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PROFESSOR: And finally, our last speaker is Brian Urlaub, who is a Senior Vice President at Salas O'Brien and their Director of Geothermal Operations. And he'll be joining us virtually.

BRIAN URLAUB: Yeah, good morning, everybody. Sorry I can't be there. [LAUGHS] I'm actually going to be in Boston all next week for more geothermal and thermal energy network conferences and symposiums, and looking forward to that next week. But let's see. Is that in screen? Sorry. There we go. OK.

Yeah, thanks for having me. So I'm going to talk a little bit about the introduction to designing geothermal energy networks, or thermal energy networks. I know Nicholas-- and thank you for that-- mentioned something about a case study. I think maybe the agenda might have gotten changed a little bit. So we're going to talk a little bit briefly about the high-level technical aspects of design considerations for thermal energy networks and geothermal energy networks.

So primarily, these are the six kind of most important topics or design considerations that, in my mind, when looking at these systems that you have to really consider, think very thoroughly through, and understand as you move forward in the design. So number 1, site selection. Obviously extremely important.

Now, I'm going to talk specifically about the technical aspects of the design. Obviously with site selection, there's all kinds of other ramifications and aspects of why you might choose a site over certain technical aspects. But just from a technical perspective, we'll go through that.

We'll talk a little bit about thermal resources. But obviously, you've been hearing all about that, and so I'm not going to spend a lot of time there. We'll also just dive into a little bit about the differences between the single-pipe ambient loops versus two-pipe ambient loops. And then what's an energy transfer station? Why or why you may or may not incorporate that into a design, what impacts that may have.

And then some of the infrastructure ramifications, pump houses primarily. Because we're pumping fluid, we've got to have a lot of these types of systems throughout the network. And so where do they get located? And that's always a really big topic and discussion with the client and the community about, where do these go? How do you locate them and what they might look like?

Then also talk just briefly about modeling these systems, because these are relatively new from the modeling community. And so to try to dynamically model the impacts and the optimization of these systems I think is really important. And then of course, gathering data on existing systems so we can continue to refine the modeling is also extremely important, which, we know HEET is doing a fantastic job with their LeGUp program.

And then thinking about future expansion, we've got a lot of pilot projects going on in the country right now. But we need to think about and have as part of the design consideration, how do we expand these systems and what that might look like? And make sure that we're incorporating proper fundamentals within the system to be able to accommodate that expansion in the future.

So first of all, site selection. Just looking at this from a technical perspective, again, first thing we always look for when we're looking at sites is, are there thermal assets that are available and accessible within that site? And what I mean by accessible is through both regulation and land agreements or access, can you make that thermal asset available to the system? So that's really important.

So it might be vertical boreholes, but where do those go? Are they on somebody's private property? Are they within the street? Are they at a parking lot? What does that look like? Is there a river or a surface body of water nearby? Any of those things that are going to be utilized, are they accessible and available? And then how do you get to those sites and incorporate that into your system?

The next thing would be the building stock. Number 1 we always want to look for a diverse load profile within the building stock that's going to be connected to the system. The reason for that is really just to try to reduce capital costs and peak loads and try to share energy. If we're not sharing energy during peak times, we still have to size the total for the sum of the peaks, right? So we don't get a real benefit from the diverse loads on the peak sizing, which then doesn't offset any capital expenditures.

So what we're really looking for is his commercial buildings that in heating-dominant climate zones have cooling-dominant load profiles so we can share that energy with then some residential buildings on that same network. That's really important. As you were going south into cooling-dominant climate zones, then you would look for things like domestic hot water and things that are using heat versus getting rid of heat.

So it depends on, of course, where this is being done, number 1. Most of the systems we're seeing today are in heating-dominant climate zones. So we're looking for that commercial offtaker that can give heat to the system.

And then also the building density. We don't want to run miles of pipe and only connect a few buildings. We want to make sure that our building density is such that we have enough connected customers to reduce that overall cost of the network and it makes sense to do that.

And then, of course, the site has to have areas for infrastructure. Where does the infrastructure go? Where do these pump houses or vaults go? Where do we put the thermal assets in how do we connect those systems? Because with these systems, you're going to have infrastructure that has to be placed somewhere, both electrically, hydraulically.

So are they within buildings? Are they freestanding buildings? Are they built into maybe new developments? Where do those things-- where are they going to be located?

And that's really important because as these get built out, I think the last thing a lot of communities want to see is all kinds of just infrastructure that has to do with operating the system throughout their neighborhoods. So that's certainly-- technically, we have to understand that and figure out where we're going to put it.

And then of course, the building age and the community that you're looking at. What is the age of the buildings? Typically, the older buildings are going to be harder to heat because of the envelopes. They need to be improved. They don't have as good insulation, windows, et cetera.

And then also, the HVAC systems are probably such that they're not easily retrofittable to a geothermal heat pump system. So the deeper the retrofits, of course, the higher the cost. So those are all things when it comes to the technical site selection that we take into account when looking at that and helping our clients really pick the best sites for these projects moving forward.

Thermal assets or thermal resources. Nick did a really good job talking about this. Obviously, we've got all kinds of different Earth energy-type systems where you're talking about vertical closed loop, surface water, open loop, reinjection energy piles. There's all kinds of really good geothermal resources, but there's also that waste heat, the waste heat that's around all of our communities that we can try to take advantage of.

And so those are the thermal assets that we've always tried to analyze, look at, and figure out, is it available? Is it accessible? And then what's the cost implication to that thermal asset?

Single-pipe versus two-pipe ambient temperature loop. So the interconnecting pipe that runs around the community or the network and how to connect these buildings is really important. Number 1, technically to put stuff in existing streets, to put new infrastructure in existing streets, you have to coordinate with all the other utilities. And a lot of these older neighborhoods and communities have a lot of utilities in the streets, so having a two-pipe system versus a one-pipe system makes that a bit more challenging and a bit more costly to install.

The other nice thing about the single-pipe versus the two-pipe is it's much more flexible for expansion, for distributed resources and distributed assets. So you can have multitude of thermal assets, and you can place those in different locations where with a two-pipe, it's a lot harder hydraulically to interconnect all of those systems, and it also becomes a little bit more challenging. And just the building connections.

Now, the downside to a single pipe is if you only had one thermal resource to draw from, then you have to size and pump the single pipe such that all the customers are still getting roughly the same temperature to those heat pumps. Usually, we try to maintain less than a 5-degree delta T Fahrenheit between all those buildings, because that way everybody's getting the same efficiency. If you start to allow 7, 8, 10 degrees between buildings, now you're impacting the person that's first off of the line versus the last off of the line differently, and that's not necessarily equitable and fair to those customers.

So that's one reason why when you're looking at a single-pipe ambient system, distributed thermal resources are key to those designs. Whereas a two-pipe system, everybody's getting the same temperature. You can locate one larger thermal asset, and everybody gets the same temperature. So it's a little bit easier to manage with a two-pipe system.

I'll also say that the single-pipe systems generally, on average, have lower flows through that single pipe through the ambient loop, which means smaller pipe, smaller pumps, less energy to operate. So those are also some benefits of the single-pipe system versus the two-pipe system.

The other thing that-- just touch on briefly is the energy transfer station, or basically in layman terms would be just a hydraulic isolation between the building fluid and piping system and the infrastructure fluid and piping system. The reason why you do that, especially for larger buildings, is if you have a lot of piping in your building, you have a lot of fluid, a lot of connections, a lot of joints, you have a larger risk for potential leaks and breakage that would impact the entire infrastructure.

So a heat exchanger to isolate the building from the infrastructure then allows every building to have its own system. The infrastructure's completely isolated. And that way, the fluids don't mix. The pressures don't mix. If I had a mid-rise or a high-rise building on one of these systems, that pressure would impact the infrastructure pressure if I didn't isolate that.

So most systems we see today have what we call an ETS or an Energy Transfer Station to isolate those systems. Keep in mind, every one of those heat exchangers, though, do reduce the temperatures and efficiency of the system, because we're not getting a straight through 0-degree approach from infrastructure temperature to building temperature. You generally lose a couple of degrees, which, then again, can negatively impact the heat pump performance. Slightly. Not a huge deal, but there is an impact there.

If you had all residential homes and just one heat pump per home, maybe an energy transfer station isn't necessary. There's a great case study, the one in Markham, Ontario, where all 300 homes do not have an energy transfer station, because there's very limited piping. There's no pressure implications of additional building height. It's all single-family. So again, project-specific, but just understand what the differences are and why you might use that versus when you maybe wouldn't use it.

And then let's talk a little bit about these pump houses and infrastructure. And where do we put those? The above-grade pump houses obviously need to have architectural designs to meet any city standards and neighborhood standards from an architectural perspective. You obviously have to have-- in certain cases have to have conditioned space when you get over certain square footages. In certain areas, the code would require potentially a bathroom to be installed.

So designing above-grade structures, number 1, there's a lot larger cost implications. It's something that people are going to see. So where do you put that? What does it look like? Great for educational purposes, but other than that, it's really just there to operate the system.

Are you going to have actual hardware installed there to operate the system, or is everything remote? So what goes into this pump house? How big is it? Some of these that we've seen on some of these pilot projects are 20 by 40 foot long. So a relatively large pump house that needs quite a bit of space and obviously can be seen.

So when you're into the beginning concepts, where do you put these? What do they look like? What are the sizes? What are the implications of having above-grade structures? And you might have one. You may have more than one, depending on how many different pump stations you might have in a system, so those are things that need to be considered.

The other thing you could consider is, what if we do this below-grade, OK? So now we don't have to look at anything. Everything is below ground. But what are the implications of that?

Well, number 1, anybody that's owning, operating, and maintaining these systems, you have to have confined space, trained and certified service technicians to be able to access those vaults and be down inside those spaces. It does make for a bit more challenging for that maintenance and repair if needed.

You also have a very high-humidity environment, so you have to be careful with some of the materials that are used. And then where do you place these? Where do you have room for these? Generally in the street, you may not have room because of all the other utilities. So are they going to be placed in private property? If so, you have to have easements and land access agreements to access these vaults.

So just thinking that all through about, number 1, who's the owner? Who's going to own and operate and maintain the system? What are their capabilities? Where do you have space for this stuff? And then what's the longevity? What are the service and maintenance implications of having something below-grade? If this was in the street, it has to be vehicle load rated, et cetera.

Here's just a couple of pictures of a project. This was the one I mentioned up in Markham, Ontario, that's been installed and operating for a couple of years now. And they had 15 below-grade vaults all located in the street.

So as you can see, you have to access those from a manhole down into the vault to be able to get at the pumps, et cetera. You still have electrical and some water pedestals above grade that you're still going to see within the community. So where do you put those? Is that on someone's private property or is it public property? Where does that get located?

So with these systems, we do have to consider technically, where does all this stuff-- where do we place all of it? And what are the cost implications? And then what do the maintenance and future accessibility to these systems look like?

And then I just talk a little bit about modeling. Modeling these systems can get quite complicated. The bigger the systems, the different types of energy sources when you're adding in any type of supplemental or hybridization of the systems.

Depending on the building loads and the different diversity of each of the buildings here, you need to model these in a dynamic, transient way that we can actually really, number 1, understand how they're going to operate hour by hour, year by year, over the long term. We need to understand and be able to run sequencing and operational models or dispatch models so we can really understand how to build proper control schematics on how to operate these so we can give those to the client.

And then also just looking at long term, what happens to the system? Or throughout the year, what happens when one building shifts from heating to cooling, or maybe one asset isn't available because of the temperature profile? So there's a lot of different things that are happening within these systems.

And then we can also really look at not just the heat pump efficiencies. We can also dive into the parasitic pump loss efficiencies, because one thing you see with these large thermal energy networks is there's a lot of pump energy. The bigger they get, the more pumping you have.

And so how much are we being penalized by connecting all this together? Or is there different ways we can do this to maintain small parasitic losses on the pump side? And so the cost to operate the system doesn't offset as if you were to go through and maybe do these in smaller pieces. So those are all things that we need to really understand and need to model correctly as we're designing these systems.

So again, the temperature profile of the ambient loop. I mentioned earlier, we want all the buildings to get roughly the same efficiency and the same temperature. So with that, we need to model that temperature profile throughout the year, and obviously at the very coldest point in the warmest point in the year and what that looks like.

So this is that project in Markham, Ontario, where you can see all the different energy sources injecting or rejecting heat into that ambient loop, and then how the temperature profile follows that two miles of pipe around the development. So we know that based on this, nobody's getting more than a 5-degree difference, which means everybody's getting really good and pretty close to the same efficiencies at their home.

And then of course, we always look at long-term net effects of the system, especially when we're looking at vertical ground loop heat exchangers, and if we have large bore fields that we could impact with either putting too much heat in or taking too much heat out, and how that impacts the Earth over time. And that's the other beautiful thing about distributed thermal assets, is the smaller you make them and the more distributed, the less we're going to have any impact of the Earth over the long haul versus if we put all that into one area.

So you can see here that you model five years, you model 10 years, even as much as 30, 40 years just to see, what's the trend of that model look like? And you can see here that there is no trend either going up or down, which means that we have a very stable and consistent load profile, both energy in, energy out, so the ground is going to be very stable over the long term.

And then we can also model all the efficiencies of the system. So these are the heat pumps throughout the year or for one year of operation. That was in the third year, both heating and cooling. So that's every heat pump in the system and looking at the COPs of those different buildings and how they're operating on the system. So we can look and go, OK, everybody's pretty much operating around the same efficiencies.

And we can also just get an aggregate of the total COP of the system, not including pump energy, but of the heat pumps and the customers that are being served by this system. So we can really get a good snapshot of how efficient these systems are. And is it penciling out to what the consumers are going to expect on their utility bills?

And then the last thing I would just say, when designing these systems, we really have to consider the expansion of these systems in the future. And how are we doing that?

For instance, one of the projects we worked on with heat, actually, in Framingham, they had put some tees and some valves on the piping, thinking about expansion. And then as we got into designing the expansion, we realized that that really wasn't done in a way that could do it the most optimized way for hydraulics and for energy sharing.

What it was initially thought was that you could just use the entire center pipe as the mix loop for connecting the two. Well, hydraulically when you add the flow rate of the second loop, that increased the pump sizes-- whoops-- it increased the pump sizes dramatically for both systems. So that really wasn't the most optimized way to do that because the pipe wasn't large enough.

So rather than digging up and replacing that entire section, creating two smaller 20-foot mix loop sections on each end and just replacing that section, and then modeling that to make sure we can still transfer enough energy within that 20-foot and see how that worked to see whether or not that was a good way to expand the system.

But we have to understand, when we look at a system, where would you expand? What's the building stock? High level, what are the loads of that potential expansion loop? Are there energy resources available on that particular expansion loop, or do I need to feed it all from the original loop? How does that all work together?

And so this is showing how that mix loop actually works, those two different spots, which you can see here at the beginning and then at the center of the loop. Where the two come together for 20-foot and mix, you can see that the temperatures actually do benefit one another and bring the two closer together as they operate simultaneously. Even though you only have two 20-foot sections, we're still getting shared energy benefit across both of the loops.

And actually, the red loop is being benefited more from the black loop, because we've got a little bit better temperatures on the second loop, I should say, the phase 2 loop. So that's benefiting phase 1, OK? And so as you can see here, we've put numbers on that where the actual mix loops are, 1 and 3-- which is here 1 and 3, and then how the systems kind of operate together.

So thinking about expansion, which direction you might expand. And then just thinking about the hydraulics of it and also the energy. Where's the energy going to come from? Will there be new energy assets being installed, or does it need to come from phase 1 of the project?

And so those are just kinds of things that you can think through high level as you're designing a project and asking clients, is this potentially going to be expanded? Which direction would you expand? Are there more customers that you already have in mind that you want to add later on? So those are all some of the design considerations that I consider when designing these geothermal energy networks. Really critical from the major-- or six most critical considerations.

So with that, I thank you for your time. Again, I apologize I can't be there in person. Wish I could have. I'm sure I'll see a bunch of you next week. And I guess we're opening it up for questions.