

[SQUEAKING]

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SPEAKER: And Juliet, we can't wait to hear about the model.

JULIET Maybe? Oh, OK. I was a little too fast. Well, hello, everyone. My name is Juliet Simpson. I'm a researcher at NREL.
SIMPSON: I'm excited to be talking to you about the modeling work that we've been doing. I know I've gotten a lot of great feed-ins from earlier today.

I will just start by noting that this is geared a little bit more towards teaching people about generally the modeling that happens for these systems and a little bit less towards results. So if you're interested in that, feel free to talk to me. And also, I'm going to be talking about modeling for these systems within the context of a model that we've been building out on the Leg Up Project. But just know that there are a lot of other models out there, each tailored to do some slightly different things and a lot of great options. And I'm just doing this within one context.

So to get started, I'm talking specifically today about techno economic modeling. And that involves two components, if you're familiar with it, as you might guess by the name, the technical model and the economic model. And this is really important because it allows us to think about trade-offs between impacts to technical design, how that impacts operation and performance of a system, and then looking at the costs of that, the economic impact.

Now, why does all of this modeling-- why does it matter? Why is it important? This really helps us to answer a lot of questions without having to go dig holes in the ground.

We can start to think a little more critically ahead of time before the design and before the build. We can think about what communities does a geothermal network make sense in? Does it make sense to just go for geothermal boreholes, or should we pull in some of the other thermal resources that have been mentioned today? What kind of monthly payment might be required from customers, or what expected total cost might there be? There's lots of questions on that side of the economics as well. So having something that can help people start to think about the finance side as well.

And then after you build, what would happen if you added one more house to the loop? Or what would happen if you wanted to change a little bit the performance set point for the temperatures or the operation or the speeds of the loop? So being able to work with some sort of modeling option, digital twin, something that lets you change those parameters before going out and impacting your customers in the real world.

A couple of components that I'm then going to talk through in a minute, both on the physical system side, a lot of the major components that we've already mentioned today, understanding your building loads, knowing when they're going to need heating and cooling throughout the year and how much of it, understanding your opportunities for thermal resources in an area, capturing the distribution system correctly. That could include knowing whether you want to go for a one-pipe system or two pipes. How big is the pipe going to be? How much thermal inertia is there in the water or whatever working fluid you have moving in that pipe? How well are your heat pumps going to perform? What's their coefficient of performance look like with different entering temperatures?

And then something we've discussed a little less today, the economic side. Estimating capital costs, operating costs, maintenance is all really difficult. It's something that we certainly struggle with. But it's really important to these systems. And then also thinking about the finance plan, what's your cost recovery look like? Who is paying for it? It's probably going to have a big impact on that. But that then has an impact at the end of the day on what customer payments look like as well.

Now, we've tried to put both halves of those models into something we're working on at NREL called heat nets. This stands for Heat and Economic Analysis Tool for Networked Thermal Systems. NREL has been building out this tool in collaboration with HEET as part of the Leg Up Project. And so we're really excited to have both halves of it up and running now. So we have this code that is written in Python. It's intended to long-term be open source, and we're working towards having that being a public GitHub repository.

The first half is the physics-based model. That's a reduced order model, as Isabel mentioned earlier. The idea there is that it's a little bit more high level. It really builds on a lot of other more detailed models to capture the energy flow around the network and the use of electricity over time. The second model is the economic model used to calculate economic metrics of the system as well.

So I'm going to give a little bit of high-level information about both of those models before talking about what kind of questions we can answer with them. So first, on the reduced order side, this is for capturing the physics of what's actually happening on the loop. Where is heat moving over time? Where is water moving? How much electricity is being used for that whole process? The major components that we're capturing are shown here in this simple diagram. But know that this is showing one building when you might have 50. And these are just going to be repeated over time.

The main backbone of this model is the ambient temperature loop. So a lot of the modeling effort here goes into the effort of capturing how does heat move physically around this loop? How much thermal inertia is in there? So if you dump in some heat, how quickly is it going to change temperature? And how quickly is that going to then propagate around the loop and affect all of the customers?

Then, plugging in and exchanging heat with that, we have all of the buildings. So that requires doing some building modeling, understanding their loads over time, understanding how the heat pumps are going to perform given different entering temperatures from that main thermal loop. There's also all of your thermal sources and sinks. So in this case, we're mostly focused on borehole fields, but there could be other ones as well. This modeling is being done, like I mentioned, at a reduced order level. So we're relying on collaborators who are doing some more detailed modeling, including models that we're getting from Lawrence Berkeley National Labs, to be able to look at what does our borehole performance look like over time?

And then, finally, having some of central control station, being able to model the circulation pumps to move the fluid around. In our models right now, we always account for the option of an auxiliary heating and cooling system. And that allows us to really play with our temperature bounds and how many buildings we have on the loop. And then having a control decision architecture that determines how do all of these pieces run together?

Just as a quick example of some of the outputs we can get from that, on the left we're showing one that shows spatial trends. So as you move around the loop, this is done in a straight line. We can imagine the end feeds back into the beginning. This relates back to what Isabel was saying earlier, that you see changes in temperature as you move around the loop. And then you also see things happen over time. So the one on the right-hand side is showing every hour throughout a year. How is heat being exchanged with the loop?

So in this case, we're showing building loads and borehole loads in blue and green. And those are generally opposite. So in the winter time buildings take heat out of the loop, and the borehole field puts heat in. We see the opposite trend in the summertime. And then some additional auxiliary heat in this model, and so you could see maybe where those areas that you might need some additional heat. And you can consider trade-offs for. Is it worthwhile to have some of electric boiler provide that or to drill more boreholes/ And again, this comes down to a lot of trade-offs.

The other half of this model is economic. I will warn you that this is the side that I spend a little bit less time on at work, but this takes in a lot of inputs from the physics-based model. So the physics-based model will tell you how much electricity are all the components using over time? Also, what were the design specs you chose for the system/ And then you have to give it some additional information. So what financial assumptions are you putting in? How much of this project, how much is financed with debt, how much is upfront? What kind of assumptions are you making on incentives you might received?

That all comes together into a variety of outputs that we can look at. One that we're particularly excited about right now is something we're calling LCOx. This builds off of the standard levelized cost of energy equation. But here we're allowing for pulling in multiple energy flows. So it's no longer just energy. Our costs are including both capital costs and the cost of the electricity to operate the system. And then our thing that we're producing in this case is heating and cooling to buildings. Right now we're looking at that as just the absolute values of them, how much total help are you putting into these buildings to maintain their climate? So heat and cool are equally valued at the moment.

And we can then get more granular with those outputs as well. So just an example of something that you could look at, this is just using, not random numbers, but example numbers for some example building. You could start to look at how much energy consumption do you expect throughout a year. How does that then trickle down into what might that user, depending on what cost recovery is being used, what might their monthly bill payment look like, things like that. So now we can start to go all the way from design decisions down to monthly bills for individual homes.

So just to wrap up that this idea showing how the data flows altogether, we have first this reduced order model. This is physics-based. We have a lot of different inputs that come into this. It really relies on high-level modeling done elsewhere that all can come together. A major output from that is the time series electricity consumption. There are some other inputs that we're going to need to get to the economic model. So we start to have to think about component costs, estimating those, knowing what our financial assumptions are, and then eventually feeding that all into an economic model where we can get outputs like that LCOx value I was mentioning, also net present value, internal rate of return, and something we're calling thermal energy price.

And then you get to answer the fun questions. So this is what we're really here for. We build out all of this modeling so that we can start to answer interesting questions. So I have two quick examples here to wrap up. The first is what if you changed the minimum loop temperature/ So in this case, we're assuming with the way our control system that we've built is set up, you have to decide when do the pumps ramp up? When does the borehole get used? When does auxiliary heat turn on in order to maintain some minimum temperature?

In this case study that we did, we found that as you increase that minimum loop temperature, the cost to the utility goes up greatly. This makes sense. They're having to work really hard to maintain a higher temperature. But the cost to the consumer goes down slightly because their heat pump is working more efficiently now. So you see this trade-off here, well in this case, we're talking about annual electricity costs, not considering capital cost that goes into that. But we have to think about how benefits are shared to all parties involved in a geothermal network.

And as one final example, you can also think about what happens as you change the number and location of boreholes around the loop. And here, we see that if you just think about electricity system costs, electricity usage, more boreholes means less energy is used in this case because we're not needing any of auxiliary electric boiler. But you have to consider that weighed against economic impacts. So how much did they cost? Was that cost worth it/ What's your trade-off look like there/

So thank you all for listening to me talk about modeling. I think that modeling can really help us to answer a lot of key questions as we move forward with building out geothermal networks. One model that we're excited about for it is heat nets, which I've talked through some examples of today. But again, a lot of great modeling going on in the space that we're excited for. But we're looking forward to the opportunity to think about the analysis of how these design and operational decisions impact both performance and economics of these systems. So thank you.

[APPLAUSE]