Understanding Your City's Heat Island: Considerations and Approaches

Webcast Transcript

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Introduction

Slide 1 and 2: Introduction Slide

Operator: This is Conference #72372744

Operator: Good afternoon. Thank you for standing by and welcome to the Urban Heat Islands conference call. All lines have been placed on mute to prevent any background noise.

If you should need assistance during the call, please press star, then zero and an operator will come back online to assist you. Thank you.

Ms. Victoria Ludwig, head of EPA's Heat Island Reduction Program, you may begin your conference.

Victoria Ludwig: Thank you. And welcome, everyone. Good afternoon, or good morning. Thank you for joining us.

Our webcast today is about how to understand your city's heat island. It's not always easy to do that, so we wanted to present some key considerations and approaches on how it's best to do that and how two cities in the U.S. have approached that question.

Slide 3: Webcast Agenda

Today, we are going to have three great speakers. I will give a quick introduction and then I will turn it over to Dr. Dave Sailor who will give an overview of these key considerations that I was mentioning.

Then, we have John Bolduc and Kristin Baja from Cambridge and Baltimore, respectively, talking about how they actually applied this idea of assessing their heat islands on the ground.

We will have time at the very end to do Q&A. And, as a quick reminder, you can type in your questions anytime during this 90-minute webcast. If you can, please indicate which of the speakers you like to direct the question to. And so, type them in anytime, but we will actually take the questions at the very end after all three speakers.

Also with me today is Brad Hurley from ICF. He's helping behind the scenes with all the important things. And so, I'm going to start – turn it over to him to give an explanation of some of the logistics for today.

Slide 4: How to Participate Today

Brad Hurley: Hi. So I'm just going to give you a quick orientation on the GoToWebinar interface. So you can see on the left-hand side of the screen you can open and close your GoToWebinar control panel by clicking on the red box that has the arrow there.

You're going to be muted throughout the webcast to minimize background noise, but, as Victoria mentioned, you'll be able to submit questions and comments in writing. And also, as Victoria said, please include the name of the presenter you'd like to answer your question. That will help us.

And you can see again on the left-hand side – or, sorry – on the left and right, you'll see a place where you enter a question and then you hit "Send" to submit the question. We are going to compile those questions and we'll ask them during the Q&A session at the end of the webcast.

And if you – if you signed up before earlier this morning you will have gotten a PDF of the presentations today and also links to where the webcast will be ultimately posted, but that's on EPA's Heat Island web site. And if you look for webcast or we'll also have an announcement in the lower box on the right-hand side of the – of the homepage, so it will be easy to find.

Throughout the webcast if you have any technical difficulties please contact me. You can send it to me – my e-mail which is down there at the bottom of that slide. And I'll do my best to respond.

Victoria Ludwig: Thank you. And, yes, just a quick reminder, as Brad said, these presentations will all be available and the audio recordings will be available after the webcast within a couple of weeks. So that – and we will send an e-mail to all of the registrants to let them know that those have been posted. So let's get started.

Slide 5: EPA's Heat Island Reduction Program

Victoria Ludwig: I'm going to start. I am the manager of EPA's Heat Island Reduction Program which EPA has had for about 15 years, if not more. I just quickly wanted to give you an idea of what the program is and why EPA works on this issue.

We provide outreach and technical assistance mainly to local governments, but because the heat island field involves researchers, industry members and non-profits, we work with all of those key stakeholders to help identify ways that communities can effectively reduce their heat island whether through programs or projects. And we have a variety of resources that support this mission and I'll explain that on the next slide.

So why is EPA working on this issue? The heat island effect has multiple negative impacts, but also, if those impacts are mitigated, it will bring a lot of both environmental and public health benefits and that, of course, is the main mission of EPA is to protect the environment and public health.

And they're myriad, as you can see there are six of them. There's a public health benefit in reducing the number of heat-related illnesses, there is less energy use in the buildings that are in the heat island. You also get better air quality, there's less smog and ozone in the outdoors. There – it reduces greenhouse gases because of the reduction in the energy use.

It also has a benefit on the water side. The – many of the measures that you can use to mitigate the heat island have a benefit on reducing the amount of storm water that has to be managed after a rainstorm.

And, obviously, it makes – because it does all these things, produces a more resilient community to deal with future disasters and climate change.

Slide 6: Heat Island Program Resources

Victoria Ludwig: The – quickly here are the resources that we have. Our flagship resource is a compendium which has chapters on details of the science of heat islands. There's a chapter on each of the main mitigation strategies which I know two of our speakers will be talking about some of those in their presentation.

We also talk about what actually is happening at the local level with heat island reduction and we explain a little bit about what local government can do within their jurisdictions to start policies or projects.

We also have a web site with – in addition to some of the similar things that are in the compendium, we have a calendar of events, a newsroom, and then related links.

And, very shortly, we will have a new couple of pages on this exact topic that we're working on in the webcast today on how to understand your heat island, so stay tuned for that coming soon. We also have a database of actual examples of what state governments and local governments are doing.

And, of course, we have webcasts. We've done – we've done ones in the past on public health, and the latest and greatest in green roofs. If you get on our mailing list, the newsletter, as you can see at the bottom, you will be able to receive information on all of these things. We send that out about three times a year and it includes the latest news on heat island. I will give some web addresses at the very end that show you those web sites in order to sign up.

Slide 7: Contact Information

Victoria Ludwig: Actually, this is the slide. Feel free to e-mail me with any questions, check out our web site. And if you don't want to write down this long URL for the newsletter sign up, there's a link on the main web site that you can go to, so feel free to reach out.

If you are a locality and you have been doing some policies and projects on the ground for heat island mitigation, please let me know because we want to add to that database of what others are doing.

Going back to the agenda slide, I think.

Understanding Your City’s Heat Islands: Overview and Key Considerations

Victoria Ludwig: So let’s get started with our first speaker. Dave Sailor is a professor in the School of Geographical Sciences and Urban Planning and director of the Urban Climate Research Center both at Arizona State University.

Dr. Sailor’s research focuses on the intersection of climate with the built environment. This includes investigating feedback mechanisms between the built environment and climate with a focus on building energy consumption and renewable energy resources, as well as both indoor and outdoor thermal comfort and air quality.

A key element of this research is on quantifying the causes and prospects for mitigating the urban heat island effect. Dave is a national expect on heat islands, so I’m very happy to have him here. He’s going to kick it off with an overview, so, go ahead, Dave. Thank you.

Slide 1: Introduction

David Sailor: All right. Well, thank you, Victoria. And I’d like to start by thanking EPA and Victoria for organizing this webinar and thank you for letting me be part of it.

So as this is an overview presentation on understanding your city’s urban heat islands, and I’ve added that “s” as really an emphasis to reflect the fact that the concept is really much more complex than a single number. And so, for any city, you can define actually multiple heat islands, but I’m going to get into that in the coming slides.

Slide 2: Defining “*the* Urban Heat Island (UHI)”

David Sailor: So, as a starting point, in order to be successful in understanding your city’s urban heat islands, you must first understand the underlying definition and its complexities, so I’ll start with that. But then, you need to ask yourself what is it that I really care about and only then can you really determine what it is you need to measure and how best to make such measurements.

So let’s make sure that we’re all on the same page to start with, with the definition. So it will seem a little simple at first, but, hopefully, by the end of this brief presentation, you’ll have an appreciation of the complexities associated with these – what’s the seemingly simple concept of the urban heat island. And perhaps you’ll even reconsider how you phrase your questions about heat and cities.

So going to the Glossary of Weather and Climate, an urban heat island is simply defined as an area of higher temperatures in an urban setting compared to the temperatures of the suburban and rural surroundings. It appears as an island in the pattern of isotherms on a surface map. Another common definition is simply that the urban heat island is the difference between urban and rural temperatures. But this definition by itself is really vague and not sufficient. So if we want say, a single number as many people do really how would we define, say, urban; or how would we define rural? Are we interested in the largest difference during the daytime or at night, in the summer, or winter? And, more fundamentally, are we interested in surface temperatures or in air temperatures?

Slide 3: What Causes the Urban Heat Island Phenomenon?

David Sailor: So before digging into the definition, let's consider the causes of urban warming in the first place. So this is the little graphic that I tend to present when I'm talking about urban heat islands, specifically, urban areas differ from their un-built surroundings in a number of ways.

So this includes a rough urban surface comprised of buildings at various shapes and sizes. This urban roughness affects the flow of air over the city, both in terms of air – of slowing air flow patterns, but also increasing turbulent mixing and channeling flow between and around buildings. The urban canyons that are formed by these buildings have an effect on trapping both shortwave radiation coming from the sun, but also long wave radiation emitted from urban surfaces. As a result, cities tend to store heat during the day, but are less able to cool off at night. And this is in contrast to the un-built surroundings that cool off rapidly at night. So urban areas also tend to have relatively little soil surface and moisture and vegetation. As a result, they are less able to cool themselves through evaporation of water. And, finally, the intense amount of energy consumed in cities, what we refer to as anthropogenic waste heat leads to large amounts of heat emitted into the urban atmosphere, particularly in the early morning and late afternoon hours.

So the net result of these various contributions to the urban climate system is urban warming relative to the surrounding un-built or rural areas. But this warming varies, as I mentioned, from summer to winter and from day to night. In fact, as a general rule, the air temperature of urban heat islands is largest overnight and in the winter.

Slide 4: Most Common Image when Searching the Internet for "Urban Heat Island"

David Sailor: So if you were to do a Google search right now on images under the heading – just type in the words "urban heat island" – you're likely to find a lot of images that either replicate this image or are slight variations on it.

Even though it's a little misleading to summarize the heat islands phenomenon as a single figure and to focus exclusively on late afternoon summer air temperatures as this one does, this figure actually has been the driving force behind a lot of heat mitigation efforts.

Slide 5: Air Temperature UHI via Empirically-Based Models

David Sailor: So it's not easy to really generate simple pretty pictures of, say, the air temperature variation across the city, but this can be done if you take a large number of weather stations and do a spatial interpolation or through empirically-based models such as the one that I'm showing here that results from some of the work that we did in Portland, Oregon in the summer.

In fact, these images actually are able to show a variation in near-surface air temperatures that you would not see in the corresponding maps for surface temperatures. Specifically, they show that on – you know – or that the variation across city and the variation on the heat island depends on weekday.

And so, if you're on a weekend, which is these top figures, or the top figure rather, or a weekend, or a weekday, the images look quite different. And so, that's evidence of the role of anthropogenic waste heat emissions in affecting urban air temperatures.

So it's interesting to contrast the kinds of images that you generate for air temperature heat islands with those that you get when you look at surface temperature heat islands.

Slide 6: Another Common Type of UHI Image

David Sailor: Specifically when you – if you do a Google search on the term "heat islands", like I said, the most common image that you'll see will be tied to the air temperatures. The next most common image that you'll see is something like this one here that happens to be for Boston.

So this is a colorized version of data that can be extracted from satellite imagery such as MODIS. It's a representation of the variation of surface temperatures across the region. Since surface materials exhibit a high special variability, however, such as you can have concrete right next to dark asphalt, the surface temperature plots like this can show large variations in surface temperatures especially when you view them at finer scales.

And both types of plots, whether its air temperature or surface temperature, are representations of the urban heat island phenomenon, but they're fundamentally different in what they represent and really how they should be used.

So what do we care about? Do we care about the surface temperature heat islands or do we care about air temperature heat islands? Well, my answer is I think we care about both and more.

Slide 7: Surface Temperature UHI is by Definition Highly Variable

David Sailor: Specifically, if we're interested in pedestrian thermal comfort, the air temperature is very important, but so too are the surfaces that radiate heat to the person, so these are not just the ground-level surfaces, but also walls, but not so much roofs, right? So your surface temperature heat island you might get from a satellite is composed primarily of ground and roof surfaces, but does not include walls.

Of course, ambient humidity and exposure to the sun and wind are also very important in determining thermal comfort and these are less commonly considered when you think about urban heat island mitigation. So that's one thing I want to emphasize here is that it's about a lot more than just temperature.

Slide 8: A Cautionary Note

David Sailor: So before I transition into talking about measuring air and surface temperature heat islands, I want to give one cautionary note.

So this actually comes from a research article published by Ian Stewart in 2011. He systematically evaluated published reports of urban heat island magnitudes and found that roughly half of them in his words “Provide estimates of UHI magnitude that are unacceptable.” So, to paraphrase, half of what’s out there in the peer-reviewed literature on urban heat islands is garbage. So we have to be really cautious when we’re moving forward.

So anyone considering measuring urban heat islands would really be advised to take a look at this article and its recommendations. Some of the key recommendations are making sure that measurement sites are truly representative of the land cover that they purport to represent (so this includes both the urban and rural sites or areas being used in any UHI calculations), following standardized reporting islands for site metadata, disclosing details of instrumentation and estimates of uncertainties in the data, and also being careful with terminology. Specifically, we should never use the term “the heat island” by itself because it’s really not sufficiently clear. As I’ve already talked about, there are many heat islands to be considered.

Slide 9: Further Caveats about Working with UHI

David Sailor: So, furthermore, I would suggest that we use the urban heat island concept sparingly. It’s useful – or it is a useful way of explaining key aspects of the urban environment, but do we really care about differences between urban and rural temperatures, or rather, do we really care about the absolute temperature felt in cities? So, for that matter, is temperature really the endpoint that we care about at all, or is it some other endpoint that, as Victoria mentioned, such as human health, energy consumption, or air quality? And all of these are influenced by temperature, of course, but they’re also influenced by additional aspects of the urban climate system. So, for example, with thermal comfort and heat-related mortality, we’re very much concerned with peak daytime temperatures, but we’re also very concerned with humidity levels and minimum temperatures at night.

Slide 10: Measuring Urban Thermal Environments – Air Temperatures

David Sailor: So let me move on to measuring thermal environments focusing on air temperatures at first. And when it comes to air temperatures, there are a range of types of measurements that we can use in our studies. These include traditional weather stations; these are some of the highest-quality air temperature data that you can obtain. The data are reported hourly and long-term records are kept. However, if you’re trying to use these for heat island studies, you’re usually limited to only a handful of first-order weather stations in any city.

There are also networks of lower-quality stations, or cooperative reporting stations. These are great because they also tend to provide hourly data and there a lot – a lot of them in the – in this country, so I think there are over 7,000 just in the U.S. They typically report the hourly data, but the metadata on the instruments and the site information is maybe not quite as good as what you find with the national weather server sites and sometimes citing a maintenance can be questionable, so care should be taken in using those sites.

Another type of measurement that you can use in heat island studies is the mobile traverse and that is where we use vehicle-based traverses to gather extensive data for model validation. It can provide some of the special coverage and control that's not available in some of the fixed stations. Of course, the problem with traverses is that they're typically conducted by small teams of researchers, sort of on an as-needed basis maybe as a before and after test for evaluating the thermal environment in a city. But they just give you very limited temporal coverage because, again, they're just episodic.

And, finally, I just want to throw out there this notion of crowd-sourced data. I think as we move forward into the future, there is growing potential for using a wide range of data sources from citizen scientists, including things such as having thousands of people walking around the city, have their telephones reporting their battery temperatures which actually can then be related to air temperatures through fairly sophisticated QAQC protocols.

Slide 11: General Considerations for Air Temperature Measurements

David Sailor: So it's important to note that the accuracy of air temperature measurement depends on a number of factors. So we tend to think of sensor type as being the primary thing we care about and we refer – oftentimes refer to our measurements as being accurate to plus or minus a tenth of a degree because that's what our sensor is accurate to, but that's not the case. While sensor type helps to determine the upper limit on the accuracy of sensor systems, some of the other considerations are things like the temporal response characteristics of the sensor; how fast they respond to changes in conditions.

Air is introduced by the instrumentation system itself, but perhaps, most importantly, air is introduced by placement of the instruments and their housing conditions. So you should take care to ensure that the air temperature being measured by your system is actually what you think you're measuring or what you intend to measure and that this temperature is really representative of the air temperature in the area of interest. So, for example, if you're trying to measure the air temperature of a neighborhood, it's worth noting that a single measurement in a backyard of one house may not be sufficient. The temperature measured there will most certainly depend upon whether the yard has grass or shade trees, whether it was recently irrigated or whether that yard happens to be irrigated more or less frequently than its neighbors. So – and then, of course, also when you start citing stations in neighborhoods, there's lots of issues with placing sensors or weather stations just too close to very warm thermally-emissive surfaces like brick walls or concrete walls.

Slide 12: Traverse Measurement Example

David Sailor: So while fixed temperature stations have one set of challenges, the mobile traverses that I mentioned have other strengths and weaknesses. And so, I think these in combination can actually be very valuable.

These traverse results that I'm showing here for Hong Kong show the expected local air temperature elevation in the central district. But again, these are just for one snapshot in time.

And if you're trying to evaluate the performance of a heat mitigation strategy with, say, before and after measurements, you have to be very careful to ensure that the underlying weather patterns for the before episode are comparable to those after.

Slide 13: Measuring Urban Thermal Environments – Surface Temperatures

David Sailor: So we move on to measuring surface temperatures. So remote sensed data from satellites and other high-altitude aircraft offer a great potential to gather fairly detailed estimates of surface temperature across large areas of the city. The maps that you get from these sources tend to be very compelling visually at least. Of course, one drawback is that these measurements ignore contributions of vertical surfaces which is very important. They also require that the radiometric data that you get directly from the satellite be turned into estimates of surface temperatures by first accounting for the attenuation that happens in the atmosphere. And even though some products like the satellite data that you see are typically presented as being the gospel truth for the surface temperatures, they can often have temperature measurement uncertainties that are on the order of several degrees Fahrenheit.

So hand-held infrared cameras are another option. They can provide both information about horizontal surfaces and vertical surfaces. We have used this in ground-based traverses, but we've also flown them in helicopters and you get some really useful data that way.

In the end though, regardless of the type of radiometric platform you use, these surface temperature estimates are not typically what we're interested in when we think about urban climate scientists or policymakers, typically local air temperatures are more of interest as they're more closely tied to the outcomes that we care about.

And relating the surface temperatures to air temperatures is still I'd say a developing field that introduces additional uncertainties into the estimates. So you have to take any estimate of air temperatures measurement in the city with a grain of salt really.

Slide 14: In Summary

David Sailor: So, in summary, I'd just like to emphasize a few things. First, it's important to be careful in defining your measurement objectives. This seldom has anything to do directly with urban heat island magnitudes. Once objectives are set, you can consider designing your measurement and analysis system. But it's often difficult to approach the ideal system given limitations in real urban environments, that is, you can't really cite instruments where you'd really like to.

And, finally, be cautious in conveying your results; provide metadata – first of all, gather metadata, but then provide it to describe how measurements were made; report uncertainties; and be clear in terms of what the reported data represents.

So that's all I have for this overview. My contact information is shown here and I'd welcome conversations particularly with cities who might be looking for academic partners for designing and conducting mitigation experiments. We're open for business. Thanks.

Victoria Ludwig: That's great, Dave. Thank you so much.

I think you did a good job of providing the context for this whole webcast. And the takeaway that I bring is that this can be really complicated. It can seem daunting, but if you – if a city or anyone who's trying to assess their heat island, if they really plan ahead of time what their approach is going to be and think clearly and thoroughly about these different considerations, if they do that before they actually dive in and start using sensors or using satellite data, then it is possible to come up with a good result that achieves the city's goals.

Poll Question #1

Victoria Ludwig: So before we go on to John, we wanted to do the audience participation part of the webcast. We have a poll question. We will have three of them. And these are really for EPA, for us to get a sense of the communities that are on the line what level they are at with this topic. And so, that helps us learn how we might be able to help. And it will help you all understand who – you know, what – about yourselves on the line.

So I'm going to read the question and then Brad is going to answer – give the answers. The question – the first question is what is the main reason that your community is interested in reducing urban heat? Are you wanting to protect public health? Do you want to reduce greenhouse gases? Do you want to decrease energy use, increase resilience, or do you want to improve overall community livability?

I know that you probably would want to select more than one, but for – to make this useful, please just select one. Take about a minute or two to let us know which one is your main reason and then Brad will be back on the line with the result, so let us know what your answer is.

Brad Hurley: OK. We have some results. So it looks like improving overall community livability was the – was the lead and the second was protecting public health, and then to increase resiliency, and then tied between reducing greenhouse gases and decreasing energy use.

Victoria Ludwig: Great. Thanks, everyone, for participating. I think this lines up well with what you'll hear from Cambridge and Baltimore.

Modeling Heat Island Impacts and its Mitigation: City of Cambridge as Case Study

Victoria Ludwig: So speaking of Cambridge, I'd like to introduce our next speaker, John Bolduc.

John is the environmental planner with the city of Cambridge in their Community Development Department where he manages the city's climate change vulnerability assessment and the climate change preparedness and resilience plan. He also coordinates the city's Climate Protection Action Committee, which is an advisory group to the city manager on local climate change policy and implementation. He administers the Building Energy Use Disclosure Ordinance and participates in a range of other municipal sustainability efforts. So, in summary, John is a busy guy. John, please tell us about how you have approached this topic in the city of Cambridge. Thanks.

Slide 1: Introduction

John Bolduc: Sure. Thanks, Victoria. And I assume everyone can see the slides. So, hello, everybody. I'm going to talk about our vulnerability assessment and preparedness planning work in Cambridge focusing on risks from heat.

We're also doing a lot of work on precipitation, flooding and storm surge flooding. It's kind of difficult to cover everything about our work on heat, but I'll try to give you a sense of the range of activities that we have conducted today.

Slide 2: Overview of Heat Vulnerability in Cambridge

John Bolduc: I'm having a little difficulty advancing the slide, so – there it is. OK. So, in our part of the country, high temperatures have not been a big concern historically. In New England we're obviously a cold weather climate.

But we observe that temperatures are rising and projections based on climate science indicate that, by 2030, we may see a near tripling of days over 90 degrees Fahrenheit going from about 11 days per year to over 30 days. By 2070, we could see four to six times more days over 90 degrees and a significant number of days over 100 degrees which is currently a rare event.

To provide a sense of what these changes mean, the chart that you see illustrates the proportion of the three summer months that will experience 90-plus-degree days. So you can see an increasing amount of our summers will be quite warm which will be a very different kind of climate than we're used to.

So, in addition to extreme hot days becoming a risk, we can expect more of these hot days will string together as heat waves and that heat waves will be longer in duration. And as a very dense urban community, the heat island effect exacerbates these temperature risks.

Slide 3: How Can Municipalities Plan for Greater Resiliency to High Temperatures?

John Bolduc: So given that extreme heat, more heat waves and long heat waves are coming our way, the city wanted to understand its physical and social vulnerabilities to increasing heat if no changes are made and develop a better understanding of how our particular urban form influences temperatures and how it could be modified to reduce the urban heat island effect. The city can't directly change temperature trends, but the city can adopt its built environment and people. So to understand our vulnerability to heat, the city needs to understand both temperature trends and the local heat island effect.

Slide 4: Translating Existing Land Surface Temperature to Future Ambient Air and Heat Index

John Bolduc: Since we don't have a good network of ground-level temperature sensors, the city's consultants, Kleinfelder, developed an approach using satellite data. The consultants recommended using Landsat data to provide surface temperature data. Landsat was chosen because the resolution provided enough detail given that Cambridge is very small geographically. We're only about 6.25 square miles.

MODIS was the other type of satellite data considered. The resolution of MODIS data versus Landsat is about 250 meters versus 30 meters, so you can see a big difference. Another disadvantage of MODIS data is that it has – it has an issue with cloud mass, so single day land surface temperature cannot be used and, rather, multiple days or weeks need to be used to extract the maximum or minimum value of each pixel to avoid the cloud problem. However, MODIS has better temporal resolution compared to Landsat daily versus a 16-day repeat cycle, which enables nighttime temperatures to be studied.

So I think which data you choose depends on the scale of study and the study objectives. For the purposes of our vulnerability assessment, we wanted to work with air temperatures.

I won't go through all the steps that are shown in this chart, but the Landsat data was processed to estimate ambient air temperature about 6 feet off the ground. They also factored in humidity to estimate the heat index temperatures which is important to understanding human health risks.

Slide 5: Translating Heat Index to Human Health Impacts

John Bolduc: We related the projected temperatures to the NOAA Heat Index, which you might be familiar with, and this shows the likelihood of human health heat disorders with prolonged exposure or strenuous activity relative to temperatures above for ambient and heat index.

Slide 6: Heat Island Impacts with Ambient Air – Present Day, Existing Conditions

John Bolduc: With the Lansat data, the consultant produced heat island maps for present day, 2030, and 2070. On this map which is based on a day that was 83 degrees Fahrenheit, there were not areas that fall within NOAA's dangerous category, which people would see more heat exhaustion and possibly heat stroke.

Slide 7: Heat Island Impacts with Ambient Air – 2030, Existing Conditions

John Bolduc: And, for 2030, we assume no changes in the city and assumed a 90-degree day which we project to have many more of by that year. We could also see this pattern today on a 90-degree day. The map doesn't show any dangerous spots, but the area of extreme caution expands significantly.

Slide 8: Heat Island Impacts with Ambient Air – 2070, Existing Conditions

John Bolduc: And then, for 2070, we assumed a 100-degree day which could happen today, but is very rare here. And you see the emergence of dangerous zones throughout the city which is the red areas.

Slide 9: Heat Islands Impacts with Heat Index – 2030, Existing Conditions

John Bolduc: So, in contrast to previous maps based on ambient air temperature, we also produced a series of maps based on heat index temperatures that factor in humidity.

This would be the feels-like temperature to a person. Humidity levels are 50 percent to 55 percent, or assumed which is common here with a 90-degree day. With heat index temperatures we see hot spots by 2030.

Slide 10: How UHI Maps were Used to Assess Heat Vulnerability

John Bolduc: So we use the heat island maps first to identify the city's physical and social vulnerabilities by overlaying the heat islands with maps of physical assets such as key infrastructure and critical facilities and demographic data.

With this analysis, we identified specifics assets that might be at risk from high heat, such as electric substations and neighborhoods with greater proportions of people with risk factors for heat such as age.

The assets and areas were rated for vulnerability and risk and these findings are being used to identify priorities for our preparedness and resilience planning.

Slide 11: Resiliency Strategies

John Bolduc: Cambridge is using the vulnerability assessment to inform the climate change preparedness and resilience plan. Our strategies are falling into four main buckets. I will focus on the last one for resilient ecosystems which covers green infrastructure and urban forests.

Slide 12: Resiliency Planning Objectives for Heat

John Bolduc: So we – so we have a good sense of the types of strategies that could help offset some of the impact of rising temperatures. But the city wanted to understand how much in effect these strategies could have in Cambridge and where they should best be deployed.

So the consultants figured out an approach to take the heat island data and join it with other data to assess the effectiveness of converting impervious surfaces to vegetation, converting more building roofs to white roofs, and expanding the urban forest canopy.

Slide 13: Preparing for and Adapting to Increasing Heat Vulnerability

John Bolduc: The heat island maps are redrawn to show temperatures in five-degree intervals to provide more geographic resolution. On this map, hot spots, which would see 95 degrees or higher on a 90-degree day are identified around the city.

Slide 14: Estimating Cooling Impact of Existing Urban Forest Canopy

John Bolduc: Then, we brought in tree canopy data. The University of Vermont Spatial Analysis Lab who are experts on urban forest canopy assessment and who I recommend contacting if you want to map your tree canopy, produced Cambridge's first tree canopy map in 2012 based on 2009 LiDAR data.

The UVM assessment measured the tree canopy at 30 percent of Cambridge's land area and estimated we have a technical potential to expand the canopy by an additional 35 percent for our 65 percent maximum. For various reasons, we can't achieve the full 65 percent, but we should be able to expand somewhere in between.

So our consultants took this data which has very high resolution and divided it into a grid of 100 by 100 foot cells across the city and then calculated the tree canopy cover for each cell. And a relationship was developed showing a 1 percent tree canopy increase relates to a 0.12 degree Fahrenheit cooling effect based on our data.

Slide 15: Impact of Expanding Existing Urban Forest Canopy

John Bolduc: So with that relationship of tree canopy to cooling effect, a tree canopy cooling effect map was developed. So to understand the potential cooling effect of expanding the tree canopy, we tested different scenarios of tree canopy expansion by modifying the tree canopy map grid and then calculating the cooling effect in each of the grid cells.

Slide 16: Baseline – 2030 UHI with Existing Urban Forest Canopy (UFC)

John Bolduc: So the first maps – the first map is the baseline showing 2030 conditions on a 90-day degree with our current tree canopy coverage.

Slide 17: Impact of Expanding the Urban Forest Canopy

John Bolduc: And this map has what happens if tree canopies – tree canopies increased by 30 percent citywide meaning the existing canopy in every cell in the grid expands by 30 percent. This is approaching the technical maximum which is probably not possible and in some cells it's probably not even technically possible because the tree canopy coverage is already high. But you see a cooling on the maps compared to the – to the baseline map.

Slide 18: Impact of Expanding the Urban Forest Canopy

John Bolduc: So, in this map, it has a targeted approach where only the cells that have 30 percent or less in tree canopy cover are increased by 30 percent. So you see a similar cooling effect in terms of knocking down the dangerous hot spots, but less effect between hot spots.

Slide 19: Impact of Expanding the Urban Forest Canopy

John Bolduc: And then, this map shows an even more targeted approach where the map cells with 15 percent or less in tree canopy cover are increased by 40 percent.

So I think these tests suggest that a targeted approach could make sense if resources are limited. And it also suggests a significant effort to expand tree canopy is needed to see a cooling effect in the face of rising temperatures.

Slide 20: Cooling Impact Relative to Streetscape

John Bolduc: I also wanted to mention the consultants looked at tree canopy from a street design point of view to provide a sense of the density of tree canopy cover associated with cooler temperatures.

They found a relationship between street tree count and tree canopy cooling effect which was that, for each tree, there was a one degree of cooling per 100 feet, or basically the 1 degree between two trees 100 feet apart.

Slide 21: Other Factors Contributing to UHI Effects

John Bolduc: So we also looked at how converting impervious services to vegetation and how that could provide cooling.

And on the picture you're seeing an area of the Alewife neighborhood in Cambridge, or sort of the northwestern corner of the city which is highly impervious, it's a light industrial area with also some new high-density residential being built. So we want to take a look at that kind of area to see how we could modify the environment there.

Slide 22: Relating Ambient Temperature and Percent Impervious Area

John Bolduc: So the consultants identified a relationship that found for – that for every 10 percent decrease in impervious area, there was a 1-degree decrease in temperature. At lower levels of impervious area this relationship wasn't as strong.

Slide 23: Green Infrastructure Effectively Reduces Impervious Area

John Bolduc: So this analysis focused on one part of the city known as Alewife which, as I mentioned, is in the northwestern corner of Cambridge. The analysis was based on storm drainage sub-catchment areas because there are other benefits to green infrastructure such as reducing runoff and reducing nutrient loading to waterways which we are also trying to capture along with heat island reduction.

So the result, the consultants apply green infrastructure measures such as bio retention basins, porous pavement and green roofs at a maximum extent practicable rate to each parcel in the sub-catchment area to estimate how much the impervious areas could be reduced and then calculated the cooling effect based on the 10 percent, 1-degree relationship.

Slide 24 and Slide 25: Cooling Benefits of Green Infrastructure and Impact of Green Infrastructure on UHI

John Bolduc: So we see this cooling effect here which is an average across the area of about 1.7 degrees Fahrenheit.

Slide 26: Impact of White Roofs on UHI

John Bolduc: This was also done with white roofs assuming that 50 percent of existing building roofs are white. This yielded an average cooling effect of 2.4 degrees. And I would say we are not concerned of what effect cool roofs have on street-level temperatures.

Slide 27: What are Some Preliminary Findings?

John Bolduc: So this is all still work in progress and we also don't want to overstate the precision. The city is basically trying to get a handle on the level of effort that will be required with different strategies to achieve a cooling effect so that we can deploy our resources efficiently and smartly.

So on this slide we're summarizing what I mentioned already in terms of the – in terms of the effect of these different measures and their ability to cool areas.

Slide 28: What is the Combined Effect of Urban Forest Canopy and Green Infrastructure Strategies

John Bolduc: So another aspect we are working on is to understand how to deploy urban forest canopy and green infrastructure strategies in combination and how much effect they have together.

This graphic shows a light industrial dense multi-family residential area of the Alewife neighborhood as mostly impervious. So we wanted to ask ourselves what can be done to cool this area by modifying it with ground vegetation and trees.

Slide 29: Next Steps

John Bolduc: So our next steps are to try to do that combined analysis to see the effect of mixing these tactics. And I also think about the analysis and the indication that targeting our efforts makes sense at a neighborhood scale rather than trying to set citywide goals, so for instance, setting a citywide tree canopy expansion goal, maybe it makes more sense to set goals at the neighborhood scale and target those neighborhoods that really need it. I think this is something we still need to discuss with the community, but I think the analysis suggests this might be a fruitful way to go.

We also need to understand night temperatures. The Landsat data couldn't provide that for us and we understand the importance of knowing what happens with night temperatures especially relative to human health.

We're also interested in taking a look at the regional effects. So Cambridge is very small and often when you look at heat island analyses, they're done at a much larger sort of metropolitan scale. So, in the Boston area, we have a regional climate change collaboration involving 14 cities and towns centered around Boston working through our regional planning agency and we're all trying to work together on resilience measures, as well as greenhouse gas mitigation measures. And so, all of those communities are just about to get the same kind of tree canopy data that we have from the University of Vermont. So I think this is an opportunity to take a regional look at this.

We do have some regional data based on MODIS from the trust for public plan which has built the tool under the Climate Smart Cities Program that has some interesting results and patterns, but I think we need more resolution, so I think we like to work on that side.

And then, we would like to do I think what Baltimore is doing in terms of trying to build a ground-mounted temperature humidity sensor network and we're having some discussions with local researchers about trying to set that up.

Slide 30: Contact Info

John Bolduc: So that's the Cambridge story and here's our contact information, so my contact information, project web site link, and then the contact information for our consultants. So thank you very much.

Victoria Ludwig: Thank you, John, for that great presentation. It's obvious that you all have been very thorough and deliberative about your work and you have thought about many of the considerations that Dave mentioned in his presentation, so I commend you. And it also sounds like you have – the work has generated some ideas for next steps and mitigation measures that you can take to reduce the urban heat. So we look forward to continuing to hear how you guys progress – excuse me, progress.

Poll Question #2

Victoria Ludwig: So we're going to do another poll question to get everyone involved. Just take about a minute or two to select one. Again, I know it's not easy, but try to do your best.

Which of the following best characterizes your community's current efforts to reduce urban heat: Are you just beginning to talk about it? Are you in the process of actually analyzing your heat island? Are you advanced to the – to the stage where you are developing a heat mitigation action plan and – or have you started actually implementing projects and program, or you haven't started at all talking about the heat island? So just take about a minute and then Brad will read the answers.

Brad Hurley: OK. We have some answers here. It looks like the majority are just beginning to talk about it, followed by in the process of analyzing the heat island, or heat islands, I should say, and then, implementing heat island mitigation projects and programs. And 16 percent haven't started yet and then 9 percent are actually developing a mitigation action plan.

Victoria Ludwig: Thanks, Brad. This is really good information for us. If you want to reach out and let me know about your exact actions, that would be great, and if EPA can help or any of the speakers in your efforts, please let us know.

Extreme Heat Implementation: Creating a Ground-Based Temperature Data Network

Victoria Ludwig: We're – I'm going to turn to the state of Maryland – Baltimore – and we're going to hear about a different approach for analyzing heat islands. We – the presenter is Kristin Baja. She is the climate resilience officer for the Urban Sustainability Directors Network. In this role, she is responsible for helping cities identify strategic ways to advance climate resilience planning and implementation and build capacity to take action. She directly supports cities by facilitating deeper relationships between local government and other stakeholders while also advancing learning, collaboration and momentum around climate resilience and equity.

She has a decade of experience – over a decade in climate resilience and sustainability and, in 2016, Kristin was recognized by the Obama administration as a champion of change for her work on climate and equity. Thanks for joining us, Kristin. We look forward to hearing your presentation.

Slide 1: Introduction

Kristin Baja: Great. Thanks so much to EPA and to the other presenters. Can you see my screen all right?

Victoria Ludwig: Yes.

Slide 2: Overview

Kristin Baja: OK. Great. All right. So I just wanted to give a little background here about the reason that Baltimore got started on this work, the approach that we took, and the reason that this was brought up. And then why we identified the partners that we have for the project, and what we've done so far, and then why community engagement and involvement was so important as part of our process. And then, we do actually have some next steps and things that we're looking to do moving forward.

Slide 3: Extreme Heat in Baltimore

Kristin Baja: So, just for some background in Baltimore, similar to Cambridge and some of the stuff you've already heard, we are definitely feeling the impacts from extreme heat. The number of days in which we're seeing 90-degree plus, and even 100 degrees are increasing. And we do have data that directly shows our urban heat island, or our urban heat islands as we were educated earlier in the presentation, are directly connected to a lot of our impervious surface. Baltimore does have a very high amount of impervious surface and a very low tree canopy and heat is a major issue for us.

In 2012, we had a large derecho windstorm come through during our high heat wave and people were without power for seven days which is just a catastrophic issue for us and has led to the reason that we've been addressing this work moving forward.

Slide 4: Risk Assessment

Kristin Baja: The way that we approached it was actually to take the city's all-hazard mitigation plan and the risk assessment requirement as part of that plan and look at how we use our historical impacts and then our anticipated impacts moving forward.

And we realized as part of that process we were able to bring in a lot around our tree canopy and different data that we had around heat, but we didn't have anything down to the neighborhood level. And so, a lot of the models that we had identified hot spots, but didn't give us as much as we wanted about priority neighborhoods.

Slide 5: Disaster Preparedness Plan

Kristin Baja: One of the things that did come up there was that there was a huge temperature difference between where a lot of our readings were coming from by the airport and what was happening in neighborhoods. And so, we created this plan called the disaster preparedness plan, and that was adopted in October of 2013.

It looked at all of our different hazards, but heat and precipitation really being the two biggest for us and focusing on all of those hazards, but identifying that we really needed to put most of our action into what are we doing around precipitation variability and what are we doing around high heat.

Slide 6: Equity

Kristin Baja: Another big component for us here in Baltimore is for every sort of plan and project really using equity as a lens for the way that we approach the process. We have a really unfortunate history of redlining and racism that has been part of our policies and practices here.

The Ordinance of 1910 led to white blocks and black blocks and our redlining has also really overlapped with where our food deserts are, where our lack of tree canopy is, where our lack of access to green and park spaces are, lower energy efficient buildings, and lack of access to resources.

Slide 7: Equity as a Lens

Kristin Baja: So this is a really important component to a lot of our work and a lot of the way that we approach this using equity as a lens to prioritize neighborhoods, where we have the highest vulnerability, but also really thinking about making sure that folks within those communities had a role in both informing us of how heat impacts their daily lives and their work lives, but also making sure that they were part of the solution and part of the data and the tracking that we were doing, so really trying to make those strong connections, build relationships, and think about benefits as part of this work.

Slide 8: Partners and Project Team

Kristin Baja: So the city did not – Baltimore, we didn't have any money for this work. We didn't have any grants, and we didn't have any funding set aside for urban heat island work.

And so, we were really fortunate to have an awesome team of folks at Johns Hopkins University and at the Maryland Institute College of Art who are a great team of experts who came together to identify how we can do data collection and assessment and how we could do this at a downscaled way.

So we put together a strong core project team with them and these are the folks here at the bottom of the page. I would say Anna Scott is really the main lead for the entire project, but I have to call out also Ben and Meredith and Katie for just being fantastic partners throughout this entire process.

They have been really the ones to bring the technology and to think about the data and the way that we can utilize the data and then they've also had to put up with me, so kudos to them on that.

Slide 9: Bmore Cool Project

Kristin Baja: But what came of putting together a project team is actually something we called a Bmore Cool Project. And, for us, the goals were to really understand how heat is a burden in our underserved neighborhoods, to identify ways that heat impacts through awareness in warnings and mitigation, and then also to really generate science-based analysis of heat.

Slide 10: Temp and Humidity Sensors

Kristin Baja: So I need – so I apologize, sorry, I just had to ask somebody here to stop on something. But we used the vulnerability assessment to work with them to determine where we were going to put sensors and how we were going to think about heat island mitigation activities.

So we came together and identified the way to use sensors where these little iButtons and the iButtons, what we needed to do is figure out how the make sure they – we had this great radiation shields as well, but within a certain budget.

So our team developed these low-cost sensors. They have a little button on the inside that also have a radiation shield that was developed directly by the folks at the Maryland Institute College of Art which was a fantastic experiment and really amazing to watch them do.

Slide 11: Sensor Distribution

Kristin Baja: But then, we were able to put these sensors up throughout the community and work with folks on having them hung in their neighborhoods and then have them sort of be part of the process as well.

The distribution was prioritized in area that we had taken from the bigger assessment, from the big sort of heat assessment and then put into neighborhoods where we knew there was the lowest amount tree canopy, the highest amount of vulnerability and risk, and also the lower access to resources.

And we chose sort of a dense network within East Baltimore in an area where we were already starting to prioritize other initiatives related to health, and storm water, and emergency management.

Slide 12: Data Collection

Kristin Baja: So we put over 150 sensors in those neighborhoods and elevated them on trees and light poles, and this is just an image of some of the data. Thankfully, Anna is on the line, so if you guys have specific questions from the data, I'm not good as good with the data as John is from Cambridge.

But it shows a lot of stuff around the question that we had about how much hotter is East Baltimore than the airport? And how can we capture the neighborhood scale such as these little intricacies where within each of the neighborhoods and inform different initiatives that we wanted to do around health, and housing, and sustainability for these vulnerable populations?

Slide 13: Accomplishments to Date

Kristin Baja: So the biggest things that we've accomplished today is we have just completed our third year of monitoring outdoor air temperatures using those 150 monitors throughout the city.

The first year we stayed in a pretty dense area. In the second and third years we expanded it a little bit more to have the ability to compare and also it helps us with publishing the research on some nighttime air temperature work which you can see under Anna Scott's name.

We also tried to overlap a lot of what we were doing with the outdoor sensors and some of the work that McCormick is doing on indoor temperatures and how they impact human health. So that was also published as part of this initiative. And a lot of the work that Meredith has been doing is working with individual residents in the exact same neighborhoods where we prioritize putting the outdoor air quality monitors. So a lot of those scientific findings have been presented at meetings. And then, we've tried to share them throughout the Urban Sustainability Directors Network as well.

Slide 14: City Greening Initiatives

Kristin Baja: What this has led to beyond just presenting and putting together papers is a lot of the work at the city and some of the initiatives at the city and how we've been able to prioritize those initiatives.

So one of our bigger greening initiatives was actually utilizing this data to focus on reusing our vacant lots in the city and identifying ways to reduce storm water, grow food and create community spaces that help us revitalize neighborhoods and also think about reducing heat island impacts.

This has now turned into something called the Green Network Plan where we're actually modeling closely off of what Boston – the Boston Metropolitan area has done with its Emerald Necklace and trying to think about an interconnected series of smaller green spaces utilizing what has been historically seen as a detriment in Baltimore, the vacant properties. But now we're trying to see them as assets and how we can use them to lower the heat island and improve livability.

Slide 15: Prioritize Plantings

Kristin Baja: Another big thing that this data has been used for is how we're prioritizing our tree plantings. Like I mentioned, our tree canopy in Baltimore is around 26 percent and the goal is about 40 percent tree canopy cover by 2030.

So we've been using this data to identify priority planting locations and also the relationships that we're built up with members of the community and different groups to help us with getting them as implementation partners and teaching them through different classes and courses we're providing such as our tree keepers courses and our weeds warriors.

Those both focus on climate change and then teaching people how to care for trees, environment, plant trees, and also other –maintain their green spaces around their homes.

Slide 16: Data – Tree Species Database

Kristin Baja: Another big piece that this data has been used for is we started creating a database of different tree plantings that would survive in our hardiness zone shifts. So our hardiness zone is already shifted by two just in the past six years and we're anticipating it to shift even more in – be more like Atlanta in the next few years. And, in that, we are trying to identify which trees we should be planting, where we should be planting them, and the different diversity we should be using.

So this data is really helping us as part of our spatial analysis tool and the data that we're putting into that along with some of the other hazard factors to determine which trees are going to be best and live and the maintenance requirements for those.

Slide 17: Engagement

Kristin Baja: And, like I mentioned, engagement in community involvement has been a huge piece of everything that we do. A lot of the work that was done around this project, we got together with members from the community initially and talked to them about the impacts like I mentioned. We talked to them about the data. We talked to them about the sensors. This is something that both Hopkins did, MICA did, and then our group at the Office of Sustainability did as well. But there has also been opportunities where we can come together and do more training.

And this is a picture of Anna actually working with one of the young kids in our community at a large town hall event showing how the shields were built for the iButton and educating about where the centers have been distributed and how they were built and really allows all members of the community, but especially kids to kind of take pride in what they see throughout the neighborhood with these little sensors.

Slide 18: Next Steps

Kristin Baja: So the next steps that we have from here is what's been fantastic is we were able to write a grant along with Hopkins and MICA, our Bmore Cool Project team to create something called the Greater Baltimore Open Air Project and Anna, again, is really leading that work around sensors that monitor both air quality and urban heat, and these are little studier than the ones that were created before, but we have over 300 air quality monitors that were assembled with a local non-profit here in Baltimore. So we also had several community meetings where folks came out from the neighborhoods and we're able to help with putting these boxes together and understanding how they work.

We're also trying to do a connection with our most famous station here at Mr. Trash Wheel with the googly-eyes and potentially put those on these little air quality monitors as well to just show some connectivity with some of the other projects within the city.

So this involves more project partners. It brings in the states and I think it scared them a little bit because they were worried we were going to take even better measurements in some locations. But it's been really great because we've been able to bring in community-based organizations and, again, get a lot of that sort of support, implementation and data tracking.

It's given I think the folks at Hopkins a real good opportunity to explain how data is used to motivate action within government and then also to get some of our other non-profits involved in this work.

Slide 19: Conclusion

Kristin Baja: And that's really all for us. I will tell you that Anna thankfully is on the line. So if you do have any really strong technical questions, she's around to answer them. But that's the reason that Baltimore City really approached this and how we approached it and I'd be happy to answer any questions around it.

Victoria Ludwig: Thanks, Kristin. I commend you on that work. It was very – it's very inspiring to see how you involved the community and you've thought of equity. I think other communities are moving in that direction, so you're example is a good one for them. So – and I hope you continue to keep up the good work there in Baltimore.

Poll Question #3

Victoria Ludwig: We're going to do one more poll question before we go to the general Q&A. That – the question is, what do you find to be, or anticipate being most challenging when you're trying to understand your heat island?

Is it obtaining the approval of city leaders? Or is it identifying and designing the best approach? Is it finding resources and funding? It is finding government, NGO and other parties? Or is the most challenging aspect finding the right expertise? If you can try to select one, we'll take about a minute or less, and we'll tally the results.

Brad Hurley: OK. We have results and they're not very surprising. Finding funding and resources is the most challenging – that was voted most challenging. And then, followed by identifying and designing the best approach, so that's – yes, that would be expected. And then, after that, we have obtaining the approvals of city leaders – sorry – finding the right expertise is next, then obtaining the approval of city leaders, and then, finally, finding partners.

Victoria Ludwig: Thanks, everyone, for participating. I wish I could say that EPA could help with funding, but in our newsletter we do advertise lots of funding opportunities.

The good thing about heat islands is that sometimes grants that are for storm water management or even smart growth or air quality, there are many opportunities of – for using grants to apply it to the heat island because of the many co-benefits that come with the mitigation of heat islands as I mentioned earlier.

Questions and Answers

Victoria Ludwig: So we have gotten quite a few questions. We're going to kick that off. We'll try to direct at least one or two to each speaker. So Brad will kind of lead the Q&A session and, if you're ready, Brad, go for it.

Brad Hurley: OK. Yes, I have questions for each person, each panelist, and then there's one that's sort of broader for all of them, but I think it's probably – I'll probably pose that one to David Sailor.

So the question here is what is the impact of covering, for example, parking lots with elevated solar panels? Could solar panel-covered bike lanes be a good strategy for cooling commuter routes and decreasing carbon emissions?

Victoria Ludwig: Is that for Dave, Brad?

Brad Hurley: Well, it's for Dave if he wants to answer it. But if anybody else feels like they want to answer that one, it's up for grabs.

David Sailor: I'd certainly be happy to take a stab at it. It's something that we've been interested in ourselves here. So trees for shade offer a lot of – a lot of benefits. But artificial shade and anyone who's walked down a city street on the – on the shady side to avoid the heat of the sun knows that artificial shade surfaces can provide some benefits also.

So using PV shading and that's actually something we thought about in terms of creating cool corridors for walking in and around sort of the commercial districts and getting people from houses to bus stops and what not, it generally has a handful of benefits in terms of providing shading. And remember the thermal environment felt by the person is a combination of the air temperature, the humidity, but also the net radiation that their body feels. So if they're shaded from the sun that actually has a huge benefit in terms of thermal comfort.

One of the possible downsides that's very interesting is that even with the higher-performance panels, these tend to be very dark surfaces that generate maybe on the order of 20 percent of the – of the solar power that the intercept turns into electricity. And so, a lot of that heat from the sun actually goes into heating the panels.

The panels themselves don't have a lot of thermal mass, so as the air flows over them they convex some of that heat wave, so it's kind of an interesting research question to really understand what is the net effect both in terms of on the pedestrians underneath, but also in terms of the – you know, the air temperature throughout the city by placing a lot of – a lot of dark surfaces.

My personal feeling is that the net effect is likely a benefit, but you always need to consider some of the potential adverse consequences in doing a full evaluation. But definitely I think there is promise there.

Brad Hurley: OK. There is a question for John and this one is, with the flash droughts that Cambridge is increasingly seeing, are there more effective ways to prevent urban forest mortality? Do we need to change the way we plant and water street trees? So, John, if you're on the line – I did see a message from – that they were having trouble sharing. So if John doesn't come on – how about if I read a – I've got a question for Kristin. So the question for Kristin is are the data from the sensors wirelessly uploaded and can they be – can they be monitored in real time or are they recorded on the device?

Kristin Baja: So, Anna, please jump on if you're on as well. My understanding is that the data from the sensors is uploaded at Hopkins and used there. But the new ones that we're putting in, the new boxes are actually something that go directly that can be access directly from Hopkins because they require a Wi-Fi directly in the community. Anna, are you on?

OK, so from the iButtons, my understanding is that that it's something that we have it sort of connected and we take that data at the end of the monitoring period and then bring it into a space where then it's uploaded and analyzed. But the new sensors actually do work off of Wi-Fi as the new boxes are going to be something that we'll be able to have sort of daily data that we can look at more often.

Brad Hurley: Great. Thanks. And, actually, Kristin, there's another – there are a couple of questions that were actually to both of you and John. And John doesn't seem to be on the line or is having trouble hearing, so I'll ask these to you.

One is, what are typical costs of building green urban canopies and the necessary irrigation infrastructure to maintain them, maybe on a per tree or a per 100-foot square space?

Kristin Baja: Yes. So I think that's a really specific question that I'd be happy to take down the – whoever requested that information. It's going to be different depending on different spaces and different projects, so I would be happy to talk with that person offline to give more estimates, but there is not like a single number that I can say this is how much it costs per tree based on this space.

Brad Hurley: OK. And then, one more. Did you engage the public health or the medical community in your planning and, if so, what ways were they involved and how did they contribute?

Kristin Baja: It's public health and emergency management?

Brad Hurley: Yes, public health side.

Kristin Baja: OK. Yes. So, yes, absolutely. In fact, public health – so the health department and the Office of Emergency Management have both been key partners both in the development of our all-hazards plan or our DP3 plan, but also in implementing all of the actions that we have around heat and flooding. So there are – they are two key partners in pretty much all the work we do.

The Public Health Department are in-charge of our code red days and declaring our code red days and using a lot of this information to identify areas for priority outreach and letting people know about shelters; areas they can get ice and water, and resources in the event of a code red day; also for distribution of information, and that is kind of a two-way street. It's been a great way also for the health department and our office to gather information from people and understand where we may have residents with more risk, those who are – have medical conditions, or elderly, or if we have children who sometimes are left home alone after – while their parents are at work.

Emergency Management also has been a huge group that's been involved in a lot of this work and both of them have been part of the individual preparedness work we've been doing, the community preparedness work that we've doing, and then also prioritizing the same sort of neighborhoods that we've been looking at for resiliency hubs and communication centers, and public outreach work on initiatives.

So it's certainly key to involve health and emergency management in any work around heat island and – or heat islands, my apologies, and air temperatures.

Brad Hurley: Great. Thank you, Kristin. Here's another question for Dave Sailor. Are there any rules of thumb for when adding vegetation is not a good idea for urban heat island mitigation?

David Sailor: All right. So I don't know about rules of thumb, but there are certainly some considerations. If – you know, if you're planting vegetation in, you obviously need to have a budget to maintain that vegetation and that could include, or that does include providing the necessary water for that vegetation to survive. So, water resources is a huge constraint as we think about using vegetation for heat mitigation.

Another thing is, depending upon how you deploy a vegetation canopy, it can have adverse consequences at the street level because you can actually really create sort of a tent effect where you actually trap emissions from the surface below that tree canopy and can actually have adverse consequences such as making your local air quality worse.

So there are certainly some considerations. These are things that don't necessarily make you want to move away from using vegetation. It just requires you to be a little bit more thoughtful in your design of how you implement it.

Brad Hurley: Great. Thanks. And I'm going to check and see if John is back on the line. He said that he got dropped from the call and was dialing back in.

John Bolduc: Yes. Sorry. I'm not sure what happened, but we're back.

Brad Hurley: OK. So…

Victoria Ludwig: Welcome back.

Brad Hurley: Yes. Welcome back. I'm just going to ask you a couple of questions here. One specifically for Cambridge, it said with the flash droughts that Cambridge is increasingly seeing, are there more effective ways to prevent urban forest mortality? Do we need to change the way we plant and water street trees?

John Bolduc: Yes. Well, I mean, that's a little outside my expertise. I'm not an arborist. The city has a pretty robust urban forestry program led by a master certified arborists and a team of certified arborists.

And so, they have – they have been updating their tree management standards for planting and have efforts to water trees and we've had drought issues especially the last few years.

But I think, from a planting perspective, we – you know, in terms of trying to increase the tree canopy, I think it's both a function of trying to maintain what we already have, as well as adding to it.

So our planning has to take into account how we're going to maintain the canopy that we have or at least – and also replace it as it naturally dies off or as subject to storm damage and things like that.

Brad Hurley: Great. Thank you. And here's another question for Kristin. What have you done to prevent sensor theft?

Kristin Baja: To be honest with you, it's been mostly about engaging with members of the neighborhoods where the sensors are being concentrated and talking with our community-based organizations in those areas and our community leaders.

There has been outreach with youth and kids within those neighborhood schools, as well as residents within those neighborhoods.

And so, it's been great to have people on board to support that process and that's been the main way. That's not to say we haven't lost of few here or there, but we certainly haven't lost as many as we could have had we not had members of community really involved from the beginning of the process.

Brad Hurley: Great. Thanks. And this is a related question for – well, actually, another trees question for both Baltimore and Cambridge and I imagine this might have a complex answer. But the question was who owns the street trees adjacent to the street? Is it the city or is it the adjacent landowner and does that have an impact on maintenance? Either John or Kristin can take that one.

John Bolduc: Well, in Cambridge, the city owns the trees within the public right of way and under state law we can also plant trees, I believe, within 20 feet of the public right of way.

We have some interest in being able to work with private property owners to plant trees outside of that zone, but I think there are some legal issues we probably have to work through on that.

Brad Hurley: OK.

Kristin Baja: Yes. In Baltimore we have – we have the ability to plant trees with the permission of the property owners or the willingness. We can do it without permission, but it doesn't happen very often. We try to build relationships and maintain positive relationships, so if somebody says they do not want a street tree, we don't put one in.

But we do have maintenance issues because of funding. And so, we do, again, try to use our Tree Keepers programs and some of the other programs on training people how to take care of the trees. And we try to utilize members of the neighborhood to plant the trees as well so that they're involved throughout the process and sort of take ownership of those trees.

John Bolduc: Yes. And I would add also – I mean, one thing that the urban forest canopy mapping did was to help us understand that most of the tree canopy is on private property. And, therefore, if we're going to manage urban forest as a system, we have to do more in terms of working with private property owners.

Kristin Baja: And the same is true in Baltimore as well.

Brad Hurley: OK. We just have a couple of minutes left and there is the one remaining question for Dave is actually a pretty big one, but I'll try to focus it a little more. So the question was what do you think of simulated data versus measured data?

And I think maybe that could be reposed as sort of is there a gold standard like if you're – you know, is there a reason to aim for directly-measured data over, say, satellite data or model data when you're doing this kind of analysis?

David Sailor: Well, you're right. That is – that is a big question. And it's phrased sort of presupposes that measured data maybe preferred. But as I said in my talk your measurements are not as good as the sensors. They're always worse than the sensors because the sensors sort of view that upper limit of accuracy and then it's how the sensors are deployed and how they're maintained, and whether the environments that they're deployed in are truly representative. You could do a heat islands study in my yard and come up with a very different result depending upon which sensors you choose to use.

On the flip side, a lot of modelers, and I fall in that category as well, tend to think of simulations as the gold standard because they're – they have so much capability to simulate sort of those what-if scenarios. And as long as they're suitably validated you can really go quite a long ways towards predicting or not – I hate to use the word "predicting", but projecting possible huge outcomes for different scenarios.

A brief answer would be that you absolutely need both simulation and measurements to really plan out a future mitigation strategy for your city. Be careful about using both, certainly whether it's at the regional scale, mesoscale models, or even the micro-scale models like ENVI-Met: they have significant limitations that are often not really appreciated by the end users when it comes to predicting some of these effects, whether it's vegetation or high albedo surfaces et cetera, so both are very important, yes, in concert.

Brad Hurley: Thanks, Dave. So I think we've reached the end of the webcast. Victoria, do you want to say any last?

Victoria Ludwig: Yes. Thanks to John, Kristin, and Dave for a very excellent presentation. I hope that the participants learned a lot. And we are all available for questions, as we said, so feel free to reach out.

Thank you very much for joining us and giving us 90 minutes of your time. If you could, we'd appreciate you to answer the evaluation survey that we have that will show you up on your screen after we close out. And, with that, I'll say thanks again to the participants and to the audience. Have a good rest of the day.

Operator: This does conclude today's conference call. You may now disconnect your lines.

END