Marta Drzymala: Hello and thank you for joining the webinar today. We're going to give folks another minute to log in and we'll get started soon.

Alright, let's get started. Hello, everyone, and welcome to the Waste Reduction Network Quarterly Webinar Series where we explore waste reduction topics, technologies, and trends. Today's webinar is called Remanufacturing and Beneficial Reuse in Industry for Circular Economy. Before we dive in, there are a few housekeeping items I would like to cover. Please note today's webinar will be recorded and archived on the Better Building Solutions Center, and we can follow up with you afterwards with a link to that. Next, you will be in listen-only mode, so your microphones are muted for now. In just a moment, I will be passing the virtual microphone to our moderators and speakers. But before we delve into the exciting presentation, I'd like to take a moment and provide you with a couple of brief programmatic updates. Next slide, please.

Summit – the U.S. Department of Energy's 2024 Better Buildings Better Plan Summit will be April 2nd – 4th in Washington, D.C. This event will feature engaging and interactive sessions as well as opportunities for attendees to network with industry peers and national experts. Registration details are coming soon, so please be on the lookout for that. Next slide, please.

Better Project and Better Practice awards – I just want to remind everyone that this is open to the Waste Reduction Network participants. Please make sure you download the application and submit it no later than January 15th, 2024. If you have any questions, you may contact any one of us. The contact information will be provided at the end of the webinar. This Better Project Better Practice award recognizes outstanding accomplishments in – at industrial facilities, at the Better Practice Award recognizes the implementation of practices and procedures more broadly. So, this really is open to many creative projects and practices. So please check it out. Next slide, please.

I want to extend our heartfelt gratitude to all of our partners who joined the Waste Reduction Network as your collective efforts have truly brought us together and taken significant steps towards a more sustainable future. Your commitment to sharing best practices among this group is making true positive impact. Next slide, please.

So, with no ado, I want to introduce you to the Waste Reduction Network team. My name is Marta Drzymala. I'm an ORISE

Fellow in the Building Technologies Office, and I am working with our Better Buildings partners across the healthcare and public sector. On the Waste Reduction Network, I have the pleasure of collaborating with John and Bruce who are representing the Industrial Efficiency in their Decarbonization office, Subodh from Oak Ridge National Laboratory as well as Jasmine and Julia, our contractors. Next slide, please.

So just a little reminder of what our team does. We aim to provide comprehensive solutions for organization seeking to enhance their sustainability initiatives. So, these – there are tons of resources that we develop permanently featured on our webpage. These are dedicated and focused on strategies to increase waste diversion, reduce source generation, harness energy recovery methods, lots of fantastic resources for you, so please don't forget to check it out. Next slide, please.

So, we have a great lineup of presenters today. Allow me to introduce you to your moderator, Bruce Lung. Bruce is a Senior Technical Advisor at Lindell and Reed, and he's working with DOE's Industrial Energy and Decarbonization Office where he supports the Better Plants and other technical partnership programs by helping with expansion of industry participation and insuring that the program offer value to manufacturers and industrial scale energy users. For more than 20 years, Bruce has supported energy efficiency and clean energy programs through research and analysis of best practices and technologies as well as outreach and policy analysis on behalf of federal, private sector, and nongovernment organizations. Bruce serves on the U.S. Technical Advisory Group to PC 242, the Advisory Committee to the Industrial Energy Technologies Conference and the Horizon 2020 Multiple Benefits of Energy Efficiency Project. Thank you for being with us today, and with that, I will hand it off to Bruce to introduce the rest of the panel and kick us off.

Bruce Lung: Well, thank you very much, Marta. Thanks to everyone who has joined us. One quick note I'll just add, we were able to add a new partner to the Waste Reduction Network last week – Eastman Chemical Companies. So please join me in thanking and welcoming Eastman Chemical right there. Today, we've got a really good presentation – set of presentations – on remanufacturing as it fits within circular economy. What I'm going to do is I'll present each speaker individually. That way we don't spend a lot of time just reading bios all the time. But our first speaker is going to be Subodh Chaudhari from the Oak Ridge National Laboratory, and what Subodh is going to talk about is a

paper that he wrote – cowrote for the Remade Conference earlier this spring that focused specifically on remanufacturing. Currently, Subodh is a Technical Account Manager at the Oak Ridge National Lab in Knoxville, Tennessee. He completed graduate studies in industrial engineering from West Virginia University. He has a lot of experience in the field of energy efficiency and sustainability from poultry farms to petroleum refineries and other industrial sectors. He has conducted energy assessments in various roles at manufacturing plants and commercial buildings. Before working at Oak Ridge, he was an energy engineer with Hudson Technologies leading product development efforts for various platforms for Chillers, Cooling Towers, and Heat Exchanges. He also worked as an engineer and scientist with the National Research Center for Coal and Energy at West Virginia Industrial Assessment Center to provide energy efficiency assistance to local manufacturers and other state and federal assistance programs. So, Subodh, next slide, please.

Subodh Chaudhari: Thank you. Thank you, Bruce. I will get us started, so in this – when we talk about waste reduction, we – and take a look at how much waste is being produced in the U.S., EPA tracks the municipal solid waste. And so, from the data released by EPA, there are 300 million tons of municipal solid waste generated every year. That is from residential as well as commercial entities, but the nonhazardous solid waste that is produced by manufacturers is not tracked. There are about 600,000 entities in the U.S. that are registered as manufacturers, and so that becomes significant waste that is not being tracked. One estimate that was created by EPA, it put the waste estimate at about 2.7 billion ton per year of nonhazardous solid waste. So, all of this waste is basically, it is not being recycled. It is going to a landfill. This graph to the right is the graph that is used by U.S. Geological Survey report, and so there we can see that in the last century, as our economy grew, our material consumption has grown with it. And we almost consume or extract four gigatons of material from the nature and which is used. One thing to note for this graph is it does not include the imported material goods. So, all of the materials that are imported are not included in this estimate. Next slide, please.

And so, in that 300 million ton that is – that we saw was the municipal solid waste that has also grown over the years the EPA has tracked it. So, from less than 100 million tons in 1960 to the last estimate which was in 2018, we _____ from about 90 million ton to almost 300 million tons. Per capita generation of waste has also doubled. So, from 2.5 pounds per person per day to 5.0 pounds per person per day. So where does all this waste go? For

municipal solid waste, we have some good idea. About a quarter of that waste does go for recycling through the material recovery facilities. This waste is directed towards different kinds of recycling, and about one eighth of that waste goes for energy recovery, but 50 percent of the waste goes to landfills. These landfills are the problem for which we want to look for solutions and avoid as much waste that is generated in our operations. Next slide, please.

So, 50 percent of the waste comes to about 146 million tons. And what is contained in this waste? The waste that goes to landfill contains about 25 percent food or 18 percent plastics. So, all this waste that is going to landfill is bad because of the organic material is has, because that creates methane which is bad from the GHG perspective for our environment, but the environmental impact is not only limited to the methane gas that is released from these landfills. It also contaminates our water table as well as creates contamination for our soils and it can lead to different diseases or extinction of the microorganisms that reside in the soil. Next slide, please.

So, the impact of waste is theorized to follow the iceberg model. So, for every 10 percent visible and foreseeable impact that we see out there, more than 90 percent of the impact is hidden, and that impact can damage our natural systems and disrupt our cycles – natural cycles that help us in our day to day living. Next slide, please.

So, what is the solution to this problem? Circular economy promises to solve this problem. We saw that our consumption has increased with the economy. As our economy has grown, our material consumption has increased with it. But circular economy promises to disconnect the increase in economy of the material consumption. So, the linear model that we have followed is modeled on take the resources from the Earth, make the products, use the products, and whatever is not usable, send it to waste. So, and this model basically has caused us the problem that we face today. So circular economy report that is used by the Circle Foundation is it tracks the global circularities core and global circularity gap in our consumption. They looked at the material – global material consumption and have found that our consumption has almost doubled from in last 20 years. We are consuming about 50 gigatons worldwide. We were taking 50 gigatons of materials from the Earth and in 2021, that has increased to about 101 gigatons. That is a significant increase, and we definitely have to think about alternative ways how we can reduce and slow this

unsustainable growth. From the method, the Global Circularity Foundation has put together, they estimate the current circularity's core for our global economy is only 7.2 percent. So almost a 90 percent of the material that we extract is used one time only. Next slide, please.

So, what is circular economy? So circular economy is basically it can be defined in three distinct pillars. Those pillars are based on the hierarchy that has been created by EPA as well as Better Plants Program. So that is reduce, reuse, and recycle. So, whatever we are using, we should reduce that. Whatever is possible, we should reuse or recycle, and then things that we cannot reuse or recycle, we should see if we – there is some kind of material energy recovery is possible from them. Then if not, we go to towards treatment or disposal. Circular economy principles follow the same hierarchy. So, the three pillars that is rests on is the source reduction. So, whatever we need, do we need that or is there a smarter design out there which we can use to reduce our material consumption? Then when we are actually using the product, how can we extend the life cycle of that product? Can we do – can we improve our design so that our life cycle is increased, or can we offer evaluative services by which the products stays in use for a longer period of time. Then at the end of life, when there is no more use possible, how can we extract the resources used in the product sustainability so that we can reuse them again? Next slide, please.

And so, there are, based on these three pillars, there are nine different pathways that manufacturers can utilize to practice circular economy principles. So those principles can be based on source reduction or today, we are going to focus more on extending life cycle and we are going to look at remanufacturing and beneficial reuse later in our presentation. As the circular economy proposes, the value of that circular economy or the pathways can bring us is high if we are on the higher side of the hierarchy. So, if we are looking at source reduction, that gives us more value in terms of sustainability and circular economy than if we are going towards recycling or recovering materials from the end-of-life products. Next slide, please.

So, let's look at the manufacturing. Remanufacturing is a process through which we look at products and end of life product and recertify them by following a process to new condition or better than new condition. So, the value that we offer to our customers is same or even better through remanufacturing. So this can prove to be really helpful strategy in terms of the waste that is created in the

manufacturing process or energy or other resources that are spent during the manufacturing process, but we have to be cognizant that this is not a solution for all the products, but for the products that have – that are based on different components assembly, this could be a viable alternative. There are different industries that have successfully practiced remanufacturing and electrical equipment industry has used remanufacturing for transformers, switch gears, and similarly, even furniture industry has used remanufacturing to acquire old, used furniture and produce newer furniture. We are going to take a look at how Volvo has incorporated manufacturing in their business model and benefitted from that. Next slide, please.

So, in the second strategy that we're going to look at is the beneficial reuse. Beneficial reuse is defined as the use of the material that would be otherwise discarded in a similar or alternative function. So, it's basically reducing the consumption of virgin materials for the alternative use. So, it highly depends on what – how much of the material or product is available and how much do we need in the alternative application. The usage of this strategy depends on the two applications, and it is restricted by the knowledge of one industry and application of that knowledge to the second industry. We have seen beneficial reuse in many industries. Plastic industry is one of the prominent one where they have used their processed waste in newer or different product manufacturing. Similarly, tires have been reused in production of asphalt or other products that are used for turfs or in other different businesses. And we are going to hear from Bryant later on how spent foundry sand has been reused by Waupaca in different applications. Next slide, please.

So, in conclusion, remanufacturing and reuse are high impact strategies that have been practiced by manufacturing organizations for a very long time. They are proven strategies to reduce waste and can bring savings in terms of material, energy as well as other resources. And the economic value that we can create from this of course varies, but it definitely can give us large savings that we are looking for and high impact waste reduction. There are barriers to the adoption but we should – when we are evaluating the strategy, we should take a look at these pathways, so that we are part of the circular economy in our production. Next slide, please.

Yeah.

Bruce Lung: Well, thank you very much, Subodh. I'll go ahead and introduce Bryant Esch real quick from Waupaca Foundry. Interestingly, Waupaca is a pretty big foundry in Wisconsin, and one of our

stalwart partners. So, Bryant Esch is currently a Corporate Sustainability Manager with Waupaca. He has over 30 years of experience in environmental engineering, environmental health and safety and coordination of environmental compliance in sustainable activities. Bryant also serves as the president of the Wisconsin Cast Metal Association Board of Directors and has been in the position since 2017. So, Bryant, take it away.

Bryan: Thank you, Bruce. Good afternoon, everyone. Thanks for spending some time with us to talk about beneficiary use in the foundry industry. We'll just kick off into it. Next slide.

And if you look at actually what Waupaca Foundry does, basically the simplest way to describe that is we are taking in scrap metals that other folks don't want and turning it into something new. Here you see some examples of different types of scrap and materials that are being used to create new castings. These castings are actually poured into a sand mold after being molten of course, and to be made into the new shape of the new item. When we talk about remanufacturing, definitely the base part of our business, and as you can see from some of the things here, we are definitely a primary constituent in remanufacturing and handling of all different kind of metallics to turn that into a new product. It's a virtual certainty that everybody on this call actually owns something from Waupaca Foundry. You just don't realize it because it's inside something else. A lot of times, we do a fair amount of automotive work, and a lot of other types of items that a part made by us will not be obviously on the label on the outside of the product, but it's in there. Interestingly, we're not going to dig a lot deeper into that element. We're going to talk more about even though we have a lot of sustainability circular economy going on here with the metallics, we're maybe right now concerned a little bit more on what's going on with other process byproducts. So next slide.

And here you can see for a number of years now, we've had our environmental sustainability vision. As you can see, there's a number of topics here. Of course, energy is a very big deal to us. We're a large consumer of energy and also you can see there in yellow is I think what we're going to focus on today which is the beneficiary use of spent foundry materials. So, when we actually create a new casting, we have to actually use a molding material that will not melt. So, when you melt iron, you're at a temperature of approximately 2700 degrees, and obviously we can't make a mold out of wood or other metal and pour that hot iron into it because it would actually start it on fire or cause that to melt, and it

wouldn't work very well. Well, it was discovered a long time ago that sand actually has a higher melting point than iron. If you can take that sand, add a little bit of clay, just the right amount of moisture, and you create a product that in the industry we call green sand, which basically is a sand that when you want to form it into a shape, it will hold its shape very nicely. As a matter of fact, if anybody was into building sandcastles at any time in their lives, it would be absolutely perfect for making incredible sandcastles. So, we are doing that and when we use that sand, we actually have a long history in the industry of recovering that sand and using it over. So, if you're one grain of sand in our process, you would actually get used a little over 30 times. But we have some other things going on in our process that eventually requires that these materials be essentially pushed out the door and I won't get into it super deep today, but we actually – if you're making a more complicated casting with a hollow interior, you have to use what they call core technology. And when you use a core that is also made out of sand, when that's done with its use, it becomes part of the sand system. Really what's happening is that even with all the reuse we have internal to the building, when we reuse that sand over and over again and put more and more cores in, we end up with sand that is just too much. Our silos become more full as the day goes on, and we have to purge some out. Next slide.

So, what's interesting is when you look at many years ago, foundry waste were considered exactly that. It was a waste material, an industrial waste. It was not hazardous or anything like that, but under the laws that existed, that had to be put into a landfill or somehow disposed of in a way that was consistent with the regulations. That continued and still continues to this day, but there was a big shift in the late 1980s. At that time, both US EPA and a lot of the states began to realize that certain types of foundries, if you do all the environmental testing on that material, it is not – there's no environmental concern. It's not toxic. It doesn't pose any kind of leeching concerns or anything like that. So, the question was asked, "Why can we not use some of these type of foundry materials such as from gray and ductile iron foundries like Waupaca Foundry, why can't we use that as a beneficiary use feedstock for different kinds of projects?" So that really – there were some studies that was done and some case study projects. Basically, from the late '80s through the '90s and to present, we've gotten to a point where this type of beneficiary use has been very well documented, has a lot of good history to it, and we're just seeing expansion of that as the years go on.

In the foundry industry, Waupaca Foundry is considered to be a large foundry. In our case, basically delving into this program results in more than 400,000 tons per years of foundry sands and foundry slags that can be used for other purposes other than disposal. So here you see some examples of the types of products or applications that are typically seen in the foundry industry. One is flowable fill. Flowable fill is where you're taking those foundry byproducts and you're adding just enough moisture where you could almost flow it like cement from a cement truck. It's really nice as a backfill on utility projects and projects of that nature. That – a lot of our facilities happen to be in rural areas. You tend to see flowable fill more in use in more urban areas. So, us personally, we have not gotten into a lot of that, but that is an application that exists. Then you'll see under the road construction side of things, you can have either embankment fills or just out and out subbase for roads. That's a very common use for things such as foundry slag and foundry sands. The beauty of these kinds of projects is traditionally if you look at the department of transportation and they're doing a large project of one of these two types, what would they normally do? They would get a borrow sight from somewhere nearby. That would be part of the contract.

Somebody would actually mine those materials somewhere adjacent to the product if they could, to keep their transportation costs down, and then put it into the project. The beauty of using foundry beneficial use materials is here you have product that's already been mined once. It's already had a full life of use, and now you can use it on a project, on a road construction and not have to implement a secondary mining activity. Then gravel pit reclamations in the state of Wisconsin, as an example, that's an area that's very abundant with sand and gravel pits that are legacy facilities have been around for a long time. So you may have some of these that before the day of having reclamation requirements and those sorts of things, you just have open pits or sores on the land that a lot of the neighbors are very, very excited about having something done to reclaim it and bring it back to not just being a large quarry-looking chasm but something where it can actually be farmed on again or some kind of wildlife use, and so on. Next slide, please.

And here you see some additional things. Slag is commonly used in cement production. It's used to replace what's sometimes called clinkers in the industry. Of course, geotechnical fill we discussed and also soil amendments in agriculture. So, there are some really neat studies out there that if you take foundry sands and mix it with native soils up to a certain percentage, it makes a very nice

growing medium. That is an accepted practice that's done in many states in the United States. Because foundry sand has clay in it, it is very good at making an impermeable layer. I'm going to show you an example of one of those coming up here in a couple slides. So next slide, please.

Here's some quick examples of transportation projects. Next slide, yep, thank you.

And here we have in central Wisconsin a large state highway. Here foundry byproducts were used to the tune of 160,000 tons. They actually relocate a highway over what was a former quarry. Without this material available, that would have been a pretty tough project to implement. Next slide, please.

Then you see a transportation project, but this also has some overlap with say a commercial project. This material is commonly used as a subbase or even a base course underneath an asphalt project. So, both foundry sands and slags do a very good job at being a nice, workable, compactable subgrade fill that is very easy to both excavate and build upon so you have a stable foundation. So, here's an example from Waupaca County highway facility to the tune of 24,000 tons. Next slide, please.

And we'll talk about some – a community project here. Next slide.

So, it really is in the state of Wisconsin, in this instance, there's a very well-defined rule that's out there for how to go about and facilitate projects. So, it's a very strict regimen on the testing that's done and how these things are used. In the case of Waupaca Foundry, our material tests very much on the wide use side of things. So, we're able to do all kinds of things with materials. One example here is in the city of Waupaca, Wisconsin. There was a very nice park facility there that was surrounded by residential. The city had very much wanted to implement a sled hill. But of course, material involved was prohibitive to them. Ultimately, it ended up that foundry sand was a great fit for building a sled hill and a recreational facility. That was to the tune of 275,000 tons. Next slide, please.

And agricultural projects – next slide.

So, as I mentioned earlier, our facilities, though we're in numerous states, we tend not to be in urban centers. We are in more rural areas. So, you see a lot of the projects that are available to us are those things that have to do in the agriculture industry. Here's an

example of putting structural fill for a barn expansion foundation. We do quite a bit of these and they're really good projects, and very well appreciated by the local farming industry. Next slide, please.

One thing that's kind of neat, this is another example of that, but one here, we're taking advantage of another aspect of foundry sand. So, you could have a large agricultural facility where they're basically told that due to current regulation, you have to have some kind of manure storage facility so that it's not just uncontrolled and having the potential to cause ground water contamination. So normally something like a manure storage or manure pit if you heard that term, one will be built. They're typically concrete-lined, and they help prevent that contamination from getting to the groundwater. What's nice about foundry sand is with that clay content, it could actually be – have two or three feet or more of that put underneath one of these facilities and compacted to meet an impermeability requirement. A common number is 1×10^{-7} and foundry sand meets that ably. So, we do a lot of projects like that where we're just looking for that extra future of foundry sand to provide extra groundwater protection for these manure pit facilities. Next slide.

And next slide. Mine reclamations.

I mentioned this earlier, but again, we are an area that are flush with historic mines. Here you can see some high sidewalls of one type of project, and if we go to our next slide…

And you can see the upper left is a pretty good example of what your typical legacy mine might look like in the state of Wisconsin. Again, there are some safety concerns and windblown material concerns. Those basically have to be remedied and with foundry sand, that provides material where these projects can be basically covered and look more like the after pictures. Some of these are very dramatically different when they're done. Next slide.

I had mentioned the permeable construction side of things. So again, taking advantage of the clay content of foundry sands. So, another use that's been put into use is the using it as a clay or a landfill liner and landfill cap. So instead of having to mine native clays from nearby a waste facility, this material can be used in lieu of that and really up the environmental balance of the project and save costs also. Next slide, please.

So just finishing up here, really the best use for foundry sand is in the foundry. So yes, we get 30 uses out of it, but we have been working hard to increase that. So, a technology that's much more common in Europe is called sand reclamation. Basically, what's done is used sand is taken and mechanically separated to get the size that's needed. It's thermally heated to basically pop off any of the clays. Then mechanically separated once again. They try to get something more like the original sand. These types of systems are very good at doing that. We've implemented two of these at our facilities. Have had a lot of success of returning sand to get more and more use within our buildings. Next slide.

With that, I'll conclude the foundry beneficiary use portion.

Bruce Lung: Thank you very much, Bryant. Those are very informative and very creative ways to reuse sand and other materials. So, if everyone is ever wondering what ever happens to scrap metal, this is one really good example. Now, we're going to turn to our third speaker for the day. Someone who is probably well known to many of us, but we'll go ahead and give him a good introduction. Bert Hill from the Volvo Group. Bert is the Health, Safety, Environmental, and Energy Manager for Volvo Group North America. He has over 35 years' experience in energy and environmental issues. He coordinates the Volvo Energy Network of North America, Volvo's forum for identifying and spreading best practices within the group. He also manages Volvo's participation in the Better Plants and Challenge program and the Better Climate Challenge, so a double challenge partner, as well as other corporate level initiatives, and is a certified energy manager. I will add that Volvo Group includes not only Volvo trucks but also Mack trucks. So, if you ever see a Mack truck, you know they're made by the same folks. So, Bert, feel free to start.

Bert Hill: Okay, thanks Bruce. I'll try that again. There we go. So, I'll jump right in here. Starting with the big picture and then we'll break it down to the actual remanufacturing process. So, Volvo's strategic ambition is to drive the transformation in our industry to shape the world we want to live in. Our industry is a transportation equipment industry. We realize that we have a long way to go to decarbonize our industry, because right now a lot of our vehicles and our construction equipment are fueled by fossil fuels. We're on an electrification journey. We'll start out with electrification, be moving into fuel cells, and also supplementing that with renewable fuels that can be used in our current internal combustion engines. We're a big enough company we know we can make a difference

and help make the world a better place to live in. Next slide, please.

So, to do this, we have our sustainability strategy divided up into the three pillars you commonly see here: people, climate, and resources. For the people pillar, we aim to make our products and our plants 100 percent accident free. We have a lot of technologies in our products like lane keeping and adaptive cruise control, things like that to help make our vehicles safer, and then we have a lot of measures in place to make our plant safer as well. Then on the climate side, we have committed to SVTI targets. We'll reduce our greenhouse gas emissions by 50 percent by 2030, and then we'll have to reduce them 100 percent by 2040, and the reason for that is to – since most of our products have at least a ten-year life cycle, if we're going to get to that 100 percent by 2050, we have to have all of our products fossil-free by 2040. We're also doing everything we can to make the best use of our resources. We intend to double our productivity to cut our resource use in half. Then circular economy is one of the tools we're going to use to get there. Next slide, please.

So, we do have a new business area. It's been around a couple of years – Volvo Group Circular Operations and Solutions. So, on the left side there, you see the operations and that's everything that goes into remanufacturing the products that we remanufacture. We have eight sites in six countries. We have over 70 years of remanufacturing experience that goes behind this. We have over 200 documented methods that we use to remanufacture different parts, and then we also have the logistics that goes behind those operations. Then on the solutions side, we're moving more to offerings where instead of selling a truck or a piece of construction equipment, we will rent that out by the mile or by the hour and the customer will pay the mile, pay by the hour, and that way we maintain control over that product's complete life cycle. We can keep it running as efficiently as possible. We can make sure we can keep it in use as long as possible. Then when it comes time to return it, then we can do the remanufacturing and the recycling. Next slide, please.

So, these are some examples of our operations, our processes, and some of the products we produce. Circular design is very important because the more effort you put into the design of the product, the easier it is to pull apart and recycle or remanufacture different parts of it. Then reverse logistics – we try to keep full trailer loads, so we don't transport air around. Core handling is part of the process. Remanufacturing – we have another business called DEX Heavy

Duty Parts that does refurbishment. So, we'll take in say a complete truck, a long-haul tractor trailer and clean it up, pull it completely apart, and then sell those parts. So, sell anything from a used wheel to complete cab on a vehicle to replace one that's maybe been damaged in an accident or something. So, we have that side of the business as well. Then on the product side, you see our traditional products – the engines and transmissions. Something that's come more lately – DPF you see there is diesel particulate filter. These are part of our emissions controls for our diesel engines that trap the particulates and keep us in compliance with the air emission regulations. Then you see a lot of other traditional products. The carrier there, that's a part of the axle. Then what we have emerging now with the electrification of our vehicles are looking more at the ESS, energy storage system. So that's the batteries from our electric vehicles, and also a compactor box as part of that. Next slide, please.

This shows you our footprint. Like I said, we have eight facilities around the world. A lot of the development is done in Europe where we have more plants in Limoges, France, Flynn and Skovde, Sweden. Then we have two plants here in the U.S. – one in Middletown, Pennsylvania, one in Charlotte, North Carolina. Bruce mentioned that we own the Mack brand. So, most of the Mack engines and transmissions and components are done at our Middletown, PA site, and then most of the Volvo products are done in our Charlotte, North Carolina site. Those are complimented with a site in Curitiba, Brazil, Hosokute, Japan, and Shanghai, China. Next.

So, Subodh went through this earlier, this definition. You may wonder how we can restore a part to better than the original condition. But what's happened there is some of these engines we have have millions of miles on them literally. Technology has advanced since then. Ways of measuring and calibrating our tolerances on these parts and also, we have the better materials that are available today. Next slide, please. Then just speed it up a little bit here.

So, sustainability side, we can preserve raw materials, reduce energy use, and reduce the embedded carbon in these products. There are many benefits for our customers and for their business. Next slide. Next slide.

So, this shows you the closed loop. So, what happens is a customer will come into a dealership. They will trade in their old engine or transmission. It'll be sent to a core hub. That's inspected and

remanufactured, and the reman part goes back to the central distribution center. The customer will be off with a new remanufactured engine. Next slide.

This shows you photographic details of the process. I'll let you look at that in your leisure. I can just say that these things, these old engines and old transmissions are pretty grimy when they come in. The first step is to really clean them up. Then take them apart, clean all the parts very thoroughly and inspect and diagnose the parts and then there's some things you have to replace like gasket covers. Then replace what has to be replaced, reuse what we can, and then test the product and send it to the warehouse. Next slide.

This shows you the different products I mentioned. On the left side, you see more of the legacy products. There's a picture of that DPF filter. That's about the size – a little bit larger than a five-gallon container for reference. Those are very expensive because they have a ceramic substrate in them that's completely reused, so that saves a lot of cost to remanufacture them. Then on the right side, you see all of the products that are coming with electrification from the batteries to the electronic axles. Next slide.

So, this just gives you the idea of the potential we have with this. Reusing an engine reuses 60 percent of the original material. So, you get huge gains here in energy and also materials consumption considering you don't have to mine the iron ore, make the steel, cast the steel, machine the steel, all of that that you have to put into the manufacturing of an engine like this. So, we're able to reuse 60 percent of that and save 56 percent of CO^2 emissions versus manufacturing an engine from scratch. Transmission reuses 47 percent and saves 30 percent of the CO^2 emissions. DPF gets even higher. We're using 85 percent of the materials, savings 81 percent of CO^2 emissions. Alternators hit a home run there. We reuse 98 percent of the material in an alternator and save 80 percent of CO^2 emissions. Next slide.

So, thank you very much for your attention.

Bruce Lung: Thank you, Bert. That was really cool, especially that last one with the amount you can reuse and with the raw materials differences and all that kind of thing. Folks, I think we have a smaller group than usual today, so if anyone has any questions, feel free to just put them in the chat box. We're not going to use Slido at this point. So, if anyone has any burning questions for any of the participants or myself or anyone else, feel free to put them in the chat. One thing that occurs to me – one quick question for Bert is if you all

have remand plants in Europe, what is the difference between the requirements or how the parts are remade over there versus here? Is it easier or harder? Is it more you can do over there versus here? That kind of thing.

Bert Hill: It's probably about the same as far as the level of technology. We place these plants closer to the product mix that's in that country. Like the Shanghai plant is more for our Volvo Penta marine engines. Those are used a lot. Same with Japan. Then of course, Sweden is our home base. So that's where a lot of the products are remanufactured there. I can say there's a longer tradition of this in Europe. Due to the higher cost of materials and particularly with the higher cost of energy in Europe, we've been doing it a lot longer there and have more of a history with it.

Bruce Lung: Terrific. Yeah. I had heard that some countries have already begun putting labels on certain products to advertise just how easy they are to recycle or remanufactured. So that's good. I don't see any questions in the chat box yet, but one thing I was wondering a question for Bryant. Are you also able to reuse fuels? I'm thinking specifically of coke from steel mills for example. That may be another example of a way to reuse a material or a fuel. Is that something you all do very much?

Bryant Esch: Currently, I cannot think of something that would fall in that category. Then of course, right now, in the industry there's, when we look at just carbon emissions in general, there's maybe a push to look a little more towards electric melt versus cupola melt. So that might eliminate some of those possibilities by shifting to electric.

Bruce Lung: Okay, perfect, yeah. Well, what I'll go ahead and do then is if there's another slide just remind people the Better Buildings Summit coming up next spring. We're going to have future webinars going on as well as the Better Buildings webinars. Oops. I see something in the chat. From Al McShan, as far as battery life, what is the projected time you can use a battery in the trucking industry as opposed to vehicles? That's a good one. Bert, if you want to handle that real quick.

Bert Hill: Yeah, sorry about that. I think it's equivalent because – but I'm not sure exactly what that life span is. I know what the range is, and I know that we can – when they're no longer able to power the vehicle, they still have 80 percent of their life left. So, they can always be reused for power storage. Our Bobo Energy division is working on that. But I think it's around 10 years, but I don't know

that for sure. But the modules and the packs are essentially the same that go into automobiles. We just use more of them than a car would to get the power we need.

Bruce Lung: Thank you.

Bert Hill: You're welcome.

Bruce Lung: Good question. Okay. So, I just want to take a quick second and thank our panelists again today. Some great information and we look forward to having you all on a future Waste Reduction Network webinar as well all the other webinars we do for the Better Buildings challenge and Better Plants as well. Thanks again and if there's any follow up questions, we'll leave the slide up here so that folks can email people. Then we'll go from there.

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