Discussions for the Papers from the 2020 ASHRAE Virtual Conference

This is a compilation of the written questions and comments submitted to authors by attendees at the 2020 ASHRAE Virtual Conference. All authors were given the opportunity to respond.

The questions/comments and authors' responses are published with the papers in the hardbound volume of *ASHRAE Transactions*, Vol. 126, Part 2.

VC-20-C023

Comparative Study on the Impact of Building Type and Location on the System Efficiency and Energy-Saving Potential of a Ground Source Heat Pump System

Rui Miao
Student Member ASHRAE

Yao Yu, PhD
Associate Member ASHRAE

Xiaoou Hu
Student Member ASHRAE

Larry Spielvogel, Larry Spielvogel, PE, Fellow Life Member ASHRAE, Consulting Engineer, Bala Cynwyd, PA: This paper is deficient in five respects.

CODES

The authors incorrectly assume that ASHRAE Standard 90.1 (ASHRAE 2016) is the energy code across the U.S. Except in one or two states, even in their home state, it is not. After determining which code applies, one must find exactly which version applies and if there are any local amendments or modifications. Otherwise, in most states the mandatory energy code is the International Energy Conservation Code® (IECC, ICC 2018), and different versions are in use in different states at different times. For example, in Philadelphia (and in other cities and states), the current energy code is the 2018 IECC, which allows the option to use ASHRAE Standard 90.1-2016, neither of which is covered in this paper.

For a church that operates only a few hours per week, which is common, compliance with energy codes and standards such as ASHRAE Standard 90.1 and the IECC is often burdensome and not economic because it requires the design of the building and its equipment to be just as efficient as a building occupied around the clock, such as a police station or a hospital. These stringent (and expensive) requirements in ASHRAE Standard 90.1 and energy codes cannot be technically or economically justified for this application.

The use of ASHRAE Guideline 14-2002 (ASHRAE 2002) to determine the fit between the actual data and the models is not appropriate since that guideline was updated and revised in 2014 (ASHRAE 2014).

BUILDING USE

The selection and performance of any type of HVAC system is very related to the occupancy and use of a building. Evaluations of the performance of hundreds of churches shows wide variations in hours of use, from a few hours per week to seven days per week. comparing ground source heat pump (GSHP) use in churches and fire stations cover such a wide range of occupancy and energy costs that it is hard to come to any rational conclusions about energy and the costs of equipment and installation, and long term costs such as service, insurance, and warranties.

The schedules in Figure 2 appear fabricated for this paper to match the results, since they do not represent commonly found schedules in real buildings. No schedules or data for the gas use in Buildings 1 and 2 are mentioned. Interval electric and gas data is generally available from utility companies to show actual data for these buildings, but none are shown here.

ENERGY COST

The variation in utility prices will be greater than the variation in energy use due to climate. In areas where energy prices are high, more efficient buildings are more readily justified. However, the opposite is also true. Engineers must look at energy cost savings as well as energy savings before coming to any recommendations and conclusions. Buildings in areas with low energy cost and short hours of occupancy will never be able to justify more efficient and more expensive buildings than those in areas with high energy cost and long hours of occupancy.

The abstract says, "Actual utility bills that were obtained from building owners…," but those bills and data are not included in the paper so readers can independently confirm the results and conclusions.

No effort is shown to determine if even the actual energy data was reasonable and representative for these three building types.

The ordinates in Figure 1 are not consistent, with some in kWh, some in energy cost, and some in MMBtu. In developing the models, the calibration was made based on only one specific published or measured input data set. Was validation accomplished by using a different set of data? That is, operational and maybe also descriptive design data. Calibration and validation are two different things. It would be of interest whether all or any other relevant data were measured (such as indoor and outdoor conditions).

The percentage energy savings shown in Tables 4, 5, and 6, and in Figure 4 do not necessarily represent energy cost savings. For example, the natural gas energy cost savings can be small, but the electric energy cost increases can be large. That does not represent good engineering practice, since both should be published.

No apparent effort was made to determine if the actual monthly energy cost and use of each building was reasonable and using graphs does not permit the actual data to be seen and verified.

BUILDING SYSTEMS

It is curious and unexplained that the fire station has 750 ft^2 per ton of cooling, while the church has 480 ft^2, and the office building has 350 ft^2. These are not what engineers commonly find. With all three buildings being in a similar climate location some explanation is in order.

It is also curious and unexplained why the fire station has 0.06 cfm per square foot of ventilation air, while the church has 0.135 cfm per square foot, and the office building has 0.135 cfm per square foot. Of note, the paper says the fire station has six additional gas fired heaters and a radiant floor, and the church has a gas fired makeup air unit whose energy is not considered or explained.

Most any type of HVAC system will "work" and is "suitable" in almost any type of building in almost any location, but any engineering analysis must show the pros and the cons of the various options as well as the economics. Therefore, the conclusion that "all the climate zones are suitable for the application of GSHP systems" cannot be supported.

It is important to look at the pros and the cons of any HVAC system in any building type in any location. No mention of any GSHP cons was seen. The authors did not examine the extensive published literature on the use of GSHPs. For example, with churches alone, the authors should have reviewed readily available literature, papers, and reports on this subject, such as those in the ASHRAE Journal and Commercial Buildings Energy Consumption Survey (CBECS). Also, industry journals such as the weekly ACHR News have news stories about both the pros and the cons of GSHP systems.

GSHP problems include limited morning warm-up and cooldown capability because the higher cost of even more capacity can make a GSHP system less economical. Because electricity is required for the operation, some electric utility tariffs include high electric demand charges and demand ratchet charges, especially for buildings with low load factors. Such increased costs lower the return on investment and increase the payback for GSHP systems.

REFERENCES

None of the references in this paper are from publications and sources that show documented experiences with the use of GSHPs. Not mentioned are some of the possible problems with GSHP. These problems include saturation of the ground requiring the addition of either more heat exchange surface, boilers, cooling towers, or even chillers.

The authors rely on some clearly biased and obscure academic references to support their paper, as they do in their conclusion. For example, would you expect a publication by the National Renewable Energy Laboratory to favorably consider any non-renewable energy?

For these five reasons, the results and conclusions in this paper are not reliable and cannot be readily reproduced or independently verified.

REFERENCES

ASHRAE. 2002. ASHRAE Guideline 14-2002, *Measurement of energy and demand savings*. Atlanta: ASHRAE.

ASHRAE. 2014. ASHRAE Guideline 14-2014, *Measurement of energy, demand, and water savings*. Atlanta: ASHRAE.

ASHRAE. 2016. ANSI/ASHRAE/IES Standard 90.1-2016, *Energy standard for buildings except low-rise residential buildings*. Atlanta. ASHRAE.

ICC. 2018. *International energy conservation code*. Washington, DC: International Code Council.

Authors: In the paper, we did not imply that ASHRAE Standard 90.1-2016 (ASHRAE 2016) is the energy code used across the U.S. The reason to use and mention ASHRAE standards in the paper rather than IECC (ICC 2018) is that a method similar to the one described in ASHRAE Standard 90.1's Appendix G was primarily used in the paper to identify the energy savings, and the authors assume that it would be more appropriate to compare the different versions of ASHRAE Standard 90.1, which are more familiar and attractive to the readers and audience of the ASHRAE conference. We would like to express our appreciation for the comment. More clarification between IECC and ASHRAE Standard 90.1 will be included in future publications.

ASHRAE Standard 90.1-2016 (or IECC [2018]) was not considered in this paper because we realized that so far it is not widely used across the U.S., as shown in the figure below (ICC

International Codes-Adoption by State (APRIL 2019)

ICC makes every effort to provide current, accurate code adoption information. Not all jurisdictions notify ICC of code adoptions.
To obtain more detailed information on amendments and changes to adopted codes, please contact the jurisdiction. To submit code adoption information: www.iccsafe.org/adoptions

X = One or more state or local agencies/jurisdictions have adopted an edition of the specific code. However, the particular code is not used as a standard for all buildings. Blank = The specific code has not been adopted by any state or local jurisdiction in the state. "15" = Number indicates the specific code edition that is adopted as a mandatory state minimum.
18 = 2018 Edition 15 = 2015 Edition 12 = 2012 Edition 09 = 2009 06 = 2006 Edition 04 = 2004 Edition 03 = 2003 Edition 00 = 2000 Edition

Jurisdiction	IBC	IRC	IFC	IMC	IPC	IPSDC	IFGC	IgCC	IECC	IPMC	IEBC	ISPSC	ICCPC	IWUIC	IZC	ICC 700
Alabama	15	15	15	15	15	X	15		15	X	15	X	X	X	X	
Alaska	12	X	12	12			12		X							
Arizona	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Arkansas	12	12	12	09	06	X	06	X	09	X	X					
California	15	15	15							X	15	X		X		
Colorado	X	X	X	X	15	X	15	X	X	X	X	X	X	X	X	X
Connecticut	15	15	15	15	15				15	X	15					
Delaware	X	X		15	15	X	X		12	X	X	X				
District of Columbia	12	12	12	12	12		12	12	12	12	12	12				
Florida	15	15		15	15		15	X	15	X	15					
Georgia	12	12	12	12	12		12		09	X	X	12		12		X
Hawaii	12	12			X				15							
Idaho	15	12	15	12			12	X	12R/15C		15	*15		X		X
Illinois	X	X	X	X	X	X	X	X	15	X	X	X	X	X	X	X
Indiana	12	03	12	12	06		12		X							
Iowa	15	15	15	15	X	X	X		12	X	15	X			X	
Kansas	X	X	06	X	X	X	X		06	X	X					
Kentucky	15	15	12	15					09/12	X						
Louisiana	15	15	X	15	15		15		09	X	15	X				
Maine	15	15							09	X	15					
Maryland	18	18		18	X	X	X	12	18	18	15					
Massachusetts	15	15		15					15		15	15				
Michigan	15	15	X	15	15	X	15		15/15	X	15	15	X			12
Minnesota	12	12	12	12			12	X	12	X	12			X		
Mississippi	15	12	15	12	12	X	12		03	X	12	X	X			
Missouri	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Montana	12	12	12	12			12		12		12	15		12		
Nebraska	12	12	X	X	X	X	X		09	X	12			X	X	
Nevada	X	X	X	X	X	X	X		18	X	X	X	X	12		
New Hampshire	09	09	X	09	09			X	09	X	09					
New Jersey	15	15	15 (IBC)	15			15		15	X		15				
New Mexico	15	15	03	X	X		X		09	X	15		X	X		
New York	15	15	15	15	15		15		15	15	15					
North Carolina	15	15	15	15	15		15	15	15		15					
North Dakota	15	15	15	15			15		15	X	X					
Ohio	15	09	15	15	15		15		09/12	X					X	
Oklahoma	15	15	15	15	15	X	15		15R/06C	X	15		X	X	X	
Oregon	12	15	12	12			12	09	12							
Pennsylvania	15	15	15	15	15		15		15	X	15		15	15		
Rhode Island	15	15		15	15		15	12	15	15		15				
South Carolina	15	15	15	15	15		15		09	X	X	X	X			
South Dakota	18	X	15	15			X		X	18	X		X	X		
Tennessee	12	09	12	12	12		12	X	09	12	12	X	X		X	
Texas	03	00	X	X	X	X	X	X	15	X	X	X	X	X	X	
Utah	18	15	18	18	18		18		18		18			X		
Vermont	15	X			15				15		15					
Virginia	15	15	15	15	15		12		15	15	15	15				
Washington	15	15	15	15	X		15	X	15	X	15	15	X	18		
West Virginia	15	15		15	15		15		09	15	15	15				
Wisconsin	15		X	15			15		15	X	15					
Wyoming	18	X	18	18	X	X	18		X	X	18	X	X	X	X	
U.S.Territories	**IBC**	**IRC**	**IFC**	**IMC**	**IPC**	**IPSDC**	**IFGC**	**IgCC**	**IECC**	**IPMC**	**IEBC**	**ISPSC**	**ICCPC**	**IWUIC**	**IZC**	**ICC 700**
American Samoa																
Guam	09	09	09	09	09	09	09				09					
Puerto Rico	18	18	18	18	18	18	18		18		18	18				
Northern Mariana Islands	09															
U.S. Virgin Islands	18	18	18	18					18		18					

Figure 1 *International codes—adoption by state (April 2019) (ICC 2019).*

2019). We ignored the local amendments in the current study, by they will be included in future work.

We are interested in expanding the study to examine if it is economically burdensome for a church building to comply with energy codes and standards. In fact, this paper briefly touches on some aspects about it, such as looking at the impact of building type and location on the energy-saving potential of a GSHP system used in a church building. We, however, did not include the result related to energy cost, because we realized that compared to energy savings, it is also an important and big topic, but due to the page limit of an ASHRAE conference paper, there was not enough space to talk about it. As mentioned in the conclusion of this paper:

> Although this study quantifies the impacts of building type or location on energy savings of a building equipped with a GSHP system compared to conventional HVAC systems, there still remain some additional research opportunities. For example, more building types will be included in future studies, and comprehensive cost-effectiveness analysis can be conducted as well to look at not only the energy-saving potential but also the energy-cost-saving potential of a GSHP system used in different types of buildings and/or climate zones (Miao et al. 2020).

Thanks for pointing out that the new version of ASHRAE Guideline 14 exists. We checked that the equations used in both the 2002 and 2014 editions of the guideline to determine NMBE and CVRMSE are the same.

We agree that various occupancy and operation schedules exist, even for the same building type, which may have significant impacts on the selection and performance of the HVAC systems. We realize that this conference paper is not able to completely address the topic currently investigated. Therefore, one of the objectives of this paper is to make people aware that building type and location have an impact on the energy-saving potential of a GSHP system, which is expected to stimulate more follow-up studies on this topic.

Regarding Figure 2, the schedules for the church and fire station were determined after talking to the end users of those buildings, and typical schedules for office buildings are used for Building 3. The gas use is not directly dependent on the people, lighting, and equipment schedules as shown in Figure 2.

As the supplemental heating source, it is affected by the indoor and/or outdoor air temperatures. Since for most of the GSHP systems, the gas use, if any, is minimal and less important compared to the electricity computation, details about the gas use were not included in the paper (also due to the page limit).

Figure 1 shows the comparison between the simulation result (dash curves) and the actual utility data (solid curves) obtained from the building owners. Gas use data for some building(s) was absent, as that information was not provided by the building owners. As mentioned in the paper,

> Building 2 and 3 were calibrated against the actual monthly energy consumption, whereas Building 1 was against the actual energy cost due to the absence of energy use data. For Building 2, only the electricity consumption was used in the calibration process for this building, even though both electricity and natural gas were consumed inside the building since the information of natural gas consumption of this building was not provided by the building owner. (Miao et al. 2020).

As the title " Comparative Study on the Impact of Building Type and Location on the System Efficiency and Energy-Saving Potential of a Ground Source Heat Pump System" implies, energy cost is not the focus of this paper, because we realized that compared to energy-saving potential, energy cost is also important and a big topic, but adding them will make our paper more than eight pages, i.e., exceeding the page limit of an ASHRAE conference paper. However, we will consider it in the future or follow-up studies, as mentioned in the conclusion of this paper,

> Although this study quantifies the impacts of building type or location on energy savings of a building equipped with a GSHP system compared to conventional HVAC systems, there still remain some additional research opportunities. For example, more building types will be included in future studies, and comprehensive cost-effectiveness analysis can be conducted as well to look at not only the energy-saving potential but also the energy-cost-saving potential of a GSHP system used in different types of buildings and/or climate zones. (Miao et al. 2020).

Thank you for the comments regarding the use of a different set of data or any other relevant data in model calibration and validation. We would expand the study if those data are available for these buildings studied.

Building 2 and 3 were calibrated against the actual monthly energy consumption, whereas Building 1 was against the actual energy cost due to the absence of energy use data. For Building 2, only the electricity consumption was used in the calibration process for this building, even though both electricity and natural gas were consumed inside the building since the information of natural gas consumption of this building was not provided by the building ownerâ€?

These sentences in the paper explained why â€œThe ordinates in Figure 1 are not consistent, with some in kWh, some in energy cost, and some in MMBtuâ€? ASHRAE requires dual units to be provided, so both kWh and MMBtu are shown in Figure 1.

Please find my previous responses above about why energy cost was not included.

Regarding the ft^2 per ton and the cfm per square foot, it is not appropriate to calculate these numbers and compare them with each other and/or with the rule of thumb in that way, since in each building there are some spaces that are considered as unoccupied, unconditioned, and/or heating-only, where cooling and ventilation are not typically needed, such as inactive storage rooms, mechanical/electrical rooms, and so on. These numbers will vary depending on how large these spaces are. Also, the cooling loads may vary depending on how much insulation is installed in the walls, how many windows, the orientation of those windows, the properties of the windows, and so on. These are existing buildings, and the authors believe that all the building codes were met for these three buildings when they were built. Again, for the conference paper, we are not able to include all the details due to the page limit. We just want to show the most important things and must ignore the rest of them.

In the conclusion, we quoted Cho et al. (2019), "all the climate zones are suitable for the application of GSHP systems in the United States," which was also indicated in a national lab report (Green and Nix 2006). We are not using it to support our paper. Instead, we intend to use our paper to further support it. We did not mention the cons of GSHP systems, but that does not mean we do not know or intentionally ignore them.

This paper focuses on highlighting the impact of building type and location on the system efficiency and energy-saving potential of a GSHP system). Other pros and cons of a GSHP system were not the focus of the paper.

Thanks for the comments about references. We will conduct a more comprehensive literature review including both pros and cons in our future studies and try to avoid biased references.

REFERENCES

ICC. 2019. International Codes—Adoption by state (April 2019). https://www.iccsafe.org/wp-content/uploads/Master-I-Code-Adoption-Chart-apr-2019.xlsx.