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Good afternoon. I'm Joshuah Stolaroff. I am a science and technology policy fellow with the American Association for the Advancement of Sciences. I'm working in EPA's Office of Solid Waste and Emergency Response. And I'll just do the disclaimer now that I'm not an official EPA employee, so my views are not those of the agency.

However, I have led development of a lot of estimates that I'm going to show you as part of the development of the climate change strategy for EPA's Office of Solid Waste and Emergency Response. And that office is concerned with broadly three things, which include materials management, like recycling, and most of the things we've been talking about here at this conference, and land cleanup, revitalization and reuse policies, or land recycling, if you will, and also emergency response and preparedness.

I'm going to talk just about those first two things today, though.

OK, so, slide – on slide 80, I'm showing a couple of the things that I'm going to try to convince you of today, which are that materials management and land management have a – make up a significant share of greenhouse gas emissions. And then, also that changes in materials and land management practices can make reductions in greenhouse gas emissions.

These are points that have been well made in a couple of the talks you've just heard. And if you – for those of you on the Webinar, if you've listened to the other series, like David Allaway's talk, you will understand these points already.

And I'm actually now going to try to get you to think a little bigger picture, and think of materials management as part of a larger story. And what I call that larger story is prevention-oriented approaches, but you may know them by many other different names. There's green design and life cycle analysis – sorry – green design and industrial ecology, design for environment, sustainable consumption or energy efficiency approaches.

And all of these things are really trying to do similar things, which is, you perform the same function, or, really, you meet the same human need with lower demand on resources and lower impact on the environment.

And the advantage of all of these prevention-oriented approaches – one of the advantages – is that you tend to make emissions reductions at lower cost, and you tend to get other environmental co-benefits while you do that.

So, if you want to take these prevention-oriented approaches, one of the things that you need is what I'll call systems-oriented thinking. And that includes life cycle analysis, and it includes consumption-based accounting, which I'll talk about later.

But in understanding how materials management fits with greenhouse gas emissions and overall climate policy, it's first good to take a look at the conventional perspective.

So, on slide 84, you see the greenhouse gas emissions as they're typically portrayed, like in the U.S. greenhouse gas inventory. I call this the sectors view. And it's essentially an allocation of greenhouse gas emissions at the point they're emitted. So, if they're coming out of an electric power plant or out of a vehicle, that's which category they fall into.

And the larger story from this kind of picture is that, if you control emissions from electric power plants and from vehicles, then you really got the majority of greenhouse gas emissions. And if you include industry in there, then you're getting pretty close to the whole picture.

And this is a useful view for targeting end-of-pipe solutions, which is, if you're looking at the place where the emissions are coming out, if you change that process so they're not coming out there anymore, that's an end-of-pipe solution. And so, carbon capture and sequestration (at) electric power plants is an example of that.

But you might also consider technology substitutions or process changes, which make reductions sector-wide. So, hybrid electric vehicles can help you get at that transportation slice.

But it's not really obvious when you look at this picture where materials management or land management fall. And in particular, as we heard about the waste – which is not usually on this chart, but if it were, it would be a three percent slice – that's not really showing the activities of materials management, which, although they do reduce emissions from the waste sector – for instance, composting does that – they also reduce emissions from many other sectors. Like aluminum recycling will reduce electricity use and those emissions.

So, we tried to – we developed another perspective of greenhouse gas emissions, which I called the systems view of greenhouse gas emissions, where we looked at what systems or what applications are driving the emissions. And there are a lot of different views you could construct based on systems, but this one is chosen with land management and materials management in particular.

And the story that you get from this chart is that provision of goods and materials – and if you consider food a material, which in many ways it is – account for about, almost half of total greenhouse gas emissions.

And then, various categories associated with land management, like the emissions from clearing land for new development, which is part of the new land development slice, or the emissions from local passenger transportation, which is affected by land use, local land use planning, those are a part of land management. They make up a significant share.

And also, this faded outer ring in the pie chart, labeled the natural land sink, represents emissions absorbed by natural lands, primarily regrowing forests. And it's important to think about that as part of the overall greenhouse gas picture, because that's offsetting a significant share of our emissions at 11 percent.

So, in the next slide, I'm just – I already talked about a couple of these things. But in general, this view is the systems view. And it doesn't have to be this one. You can draw other systems views. But in general, these are useful for targeting prevention-oriented strategies, because prevention-oriented mitigation tends to reduce emissions from a bunch of different sources, but they do act on a particular system.

And so, if you take this perspective and you say, OK, land management practices and materials management practices influence a pretty large share of greenhouse gas emissions, the next question is, can changes in those practices reduce emissions?

And so, that's what we try to answer in the next analysis, where we did – oh, I'm sorry. I'm getting ahead of myself. I'll just give you a little more detail on the pie chart.

And so, to give you a flavor of what's included in each of these slices, this is a breakout of the provision of goods and materials slice. And you can see that the emissions come from a bunch of different sources.

You've got industrial sector fossil fuel combustion. There's electricity used by the industrial sector. You've got process emissions in industry like non-CO2 greenhouse gases. You've got emissions from freight moving all of the materials around from place to place, and from waste, including landfills.

And then there's an adjustment to account for some of those emissions that are in other slices. And what you end up with is close to three billion metric tons of CO2 per year that's attributable in this provision of goods in the materials slice.

And the new land development slice, which actually includes some new research – so, some of these emissions are not included in the U.S. greenhouse gas inventory – you can see that this story looks a little different. We're actually dominated by the biogenic carbon, that is, lost soil carbon, lost above-ground biomass and lost dead (ph) or (ph) net (ph) organic matter when you clear land for development.

And there's also emissions from building roads and sewers and pipelines. And adding all those things together, the emissions from clearing land, roughly 2.2 million acres per year of land in the U.S. is cleared for development, that comes out to about five percent of total emissions.

A very rough number. Maybe it's two percent, maybe it's six percent. It is a first-cut analysis.

But the point is that it's significant on this scale of our (ph) total greenhouse gas emissions, and that land development should be considered in our greenhouse gas policies.

And so, if you think about the potential for land recycling, this is sort of the maximum potential. If you most efficiently managed to reuse land instead of clearing new land for development, this is the size of the emissions slice that you'd be able to squeeze, if you will.

On the next slide, getting back to what I was saying earlier, so, this is our rough analysis of the technical potential of a bunch of different materials management mitigation opportunities.

Technical potential is just – it's a scoping analysis. It says, what happens if we did all of it? What sort ordered (ph) number are we talking about? Is it big enough to worry about?

And that's really the intention of these calculations. And most of these are based, they're extrapolations of information in the WARM model.

But going down the list here, we can see that, if you source reduced 25 percent of a whole bunch of stuff that's covered in the WARM model, including cans and plastic and consumer paper, depending on how such a huge change in materials use affects forest management, your reductions range between 30 and 100 million tons of CO2 reduction per year.

Or as sort of an alternate take on a similar change to the materials system, if you reduced packaging use overall by 50 percent, then you could make 150 million tons of CO2 reduction per year.

Again, so, this is compared with the total of 7,000. So, these things are significant on that scale. And actually, they compare with other greenhouse gas mitigation policies that are frequently discussed on the sort of national policy scale.

So, for instance, if any of you have seen the report from McKinsey and Company, titled "CO2 Emissions Reductions: How Much at What Cost?" – a very influential report where they tried to go through every sector of the economy and looked at where could you make greenhouse gas reductions between now and 2030 for costs that are reasonable. One of the sectors that they found you could get 60 million tons of

reduction from building shell improvements, so, essentially, from improving the insulating capacity of buildings.

Or cellulosic biofuels, if you made those work and used them up to their economic potential, you could make 100 million tons of reduction.

So, I mean, these are things that are frequently discussed as part of climate policy, and they're on the same order as reductions that you get, or that you could potentially get, from materials management changes like recycling.

But on the other hand, these numbers are not – they're not so big compared to that three billion tons of total emissions from provision of goods and materials that we saw in the pie chart.

So, there's still a connection to be made. And this is a challenge for the recycling community, or for the materials management community more broadly, is that it's not just about recycling. If you go and recycle essentially everything you possibly and/or economically could, you're still a pretty far step from that 3,000 million tons potential.

And so, you have to think about other strategies, too, which include source reduction, changes in how, which materials are used, extending product lifetimes, service (ph) sizing (ph), all the sort of more advanced things. And those are more challenging activities to assess the potential of. And so, that's something we continue to work on, is how do we think about the more advanced materials management practices and the reductions possible from those?

But, so, it's just important to keep the perspective on both sides, that recycling matters on the scale of national greenhouse gas policy, but it's also not the whole story, if you want to think about materials management broadly.

So, another thing we're interested in for the OSWER climate strategy is, what are the effects of land management policies, in particular for us, land recycling policies, again, doing the same technical potential sort of calculations. You know, if you went out and did all of this stuff, is it big enough to matter?

And to answer those questions, we first had to figure out how much contaminated land out there is there. It's sort of the equivalent to how much material is currently going into landfills – which was not an easy question to answer.

But looking at just the databases that we have available in EPA, we find that there's about 17 million acres of contaminated land out there, which is roughly the size of West Virginia. And a lot of that is remote, sort of abandoned mining sites and things that are not what you would imagine like developing houses on.

And so, part of the question is, what can you do with urban sites to recycle them into new housing, for instance? But then, what do you do with all of these remote contaminated sites that may be lying barren after being mine scarred and have nothing growing on them? Is there something useful you can do in climate terms with those sites?

So, on the next slide, we look at – slide 92, for those of you following along – we look at some opportunities for the new land development. Of course, implied in our pie chart calculations is the potential for urban land recycling, which is in the hundreds of millions of tons.

But also, there's a lot of acres of abandoned mine lands that could be reforested. And so, a very rough estimate of the emissions you could offset by doing that is about 80 million tons per year.

And then, if you looked at all these 17 million acres of contaminated lands and took all the ones that are on solar class six and seven sites, and put utility-scale solar on them, you could – well, you could almost have enough electricity to power half of the country.

A similar story with – or a similar calculation for wind. If you took all the solar class – sorry – wind class five and six sites and put windmills on them, you could get 30 million tons of reduction by offsetting fossil, the current mix of electricity.

And then, also, as we clean up all these sites, which tends to be an energy-intensive process, if you make the cleaning process more energy efficient, there's four million tons out there to grab.

So, some of the points that I hope come from these kinds of analyses is that you need systems-oriented accounting to target prevention-oriented policies. You can't look at the conventional sector's pie chart and figure out where your prevention-oriented policies are going to be.

You have to figure out where are the systems. And then, when you look at the system and say, how do I make this system more efficient, cutting across all of the various sources that make it up, then you can figure out the scale and the benefits of those policies.

And then, you can use technical potential calculations like these. The OSWER climate strategy is slated to be public in September. And at that point, hopefully you'll be able to see the methodology for these things. But certainly, contact me if you're interested in details.

But this is a kind of process that can be applied across any scale of strategy. If you're a locality, and you're looking across your options, the first-cut analysis you can do is, well, if I went and changed all of the zoning regulations this way, what would be the technical potential reduction from that? So, the technical potential calculations are useful for scoping out potential policies.

And then, the analysis, the sort of systems-oriented pie chart can be done at a lot of different levels. It can be done for a city or for a state, or, in this case, for the country. And I'll give one example of extending this analysis.

So, the previous chart I showed included only domestic emissions, as the U.S. greenhouse gas inventory does. But you can imagine accounting for emissions based on consumption rather than production.

So, if we think about all of the goods we consume in addition to all of the activities that we do domestically, the emissions associated with those systems, and then we subtract the things that we produce that are consumed elsewhere, then you get a consumption-based accounting. And I put our analysis together with some numbers from the paper cited at the bottom there, to figure out what does this picture look like, if you include international emissions for producing goods we consume here, and then subtract out emissions from goods we export.

And what happens there is, the goods and materials emissions increase by about a third. And so, that takes up an even bigger portion of the pie now. But food emissions decrease slightly, because we export more food than we consume here. But overall emissions increase 12 percent, with an uncertainty range of four to 18 percent.

And in a sense you could say, well, you know, that's bad to do consumption-based accounting, because it looks like we emit more. But on the other hand, the advantage of this is that it puts more emissions on the table for you to reduce.

So, if you're a locality or a state, and you want to use prevention-oriented policies to reduce emissions, you need some sort of systems-based accounting to be able to see that. So, if you draw the border around your municipality and you don't have a manufacturing plant there, but you reduce emissions by recycling that reduce emissions at a manufacturing plant, that's not going to help you meet your climate reduction – you climate change emissions reduction goals.

But if you have an accounting system that's based on consumption, then those benefits of recycling will show up. And similarly, even looking at the whole country, if we have a policy that reduces emissions, say, by increased recycling of steel, but what that offsets is steel that we've imported from abroad, then those emissions reductions are not going to show up in our national reduction target.

So, there is a role of consumption-based accounting in that it puts more opportunities on the table, because a lot of these prevention-oriented strategies – again, lower costs, and have (ph) environmental co-benefits compared with end-of-pipe solutions. And the end-of-pipe solutions will always reduce emissions at the point that you're targeting.

So, if you're a municipality and you do have a manufacturing plant, and you use an end-of-pipe strategy to reduce emissions from that plant, it'll show up in your accounting, but the prevention-oriented strategy, not necessarily. So, that's why – or that's one reason why these things are useful.

And I hope that it's clear from this discussion that materials management, a lot of the materials management approaches, fit in this systems and prevention-oriented framework.

And that's all.