Introduction to the Global Wind Atlas

—Transcript of a webinar offered by the Clean Energy Solutions Center on 20 November 2019—
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Webinar Panelists

James Knight	World Bank Group
Ides Bauwens	Nazka Mapps
Jake Badger	Technical University of Denmark
Søren Bo Krohn Hansen	Consultant
Gil Lizcano	Vortex
Brian Ohrbeck Hansen	Technical University of Denmark
Neil Davis	Technical University of Denmark

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Moderator   Today's webinar is focused on the introduction to Global Wind Atlas. Before we begin, I'll quickly go over some of the webinar features. For audio, you have two options: you may either listen through your computer or over the telephone. If you choose to listen through your computer, please select the "mic and speakers" option in the audio pane; doing so will eliminate the possibility of feedback and echo. If you choose to dial in by phone, please select the telephone option, and a box on the right side will display the telephone number and _____ you should use to dial in. If anyone's having technical difficulties with the webinar, you may contact the GoToWebinar's Help Desk, at 888-259-3826, for assistance. If you'd like to ask a question, we ask that you use the question pane, where you may type in your question.

The audio recording and presentations will be posted to the Solutions Center training page, within a few days of the broadcast. And will be added to the Solutions Center YouTube channel, where you'll find other informative webinars, as well as video interviews with thought leaders on clean energy policy topics. Finally, one important note to mention before we begin our presentation is that the Clean Energy Solutions Center does not endorse or recommend specific products or services. Information provided in this webinar is featured in the Solutions Center resource library, as one of many best practice resources reviewed and selected by technical experts. Today's webinar agenda is centered around the presentations from our guest panelists, who have joined us to introduce the Global Wind Atlas.

Before we jump in, I'll provide a quick overview of the Clean Energy Solutions Center. And then, following our panelist presentation, we'll have a question-and-answer session where the panelists will address questions submitted by the audience. And then at the end of the webinar, you'll be automatically prompted to fill out a brief survey, so thank you, in advance, for taking a moment to respond. The Solutions Center was launched in 2011, under the Clean Energy Ministerial. The Clean Energy Ministerial, the high-level global forum to promote policies and programs that advance clean energy technology, to share lessons learned and best practices, and to encourage the transition to a global clean energy economy.

Twenty-four countries in the European Commission are members, contributing 90 percent of clean energy investment, and responsible for 75 percent of global greenhouse gas emissions. This webinar is provided by the Clean Energy Solutions Center, which focuses on helping government policymakers design and adopt policies and programs that support the deployment of clean energy technologies. This is accomplished through support in the crafting and implementing policies related to clean energy access, no-cost expert policy assistance, and peer-to-peer learning and training tools such as this webinar. The Clean Energy Solutions Center is cosponsored by the governments of Australia, Sweden, and the United States, with in-kind support from the government of Chile. The Solutions Center provides several clean energy policy programs and services, including a team of over 60 global experts that can provide remote and in-person technical assistance to government and government-supported institutions, no-cost virtual webinar trainings on a variety of clean energy policy topics, partnership buildings with development agencies and regional and global organizations to deliver support, and an online library containing over 5,500 clean energy policy-related publications, tools, videos, and other resources.

Our primary audience is made up of energy policymakers and analysts from governments and technical organizations in all countries, but we also strive to engage with private sector, NGOs, and civil society. The Solutions Center is an international initiative that works with more than 35 international partners across a suite of different programs. Several of the partners are listed above, and include research organizations like IRENA and IEA, and programs like SEforALL, and regional focus entities such as ECOWAS, the Center for Renewable Energy and Energy Efficiency. A marquee feature the Solutions Center provides is no-cost expert policy assistance known as Ask an Expert. The Ask an Expert service matches policymakers with more than 60 global selected experts, as authoritative leader on specific clean energy finance and policy topics.

For the example, in the area of wind technology, we are very pleased to have Ian Baring-Gould, wind technology deployment manager with a national renewable energy laboratory, serving as one of our experts. If you have a need for policy assistance in wind technology or any other clean energy sector, we encourage you to use this valuable assistance. Again, it's provided free of charge. If you have a question for our experts, please submit it through our simple online forum at cleanenergysolutions.org/expert, and you can also

see the link on the slide. And we also invite you to spread the word about this service, to those in your networks and organizations.

Now, I'd like to provide a brief introduction for our great panel that we have gathered today. First up is Oliver James Knight, who is the senior energy specialist with the Energy Sector Management Assistance Program, or ESMAP, at World Bank Group. Following Oliver, we'll hear from Ides Bauwens, who is the cofounder and managing partner at Nazka Mapps. Then we'll hear from Soren Krohn, and wind power consultant for the World Bank and ESMAP, supporting the Global Wind Atlas. Following Soren, we'll hear from Gil Lizcano, who is the R&D director with Vortex.

Then we'll hear from Brian Ohrbeck Hansen, who is the senior development engineer for the Department of Wind Energy at the Technical University of Denmark. And then, our final speaker, today, is Neil Davis, who is the technical lead for Wind Resource Assessment Applications in the Resource Assessment Modeling section, for the Department of Wind Energy at the Technical University of Denmark.

And with that brief introduction to our amazing panel we have today, I'd like to welcome Oliver to the webinar.

Oliver Knight   Hi, there. So, welcome to the webinar, and thanks for joining us today. I'm Oliver Knight, and I'm from the World Bank—on the World Bank side, but in a unit called ESMAP, which is a multi-donor trust fund, operated within the World Bank and supported by around 12 bilateral donors.

And just going to briefly go through some of the context to the Global Wind Atlas and how it came about in its current form. I've put, up here, that it's essentially a public-private partnership of sorts, in that we have the World Bank and DTU kind of more on the public side, but we're also collaborating and using privately provided data. So, this goes back to 2017. DTU already had a Global Wind Atlas website in the public domain, but we'd just launched the Global Solar Atlas, and we were keen to work with DTU to improve and relaunch the Global Wind Atlas, and bring them into the same kind of usability, and also update the data. So, we've taken funding from ESMAP, on behalf of our donors, and we issued, from the World Bank, a contract to Vortex, who is a private provider of wind data and other renewable energy data. And Vortex essentially carry out the mesoscale modeling, which is—they'll tell you more about, but it's essentially the hardcore computer modeling.

That is then passed over to DTU, who then carry out the microscale modeling. And then, DTU have a separate contract with Nazka Mapps, who have redesigned a very nice website that we now have, and this is what we are essentially operating today.

So, what is the Global Wind Atlas? It's primarily a website, available at globalwindatlas.info. In fact, we launched version 2.3 yesterday, and you'll hear more about that. If you go to globalwindatlas.info, you'll get to this page, and you can do a lot right from the get-go, just by pointing your mouse and

gathering data and doing various different tasks, so you can zoom in, et cetera. So, we have, on the website, we have Web-based calculations.

The Global Wind Atlas also, now, has the ability—we have some precooked maps like this global map, but also, maps by region. And you can see a couple of them here. And also, by country. And that's Pakistan, Vietnam. And a newish feature that we have launched, recently, is the ability to essentially generate a map for any country in the world. And so, you can get that on the website.

So, poster maps, which we find very popular with countries and with people who are essentially looking for materials for presentations or looking to do some basic analysis.

What else is also there is, we also have generalized wind climate files, so you could actually download some of the data, and just recently, also, GIS files. So, a lot of the data behind it is now freely accessible, and we encourage people to use that.

We have a very good—we're very pleased with the reception of the Global Wind Atlas. As you can see, it's been growing since the relaunch. So, it was relaunched in November 2017, with this collaboration between World Bank Group and DTU. And since then, the numbers have been going upwards quite steadily. We're at around 7,500 users per month, right now, and you can see, here, some of the statistics. And we really hope to grow that over the next year, ideally, with your support.

I just want to mention that Global Wind Atlas has a couple of sister sites. We have the Global Solar Atlas, which is run by the World Bank Group, as a separate project but very closely related. And this is a good place to go for solar data, and you can also get the country maps on that website. And the address is very similar: globalsolaratlas.info.

And we also run another sister website where we—called Energy Data. The World Bank and ESMAP have actually been commissioning solar and wind measurement campaigns, globally, over the last few years, and we've installed quite a lot of wind masts in various different countries and solar stations. In fact, you can see the locations of those on the Global Wind Atlas and the Global Solar Atlas. And the data for that we post into energydata.info. And you can see, here, an example of that.

There's also a lot of other energy data available, there. The World Bank publishes—we try to publish all of our energy-related working data on this website, and we have a few other applications that are also available from that website. And the address, a very similar format: energydata.info.

So, thank you for your dissemination—we really rely on our partners and interested enthusiasts to spread the word. Please use the website, use the tools, give us feedback. We're still working on a new version that will be coming out in 2019, so there's still room for improvement, and we're very keen to get any feedback and comments you may have. Thank you.

Moderator	Great, thank you so much, Oliver, for that introduction.
	Now, I'd like to welcome Ides to the webinar.
Ides Bauwens	Yes, hello, everyone. I'm Ides Bauwens, the managing partner at Nazka Mapps, and we have been building on the interface of the Global Wind Atlas. And I will now take my time to shortly show you the main functions of the application that will help you to travel through it.

So, I'm going to do that using the help section, to which you also get access. So, we start, from clicking on the help section, you get some general information about the Global Wind Atlas, and also, two links to the sister websites which were also just mentioned by Oliver, the Global Solar Atlas and the energydata.info. So, but let's move to the next step.

We have a very common—everyone knows this, I guess—search location bar here, where you can simply add a place, and then the map brings you to that area. But what is special, here, is that when you enter the name of a country, this search bar can bring you directly to the wind profile of that country. So the map brings you to the specific selected country, and on the right, on the sidebar, you see the wind resource information of that country. So, before talking about wind resource information, let's have a look at the layer controls here on the top-left of the map.

So, the layer controls can simply be selected by clicking on the name, which will toggle them on and off, and you will see that there are two main groups also located here. You have the wind energy layers, where you have three types of capacity factor layers. You have the explanatory layers, where you have different types of layer that explain on how the power density layer is created. You will see that for each layer, there is a small info button appearing next to the layer name, so if you move over this info button, you get more, let's say, basic information about this layer. All the layers shown here are fully covering, our global layers, let's say, are fully covering the globe, with an exceptance, here, in the wind measurement stations. This is a point data layer, where, if you hover over a point and you click on it, you get more information about the wind measurement station that is located in this area.

Important, here, to mention, as well, is that for some layers, namely, the power density and the windspeed, these layers are available at different height. So if we, for example, select the power density layer here, and we go to the bottom-right of the map, you can see the interactive height legend here. So, we are now looking at power density at 100 meter, and by simply clicking on the interactive legend, the map adapts to the other heights. The heights are available at 5,100 and 200 meter.

Another nice feature is, when we hover over the map, you will see that the value is—there's small arrow appearing next to your layer legend, here, which indicates the value you are looking at where your mouse is hovering. When we have a layer selected with the unit that is available in different standards, let's say, you can click on the unit, and this gives you access to a different unit

system. So, if you're used in working in another system, you can change that over here.

Okay, so, if we click in our help section again, and we move on, we see that here on the top-right of the map we have basic map controls. These are standard map controls that allow you to change the backgrounds of the layer, remove the labels, go to maximum screen overview, go to the location where you are located yourself, go to the global map again, and zoom in and out.

Okay, it is also, and side note, it is also possible to, at the bottom of the map, now, again, it is also possible to hide the legend and show it back again. This is important when you're working on different types of devices. Here, we are looking at the desktop or the laptop screen; there is also a design for mobile and tablet. So, the application is also accessible on your mobile and your tablet.

So, moving on through the legend, through the help section—I'm sorry— _____ see, here, we discussed about the layer legend, and we moved to the sidebar. The side panel is an important part of the application. Why is that? Well, there's on the one hand, of course, the wind resource information that is shown here, but it also gives access to specific functions like map printing and GS file download. So, in the side panel, we have two important sections: we have the customized areas and we have the country and regions. And I'm going to start, here, with the customized areas.

So, there are three ways to access data for a specific area, through the map. There is the point way, there is the rectangular, and there is the polygon way. Simply by selecting one of those and drawing on the map, you can draw the specific geometry that you are most interesting. So, if we move back to the point, here, for a moment, you can simply select that, and you can keep on putting points on the map, and you get more information about that specific point, at least the area around it, on your side panel.

The area around it, what do I mean with that? Well, when you place a point on the map, you don't get the exact point value, you get the data, wind data, for an area of 10 by 10 kilometers around this point. So, when a point is selected, you see, here, that the power density plot, the wind roses with three types of wind rose information. More information about the content of this data will be given in the next _____. And the windspeed, these plot data, are shown over here. And the data that is plotted over here can also be downloaded by clicking here, where you can select which data you are interested in, and the form that you want it to download in. There's also the possibility to download a GWC file _____ file, by clicking on the button over here.

So, another important part of the customized area is that you can save your area in your local storage of your browser. So, let's say we have this point now drawn on the map; I can click on the safe icon and safely say "webinar test," for example, save, and now it is saved in my browser. If I go to my saved areas, I can see that I can bring it back up through the menu over there. So if I am using the same browser on another day, I can always go back to my

saved areas. Next to the saving the area, you can also share a link to that specific customized areas with other. You can download GS files—this is an important feature. So, once you have a customized area drawn on the map, or a country or region area selected, you can decide to download the original TIFF files for that area.

Now, the file that you will be downloading, when clicking on this icon, is the layer that is selected on the side panel here on the top, on the layer panel here on the top-left. So, in this case, we are looking at power density with a height of 100 meters, so if I download this one, I will get a TIFF file with the original power density values from my custom areas, together with the geojsn file that has the boundaries of my area of interest. Now, it's important to notice, here, that especially for countries, these files can be quite large and can only be used in the correct environment. So you need to have background in working with GS data, and you will need, as well, GIS software to further process and work with this data.

Okay, so, second part of the sidebar that we have, here, is the country and region section, where you can select predefined areas, let's say. So, here on top, you have a dropdown list, global dropdown list, of countries in the world. You can just start typing here, select it, and the map will go to that specific area. And the wind resource information for that area is then adapted and shown over here. Now, once you are in a country, you can also choose to select a region in that country. You can do that by clicking and selecting in that dropdown list, or simply by clicking on the map.

Now, one feature that I haven't shown, yet, is the map printing. So, if we are in a certain customized area or country and region, you can click on this icon here, and you see that the map adapts to that. So, for the layer that we have selected and the area that we are looking at, the layer is then showing the information, here, over the map. You can print this information in a PDF map, but before doing this, you can decide to adapt some parameters. You can, for example, include a buffer area, by selecting it here and sliding the buffer slider. And this is interesting, especially when you're looking at coastal areas, for example. You can also decide to rescale the color legend.

So, the color legend that we're looking at now is between 25 and 1,300 *[distortion interferes with audio]* square meters power density. If I say scale to the min and max values that fall within my area of interest, you will see that the map adapts, the legend adapts, and it's possible to see much more variation in your image than before. If we then, say, we click, we want to print this as a PDF, you get a result like –

Moderator	Ides *[audio cuts out]* I'm so very, very sorry to interrupt. We've got to start to move on to our other presenters—can you wrap up in a minute or two?
Ides Bauwens	Yes, I'm almost there, no problem.
Moderator	Wonderful, thank you so much.
Ides Bauwens	No problem.

So, if you print the PDF, you get a result like this. This is calculated on the fly, so it needs 10 to 20 seconds, and it can then be saved on your hard drive.

Now, to end—we are at the end—I just want to highlight, also, in the navigation top bar, there is a lot of information in the background pages *[distortion interferes with audio]*, et cetera. You have the downloads page where you basically have short links to the GS file downloads and the map printing that I just mentioned. And, of course, you have the contact form— very important. If you have specific questions or you have remarks that you want to give, you want to share with the Global Wind Atlas team, don't hesitate to do so.

So, that was all for my part. We are there. Thank you for your attention.

Moderator   Wonderful, thank you so much, I really appreciate it.

Now, I'd like to welcome Jake Badger to the webinar. He is the head of the section for wind resource assessment, at the Technical University of Denmark. Jake, welcome to the webinar. Thank you so much for joining us, today. *[Crosstalk]*

Jake Badger   Hello, world. Good morning, good evening, and—yes—good day to everyone. And I would like to tell you about the ability to use the Global Wind Atlas for investigating country wind resources. So, yeah, I've been introduced, yes, I'm from DTU Wind Energy. And I would like to say thank you to Clean Energy Solutions Center, for hosting this webinar and giving us the possibility to tell everyone about it. So, I just need to get to the next slide. *[Laughs]*

Yes, so, all of this would not be possible without our team, and I would like to just acknowledge the team, right now. So, I have a number of colleagues at DTU Wind Energy, who have been working hard on all of the microscale modeling and liaising with our consultant, World in a Box, in Finland, who's been partnering with us on the microscale modeling system. And then, of course, Nazka Mapps, who we've just seen from Ides, the work that they've done to create a really nice interface with the data, and tools that are provided by the Global Wind Atlas. So, thank you to them.

Also, to Vortex, in Spain, who have been doing the mesoscale modeling, and providing that to us, and Gil will get a chance to talk about that part, a little later. And then, of course, the World Bank, because of the funding that's made this sort of new wind atlas development possible, so we're very grateful for that. And also, not just the funding, but also a lot of great ideas and sort of, yeah, really good fresh motivations to create new tools and datasets. And also, to connect it to many other of the ESMAP projects.

So, my next slide is a sort of schematic showing the modeling down chain, and we'll talk about that again, a bit later. But the main thing I want to talk about is, it's a downscaling from largescale reanalysis data, and then we do this mesoscale modeling step, and that's under the responsibility of Vortex. And I've marked it out by this stashed box, and I'm gonna be using this to

signify the modeling influences, later on. And then when the Vortex have done their mesoscale modeling, then that is passed to us, where we do generalization and microscale modeling. And I've shown that by this now dotted box, to indicate the microscale modeling.

And here, we go from scales of around 3 or 9 kilometers, down to our calculation: every 250 meters around the world, we have a high-resolution wind climate calculated. So, if we take an example of what you can now do with the latest version of the Global Wind Atlas—and Global Wind Atlas 2.3 is the latest version—we can create, as he just explained, these country poster graphics. And I would like to say everything I'm showing, apart from a couple of figures, are actually screenshots out of the Global Wind Atlas, which can sort of demonstrate what you can do just by going onto the Web browser. So, here we have what has been generated by the Global Wind Atlas for the Philippines. And I thought that was an interesting example because it features some mesoscale influences flow, and also some microscale flow features.

And if we look at the poster map, we can see that there are some places with low winds below three meters per second, and some places with higher windspeeds up to around ten. And if you look at this figure we have on the right, it indicates that—if we look at this graph, on the x-axis, it shows a percentage of windiest areas. So when that is 100 percent, this is actually saying what is the country average windspeed. And if we read it off this graph, it says it's 5.3 meter per second. But actually, wind is deployed in the favorable sites, so what we're interested in doing with this high-resolution Global Wind Atlas is looking at the best sites.

And we can do that by gradually looking at a smaller and smaller area, saying we're only looking at the windiest areas, and that's what this graph is indicating. So, with this graph, we can look at, for example, the ten percent windiest area; we can see that we have a mean windspeed of around eight meter per second—a bit higher than that. And so, that's how we use this graph and using the high-resolution Global Wind Atlas data, and we can do this for customized areas and also countries and administrative regions. The next thing we can do is look at it from the point of view of power density. So, it's the same kind of poster map produced again, and then, on the righthand side, you can see the power density graph showing the percentage of windiest areas, and then increasing in the power density mean as we look at the windier and windier areas.

So, here you can see the country mean power density is around 220 watts per meter squared, but if we go to the windiest areas, _____ 10 percent windiest areas, we see it's around 700 watts per meter squared. So, this is, like, the whole essence of why we did the Global Wind Atlas, was to make sure that the windiest areas are emerging in our assessment of wind resources. So, I want to, now, explain a little bit about, if we're looking at a country, what kind of features can we examine and investigate. So, here we are, we're gonna zoom in on a part of the Philippines, the Calamian Islands and the Guimaras

Strait. And the reason I do that is because, if I can highlight it with this sort of red pointer—I hope you can see that—we've got this dashed ellipse.

We've got two dashed ellipses which represent two mesoscale features that are caused by a kind of gap flow that's occurring in the straits between these main islands of the Philippines. And if you look on the righthand side, we've got the elevation map, which is from the Global Wind Atlas again, and you can see these gaps, these straits between the islands, where there's elevation going up to around 1,500 meters. So, it's really interesting to be able to sort of browse the world and pick up these interesting mesoscale features that are enhancing wind resources.

If we look at the next slide, we're zooming in much deeper, now, into the Guimaras Island, and again, I've put in the dash lines. We're showing the mesoscale feature of this gap flow through the strait. And if you look on the right, now, you can see the wind rose that has been created by this point customized area that has been put down on the island. And you can see that the winds are predominantly coming from the northeastern sector, which is consistent with this gap flow concept, and this is where the main winds are coming from. But if we look at the island, we can see, now, a lot of variation of the wind resource, and this is the windspeed plotted. We see a lot of variation, and now we need to kind of examine why is that happening.

So, we can look, using the Global Wind Atlas, at the elevation map, and also the roughness map. And the elevation, we can see, it's not super high, it's not like the elevation on the main islands to the west and to the east, but we are seeing variations of a few hundred meters, on that island of Guimaras. And also, if we look at the roughness map, we see variation of around five centimeters to around one-and-a-half meters. And this is also representing cultivated land, and also some forest areas, and also some city areas. So, we see variation in elevation, we see variation in roughness. And now, we go back to the windspeed map for the island, we can see different features that are caused by this.

These are now microscale features that are being picked up and showing where the strongest resources are. If we look at the west coast of the Guimaras Island, we can see some good—so _____ just highlight that with my cursor—here, we can see some strong resources. This is a combination of the low roughness because of the seashore, and also headlands, where there's some orographic speedup effects, this flow has to go over the terrain. So this is just the sort of way of interpreting the different kind of influences of mesoscale and microscale that you can do with the Global Wind Atlas.

Another thing you can do with the Global Wind Atlas, as you know, you can have different maps, a sort of underlay. And I think this is very nice, because, for example, a roadmap, you can get an idea of the human geography surrounding your site of interest. Not just the meteorology, but here, for example, you can see that there's quite a large city nearby the island and nearby the strait. And you can also, yeah, look it up and kind of get a context for the kind of place you're examining, for example, *[distortion interferes with audio]* 500,000 people. You can also look at the satellite imagery, which

can give you a check of the land cover. Also, wind features: if there's a desert, for example, you can sometimes see sand being blown, features which can then confirm what the Global Wind Atlas is saying. And here, we see cloud streaks, which also is confirmation of a northeasterly wind at this time.

You can also put—the capacity factor data now is a new feature that's very nice, that you can actually get a feeling for, if I had a turbine placed in the terrain, what would be—you get an idea of the production. So, here, you can choose between three different IEC class turbines, and this is a nice new feature which goes beyond just showing sort of meteorological information. What I always like to do with this feature is to add the ruggedness index, which gives an indication of the complexity of the terrain. In _____ terrain, we know that our _____ flow models are kind of more limited, so the recommendation is that if you're in an area with a rather high ruggedness index, this means it's important to go towards some more modeling, possibly using CFD modeling, and also go towards more measurements onsite. But where you see the low ruggedness index, so where it isn't masked out, we can be quite confident about the results that are being shown by the Global Wind Atlas.

[Distortion interferes with audio] to validation. So we have done an inhouse Global Wind Atlas to validation, using 60 wind measurement stations in seven countries. So, the summary of those results are, you can see the graph, here, of the Global Wind Atlas derived speed plotted against observed windspeed. But we are seeing a mean bias around minus-three percent, and a mean absolute error of nine percent. And this is work that is very important to continue and to disseminate into the Global Wind Atlas, and that's why we're very happy to have the sort of integration of the data from the ESMAP country wind mapping projects—and connecting it to the energy data info webpage. So, here on the Global Wind Atlas, you can see the location of the measurement sites, and these will be integrated into our validation.

And it's important to remember, the validation principle is that these data form these very high-quality measurement sites are independent measurement data. And then, they are compared against our Global Wind Atlas model data. So, it means that they're not mixed *[audio cuts out]* a matter of calibrating the Global Wind Atlas data to fit the independent measurement data. No, they're totally independent. So you have Global Wind Atlas model data anywhere in the world, but the best thing with all this is to be able to see that you have Global Wind Atlas data and a validation with measurement data. And that's what we'll be able to provide in future versions. And it's important, here, to mention our partners, there, which were involved and are involved in the ESMAP country mapping projects. And that's DNV-GL with their in-country partners, and 3E with their in-country partners, too.

So, in summary, _____ _____ _____ makes the go-home messages, which is, with the Global Wind Atlas, you can understand physical phenomena that give rise to wind resources. And these can be thought of in terms of mesoscale effects, microscale effects, and you can investigate windspeed distributions and wind roses *[audio cuts out]*. You can also quantify the

resource with wind power density, and now with capacity factors. And you can estimate the level of uncertainty, using the ruggedness index mask. And in the future, with our next steps with validations, they'll be built into our website, so you'll be actually able to get some kind of feedback for the validation work within the Web layers.

So, that's it. Thank you very much for your attention.

Moderator   Great, thank you so much, Jake. Now we'd like to welcome Soren to the webinar. Soren, welcome to the webinar. Perfect, your screen looks great, Soren—thank you so much.

Soren Krohn   Sorry, I was muted. *[Laughs]*

Moderator   No worries.

Soren Krohn   Okay, so, anyway, one of the best new features of the Global Wind Atlas, in my view, is the fact that we can display capacity factor maps, to see where the wind resources are. So, this presentation is about the data you can download from the Global Wind Atlas, and it's very much oriented towards practical use, towards wind farms, and it's primarily for people who would want to download the data to their own GIS system. Now, as my example, I'm primarily using Uzbekistan, because a few years ago, I wrote the terms of reference for a mesoscale and microscale study in Uzbekistan, in order to find the wind resources. Now, I wouldn't do that today, and the reason is that we have the Global Wind Atlas.

And the Global Wind Atlas, to my mind, actually gives us a very clear indications of where we find the good wind resources. Now, what I've done here, is, I went on to the Global Wind Atlas and I did the color focusing that Ides was talking about. So, I said, here, "Well, I'm really interested in stuff that's between 35 and 45 percent capacity factor, for a class one turbine." And I get these; you can see about five patches, roughly, in the country that look interesting.

Now, this is what it looks like on my own system, and again, I do the color focusing on my own system, and I get the same picture. Now, then, I overlay it with a grid map. Now, this is not a feature we have in the Global Wind Atlas, yet, but it's coming. But I know how difficult it is to get hold of this data, because many countries consider it an important security issue, and it's very hard to have it properly updated. But we're lucky enough that we have the grid in Uzbekistan, and as you can see, a lot of the connections actually run through the neighboring countries, and you have connections to the former Soviet Union, which really is part of the whole grid.

So, the interesting wind resources, as we can see them here, the ones which are to the northwest, well, we can't really reach them because there is no grid there. But we have these four to five patches which are interesting. And then, I add on the future grid, I mean, the planned grid extensions, and we get an idea that we might even be able to tap the resource up to the far northwest.

Now, what I'm interested in seeing, now, is what actually happened, or what did the consultants really choose when they picked the two wind sites where they wanted to do measurements. And of course, they picked two of the spots we have, which happen to be near the grid.

Now, one of these spots is called Nukus; it's near the town of Nukus. It's out in the middle of the desert, as you can see. This is from Google Earth. And the met mast, I could actually find it on the map by seeing its shadow, but it's out there in the middle of the desert. And we have kind of a ridge, to the left, that looks a little bit interesting, I think. The consultants, before they did this, actually did the mesoscale modeling, using a model called FITNAH. And they said that, "Well, we think at 85 meters we'll have 7.3 meters per second." And when they measured for a year, and corrected it to a long-term mean year, they got 7.6 meters per second.

And of course, I'm curious, now, to see what does the Global Wind Atlas say. Well, when I look it up, we actually hit the 7.6 meters per second, but this was done for 100 meters and not really done for 85 meters. And this is where my own program comes into play, because I can then adjust to 85 meters to see what happens there, and there we get 7.45 per second, just about. Which is right in the middle of what the consultants estimated originally and what they actually measured on the site.

Now, how do we do this? And this may look a little bit shocking to some people, and if you're not into statistics and math, you might relax for a while. But basically, the way we can do this is that we can first of all look at the graph to the upper-left, which shows the three points where the Global Wind Atlas *[distortion interferes with audio]* windspeed estimate. And then, I assume that we have logarithmic winds here, and that's how I estimate the blue and the red curve. And the grey curve is just there to show what happened if we estimated all the way between 50 and 200 meters. The next curve shows the wind power density from the Global Wind Atlas, and when have those two figures, and if we assume that we can represent the windspeed distribution with _____ distribution, we can actually find, in the graph to the extreme right, we can find the _____ factor by height.

And once we have that, in this case, you can see that it actually keeps dropping with height. This is typical for offshore areas or, like here, tested areas with super low roughness. If we use that curve plus the wind shear from the curve to the extreme left, well, then, we can actually work our way backwards and get the _____ distribution factor. And then, in the graphs on the lower part, I have indicated the windspeed distribution for the height we're looking at right now, which is 85 meters. I can change that. I have a power curve for the wind turbine, which I've selected, here. And I then adjust it for the local air density, which is a layer you can also download from the Global Wind Atlas.

And then, I can get the next graph, I mean, number two, at the bottom, which actually shows me what is a capacity factor by height, in this spot. And in this case, with this particular turbine, there are two available _____ heights, which I have indicated, there. And the final graph at the bottom, at the left, is a

graph that shows you the power density distribution, and how much of the power density is actually converted into electricity.

Now, again, to satisfy our curiosity, if you just hover over an area on the Global Wind Atlas—in this case, it's on my system—you'll find that we have a capacity factor roughly around 40 percent, on this side, a gross capacity factor. And if I adjust that and I actually, here, took the turbine layout that was done by the consultants, and they, too, actually thought that the ridge was interesting, which Global Wind Atlas think, too, then we get an average gross capacity factor of 42 percent, in this case. But if we adjust that—and this is what I can do with the program, as I told you—we go to a lower hub height of 94 meters, and instead of having a rotor diameter of 112 meters, we have one of 101 meters. Well, then, we actually hit a capacity factor of 39 percent, which is extremely close to what the consultants estimated in the first place.

So, this is actually, of course, a success, but don't expect that everywhere. This is the other site in Uzbekistan where I did the same calculation; we're off about three percent, with the same turbine, same hub heights, et cetera. But still, it's pretty impressive, and we're pretty close.

Now, I'll take one more example; this is from Morocco. This is a fantastic site; it's called _____. It's located on a ridge, a 200-meter-tall ridge, right next to the Strait of Gibraltar, next to Tangiers. And again, here, you can hover with your mouse over the spot, and what you find is _____ you pass the factor, gross capacity factor, of around 50 percent. And, actually, this wind farm has been operating, I think, for 18 years, with a Vestas turbines—wait a minute, I have the graphic—no, we'll just go back—with a Vestas V44 turbines. And it actually has the capacity factor of 47 percent.

So, we're very close in our estimate, but here is one of the dangers of this estimate: you have to be very careful, because on places like this where you have a steep terrain and where it's not completely flat, then you'll find that if you move from one pixel to the next and look at the graph in the upper-left corner, this graph looks fine. And the next one actually shows that we have inverse wind shear, which is probably perfectly true, but it means that you can't rely on the resolution of the Global Wind Atlas. You need to do actual microscale modeling, in order to make this work.

So, the—let me just see, here—this is another example. This is Bangladesh. We measured, with a LIDAR, we measured about 5.2 meters per second, at 107 meters. The Global Wind Atlas is a bit off, 100 and with 5.5 meters per second. But still, we're within the margin of uncertainty.

And then, I decided to pick an offshore windfarm in Denmark; this is a large offshore windfarm that's been operating for seven years. We get something which is extremely close to the real figure.

And just to finish off—this is kind of for fun—I took all the 57,636 turbines in the United States, and if all of those turbines were the ones we used in our example in the Global Wind Atlas, then we would have a capacity factor of 33 percent in the United States. But what's interesting this is that you can

actually go onto the map, and you can actually study how the developers placed their turbines. And you can see that the Global Wind Atlas is pretty much in line with what the developers do.

So, to conclude, I think the Global Wind Atlas is a great if not fantastic tool for finding windy sites, and particularly if you use the color focusing feature on the maps, you have a great chance of doing it. It's often very accurate, even for local wind resource details like wind shear, reverse wind shear, and what we call Weibull k-reversal. But it's not a substitute for microscale modeling, so, don't rely on the Global Wind Atlas for siting your windfarm, but do rely on it for finding good spots.

Thank you very much.

Moderator   Wonderful, thank you so much for that. And, you know, we're gonna pause, here, and take a few questions from the audience, from our attendees. Please feel free to submit a question at any time, using the question pane.

I would like to begin with a question for Oliver: For the wind GIS file or data, is it freely available for the attendees or other registered to use and do analysis for their very own countries?

Oliver Knight   Yeah, so, I mean, essentially, everything on the websites is free. So in that sense, it's all freely available. And the GIS layers were just added with version 2.3, so that's a new feature. But all the maps, GIS layers, and anything else you can get from the website, is entirely free. And there's no need to register, because we actually don't have a registration system on that website, on purpose. And all the saving features you saw, that Ides demonstrated, they're all saved on your local machine, so there's no communicating back to the server with that.

Moderator   Great, thank you so much.

Our next question is for Ides. Ides, this participant says: For Zambia measurements, how many years is the data available?

Ides Bauwens   I think we should pass this question more to Jake or Soren, maybe *[crosstalk]*.

Soren Krohn   Yes, this is Soren. We have been measuring in Zambia for almost 24 months, now. Actually, in one month, we will have 24 months' worth of data, and that's quite interesting. And one of the things I can tell about Zambia is that there is a better wind resource than we thought, only, you have to go very high up, because it's extremely high roughness. So, you should move to at least 130 meters of height, in order to get some real wind resource down there.

Moderator   Great, thank you so much.

Back to Ides, a question is: When placing a point on the map, aerial statistics are provided in the sidebar. How is that calculated?

Ides Bauwens	Well, the data that comes in we receive through the API of DTU, so the actual calculation of the data, again, I should pass _____ to this time I think Neil.
Neil Davis	Yes, so, the data that's taken—so, basically, we get the points, so we get the region, and then we clip that area out of the raw data from our microscale modeling, and then we end up calculating just the gross statistics that get sent back to be displayed on the website. So, like, for the averaging fields like Jake was showing, it's just a simple average over _____ of each percentile, as you would expect.
Moderator	Great, thank you so much, Brian. Our next question is for—who's our next question for—is for Jake. Jake, it says: Does the downscaling from meso to microscale flow always produce high-resolution model turbulence? And what is the uncertainty of the model turbulence? Is it recommended for use in turbine stability studies?
Jake Badger	Okay, so that's a very good question, and it's not something we address in the Global Wind Atlas, at all, actually. So, these are all wind climate statistics for the purpose of doing production estimate, so it's a wind resource as in the production, annual energy production of a turbine, putting it through a turbine power _____. But it is something we are interested in pursuing; actually, we have a project starting next year, called the Global Atlas of Siting Parameters, and it will address exactly this. So it's a project with Danish funding, and we have a partner, EMD, in Denmark. And what we'll do is try to create the meteorological data that's required for IEC turbine class typing. So for that, we'll need to know things like the extreme winds, the turbulence intensity, inclination angle, these sort of things. So it's not something available yet, but it's something we're moving onto in a project that is very much related to the Global Wind Atlas.
Moderator	Great, thank you, Jake. And to follow that up, for maybe you or Soren: Can the GWA data be improved with measurement data?
Soren Krohn	Yeah, go ahead, Jake.
Jake Badger	Okay, so, my take on this one is that we actually try to keep these things separate as possible. So, we do it as a validation, I mean, you can find out whether the Global Wind Atlas is reliable against a good-quality measurement. So, if you have a site measurement very close to where you're thinking of your windfarm development, then go for the very high-quality wind measurement; that's not substituted by the Global Wind Atlas. But we're not interested so much in sort of making a calibration of the Global Wind Atlas by sort of adjusting it to a measurement. So, Soren, do you want to follow on that?
Soren Krohn	Yes, I can say that we think the validation program is very important. We are operating, I think, about 60 80 meter masts, around different countries, and we have 3 light hours up and running. And we think the—it's important for

developers to know the uncertainty of what we're doing, and that is why it's important not to recalibrate the data we have in the Global Wind Atlas. But it's much more important that we know how certain or uncertain is the data, and that's where local measurement data actually helps us. And to the extent that there are countries that have very high-quality measurement data, the World Bank is actually interested in getting hold of that data, so that we can do even further validation of the Global Wind Atlas. That's how we did it in Vietnam, where the German development agency had already done wind measurements. Thank you.

Moderator

Great, thank you so much, Soren.

Our final question for this little segment of questions is, for Ides: Is it possible to access to the data directly via an API, or only via the website?

Ides Bauwens

[Distortion interferes with audio] possibility to download some data, as was shown during the demonstration, but there is no direct link to an API for the data, no.

Moderator

Okay, just to clarify—we had a little bit of audio issues with your audio—so, it is possible?

Ides Bauwens

No, at this point, it's not possible to access the data on the Global Wind Atlas through an API. So, the only way to access the data, at this point, is by, yeah, looking at it *[distortion interferes with audio]* downloading the plot data or the GS files through the interface.

Moderator

Thank you so much for clarifying that. Wonderful. Great, well, we're gonna break from the question and answers; we're getting some great questions from the attendees. Again, you can ask a question at any time, using the question pane. And if we're not able—we have so many questions—if we're not able to get to the questions today, we will follow-up with the attendees, after the presentation.

I would like to now welcome Gil to the webinar, for his presentation.

Gil Lizcano

Hello. So, this is Gil Lizcano from Vortex, and I will now give you an overview of what we are doing now to provide the new mesolayer for what will be the next version of the Global Wind Atlas.

So, I'm working at Vortex, which is a company that we—our specialization is to provide wind resource _____ model, weather model. We use _____ model as our core engine, and we provide—our target is to provide the highest quality resource information for any place in the world. We focus on on-demand simulations, so the simulation that requires quite a lot of computing _____, so our target is to provide this access to the end-users. And we relied on their reanalysis, as they grow our input for the—to drive the simulation, and as I say, _____ on the reanalysis and atmospheric modeling technology.

So, for the Global Wind Atlas, we've been producing a transition layer between the reanalysis and the microscale. So, what we try and what we have

tried or what we have done is to enhance the reanalysis with the missing element that is _____ mesoscale and _____ flow adjustment. So, we use the model WRF; that's a weather model _____ _____ model that we provide for the weather prediction _____. But we run this model with _____ _____ so back in time, so, using the _____ reanalysis as input data. And then, we produce for a global layer of windspeed direction and other variables, that all together allow us to generate the generalized wind climatologies that is what we handle to DTU and to World in a Box, _____ to proceed _____ _____ streaming with WAsP.

So, as Jake showed before, this is like a—this is the diagram of the methodology. We have, on top, the reanalysis that give us the best approach to the atmospheric conditions over the last 13 years. And then, we enhance the reanalysis with the _____ _____ providing the necessary information for the microscale chain _____.

So, _____ the version 2, that is the one that you have alive, we employed a _____ on a _____ _____ of 9 kilometers. So we run model WRF _____ with nine kilometer, driven by the _____ ERA-Interim. Now, what we are doing now is updating this mesolayer for what is gonna be the new version of the Global Wind Atlas. We changed the driver, so we use, now, ERA5, which is the latest generation of reanalysis. And we increased the resolution of the mesoscale layer up to three kilometers. So, at the end, we are getting a pixelized wind resource information _____ _____ three kilometer resolution.

So, just to give you a brief idea of what is changing, we're changing the resolution of the driver of the reanalysis. ERA5 has up to 30 kilometers of resolution, and much more vertical level, that is very important for the mesoscale model quality, capturing the quality of the mesoscale model performance. And then, we improve the mesolayer with the _____ three kilometers, and we extend the offshore domain up to three kilometers. And then, we provide all the microscale information, and also, we are generating 24/12 tables that _____ _____ average values of the daily cycles for _____.

So, as for the version 2, what we had done is to divide the rolling tiles _____ _____, specifically, we produced 2,460 tiles, each tile with 3 kilometer. _____ _____ the size of the tile depends on the regions, but the minimum size is 3 by 3 _____ and _____ _____ we have a buffer around to _____ any noise on the border of the model. So, we are gonna finish this new run of this new mesolayer *[audio cuts out]* mid-January of 2019.

And this is where we are now in the _____, we have already simulated most of the world, we are just missing part of China and north Siberia _____ some regions in Alaska. But the rest of the world has already been done, so we are on time, so, to finalize the simulation.

And this is _____ the mesoscale _____, as I said, we generate the generalized wind climatologies, that is the main input for the WAsP scaling. So, next year, all this will be there in the new version of the Global Wind Atlas.

Thank you.

Moderator	Great, thank you so much for that. Wonderful.
	And we'll now move to Brian for his presentation. Brian, it seems that we're having some trouble—we will try to change the presenter to you again. Oh, it looks like we were able to.
Neil Davis	Yes.
Moderator	Great, thank you so much.
Neil Davis	So, yes, this is actually Neil presenting, so, yeah, I'm, going to be presenting the—also about the Global Wind Atlas version 3. But I'm gonna talk, now, about the microscale modeling improvements, and I'm gonna give a little bit of an overview of the microscale modeling and how we've kind of done that.
	So again, this chart that everybody has seen a number of times. So, when we're talking the microscale, we're talking about this piece, the generalization that Gil just talked about a little bit, where we kind of couple in-between the mesoscale and the microscale, and then the microscale modeling itself.
	So, at DTU Wind Energy, we have developed this microscale methodology that we've used for quite a long time; it actually was developed during the European Wind Atlas, in 1989. And the idea, here, is that we can use a two-step process in order to predict the wind at a fine resolution at a local place. So, we'll start with something like the mesoscale wind climate, which gives us a relatively coarse idea of that. And then we can remove some of the effects of that; I'll describe this on the next slide in more detail. And that gives us something that we call a generalized wind, so, this is a wind that doesn't have the mesoscale topography involved in it.
	And then, we can take a high-resolution topography, and we can apply that, and we can get the predicted wind climate. So, now I'll talk about those steps in a bit more detail. So, when we talk about the generalization, the reason that we have to do this is because the mesoscale model has a coarser representation of the surface features than what we know is happening in reality. So we can see, here on this image of the topography, that the yellow line would be kind of how we might see this terrain inside of a mesoscale model. While, in the microscale model, we'd be able to see all of these smaller hills and all of these individual speedups and things like that. But we don't wanna double-count the terrain that we had already from the mesoscale model, so we need to remove that, and so that's the process that we work on in generalization.
	Then, the other thing that we look at is the roughness characteristics, as Jake mentioned. And one of the biggest roughness characteristics that we care about is the coastline. And here, you can maybe see that there's green tiles and there's blue tiles? The blue tiles are what are water, inside of a mesoscale simulation, and the green are the land. And you can see that these don't necessarily match up with the coastline of Denmark in this image, where we have a coastline where maybe a quarter or more of this box is looked at as being over land, but it's actually all represented as water inside of the

mesoscale. So we have to remove kind of those limited representations of the topography, so that way, we can do the microscale modeling and we can add those in.

So, when we are interested in these two features—yeah, the reason that we're interested in these two features for wind is that, when we have flow that's going over a hill, as shown in this image on the left, we get a compression of the stream lines as we go over the flow, or, over a hill. And that means that the flow is actually speeding up over the top of the hill, so we end up with faster winds on the hilltop than what we have on either side of the hill. And that's one of the reasons that we wanna take this high-resolution orography into account. When we look at the roughness features, here, we might have an upwind roughness that's really smooth, like the water, and then, when we go over land, we have a more rough surface. And that means that we also have slower winds. However, that transition is not an abrupt transition, so we actually model, in a roughness change model, this transition layer that happens inside of this.

So, given that kind of background in the microscale modeling, what are the improvements that we're looking at in the Global Wind Atlas version 3? So, first of all, as Gil mentioned just before, we're gonna have updated mesoscale data, and that will be a big improvement in our microscale modeling, as well. Then, we also are improving the terrain dataset that we have; we're doing some behind-the-scenes processing of that. Then, we're actually using an entirely new roughness dataset that's a much-improved ESA CCI landcover dataset, as opposed to the GLOBCOVER dataset that we have used previously. One of the really nice things about this, also, is that the CCI landcover is a much more recent landcover dataset, so, therefore, it better represents the land as it is today.

And then, in the microscale modeling side of things, we're going to be moving to the latest version of WAsP, so we have a number of improvements over the version that has been used before, and all of those will now be brought into the Global Wind Atlas. There's also been some performance improvements, and then we're working on running everything in a lat-lon space instead of running it inside of the UTM space that has previously been done. And this will mean that we'll have better analysis and better visualizations that we'll bring to you on the website itself.

And that flows into this slide about the new features of the website, so, we're going to be adding a number of new map layers. At the fine microscale resolution, we're going to be providing you with an air density map at 100 meters. And then, we're going to be using the mesoscale data that's being provided to us, to provide more information about the temporal nature of the wind. So, we'll give you a diurnal wind pattern map, and we'll give you some interannual windspeed maps, both of windspeed and of power density. We're also going to be providing new charts on the sidebar, of this monthly diurnal time series table, which was this 24/12 table that Gil mentioned.

And we're going to show you a time series of the ten-year interannual windspeed, so that you have a better idea of how the wind varies in time. And

then finally, as has been mentioned before, we're going to be doing some enhanced validation. We're going to be adding in approximately 28 sites from Pakistan, Vietnam, and Zambia, as well as other ESMAP sites. And then we'll be comparing those for both the generalized and the predicted wind climates. And our validation results will also help us determine what areas we should use to drive the future measurement campaigns.

So, that's all that I have. Thank you.

Moderator

Great, thank you so much, Neil, for that great presentation.

And thank you, to all of our panelists, for all the outstanding presentations. As we shift to the question-and-answer session, I just wanna remind our attendees that, please submit your questions using the question pane at any time. We also keep several links up on the screen, throughout, for a quick reference, that point to where you'll find information on other upcoming webinars, and how to take advantage of our Ask an Expert program. We've had some great questions from the audience that we'll use the remaining time to answer and discuss, now that we're finished with all the presentations. I'll address it to—I'll do my best to address to the appropriate panelist, but please feel free for anyone to jump in and also answer the question.

I will begin with: Gil, are you using the same WRF setup in all the regions of the world?

Gil Lizcano

Yes, we are using the version of WRF, to preserve the consistency of the model across the simulation.

Moderator

Okay, great, thank you so much.

Our next question is for Soren: Soren, how long, a month or years, will it take to make field measurement on wind spot area, before installing wind turbines for power generation?

Soren Krohn

In most cases, we would recommend two years, I think. But you do see projects which are done solely on the basis of one-year measurements. It depends a lot on how good reference data you have, in order to convert your time theories into something that represents a long-term wind climate. But I would say one to two years is normally what is required in order to build a windfarm.

Moderator

Okay, great, thank you.

My next question is for Jake, or maybe Neil: Can the GWA also help the user to visualize the flow turning or veering enforced by complex terrain or roughness features?

Jake Badger

Yes, I could try to take that. Hello? Jake, here. So, yeah, you can look at wind roses at different heights. But I would say in complex areas, then it's—remember that the flow model isn't gonna give you such a trustworthy result,

say, compared to what you might get from a CFD, a computer fluid dynamics code. So, it's kind of yes, but with caution.

Moderator   Okay, great. And to kind of follow that on, how –

Jake Badger   Oh, sorry, could I just say one other thing I forgot? One important thing to say is that you don't actually, in the Global Wind Atlas, you can't get so much detail down to the point, because we allow the tools to work on the minimum size is a 10 by 10 kilometer area. So, you won't be able to examine a point in the same way as what, perhaps, the questioner is wanting to do. So in that case, I think you really need to be able to do the modeling by yourself, if you wanna get down to that level of detail.

Moderator   Great, thank you so much. And just to follow on with that, kind of a two-part question: How reliable is the data in the GWA? And also, does the GWA, in general, underestimate or overestimate in the wind resource?

Jake Badger   Okay, so, I could take that again. I showed, in the Global Wind Atlas 2, we did this validation with 60 sites. And this is the validation as we see it should be done, where you actually have information at the measurement sites. And you need to account for the measurement characteristics, so, if it's on a hill or what kind of roughness situation it is in. And these can be, then, compared to what the Global Wind Atlas is giving you. And we see a—I think it was a mean absolute error of around ten percent, and a bias of minus-three percent, so slightly conservative, but only slightly. But what we want to be able to do more is to actually say that we can make a prediction for the uncertainty, given the site.

So, if we're looking at a site which has very low ruggedness as a—so it's very, very flat, it has a very simple roughness, we would expect the uncertainty to be lower than that, maybe within one or two percent. And if we're in a place where there's roughness complexity but very flat, still, then we might say it's around five percent. And if we're in a place which is complex terrain, simple roughness, then we may be looking at 10 to 15 to 20 percent, depending on complexity. So, I think we can do—what we're working towards, in research projects, is to be able to make predictions of the uncertainty, given the site characteristics. And that's something we can build on with all of the validation we're doing, together with the ESMAP projects, too.

Moderator   Great, thank you so much.

And we keep having great questions come in, so I appreciate our attendees for asking so many great questions.

Soren, what are some of the wind measurement instruments that you have used out in the field of the wind area, to measure windspeed and wind availability?

Soren Krohn   On the, approximately, as I said, 50 or 60 masts, we have only first-class instrumentation. So, we have absolutely, you could say, top scientific-grade instrumentation, and _____-calibrated instruments. So, these measurements

are sort of textbook-like, the best you can. And then we do have about—we have four LIDARs right now operating in some places. And I would say, by the way, that LIDAR is much easier to deal with. I mean, planning permission has been hell *[laughs]* in many of these countries, but it's topnotch equipment, and we measure at multiple heights, up to 80 meters. And in the case of LIDAR, we measure up to about 200 or 300 meters, depending on the instrument we're using.

Moderator   Great, thank you so much.

Our next question, I believe, will be for Neil: Neil, what is the minimum and maximum mesoscale measurement efficiency? And what are the minimum average wind resources needed to be viable?

Neil Davis   I'm not quite sure that I fully understand the question. Can you run that by one more time?

Moderator   Yeah, absolutely: The attendee wanted to know what is the minimum and maximum mesoscale measurement efficiency, and what are the minimum average wind resources needed to be viable?

Neil Davis   Sure. So I guess by the, like, mesoscale efficiency, I guess that they're asking, like, how coarse of a mesoscale could we use in order to refine down to the microscale. And so, assuming that that's correct, then, I would say that it really depends on how many—on the scale of the mesoscale features that are impacting the region of interest. So, of course, when we're looking at something that's global, we kind of want this fine of a mesoscale as we can get, so that way we can capture these features like the gap flows that Jake showed in his presentation, as well as things like sea breezes and other mesoscale effects that are important to capture. However, I would also say that our very first Global Wind Atlas, we actually used some reanalysis data that was quite coarse; it was at about 50-kilometer resolution, and that at least gave us kind of a starting point. But I would say, you know, as is often the case with mesoscale modeling, that you should look for, you know, as good of resolution as you can afford, I guess.

And then, the second question I'm not sure that I have an answer to. *[Laughs]*

Soren Krohn   I can pick that up. This is Soren.

I would say that it really—it would mean—the economically viable windspeed really depends on the country. If you're up against diesel, say, you are in the middle of the Maldives, _____ it's perfectly fine even if you _____ _____ _____ it will cost you 25 US cents per kilowatt hour, because diesel is twice as expensive. So there, 5.5 meters per second is fine. If you go to a developed country like Canada or the US, you have to be competitive with other sources of local power generation, and there you might want seven meters per second. But it's very hard to give a general answer, because a lot depends on the wind distribution, and a lot depends on the air density. So, there's not a simple answer to that question.

Moderator	Great, thank you so much, Neil and Soren, for answering that.
	And back to Neil: How well does the GWA data perform at micro-siting?
Neil Davis	I guess that we would, again, kind of lean back towards a little bit of Jake's analysis. But I would say that our general—the general way that we point at the way to use the Global Wind Atlas is to not use it for micro-siting. There are a number of assumptions, kind of Gil mentioned, about using a common WRF setup, to be consistent. We do similarly for our topography and for our roughness _____, where we make choices to try to be consistent across the entire globe, that may or may not be the most representative for a very specific site as you need for micro-siting. So, our general point of reference, and also as Soren kind of talked about in his presentation, is if you are very worried about micro-siting, you should—yeah, you should do your own custom microscale modeling, with your own topography and roughness maps that are taken from onsite observations.
Moderator	Great, thank you so much.
	Oliver, a question for you is: How does the GWA compare to commercial wind data or wind development software?
Oliver Knight	So, we've purposely, I mean, with both the Global Solar Atlas and the Global Wind Atlas, we're very much trying to bridge the gap between having basic understanding of resource but also not reading on the toes of commercial providers. And I think with the Global Wind Atlas, that's very clear. Because if you're developing a windfarm, you're going to need to go to a level of detail beyond what the Global Wind Atlas can provide, and you're gonna need to do analysis that is much more detailed, and you're also gonna need ground measurements. But what we're trying to do with these resources, and specifically with the Global Wind Atlas, is provide a better starting point both for governments and developers, so that everybody's on the same page, so that there's one single dataset that covers all countries, that could be compared between countries and within countries, so that everybody, essentially, has access to some good-quality data to do planning and to do initial site scoping. So that's very much the position we're trying to take: the Global Wind Atlas doesn't take you to that next level of fully developing a commercial windfarm, and it's not intended to do that.
Moderator	*[Crosstalk]* Oh, please, Jake, go ahead.
Jake Badger	Yes, Jake, here—I just wanted to follow-up what Oliver said. So, yeah, agree completely with that. I think we can use the Global Wind Atlas as a guide to what should be the next steps in the country: Should it be a measurement campaign? Where should the measurements be placed? Or is this country requiring some other modeling effort, perhaps where we know that there are some mesoscale features that need some extra custom mesoscale modeling? Or maybe it's complex terrain, so we say that we need to do something custom for the microscale modeling. So I think we can use the Global Wind Atlas, in a way, to steer what should the next steps be, and do that in an efficient way, effective, because you can actually, then, skip out the parts that

are already sort of—you can avoid making mistakes, and use this as a guidance for more rapid deployment of wind in countries where that's relevant. And that's what the Global Wind Atlas can point to.

Moderator
Great, thank you.

A question just came in, is: Were the visualized turbines and the grid systems input outside of the Wind Atlas online map?

Soren Krohn
Yes, they were. And as I was saying, the option of showing the grid map is something that will be coming to the Global Wind Atlas, but it's quite some work to get that done, but everything I presented in my show was done on my own computer and with my own system, using the data downloaded from the Global Wind Atlas.

Moderator
Great, thank you so much, Soren.

Our next question is for Gil: Gil mentioned he—this attendee referenced your presentation _____ mesodata period of 30 years. Does GWA allow the user to change the reference period, like, to 10 or 15 years, and check the modeling outcome?

Gil Lizcano
No, that's not possible, because we need to fix this period for the mesolayer prediction, so we are producing the timeseries of the mesoscale simulation for the last ten years. That is the period available now, based on ERA5, so it's covering 2008 to 2017.

Moderator
Okay, great. And then, keeping you on the line: What improvements do you expect in version 3?

Gil Lizcano
Well, it's clear that we expect the models to improve the regions where the version 2.0 is still is not as quick as we want. And because we have already looked at some outputs and some internal validation, and also because the improvements in the ERA5, as well, we expect the model to improve the results in the Southern Hemisphere. And especially in tropical and subtropical regions, that is where the driving conditions has improved quite a lot. And as well, in regions where the topography is really complex on this link between the _____ the mesoscale and some kind of microscale effects are mixed up. An example is Ethiopia, where you have quite a complex terrain, we expect the results to improve in some of the areas, as an example, this is. But this is a—if you have a project in the Southern Hemisphere, the next version is gonna _____ _____ that is gonna be closer to reality.

Moderator
Great, thank you so much.

For Ides, we've had a few people ask about using the application on different things like their smartphone or tablet or laptop: What is the best way to use the application? And if they're having trouble downloading it, what should they do?

Ides Bauwens	Well, yeah, the application, it's a Web application, so, it's not necessary to download it; you can just visit it through the link, globalwindatlas.info. And the best viewing mode to watch it is either desktop or on laptop. But tablet and smartphone is also possible. On tablet, if it is sufficiently large, you will still have the sidebar appearing on the right of the map, and it will still be possible to download files. On smartphone layout, your sidebar is moving to the bottom of the map, and it can still be interesting to use that mode to place points and to get, quickly, some overview or some details about certain areas. But if you really want to work with the data, you want to download GIS files, for example, or use the plot data, it's most of interest to work on a desktop or laptop.
Moderator	Okay, and then, another question on that is: Can they download the layer from GWA, and apply it to Google Earth?
Ides Bauwens	Well, you can download the GS file, which is the TIFF file, and that's maybe something important to notice. So, the layers that we see in the application are the TIFF files which have been processed in order to show the different colors and according to the legend, right? While, if you download the GS file, you get the original TIFF files, which don't—if you open this in the GS software, you will not see the colors, the fancy colors you see in the Web application, but you will get access to the original values of the data. So, this is of high interest if you want to do further processing or your own analysis, but to open that in Google Earth, you need to do some GS processing steps, in order to generate the KML, et cetera, and to upload it in Google Earth.
Moderator	Great, thank you.

And unfortunately, I think we might be out of time for this question-and-answer session And for any questions we didn't have time to, we'll connect with those attendees, after the webinar.

On behalf of the Clean Energy Solutions Center, I'd like to extend a thank-you to all of our expert panelists, today—we had such a great panel. And to our attendees, for participating in today's webinar and asking such wonderful questions.

We very much appreciate your time, and hope, in return, that there was some valuable insights that you can take back to your ministries, departments, or organizations. We also invite you to inform your colleagues and those in your networks about the Solutions Center resources and services, including our no-cost policy support through our Ask an Expert service. I invite you to check the Solutions Center website if you'd like to view the slides and listen to the recording of today's presentation, as well as previously-held webinars. Additionally, you'll find information on upcoming webinars and other training events.

We will be posting this webinar to the Clean Energy Solutions Center YouTube channel. Please allow about a week for the audio recording to be posted. |

Finally, I would kindly ask you to take a moment to complete the short survey that will appear when we conclude the webinar.

Please enjoy the rest of your day, and we hope to see you again at future Clean Energy Solutions Center events.

This concludes our webinar.