Siting Distributed Wind (Evolving)
June 10, 2014

Operator: Welcome everyone and thank you for standing by. At this time all participants are in a listen-only mode. However, during today's conference we will be conducting a question-and-answer session. To ask a question you may press star-1 at that time.

The conference is being recorded. If you have any objections you may disconnect. I would now like to turn the conference over to Tony Jimenez. Thank you, you may begin.

Tony Jimenez: All right, good afternoon everyone in webinar land. Today for the ASES Wind Division webinar we have Charles Newcomb, a long time wind industry veteran who's going to talk about micro citing distributed wind.

And his experience in advancing new energy technologies was developed over more than a decade spent at the National Wind Technology Center. He managed the DOE's Wind for School's Program and it's Wind and Water Deployment Group.

His research at NREL ranged from performance and duration test and field engineering to serving as a (unintelligible) matter expert for various federal agencies for the Departments of Agriculture, Interior, and State.

On these private industry side, he served as a managing director for Integrity Wind Systems, Chief Technology Officer at Next Gen Energy Partners, and now Technology Director for Endurance Wind Power.

Charles has lead technical project development teams and work closely with suppliers and customers to ensure optimal (unintelligible) performance and now provides guidance and oversight for Endurance's in house project development including citing, design, and construction, as well as product development and improvement. With that, Charles, it's all yours.

Charles Newcomb: Thanks very much. All right, so I'm going to apologize in advance if this presentation is not an elementary level. I figure with the ASES group who may be viewing this now or viewing this in the future you guys will all have some sort of a background on wind energy. So we're going to dive right in if that's okay.

Of course, you can't dive into wind energy without talking a little bit about where it comes from and what it is. And we all know that the warm equator and cold poles is going to cause some sort of flow and you start spinning the globe and stratifying the atmosphere and you get weather patterns.

And that image on the bottom right is not a bad hair day if you've never seen this before for the US. It's the flow at a particular time. The small image is actually from this morning and the big image is a prettier version of some other day.

But when you integrate that over longer period of time you move from the weather to weather pattern kind of perspective and the pattern is the wind resource that we in the industry like to take advantage of.

I think the other obligatory slide is going to be this slide, which pays homage to the fact that wind energy really depends on the wind speed and it goes by the cube of the wind speed.

And that derived from a kinetic energy equation where mass has a lot to do—has everything to do with the volume of air and the volume of air that goes through a rotor on a wind turbine has to do with how fast that wind is going. And thus you get the B-cubed function.

So with those out of the way we're going to jump right in to the citing guidelines. And most of you are going to be familiar with the fact that if you read any guidelines out there, setting guidebooks or whatever, they're going to tell you useful things like, you know, thou shalt align your wind farm along with the ridge that is perpendicular to the prevailing wind.

Or thou shalt seek high ground. Or thou shalt choose a gap such as (unintelligible), Palm Springs, you know, (unintelligible), (Alta Mont) pass. Choose a pass where wind is being forced through a small (unintelligible). And that works very well in big wind world but in small wind world we have a really different equation at hand.

Mainly that we're usually given the land and someone says, where should I put it? And so this is an example of a little project in Western Ohio that I worked on years ago where they said, look, I've got—I thought the number was 60—did not look like 60 to me, looks like maybe 16 acres or 20 acres.

And they're, like, well, we have all this acreage, where are we going to put the wind turbine? And by the time we kind of did these exclusion maps we came down to an area, not the size of my living room, certainly not, but certainly the size of my house.

And so that's what we had to work with in the distributed wind world is that we have exclusions, we have set backs, we have this kind of stuff because

we're dealing with smaller properties and these properties are often your homes or the competing uses. So that's an important thing.

The next thing is that, you know, when people think about wind resource assessment, which micro citing is not, they think about it from the big wind perspective. And in the big wind world one way to look at it is it's not too much unlike looking at the world from Google Earth.

You know, you tip the horizon, you get different land uses, you get some land classifications, you get a little different types of ground cover that give you roughness.

And you push the flow across the different types of ground roughness and you can end up with a net result at some point.

In our world, in the distributed world, this image—instead has three dimensions. It does have an XY for sure but it also has a Z and those Zs are not just, you know, the height of the road or the field. It's also the height of that tree next to the power line or the height of that barn.

If you look closely enough you'll see three sky streams on the far stream of that barn and the wind is coming from down the valley, far in the distance, right in—into our faces. So those small sky streams are located on the upwind side of the barn, that's a good start.

The question is what happens when the wind shifts and it comes out of the northeast because our back is to the northeast? Then it's going to be coming over the barn and that's where the fun starts in terms of micro citing is assessing what is going to happen to that wind.

Indeed the wind is not—the world is not flat nor is it this rocky forest, those of you that have looked Google Maps and three dimensions or user Apple Maps, you may be familiar with this and I think the reason why I bring this up is this is where I think we could go.

This is an (ortholydar) imagery where you're flying around typically in a fixed wing aircraft pointing (lydar) laser detection and ranging device coupled with optical cameras and you're imaging what's below you at an angle, an oblique angle. And what's being echoed back from the laser is a position, an XYZ position.

And therefore I can get pretty accurate heights. This map is not that accurate as you can tell from the broccoli so maybe it's a half meter or so but tachometry, if you've heard of them or if you haven't you've probably seen them.

So if you download a Bing image on Bing Maps and you've looked up for the bird's eye view, all of that imagery is provided to Bing by (Pictometry). And that has a 6 centimeter resolution.

So that's kind of where we're going and as we begin to outfit UAVs, (Lydar) sensing equipment we can begin to generate these maps, not just in the populated urban areas but also in the rural areas and I'm excited about that because I think that could be a fun way to do citing.

So looking back at big wind, what's their approach and how—so we can understand how ours is different? Well, they tend to start with the prospecting map. They know kind of what windy areas are based on a wind map. And then they do a flow study.

They do some sort of CFD whether it be (mediodine) or wind farmer or open wind or open foam or you name it. They're going to run some way to understand how the wind is going to flow across the topography, how it's going to interact with those hills. They're going to decide where to put a met station.

They're going to put the met station out there to anchor their map, to validate their map, to kind of make any corrections that are needed to the map in that location. And then they're going to extrapolate the information from that met (unintelligible) to the area, corrective wind map if you will in this bottom right image.

And they'll put turbines out there, virtual turbines, and they'll figure out what their capacity factor is. And they'll make a PPA play. That's how they do it in big wind.

We see the world pretty differently because in our world we don't have millions to spend nor do we have years to spend assessing the wind resource. We like to start with something else.

We typically start with the wind map or maps, multiple maps, and then we make some assumptions about the roughness length or the sheer exponent that we would use to describe this curve. And what this curve shows is that as you're at the ground there's very little wind, that would be the zero offset height where there's no wind and no slip condition.

As you go up higher you get 150 meters, you're at ten meters per second or so. And so that curve is described by an exponent and that exponent has a lot to do with what is on the ground underneath this point. And so if you're over forest, that exponent might be 0.28 or 0.35, depending on the forest height and

the density of the canopy and whether it has openings or not and that kind of thing.

And if you're over grass or water you might—or mixed grass and water like a swamp or—my mind suddenly went to the Lord of Rings and I was thinking about that swamp out there, that would have a sheer of, you know, 0.12 or 0.13 because it's kind of a mixed water, grassy kind of sad place. Anyway, so that's what we use. We're using exponents to bring it down.

And then we look at objects and how do we look at objects? Well, you know, we think about them from guidance in these documents. So this is one document on the right, which is the wind resources assessment handbook written ages ago by I think (Bruce Bailey) was probably leading this with (Dennis Elliot) back in 97 when I started thinking about wind.

Or we'll look at the (McGauen-Manuel) book and, you know, we'll look at the GTO—IOD, that (Griggs-Putnam) index. And we'll kind of—in the small wind world we kind of try to look for some sort of evidence on the ground that there is wind present, what it looks like, where it's coming from, where it's going, that kind of—how strong is it.

The good news is that there's also been a lot of work because lost, which is the wind assessment program out of (unintelligible), now DTU over in Denmark, they thought a lot about this and they were developing one of the earlier maps using these kind of methods of looking at obstructions, anything for which you're closer than 50 times the obstruction height, they start to look at those things like obstacles.

And they discovered that—well, there's a guy named (Pereira)—it's interesting, you think back, people were planning wind breaks forever without

really having any analysis behind the wind break to say here's how far you plant your trees and that kind of thing.

So (Pereira) was actually an ag student who said, let me look at this and let me take it into wind tunnels. So he's one of the first guys to kind of look at this loss assessment from that perspective, putting an aluminum plate that simulated an object and drilling holes in it to give you different porosity and using different height plates to give you different height objects.

And then using a hotwire anemometer to actually determine what the wind speed and how it was being effect downstream using different roughnesses, whether it be sandpaper or something else in the wind tunnel to simulate roughness. So he kind of did this micro scale model, and I'll be darned if the guy didn't actually nail it.

So people now have embedded this into the heart of (WASP) and they've never looked back. I mean people look back constantly at (WASP). They're constantly coming with a new methodology and saying how much better it is than (WASP).

But frankly, if you developed a model and 20 years later when you have this—what is the (Moore's) law or whatever it is, doubling of computer power for 20 years, I mean take two to the 20th, that's a big number change from when WASP was developed and that model's still around. No pun intended, that's an enduring model. And so that's kind of cool.

Anyway, so that model—the good news is that model is—pieces of that model specifically with respect to sheltering and objects and things like that are—run reasonably well and it's in a spreadsheet and they work well on a web tool and we'll show you some of those things.

So this model actually is good enough—the (Pereira) loss formula is good enough that it's been sort of put into the 6.1400/12 standard for how you test turbines.

And when you go to do a power performance test on a wind turbine you have to evaluate the site for obstructions and whether you're going to throw out that sector or how much that sector's going to be affected by that tree or that test building or whatever it is.

And that formula is called for in /12 and here's the formula in a spreadsheet form so you can just copy—white copy, paste, drop it in a spreadsheet and you too can calculate losses and create a table like this on the right hand side that gives you a sense of where—what losses would be at what distance or what objects of what height of what porosity and your height.

And so given all those elements you can actually determine what the loss would be consistent with the /12 standard. So I think that's pretty handy. And when we discovered where that formula was and how to use and how to code it in, was not hard.

Things got a lot easer for us because prior to that it was a pain. And we didn't know how to evaluate things besides going to this website. And this website down at the bottom left, you can just click on it and it's a nifty little site that allows you to put in those various parameters and visualize and calculate in the bottom left of the calculator, not the untitled window, but it shows you that it's 15% of energy loss in this sector.

So you can walk through this sectors and do a sector-wide analysis and say, okay, these trees are going to cost me 15% of the energy from that sector.

And thus the example starts, right. It doesn't always work, there are times when the model will fall apart.

So if you look really closely, if it's not too blurry on your screen, you'll notice that a shorter tower actually does better than a taller tower. Most of us would know that that's probably not true and so therefore that's an example of where the model is falling apart. You can't expect the model to always work. It's really important to know when it's not working through.

So what is going on? Well, part of it has to do with the simplistic linear models. If you have any flow separation or something else that's going to cause the fluid flow, the air flow over the area to break apart and not flow in a laminar fashion is going to make the model perform poorly.

I think that's an important thing. These are the computers they were using. Actually this document here is the proceeding from the year that the Danish wind map—wind atlas I guess came out. And those are—those have got to be, like, 80-86. They predate to 86—well, that could be a PS2 though.

I'm not sure. But it's a 5.25 whatever floppy so you know that it's old, right. and again, that makes the computation efficient, it works in your spreadsheet.

So again, where WASP works, these linear models work, is where it's neutrally stable, that means you're not getting big flow separation, you're not getting big tumbling turbulence as a function of flow separation or from buoyancy effects. But it does mean that the atmosphere down low is behaving relatively well.

Or that the terrain is not too steep and, again, this 30% sort of slope is where you do get natural flow separation over a grassy hill. You throw a tree in

there, you don't need that 30%. You will—it will trip the (turbuline) and cause the flow separation a lot earlier. So when you're on a down slope like that you have to be very careful.

So one of the things that we've begun to use when we use this formula is we've paid homage to the hill model, the notion that wind flows generally parallel to the surface. So it—there's a sheer even going up the hill, that seems logical, why would it go away, right. And there's sheer coming down the hill.

And so if you have a wake that's forming down the hill from you a lot of times—I remember when people used to say, well, put the turbine on the top of the hill because, like, putting it on a taller tower.

Well, on one hand it's kind of like putting on the top of the tower—taller tower, it's really more like putting the tall tower on the top of a hill because—in fact, the weight will propagate up that hill. If you have a taller tower there's no reason for the weight to propagate up your tower. So they're not exactly equal.

You will get some flow compression going up the hill obviously and so you get a benefit. There's no question that you get a benefit from being on top of a hill. But you—it doesn't mean that you get to—and this is hilarious, I'm just looking at these images of our turbine and I've put them in the image backwards.

They're downwind machines facing upwind so don't mind that, they're in park mode. I'm going to have to fix that. At any rate, you can see how the flow comes—weight coming up the hill is impacting that turbine or would impact that turbine.

So when I find myself in a rising terrain situation I pretend that there is no hill. And I assume that the height of the tree is the height of the tree and I get no hill benefit and I run the (Pereira) formula that way.

If on the other hand I'm in a falling terrain kind of situation where the object is higher than me in elevation then I will add the elevation difference between the base of that object and the base of my tower to the object's height. And then I think I get a more realistic performance.

Up to a point. Now you saw earlier that when the object height approaches the turbine height things start to fall apart because we get on the wrong side of that loss bubble. And so you have to be cautious, you have to not just run it blindly, that's important.

Can this model—can the (Pereira) formula be used to model neighboring turbines? I mean a turbine looks a little bit like a tree, right, it's got a bunch of drag up high and it's got a long poll if you will.

The folks that have developed the WASP and put all that documentation out there that you can find caution strongly against that. And they've developed their own wake model. And this model can—again, it's nice and straight forward, doesn't have any weird formulas in it. You can use this to develop your wake loss behind the machine.

And there's an example table for our 19.2 meter rotary machine that as you get five rotors downwind in a 6.5 meter per second wind speed you're losing about 24% of your energy during the time that the wind is coming from one turbine to the other, not when the wind is coming from some other direction. So that's an important little formula that you'd want when you're micro citing.

So let's move on to the example now. Most people will be familiar with the method of bins in which you take a power curve, which states—which has been empirically determined that a turbine at a specific wind speed will generate a certain amount of power.

And then you take a wind speed distribution that has been empirically measured or mathematically estimated out of a wind map or something else that says at that same wind speed I expect this many hours to occur.

So when you take the number of hours times the number of kilowatts at that wind speed you get a kilowatt hour figure, which is shown here to be a little over between 26 and 27,000 kilowatt hours.

That's the method of bins, you sum up all your bins and you're done, right. so how do we do that in real life? Well, we don't really worry about that very much yet because it's all done mathematically on the spreadsheet, which is nice.

But more to the point, how do we come up with a wind speed? So our first step is we'll look at a variety of wind resources. So Three Tier, which is now part of (Bisala), has a nice map. They'll tell you that they're horizontal, their spatial resolution is a few kilometers, three to five, six, depending on where you are on the poll. But—sorry, on the planet.

AWS will tell you they have around a 200 meter resolution. Wind Scout—now if you haven't come across this it looks a little campy because it's an iPad or iPhone application but don't be fooled, it actually talks to vortex map, which is downscaled reanalysis data. It is real data. It's just pretty course, nine kilometers.

So how much use is that? Well, you'd be surprised. At 80 meters, a lot of these models will come close. They'll begin to approach. And so it adds to the conversation I think.

NCIC is the National Climatic Information Center, don't be hunting for that in the US, that is a UK data set. And it's a one kilometer.

So we have chosen to weight these things a certain way so that when we get to the very bottom we have a weighted average wind speed that we feel is conservative, not hyper conservative, not too ambitious, but we think it's conservative and on the various—we've probably done a dozen validation checks with it and we think that our weights are reasonable.

And I'll tell you what they are. The AWS, we give it a one. And Three Tier is like a 0.7. And NCIC would be about a 0.1 and Wind Scout would be about a 0.6 or something.

And we always meant to go back and revisit these weightings but the fact is that they seem to be working well out of the box and maybe it's because we just kind of guessed at them after having used them for a long time and maybe it's we're just lucky and environment in which we work is pretty constrained. And I don't know, I don't know what it is, but I would encourage you to come up with your own weights.

And then we'll take the wind rows and we'll decompile it so we—we'll figure out how much of the time or how much energy—not how much of the time because these are energy rows, how much energy comes out of what direction? And we'll use that to come up with a sector-wise energy budget.

Because when you do a loss statement on a sector-wise basis you don't want to treat all sectors equally, you want to treat the sectors according to how much energy is out of that sector, that makes sense hopefully to everyone.

So that's done 16 times. There's a—the wind rows overlaid over a project site. This is kind of a fun one. It's over in the UK. And it's largely agricultural but it has some buildings to keep things interesting. It's got some sort of hedge rows that kind of got overgrown and you had some bigger trees and you can see those trees in the street view.

Thank goodness for street view, street view has kind of revolutionized the way we can do desktop studies of distant locations because we can kind of drop in and say, wow, I see that tree, there's a telephone pole, it's a 30-foot pole, I can compare the tree height and that kind of thing.

In the foreground in this image you can see some fences so those are, you know, five-foot tall or four-and-a-half foot tall fence posts. Well, unfortunately they're not next to anything useful but there's an object for you, right. So you can use this to start to understand what the size of the object is and these are all deciduous so they're all going to have relatively high porosity when it matters. So they're going to generally have 70% porosity or better.

It's interesting, if you talk to the CFD guys they'll tell you that porosity for trees is actually very high, north of 95% from the CFD perspective. It's important to understand that the porosity here in this (Pereira) formula is not the same thing as the CFD porosity. It's not an absolute. It's just what he calculated, I don't know.

You'd think that you'd figure out porosity by drilling a whole in a piece of aluminum and that'd be pretty close. But the fact that it differs so dramatically

from what the CFD guys would tell you, I'd say use caution and use their recommendations that come right off the Danish wiki.

So on the bottom left is a little image and it's got a distance bar, 44 meters or so from where the proposed turbine would be or where the center of that wind rows is. You can see it heading out.

And then it's got another cross bar, a T-bar if you will. That T-bar represents the sector width at that distance. And remembering that the circumstance of something is 2-pi-R in radians, right, if R is—equals—the circumference is 2-pi.

So the arc length of that T-bar is going to be equal to S times the arc—sorry R times the arc length, which is (RD theta) I should say, D theta. So 2-pi divided by 16 is roughly around 0.4.

So there's your S=RD theta, that allows you to kind of calculate how much of that sector is filled up with whatever that object is you're looking at. So I've shown you the northern sector and it's 40—almost 45 meters, that looks like that bush kind of fills up the whole thing.

The next question is how tall is that? And I guessed at 4 meters. I could be off. But you know, you look at the shadow and you kind of think about objects and you see a taller tree to its right with a deeper shadow. I don't know. How do we know? Well, let's take a look.

So there's an image of the same scene and you can see the pin in the distance and you can see the same kind of vegetation and you can see that there's a tree in the foreground. And that tree has enough detail—if you've looked at trees before you can tell it's not ten feet tall, right.

There's a little something on the ground—it's not ten feet tall, it's not 20 feet tall, it's not 80 feet tall. And pretty soon you start to go, I think it's between 40 and 50 in a heartbeat. It didn't take you but four seconds and you're like, I think that's a 40 to 50 foot tall tree.

Okay, call it 15 meters, let's see how it goes. In fact, if you're off by a meter it's not going to make that much of a difference. And you can then start to say, I can look around and I can see there's a lot of those kinds of trees and they're all probably about the same height because they're mature.

And then there's a bunch of those stubby little things that, you know, if they weren't flowering I'd call them Russian Sage and call them five meters tall, right—not Russian Sage, whatever, there's a tree, like an olive like tree that grows a certain height and doesn't grow any taller.

So like a fruit type of tree, they're flowering, they're not going to grow that tall. So four to five meters, probably not a bad number. And this is done, again, 16 times.

Now what's interesting is that just a week ago this camera cross my desk and somebody said, your model seems broken, can you take a look at this project? Because when I run your model I come up with about 2,005 kilowatt hours and yet the turbine itself is putting out less than that. And how are we going to explain this to somebody because we've got a bit of a discrepancy?

So you can see that turbine in the background, the lower image, and that tree is, yes, indeed about 45 feet, that's about an 80 foot tall tower. It's between 40 and 50 feet, 15 meter is a good number.

So when I ran through this in 16 sectors and I plugged in all the objects and I correctly—so this was the error, somebody had—it was a transposition error in the—when they had entered the wind speeds in the sheer portion of that tool they hadn't then carried them down to the wind speed estimate section.

So it was a minor clerical error. I came up with this—these figures here, which you can kind of see that the 24 meters net before availability losses is around 158,000 starting from 165 or so. And that when you take 98% of that in terms of availability which is what our fleet generally runs in the UK, came up with 155. And the measured was 157.

So you're like, wow, that's really good for not taking onsite measurement, how do you do that? Are you just lucky? And the answer is, yes, we're probably pretty lucky because the wind mass in this area are generally okay. UK, you can see that bottom left corner image, it comes right out of the wind trends from AWS and the bottom right is the scale.

It was around—kind of a normal year, slightly above normal, well, 157 is slightly above 155. It's a pretty good result.

So does it work like this all time? Yes, actually it does. I mean it's—we've done a dozen validations, ten or 12 validations, and we're usually within about 5%. Again, it's very controlled circumstances. We happen to be in one country where they have homogenized their landscape largely.

There's no wild spaces in England. It's pretty cultivated. And therefore, it's pretty consistent in terms of performance, in terms of sheer. We've got that down.

If you put me in Wisconsin I'd probably have a cardiac because I wouldn't know what to do and have to start all over, right. I mean I may not start all over again but I would have very little confidence in my first take in a new area.

And I'll tell you, when I started working in Nova Scotia this year, I—we don't have any turbines up there yet for me to compare to and I'm pretty nervous. And I'm overly cautious and every time I can I trim another 10 or 20,000 kilowatt hours off the number if nobody's looking.

So we know that flatter sites definitely work better, the models are well behaved in flat sites. We know that less clutter is easier because I can say, look, there's a tree row at 150 meters and the next one is at 800 meters. I'm going to choose 150 meter one.

Well, what do I do when I've got a lot of clutter? So Nova Scotia's another great example, that place is—if you haven't been up there, is a lot like Maine—or if you haven't been to Maine I don't know what—how to compare it to but maybe parts of—well, New England. It's a lot of hardwood, mixed hardwood, and softwood pine. It's a canopy typically in the 14 to 18 meters.

It's—it is some places it's very thickly covered and other places it's inconsistently covered. It's kind of a mess, that's the bad side. The good side is that it's pretty consistent. And so the wind mass are amazingly good. And how do we know that?

Well, we have access to maybe six or eight anemometers on 60-meter towers up there and we're doing comparisons nonstop. And I'll be darned if the wind maps aren't within—certainly within tenths of meter per second if not better in some locations.

So when you've got a lot—what do you do in a forested area? I don't think that objects—that approach is going to work. I think it's going to make you crazy because there are too many objects and you're going to be trying all different distances and everything else. It's better to just do a straight up displacement height and call it good. It's a little bit more conservative.

The question of displacement height is does the wind get truly displaced as the Z (naut) or the zero displacement height truly the canopy height? The literature will tell you that the Z (naut) or the displacement height is equal to where the branches from one tree touch the branches of another.

Well, what happens when you have another tree just upwind of it, you know? And how do I handle inconsistent forests and everything else? I don't know the answer to that. You got to just try it out and see and compare it to some data that you do have.

And I've found that—you know, when I've done a displacement height to try to adjust it for forested terrain the adjustment that I've had to do over forest is zero, meaning the wind map is very, very good with regards to they're on a displacement height already.

When I'm in areas with mixed then I usually use a displacement height of around 85% of the canopy height, something like that. But it varies, it's all over the map.

One good thing is that we're beginning to develop an intuition and—of when it's going to be worthwhile to spend the time to look at the model and when is it going to make more sense to just turn and run. We kind of turn and run

when we think we're getting these kinds of effects, this is a—our high tech CFD on my iPhone.

But what it simulates here is that by having a kind of a sharp drop or something else you'll get flow separation and then the linear models won't work so well. It also shows you the landscape types that I think land classification 1, 2 work fine.

Land cover—land classification 3 works okay if there's not a lot on it. Same—these classifications come out of the Danish wind atlas. There's also a land cover classification—so this is a terrain classification, sorry. There's a land cover classification, looks a lot like this, where it's just open fields and perfectly flat, nothing on it, that's a Class 1 and that's sort of where the turbine would have been tested.

And Class 2—Category 2 I should say is where you have some trees and, you know, you're down to 10 hectare fields and you have some trees in 6 meters with the occasional 8 meter trees.

And then Class 3 is where you have some mixed houses and trees and that kind of thing. You can imagine how the models have worked reasonably well in Land Class 1 and Cover Class 1, Land Class 2, Cover Class 2, but start to fall apart when you move into 3s. So getting that intuition will save you a lot of time.

The image in the top left is actually our operational fleet—about a month ago actually, I didn't update that. So I think today we have over—I think, either closing in or just over 500 machines flying in the UK, which gives us a lot of validation points. Because we—all of them are (unintelligible) enabled so we can actually go back and see how they're doing.

When our models fall apart and we can detect or intuit it we don't like it. So we had a situation three weeks ago where we have these two sites that had hills that were lightly covered with objects, I should have put that image in here instead of this one.

And normally you'd say, that's totally fine, I think we can handle that except that there's a deep and steep valley beyond the hill that drop down like 100 meters or maybe 60 meters. And then pop back up another bald hill. And that's where my intuition falls apart, I don't know if that hill is going to huff at some sort of frequency and give me crazy turbulence intensity on a large scale.

And so that's when we would want to throw some computational fluid dynamics muscle out at it. And there's a group out of Bristol UK, (Marrow) and Company at Digital Engineering. And they will run open foam which is a CFD open source CFD program down to the half meter resolution. So they can see trees.

You can see how the trees have dimension to them. They can see buildings and they'll extrude those buildings through the ordinance survey extruder effectively so they'll get very sharp edges on buildings, not half meter—plus or minus half meter buildings but sharp edges on buildings.

They will give buildings that—the correct type of roof. They'll check porosity and height of objects. And when they run this against (unintelligible) towers, they've had effectively a zero bias, very, very low bias, and extremely good effect.

So we use them when our intuition falls apart and we've been really happy with them. We're also beginning to experiment—I say experiment seriously with these UAVs. I wouldn't say that we operate them commercially because that's illegal but we operate them experimentally, which is in the gray area.

And what we're using them for—not just to take pretty pictures of our turbines like in the bottom right, but we're using them to actually do object assessments. In this image, you can see that tree and in one picture the distance is 3 meters so this thing is 10 feet away from me. And in the next I'm taking a picture of a tree 90 meters away.

At 10 meters a second it takes me less than 10 seconds to get out to that tree and then maybe 5 seconds to correctly position the vehicle so I can see across the top of the tree and to the horizon. And intuit it's got a 27 meter height.

Now it's off by a known amount because it's a barometric altimeter on the thing, that's good enough for it to auto land so it doesn't come crashing down. It will auto land. So it's got a very linear offset as the slope is about 1.1 times real so that's an 82 foot tall tree. And I could do that in less than 15 seconds.

So you can hit—you can generally survey an area in less than ten minutes. Certainly eight minutes is what I've done on many occasions, not like I do this all time, I'm—this is experimental.

But it's fantastic in terms of photo documentation as well because you can look up and over the first line of trees in a forest and say, that's a line of trees or that canopy is at, you know, 16 meters and it goes on to infinity, those kinds of things are very hard to do from the ground. And it's been revolutionary for us to be able to see from the hub height.

And then speaking in terms of hub height, you can fly up to the hub height, look around, and do a rough assessment of how many houses—and what houses, you can take a video, a 1080 P video, and see which houses can see the hub and which houses can see the tip.

And so it's kind of a nice way to see from a masking perspective where I'm going to have flicker issues or not and who's going to care, that kind of thing.

So a few final thoughts, micro citing, what it is about, it's about setting expectations, it's not about doing resource assessment. It is about choosing a—the best location on the property to use what you have, it's not going to be the best location in the county. You have a piece of land to work with, not a county.

It's also about knowing when to walk away from a project because it's simply too sheltered or too something else. And our methodology relies heavily on wind maps and we have found times when wind maps are just off and how do you know that they're off?

Well, we don't know the whole map is off but we'll show up and the trees are all blown southwest to the northeast in a big old way, like a 7 meter per second average wind speed for these exposed trees. And the rows will show that there's winds that come out of the southeast. It's like, you know, what, you're off by 90 degrees. So we throw the model out at that location.

So we have certain areas in complex terrain like up in Scotland or in Nova Scotia where you get funneling, channeling of air, and in those situations we are cautious not to use 9 kilometer models that are going to complete miss that.

And whenever we do have onsite data and we—you know, it's interesting, in Nova Scotia, the community feed and tariff program up there tends to incentivize people putting in 800 kilowatt intercoms and then we follow along with a couple of 50s. Well, that means that there's been an anemometer up there for a couple of years or so and that's been really fun to actually have onsite data.

So I appreciate the big guys when they talk about the need for wind on—you know, onsite wind data but there are ways around it if you're careful. The wind map is never—rarely an answer I should say, I shouldn't say never. It's rarely the answer but it's usually a great start.

And I think that's it. The last one is a nice picture of one of those 800s out at Kaiser Meadows just north of (unintelligible) in case you ever want to visit it. And I think with that—questions, Tony?

Tony Jimenez: Yes, we're going to have the Operator open up all the phone lines and you can just ask your question verbally. So I guess we'll hit star-0 to do that.

Operator: One moment while we have—wait for questions. If you'd like to ask a question just press star-1.

Tony Jimenez: Hi, we'd like all the phone lines opened up now for Q&A.

Operator: Sure, just one moment. The lines are opened.

(Heather): Should we just dive in?

Operator: Yes. The lines are open.

(Heather): Tony, I have a question. This is (Heather).

Tony Jimenez: Hi, (Heather).

(Heather): Hi there. Charles, I wonder if you could go back to your Slide 20 and 21.

Charles Newcomb: Twenty and 21. There's 20.

(Heather): Yes, I love that concept for one and you did a good explanation of it. So then the next one down kind of had a spreadsheet version of it, right. (Unintelligible) kind of a proprietary tool that you have or is that available for other people to use as well?

Charles Newcomb: This is available for friends and family and you would be friend—and family frankly. No, you know, I think I've got—so we had a reorg—this is kind of fun. We had a reorg and (Jeff McCauly) became our COO and he's a reasonable guy.

And he and I agreed that there's no faster way to find an error in our spreadsheet than to let it out. And so I—you know, if you personally request it from me I will personally send it to you with the caveat being that you're going to have to figure out your own initial AEP. It is kind of slick.

You know, what's not shown down here—and it would blow your mind. You know how I—back when I was doing the (FVP) stuff I had these—I remember (Henry Dupont) yelled at me one time because my spreadsheet was killing his—whatever it was computer because I had 50,000 array commands all operating at once and it was a dumb way to do things.

And I've since gotten a little more sophisticated. But these equations here that give you the net energy out of each direction by town height are pretty awesome. And so you'd want to decompile them and figure out what the heck they're doing.

So it's not going to—I'll send it to you, it would not come with a manual, that's the long way of saying that.

(Heather): Right, right, it sounds like it's easy to overwrite cells and maybe make a little mistake there.

Charles Newcomb: Well, that's why Gmail or mail is so great because you just never delete it from there and you always have a clean copy.

(Heather): Okay. Great. I had another question too but I'll let somebody else ask...

Charles Newcomb: Yes, while I'm on this slide I would point out the wind rows and why there's two columns. There's an end or an estimate here and it goes back to, you know, when you think about how much energy comes out of a direction and let's pick the southwest and say that's like 8 or 9%.

And what did we guess, 9%? Okay, so what if it's 10%? What if I'm off by one percent? Well, one percent more energy comes out of that direction than should and now I've got, you know, an object that is creating 2% more or less loss or whatever—you can see how the numbers becomes insignificant in a hurry.

So when you're decomposing your wind rows—and I've actually asked (unintelligible) AWS, can you just give us these in tabular form so we don't have to do this step and they're, like, well, we'll see if we can. Obviously they

have the data but I usually encourage people to just go for it and give yourself a grade there. That 95 down at the bottom is the sum of the amount of percent.

I'd say that's an A. In fact, it's not A+ but it's an A and that's good enough. And then what have we done in the adjusted figures is we've divided those figures by 95 in this case. So that—so that the total equals 100% because in energy rows it's meant to account for 100% of the energy. It's not a time rows.

A time rows can have (unintelligible) moments and so a wind rows—an occurrence rows is not going to equal 100% but an energy rows will and that's why it's important to take that last step, otherwise you'd be off by 5% before you even started the game.

Other questions? (Robert), Tony, (Karen)? Anything else that I can talk about? I think the other thing that we don't do, which is not obvious in this tool is we've been terrible, we've been bad people, and we haven't taken this from a corrected air density perspective. And we're using the AP table, which has a (unintelligible) of 2 or a K of 2. And there's a shortfall there.

So we need to upgrade it for that so anybody uses this tool needs to know that it's really good from a loss perspective. It's—I mean the reason why is we really wanted—when somebody plugged in 6.5 meters per second they got a number that they saw on the brochure because we didn't want to answer a lot of questions of, like, why is it 5% higher than the brochure or 2% lower?

Well, the answer is because you have a non-K not equal to 2, it's something higher or lower.

Man: (Unintelligible).

Charles Newcomb: We assume a standard wind distribution. And so that's the other weakness, it's the one criticism I would say. I would also say that we do not have—we don't—we haven't settled on appropriate displacement heights and we haven't also begun to draw a link between loss and turbulence intensity.

So that's this summer's exercise and it's fun to see (Nate Schmidt) on the list because he's going to be the (unintelligible) hopefully who helps with our new citing guide. Part of our citing guide is going to be throwing virtual map at digital engineering saying here's some trees, here's a building.

You know, let's create a map that gives us turbulence intensity from a CFD perspective at different distances, different slices around these building and trees so that we can begin to see if there is a link between turbulence intensity and the loss behind that object.

And then heck, we can start to look at the sheer because you can use this tool to actually not go to hub height but you can change the tip height and bottom of disk height and look at the sheer across the rotor. And then you can say, okay, now can I plot sheer across the rotor with turbulence intensity?

And the chances are that you're probably going to get—because that's what turbulence is, right, sheer causing rolling, right. Then when you'll see a clearer relationship between those and anything else. And then we can start to use the (Pereira) formula to back calculate turbulence intensity. And that's when things get interesting, that could be fun.

I think the other thing that I would add is the notion that, you know, a lot of people from a citing perceptive think in terms of 5D, 10D. So if you've got a

directional wind, you're going to put two turbines out there side to side you want to be five rotor diameter side to side and you want your rows to be ten diameters front to back.

Well, what if you only have two machines, how close can you get them together? Well, I see—or the—shoot, Class 2 Wind sights, at 8.5 meters per second, 18% turbulence intensity for A or whatever it is. So the question is, well, what if my native cite and turbulence density was 18%, where could I put that other turbine?

Well, you couldn't because you've already exceeded—you're at your limit. Well, what if I was near the water and I had turbulence intensity—average turbulence intensity at 13%? Could I put another turbine a little closer because I'm not getting the kind of typical loads that I would get in a more turbulent area?

And if you do the math you can actually back calculate what percent of the time you can tolerate a nearby turbine given its distance. And the turbulence that it shed. So we're beginning to play around with these kind of rules. Why? So we can sell more turbines.

Of course you want to sell more turbines so you can change the planet and save the planet. But as long as you stay,, you know, above three rotors, which is arguably what these machines—these utility machines are out of the wind cite, they're three rotors or so, right.

And you know, greater than three rotors so nobody laughs at you and you're good to go. In fact, there's lots of wind walls in California with these highly directional winds where they're less than three rotors, they're 2.5 rotors I think.

So we know that we can (unintelligible) closer and closer, the question is can we revisit that?

Can we get some kind of accord in the citing community that says, yes, that math makes sense. And yes, of course you can have a table that says, for varying cite turbulence intensity you can tolerate different amounts of time at different rotor diameter separations. So that's another thing that we've been working on.

(Trudy): Charles, this is (Trudy).

Charles Newcomb: Hi, (Trudy).

(Trudy): Hi, one of the things that's interesting about—when you have only forested areas and you don't really know what to do in terms of turbulence intensity is that IEA task 27 that I'm involved with has recently come with a whole set of major data that they've (unintelligible).

What they've decided is that the turbulence intensity is 40% (unintelligible) forest. I just wonder how that would play out for one of your cites instead of changing displacement?

Charles Newcomb: Well, I have a sample size of one, (Trudy). And it's a little depressing. I do have an anemometer on top of a hill. It's kind of the worse case scenario but it's a short canopy. It's interesting. It's only about a 7 meter canopy. So you'd think the turbulence intensity wouldn't be that high, it's 27%.

(Trudy): That doesn't surprise me at all.

Charles Newcomb: Yes, at 40 meters. So yes, your high turbulence numbers are not that far off and the—you know, the next thing is—the other question is, okay, so at 8.5 meters per second, 18%; what is it at 7 meters per second from a rain flow, you know, low counting perspective?

Can you tolerate what, 22%? That's another table I want, right. And apparently that's not that trivial but a table that says as you drop in wind speed the loads are less. So you can tolerate higher turbulence, right.

And that way we can say, yes, well, if you're at 5.5 meters per second, which is barely cutting it in some locations, but there are people who are willing to do that, especially in a 50 (unintelligible), right. And you're like, okay, well, I think I can tolerate a lot more turbulence at 5.5 meters per second.

So I think (TASK 27) has a lot of work to do, (Trudy).

(Trudy): Actually, (TASK 27), we're just going to skim the upper grounds of what you're describing there. So sorry, Charles. But you know, there is a task that (Pat Moriarty)'s involved with that looks at the 5D, 10D, whatever those relationships are in wind farms. You might want to catch up with him. And then there's the new IEC task, I think it's /15 and I think (Jason Fields) is the NREL representative.

And not that standards (unintelligible) really reflect cutting edge methodologies, they don't. They tend to represent consensus sort of kind of over knowledge basis but that might be interesting as well.

Charles Newcomb: Okay, that's great. And then I guess (David Lano) was also encouraging me to look up (Neal Kelly).

You don't happen to have his—well, we wouldn't do it online but, yes, I need to look up (Neal) because apparently he's looking at deep array wake kind of studies, you know, five years before anybody else was really thinking about it. So he'd be another fun resource. So I appreciate that, (Trudy).

(Trudy): Sure.

(Heather): So Charles, I typed a question in earlier. I kind of got a more broad question. I'm sorry if I missed it but who normally pays for all this work? Is that considered part of your development or does the customer help fund it? And then if they do how much does it cost?

And I gave you a little estimate—kind of a follow up from our webinar last week on one piece of it but I'd love to hear your thoughts on, you know, this—is less expensive I would think than putting up a met tower but how much money does it take to run through this?

Charles Newcomb: Well, so firstly we do this for our own projects. In fact, so I guess (Steven)'s point next week I'll be doing this very presentation but it will be relabeled, you know, wind resource or micro citing when you own the turbine or something like that, I can't remember the title I came up with for (Mick), but the notion was that when you have skin in the game, not just as a analyst and that you have, you know, no insurance but that—your half million dollars that you're putting out there, you really want to—it matters.

And changes your level of conservatism in a way and you trying to make things different. So we're definitely doing this for our own projects and we're—we now have—I think a sum total of maybe 20 machines that we own, which is so exciting for us.

So we don't generally dot his for other people with the exception that in Nova Scotia we're doing this for all of our projects because we're supporting our staff up there that is formerly the (C-force) group and they've—we've gone from frenemies to friends, it's great.

And they're really fun group of people who really know the market well and know that area. So we're doing it up there.

I think if we can get this kind of an approach out there in the market where people have access to it then anybody can do it with a little bit of training.

And when I say anything because anybody—I say that seriously because our staff that goes out and does these site findings and does these analyses and generally get it spot on, these guys are car sales people, they're carpenters, these are not wind engineers. They—many of them never took math in college, you know.

So with training and the right tools and the right oversight kind of anybody can do it and it takes you—when you get good at it, you know, 45 minutes to give you a sense of how long it takes.

We are talking about if we can find the money turning this approach into an application for an iPhone or an iPad and the notion would be something along the lines of having grades, you know, where you have the green—I think, (Nate) was saying,, you know, the green, blue, black, diamond kind of approach, which I really like.

And the green would be just sort of site characterization and then you'd take it back to spreadsheet. The black diamond would be somebody who has access to the (Pereira) loss formula on the application, that'd be slick. But the main

thing is it would kind of standardize the approach for micro citing and people would say, I get it.

I can see the circle, the fall radius of my turbine times 130%, I get it. I have to stay outside of that per house or I've got an acoustic setback. You know, you plug in your DB—your sound power level and it says, okay, your setback is 260 meters or 180 meters and creates a sound setback from property lines or whatever it is or biological setbacks of, you know, 70 meters or depending.

So I like the idea of doing that and then anybody just pays their typical $1.99 for an iPad app if we can get there.

(Heather): That would be awesome.

Charles Newcomb: Yes, and then to answer the last question, the Digital Engineering is indeed cheaper and much faster than the anemometer. It's like 3,000 pounds so $4500. So if you're going to put up, you know, a turbine where it made sense to spend that amount of money their typical turnaround is two weeks. And the only reason I bring them up is they have a unique—it's always about a niche, right.

And what these guys have as a niche is they have access to NHPC, which is a 2,000 core super computer that is jointly owned, I think, by Airbus and Rolls Royce and then British Government. And the British Government ensures that the small people like Digital have clock cycles.

So they can run these fairly simple models—not simple but models that were not designed for computational efficiency. They're designed for accuracy so that's how you do, like, formula one wings and that kind of stuff is using those kind of CFD models and running it on a monster computer.

And then allowing you to run half meter resolution over a kilometer. So it's that kind of stuff for $4500, gosh, you can't even buy a used tower for that let alone the instrumentation.

And then WASP, you know, the other reason why most people aren't running WASP is there was a training here in February I guess it was, $10,000. Is that right? Ten grand? It was something like—it was cost prohibitive to send somebody to WASP training.

(Heather): The training, well, okay, but to actually run an analysis...

Charles Newcomb: Yes, much—I don't know what that would be, $1500 or $1,000 to run that.

(Heather): Yes, that's what (Wes) said, between $1,000 and $2,000.

Charles Newcomb: Yes, I think that'd be reasonable. Now we do have—yes, I mean we do have—when we partnered up with Norwind we also got a few folks and we have a copy of (Mediadyne) and we do have a copy of WASP and we have a guy that knows how to run it.

So it's kind of fun to have some of the in house that does those tools. I don't but he can validate them for us and it's been gratifying to discover that our weird simplistic model works pretty well. Not that weird, it's in the standard.

Why would I call it weird? Just because we've never done it this way before, it's exciting. So we have a business meeting that starts now at 2:00?

Woman: Yes, let's wrap this up and transition to the business meeting.

END