

*Bruce Kinzey:* Welcome everyone. This is Bruce Kinzey with the Pacific Northwest National Laboratory and Director of the U.S. Department of Energy's Municipal Solid-State Street Lighting Consortium. Welcome to today's webinar, Lessons Learned From Outdoor Connected Lighting System Installations brought to you by DOE's Better Buildings Challenge.

Like other webinars we've conducted this is intended to provide some increased depth on a topic that you've been hearing about likely from vendors and others and you'd like to know more about it but from an objective source. We'll hopefully answer many of the questions you may have during the presentation, but if not you'll have an opportunity to get them answered directly at the end. I'll have a bit more to say about that in a moment, but before we get started I want to hand the mic over to Crystal McDonald of the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, to say a few words of introduction. Crystal?

*Crystal McDonald:* Very well, thank you Bruce. Good day everyone. I do lead the Outdoor Lighting Accelerator, which sits on the Better Buildings platform. We engage municipalities that are working on updating outdoor lighting projects to high performance outdoor lighting and that includes street and roadway lighting and exterior lighting in parks and recreations, et cetera, et cetera. So we've been doing pretty good work I would say over the past year-and-a-half or so. We have about another year to go with our accelerator efforts.

I am pleased to say that we currently have three states, five regional energy networks, and fifteen cities. We now have 23 partners in total with an addition of the City of Chicago. I'd like to welcome the city and look forward to gaining and sharing Chicago's experience to help advance other municipal outdoor lighting conversions. We're pulling together resources from all of our partners that are captured in a tool like our Outdoor Lighting Decision Tree tool that's available on the Better Building Solution Center website.

We're getting very close to meeting the President's challenge of committing at least 1.5 million outdoor lights to high-performance upgrades. We're now at about 1.3 million, so we're looking to work with more municipalities and increase project estimates to get us across that 1.5 million finish line; so this effort every pole counts.

The commitment we gain via the Outdoor Lighting Accelerator will also count towards the global lighting challenge announced by

Secretary Moniz at the 21st session of the Conference of the Parties in Paris last month.

Finally I encourage you to register for the DOE Better Building Summit. This year's summit will be held May 9-11, 2016, in Washington, D.C. at the Washington Hilton Hotel. More information can be found on our website regarding that. We do intend to have a cohort, AMEDA, technical assistance office hours, along with other external and internal lighting sessions during the summit.

Once again thank you for your attendance today. I will now turn the mic back over to Bruce. Thank you.

*Bruce Kinzey:*

So today's webinar is focused on what we are used to calling "street lighting controls." Much of the community has now adopted the phrase "connected lighting" rather than lighting controls to reflect all the additional capabilities that are going to be enabled with the implementation of these systems. These systems are essentially becoming city-wide networks with nodes at each street light that will happen to offer monitoring and control of those street lights as just one of potentially many features.

I don't want to steal any thunder from our speaker today, but while control of the street lights can offer an immediate value proposition we believe that the additional capabilities are ultimately what's doing to drive the implementation of these system as part of the current movement towards smart cities and internet of things and whatever else you want to call it. So I think we're all wise to be learning as much we can about these systems now while we're still just in the initial stages of what's forthcoming see change.

Okay? So let's get started.

Our speaker, Michael Poplawski, came to work on our solid-state lighting team about 6 years ago, following 12 years in the commercial semiconductor industry. He's becoming increasingly involved in the connected lighting arena and largely organized the first of DOE's workshops on this topic last November and a very successful meeting that was too. In fact if you're interested following this webinar you can find the presentations from that meeting posted on DOE's Solid-State website. For that matter our second Connected Lighting Workshop is scheduled for this June. I don't think registration is open for that yet, but you can sign up to be kept updated on that meeting or just monitor the site yourself

for when it comes available. The home page is at ssl for solid-state lighting, [ssl.energy.gov](http://ssl.energy.gov).

So back to the topic at hand Michael really knows his stuff so don't be shy about throwing your questions at him. Again you can submit these at any time using the Questions screen on your computer. We have about 40 minutes scheduled for his presentation and then perhaps up to a half-hour or so for Q&A as needed. So I think we've got plenty of time. We can always end early if needed.

So without further ado let me turn it over to Michael.

*Michael Poplawski:* Okay so we're going to be talking again mostly about lessons learned from existing installations of pilot projects right? Lessons learned by talking to municipalities and utilities, maybe engaging with them during their project or pilots or actually directly supporting them. So more on what's been done thus far and less on kind of what the future might hold and where people are at again in terms of leveraging the capabilities of this technology towards smart cities and whatnot.

So here's just a brief outline of the slides I'm going to go through and the topics. This presentation is very much based on a presentation we gave at Strategies in Light lecture in case anybody was there. So we'll do a little introduction on what is a networked outdoor lighting control system and who is interested in them and why thus far, not comprehensive of course but just a sampling of again some of the more prominent installations in the United States and at least what drove them.

Then we'll talk a bit about kind of one of the key value propositions that are at least getting people to consider connected lighting systems, so maintenance improvements and in particular energy savings, additional energy savings enabled by adaptive lighting, which if you want to convert them into financial savings require consideration of utility tariffs and so we'll talk a little bit about that and a related item for many people, many municipalities in particular today around lighting system ownership.

Then we'll go over kind of a few and not comprehensive of the maybe issues or things to think about that have been uncovered in some of these early installations around installation start-up and commissioning and how that relates to various features and capabilities amongst the different offerings in this technology area.

Then I'll just say a few words about some future possibilities and challenges.

So to start here you know we had at least decided you know this is about connected lighting so this is technology that allows you to network your outdoor lighting system and to both control and pull information back remotely from that system, right? So at a high level, at a block diagram level most technology solutions available today kind of fit the diagram shown here, right, where you're going to install some device in the field onto your streetlights that maybe enables you to control their output and collect other information. You may install other types of devices that could become part of that network, such as meters or various sensors.

Then typically not for every system but for most systems information going to-and-from those field devices goes through what is often, not always, called "a gateway" or it could be a router or some other – some people use other phrasing, but again this is basically an interface between the devices in the field and the bigger, broader often, but not always public network infrastructure. So again this doesn't cover every possibility. Some systems don't require a gateway and there are various technical implementations of the network.

You see kind of two extremes I'm just showing them in the diagram here. Some networks in the field are formed using a star configuration where every device talks directly to a gateway. Other networks are formed where let's what is called a "mesh" configuration, where devices kind of broadcast their information and it goes to their nearest neighbor and it's relayed, so many of the devices are both relays if you will or receivers and repeaters. In fact many systems out there actually behave in some kind of hybrid way between the star and the mesh. It's just kind of a good idea to understand the broad differences there.

Again a gateway often is necessary to bridge if you will or connect the field of device network with a broader network. It could be connected through Ethernet, to the internet for example or a privately owned network or wireless state. Perhaps you have a cellular network, again to the internet or a privately owned network. Once communication is enabled to that broader network infrastructure, well any computing device could through that same infrastructure communicate with and potentially manage the field devices, right? And the other piece of equipment and technology that completes a system is often referred to as an "essential management system." So a set of software installed often on a

server, although could literally run on a single desktop PC. So it's software usually tying into again a local or remote database and providing access to one or more workstations. That again will allow for the configuration, control, the scheduling, programming, and collection and data from the network devices or from the devices out in the field.

So hopefully you get a feel from that diagram and brief description that systems are more complicated than devices right? So when you look at outdoor lighting control past, right, most outdoor lighting systems in the United States are controlled, but they're controlled by a single device, right? Attach one per street light. That is literally a component you know that becomes part of the streetlight and there's a little bit of consideration in terms of how you select and install that.

But here we're talking about a much more sophisticated system. The process that I think we've seen that's required to really correctly figure out what you need and specify and create requirements and solicit and deploy and eventually own and operate these types of systems really demands some additional thought and consideration.

So this slide is attempting to kind of at a high level again show some steps, right, that one some delineation between some stages if you will of deployment that we find most people end-up having to go through, whether they initially considered them or not. And under each if you will category are some specific additional considerations, right? So at the beginning often what's required is to really take a hard, often it may be a first time in a long time look at acknowledging what is the status of your existing infrastructure, right?

What are your data acquisition, existing capabilities out in the field? But really as highlighted in red what are your needs and goals? Why might you install this technology? Then you're going to want to you know think about establishing requirements. Maybe that's a detailed specification, maybe that's a less detailed communication of problems that you want solved and/or business opportunities or partnership models that you're open to, right, because more and more people are approaching the deployment of this technology from a variety of strategies if you will rather than a traditional procurement and transfer of ownership if you will.

Then solution and design and selection. Sometimes, but not always this might include the specification of a specific technology, but

it's more often what makes more sense is to again to focus on performance needs, problems that you want solved. In some cases there might be some modeling or scenario analysis that you might want to do it as a user if you can or consult with someone to do or one or more technology providers might be willing do for you.

Deployment is a multi-stage needs to be thought about I think as a multi-stage process. It's not just install something and turn it on and it runs. We like to think of this in multiple phases if you will that I refer to as "installation, start up, and commissioning." I'll go into a little more detail what I mean by those words in another slide or two.

Finally operation and management. Once again acknowledging that this technology in practice, but frankly in terms of leveraging its full capability is not something that you again just deploy and turn on and let it run. You're going to want to leverage its ability to report back on how it's performing, analyze that feedback, maybe challenge some of your initial assumptions, you know make changes, improve the performance over time. And then again in addition some of the core features and capabilities involved in offering data that might help improve maintenance services and more and more the ability to measure things out in the real world. They initially may be street light characteristics but more and more other variables, other you know environmental conditions, et cetera. That data enables other value propositions and creates other things to think about.

So here I'm just going to briefly review again some of the major installations that we've been aware of in the United States. These could be installations that are by-and-large completed or in process. Just say kind of a few words about maybe not the only but one of if not the main value proposition that drove the installations, right?

So many people I think are aware of Los Angeles' leadership position and you know willingness to really test technology as soon as it's available. That was certainly true for LED. They were one of the earliest adopters and installers of lighting control systems also. They predominately did this to get a better handle on their maintenance needs, right, especially when they were going out early with you know as yet unproven in those numbers LED technology. So they installed a good portion of their initial LEDs together with the Acuity ROAM system. Maybe if you followed some of the press they are currently transitioning their control solution to a system or technology offered by Phillips.

San Jose also in California another early adopter of this technology but for very different purposes, right? They were interesting in taking advantage of the adaptive lighting capability, right, and adjusting light outputs over the course of the nights to both save energy and potentially address environmental needs given the presence of an observatory, very high-profile observatory in the San Jose area. To date they've installed the Owllet system.

Glendale, Arizona, another early adopter that installed the Acuity ROAM System, again are really focused on maintenance, right? They had a growing suburb or a growing city and growing streetlight control system that soon grew beyond the traditional means and capabilities of maintaining that system and the pursuit of this technology solution was very much focused on creating an improved ability to manage outages and day-burners and whatnot. So notably they're system controls were not installed together with LEDs. They were put up on the existing lighting system where in L.A. and San Jose they were installed together as part of an LED transition.

Mississauga another – this is up in Canada if you're not familiar, another value proposition really kind of drove the technology consideration and deployment and that was adaptive lighting not again necessarily for environmental purposes, but to maintain lumen outputs or maintain luminance over the life of the system and as a strategy to save energy, right? So it's not over like the city initially as when they transitioned to LED, but dim the nights initially and then raise the power over time to maintain a uniform illumination level as the LED lighting system aged.

Seattle did some pilots of lighting controls. Kind of initially interested in adaptive lighting just like San Jose was. They put up a solution in their business district. They were particularly interested in kind of the entertainment area and maybe even adjusting light levels based on busier hours, maybe raising them, maybe raising them up even higher at closing time, et cetera. So kind of explore some unique ideas. But to date they have not found a value proposition or two or three to drive a major installation in the city. So I would say they're kind of still searching for that those one or more propositions to drive an installation.

The same is true here in Portland where I live and work, along with Bruce. A pilot was done, again initially interested in adaptive lighting pretty much to supplement or increase the energy savings. But again the pilot and the ability to use or the perceived energy

savings that would be delivered wasn't enough to justify a city-wide installation yet and so they're still searching also.

One more slide a few more examples. San Diego, a technology offered by General Electric was installed, driven by two interests initially in the downtown commercial business district area. The ability to tune the light, so put up the same luminaire everywhere, but in this case post-house, but maybe adjust the light level in different areas based on the exact needs of those areas. Then to follow that up by pursuing again the depth of lighting strategies, right, to adjust lighting over the course of the night based on one or more perceived needs or opportunities to either save energy or improve the environment for the residences.

I'm going to talk a little bit now about a few non-municipal cases, right? Georgia Power is in the process of installing or actually installing LEDs and defining the needs for the expected accompanying control system that's going to be deployed. Initially really focused on again maintenance, right, utilities big coverage area especially down in Georgia Power region, they have a large customer base over a large physical area. So it will improve their maintenance performance and at the same time improve customer satisfaction. Again it's still early days for them in terms of the deployment and they have not picked a single or set of technology providers yet.

The State of Colorado, in particular the DOT and some of the municipal areas together have been jointly investigating the deployment of maybe a single technology solution for outdoor lighting control, driven very much right now by again asset management. So you kind of hear that theme over and over again, right? It's not a strong value proposition for everybody, but for many people especially when you're addressing large physical areas it can perhaps justify the technology all by itself.

Many folks probably are aware of Boston's pursuit of technology solutions for various purposes, including security following events there a number of years ago. While they have looked at connective lighting systems that could address security, kind of one of the novel security needs, one of the more novel and newer value propositions. To date they have not installed a connective lighting system to address that, but rather installed to stay a video only system to address their desire to improve security needs. So I would say they're also still searching.

Finally Florida Power and Light again if you follow the press has been in quite a bit of the news about their initial deployment of network lighting or connected lighting system. Not again as part of an LED transition, they're installing this on existing mostly HPS streetlights, but with kind of two value propositions driving that, right? One is to strengthen the AMI network that's been deployed down there for awhile and improved its performance. Number two again common for a utility to improve maintenance and customer satisfaction.

Finally another maybe a little bit more novel example, right, Maui has been doing some pilots and investigations and done some deployment of connective lighting system, really driven again by the needs to address environmental concerns. Again, including driven by the presence of a local observatories, right, where especially on certain nights of the year desire to either reduced outdoor lighting or if possible turn the outdoor lighting off to improve viewing conditions.

So just on a kind of an overview again of some of the initial installations and kind of show a cross section of the value propositions driving them. Kind of the key I think pointing to what I've come across with is that even in these early days while there are a lot of value propositions still being developed and explored there are quite a bit of variation that are driving things thus far. There's not what I would call a killer application, right? There's not a single value proposition that all by itself is really compelling to everybody, right? Even the most basic ones like asset management or potential improvement on energy savings aren't compelling for everyone and we'll talk a little bit more about that in a few minutes about some of the reasons why.

Again focusing on kind of those two most basic value propositions and once they are poised to offer you know there's the cost and impact of operational costs both in maintenance and energy and maybe the energy that ends sustainability impact. But there are a couple of things to think about there, right? So a maintenance cost typically maybe going to be reduced more efficiently, identifying and mitigating failures, and that may affect, right, the replacement components and the labor associated to get those components out in the field.

Now energy, right, while adaptive lighting or other you know techniques to adjust light output at the same time do a just power and offer the ability to reduce energy consumption raises the question of well does that end reduced energy turn into reduced

costs, right? And as most people know most outdoor lighting systems in the United States are unmetered and we'll talk a little bit more about this in a minute, in order to convert energy savings into cost savings you need to address that.

This kind of leads to what for some people it becomes a chicken and the egg kind of a question, right? Because to turn energy savings into cost savings municipality in particular will need to have a tariff on the utility that accounts for that, right? In many cases there is no tariff, an existing tariff that would allow them to again turn that energy savings into cost savings and they need that to get in place, right? But then sometimes in order to get that put in place the business arrangement between them and the utility, specifically who owns the lighting system, may need to be considered and they need to even transition, right? So some people again kind of the chicken and the egg thing is, "Well what do I focus on first getting the tariff in place or if I don't own and maintain my own system do I need to do that and how do I go about doing that?"

I can spend just a whole webinar talking just about that and some of that I think is covered in more detail in one of the DOE VBA decision tree resources that Crystal talked about at the beginning.

But certainly monetizing again energy savings requires a new tariff for many utilities and in many regions. That's because that causes – that can create issues, right, or needs, right, in addition or beyond just what is normally required to propose and get a new tariff accepted by the regulator, et cetera, et cetera.

So while the technology available, right, today for most providers facilitates the measurement per streetlight of the energy consumed by the streetlight and again the network infrastructure would allow you to collect that data. So while again the deployment of most solutions today would allow you to collect and obtain exact usage from your streetlights, many, if not most cases the existing utility infrastructure does not support accepting this metering data, right? So there's not an easy way to just create a feed or whatever if you will or to integrate this data coming from the municipality into the utility billing system. Or there's other challenges with regards to business practices in terms of who owns the meter, how is it characterized, et cetera and does my regulator approve of me using this data to bill customers?

There are existing standards for characterizing the accuracy of these kinds of meters, certainly there needed to be or to allow for

the use of the meters that exist on our homes and buildings. The standards that describe how to characterize those types of meters in this country or North America, including ANSI 12.1 and 12.20, which again discussed the accuracy performance levels and tested measurement procedures and some amount of data security for building purposes, but they're not really directly applicable to the devices, right, that are part of connected lighting systems if you will. The obvious big difference is those meters were designed to monitor entire you know homes or entire buildings, right, much bigger power and energy levels and not you know a 20-, 30-, 40-watt street light, right? So the arrangements and the test procedures and what not aren't directly applicable.

In response to that there has been I know it's been over a year now I think the ANSI committee formed in the C1306 group and they're working on actually two standards now, .50 and .51, very much focused on this goal, right? Tentative title for .50 is shown here: Revenue Grade Energy Measurement Device, again very much focused on setting accuracy performance levels and defining testing measurement procedures to verify that this type of a device, right, a controller or something that would sit out in the field as part of a connected lighting system can accurately measure power and reports energy consumption.

Now there have been some alternatives discussed in various locations in the United States. Alternatives to collecting and using again the data that these controllers can produce in order to facilitate billing, right, and allow municipalities to turn energy savings from adaptive lighting into cost savings. This slide just kind of attempts to graphically show the general idea. The general idea kind of pays homage to the frankly the uncertainty around how outdoor lighting energy is billed today, right?

It's done today based on estimates of consumption, right, based on an estimate of the power that a light source is going to consume, which actually can vary over its life, but typically a fixed number is used. Then how many hours that light source is going to be either on or off, typically based on triggering from a photocell, again using an estimate of you know dusk and dawn and how it's going to trigger that photocell for a given region in the country. So there's an average hours of use estimate that's produced, multiple average wattage, times this hours of use estimate and that's how the tariff is established. Again there's some uncertainty around how accurate that approach is, but nevertheless it works for everybody. It's perceived that the uncertainty and the risk associated with it is equally shared between the utility and the municipality in this case.

A similar approach has been taken to bill LEDs, right, because traditionally our traditional lighting technologies really only came in four, five, six power levels, right? There's not an infinite number of HPS wattages if you will. So you could have a tariff that describe okay here's the rate for 100-, 150-, 200-, 250-watts light source and that's pretty much going to cover everyone's needs.

But when LED came along and this is still the case today, right, given continuous improvements and efficacy the power or you know wattage of an LED that's say produces an equivalent amount of light to a 150-watt HPS varies quite a bit from manufacturer-to-manufacturer. Based on what chips they're using it will be less tomorrow than it is today. In order to create tariffs for LEDs utilities have had to take the same approach, right? So likely typically they have created some bands if you will where they say, "Okay anything between 50- and 100-watts, right, will get billed according to this average power estimate," maybe halfway between the 50 and the 75, right, or 50 and the 100. And anything from 100 to 150 will get billed at say 125-watts as the average power estimate.

So again some uncertainty there and how things are being done today. So if you take those ideas and apply them to adaptive lighting again you kind of come up with the examples potentially shown here. That maybe one might create tariff that would describe a model for an adaptive lighting strategy. Two of them are shown here, right? So a model that says, "Okay on average perhaps or typically maybe I'm going to dim my street lights between 2:00 and 6:00 AM to 50 percent." Maybe I have a second model, Model B or you know I'm calling it "Adaptive Lighting Tariff 2" that says, "On some of my lights I'm actually going to turn them completely off between 2:00 AM and 6:00 AM.

So the idea would be well if I came up with two, three, four and I don't know how many of these models would I kind of cover the range of what people might do, right? And might I tell people, "Okay here are my models. Here is the again total energy consumption over the course of the year that a luminaire performing according to this model would consume and then associated tariff. Now go tell me which of your lights are closest to or most representatively going to perform according to Model A versus Model B and Model C," et cetera.

Maybe I'd have to so some trust but verified plan to make sure you know if I'm a utility that my customer actually controls the lights

according to the way that they would when they suggested what tariff was appropriate. Or maybe I am providing the lighting control technology and solution and I'm programming it and I know exactly that they're doing what they say they're going to do and that's not a concern for me. So this discussion is being talked about in some parts of the country also as an alternative to again figuring out how to collect and bill according to the data coming from every single street light.

Some review a little bit here. Again the different types of tariffs that exist again at different utilities across the country and again show a couple of different examples. So most often we kind of breakup outdoor lighting tariffs into kind of these three categories. I already talked about the predominate one, right, where there's a flat rate calculated, whether their outputs is fixed or variable and it's calculated based on an average differently over the course of the year and divided by 12 and you get your cost per kilowatt hour, per light, per month.

Then there's also some utilities, again less common, offer a fixed energy tariff that does require metering, but by a utility-owned meter typically, right? They don't allow a customer to put their own meter on the resource or assets, but you know maybe the utility would deploy one of its own meters. The cost of that would have to be accounted for, often with a per-month meter charge. Then you can bill according to actual energy consumption.

Then again some utilities also offer a time of use energy consumption, even more rare, right, but again requiring a meter. Perhaps utility or customer owned, but again mostly utility owned, but since this is newer people are maybe more thinking about both. And instead of a fixed dollars per kilowatt-hour cost there's a variable dollars per kilowatt-hour cost based on the time of use in the day.

So here's again not comprehensive at all, but some examples of these different types of tariffs being offered by different utilities in North America. Actually here your first example is B.C. Hydro up in Western Canada Region, both offers a flat, but also variable outputs tariff. So it's calculated but they will allow you to as part of that calculation not just estimate hours, but estimate variable outputs say according to a calendar schedule if you will, 50 percent certain amount of time, 100 percent the rest of it.

PG&E in California offers a flat fixed output and a fixed energy tariff. SDG&E has long offered a fixed energy tariff. Xcel in

Colorado, right, offers a flat variable output tariff. There's some discussion there in particular about municipal versus utility meter ownership. So that's one of the places where that's going on. A little more novelty Georgia Power has actually put into place now a time of use energy tariff that not only is available but is the required default tariff for anyone who wants an LED. So there's that you can go look up and get the details on that. Finally, NV Energy offers a flat fixed output tariff, right. Again I think it's not too difficult to go find details on all of these.

I'm going to show you some representative texted from a few of them just to get some idea of what the conditions are.

So here's some specific representative texted from the PG&E flat fixed output tariff. So you see there's some accounting for variable wattage and even a ballast factor, but otherwise it assumes a fixed output from the luminaire and a fixed power level and therefore energy consumption. Now there are some special conditions in this tariff. You see at the bottom for operating schedules other than and they describe the type of adjustment that can be made.

Okay here's an example from Xcel Energy that fits the flat but variable outputs. There are links you see at the bottom of these slides to get more full details of the tariff. Here's some additional detail of that Xcel variable output example. So they do allow for variable kilowatt-hour use determination based on lamp type, size, ballast, lighting control device, number of lamps or groups of lamps operating together under the same control. Obviously hours of operation and the dimming schedule during the reduced wattage or dimming schedule during dimming hours of course.

You also see how they are implementing trust but verify, right? They may install a temporary meter or do some other periodic testing to verify that the municipality is not rating the light according how they told them they would operate it.

Here are some additional details on the Georgia Power time of use energy sample, right, and in particular there's a contrast between the previous tariffs for the HPS lights in terms of what the three different solutions, right, photo of control, continuous burn, part nights. And the cost and the again new required for LED time-of-use energy tariff where you see variable rate based on hours of operation during the day or watt hours the lights are operated during.

So I'm going to transition now and say a few things about lighting system ownership, right, which often drives the discussion around needing a new tariff and is more and more also becoming part of the discussion about how network or connected lighting systems might get deployed and used. Especially in cases where a municipality doesn't own and operate the system today, but wants too or feels like it needs too to deploy technology that they want whether that's LED street lights or in a connected lighting system.

There are some very important questions that people are still kind of trying to figure out a blueprint for. Again I think some of that's covered in the resource discussed earlier, but where do you even start, how do you start that conversation? Is there a methodology in place to go purchase the lighting system? If not again how do I start that conversation? In some parts of the country this has even led to lobbying and legislation requiring that discussion to happen and that methodology to be created, which then leads only to the next question, right, which is: Where is the line of demarcation between the utility distribution system and the street light, right?

Is it up at the street light connection? Is it at the pole? Where exactly in the pole? Often in a line of demarcation needs a marking points, maybe an in-line fuse or something. Different approaches have been taken in different places to define that line of demarcation. Then that maybe then only leads to the next question which is, electrical system compliance with the appropriate code, right? So many of you hopefully are familiar with the NESC and NEC codes, one or more are required for compliance by utilities and then the other required for municipal use and typically more stringent. So sometimes then this discussion on transitioning a system, defining the line of demarcation, but then now taking some part of that system that is now transitioning to the municipality and previously net one code, well now all of a sudden needs to meet the different, more stringent codes and what does that require? Who is going to bear the burden of those upgrades and how does that affect the overall cost and value proposition of the change that wants to get made?

Kind of just a high level you know I call it a "roadmap," but a set of discussions that typically needs to take place here, right, is I'm going to do this transition. Well I need an evaluation of the infrastructure that's going to transition, right? And based upon that evaluation can be continuous, various models people attempt to use or want to use to set that evaluation. In some cases it doesn't make sense and the municipality may decide they want to abandon the assets completely and install new assets or they do want to go buy

it back. Then again you have to address this separation, demarcation electrical compliance questions that I mentioned previously.

There's a resource here I'm showing a link to that kind of goes into kind of this diagram in quite a bit of detail and is an interesting dialogue to read through if you're considering this.

Okay, once maybe you're through those hurdles, right, and you want to go plan a deployment, here I mentioned, right, I think it usually makes sense to think about that deployment not as a single step but as three steps. In particular due to who might be responsible, a big part of I think deployment is to consider a different points and phases and ultimately when things are deployed who's responsible for what, right? And you may have a different party be responsible for installation versus start-up versus commissioning. Again these are not universally held terms and demarcations, but I think conceptually they're useful to consider, right?

Installation is literally just physical, electrical, mechanical, mounting of devices connecting to input voltage, wiring, et cetera, right? Do devices have the basic necessities for operating as intended, but they're certainly not performing any functions, right? Start-up is that extra set of activities required to enable the devices to operate as intended, right? To be able to do everything the manufacturer said they can do, right? To be able to provide all the features and the capabilities that are on the datasheet. So everything is available to the user, right?

Here you are dealing with setting up the communications network and provisioning and addressing any spectrum or interference issues. Again, kind of making those connections I mentioned at the beginning you know between the field device network and the network infrastructure and the central management system, et cetera.

So everything the technology it can do all its intended to do, but it's still not customized yet, right? Here I'm using the word "commissioning" to describe the stage or set of activities where system functions and capabilities are configured exactly according to user needs, right? So here is where you are grouping and scheduling, maybe configuring sensor algorithms, implementing adaptive lighting schemes, et cetera. So I think these things go in sequence. You can't do – you can't skip steps and often you may

want to consider different parties to perform and be responsible for the activities under each phase.

Okay another thing that needs to be considered again and this is not exhaustive at all, but I have some very other high-level things when planning a procurement is what luminaire integration plan or strategy do I want to pursue and what options are available to me from different technology providers? So kind of four broad categories here, right? Something installing a device external to the luminaire, but maybe where I only want to be able to turn the luminaire on-and-off and here I can deploy a ANSI 136.10 or .41 hopefully runs familiar with these now; compliance device that can plug into a receptacle available on the luminaire.

However, if I want to do dimming or adjust the light output I need to definitely facilitate the ability of that external device to send a control signal into the luminaire. Historically a number of people or manufacturers have enabled that with the traditional three-prong receptacle by requiring you to install something else, right? Drill a hole and send some wires through the luminaire, maybe creating a power-line carrier signal and then planting a decoder inside the luminaire to read that signal or sending a short wireless signal literally again from the external control into the luminaire.

But more and more now with the broad availability of ANSI 136.41 compliant luminaires, right, and manufacturers offering that five-to-seven pronged plug on the external controller that is the simplest and most efficient way to provide that dimming signal into the luminaire.

Now some manufacturers from the beginning and today also offer solutions to install a controller internal to the luminaire, which has a number of advantages, potentially including lower cost, but definitely raises a new kind of question which is: Who is going to do that installation and who's responsible for the end performance, right? If something doesn't work who's responsible? Was it the luminaire maker? Was it the control manufacturer? Is it a third party who installed the one into the other, et cetera?

We have seen some issues in the past where that internally mounted device maybe was mounted too close to or even in some cases right on top of the LED driver and resulting in a rise in heat or thermal – you know temperature on both of those devices potentially degrading performance, et cetera. In the future that's not any of these solutions that I'm aware of yet in the United States, but certainly a number of manufacturers are building and even

deploying in other parts of the world solutions where the control technology is just integral to the luminaire, right? It's integrated into the driver. It's kind of like the way people addressed dimming today, it's there whether you want it or not. Maybe you're going to have to pay to have that feature turned on, but it's just part of the capability offered by the luminaire.

So kind of some graphical again examples of those three different types. Again, external mounted controller you see an example on the top of what looks very much like the traditional photocell, maybe a little bit bigger. In the lower left-hand corner you see an example of an integral solutions, right, where only the antennae is exposed. Again soon at some point maybe even this year we'll see solutions on the market where the control technology is just built into the luminaire.

Some lessons learned I guess from some of those various approaches at some of these private projects. In some cases the location of that externally mounted antennae has proven to not be ideal or the durability of that antennae. You see kind of an example here of an antennae that has suffered some deformation as part of its transit if you will and may not be performing ideally. There isn't a standard yet that describes maybe where to put an antennae mount on a luminaire or define a connector, right, by which a remote antennae might be screwed into a luminaire and/or define characteristics of an antennae, et cetera, such that maybe the antennae could literally be mounted out in the field as part of the luminaire installation instead of what is often the case having to be done somewhere else in the lab, in the factory, et cetera and then you got to deal with again maintaining the durability issues and maintaining the physical viability of that antennae during transit, et cetera.

Another consideration, right, that sometimes actually in some cases gotten overlooked initially, which is do you know the various input voltages that are serving power to your existing system? And does the technology provider offer controllers for all those voltages, right? So here is just an example. This now is maybe a year old of a survey done of different vendors showing you the various \_\_\_\_\_ voltage options of their connective lighting solutions. You see not everybody is offering every solutions, right? Some people offer only fixed voltage controllers, they only work at 120 or 240 or whatnot. A number of folks offer universals that offer say work between 120 and 277. Then in particular the high-voltage offerings maybe are only offered by a few people here and there. So some of

this has maybe changed over time but it's definitely something to investigate.

Now of course there are ways to deal with this, right? You can install an internal transformer to the luminaire to bring higher voltage feeds down to the level needed by the controller, but then you again one more thing that has to be get mounted in the luminaire and selected and who's responsible if it doesn't work, et cetera, et cetera.

Lighting control protocols. So I already mentioned, right, the decision of am I just going to want to turn my light source on or off or am I going to want to dim so I can enable adaptive lighting and pursue those energy savings and enjoy the fun of trying to get those savings turned into dollars, et cetera? Well there are multiple ways to create that control signal especially from an externally mounted device and send that control signal into the luminaire and adjust the light level. The two predominate approaches available in luminaires today are there is the ten-volt and DALI.

Some very important high-level differences between the two, certain needs of the 10-volt is much more predominate, much simpler. However it only allows for one way analog communication with the driver of ballast, so you cannot read any information back from the driver ballast or luminaire, right, you can only send a single communication signal if you will into the luminaire that is going to be interpreted as a dimming or a reduced lighting level. But that protocol does not allow you to set a specific power light level. Then if you are unfamiliar you can read or ask a question about it later, but that protocol really just describes okay above a certain control signal level you should be at full outputs, the lowest certain level you should be at minimum output whatever that is and in between you do whatever the heck you want. So it requires extra configuration and steps to allow someone to specifically say, "Hey, I want to be at 50 percent power" or "I want to be at 50 percent relative light."

The DALI protocol is two way. It's digital communications so you can both pull information back and send that dimming control signal. You can set a light level, because that relationship between control signal and light level is defined by the protocol. You can theoretically extract out information from the luminaire or from the driver of ballast, such as maybe make and model and powerful file, et cetera or maybe even dynamically changing characteristics like temperature. And in fact there are some in particular utilities who are pursuing this approach to again contribute to their ability to

better maintain their lighting system and deliver value and satisfaction to their customers.

Here's kind of an example of again how that relationship between control signal and light output may vary between two different luminaires and how that relationship is defined for the DALI protocol. Now the two different plots here you're seeing are for measured light versus preserved light; important to know the difference there. But it is also important to know that just because a luminaire since it complies with the DALI protocol does not mean that that luminaire goes down to a minimum dim level, right? So you are maybe going to specify relative light output, you can only specify a level down to where the luminaire goes, right? So DALI source luminaire A may go all the way down to 10 percent, but source B may only go to 20 percent. You send a control signal asking for something less you're just going to get the bottom floor that it enables.

Okay and wrapping up a few more again other things to consider, including location conditioning, right? So how are you going to record where this controller is being installed or where the full luminaire that it's being installed on is, right? And the technology solutions available in the market vary from having no capability at all to assigning the controller to a location that exists already in a database so you're doing that solely at the you know in your back office with the central management system.

A very common approach is you can capture that information out in the field, but you need to use some field commissioning device, some kind of you know PDA tablet-looking device that has a GPS inside of it. You maybe scan the barcode of the controller you're installing. You press a button and you wait for that device to capture the GPS location, maybe it takes like 10 seconds, 20 seconds, a minute and then it attaches those two things together, sends it over to the communication network and the two are associated with each other.

The most sophisticated approach but obviously the most expensive too there are a number of solutions on the market where each controller has a GPS receiver in it. So from an installation standpoint you can just go and install the controller and move onto the next one and in the meantime that device will lock into a GPS signal however long it takes and automatically record it back and thereby log the location.

Some pretty straightforward if you will lessons learned or comparing and contrast of those approaches, right, and a lot of them are revolved around the use of GPS and I kind of already alluded to them, right? If you're going to use that field device how long does it take to get an accurate location reading before you can move onto install the next device? There's a tradeoff there in accuracy, wait 10 seconds you get signal from 2 satellites, you're so accurate, you wait longer and you get signal from more satellites, you're more accurate versus you know you purchase something where the GPS is already in the controller but you're paying more, 10 maybe 20 percent more per controller nodes to have that capability.

And kind of making that decision I think from what we've seen really kind of comes down to the municipality utility having a good idea of how often might they be moving these controllers, right, for one reason or the other? And how many do they want to install, right? There's definitely a big difference between wanting to install a thousand of these total where maybe waiting a little bit longer per controller is not a big deal, to maybe being someone like the City of Los Angeles that wants to install 1,000 of these a week or 2,000 a week, right? So I think size matters there.

Okay looking to the future again I've kind of already talked about adaptive lighting from an energy savings you know standpoint and the issue of maybe turning that energy savings into cost savings and needed a tariff to account for that. But there's the other side of adaptive lighting which is well if I'm going to do this how do I know what light level to adapt too or concept my system to and what's appropriate and safe and whatnot? Here I really just want to alert you to a relatively new publication offered by the FHWA, including that describes design criteria for adaptive roadway lighting. There's also a little bit of discussion about non-energy benefits and whatnot in there.

Certainly there are a whole host of other value propositions that are starting to be offered or being offered by this technology and people are I think still very much in the early days of figuring out how to qualify or quantify them and consider them in the cost benefit analysis if you will and just a small set of those are shown here, right? Again enabling your lighting system to become a data collection platform and leveraging emerging you know big data and analytics and cloud computing capabilities to turn that data into knowledge if you will information. I already alluded to you know using the system to provide security benefits or even public

relations benefits through the use of integral displays or even speakers.

A little bit here about again that first value proposition I mentioned doing and implementing adaptive lighting according to some guidance if you will, right? And so that FHWA document does talk about how to adapt to a number of varying conditions, right? You see a list of them in the left-hand column here. I've highlighted one, right, where maybe I would adapt to traffic volume, right, and here are some categorization. There's three categories suggested here, high, medium, and low and then three kinds of traffic levels with three criteria that would lead to a waiting value. I'm not going to go into how these waiting values are used because there's an equation provided if you're going to implement multiple of these strategies where you add the waiting values together to determine what light level is appropriate.

But at the end of the day again this kind of raises another question. Okay I want adaptive lighting, I want to save energy. I maybe have a tariff that will allow me to turn that into cost savings. I understand – you know I believe in someone's guidance or I want to follow someone's guidance on what I should adapt too and what metric or criteria I'm going to use to adapt to Level A, B, or C. But then I have another question, right? A number of cities are really kind of at this stage I see know where, well how do I know that my criteria in this case traffic volume had transitioned from 750 to you know 750 to 1500, to more than 1500 vehicles hourly per wait? Certainly many cities in some locations have traffic sensors that enable that kind of data collection, but they're certainly not available everywhere. So what do I do if I want to enable this strategy right, right?

Do I come up with average use cases? Can I interpolate between where I do have that data available? Can I associate or correlate the other types of data that I have, such as mass transit schedules, et cetera? Quite a bit of thoughts going on and discussion again around how do I collect the data that I might need to enable the deductive waiting strategy that I want to deploy?

Here's an example of how one municipality went about that. You know not everyone is going to be able to do this, but they hired a consultant and then went and collected data, right, in some strategic locations. Then they kind of assigned or categorized the rest of the city as complying with one or more of these locations. So they're going to you know base their calculations if you will

traffic calculations based on the data collected you know in the representative areas.

So with that I'm going to conclude and open it up to questions. I'll note here that there's another DOE resource that's been available for awhile in its second version. We may release yet another version sometime in the next year or two, but this is a model specification for network outdoor lighting control systems. So it kind of goes into detail on many of the variations you see and commercially available technology offerings. It's a template, right, so it's not a fixed specification where you might go hand it to a technology provider and say, "Can you meet this or not?" But rather it's a template that guides you through thinking about again many of the ways, the systems or their offerings vary and offer you the opportunity to you know select or not certain requirements based on your needs. So there's a link at the bottom there provided for how to go download that resource.

So with that I'll close and thank everyone for their attention and see if we have any questions.

*Bruce Kinzey:*

Thanks Michael, very informative and obviously there's a lot to be learned with these systems so good job sort of turning on the fire hose and drenching everybody here with this.

I have a few sort of crystal ball questions for you, you're favorite type. Given that what you know the barriers and what you know is going on out in the industry right now, the things that people are trying to – the initiatives and so on that are going, what do you think the actual tipping point is likely to occur in terms of these systems heading for mainstream sort of application?

*Michael Poplawski:*

Well I don't think there's one, but I think there are a couple that are coming, right, and they're both kind of momentum-types of things, right? Where once they get rolling I think more will happen. So certainly one is cost coming down, right? So the more interest, the more deployment, the more competition, the more manufacturers actually believe that there is going to be a big market here, the more we see interoperability become available that will allow manufacturers as I mentioned you know more of them to pursue integral options, right? Where most of the additional technology required to do this is just going to be integral to the luminaire. That all by itself can reduce costs tremendously, right? The additional cost to deliver these features and capabilities you might have heard some people say it will reduce costs 50 percent, 75 percent of where they are today for the same features and capabilities.

So as the cost comes down and frankly related to cost is you know new business models become more I should say prevalent, they're already out there, but become more established, right? Everything from I guess a manufacturer just deciding, "Well I'm going to sell all my luminaires with technology built in and you'll just pay extra today, tomorrow, or you know three years down the road to turn it on," to you know lighting as a service and whatnot. So I think improving the cost, reducing the cost is one end of it.

The other end of it is kind of the other half of the you know equation if you will. There's everyone's looking at the cost of value, right? So reducing cost improves the adds, increasing the value is the other half. Again, there's some activity, right, where difference you know cities or users are you know venturing out there and saying, "Well I'm going to be the guinea pig to really look at some new value proposition, right, whether it's you know parking lots management if you will, right or collecting environmental data to get a handle on and try to improve the air quality in the city, right?"

As significant people really evaluate and vet and in some way qualitatively and ideally quantitatively can wrap their heads around the benefits of that value proposition and communicate that to other people that's something then you know we at DOE are definitely trying to help happen, right, or a role we're trying to play, right, as people learn those lessons we want to help communicate them out to the broader set of users if you will. So as that starts to happen I think you'll see more interest also.

*Bruce Kinzey:*

So you emphasized cost quite a bit in that answer do you think it's more of cost than capability driven? You don't think like there's going to be a killer app that everybody will say, "Okay that's it. We have to pay more for this but the value proposition is basically so high on this that that's what's going to drive it."

*Michael Poplawski:*

You know I got to have a crystal ball and I don't really have a crystal ball so you're just guessing. I don't see a killer app now. I don't see a killer app emerging later. I think there's just going to be a growing number of applicator value propositions or applications and it will be more likely that people will be able to quickly you know or in some efficient way realize, "Yeah these three work for me" or "these four" or whatever right? So it will be matching a growing set of value propositions, a growing set of verified, qualified, you know quantified value propositions to their needs, right?

And I think there's also just general education around that too, right? What is available? What can these things really do or not do you know even comes first? Then who has looked at something and proven them out and then yes A, B, or C you know are going to make this compelling to me.

You know I think we've seen in other areas sometimes for some uses that equation always requires cost, right? I'm always considering the benefits in relation to the cost, but for some cases users you know there may be benefits that are so compelling that cost becomes more in the background, right? I have this problem, I have to solve it, right, and I don't know of another way to solve it. Or I know you know a non-technology solution, a way to solve this is going to be way more expensive, right? You know whether it's you know I don't know around you know redoing traffic lanes, right, or you know physical infrastructure or whatnot.

And in some cases some of the value propositions we already see, right, are potential revenue producers, right? So that maybe doesn't change the initial cost but the ongoing cost, right, can be dramatically reduced or maybe even flipped around if the data say for example collected by a network or system here is capable of producing revenue. Not a lot of examples of that right now but that's potentially coming in the future.

*Bruce Kinzey:*

What you said sort of parallels sort of the implementation of LEDs in street lighting applications. That is they've been you know in some locations people have been willing to maybe spend more to get those out there because they offered I guess capabilities or features that they were interested in. So do you think control systems is likely to sort of parallel that in terms of its rate of application or do you think there's going to be a much more rapid adoption rate once we sort of cross that, whatever that tipping point is?

*Michael Poplawski:*

Well now I don't know, now you're really out there in the crystal ball I think.

*Bruce Kinzey:*

Just wait I've got another one for you.

*Michael Poplawski:*

Well I think you know again I think when you really start to consider that the opportunity to turn your lighting system into a resource that does more than produce light and again I'm talking about collecting data, that starts to become interesting and relevant to say in a city if you will or even to a municipality, right, to a

greater cross section of again the municipality or the utility, right? It's not just about changing the you know economics or the equation for light, right? It starts to create opportunities to again improve quality of life and improve air quality, generate you know revenue if you will.

So that's the direction I think connective lighting is going in in general, right? It's not just about lighting, it's about things beyond producing light. There's a lot of energy I do think building around that again turning lighting systems into data collection platforms and leveraging that data for all sorts of uses that you know maybe the killer apps are out there that no one has just thought of today. The better analogy there instead of LED is you know you're mobile devices are computing devices, right, once you enable that capability you create a platform for ideas and imaginations to really flourish and all sorts of things maybe come out of that.

So if and when that happens then I think things will go faster than they did ongoing with LED. Until that happens I'd go slower.

*Bruce Kinzey:*

Do you think we'll get to the point ever where people it's kind of like your smart phones which has all these capabilities, it has a camera, it has all these things in it and then you've got the people out writing app basically for the smart phone. Do you think we'll ever to get that point where people are writing apps that maybe not obviously not to control the streetlight, but maybe to use data that's been generated from using different systems, you know data streams that are available as a result of this?

I'm thinking of things like in Portland where people are accessing the bus line information for example and now you can get an app that's been privately developed that basically tells you when the bus is going to arrive at the next stop and things like that. Do you think we'll ever get to that kind of point with these systems?

*Michael Poplawski:*

It's a real guess, but I would guess yes, right, because like I said I think there's a lot of energy building around this opportunity. I think more and more people are thinking about the possibilities already. More and more technology providers of all types, right, we're not just talking lighting companies, but you know IT companies, you know Cisco's, Intel's, and Microsoft's again are thinking about the opportunity here of collecting and leveraging data out in the physical environment from lighting systems where there's already a lot of momentum is being created to retrofit existing lighting devices with a new device, right, driven just by the energy savings of LED. So there's this opportunity, "Well I'm

going to go do that anyhow why don't I put in a device that again has these other features and capabilities? How much more does going to cost? How much more does that enable?"

How many other mechanisms can we create to get more people to do that? I think there's enough energy and opportunity and need for that to happen. Even just to continue supporting technology development out in the industry, right? And literally technology GDP literally that if I had to guess, it's just a guess, but if I had to guess what will happen I would probably guess that it will.

*Bruce Kinzey:* You mentioned Cisco and some of the other majors, do you think that you will continue to see smaller players in this space or is probably going to be the larger companies that will move in and maybe even companies like Google or somebody else like that getting involved?

*Michael Poplawski:* I just like historically is true it's a cross section, right? So this is a big I think opportunity that opens the door for lots of people to think about a role for themselves, whether it's a big established person who maybe has reached a plateau in growth and revenue and looking for a new way to continue growing versus a new guy, right, who's got a neat idea or a neat piece of technology and looking to you know get a foothold at the bottom, at the beginning of a you know of an avalanche here if you will. But then you know that has a life of its own often anyhow, right? Only a small number of those small guys can grow to become big guys. The rest of them either don't survive or get acquired by somebody else and that's happened a hundred other times before; you might have it here too.

*Bruce Kinzey:* Okay. I have a couple of very specific questions here. Let me modify this one because I know the answer is "Yes," to the first answer. The question is: Since LEDs are instant-on devices has anyone tested control by motion sensors? Let me modify that a little bit. Do you know of any street lighting applications where anyone is using – there's definitely installations in parking garages and lots of other places where LED luminaires are being controlled by motion sensors, but do you know of any actually street lighting applications where that's being used?

*Michael Poplawski:* So I know of a number of people who have piloted that, right? So in brief, right, by and large people are looking at leveraging previously you know developed technology, right, passive infrared, maybe ultrasonic, right, that sensor technology to do the actuation. And as you might imagine that works outdoors that works best in the environments that look more like where about technology has

historically been successful, right, where it looks more like indoor installations. So you mentioned one, right, it works best in garages and I think it's being deployed quite a bit in garages. It doesn't quite work as well in parking lots and you know pedestrian areas by and large because of where are you going to mount that sensor, right? If you mount gets integrated into the street light it's at a much higher up and you need you know a much bigger coverage range than again what a lot of initial offerings can do or what even the technology is capable of.

But are there people who have done it? Sure, right, there are pedestrian especially I know post-op installations where they're leveraging that traditional passive infrared technology to do adaptation and you know it's a subjective evaluation to kind of comment on how well it works or doesn't work.

There are a number of folks also working on what I would call "new technology," right? So new types of sensors or sensor technology that are more suited to the outdoor environments, right, and more suited to the other applications, including you know even street lighting, right? Those are using again broadly microwave and video-based technologies. I've seen some of them. Some of them work quite well. I think the bigger challenge there is how do you get the cost down to the point where you might consider you know putting lots of them out there, not just one here or one there where there's a really critical you know or high-value need. So I would say that's coming

Then there's actually other ideas around how you would detect the presence of people or effectively people, right? Instead of again using a sensor that is outward looking, maybe I would you know want a – an easy to think about example is detect the proximity of cell phones right, which are more and more on people or in cars and whatnot and there are various approaches to be able to detect fairly accurately how many of those are in a certain vicinity and even how far they are away from a particular location.

*Bruce Kinzey:*

What about Wi-Fi? That's the next question I had. Is anyone offering Wi-Fi via modulation on the LED light beam so essentially they're talking about Wi-Fi? Do you know of anybody using?

*Michael Poplawski:*

Not outdoors I don't know, people are doing that indoor. So you got to be careful there, right? So you can use the light modulation both to kind of replicate or serve the needs of Wi-Fi for like high bandwidth, right, high data rate needs. Or in simpler incarnations

you can do it to provide a low-band width or low data rate needs, right? Say maybe this isn't being done right, maybe to send to determine where someone is in a shopping mall and based on where they are send them a coupon, right, to their cell phone. That's certainly being done in both ways, more for the location and low data rate needs indoors. Lots of people have that solution and there's a number of installations, a growing number of installations that have it. I'm not aware of it being done yet.

*Bruce Kinzey:*

Okay. Well thanks. We're out of time here. Thanks again Michael for a very informative presentation. For the people still on the line we're very interested in getting your opinion of the material that was presented today and maybe what related topics you might like to hear more about in the future if we decided to do another one of these. So we're planning to follow this up with just a brief couple of questions via e-mail and would appreciate your feedback on this.

So thank you for participating in today's webcast that's brought to you by U.S. Department of Energy's Better Buildings Challenge. We hope this was helpful in bringing you a little bit more up to speed on connected lighting systems and that you'll join us for other webinars in the future.

So you all may now disconnect and thanks again.

*[End of Audio]*