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**NATHAN** Introductions, Audrey Schulman.

**PHILLIPS:**

**AUDREY** Hey.

**SCHULMAN:**

**NATHAN** HEET, Home Energy Efficiency Team. I'm Nathan Phillips. I teach at Boston  
**PHILLIPS:** University. And the previous speakers, I think, really talk to how the environmental problems that we have are either invisible or very hard to grasp. So being able to see these things with evidence, photographs or having simple and precise metrics to understand the magnitude of our climate impacts is important.

So this is very much in line with this. And so some of you here have been with us from the start, when we met here a couple of weeks ago. Some of you came in midstream.

So we laid out this problem about the methane gas leaks from the natural gas pipeline infrastructure under Boston, Cambridge, Somerville, Eastern United States. Then we talked about solutions. We had a hackathon about a week and a half ago or a week ago. And then, yesterday, Audrey and I, and some of the people in this room, hopped in a van, and we started sniffing these gas leaks and mapping them on Google Earth.

And so we just wanted to share with you-- how many people were actually in the van with us? So a good chunk of us here. So this was us yesterday. And this is a combined map here of both of the trips that we took.

So the first van load, we had a full van of 12 people, and we drove from here to Somerville and back. And then we pretty much did the same thing with a little slight variation in the second trip. So let's see-- so that's where we are right now, is that

correct, Audrey?

**AUDREY SCHULMAN:** Yeah, and an important thing to know is that there's a baseline about two parts per million in this, so that the wall, everywhere, is just a baseline of methane that exists. That used to be lower--

**NATHAN PHILLIPS:** No, let's share this, please. But actually please--

**AUDREY SCHULMAN:** Sorry?

**AUDIENCE:** So it's Mercer Street, that's the methane leak?

**AUDREY SCHULMAN:** Yeah, so there's a big league somewhere here, right in front of the most iconic part of MIT.

**AUDIENCE:** [INAUDIBLE]

**AUDREY SCHULMAN:** Oh sorry, you want me to?

**NATHAN PHILLIPS:** Oh, I'll do it.

**AUDREY SCHULMAN:** But the wall here that you see of everywhere where we drove? That's sort of just the parts per million of methane that's just background noise. And the big spikes are where there were leaks.

So and what's interesting is, we did a US survey of Cambridge and Somerville two years ago, and there was a leak here. So there still is. It's nice to know. What do you want to say?

**NATHAN PHILLIPS:** Well, how about we go to the area, where it was it, Prince Street in Somerville?

**AUDREY SCHULMAN:** Pearl Street.

**NATHAN** Pearl Street. Let's take a look at.

**PHILLIPS:**

**AUDREY** So here's us going by Kendall. And then back-- I'm having a prankster.

**SCHULMAN:**

**NATHAN** Thanks for driving, Audrey. I'm not good at Mac.

**PHILLIPS:**

**AUDREY** OK, yeah no. Mac is my language. So that's Pearl Street there, the big mountains.

**SCHULMAN:**

**NATHAN** Now. These are all National Grid, right?

**PHILLIPS:**

**AUDREY** Yeah so the difference between Eversource and National Grid is this train track right  
**SCHULMAN:** here. So this is Eversource down here, this is National Grid up there. And we don't know what's going on, whether there's a difference in its operating pressure of the pipes, or age of the pipes, material of the pipes, or difference in how the two companies deal with leaks.

But you know, two years ago, when we did the survey, there were-- you know, this area of National Grid's was the Swiss Alps of Somerville. And it seems to still be that way.

**NATHAN** So just a couple of observations. And please, you were there, so offer your own  
**PHILLIPS:** observations or questions about this because this is a very rich data set there. It raises lots of questions to me. So you can see here, there's actually a couple traces, right? Here there's two traces.

We drove it two times in two trips. You see that there some variation each time. And we talked about the vagaries of wind, and you know, if the wind's blowing harder in one direction one time, you'll get something slightly different.

So is this a leak? Is it the same thing as this? What do we actually-- how do we take continuous data like this and objectify it in terms of, well, there is a leak. It's difficult. It's tricky to do.

And you know there are pipeline leaks. There are holes in pipes. And then there are

methane leaks. And they come out of the ground. So even the terminology we use is not quite fully worked out. There's a lot here.

Some of the things that-- so in terms of, at one level, at a very broad level, Pearl Street is a mess. It's leaking methane all along that street.

When we get to policy, state policy makers and the utilities, and the regulators want to know, well, how many leaks are there? Because that determines, like, how many crews that are going to go out, and how they're going to schedule, and how they're going to get reimbursed, or repaid for a fixed number of things that they do.

So this is a complicated kind of policy science type of framework. Do you have any other observations?

**AUDREY SCHULMAN:** Yeah, I want to point out one thing in terms of policy. This area right here is where they'd taken out the cast iron main that is quite old and put in plastic. And we could see-- I think that that's right.

**NATHAN PHILLIPS:** Franklin, is that Franklin?

**AUDREY SCHULMAN:** Yeah I'm assuming that is. We can go in closer. But there was one part where we saw that they've taken out the old gas main and put in a new, better one. And I'm betting it's that area.

**AUDIENCE:** So, were you surprised by this?

**NATHAN PHILLIPS:** Not any more. So when we published our first publication in late 2012, early 2013, it basically made it a problem that was well known to the utilities known to, at least, I don't want to say everyone, but people who saw the paper, and members of the public that read some of the press that came out about it.

So that was unexpected to the utilities. And it kind of knocked them back. It's like, oh, we have data that's coming out. So they didn't control the data. And so just by virtue of having data out there, it has basically, kind of say, balanced the power a little bit, or a lot, to get change to happen and policy to be made. Is this Franklin?

**AUDREY** Yeah, I don't know. I couldn't see. I tried to figure it out. Anybody know Somerville

**SCHULMAN:** really well? What's the street parallel to Roland?

**AUDIENCE:** Can you assign these leaks to a specific pipe? What's the spatial resolution of assigning a spike to the--?

**NATHAN PHILLIPS:** Yeah, so when we go by here, any one of these kind of discrete spikes, the window in which leaks may be coming out is probably on the border of a few tens of meters. And that's dictated both by the spatial source. It may-- even one pipeline leak, like I said, could be coming up in various locations, and then the wind may be blowing it around.

So that's what this is allowing us to do. But then streets sometimes have multiple pipelines running down the same street. Sometimes they only have one main running down the street. So you have to go in a little more carefully and use, basically, probes that check what's coming out of the ground to actually pinpoint the actual pipe and where it's leaking. So this doesn't do this.

This basically just says, Pearl Street is a mess, and it's got a lot of leak problems. And it requires a walking survey to go back and to be more--

**AUDIENCE:** Have you done some very basic signal processing on it? So run a low pass filter just to get rid of the small frequencies?

**NATHAN PHILLIPS:** No, and I think that's the type of analysis that would be fabulous to do here.

**AUDREY SCHULMAN:** Know anybody who can help?

**AUDIENCE:** I can take it farther.

**NATHAN PHILLIPS:** Yeah?

**AUDIENCE:** [INAUDIBLE] You can detect the pattern that reflects the leak--

**NATHAN PHILLIPS:** Yeah.

**AUDIENCE:** [INAUDIBLE]

**NATHAN PHILLIPS:** So here's one thing that I think we all Audrey and I have been trying to make progress on is, how do you take this data and use it to help us start to quantify how much is coming out? And that's also a very difficult thing because, first of all, you're looking at this, and it implies something quantitative, but you don't see any numbers here, right? So probably you're wondering, well, how big are these spikes?

And actually, you know, this data just came out, so I haven't been able to process, but we know that this is sitting right around 2.0, maybe 1.95, I forget what our baseline is. It's in the KML file. We could open that up. It's just a text file. It tells you what we set the baseline at-- that baseline can shift from day to day, by the way.

What is this value? I'll have to find it out. It would be great to have-- we were talking about something that some students could do is come up with a processor that just basically plops numbers on here. So we could see that. What was the concentration?

If we go, you know, just for setting the scale, I remember, and the four of us in the van for the second round, we went to Sullivan Square. And I think, what was the top read we got there? We were reading it off.

**AUDREY SCHULMAN:** It was like 90, wasn't it? Wasn't it something really ridiculous? I've never seen that number before.

**NATHAN PHILLIPS:** I recall up around 67 or 70 parts per million in the air.

**AUDREY SCHULMAN:** So it's that spike right there, see?

**NATHAN PHILLIPS:** So there's something really interesting about this. So we can put numbers on that. We have done that, and it's just, we haven't had a chance to do it. But actually this is really a very interesting issue of data display.

I'd be interested-- who's that data person that, the display of data--

**AUDIENCE:** [INAUDIBLE].

**NATHAN** Yeah, I'd be interested to hear someone like that's take because there was a utility

**PHILLIPS:** person from National Grid that basically called us out on this. And the point this person made was, it's like, you're scaring people by doing this. You're taking-- it's an apples and oranges thing. You're putting some data.

And all of the houses, and all of us, are, like, down here, and you're creating these things that are just making it look like the world is ending. And I kind of get that, at one level, is that this is really apples to oranges type of thing because we're conflating PPM values parts, per million with meters, or space. And they are two different beasts, and we're like putting them together.

But I will say this. As a scientist, the first thing I was trained as a freshman was, if you have data, and you're going to graph it, use the space available to fit your data, you know, and maximize that space. So when I want to plot this, I want to make it visible as best I can.

**AUDIENCE:** [INAUDIBLE] I think it might be useful to come up with a unit, that is understandable as a measurement unit. It could be anything. And I will not mention that word, but stuff that comes out of us as-- I say, you know, what is the concept? So something that says--

**AUDREY SCHULMAN:** Nathan's idea is to sort of take just sort of some number that covers this whole area for this leak, so that it adds up the whole area underneath that.

**AUDIENCE:** So you can bin that. But what I'm saying, as an understandable measure, something that says the height is measured in terms of a unit that we all recognize as a relevant unit for gas. [INAUDIBLE]

**AUDIENCE:** But you could be able to reverse model it, right? So put it in an atmospheric model and say the concentration at three feet above the ground is X. What's the leak rate have to be to get that concentration here in this pattern? And figure out, how much they're actually emitting, and then you have a number that is at least in terms of their dollars, right?

**AUDREY SCHULMAN:** But it's hard to do that somewhat because the wind will be going by.

**NATHAN** Right, but the wind, so you do it on a couple of days, and you have, you put in the

**PHILLIPS:** wind data to your model. And then your model says, this methane at this first rate, it back-calculates-- from your concentration, back-calculates an emission based on the weather data as well. Normalize that over multiple days of testing, and then you say, this roughly equates to X emission.

And there are research groups that are trying to do exactly that. So what you have are the turbulence experts, the people that study micro meteorology, and boundary layers, and I'm not that person. I know that person.

**AUDREY** I don't even know dispersion.

**SCHULMAN:**

**NATHAN** But these are the future areas to take this and to try to model.

**PHILLIPS:**

**AUDIENCE:** See, I'm wondering against whether this is a physics problem or a statistics problem.

**AUDREY** Yes.

**SCHULMAN:**

**NATHAN** Yes, it is.

**PHILLIPS:**

**AUDIENCE:** Because I feel like some of these things, you could get very complex physics because of the nature of the scales at which you were trying to model this thing, or run a machine learning algorithm against it and see what is your best predictor.

**NATHAN** And I just want to make a really quick point here is, like here's one of these spikes, right? This value, let's say it's 10 PPM, that's important on its own because, for example, air quality is related to concentration of methane in the air. It's a precursor to ozone.

The area under this curve, we think, may be a correlant for how much is coming out. And that becomes an energy point, or an equivalent carbon unit is this area under the curve. But you know, these need to be validated.

Everyone in the class now, I think, I sent the email out, you have the KML file. You have this data. You have an ASCII data file, which generated this. You'd have to-- the

columns are actually pretty easy understand, for the most part.

But you are now empowered. This is community science. And you can explore, and analyze, and run with this data.

**AUDIENCE:** I could forward it to everybody who's signed in. Nathan, I have an unrelated question that I'm really curious about. Have you ever driven near a cow farm, a beef farm?

**NATHAN PHILLIPS:** So the one that sticks out in my mind is driving from San Francisco to LA on Interstate 5 getting close to the Southern Mountains, giant feed lot right next to I-5, and very flat baseline, and then, you know, this very sloping increase as we passed by that feed lot to about, I think it was 2 and 1/2, 3 parts per million of methane going from below 2-- but the thing there, it's not like this spike like we're seeing here. It's just this blob. It's a very extended blob.

**AUDIENCE:** That's why I think integration is important. So you want to do not just a spike but a spike times area.

**AUDIENCE:** Which an air dispersion model would essentially-- would do.

**AUDREY SCHULMAN:** So we're going to need somebody to help us with this.

**NATHAN PHILLIPS:** Yeah, these are great ideas. Question?

**AUDIENCE:** I just wanted to know, can you get ahold of this device? How much does it cost?

**NATHAN PHILLIPS:** The Picarro analyzer that we used-- and that's now six, seven years old, that was about \$60,000. And the manufacturer, it's kind of like, they don't have a price list. They're like, call us and let's talk.

**AUDIENCE:** So that's just for the box with the mirrors and the laser.

**NATHAN PHILLIPS:** Yeah, yeah. So you know, it's not really--

**AUDIENCE:** This is the kind of stuff we have to [INAUDIBLE]

**NATHAN PHILLIPS:** Yeah. But, what I will say is that, or maybe Audrey wants to talk about the hand held? The Sierra Club HEET thing.

**AUDREY SCHULMAN:** Yeah HEET might, at some point have a through Sierra Club, Massachusetts have a handheld device with which you could check something like that combustible gas indicator for anybody who is on the ride yesterday. So you'd be able to check the gas in the soil to find out if a tree is being poisoned by gas-- et cetera.

**NATHAN PHILLIPS:** And I can't forget-- someone, who was it, came up with the idea of a bike, a bike trailer.

**AUDIENCE:** You did. That was your idea.

**NATHAN PHILLIPS:** Huh?

**PHILLIPS:**

**AUDIENCE:** You were talking about it. That was your idea.

**NATHAN PHILLIPS:** Oh. Well--

**PHILLIPS:**

[LAUGHTER] So that would be amazing. And there's a reason for it. Because, as you mentioned, you know these mains, they can run, more times than not, they run kind of down the middle of the street. But they can go on sidewalks. They can go on angles. The service lines leak.

And so much of what we've done has not been looking at service lines, the perpendicular, smaller pipes that go into the houses. So with a bike or a cart, or an ability to get on sidewalks-- and to be able to move around in Boston or Cambridge, you know, if you ride a bike, that's the most efficient way to get around. I mean, if there's a gridlock, you're just going around. So--

**AUDIENCE:** Baby carriages.

**NATHAN PHILLIPS:** Or baby carriages. And so Picarro does sell a smaller unit than that one, it's like a backpack unit. But it could go in a Burly trailer, or it could go on your back while you're riding a bike. So I would love that. It would be the first one in the nation, and I think it would be amazing. So if we can crowdsource that, generate some funds,

that would be great.

**AUDIENCE:** Well, couldn't the existing Picarro that you had in the van, can that be mounted, that and the battery or power, could that be mounted on our trailer behind a bike?

**NATHAN PHILLIPS:** Yeah, it could. We could actually make a video with that, and that would be like, let's do it better-- because what you would use there is, like a garden cart, with those big balloon knobby tires to provide some shock absorption.

**AUDIENCE:** Yeah, actually let me make a point of some order, which is now that we-- I think the formal portion of your presentation is done, right?

**AUDREY** Right.

**SCHULMAN:**

**AUDIENCE:** So I think that we can now ask questions of all the speakers, not just--

**NATHAN** After giving Audrey a hand.

**PHILLIPS:**

[APPLAUSE]

Can we have Susan's last question?

**AUDIENCE:** I just was wondering because, on the field trip, I learned what the symbolism is by the gas company, and what kind of cast iron, it was written on the sidewalk here. If the company has the infrastructure in its archives, is there enough of a relationship between the age of the pipe and the material to know the leak, so you could make big assumptions about, OK, if you know that, then you don't even have to do the monitoring.

**AUDREY SCHULMAN:** The Department of Environmental Protection is making that exact point, in terms of basing all of the state-wide greenhouse gas methane emissions based on exactly that calibration-- miles of cast iron, miles of bare steel, et cetera, and making an assumption that-- they know the exact rate of emissions per mile of cast iron main, and that they don't even have to check, either top down, or bottom up, either.

And I think that's-- you could make a guess at that, but you have to check to make sure it's right.

**NATHAN PHILLIPS:** Yeah, they call the emissions factors and activity factors. And multiply A by B and get a leak rate.

And these, I call them fudge factors, they basically say, cast iron has this many leaks per linear mile. That's your emissions factor. Well, how many miles do you have? That's your activity factor, multiply a by d, there is your leak rate. But those are based on very old-- not just old data, but very sparse data.

**AUDIENCE:** But can you calibrate that with you leak data?

**NATHAN PHILLIPS:** Yeah, that's we're doing.

**AUDREY SCHULMAN:** I don't think it has much to do with each other. The Department of Environmental Protection emissions factors make it look like-- the problem is solved! And I don't think that that's true.

**AUDIENCE:** There are [INAUDIBLE] emissions factors, right? So they are from the industry, and they're way outdated. Like, this is true, they're outdated for refineries, so when they go out and do modern testing on refineries they see the tanks leak at much higher rates than their emissions factors account for.

**NATHAN PHILLIPS:** So there's a really interesting point the Commonwealth of Massachusetts apparently has done an enormous job at cleaning up our methane leak problem because, what they did was, the DEP utilized an early set of emissions factors natural gas leakage from the mid 90s, and then one that was much lower, from 2015 publication, and they linearly interpolated an emissions factor, so that-- they hardwired in a reduction because two studies showed two different emissions factors for the same kind of pipe. So result you get, it appears to make it look like we've done really, really well.

**AUDREY SCHULMAN:** Kind of like, everything is solved. And part of the way they did they was, they got rid of superemitters, or one of the studies discarded any outliers.

**NATHAN PHILLIPS:** Right, so the emissions factors are based on leaks are distributed like this. But what we know is that leaks are distributed like that. They're long tail with a few--

**AUDIENCE:** I mean, I would say that the normal versus long tail is an error across so many problems and industries.

**NATHAN** Yes.

**PHILLIPS:**

**AUDREY** And we can all take a look at this data and make a guess as to where

**SCHULMAN:**

the long tail problem is. It's fairly apparent.

**AUDIENCE:** So it's 50% from 7%?

**NATHAN** That's what we-- Margaret Hendrick did a study-- that we did together-- that 7 of

**PHILLIPS:** 100 leaks accounted for 50% of the gas loss.

**AUDIENCE:** If you take this data as kind of the sample, and multiply by the number of rows and pipelines, and you try to match it with entire methane inventory of the US, just to see if the numbers are the same orders of magnitude--

**NATHAN** Yeah, we did. Not with the entire US, but we did it with Massachusetts

**PHILLIPS:**

**AUDIENCE:** [INAUDIBLE]

**NATHAN** Yeah, so we found that, if we took the chamber measurements of leaks, 100 leaks,  
**PHILLIPS:** and we just kind of multiplied that out by the frequency of leaks that we got previously-- that amount is consistent with other estimates, and are about one third of the total methane emissions estimated for the Commonwealth of Massachusetts. One third.

This collaboration, we have to me, and with Mothers Out Front as a kind of hybrid advocacy science nonprofit kind of coalition, I've never been involved in anything like that, and it's just been the most fulfilling kind of partnership for research science and policy.

**AUDREY** Yeah.

**SCHULMAN:**