alternative to electric resistance for heating. This article explores heat pump systems as one way building decarbonization can transform HVAC.

Buildings in the U.S. account for 40% of carbon emissions. Eighty percent of that is from electricity use and the remainder is from the combustion of fossil fuels for heating and other uses at the building. Many states, utilities, and large corporations are moving to get electricity from clean, carbon neutral sources. Duke Energy, one of the largest investor owned utilities in the U.S., has committed to having 100% of its energy from carbon-neutral sources by 2050. In addition, many of the U.S.'s largest corporations including Apple, Microsoft, Kohl's, Walmart and Bank of America have made commitments to achieve carbon neutrality or to get their electricity from carbon free sources, namely solar and wind energy.

It is clear that electricity is becoming the carbon free choice of energy for many in the U.S. Buildings that use natural gas and other fossil fuels for heating will be stuck producing carbon emissions, as electricity becomes increasingly carbon free. For that reason, many are starting to look at all-electric options for providing heat to buildings. An all electric building coupled with a renewable or carbon-free source of electricity is considered to be decarbonized in its operation.

In addition to operational carbon, buildings have embodied carbon. Embodied carbon is the total greenhouse gas emissions from the materials and the construction process throughout the life cycle of the

Peter Rumsey, P.E., is the founder and CEO of Point Energy Innovations in San Francisco and cofounder of the Stanford Building Decarbonization Learning Accelerator in Stanford, Calif. Jorlyn Le Garrec is a project engineer, and Avril Levasseur, P.E., is an associate engineer at Point Energy Innovations in San Francisco.

Many factors determine whether there is really a benefit to the electrification of a given heating system. Chief among these is the ability of the heat pump to operate throughout the heating season at an average COP (corrected for any backup electrical resistance energy consumption) high enough to compensate for the incremental generation and transmission losses associated with the use of fossil fuel derived electricity. Colder climates, older buildings, higher hydronic system water temperatures and more carbon intensive electrical grids all tend to work against building electrification saving energy or providing any real GHG reduction.

If one looks at operating costs, the COP must be even higher to compensate for electricity costs that in the U.S. average more than 3.5 times as much as natural gas on a cost per unit energy basis (DOE March 2021 data). When compared to a gas boiler having a seasonal efficiency of 84% this means that the seasonal COP needs to be at least 2.94 for the heat pump system to result in lower operating costs.

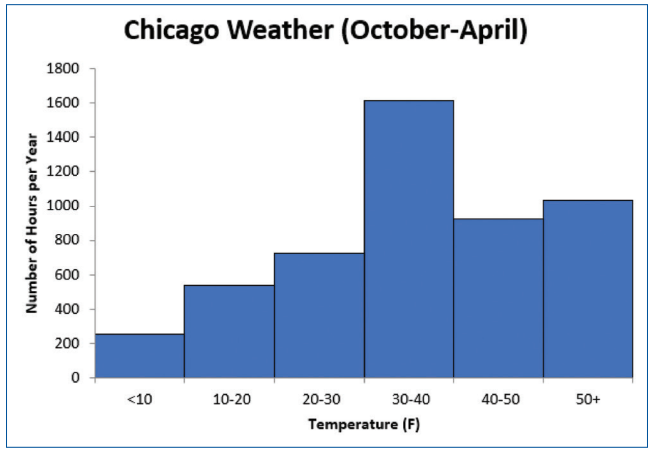
The authors, as well as ASHRAE's leadership, seem to regard building electrification as a panacea. Much as they may wish otherwise, fossil fuels continue to produce over 60% of the electricity in the U.S., grid capacity is marginal in many areas and heat pumps are not up to the task of replacing fossil fuel heating equipment in all applications. These realities may change over time but to assume so would be irresponsible. A premature, one-size-fits-all rush to building electrification will result in higher operating costs, lower grid reliability, and greater GHG emissions. These consequences, along with any resulting decrease in system performance, are contrary to ASHRAE's purpose and the interest of the public we serve.

Keith Page, Member ASHRAE, Zeeland, Mich.; David Scearce, P.E., Member ASHRAE, Reading, Pa.; Paul Sohler, Member ASHRAE, Merchantville, N.J.; Cory Weiss, Associate Member ASHRAE, Warren, Mich.

The Authors Respond

Thank you for your interest in our paper and for taking the time to express your concerns. The primary concern expressed is about heat pump efficiency at low temperatures, which result in higher operating cost and greater greenhouse gas (GHG) emissions. You bring up a good point that heat pump COPs will drop in cold temperatures. In talking to multiple heat pump manufacturers, we have found that heat pumps are already available—or will be in the next two years—that produce 160°F with an average COP of 2.0 below 20°F. While a COP of 2.0 would indeed bring down heat pump efficiency resulting in less energy and carbon emission savings, this condition occurs for only a fraction of the heating season.

Chicago is one of the coldest large cities in the U.S. The histogram above shows the binned hourly temperature of Chicago during a typical heating season. While



temperatures do frequently drop below 20°F, they only do so for less than 16% of the hours in October-April. While we will lose efficiency during those hours, over the entire heating season, the heat pumps will maintain an average COP of 3.0 and above.

Our modeling study, which used industry standard EnergyPlus software to compare natural gas boilers and all-electric alternatives, supports this conclusion. The study modeled office buildings in eight cities around the U.S. for a year, which includes all equipment performance curves throughout the year. This means that we modeled the energy consumption of heat pumps in 10 minute intervals over an entire year using the ambient temperature of the associated city and resulting heat pump efficiency.

Our results show that all-electric heat pumps result in less annual carbon emissions than their natural gas alternatives in all but the most carbon-intensive grids. Additionally, we show that while there are no operating cost savings, the operating cost for heat pumps is comparable to natural gas alternatives in most U.S. cities. While heat pumps may not be the solution for all buildings, they are already a viable solution for the majority of buildings. Time and technological improvements will only expand their applicability.

We agree that the electrical grid is in need of improvements; however, these improvements will be required whether or not buildings are electrified. The majority of the electrical grid and natural gas distribution infrastructure are several decades old and will be going through upgrades regardless of building electrification. Your letter notes that "fossil fuels continue to produce over 60% of the electricity in the U.S." While this may be true of the current generation, in 2020 renewables accounted for 76% of new electricity generating capacity (EIA, U.S. Energy Information Administration), and this number is only expected to increase in 2021. Renewable energy generation is now more cost competitive than other generation options. As we pointed out in the article, even with a grid that is 100% natural gas powered, heat pumps using the annual average COP have almost 25% lower carbon emissions than burning natural gas in a boiler.

Regarding all the issues brought up, you agree that "These realities may change over time but to assume so would be irresponsible." The basic facts are that the realities are already changing with states, cities, companies and even utilities across the U.S. already committing to carbon neutrality. The climate crisis is already upon us, and the building sector, which accounts for 40% of U.S. carbon emissions, must respond.

The mission statement of ASHRAE clearly states, "to serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning, refrigeration and their allied fields." We argue that it would be irresponsible as members of ASHRAE to overlook the opportunity for applying more energy efficient and low carbon equipment in the many possible situations that exist today. We, as part of the building community, due to the dire circumstances and large impact of buildings, need to prioritize building decarbonization.

Peter Rumsey, P.E., Fellow ASHRAE; Associate Member ASHRAE; Jorlyn Le Garrec, Associate Member ASHRAE; Avril Levasseur, P.E., Associate Member ASHRAE, San Francisco

Optimizing Coil Loop Energy Recovery Systems

The article "Optimizing Coil Loop Energy Recovery Systems" by Gene Nelson, P.E., Life Member ASHRAE, in the November 2021 issue is not clear on how to size the heat recovery coil. The article mentioned selecting the lowest fluid flow rate.

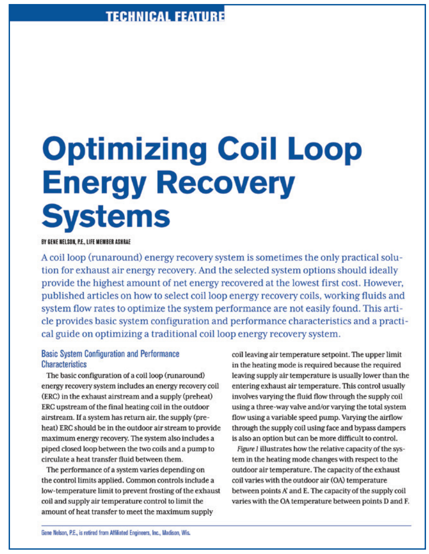
However, in the coil sizing procedure, it did not mention the flow rate at all. Also, the procedure mentioned starting the selection with Q_{max}, a capacity the heat recovery coil is unable to achieve. Please advise.

Somchai Paarporn, P.E., Member ASHRAE, Potomac, Md.

The Author Responds

The article discusses how to determine the minimum tube velocity using the Reynolds number equation. The flow rate per tube equals the flow area of one tube times the minimum tube velocity. To make the units work out, you will need to convert the flow area to square feet or square meters. The product will then be in cubic feet per second or cubic meters per second. These terms can then be converted to more familiar units of gallons per minute or liters per second using conversation factors in the *ASHRAE Handbook—Fundamentals*, Chapter 39. Be sure to use the inside tube diameter in calculating the tube flow area.

The next step is to select a coil following the procedures discussed to minimize the number of circuits. Coil selection software will usually tell you the number of tube rows in the height of the coil. The total


TECHNICAL FEATURE

Optimizing Coil Loop Energy Recovery Systems

BY GENE NELSON, P.E., LIFE MEMBER ASHRAE

A coil loop (runaround) energy recovery system is sometimes the only practical solution for exhaust air energy recovery. And the selected system options should ideally provide the highest amount of net energy recovered at the lowest first cost. However, published articles on how to select coil loop energy recovery coils, working fluids and system flow rates to optimize the system performance are not easily found. This article provides basic system configuration and performance characteristics and a practical guide on optimizing a traditional coil loop energy recovery system.

Basic System Configuration and Performance Characteristics

The basic configuration of a coil loop (runaround) energy recovery system includes an energy recovery coil (ERC) in the exhaust airstream and a supply (preheat) ERC upstream of the final heating coil in the outdoor airstream. If a system has return air, the supply (preheat) ERC should be in the outdoor air stream to provide maximum energy recovery. The system also includes a piped closed loop between the two coils and a pump to circulate a heat transfer fluid between them.

The performance of a system varies depending on the control limits applied. Common controls include a low-temperature limit to prevent frosting of the exhaust coil and supply air temperature control to limit the amount of heat transfer to meet the maximum supply coil leaving air temperature setpoint. The upper limit in the heating mode is required because the required leaving supply air temperature is usually lower than the entering exhaust air temperature. This control usually involves varying the fluid flow through the supply coil using a three-way valve and/or varying the total system flow using a variable speed pump. Varying the airflow through the supply coil using face and bypass dampers is also an option but can be more difficult to control.

Figure 1 illustrates how the relative capacity of the system in the heating mode changes with respect to the outdoor air temperature. The capacity of the exhaust coil varies with the outdoor air (OA) temperature between points A' and E. The capacity of the supply coil varies with the OA temperature between points D and F.

Gene Nelson, P.E., is retired from Affiliated Engineers, Inc., Madison, Wis.

number of circuits equals the number of tube rows in the coil height times the circuiting percentage. Examples of circuiting are 1/3 (33%), 1/2 (50%), full (100%), or double (200%). One can estimate the number of tube rows in the coil height by dividing the coil height by 1.5 (38 mm) per row. The total coil flow rate is equal to the flow per tube times the number of circuits.

In determining the value of SERR, any value of Q at a given OA temperature using a temperature close to the entering fluid temperature will work. Q_{max} is suggested because this value can be used in scheduling the maximum amount of heat transfer, which is based on the limits imposed by the frost controls.

I would also like to encourage designers to explore retrofit opportunities using these guidelines. By changing out the working fluid, adding VFDs to pumps and additional frost controls, the system performance can be greatly improved by using these low-cost changes.

Gene Nelson, Gene Nelson, P.E., Life Member ASHRAE, Madison, Wis.