Andrea Doukakis: Hi, everyone. We'll get started in just a moment. I see some folks are still rolling in. And if you wouldn't mind, if you are not one of our *[interference]* today, if you could keep yourself on mute and keep your camera off that will help with some backend logistical things. Okay. It looks like we have quite a bit of folks *[interference]* at the moment so *[interference]*.

So hello everyone, welcome. Welcome to our fourth quarterly call. Today's topic is going to be on E-Waste and I need to get started with a quick housekeeping note for everybody. This WebEx call is being recorded and may be posted on DOE's website _____ _____. If you do not wish to have your voice recorded please do not speak during the call. If you do not wish to have your image recorded please turn off your camera or participate by phone. If you *[interference]* call or use a video connection you are presumed consent to recording and use of your voice or image.

So once again, hello everyone who just popped in and welcome, and if you would like to keep yourself muted that would help with any background noise or anything like that. And Clifton, you could take me over to the next slide, please.

Perfect. So welcome, again, to those of you who are joining today to our fourth quarterly call for the Waste Reduction Pilot. As a quick refresher, we are using quarterly calls to share best practices and resources as well as provide a forum to work through challenges and opportunities. We hope you find these very valuable and welcome any suggestions for topics for future calls. Next slide, please.

Today's session will be moderated by me, Andrea Doukakis, and Hannah Debelius from DOE. I am Andrea, hello. A lot of you know me. I work at RE Tech Advisors as a *[interference]* consultant. I focus mostly on the commercial real estate and healthcare sectors for the Better Buildings program. And of course, I am also part of the Waste Pilot team. And Hannah, please go ahead and introduce yourself.

Hannah Debelius: Yeah, hey everybody. Great to – well, I guess I'm not seeing you yet but great to join you again for the Waste Pilot. You all know me, I've done some of these working with CRE and higher ed and then also the Waste Pilot for this. Today I'll be popping in and out a little bit just to help with moderation including Q&A. So as a reminder _____ _____ have a question you can go ahead and put 'em in the chat box and we'll get to those at the end.

Andrea Doukakis: Okay, thanks, Hannah. And _____ take the next slide. To start, we'll go through a few Waste Pilot updates followed by our speakers. First up we'll have Jim Henry, Global Data Center Compliance Manager from Iron Mountain Data Centers. And then after that we will have ED Daniels who is a project engineer from the REMADE Institute. And then as Hannah mentioned, we will close with some Q&A. Next slide, please.

As always, thank you to all of the Waste Pilot participants, many of you who are on the call today. We have over 40 participants now which is amazing. We love to see that our group here is growing and expanding and, you know, allowing more opportunities to learn from each other so we're very excited about that. Next slide, please.

And on that similar note, let's welcome some new participants to the pilot _____ the industrial, multifamily, local government, healthcare and commercial real estate sectors, we're very much looking forward to the partnership with you. Just a quick reminder that our recruiting lines are still open so please reach out to your account manager, Bruce Lung or Hannah Debelius or myself if you are interested in learning more about how to become a full participant if you are just listening in today. Next slide, please.

As a quick reminder, here is our Waste Pilot team. Those of us from DOE and ICF and myself from RE Tech. Please reach out to us with any questions that you might have regarding recruitment or topics for future calls or anything like that. Next slide, please.

We have just a couple of program updates for all of you. Summit 2021 will be held this coming spring. Please send any ideas for speakers or session topics to Hannah or Bruce. Similarly, our next quarterly call will be held in February and we are always happy to take suggestions for speakers or for call topics from you guys as well. Data collection is also approaching. Please reach out of us if you are anticipating any concerns about reporting your data in March. This applies to Better Buildings challenge partners or Better Plants partners who are committed to the data collection piece.

For those of you who are using the waste reporting form as opposed to _____ manager, we will have that ready for you soon. And as always, please check out our home page for our e-mail bulletins and other resources. And then the slides from today will be sent out soon so you will have all of these links to refer to later. Next slide, please.

And a quick update on Working Groups. The Plastics Working Group largely focused on the industrial sector of your second call last month. Please reach out to Bruce if you'd like more information on the findings and any next steps that might be involved there. And the commercial sector, Outreach and Engagement Working Group held their first call on November 9th. You could talk to me or Hannah if you are interested in participating in our second call which will be in early December. All right, next slide, please.

And please give a warm welcome to our presenters. Today we have Jim Henry and Ed Daniels. First up is Jim. Next slide, please. Jim Henry is the manager of Global Compliance Iron Mountain Data Centers and leads the division's Enterprise Information Security, Environmental and Energy Management Compliance programs. Jim is primarily responsible for enterprise compliance management and information security governance but also leads the overall program management and development of the ISO 50001 and ISO 14001, Certified Energy and Environmental Management Systems. Jim, take it away.

Jim Henry: Thank you. Hopefully you can hear me okay. I know some folks are having audio issues so I switched my video off to try to accommodate some of that. So if you all can hear me, hopefully you can.

Andrea Doukakis: I can, you're good.

Jim Henry: Perfect, thanks, I wasn't sure. As Andrea said, I'm from Iron Mountain Data Centers, which is a division of the larger Iron Mountain that probably most folks on this call are familiar with, who handle, you know, shredding, you know, e-waste, one of the things that we do, and document storage and management. So one of the things that, you know, I'll kind of talk about and kick off with before we get to the next slide is, you know, the fact that being a data center company, we deal with a lot of organizations that ask questions about e-waste because it's one of the largest IT industry waste streams, if not the largest.

Packaging and things like that are definitely an issue in the IT industry. Folks are still using Styrofoam and all kinds of other packaging materials that are, you know, difficult to recycle. But largely, you know, IT waste and e-waste is the largest waste stream and the largest issue. So with that being said, the reason it ties into my world is because as a compliance professional and an auditor

by trade, you know, running the ISO 14001 environmental management system, that's one of the waste streams that we track. So I'll get more into that as we go through. Next slide, please. There we go.

So I'll start out by describing kind of, you know, why is this such an issue, why should folks care about it and why should it be on everyone's radar and where does it actually come from. So of course, everyone on this call, I'm sure you have offices, you know, when we're not living in the COVID world, that you're in, and you know, computers and monitors, so servers, all kinds of other stuff, keyboards, all of that's e-waste, right. But there is a larger waste stream that some folks have on this call that you may not even know about and, you know, why should we care about it, that's a colocation data center or an enterprise data center.

So whether you know it or not, everyone, even if they don't have a data center that they rent or that's proprietary, we're using one every day. So that basically comes from if you have a smartphone, if you have a device streaming Netflix or you're playing video games or you're using cloud storage for your photos. Everyone uses a data center in one way or another. Data centers are these gigantic storage buildings full of servers that either run, you know, banking, you know, streaming, gaming, social media, government services, healthcare services and records for hospitals.

And then beyond that, those industries also use data centers for backup and disaster recovery. So that said, you know, they contain everyone's servers that they're running the production stuff on. But as you can see in the photo, just a fraction of a data center has – you can see down into the racks themselves there, there are a ton of servers which amounts to something that has end of life or EoL and all IT gear has a specified or theoretical end of life. So when you get to the end of life something must be done with the server. Next slide, please.

So in a colocation data center, which basically means it's a whole army of different industries, different customers, everything else, that's the industry that Iron Mountain Data Center serves. But like I said, some, you know, government agencies may have their own proprietary data center. Some private companies may have their own proprietary data centers as well. But in colocation specifically, which is the industry that I'm, you know, very familiar with and working in it, our customers and their customers are moving servers in and out of the data center. So this doesn't just go for Iron Mountain, this is all of our industry peers, right.

So in colocation if you have all of these racks you may have one rack with brand new equipment and you may have a row of cabinets that has all old stuff and you're decommissioning things, bringing new things in. So with that said, some of the things that are frequently swapped out are servers, hard drives, IT assets such as, you know, crash carts that have keyboards and mice and monitors, anything that you could think of.

They all need two things in order to be decommissioned in the IT world's eyes effectively, which is a secure chain of custody, removing the data from them because of course, privacy is an issue, data migration, where the data lives and all of that, it's paramount. So you don't want any leak of information. So that's usually the first task, is to make sure that everything's erased from it so that there's no risk of data being let out.

But then beyond that, the second thing is, once all of that data is gone how does it actually get disposed of and why is it important to do it in a sustainable and responsible way? In most cases, and up until recently as this has become more of an issue and more important, the second is an afterthought. Next slide, please.

So given that it's an afterthought there need to be solutions to solve the complex problem. So if you rent colocation space or you own your own servers, like I said earlier, you have IT assets in your scope. If you think about it in like emissions, right, if you have a colocation data center that you rent from anyone, it doesn't matter who it is, that's typically your scope for emissions, right. So the electricity that you use.

But think of it this way. If you're renting colocation space at a provider and you're in a data center, your servers are doing something for your network or whatever your service is, those servers are going to have to – you know, so you're managing them, your IT team, your technology team is managing them, something has to be done with them. So it's imperative that you know what your options are and how to do it sustainably.

So with that said, you know, I don't want to plug the product that Iron Mountain has to take this over totally, but regardless of what you're doing with your e-waste there are options out there that can – you know, can accommodate you as a private sector or, you know, government entity. So with any good process, you know, ours too, you should make sure that end of life products are handled in accordance with e-Stewards procedures. These are the

highest compliance and regulatory standards, minimizing carbon footprint and boosting green credibility.

So that doesn't just mean it's all for show. It means that when you decom, you know, the things that I have listed here, desktops, laptops, servers, mainframes, printers, cabling, wiring, copier, scanners, fax machines, A/V equipment, tapes that have data, hard drives that have data, CDs, DVDs, and any other assets such as batteries, point of sale machines, medical test equipment, whenever you're decommissioning those things you want to look for a process that is in accordance with something, either the e-Stewards procedures or something comparable that ensures that you're doing it responsibly and that none of the issues that we'll talk about here in a second arise. Next slide, please.

So this is just a high level life cycle of e-waste, and I'll get into why it's important to do these things responsibly as an organization as we walk through it. So obviously you've got your producers, your Cisco, Dell, HP, Apple, you know, Palo Alto for switches and things like that, all IT gear, right. It goes to a retailer and then the enterprise, which is your company or you, the user, ends up buying it, and after you use it for a set amount of time it becomes obsolete or it hits your tech refresh period and its end of life, which is our yellow-orangish triangle.

Now, there's two things you can do, and sometimes there is a little bit of a gray area here as well, but it can go to a waste hauler that claims they do e-waste recycling and, you know, sometimes if that's not an accredited program and they're not in compliance with law and regulation it could end up in a landfill or to illegal export, which we'll talk about here in a second and why that is so important to avoid. But if you're doing it the right way then it could go to a recycler or a re-user, which is responsible disposal refurbishing. So it's incinerating it responsibly, reusing responsibly, whatever their method is, it's important to understand how that life cycle once it gets to the recycler actually lives and what happens. And then also recycling of applicable components in a responsible manner.

So the reason why we should be so concerned with this, if you don't already know, is because 50 to 100 containers of e-waste arrive in Hong Kong every day with 90 percent of it coming from the US. Now, if you look above in the little diagram, you can probably imagine that that is because of waste haulers that don't do what they need to do in a responsible way. These are waste haulers that are not accredited, they're not abiding with, you know,

compliance with e-Stewards and other practices. They're not ISO 14001 certified. They don't have third parties looking at what they do. So that's why it's so important.

And the extraction of precious metals in third world countries, once it gets to places like Hong Kong or other areas, this is typically performed by coerced child or extremely low wage labor. So it doesn't just become an environmental problem because of the components in e-waste, things like arsenic and mercury that are actually in the components, but it becomes a social governance problem too. So we want to make sure that we're doing it responsibly for the environment but also because of labor and in fair practice. Next slide, please.

So a little bit about the e-Steward standard. This is not an Iron Mountain thing, right. So this is just an enterprise or user program that sets compliance with responsible e-waste recycling and standards. So basically when you look at any program that is in accordance with the e-Stewards standard, they prohibit the export of hazardous electronic waste, as I said before, from getting to the developing countries while allowing viable technology to be reused. It includes the ISO 14001 standard, which is something very close to me and close to Iron Mountain because this is how we track what our waste impact is. So it's a one-stop shop for responsible use electronics management. The certified e-Stewards recyclers are independently audited, right. So if you're a recycler, whether it's Iron Mountain or someone else, and they're certified under the e-Steward program, they are independently audited to assure conformity with the standard, including downstream accountability.

So it's really important that you not only research who you're using as a recycler but that you look for that standard being in place and that all the things that they're doing with their components that they recycle are being audited by a third party. So this is the highest standard for global responsible electronics recycling. It's supported by the US EPA, and as mentioned before, Iron Mountain Data Centers are including e-waste in our ISO 14001 reporting annually for all of our global locations and for ourselves and what we actually decom from our own data centers that we own. Next slide, please.

So to kind of bring it all into one. I didn't mention that much about the program that we run at Iron Mountain. But we do have a secure IT disposal business line that does these things, but kind of the messaging that I want to get across on the broader spectrum and

why I have connected with Andrea and Hannah on this, is because it's really – when we think about data centers, they're kind of these buildings tucked in industrial parks and things like that, but really everyone has a data center issue in one way or another, whether it's scope 3 emissions for energy and electricity use or whether it's because of IT assets that need disposed at end of life.

So I know everyone who works in an office when it's not, you know, this COVID situation that we have, you know, sees the monitors, the keyboards and everything else, you know, we see those being hauled away and those certainly should be going through an e-waste program. But beyond that, the whole mission that I am on here is to get folks to think about what you don't see. Where is your data center? Where is your colocation space that you're renting? Or where is your cloud infrastructure if you own that infrastructure and what are you doing with it when it's end of life?

Typically, the IT folks don't talk to the sustainability folks, right. So bridging that gap is really important and getting folks to understand the environmental impact of their downstream equipment in order to reduce that impact. And then understanding the impact on, you know, third world and developing countries where some of that stuff ends up when it's not taken care of responsibly. So it's not just an environmental and a health and safety problem but it's a social, governance issue when we get into all of that waste being just trucked away from the United States illegally.

So, you know, just getting everyone thinking about that is important. Think about your scope. Think about the things, the data centers in the basement, and if you need more information certainly reach out to me or to Iron Mountain, because even if you're not one of our customers, you know, we can bring you in as a customer if you need e-waste handled. So with that, I'll hand it back over to Andrea and Hannah, and thank you all for your time.

Andrea Doukakis: That was great. Thank you so much, Jim. As a quick reminder, we will be taking questions at the end but feel free to put them in the chat so we can begin to compile those for our Q&A later on. Next up we have Ed Daniels. Ed has been with the REMADE Institute since December 2017. At REMADE, Ed is responsible for managing technology R&D projects that are focused on recovery and recycling materials, integration of recycled materials into the manufacturing supply chain.

Prior to joining REMADE, Ed was with Argon National Laboratory for 32 years. During his career at Argon his research focused on the development of sustainable manufacturing processes in collaboration with the iron and steel, aluminum, chemical _____ and automotive and _____ recycling industries. Ed, take it away.

Ed Daniels: All right, thanks. A pleasure for me to be here this afternoon. Jim, I appreciated your presentation there and I think a lot of what I have to say kind of follows on with your intro, so I do appreciate that. So let me start with the next slide, please.

So what I'm gonna do is I'm gonna give you a brief overview of the REMADE Institute. I'm gonna talk a little bit about the challenges associated with e-waste recycling in general, and then touch on some of the projects that we're actually conducting to enhance the recycling of materials that can be collected and recovered from e-waste. So next slide, please.

So REMADE is a public-private partnership. Actually our partner is DOE, the Advanced Manufacturing Office. We're one of the manufacturing innovation centers that have been launched by – actually through the US government. Some of the institutes are managed by DOD, some by DOE, and I think one is actually managed by NIST.

So the goals at REMADE is we're actually focused on recycling and remanufacturing. So that is what do you do with materials and equipment at the end of life and how do you handle them and how do you extract the resources and do it in an environmentally compliant manner and achieve the benefits that necessarily derive from recycling and remanufacturing materials? So we're really focused on developing transformational technologies that enable US manufacturers to expand recycling to reduce their primary materials consumption, increase use of secondary materials. And then what comes along with that is reducing energy consumption and industrial manufacturing and emissions – reducing emissions. Next slide, please.

Okay. So US manufacturing today accounts for about 25 percent of US energy consumption, so about 25 quads of energy. REMADE is currently focused, as a result of its charter, on four classes of materials. These include metals, polymers, fibers which includes paper, and e-waste. If you look at those four materials classes their manufacturing currently accounts for about 7 quads of that 25 quads of energy that's consumed in US manufacturing.

So to the extent that we can recover and recycle materials at the end of their life, we can, of course, reduce the total energy consumption, the seven quads, to the extent that we can recover and reuse those materials. Next slide, please.

So the way we approach work at REMADE is we actually have five nodes that are related to material life cycle. We have systems analysis and integration where we try to understand how materials actually flow in the economy including end of life materials. We look at design, are there design options that can improve the recoverability or minimize the energy consumption associated with production in these materials. Manufacturing materials optimization, which is really focused on how do we integrate secondary materials back into manufacturing. Remanufacturing, which is of course, many people aren't aware of this, but remanufacturing is actually a thriving industry in the United States and some of the equipment that are remanufactured are, of course, automotive components and even electronic components are remanufactured for reuse. And then of course, materials are recycled and then recovered and so we have research programs in all of these areas. Next slide, please.

We are a membership organization. Our members include industry, academia, affiliate organizations which include organizations such as the Institute of Scrap Recycling Industries, other trade associations, five national labs. We pretty much cover the country and our affiliate organizations also give us a network of an additional 3,000 individual companies, many of whom are directly involved in recycling and remanufacturing. Next slide, please.

These are just some of the institute highlights. Our research agenda, we issue request for proposals, so all of our projects are awarded based on competitive solicitations, very similar to processes at DOE's just for its own solicitations. To date we have awarded something like $20 million in projects. We have just released an RFP actually the response date has just passed this past week. The RFP that we had on the street was for a total value of about $70 million. All of our projects must be cost shared dollar for dollar, so a dollar of federal funding requires a dollar of cost share. Next slide, please.

So just a couple of statistics on e-waste. I'm not gonna go through all of these slides in detail. But the latest numbers that we have from EPA are there are about ten million tons of e-waste that are generated annually. Currently roughly about 31 percent of that are

actually recycled and that's not to say that the balance is disposed of inappropriately. Much of it may end up in landfills but with small components such as computers and cell phones and so on and so forth, many of us have old cell phones. In fact, I've got an old cell phone sitting right on my desk. And so a lot of those materials just don't enter the recycle stream.

The other thing I want to point out, so we've talked about e-waste. It really need – you need to define what your starting point is. So EPA currently includes in e-waste large component, such as refrigerators and washing machines and dryers and that actually accounts for about five million tons of the ten million tons in total. The interesting thing about large components is that they are currently recycled through a process. Today, commonly they're recycled with obsolete automobiles through auto shredders.

And if you look at Europe, Europe actually has something like six different classifications in e-waste. So when we look at the work that we're doing at REMADE, it's really focused to date on small IT equipment, A/V equipment, those types of equipment. Next slide, please.

The typical materials composition of e-waste, so we have ferrous metals 34 percent, non-ferrous metals 17 percent, polymers about 33 percent, and then we've got a mix of other materials, and it really depends on the type of material we're talking about. So, for example, if we're looking at large components, they tend to have more metals in them relative to polymers. If we start looking at things like mobile phones, very high polymer content relative to metals content. Same thing with televisions and home A/V equipment is pretty equally balanced. But it really depends on the type of equipment that you're looking at. And of course, at the end of the day all of these materials are ultimately recyclable. They are not necessarily recycled, though, and part of that has to do with technology. Next slide, please.

So Jim talked about – well, one comment about precious metals and precious metals are, of course, present in e-waste. They are typically present at contents of below 100 parts per million. And typically those folks who are in the e-waste recycling business will usually send their e-waste that contains precious metals to a smelter. Hopefully it goes to a smelter such as those that are located in Canada as opposed to being illegally shipped offshore and end up being processed in some of those third world countries such as Jim mentioned.

Nonetheless, what we see is that – what we've heard is that the precious metals content in many of these components is, of course, decreasing for obvious reasons, it's expensive stuff so you try to lay it on as thin as you possibly can to achieve the objectives of your product. And to the extent that the precious metals content is decreasing that of course decreases the economic incentive for recycling a lot of these materials to begin with. Next slide, please.

Another challenge in e-waste is, of course, the polymer content. Typically we can separate the polymers from the metals in e-waste, but separating the individual polymers from each other is yet another challenge, and fortunately what we see is that there is a significant concentration of specific types of polymers in e-waste, although there are more than 100 different types of polymers that are actually used depending on the product. But in general, the bulk of polymers in e-waste are the polystyrenes, the ABS's, PC/ABS alloys and high impact polystyrene, which actually gives us an opportunity to start looking at recovering those individual polymers and recycling those individual polymers as opposed to many of those that would otherwise end up in landfill. Next slide, please.

So let me just briefly summarize some of the projects that we have going on in this space. So the first one is mapping the materials base for REMADE. So one of the key challenges that we have is that a lot of times, and it's especially true with e-waste, we really don't know where a lot of this material ends up and so we're trying to track the sources and supplies of these materials so we can understand how we might bring them into the recycle stream.

As I mentioned before, the best numbers that we have indicate that something like 20 percent of these materials are recycled. These are the small components such as computers and small electronic equipment. So from our perspective, we'd like to get a much better understanding of where all these materials are at their different stages of life cycle so that we can understand how we might better intercept them into the market. So we're actually doing this not only for e-waste but all of the other materials that are relevant to REMADE such as polymers, fibers and metals.

Of course, the data that we have to date for metals is pretty – that's really pretty good data so there's not much effort that we need to put into that. But e-waste is really problematic in terms of figuring out exactly what's out there. Next slide, please.

Another challenge that we have with e-waste, especially – many of

the e-waste recyclers in the US are relatively small companies and they focus on a local area and all you have to do is google and you can find an e-waste recycler in your area. One of the challenges that they do face is they really don't have sophisticated logistics models that allow them to source material and bring it back into their operations to effectively process that material.

So one of the other projects that we're working on is we're developing a reverse logistics model for local e-waste processors so they can understand how far they can actually go to collect and source material and hopefully scale up their operations to, you know, capture more of this material and bring it into a legitimate recycle stream. Next slide, please.

I think a key thing, as I mentioned earlier, is that some of these materials could actually be remanufactured as opposed to recycled for their materials value but they can be remanufactured and reused. And one of the challenges that we have with that is it's difficult to assess the condition of used electronics and so typically if you – the bulb test that you have usually do a sample and you sample to destruction, you run the test to destruction. And then if you *[interference]* destructive test actually passes then you pass the sample.

What we would like to be able to do is to have nondestructive tests to actually evaluate the condition of these used electronics when they come back. So one of the projects that we have that we're looking at is actually various microscopy and spectroscopic technologies that would allow us to do nondestructive evaluation. And of course, all of this has to be done at very high speed, very high throughputs in order to meet the economic challenges that also impact e-waste recycling. Next slide, please.

In the production of electronic materials, not necessarily e-waste but in the production process there are of course rejects that result in the production process and circuit boards is a key issue. Now, if you have a high valued circuit board, you're of course gonna go through the exercise of trying to recover that circuit board, but for lower valued circuit boards you're often just going to reject them. So one of the things that we're trying to do is to develop, again, high speed techniques for removing the plotting material from defective circuit board components. The challenge here is that you want to remove the plotting material but you don't want to damage the underlying circuit board otherwise you've destroyed the board, right.

So we're looking at two techniques, these are laser ablation and media blasting. Right now the laser ablation at this stage of the project seems that it might be successful, although it's gonna be staged laser ablation. The closer you get to the base of the circuit board you really have to slow down your process so you don't damage the base on the board. But again, you know, the real challenge here is to get these processes to be high speed, high throughput, again, to meet the economic challenges. Next slide, please.

So we talked about materials recovery. One of the challenges, of course, with e-waste is it is a blend of these materials that metals, polymers and the precious metals. And actually when we talk about precious metals, typically when materials are sent to a refiner who actually recovers precious metals typically using a pyrometallurgical process, this would be a very high temperature process, they recover not only the precious metals but they'll typically recover the copper. And usually the fee that's paid by the refiner is based on the copper content as well as the precious metals content for these materials.

Now, as the composition of the content to the copper, gold, silver, and in some cases other materials but lesser extent *[interference]* decreases, it becomes less of a value proposition to actually send these materials out for recovery. So one of the things that we're trying to do is to actually take these e-waste fractions and you see some of them where after they've gone through a shredding operation, and basically apply a novel leaching process. This is somewhat an adaption of heat leaching that's used for ore processing in the US today. But we're doing it in small columns and the focus here is to recover the gold and silver and also the copper and to do it at a much lower cost and to be able to do it effectively at a much lower precious metals content than you would otherwise need if you were going to send these to a large-scale processor.

So at this point, the work appears to be relatively effective certainly in terms of copper recovery. The challenge that we have with this particular process is that it's not as effective on the silver recovery, so we're trying to push the processes a little bit harder to see if we can be a little bit more effective there. Next slide, please.

So as I mentioned earlier, plastics are a key component of e-waste and what we would like to be able to do is to first of all not only separate the plastics in bulk from the metals, which is actually pretty easy to do, pretty straightforward to do that. Recovery of the

metals other than the precious metals is actually pretty straightforward using conventional technology, but selective recovery of the polymers is a challenge, again, especially at the relatively small scales that most e-waste processors operate.

So work that we're doing here is actually using solvent extraction to selectively recover the individual polymers. These include – actually the target polymers for this project are the ABS and the high impact polystyrenes and the work is proceeding quite well.

Another challenge that I think is worth mentioning just in terms of recycling these materials, in general, is quite often there are residual materials that are included in some of these products for very good reasons, such as brominated flame retardants are included in some of the polymers to prevent fires or, you know, burning of some of the – inadvertent burning of some of this equipment. And then by the time the product is introduced to the time it gets to the end of life their regulations that may change so we're faced today, not so much in the US but it's coming, but certainly in Europe, you cannot recycle brominated polymers.

So the thing that you need to do is you need to be able to remove the bromine compound, excuse me, compounds from the polymers, and one effective way of doing that is by dissolving the polymers in a solvent and then precipitating the polymers out of the solvent and leave behind the brominated compounds. And this slide I think is my final slide. So if you have questions, be happy to answer them. You can also look at our website for more additional information or additional information.

I would say, you know, most of the projects I talked about here today have only been ongoing for about a year and they typically run about 18 months to two years. We're very hopeful that these projects will be successful and we look forward to making an impact with regard to how these materials are recovered, remanufactured and recycled. So that's all I have for you today.

Hannah Debelius: All right, thank you so much, Ed, and Jim as well for all this information. _____ mentioned in our planning but as a consumer oftentimes the only interaction we really have with e-waste is just, you know, dropping my cell phone in a box somewhere and it's really _____ to pull back the curtain and just learn a lot more about the process behind that so thank you both so much.

I'll start just with a quick clarifying question, Ed, that came in from

you which was a question about if the emissions impacts that you showed _____ in your 2019.

Ed Daniels: Yeah. So actually I think that – the data that I showed – so the emissions are actually based on the reduction in energy and I think it was based on 2017 data.

Hannah Debelius: Okay.

Ed Daniels: 2017.

Hannah Debelius: Great, thank you.

Ed Daniels: It might have been 2016 but right around that timeframe. Yeah.

Hannah Debelius: Great, thank you. I also – so I see that there is another question for you, Ed, but I want to switch over to Jim just real quickly. Jim, you spoke a lot about the certification that you all work with, I believe e-Stewards is what it's called and it's really interesting. So as I'm asking this question of you, I'm also curious if anyone else on the call, particularly maybe on the commercial side, who might be relying on that to make some – relying on certification to make some of these decisions, if there were any other certifications that you have looked into or utilized. So if you have an answer to that go ahead and put it in the chat.

But Jim, I'm curious. You mentioned the importance of kind of making communications connections in between IT and the sustainability or facility staff that need to work together on this but don't always have that line of communication. Do you have any suggestions or best practices for making that connection?

Jim Henry: Well, most of it's about third parties, right. So when you're engaging with like a data center provider or someone who is going to be doing some IT work for you in one way or another, it's just really good to start thinking about connecting the folks in the IT department with the sustainability or the energy management people. Internally, of course, it's always easy, right, if there is a big IT project underway and you own your own data center or you're working on a big refurbishing project or something like that, the people talking internally it's always the easy part. But if you're outsourcing a data center or something like that, it really falls on the third party to kind of ask the right questions to connect the dots.

It's something we're still working on when we have customers

come to us. You know, two years ago we would have never asked the question, hey, have you talked to your sustainability folks because we can help you, you know, reduce your emissions and we can help you with IT asset disposal. But I really think it's just a – it's a culture shift. IT, you know, whether it's data centers or anything else, there is a lot of consumption of energy, right. So that plus e-waste plus social impact, I think it just really takes a culture shift to make sure that the IT folks and the sustainability folks all get on the same page, that way you're focusing on your emissions, your assets and ultimately, you know, the impact that you have on the environment.

Hannah Debelius: Yeah. That really resonates with me especially since we've had so many conversations with partners that are on the call also about creating that culture shift and sometimes it's kind of top-down and sometimes it's bottom-up, so that's great.

Andrea Doukakis: *[Crosstalk]* question, Hannah?

Hannah Debelius: Yeah, sure.

Andrea Doukakis: So for Jim or for Ed as well, if you'd like to share a thought on this. On a similar note, do you think, you know, due to the rise in ESG reporting and how that's becoming more mainstream, do you think more, you know, clients or customers, you know, who are using the colocation space, do you think that they might be – do you think there is more of an increase for space that is managed by e-Stewards or other certified areas?

Ed Daniels: So I think Jim probably knows much more about this than I do, but I would just comment that what I see, especially for folks that are producing small consumer products, right, there is much more interest by the producers of these products, such as phones and laptops and so on and so forth to ensure that at the end of life that their products can actually be recycled in an environmentally acceptable manner. And actually we're starting to do work with a number of companies in this space to actually help them design their products so that they're more effectively, or more easily recyclable.

So I think there is an increase in the interest. I think it's gonna be coming even greater in the next few years, you know, so. I don't know if you have any – I think that in general, though, it's a little bit easier to – especially if you have – it's a little bit easier to deal with commercial consumers of these equipment as opposed to the individual consumer. Because quite often the individual consumer

doesn't quite know what to do with their old cell phone or their old computer or, you know. So it's a little bit more of a challenge in that space.

Jim Henry: Yeah, I would echo most of that and just say that the increase of pressure to have a corporate sustainability report is really – that pressure is good, naturally, because it's forcing folks to start reporting on the things that, you know, five years ago you really didn't want to talk about. So with that said, you know, whether it's emissions or whether it's waste and what you're diverting from the landfill, I think there is an increased pressure for folks to think about what they're buying and what they do when they need to get rid of it.

But you know, beyond that the reason that I always go back to data centers isn't just because I work for one but because data centers are really this – it's the machine driving everything that we do every day, right. The call we're on today, right now, is being run out of a data center somewhere. I couldn't tell you where but it is, you know. Our phones that are connected, our TVs, the streaming, everything – every single thing you do ultimately, you know, the cloud lives in a data center. So whether anyone likes it or not, data centers have to exist and they have to scale with innovation and with inventions and other things and applications that are, you know, contrived from ideas.

So data centers are only going to grow more and right now data centers rival the airline industry with emissions globally, right, just on emissions. But so from a waste perspective, it certainly makes sense that folks who use data centers and own their own data centers include e-waste and include waste stream in their corporate sustainability reports because it'll drive the industry to make wiser decisions about, you know, what Ed has mentioned, create your products in a way that they can be disposed of easily and responsibly.

And then, you know, one thing that I constantly battle with is package your product so that the packaging can be disposed of in a responsible way. You know, stop using Styrofoam, make better decisions about how you actually ship those things to your customers and think about your supply chain. So I think that the corporate sustainability reports will be really important in figuring out who is doing the right things in the next few years.

Hannah Debelius: Thanks so much. And, you know, both of you mentioned a little bit about kind of _____ _____ analysis or planning for the disposal of

the product and trying to reduce the waste there from the very beginning, right, _____ before you create it. So I'm gonna throw the question back out to our audience a little bit if you want to answer it in the chat which is, do any of you have success stories about the reduction of e-waste and how you're reducing it, you know, before you even get down the line of trying to responsibly recycle it?

And hopefully while you're doing that, another question came in, I believe for you, Ed, which says curious on the reverse logistics part. Can you share any info on that?

Ed Daniels: Yeah. So of course, you know, the real challenge with – as I said, many of the e-waste recyclers in the US are actually relatively small, they're regional and, you know, if you just put down a bunch of regional circles in the US you're gonna have a lot of open space where materials aren't recovered from. So one of the things that we're trying to do with the logistics model is actually determine, depending on what kind of vehicles you're running or how you do your collection of your materials, how far you can actually go to recover materials depending on the quantity of materials and whether or not you might need to consider whether you have feeder locations or you just have one central location.

So looking at those types of challenges. And of course, when it comes down to the whole business of recycling these materials, that's another logistics issue because you need to have enough material to process where it actually makes business sense for someone to actually get into that business, right. So there are all kinds of volume limitations that face this industry. And so that's what we're trying to do with the logistics model at this point. We're actually building a case study on a very specific system and then we'll be trying to adapt that case study to other systems in the next year or so.

Hannah Debelius: Great, thank you. And we had a follow-up on that from the same person, which said reverse logistics are one of the hardest _____ _____ in a circular economy. So it sounds like we'll keep an eye peeled for resources you have coming out for that.

Ed Daniels: Right, right.

Hannah Debelius: I had another question come in through the private chat, which is – I think – well, maybe _____ Ed but I hope both of you can weigh in. Which is, how much more remanufacturing is possible and what sectors could do more?

Ed Daniels: That's a really good question. So, I've forgotten exactly what the numbers are, but roughly we estimate that about 2 percent of the manufacturing business volume is actually due to remanufacturing, so it's really quite small in that sense. But if you look at the energy benefits and the environmental benefits, it's actually quite significant. So we're talking about numbers on the order of let's say a quarter of a quad of energy per year and then whatever the associated emissions would be with 250 trillion BTUs a year.

Now, the real question is how hard can you push that and how much of an increase can you get. So what we're looking at is – so many large components such as automotive components and heavy-duty off-road components are remanufactured, and medical equipment is remanufactured. And so what we're really looking at is trying to increase the remanufacturing of, you know, smaller, lower valued components. These could include driveshafts, you know, and especially mechanical and electronic components which is really an open area these days.

And here, the name of the game, as I said in some of the work that we're doing, is actually to take manufacturing process technology but be able to scale it down and adapt it for high speed, low volume remanufacturing operations. If we can do that we anticipate that we could have a very significant increase, more than a 50 percent increase in remanufacturing across the board. And it goes for almost all sectors, so medical equipment, aerospace, automotive, heavy-duty off-road, electronics. So you name it. There something – remanufacturing that goes on in just about every manufacturing sector today.

Hannah Debelius: Great, thank you. Well, we are gonna need to wrap up here, but Jim, any other final thoughts or words of advice you would like to share to close us out?

Jim Henry: I think just looking at some of – like the research that Ed has, just going at a really granular level is really good. I think that's what folks need to see in addition to understanding why it's really important to care about e-waste. So it was really good to see that stuff. I mean that's not something I think about. We often talk to our customers about why it's important to do something responsible and then, of course, downstream, the more you know about how things are remanufactured and refurbished, it's really impactful.

So seeing that side of it from Ed is really interesting to me. And

now I've got to wonder how many components sitting in our data centers are remanufactured. So it's gonna be really interesting to ask our customers about that.

Ed Daniels: Yeah, yeah, yeah.

Hannah Debelius: Great, thank you. Well, I'll turn it back over to Andrea to close us out here.

Andrea Doukakis: Thank you. I'll take _____ _____ question. Just wanted to say a quick thank you to everyone for attending. We love having these events so again please let us know if you have any comments or feedback or ideas for future calls. The slides of the recording will be available soon. We'll let you know when those are ready. And our contact information is up here in case you need it. But _____ _____ of you know how to get ahold of us. So thank you so much and enjoy the rest of your week.

Ed Daniels: Thank you.

Jim Henry: Thanks _____.

Ed Daniels: Bye-bye.

[End of Audio]