[SQUEAKING] [RUSTLING] [CLICKING]

SPEAKER: So today, we set aside that part and look at what is often the hardest thing to actually make it real, to put in the ground, design, build, learn, research. So we get to work in a sense. And just like yesterday, there are many people, experts, ideas that we couldn't ram into this two day session in 10-minute segments.

And so we are so aware of that. There is still a whiteboard. At the break, you can add the names of people and experts and ideas that you really think need to be in here. We may have attempted to get them here, but we really want to hear that from you as well as feedback. We're trying to capture and share a pulse of information, the state of knowledge. As you saw yesterday, there's all kinds of views, all kinds of perspectives, all kinds of voices and language, and we just welcome them all.

We're not saying that we shouldn't have some healthy debates. So I really hope it goes as well today. And I want to pass it over to Juliet, who will be moderating our very first session.

AUDIENCE: Yay!

[APPLAUSE]

JULIET: Hello, everyone! We're excited to start our day off with some talks about design principles for geothermal energy networks. We have three great speakers, two of them in person and then one online. So we'll start our day with Connor Dacquay, who is a licensed engineer at GeoFease and who teaches in IGSHPA ground-source heat pump course. Connor?

CONNOR DACQUAY: OK, good morning, everyone. So I spoke with Zainab before this meeting. And I just wanted to thank all of HEET for putting on this session. I left yesterday quite optimistic on the geothermal district space in the United States, which is-- it's very relieving, I'll say, with the times. So thank you all for putting this on.

So my background is in engineering. I have a doctorate in what's called Earth energy resource engineering. I'm a licensed engineer in the state of New York and also the province of Ontario and Canada. I also help teach the certified geoexchange designer course, which is run by IGSHPA, International Ground Source Heat Pump Association.

And this specific slide deck today just goes through that introductory level, CGD-type course. So we thought we'd start with the fundamentals of heat transfer to get into the ground-source heat pumps and how they work. So we have conduction, convection, and radiation. By definition, conduction is when heat is directly transmitted through a substance when there is a difference in temperature.

So if you're holding a metal rod, and that metal rod heats up on one end, you feel that heat through your hand through conduction of that metal rod. We have convection, which is the rising motion of warmer areas of a liquid or gas, and the sinking motion of cooler areas of liquid or gas. So if you're holding your hand over a fire, that heat, you're not physically touching anything, but you feel that heat, and that's convection.

Lastly, we have radiation, the process where heat energy is transferred from one object to another through the emission of electromagnetic waves. I promise the rest of this presentation won't be this dry. Just getting through the fundamentals. But when your sun-tanning, you feel that heat, that's radiation.

So geothermal. What is geothermal? Well, "geo" means relating to the Earth, and "thermal" means relating to heat. So the Earth temperature is relatively constant throughout the year. It's around 50 here. I think it's 55 degrees Fahrenheit. Whereas in the winter time, it's 10 degrees outside. And then in the summertime, around 90 degrees outside. But the ground stays that same 50, 55 degrees Fahrenheit.

And to harness that energy, you can install a ground heat exchanger, which is plastic pipe that's buried in the ground. And it transfers heat to a volume of Earth around that pipe through various ways. Shallow ground heat exchangers take advantage of radiation, mainly conduction, but there's also convective heat transfer with that ground water.

You have heat exchange fluid that's pumped through the pipe. I'm getting used to this laser here. Heat exchange fluid that's pumped through this pipe and then connected to that heat pump. And the reason why these systems are more efficient is because of this sine graph here. So the source temperature is going to that heat pump from the ground heat exchanger range between around 40 to 90 degrees Fahrenheit, sometimes as low as 30.

But this specific graph is collected from four years' worth of data in a very cold climate in Winnipeg, Manitoba. So during this same time period, the outdoor air temperature ranged from negative 20 to plus 100 degrees Fahrenheit. So you can imagine that getting your source temperatures from that more extreme air compared to your ground heat exchanger temperatures makes the heat pump work harder. It has to work harder to deliver that same amount of heat.

So heat pumps like to receive more moderate temperatures, so they don't need to work as hard. And how a heat pump works is just like a fridge. It's the vapor compression cycle is what it's called. It's no different than a fridge, other than a reversing valve. But the process is you have an evaporator that transfers heat with your external environment, so your air, your ground, or your water. You have a compressor, which compresses the refrigerant and increasing the pressure and temperature.

Chemistry 101, if you increase pressure, you increase the temperature. You have your condenser which condenses the refrigerant vapor into liquid. And that phase change transfers large amount of heat. And then your expansion valve to rinse and repeat, reduce the pressure and temperature to prepare for the next cycle. So our ground-source heat pump in heating, again, we have this reversing valve, which differentiates our fridge from our heat pump. So we can also do heating. Be strange if a fridge did heating.

But we extract heat from our ground loop, where we have three units of heat coming from the ground. We have our compressor, which uses electricity to compress and heat the refrigerant. That electrically powered equipment generates heat as well. That's your power input, that compressor. There's also the circulation pump and fans. And then you give those four units of heat to the building.

So that hot refrigerant is pushed through the condenser and then rejects that heat to the air in the building. And this is how you get your coefficient of performance. So you may have heard the word COP, or coefficient of performance, and this is how it works. You transfer those four units of energy, which is combined thermal and electrical energy to the space by only paying for one unit of electrical energy to power that compressor, circulation pump, and fans.

In cooling mode, we have our heat that's extracted from the air in the building, vaporizing the refrigerant. So those three units of heat from the building. We have our compressor again that compresses and heats the refrigerant or reversing valve is on. So we flip that flow of refrigerant. So it's going in reverse now. And then that hot refrigerant is pushed through the condenser and rejects heat to that ground heat exchanger. We need to get rid of that electrical energy and electrical heat and that heat from the building. And we put that in the ground loop.

So what's the difference between Earth energy resource engineering or geothermal engineering and conventional HVAC systems? Well, the main difference is that for ground-source heat pump systems, you should be considering the total demand. The total demand of a building, not just a peak of the coldest day of the year or the warmest day of the year, but your total heating and cooling on an annual basis to determine your total supply. Because you're designing your source.

And so in a conventional system, you have a pipeline that's large enough to meet the peak heating day, the coldest day of the year. You have your natural gas pipeline that's feeding that equipment. You have your water utility line that's feeding your cooling tower to dissipate heat on the warmest day of the year. And as long as you pay your energy bill, you should be OK.

But for a ground-source heat pump scenario, we are also considered with our total loads. Again, because we're designing our source. So this example illustrates this. So we have a church, a retail store, and an apartment building. They may have the exact same peak heating and cooling loads, 40 tons of cooling and 385 MBH of heating. But due to the difference in occupancy of those three different buildings, the total heating and cooling loads are going to change quite dramatically.

You think about that church, probably highly occupied once or twice a week. You have a lot of people in the room like this space. You have a lot of lights on. Those internal heat gains help heat the space, and that's only available maybe once or twice a week. So your heating load over an annual set of data is probably going to be higher than your cooling load.

Whereas your retail store, you could think of maybe an IKEA, you have a lot of internal heat gains, a lot of people, a lot of lights, a lot of internal heat gains that you need to get rid of. So you put those in the ground, right? You need to reject that heat. And the apartment building probably relatively balanced between heating and cooling. So the heating and cooling load ratio can change even if the peak heating and cooling loads are the exact same.

And how this affects the ground loop and why it's important is because-- and this is especially true for a vertical ground heat exchanger scenario with a lot of conduction-- you have a fixed volume of Earth that you're exchanging heat with. And so it's more similar to a battery in that case compared to a conventional system. There are nuances, right. And each project is unique.

But even in open loop systems, for example, where you're tapping into an aquifer and pulling heat and rejecting heat to an aquifer, we've been measuring a system in Winnipeg over the past five years or so, and they've increased the temperature of that aquifer by 5 to 8 degrees Fahrenheit. Just because they're rejecting so much heat into that aquifer.

So what can happen is this curve here, this temperature drift, where you may fall outside of those efficient operating parameters. When we talked about that ground-source heat pump, it likes to be fed 30 to 90 degrees Fahrenheit water. But what can happen is you can fall outside of those efficient operating ranges if you're not considering your total loads, if you're only looking at your peak loads.

So it's important to not only design, again, off of your peak loads, which are certainly important, but your total loads are also important to determine your total demand to design your supply. So when you have a customer or anyone, frankly, who's interested in a geothermal system, where do you start? If they say, hey Connor, I've heard of this geothermal technology. I've heard it's pretty cool. What do I do?

Well, you'd probably want to start with the building. Again, determine your total demand to determine your supply. And then you can start looking at your mechanical system, your geothermal mechanical system, and your site and geology. The site and geology is going to dictate what type of ground heat exchanger you go with. There's many different ways to exchange heat with your external environment. Again, all you're doing is obtaining moderate temperatures so that your heat pump doesn't need to work as hard. So that could come from the air.

In Seattle, it's pretty moderate there. So air source works fine. But in Winnipeg in a cold climate like that, not so much. So you could have a vertical ground heat exchanger, horizontal surface water aquifer. I'm staying at Susan Murcott's house right now. She's a professor here at MIT, and she has a standing column. And that was pretty interesting to see.

So there's many different ways to give your heat pump source temperatures that are moderate. But at the end of the day, what matters? Well, what matters is we're trying to save on energy. That's why we install these systems. But if it's going to cost you an arm and a leg to do that, it's probably not going to make a whole lot of sense. So to balance the energy cost with the construction cost is the most important thing to make sure that it's practical. Because if it's too expensive, nobody's going to buy it at the end of the day.

And there are intangibles. A lot of people value carbon in different ways. In Canada, we have a carbon tax. So that's quantified. But the main thing to consider when you're looking at a geothermal system, in my opinion, is to balance these two things-- construction cost and then the energy savings that you're getting from that investment, because you're buying an asset, which is that ground heat exchanger.

So before I pass it to my colleague Nick, I thought I'd throw in a little segue slide here. I believe one person had a similar slide yesterday where it looks at the temperature in the distribution piping of district systems. We used to use really high temperature. I mean, we still do today, pressurized steam, but that leads to low efficiency. And so over time, we've been able to reduce our temperature in our distribution piping, which has led to an increase in efficiency. So now we're dealing with ambient temperatures, which has increased our efficiency in these district energy systems quite dramatically. So thank you folks for listening, and I'll now pass it to Nick.

[APPLAUSE]

OK.