Recorded voice: The broadcast is now starting. All attendees are in listen-only mode.

Maria Vargas: Hello, everyone. This is Maria Vargas with the US Department of Energy. We're very excited that you're joining us today on the webinar. We're just gonna give everybody about one more minute to join us, so if you will just bear with us one more minute we will get started shortly.

[No conversation from 0:00:24 to 0:01:13]

Hi, there. This is Maria Vargas at the Department of Energy. I think we're gonna go ahead and get started with today's webinar. We want to be respectful of everyone's time. So it is a pleasure to welcome everyone to the first webinar of the 2019/2020 series. As those of you who've joined us before know we use the Better Buildings webinars to really profile the best practices of Better Buildings challenge and alliance partners and some of the other organizations that we're working with to improve energy efficiency in buildings. Today—Nina, if you want to forward the slide please—we are very excited that we get to revisit the 2019 Better Buildings Better Plants summit that we held last July, this past July in the D.C. area.

Every year we ask attendees—and we had about 700 this year—tell us which were their favorite sessions, and the speakers you're gonna hear from today are some of the top-rated presenters and presentations that we had from this year's summit. So, today's a rare chance to catch up on one of the talks that you might've missed. So, on your screen you'll see today's speakers and the topics of today's webinar are we're gonna be talking about buildings of the future and some commercial building strategies for building resilience. We're gonna talk a little bit about grid modernization and the role of grid-interactive buildings and best of the betters. We're gonna have one of the folks working with us in the Better Plants program talk about some of the work that got highlighted under better project and better practice awards.

So, without further ado let me introduce our presenters. They'll speak in the order that you see them on the screen. So, our first panelist Aaron Daly from Whole Foods Market. Aaron is the Global Director of Energy Management for Whole Foods Markets and oversees the company's programs in energy procurement, energy efficiency and renewable and onsite power generation. Prior to working at Whole Foods Market, Aaron was the National

Account Manager at PECI, a not-for-profit energy efficiency consulting group based in Oregon.

Sara Neff from Kilroy Realty is our second speaker. Sara is a Senior Vice President for Sustainability at Kilroy Realty Corporation. Sarah took Kilroy from having no sustainability program to being recognized by GRESB as the number one publicly traded real estate company on sustainability in North America, and under her leadership the company has recently committed to becoming the first carbon neutral real estate company in North America by the end of 2020. At Kilroy, Sara oversees all the sustainability initiatives, including solar and battery deal-making as well as a slew of other things, so we're thrilled that Sara is joining us.

And our third panelist is Alexander Woolf from Lineage Logistics, and Alex is a Principle Data Scientist at Lineage Logistics, the world's largest cold storage warehousing provider. He oversees Lineage's energy portfolio with a focus on new technology development for the company's over 200 facilities in the US and Europe. Lineage was named as number 23 in the 2019 most innovative list by Fast Company and number one in data science, and Alex has been doing a lot of work and holds a number of patents, including—and is published on things including thermal fly wheeling, et cetera.

So, we are thrilled to have all of today's speakers with us today. So, before we get started I just want to remind everyone on the call that we'll hold your questions till the end of the hour. Please—on your screen you'll see that you can send questions through our chat box and we'll try to get to as many of them as we can. This session will be archived and posted to the Better Buildings Solutions Center for your reference. Each of the speakers have been asked to talk for 10 to 12 minutes so that we'll make sure we get everyone and their presentation in.

So, without further ado let's get a primer on resilient buildings from Aaron with Whole Foods. Aaron, would you mind going up next?

Aaron Daly: Thank you, Maria. Thank you, everyone. It's a pleasure to be here today and I am gonna be going through quite a bit of material and moving fairly quickly, so I imagine I'll be able to address questions as we get to the end. Next slide. The presentation that I gave at the Better Buildings Summit this year was on resilient buildings in practice and is a rather quick run-through the various areas where we've been focusing on resilience in our building management. Next slide.

In order to get started I just wanted to give a quick snapshot of our company to give you a better sense for who we are. Next slide. Whole Foods Market was founded in 1980 and we currently have a little more than 500 retail stores in the US, Canada, and the United Kingdom, and we were founded as a purpose-driven company, one of which I flagged here today for you which is the purpose to nourish people and the planet. And it's based on that purpose that we developed our energy management and resiliency programs. Next slide. So, before we get into developing a resiliency program, we've been thinking about how do we value resiliency; how do we incorporate it into business metrics?

Next slide. Everyone these days is aware of electric grid outages, storms hitting in various places, floods, fires and other natural disasters, and there is increasing awareness of the impact that that has. Many of the questions though that are necessary to answer in order to understand how to build a resiliency plan are how often are these going to occur, where are they going to occur, what kinds of outages might come as a result, how long might those outages occur for, and will they indeed be increasing over time? Next slide. Within the supermarket space, once we get a sense for the outages or the impacts on power supply we also need to understand the impact on our business.

There's the obvious one of lost sales as the power's out in the building, but as well we might see lost product in refrigerated areas if a power outage is extended. We're almost invariably going to see added labor costs for our company just needing to make sure that customers are taken care of in the event of an emergency, needing to make sure that food quality is protected and otherwise. And finally, we may see equipment failure when power flicks on and off and we might see spikes. Next slide. In our energy program, which we've been running obviously for a very long time, we started to incorporate resiliency as a core metric.

Next slide. We look at our energy programs through a lens of a three-legged stool, the first of which is cost savings, just making sure we can operate as efficiently as possible, the second, environmental savings and reducing the environmental impact of our energy consumption, and the third is business resiliency. It's really in the nexus of these areas that we find the best opportunities for investment. Next slide. To better understand where to make investments we need to understand where we consume energy in our buildings. In this graph you can see that between air conditioning and refrigeration it accounts for a very significant component of our energy consumption.

In some cases, as much as 85 percent of the building load can be related to cooling. Next slide. As part of our commitment to the Better Buildings challenge we've been investing in energy efficiency and we see it as a primary driver for cost savings, for environmental improvement, and for resiliency. Next slide. In these pictures here you can see some examples of the technology infrastructure that we have in place in the supermarket environment.

We have refrigeration systems, we have back-of-house cooling boxes, we have display cases on the sales floor, air conditioning, lighting, kitchen equipment, controls and otherwise. Next slide. These are some examples of energy efficiency investments that we've made over the last number of years. You can see a lot of them are in the areas of LED lighting, some in the areas of advanced or efficient motors, as well as building controls and advanced analytics. Next slide. Since 2001, we've been investing in rooftop solar systems.

We now have over 60 stores and distribution centers with rooftop solar, totaling over 10 megawatts of capacity, and are investing in additional sites as we speak. Solar affordable has the added advantage of helping us to control our energy costs, helping us to procure onsite clean energy resources, and when paired with other resources can be used as a resiliency strategy. Next slide. In addition to solar, since 2015 we've been investing in onsite electrochemical battery storage, the primary focus of which has been to reduce our peak energy consumption, but more recently we've also been investing in using it paired with rooftop solar to firm the solar generation as well as we're just starting to get into some projects using battery storage for backup power assistance.

In addition to electrochemical storage we've also been investing in a number of sites looking at thermal energy storage. Here's an example of a refrigeration system, thermal energy storage system that we've deployed. This has the advantage of allowing us to buy energy at night when power's cheaper and cleaner and then use it during the day instead of buying when the grid is most expensive and the dirtiest. Next slide. In addition, we've also in many cases been investing in resources that can supply energy for our full store requirements.

In this picture you can see a CHP fuel cell system that generates 400 kilowatts of electric power as well as all of the heating and some supplemental cooling needs to the building. Next slide. We've also in a few cases invested in onsite CHP systems based on gas engines. These can most be used as a resiliency solution; they reduce our costs, they operate very cleanly compared to the grid in many places, and they can be used to supplement cooling by using the waste heat from the systems. Next slide.

In many cases we've partnered with third parties or other groups to understand what the best practices are in building and energy management. In this case, we did a project with a number of partners in the city of San Francisco to understand how we could combine investments across a number of different areas to produce what we hope will be the nation's first net zero energy grocery store. Next slide. We also have a few pilot projects we've been doing. In this case we're trucking our used cooking oil from stores in a given region to a distribution center and then burning that used cooking oil to generate electricity.

Next slide. We've also been using a system called waste—or Grind2Energy rather, where instead of us sending our food scraps from the stores to the compost we put them into this Grind2Energy system and they end up being put into a biodigester and generating electricity, and then the effluents can be used for fertilizer and other things. Next slide. So, to bring it altogether and kind of up to date, what we're working on today is taking many of the investments we've already made in things like onsite rooftop solar, battery storage or onsite generators that we use for backup power and combining those systems into microgrids.

That obviously has the benefit of providing a backup power system for when we see grid outages, but it also utilizes onsite assets that we've already paid for and brings them together in a novel way so we ultimately get better economics, and it also allows us to get away from just using fossil generation for backup power, which allows us to focus on our environmental initiatives as well. Next slide. In addition to energy, we also see water management as a key resiliency strategy. Next slide.

One of the main reasons for water management being such a key strategy is that a cutoff in water supply would have almost the same impact as a cutoff in energy supply. As you can see here we use almost half of our water for cooling. Next slide. These are some examples of water efficiency measures we've deployed. Next slide. We also have invested in onsite storage, capture and storage. Next slide.

These are hybrid condensers. They are an energy efficiency and water efficiency investment. Next slide. We've done investments in onsite constructive wetlands for flood control. Next slide. And finally, here's a schematic of a case study project we did in New York where we're looking at reusing onsite water that we've captured in things like toilets and others. Next slide.

So, I sped through a lot of material and I'd be happy to address any questions or thoughts that come up afterwards, but thank you very much for the opportunity to share.

Maria Vargas: Thanks, Aaron. You guys are doing an awful lot. I'll be curious about the questions. So, thanks again for sharing that with us. Now let's here from Sara Neff with Kilroy Realty on grid modernization. Sara.

Sara Neff: Absolutely. Thank you so much for having me. This is really exciting. Better Buildings is a great event and I'm so happy to share this with a wider audience. So, what I was asked to talk about at Better Buildings was what's the current state of how buildings are interacting with the grid and how is Kilroy currently navigating that? So, that's what I'll be talking about today. So, next slide. Next slide. Great.

So, we're in a really new world within building. So it used to be even just five years ago that the building grid relationship was one way, right? I mean we bought power from the utility and utility produced the power and that was the end of it. We were consumers of electricity and now we're in the world of the prosumer, right? So, now we have buildings that are both producing energy and taking and pushing it back to the grid, consuming the energy, deciding when they're going to consume energy, so it's a very new world and we're all trying to figure it out.

So, the ways that we are interacting with grid right now fall into two main categories. One is in-demand reduction and then the next way is the storage, and I'll go into both of those. Next slide. So, demand reduction. A lot of what that looks like is energy efficiency, and you saw a lot of that from Aaron and his work is amazing. So, we're talking about HVAC upgrades, lighting upgrades, onsite renewables, so solar in my case, and then things you're doing to the envelope which are likely window film. Next.

And then there is demand response. There's a couple ways that we are doing demand response in those to interact with the grid. You know, so all of those energy efficiency measures are things we're doing right now at Kilroy. Happy to talk about anything we're doing with HVAC, lots of lighting, always dealing with window film upgrades and have a really cool window film on _____ right now and we have filler going in, in a lot of places, and we're also doing all of these things within demand response.

We're shifting our load when we can, we're shaving our peaks, and we also have a relationship with automated demand response programs in a couple utilities. Next. So, here's how demand response work. There's a couple of ways to do it. So, what is demand response? Demand response is when you reduce the energy demand of your building in response to utilities telling you that it is a time where they have a lot of energy demands and they—instead of turning on a kind of dirty peaker plant they would much prefer customers to use less energy. So, there's a couple of ways that that works.

The first and the most sort of basic is what's called manual demand response. This is one of my buildings in San Francisco. It's a lovely building. It was built in the '50s, and so what—and that will be important in just one second. So, what we do is an annual demand response and utilities sends a signal saying please use less power. We get that a day in advance. The engineer precools that building, so it runs a lot of the cooling procedures at night when power is cheap, and then because this building was built in the '50s what do we see here in this picture? We see tiny windows, right?

This is how buildings were built back then. It has a lot of thermal mass. This building does a great job keeping its cooling throughout the day, so it doesn't need to run its cooling procedures until very, very late in the day and it works out great. Next. Great. But then we have more modern buildings. This is where things get tough with the grid. So these are buildings of mine in Long Beach, California. It's a much hotter climate, and what do we see? I don't see tiny windows anymore.

I see a lot of glazing. These buildings don't do a very good job of being able to retain thermal cooling, so they're required to be a bit more sophisticated. So what these buildings do is instead of just the engineer gets a signal and then goes and does something, these buildings have very sophisticated software that helps them modulate the power that they're using. They do that at the VAV level, the variable air volume box level, and basically what they're doing is turning off sections and then turning them back on later and that enables them to do a little bit of peak shaving while still being able to keep everybody comfortable.

Next slide. And this is one of the things that I want to say about demand response right now, which is that demand response is something that is pitched a lot to us as customers. It's like, hey, it's free, do demand response. It's so great. You'll save money on your bill, it really helps the grid and makes the grid more resilient. It's awesome.

One of the things I've learned about the word free when I work in energy efficiency is that there's a big difference between a free beer and a free kitten, and demand response is very much in the free kitten category. Yes, it's not a big upfront capital cost but it's a lot of work in terms of maintenance and in terms of making everybody—you know, put in a lot of effort in messing up the commissioning and heating up your tenants on a hot day, so those are really, really difficult. So, we do demand response and automated demand response and we're proud do to it but we are looking for other solutions and I'll get into that really soon.

And I want to talk a little bit about even though why it's so difficult you've bothered to keep doing demand response and that is because of that peak shaving I was talking about before. So basically, what we're able to do at Kilroy is be—we work with a software provider. A software provider can predict for us the days in the month that we are likely to hit our peak demand, 'cause as you guys know there's two parts of an energy bill. One is the actual kilowatt hours you're consuming and the other is a charge on the peak kilowatt hours you're consuming.

So, we want to reduce that peak, and just a little bit of shed on those days really helps us save money. The ROI on putting that software in was like 2,000 percent, because just a little bit of shed does a lot and the software wasn't that expensive. So the demand response itself is pretty hard to do on its own, but there is a way to combine it with other programs to really make you a little bit more sophisticated and really get bang for your buck, but demand response is still hard. So, next slide. So, we have been moving into storage. No you saw some storage in Aaron's slides, you'll hear more about storage in the next presentation, so storage is where like the next phase of our relationship with the grid does.

Now storage isn't new, right? There is thermal storage, which is represented by the ice cube tray. So we have a couple of buildings that back in the '80s put in ice plants. These are buildings that make a giant chunk of ice at night and then during the day the building uses that ice for its cooling and then it doesn't need again to use the power from the grid on the hottest days. That is the oldest technology that there is and it works great and it still works great.

But now what we're moving into is onsite battery storage, so that's the next circle you see on this slide. This is a picture I took on my phone of my own battery project again in the Long Beach portfolio, and then the next phase that we keep hearing about and I put it on here, but even though it hasn't really happened yet, is can we use the batteries of electric cars themselves as storage that can somehow help the building? So that whole customer-backed grid is sort of the next phase. Now I drove my Chevy Volt this morning here; I would be nervous if my building drained the whole battery and then I needed to drive home, but there are gonna be ways to do that where you can put in settings, okay, you can drain me to X level and then I'm okay and then you're gonna compensate me for that.

So that's what I'm hearing about, so that's what the trend is, but let me talk a little bit more about storage. So, next slide. Great. So there's basically two current flavors of battery storage. There's exterior battery storage that is what is most common. So these are some batteries that we've put in, again, in Southern California. So, I have battery contracts with two different suppliers because I just love negotiating battery contracts.

And the way that batteries, the way that those work, is they're a little unusual. So, what a battery does normally is you install it and then the building charges up when the power is cheap and then it discharges, so the building runs off the battery when the power is expensive. So, that is basically what you're doing; it's energy arbitrage and you're getting some operational saving. That's actually not how my contracts are set up. We actually have a landlord tenant relationship with these batteries where they are paying us rent to lease this space on the building's campus, and I think that's really important here because as we're in this new world of renewables and batteries and storage and all that good stuff, how the contracts are getting written isn't set in stone.

There's a lot of ways to sort of skin the cat in terms of making a battery project work for you. Getting the rent payment and being a landlord was really, really helpful for us, but that's now it's gonna work everywhere. Some companies just want the operational savings and that is totally great as well. So, I also want to point out with batteries, these are not saving energy, right? These are, in fact, use a little bit of energy because they're not perfectly efficient. You do have to charge them.

But the reason that we want to use the batteries is I live in California where most of my portfolio is and the rest is in Washington State which has similar targets. California is trying to get to 100 percent renewable grid by 2045, and it's not gonna get there without a whole lot of storage because the sun has this terrible habit of going down at night, and so unless you can store the solar power, the excess solar power when it's not needed, you're never going to be able to make something 100 percent renewable. So, storage is really a larger piece of a much larger puzzle, and we think it's really the right thing to do.

These aren't a resilience play if there's a blackout. My building doesn't run off the battery. They go offline too. But we put these in (a) because we get the rent payment and (b) because this is what we think of as really important as we are transitioning to a more modernized, more renewable grid. So, next slide. So then it's the—so then it's interior battery storage. This is—we've also done a little bit of this.

It is much harder. Right now the state of things, the batteries themselves that we use are fine. So, we have some Stem batteries, you saw some Tesla batteries. Those are provided by a company called ANA, but what's happening right now is that we're finding that fire departments and insurance companies are much less familiar with battery technology, and so they are making interior battery storage a lot more difficult. This is something that we're just grappling with right now.

I think that the market will get much more sophisticated and mature about this within the next two years, so I would say now is a great time to go be signing your battery contract. I think when we signed ours back in 2016 and '17 we thought the market was gonna speed up a lot faster than it has, so you get to enjoy the fruits of our labor, but the interior battery projects that we do then are hard from just getting all the pieces to work out and getting a permit and all that good stuff. And then I'll actually go to my last slide next.

So a question I get asked a lot is, okay, Sara, you've got all these energy efficiency programs on this software that's helping your HVAC work and you've got your VMS systems and you have solar and you have batteries, you know, are they all working together in a harmonized way to be able to reduce power in your building? And the answer is the current state of things—remember, my talk is the current snapshot—is no. Right now these systems don't talk to each other.

My sophisticated software that helps my buildings reduce energy doesn't talk to the battery and the solar doesn't talk to anything. Everything's just kind of doing its own thing and everything sort of has its own protocols for when it kicks on. Now why is that? Like why did I have everything be a little bit siloed? The answer is we were chasing incentives and all of the incentives sort of showed up at different times. Solar plus storage wasn't incentivized back when we were doing these contracts, and actually if you tried to put storage on a meter that already had solar it wouldn't work because all the demand charges and _____.

Now things are a little bit different. But often, I gotta say, the incentives are better when things are separate. Sometimes they're better when things are together. This is something that you should really look at if you're considering the whole suite of everything. It might make more financial sense to break it up, it might make more operational sense to put it together or break it up, but currently I can say that even though the systems don't talk to each other they all seem to play nicely together.

So, the battery companies are aware of what's happening with solar and can predict that, when it's in charge and discharge. Same is true of the software that runs the HVAC systems and when the demands are high. So, currently the state is—we're not having one big pretty dashboard where I can see everything for a building, but we are having a lot of success with layering on each of those things. So, starting with energy efficiency, then adding renewables and then adding storage; each of those has been a win for the company, it's all been financially _____, and we are really excited to do more of all of this work. So with that I will turn it back to Maria. I'm happy to take questions at the end.

Maria Vargas: Great. Thank you, Sara. Really cool work and really on the forefront of a lot of these things, and I like the fact that you enjoy negotiating storage contracts. That's good. I like that. Just a quick reminder—

Sara Neff: I was lying. I don't actually like it.

Maria Vargas: I was being sarcastic right then.

[Laughter]

So, just a quick reminder for those listening, a quick reminder to send in any questions you might have to the webinar chat box on your screen. So, we're collecting those now for our Q&A which will happen in about 15 minutes. Now I think we would like to hear from Alex Woolf on thermal fly wheeling. Say that three times fast. Alex, tell us more.

Alexander Woolf: *[Laughs]* Yeah, that's right. Thanks for the introduction. So, can we go to the next slide and I'll—what's great about this webinar is that the work has been motivated quite well by Aaron and Sara. So, you know, we've gone from Whole Foods, which is the grocery store where you pick up your food, and then you can take it to your home or office which Sara operates, and then what I'm gonna talk about is more on the industrial side of what happens to the food before it even shows up at the grocery store and how can we leverage it for some of the topics we've been discussing for demand response and energy storage and all that? So, next slide.

So, here's the business. We operate a cold storage facility, and the reason we have these facilities is to eliminate waste. So, if you take a pig, you know, you may in Fourth of July may want to have a baby back rib but then you would waste the rest of the pig if you didn't have a way to save it. Next slide. And then the counterexample is Christmas ham, but then you've wasted your baby back ribs. So, clearly that's not good for anybody, especially pigs, and so if you go to the next slide the solution is a time machine for food.

So, it's at 0 degrees Fahrenheit, which is quite cold, and that stops aerobic decay of food, and so you can pretty much have it sit in there for years and that mitigates the waste associated with this very precious commodity we have. Next slide. So, what do these buildings look like and who is inside? Well, everyone's inside. Anyone and everyone. So, we've got roughly a third of the US frozen food supply under our roof and that's 209 facilities to date across the United States and Europe.

No one knows about us because we're not consumer-facing, but we do mediate a lot of the supply chain. Next slide. And what do our buildings look like? Here's one of our brand new buildings we built in Oakland, California. They're huge. There's trucks coming in and out, rail coming in and out, and then you have food sitting in this cold environment. And this facility is actually used for export meat going a lot to Asia, so it's coming from the breadbasket of America in the Midwest on rail and or via truck and then it goes off on a ship from the Port of Oakland. Next slide.

So, what's it look like when you get inside? Well, it looks kind of boring. At first you wonder what you're gonna do, be it the simple—the system looks so simple. So, on the left side it's just a bunch of food. The facilities range in size from 100,000 square feet to on the order of a million square feet and it's cold in there, and on the right side you can see what makes it cold, which is a vapor compression engine room. We use a lot of ammonia in our systems and it takes a lot of power to keep a room cold.

So, next slide. And then just to reiterate kind of our locations, we're all over the United States and often where there's high population densities, right? So, our energy strategies actually have to be market specific because some regions like California maybe have some incentives for certain programs and then others like the Midwest may not, and so that's quite interesting and it makes it an interesting challenge to come up with a scalable solution across the portfolio, but that's what I'm gonna talk about. Next slide.

Okay, so how do we think about power? So, Lineage Logistics is owned by a big private equity firm and everything is cashflow for this business, so that's just EBITDA, which is earnings before interest, tax, depreciation, and amortization, and how do you get cash for this business? Well, there's how many of the quantity of goods you're storing, which in this case is pallets, times the price you charge per each pallet, almost like a hotel nightly rate, and then your two big cost centers, right? The labor's our biggest cost center by far.

It's around $400 million, and then power is our second biggest, coming in around $100 million a year. And if you break out power, I like to think of it in terms of kind of the multiplication of three things. If you want to use a car as an analogy, the amount of money you spend on fuel is the number of miles you drive, which in our case is the thermal work, how much heat do we need to remove from the freezer, times the miles per gallon of your car, which in our case is the efficiency of the refrigeration system, times the price for fuel, which is in our case the price for either usage, which is just the rate for kilowatt hours delivered and demand.

And so this is specifically talking about the price component and how we can use that to our advantage to reduce cost. So, next slide. Okay, so this is—we're gonna do single A baseball before we try and go in the Major Leagues. So, this is a very simple facility. This is 129,000-square foot facility. It consumes about a megawatt, bills roughly $450,000 a year. There's no demand charge and there is real-time pricing. So, that's a pretty simple and straightforward system. Next slide.

Look at the price differences. So, on the 17th of July—this is a few years ago—there was a huge heatwave that came through Georgia and the grid had a massive price spike just due to the competitive equilibrium associated with supply and demand and everyone needing to turn on their residential HVAC systems. We had 40X intraday price swings, so we went from 2 cents a kilowatt hour and then eight hours later we're at 80 cents a kilowatt hour, and the traditional cooling method would essentially just be to ride out continuously through all hours of the day, so we would then pay more when the rates are higher and less when the rates are cheap.

This motivates an interesting idea; can we perhaps schedule our energy usage to mitigate our energy costs? Next slide. The idea is we're gonna use thermal storage. We're gonna essentially overcool the building when rates are cheap, make sure that the temperature goes below 0 Fahrenheit, and then when rates are expensive we're gonna turn the system off while making sure the temperatures don't go above zero, and we've done a fair amount of food safety studies to show that at these temperature ranges for these swings we're talking about there's no deleterious effects on the food, which is good. Next slide.

So as I mentioned earlier, the industry standard is, okay, the building needs to be at 0 degrees Fahrenheit, which is that blue line on the left axis, so my refrigeration system on the right is gonna consume power pretty much continuously throughout the day, and when I have peak hours I'm just gonna pay more for it. Next slide. Here's the fly wheeling strategy. Sorry, go back if possible. There we go. Here's the fly wheeling strategy; I'm going to overcool the building when rates are cheap, and so you'll see the green lines consuming power, and then when the peak hours hit I'm gonna turn everything off, make sure I don't go above zero, and not pay those expensive hours and then I'll turn it on again when rates are higher.

You can see I have to use more power with this strategy during nonpeak hours because I have to overcool the building. Next slide. Okay, so here's the model for this system. Being a physicist, this is what we do. We think of the simplest things we can and then we try and make a simple model for it and see if that actually works. So if you click you should start to see some stuff coming up.

What's inside the building? Well there's food and air. You can just model those by the heat capacity of the food and the heat capacity of the air and the temperature of both. If you click again they're coupled, so they're transferring heat, and that can change based on the environmental conditions and the packaging of the food, so on and so forth. And click again. And then heat comes in and out of the building.

There's heat that infiltrates either through the walls or through doors, there's even—people radiate heat. Not too much but they do. And then the refrigeration system is what we're spending all the money on to try and remove that heat from the system. Next. So, you can write a differential equation which essentially describes the temperature of the system over time and it's extremely simple surprisingly with a simple solution, which is if this model is true I expect the temperature to vary of the air and the food as the constant plus a linear term plus an exponential term.

So what we're gonna do is we're now gonna see if that's true, if this simple model's actually accurate remodeling our system. Next slide. So what you need to do first is make sure you don't ruin any food. Traditionally, a lot of these spaces just have one temperature monitor somewhere in the center. If I decide to turn everything off then maybe I have a hot spot in the corner I wouldn't know about and that could be a big problem, so what we did is we installed at this facility 175 wireless temperature probes that relay temperature signals every 10 minutes and then we're able to make these nice heat maps as well, which is also good for kind of preventative issues.

If something goes down we know about it instead of just kind of running blindly, but this also allows me to understand what the affects of turning the freezer off are. Next slide. So, I'm gonna save you a lot of funny stories about trying to get this thing to work and just give you the results. So here's what it looks like. You start the freezer at minus one, and that's kind of the black dots on the left, and then you turn the system on full board for 15 hours, and then those are the blue dots that kind of slowly go down to, I don't know, minus 7 Fahrenheit, and then you have a funny conversation with the engineer where you tell him to turn everything off, and he gives you a funny look but he'll do it.

And the system remains off for eight hours and then it slowly heats back up to where it started at minus one. So, the takeaway from this is twofold; one, I can turn the building off for eight hours and never go above my initial temperature which is great, and (b), wow, that fit function, that crazy simple model actually worked. That's amazing. And if you go back—at least I remember going back to my college days, that equation that we have for our fit function is actually the same equation you would get for an RC circuit, which is just a battery.

So these thermal—this food in the warehouse is truly acting as if it was just a battery and now we need to come up with a way to decide how to charge and discharge that battery. Next slide. So, the simplest one would be, okay, I know I can turn off for eight hours. Just take the most expensive eight hours, you know, rank all the hours in the day, take the most expensive eight hours on the right and just turn off for those, and that's pretty simple and those hours have changed throughout the day. Next slide.

That works and it doesn't work. So, on the bottom here you can see in gray there's the price fluctuation. This is November. There's not a huge amount of price fluctuation. And then in the pink you can see how the power's fluctuating from this refrigeration system. I'm just essentially avoiding the expensive hours. And so when the pink bars are high when the rates are low, meaning I'm using more power when rates are cheap, and then when rates get more expensive I turn off.

And then in the top is the effect that's having on my warehouse. When rates are cheap I'm cooling, temperatures are dropping, and when rates are expensive they're rising. Now what's interesting is that blue line actually drops over time. It's getting colder, which could be a problem. It means I'm overcooling the system, so that nice eight hours I thought I found isn't actually a constant value. So, I need to somehow figure out a way to update that and try and automate this process so I don't have to babysit it every night. Next slide.

Okay, so we have some good learnings from our small facility. Now let's go from single A to Major Leagues. This is our second largest power consumer in the portfolio in Mira Loma, California, which is in the Inland Empire about an hour east of Los Angeles. This is a 700,000 square foot facility, it uses 4 megawatts, and the annual bill is over $2 million. It's got time-of-use rate usage and then it's also got demand, which can be tricky. So, next slide.

So, here's the trick with demand. I'm trying to juggle, right? So, I've got price arbitrage and usage but then if I decide to turn everything off when rates are cheap and then turn it back on—

yeah, turn everything off when rates are expensive and then turn it back on when rates are cheap, what I'll do is I'll set what's akin to a speeding ticket for the month, and these can be quite significant and in this facility there's multiple speeding tickets you can be charged. You can be charged a flat one, which is just the max usage for the month but can occur anytime, and then there's also on peak and mid peak speeding tickets you have to pay.

Now what we have to do is figure out how to juggle the freezer loads in order to try and take maximum advantage of this price arbitrage without setting a demand peak. Next slide. So, that problem is not solvable by a human. This is where things get interesting. What you can do is you can hand it to a computer and say here's my system as I understand it and here's the constraints; can you tell me the cooling schedule? And this is a well-established field in mathematics known as convex optimization.

The nice thing is you're guaranteed two things with this technique. One is the solver, the computer program, will always give you a solution, and (b) that solution will always be the mathematically optimal one. So as long as I can figure out how to represent my problem in this format then I can just hand it to a computer and it will tell me what to do. Next slide. I won't spend long here but we've figured out how to do this. So, you just send it to—you essentially frame this problem I described with the constraints with that thermal model and then the price and the demand charge and everything and then you—I love this last line—you just say problem dot solve and it gives you the solution.

I kind of wish my Ph.D. was like that. It would've been a lot faster. Next slide. So, here's how it works. It takes in the energy rates—if you mind clicking again—and then the solver comes down and says here's the temperature set points I think you should use for these energy rates, so we're gonna cool when the rates are low and then we're gonna let the temperatures rise when they're expensive. Next—click again. And what it's doing is it's picking that temperature schedule to give the resulting power draw that optimizes—that actually minimizes our energy costs.

So, it takes in this case four rooms, from 9, 7, 8 and 10, and decides to cool them while not exceeding this blue dashed line which the optimization algorithm decided was the highest it wanted to go in order to not be excessive regarding demand charges. Next slide. Okay, here's the results. It actually works, unbelievably. So on the top panel is the amount of heat being removed by the freezers and that's in units of thermal kilowatts, and you can see in the very bottom panel is the prices on the real-time energy markets that this facility is on direct access.

The middle panel is the power consumption from the refrigeration system, specifically I highlighted the compressors here. So, you can see, okay, prices are high, so the system knows to stop removing heat from the freezers which then means the refrigerator system consumes less power, and this is fully automated. There is an optimization algorithm that decided to use this schedule and it kind of looks right. Next slide. So this falls under something we've been joking a lot about of essentially the piña colada principle, which is a problem's not really solved until you can go and drink piña coladas on the beach and it's still working.

And so this is kind of hitting on what we heard earlier from Sara about this kitten and beer dilemma of hopefully we can use automation in some way to transmute this kitten into a beer, and this is fortunately passing the smell test. It's fully automated and works with the cloud. I'll show you that on the next slide. If you want to see the guts of it this is what it really looks like. On the left side is essentially everything in the cloud, and it has that fly wheeling algorithm I just described in the bottom left highlighted in red. It talks via an API, which is just essentially a web database to get the rates for that facility and the demand charges and it then gets all the information from the facility it needs to decide what cooling schedule it should do.

And then it sends that to the facility. And the nice thing about this is it's designed to be saved, so you can make sure that you have safety overrides on the facility side so if a Russian hacker or someone else tries to ingest nefarious sets points the system will actually override it and not take anything. Next slide. Financial results. Formatting got a little goofy, but so here's the facility in 2016. It consumed $1.94 million. The rates for that facility went up 9.9 percent and the volume—we had a huge spike in volume—it went up 50 percent.

And so just based on our pro forma cost we would expect the facility to use around $3.18 million, but due to the fly wheeling technique we also did other things like hardware upgrades, we replaced doors, we changed the rate schedule to direct access, put in new condensers, put in DSDs, we put in motorized valves on the refrigeration system. I don't have time to get into all those but that saved us $1 million a year this facility and now we are scaling it throughout the portfolio. So roughly just high-level numbers, at the first facility I talked about we saved—I think it was the number came in 46 percent, something like that on refrigeration costs, and here we dropped it $1 million a year based on what it would've been otherwise, so that's significant for our business. Next slide.

Maria Vargas: Great. And Alex, we're gonna wrap up pretty quick 'cause we want to make sure we get to some questions.

Alexander Woolf: Yeah, yeah, I'm almost done. Fortunately that was patented and then that's the last thing. So hopefully—the nice thing is this technique can be generalized to other systems and industries and we're looking at that as well. That's it. Thank you.

Sara Neff: Nice picture of your team.

Maria Vargas: Thank you, Alex.

Alexander Woolf: Thanks.

Maria Vargas: I appreciate it. Thanks to everyone. So, let's just go ahead and take some questions from the audience. I'm gonna start with a question for Aaron and then we'll get to ones for Sara and Alex, too. And just to let folks know, I have us at about 3:53 Eastern. We'll go a couple minutes over to try and see if we can't get to a couple of these questions. So Aaron, one of the questions people have asked is how do you decide what stores get what resilience resources? What factors go into that decision-making? Can you share some of your thinking?

Aaron Daly: You bet. Yeah, thank you. It's not an easy decision to make and a lot of factors go into it. I'll give a few examples here but I won't be able to cover the full scope of it. So as far as resiliency investments, obviously the need is sort of the primary driver for it. Where do we see the need? You know, we're not gonna put resiliency investments in places where we don't have interruptions in our power or supply of other resources, so that's the primary driver.

Secondary to that would be other things such as, you know, can we make the economics work, are there other types of economic drivers we can take advantage of? Places like, you know, the Northeastern US or California or Hawaii have generally higher energy costs, more flexibility in how you procure energy and incentives for resources such as batteries and solar and otherwise, so that tends to help us drive investment toward those types of things. And then I would say third would be just the logistics of our buildings in general, things like do we have locations where we can put things?

A lot of our buildings are part of mixed use high-rises or otherwise and can be very difficult to locate solar, et cetera, so that gives you a general sense for it.

Maria Vargas: Awesome. Thanks, Aaron. Sara, you guys all got a bunch of questions so I feel—I want to ask you all these, but let me just start with Sara. Can you explain the exterior storage rent payment structure, like who owns the battery system and who's paying the rent, et cetera?

Sara Neff: Yeah, this is short and easy. We don't own the system. So think of it like a solar power purchase agreement. We don't own the batteries. So we have two contracts. One is a managed services agreement that deals with the operation of the battery and then separate from that there's a lease that defines things like rent and that kind of thing, so we don't own.

Maria Vargas: Well, that was quick. Thank you. Okay, Alex, one for you. Does—I'm gonna merge two questions into one. So the question is, does overcooling the building mean you're overcooling the food too and then part of that is it sounds kind of like you're using food as storage—is that right? Do your customer—have you talked to your customers about the thermal fly wheeling or what it is you're doing to cool facilities?

Alexander Woolf: Yeah, exactly. So yes, we are overcooling the food. The good thing is we're already 32 degrees below the freezing point, so 0 degrees Fahrenheit's quite cold and the affects associated with changing a material from 0 degrees Fahrenheit to minus two or minus three Fahrenheit is actually minimal. And the other thing is this technique is actually smoothing out the temperature swings of this facility surprisingly enough, because on this traditional algorithm it's essentially a bang-bang control system where you turn off if things are too hot and then turn on when things are—sorry, turn off, yeah, when things are too cold and turn on when things are too hot. And so by using this technique it actually gives you a smoother temperature profile and then you can selectively decide how cold you want to let it go and that's always a conversation with customers and they are aware of that and have been quite supportive.

Maria Vargas: Interesting. And then one followup question for you, Alex. If and when, heaven forbid, you lose cloud access, is there a plan B?

Alexander Woolf: Yeah, absolutely. So the facility is running on its own temperature schedule that would essentially be the baseline case, which is cool all the time in the traditional strategy, and then what this—the way we set this thing up is you can override if the engineer onsite wants to. We can override the standard strategy and then receive a temperature set point from the cloud. And so if the system doesn't receive a temperature set point from the cloud it will just continue as it was planning on doing anyway.

Maria Vargas: Oh, interesting. Okay. Aaron, back to you. One slide showed a negative 20 kilowatt hours per square feet below a 2008 baseline EUI goal. Can you share with us what the current EUI of some of your most efficient stores is now?

Aaron Daly: Yeah, you bet. What I can say is that, you know, that 20-plus savings is really across a very diverse portfolio of buildings, some of which as I mentioned earlier are pretty constrained in what we can do with them. A great couple of examples; we took over what used to be an old train station in one store and converted it into a grocery store and we have a variety of historic buildings and otherwise that can be very difficult to make operate efficiently. On the other end of the spectrum as the question speaks to, yeah, I mean our most efficient buildings are in the kind of 20 to 40 kilowatt hours per square foot, and I say 20 to 40—it's a big range. Kind of the 35 to 40 would be sort of a very typical, standard building and the 20 range would be deploying some of the more advanced technologies, you know, such as I demonstrated earlier.

Maria Vargas: Interesting. Thanks. Sara, just a quick question—and it's not my question. These are all questions coming from people who've submitted them. How is your organization sending value to resilience infrastructure? Is it reducing avoided loss, insurance policy thinking, et cetera? How are you sort of feeling with and assigning value to this work you're doing?

Sara Neff: It's a tricky thing. Yeah, it's a tricky thing. Right now it's a couple of things. It is an avoided loss. I think the calculation is more around avoided loss, but ideally I think what you've been hearing this whole presentation is that resilience infrastructure itself needs to make financial sense, and so what I think of that is our resilience infrastructure also makes financial sense without a resilience play to it. And what I'm finding with insurance is the insurance community is getting up to speed on what building resilience looks like but they don't have, you know, a formal table that says, okay, if you have a battery then your premium is this and if you have solar your premium is that, so we're all kind of figuring that out together but we don't do resilience work currently for a specific understanding in insurance premium reduction.

Maria Vargas: Awesome. Thank you. So with that, I'm looking at the clock and it is an hour and we told folks we'd end, so I'm gonna wrap things up here. I really appreciate Aaron and Sara and Alex, you guys all being on today's call and giving again the presentations you gave at summit. They were really, really interesting. So, thank you on behalf of us here at DOE but then everyone on the phone. And to just close out I just wanted to remind folks that we do have—this is the first of this year's webinar series. We go October through the summer and—I guess September through the summer—and the next webinar is gonna be on Tuesday, October 1st and it's talking about overcoming barriers to tenant data collection in the multifamily sector, and that'll be a really key one.

We've done a lot of work here with a lot of the multifamily owners we're working with in Better Buildings to think through strategies and you're gonna hear from partners who have overcome some really big barriers to do that, and I think they've got really important lessons for all of us. So, please plan to join us. So with that, again, I want to thank our panelists today for taking the time. Thanks to everybody on the phone. Folks on the phone, feel free to contact our presenters directly with any additional questions, if we weren't able to get to your question during the Q&A period. I do want to remind folks that we do have a date for the next summit, so hopefully you can hear some of the great presentations, some of which you've heard today.

So it's June 8th through the 10th in Arlington, Virginia. If you want to learn more about the Better Buildings challenge or the alliance check out our website please. And then lastly, you'll receive an email notice when the archive of this session is available online. So on the screen right now, again you can see the folks that presented today as well as myself and some of the key program support that we have, so if you have questions for any of us or want to follow up with any of us please do so. Sara and Alex and Aaron have very nicely said that they'd be willing to answer questions that people have.

So with that, I just want to close us out and thank everyone again for being here and well look forward to seeing you on the next Better Buildings webinar October 1st. Thanks, everyone.

Sara Neff: Thank you.

Alexander Woolf: Thank you.

[End of Audio]