

# Assessing Wind Energy Potential with the New Global Wind Atlas

—Transcript of a webinar offered by the Clean Energy Solutions Center on 3 November 2015—  
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## Webinar Panelists

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**Tim Reber** Hello everyone. I'm Tim Reber with the National Renewable Energy Laboratory. And I'd like to welcome you to today's webinar which is hosted by the Clean Energy Solutions Center, in partnership with the International Renewable Energy Agency and the Technical University of Denmark. Today's webinar will introduce the newly released Global Wind Atlas which aims to provide freely-available high-resolution global wind data for the very first time.

One important note of mention here before we begin our presentations 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's resource library as one of many best practice resources reviewed and selected by technical experts.

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 your 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 any feedback or echo. If you choose to dial in by phone please select the telephone option and a box on the right side of the screen will display the telephone number and audio pin you should use to dial in.

If you are having technical difficulties with the webinar you may contact the GoToWebinar helpdesk at 888-259-3826 for assistance. If you'd like to ask a question—and we certainly encourage everybody to please do so—we ask that you use the questions pane on the right side of your screen where you may type it in directly. If you're having difficulty viewing the materials through the webinar portal you will find PDF copies of the presentations at <http://cleanenergysolutions.org/training> and you may download and follow along as our speakers present.

Also an audio recording of the presentations will be posted to the Solutions Center Training page within a few weeks of the webinar and will also 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.

Today's webinar agenda is centered around the presentations from our guest panelists: Dr. Nicholas Fichaux, Jake Badger, and Abdulmalik Ali. These panelists have been kind enough to join us to provide an overview, a demonstration, and technical information about the newly released Global Wind Atlas which is a new dataset and suite of tools available via the IRENA Global Atlas platform.

Before our speakers begin their presentations I will provide a short, informative overview of the Clean Energy Solutions Center initiative. And throughout the webinar we will also have short question and answer sessions between each of the three presentations at which the panelists will answer questions submitted by you the audience. We'll also spend a few minutes at the end of the webinar with a more general closing question and answer session. Finally we'll close the webinar with a brief audience survey.

This slide provides a bit of background in terms of how the Solutions Center came to be. The Solutions Center is one of 13 initiatives of the Clean Energy Ministerial that was launched in April of 2011 and is primarily led by Australia, the United States, and other Clean Energy Ministerial partners. Outcomes of this unique initiative include helping countries and emerging economies through enhancement of resources on policies relating to energy access, no cost expert policy assistance, and peer to peer learning and training tools such as the webinar you're attending today.

The Solutions Center has four primary goals. It serves as a clearing house of clean energy policy resources. It serves to share policy best practices, data, and analysis tools specific to clean energy policies and programs. It delivers dynamic services that enable expert assistance learning and peer to peer sharing of experiences. And finally the Center fosters dialog on emerging policy issues and innovation around the globe. Our primary audience is energy policy makers and analysts from governments and technical organizations in all countries though we do also strive to engage with the private sector, NGOs, and civil society.

One of the marquee features of the Solutions Center is the no cost expert policy assistance known as Ask-an-Expert. The Ask-an-Expert program has

established a broad team of over 30 experts from around the globe who are available to provide remote policy advice and analysis to all countries at no cost. For example, in the area of renewable energy policy we are very pleased to have Louis Seck, former Senegalese minister for renewable energy serving as one of our experts.

If you have a need for assistance in renewable energy policy or any other clean energy sector we encourage you to use this valuable service. Again the assistance is provided free of charge. If you have a question for our experts please submit it through our simple online form at <http://cleanenergysolutions.org/expert>, or to find out how the Ask-an-Expert service could benefit your work please contact Sean Esterly directly at [sean.esterly@nrel.gov](mailto:sean.esterly@nrel.gov), or call him at 303-384-7436. We also invite you to spread the word about this service to those in your networks and organizations.

And now I'd like to provide brief introductions for today's panelists. Our first panelist today is Dr. Nicolas Fichaux. Dr. Fichaux is currently the program officer for knowledge at IRENA, in particular supporting the Global Atlas for Renewable Energy and Resources. Prior to IRENA Dr. Fichaux served as the secretary general of the European Wind Energy Technology Platform and head of policy analysis at the European Wind Industry Association. He has a Ph.D. in offshore wind energy.

Following Dr. Fichaux we'll hear from Jake Badger. Mr. Badger has over 14 years of research and development experience on numerical wind resource assessment methodologies, including serving as the principle modeler for more than 14 international wind resource study projects. His research primarily focuses on improving accuracy of resource of assessments, obtaining reliable uncertainty estimations, and modeling of wake effects and application of satellite derived wind data in resource assessment systems.

Our final presenter would be Abdulmalik Ali. As an associate program officer Mr. Ali brings extensive experience and information systems in implementation to IRENA's internet based Global Atlas for Renewable Energy. Holding a degree in theoretical physics his IT experience has been an asset to several projects across Western Africa.

And with those three introductions I'd like to go ahead and welcome our first speaker, Dr. Nicolas Fichaux, to the webinar.

**Nicolas Fichaux**

Good morning, good afternoon every one, or good evening depending on where you are. My Name is Nicolas Fichaux. I work for IRENA, particularly under Global Atlas for Renewable Energy. And today I have the great pleasure to make a short introduction on these new \_\_\_\_\_ of the Global Wind Atlas.

**Tim Reber**

Nicolas real quick, sorry, before you keep going we're actually seeing the entirety here of your slide interface. I don't know if it's possible to try and go to full screen. Otherwise I guess we'll just move forward with this.

**Nicolas Fichaux**

No, no. Any better?

**Tim Reber**

There we go, much better, perfect, thank you.

**Nicolas Fichaux**

Thank you for telling me. Okay so where is this project coming from? Both the Global Atlas for Renewable Energy which is the platform of IRENA and also the DTU Global Wind Atlas. Both projects are coming from initiatives that started in 2009 and that was called a major economic forum. And in this major economic forum the idea was to provide concrete action plan and solution for preparing the COP15 in Copenhagen at the time. COP15 took place and then these \_\_\_\_\_ were very developed in particular the wish to give the world a global solar map and a global wind map that could be accessible through a central portal—a global atlas portal.

So three countries took the challenge up and Denmark, Germany, and Spain decided to continue the effort through the Clean Energy Ministerial. And within the Clean Energy Ministerial they created a group that is called Solar and Wind—Multilateral Solar and Wind Working Group where IRENA was invited to join. When the agency was created in 2010/2011 we started interacting with the group.

Within the group you had the best institutes working on solar energy and wind energy modeling including DTU and for the wind part it was decided that Denmark would be contributing and providing a global wind map. And that IRENA would be working on publishing this map and creating in the meantime a global platform for disseminating solar and wind maps and in part with \_\_\_\_\_ which is the Global Atlas for Renewable Energy.

Over time—s, from these three countries: Germany, Denmark, and Spain—the partnership was enlarged within the framework of the Clean Energy Ministerial to 12 countries, and then at the COP also—COP19 in Qatar where Qatar joined the initiative. And finally within the framework of IRENA there was a huge addition onto the project from 67 countries in total that decided to join the initiative. These countries in the Global Atlas for Renewable Energy coordinated by IRENA shared their study. They share knowledge. They share data.

And they make this data available through the Global Atlas for Renewable Energy. And today what we do is that we are publishing the results of this international cooperation, but the Global Atlas for Renewable Energy that is available on line since 2014 and now the integration of this commitment of Denmark to the Clean Energy Ministerial and to the Major Economies Forum where they wanted to give the work very detailed wind data.

What are we launching today? We are launching the most accurate wind dataset ever made available in the public domain. The data that you will see today are one kilometer resolutions that were simulated at 250 meter resolution on the whole globe. We gave also with integration through the Global Atlas a complete instrument that helps to prospect new markets for wind power including in an area where we know that there is some resource. We are not sure about the policy regime.

We are not sure if companies would need to prospect, if policy makers would need to step in in order to develop wind power. It is no possible to prospect this country and this area today. It's also a decision to purchase them for policy makers because when there is uncertainty about the resources very often a \_\_\_\_\_ for future development. And now with this tool it's possible to have a dialog with local communities to zero in on some area that can be of future interest using the grid, using population density, in addition to the wind resource.

And finally we also believe that this is an incredible platform for learning about wind energy, about wind power, and how the wind resource is being influenced by the topographic \_\_\_\_\_ detail and also how you can think in terms of zoning, in terms of projects in the future, and what happens at a country level when you have this kind of data that is made available. Today you will see different aspects of the same thing. So all through the discussion and presentation you will be talking about one dataset.

And these dataset is the Global Wind Atlas that was created by the team. In these dataset what you will hear is that there is average annual wind speed one kilometer resolution and wind statistics that you can download. And what you will see in the different presentations is these dataset was created, how you can use it, and how you can access it. And on the access I would like to insist on a point that we give different access points and we don't want users to be confused.

The IRENA Global Atlas is a tool that is particularly suited for policy makers and market analysts that want to have an idea of the resource, but not only that. They want an idea of the location of the grid, protected area, population, and \_\_\_\_\_ roles, being able to launch an analysis tool for accessing the wind statistics but also to access policy databases for the different country and to access to knowledge brought out of IRENA directly from the Global Atlas which is more this profile that we are targeting.

We have another platform. That is the Global Atlas Pocket. So this is an app that you can download. You go to any app store with any platform: Android, BlackBerry®, a Windows phone and also Apple iOS also. You go to the store. You search for Global Atlas. You can download an app. The app is different from the—the tool on the app allows you to search for any location in the world and have an idea of the value. But you don't get more than one value. However in the dataset there is much more.

And there is much more. You can find it if you are an expert, if you are an analyst that is working with wind power modeling for example or energy systems modeling. You would probably go to the DTU Global Wind Atlas platform because Jake has created a very great interface where you can access the data in a very searchable manner when you are an expert. If you are more of a generalist you need more explanation of global data and this is where you would go to the Global Atlas

And finally in case you are a GIS analyst and you are competent and you are able to deal with maps which is a very difficult thing to do you would be able

with the GIS software to use the links directly to the map. And you would be able to view this map and manipulate the information inside your own GIS software. And for that you will use the Global Atlas Catalog which is the <http://www.webservice-energy.org>.

So first access is IRENA Global Atlas, more generally for zoning; two, Global Atlas Pocket: when you're on the move you can access the value; three, you are an expert and you are an expert in wind power, wind modeling; you go to the DTU Global Wind Atlas and four, you are a GIS analyst and you go to <http://www.webservice-energy.org> to the catalog of the Global Atlas. And again we are talking in each case on one singular dataset where you can access the information in different manners depending on your level of expertise.

I thought it was important to say that today. And finally I will leave the floor to Jake for the presentation of the Global Wind Atlas, how this incredible dataset has been created. And I wish you very good listening for this webinar. Thank you very much.

**Tim Reber**

Great. Thank you very much Nicolas. We appreciate that intro. We will provide just a couple minutes or two for any questions that may come up at this point. Otherwise we'll get to more questions later on down the road. We do have one so far. Wondering for which period in detail the data covers?

**Nicolas Fichaux**

Hello. So I can answer this question but I will not because Jake is going to present the dataset. And I think it is worth listening to what he has to say, not only on the peril of time but also how this very detailed, special resolution was created, and how they managed to include the topography. So it's not about time and duration of the dataset. It's also what they did on the special aspect of the dataset. So I would ask to wait a little bit to audience. I'm sure the detail will get the answer after Jake has spoken for sure.

**Tim Reber**

Okay great. Well in that case we'll just move right along and move into Jake's presentation then. And Jake it does look like you are still on mute. Just go ahead and –

**Jake Badger**

Hello? Can you hear me now?

**Tim Reber**

Great, perfect, thank you.

**Jake Badger**

And can you see my screen?

**Tim Reber**

We can.

**Jake Badger**

So I just put it on full screen.

**Tim Reber**

Perfect, looks great.

**Jake Badger**

Okay so thank you very much. And first of all I would like to say thank you very much to the Clean Energy Center for hosting this webinar. It's really an opportunity to explain more details about the Global Wind Atlas and the

methodology. And thank you very much also to Nicolas Fichaux from IRENA for setting the scene and the context of the project. And I have to also say that this is a big team effort. And on the screen you can see the members of the team at DTU who have put this together.

So it's really much more than me as Nicolas said, but many people putting it together. I'm also very happy to have been working with IRENA in this collaboration because although we have a website we know that IRENA with their Global Atlas have a far greater outreach and the contacts they have around the world can add a lot of value to the dissemination of this dataset. It's been great working in collaboration with IRENA on this. And the result is this integration which you will see today demonstrated in the third presentation.

Okay, so I'll move on. So the title of this talk is The Global Wind Atlas: The New Worldwide Microscale Wind Resource Assessment Data and Tools. And the idea is to give you sort of some background information about the methodology. The outline is to tell you about the model chain, to tell you about the input data, the kinds of outputs you get, and also some validation of the outputs. And then some sort of future ideas of how we can use these datasets to create a global assessment of technical potential which I think is a very exciting area for application of this data.

So first of all I'll explain the objectives of the Global Wind Atlas. All those years ago when we were talking about this in the infancy of the project around 2009 and thereafter we wanted to create a wind resource dataset that accounted for the high resolution effects. We were seeing at that time that the high resolution effects are very important in order to capture a more accurate picture of actual wind resources.

We wanted to use microscale modeling to capture the small scale variability. And this is a crucial thing to get a truer idea of wind resource. Up until that point only coarse resolution datasets have been used for example in the integrated assessment modeling community to get sort of regional wind resource estimates. And this meant they were underestimating the wind resource how the importance of the wind resource in future energy mixes in the next 100 years or so.

We wanted to use a unified methodology so that all around the world the same methodology was used. This is to sort of combat the kind of patchwork nature that we see quite often in wind atlases: different providers giving national wind atlases for some nations and other providers for other nations. But we wanted to have a way to cover the whole world using one methodology which would make it easier to sort of make comparison across different nations and sort of have a standard approach.

We also wanted to have a transparency of the methodology. We don't really want to do have any secrets about how we do this. So part of that is this dissemination here today but also if you look at our webpage you can get into the details of the methodology—the input data. So we're very open to people coming back to us and being critical about, for example, the roughness

lengths we used or about the different aspects of the input data. Our main objective is to try to improve this and it's a process. This is our starting point.

And we also want to validate the results in representative areas. So we have a number of ways to do that and I'll explain in a moment. Again there's the transparency about that. We want to show where we think this method is working and where we think it isn't working so well. The users of this dataset are, as we referred to already in the introduction, the energy integration modeling community, policy makers, energy planning. And they will use it by aggregating over areas and upscaling the analysis.

So that means it's not for wind farm siting. It's not for micro-siting of turbines. And it's important to understand the appropriate application because of the uncertainties that this global methodology entails. So why are the high-resolution effects so important? What I'm showing you on this slide is I'm trying to use the mouse. I've made the mouse quite large and with a sort of trailing tail.

So I hope you can see. I'm pointing now to the picture on the left-hand side which is an area 50 x 50 kilometers modeling with mesoscale modeling with a resolution or grid spacing of 2.5 kilometers. And on the right-hand side there is exactly the same area—the 50 x 50 kilometers modeled with a microscale model. So we've taken data from the mesoscale model and downscaled it further to microscale with a calculation every 100 meters.

Now what you see in the colors is the power density where the lighter the color the higher the power density. Or you can also say the better the wind resource. And you see the two pictures are quite different whether you're using 2.5 kilometer resolution or 100 meter resolution. And what you see in the black figures here is the mean power density for the whole area. So you see when you're using the mesoscale modeling output directly you're seeing a mean power density of 323 W/m<sup>2</sup>.

When you look at the results from the microscale modeling you see a mean power density for the same area of 505 W/m<sup>2</sup>. So already this is quite interesting that we see some more resources apparently because of the emergence of the features that are causing an enhancement of the winds. In this case it's mainly the orographic effects on the ridges and hilltops where you see the best sights for wind turbine setup. These areas are being captured when you're doing the microscale modeling.

What is even more dramatic is if you look at the—in red the values there are the mean power density when we only look at the windiest half of that area. So if we look at the mesoscale result we see that the mean power density for the windiest half of the area is 410 watts per meter squared. But when we look at the mean power density for the windiest half from the microscale modeling we see much more. We see 641 W/m<sup>2</sup>.

So what might've been considered an area looking at the mesoscale results and the figure in black showing a mean power density of 323 W/m<sup>2</sup>—if we actually look at the sites where it's more likely that the wind turbines would

actually be placed and we aggregate this up we see that the mean power density is more like 641 W/m<sup>2</sup>. So it's giving quite a different picture. We'll be showing some of these kinds of results of looking at the windiest area when we look at the output from the Global Wind Atlas.

So the model chain: what we have here is kind of a representative schematic of the model chain. We go from large-scale which is in this diagram something kind of in the order of 20 kilometers to 200 kilometers. And we go down the diagram to medium scale and small scale where we're looking at sort of in the 100s of meters scale. We want to go from large-scale to small scale in this downscaling process. And the way we do that in the Global Wind Atlas is we start with reanalysis datasets.

These are datasets that describe the state of the atmosphere at around 50 kilometer resolution. And they come from a number of centers that are doing atmospheric research or operations. And now all of the ones we talk about are in the public domain. We make a process called generalization which to any WAsP users out there listening will be a familiar process. The reason we do this is it allows us to feed the description of the large-scale wind climate into a microscale model. The microscale modeling is very similar to WAsP microscale models. And I'll talk about that in a moment.

What we need to run the microscale modeling is not only the generalized wind climate information but we also need the high resolution topography information. So these are sources we need data for. And the output is the wind resource at high resolution. So this is the way we're doing it in the Global Wind Atlas. We also have what we call verification streams which are the ways we compare output from the Global Wind Atlas with other ways of producing Wind Atlas data or wind resource data.

So we have what I've here called here NWA which is a Numerical Wind Atlas methodology which we've used and developed here at DTU for some years. In this step we actually take reanalysis data and put it into an intermediate stage with is a mesoscale modeling. The mesoscale modeling requires atmospheric data for forcing. And it requires aggregated topography data at roughness and height elevation of land amongst other things. With that you can then downscale further to microscale and provide a wind resource at high resolution.

So this is actually how we typically do National Wind Atlases. And we're doing that now in a number of projects including those with World Bank and the ESMAP program. And then we have another verification strain called S-Force which is a Synthetic Aperture Radar methodology where we take a lot of scenes from satellite platform and we can aggregate those together to create a sort of remote sensing-based idea of wind resource at medium resolution. So in purple we have sort of output that we can compare and I'll show you that later in the presentation.

The model chain: how did we actually do this in practice because it's a lot of calculation? How do we take the earth and make it into something manageable. The earth is split up into convenience size packages on which

the calculation is done. And we found a very kind of useful structure or system that already existed called the Military Grid Reference System (MGRS) which forms the basis of the job structure. In fact those grids are still a bit too big so we actually split those zones into four.

And what we end up with then is 4,903 MGRS zones or jobs. But in fact although we call this a Global Wind Atlas we do actually calculate the land and 33 kilometers of the coastal waters but not further offshore than that. So in the end we end up with 2,439 jobs required to cover the land and the 30 kilometer offshore buffer area. Then we have a system called Frogfoot which runs a like WASP so WASP users may be familiar with this idea that you can create what's called resource grid calculation in WASP.

What the Frogfoot system allows you to do is actually to do a very, very large resource grid calculation where you can actually use more than one generalized wind climate. So it incorporates a way to interpolate generalized wind climates and it also allows you to specify different kinds of boundary for where the calculation is to be performed. And also the system manages all of the data that's created and all of the input data that's required.

So the input needed for Frogfoot is to generalize with reanalysis winds and high resolution elevation and surface data. So the Frogfoot system looks like this. This is kind of a flow diagram. And this was developed in partnership with World In A Box, a software development company in Finland, that's sort of created the way the different elements talk together to manage all of this data that's created. And also to manage all of the different jobs that are required as I specified in this structure.

So we start with the inputs we need—these purple elements. They're the generalized wind climates here and this purple one, the orography and roughness maps. And these go into different services which provide the job allocation and job service. So the climate service is providing climates when needed. And the terrain service is providing maps at high resolution when needed.

The job service manages all of these jobs—all of those 2,400 jobs—and divides them into a number of WASP workers which work on a small element of those maps and those climate data. And then the result service collects all of these results together. And then there's a system to export it. And then we process the data to make it so we can serve it on the web service. The Frogfoot components look like this. This is the way the user can interact with the Frogfoot system.

And this is just to show that the WASP workers are many. And that means in this distributed system we actually can have a large number of WASP workers running on a large number of computers over a limited area network. So you can actually multiply the effect of many computers to be able to make the calculation over a few weeks rather than taking much longer than that.

So what does the microscale modeling capture? Again this is very much in the WASP kind of world. We have orographic speedup effects are captured by

the Global Wind Atlas methodology. So what I'm showing here is a sort of schematic or flow going over a hill. And the lines here are streamlines. The streamlines come closer together at the top of the hill. And this is associated with the speedup of wind over hills.

And what we see in this diagram here is that the actual speedup is a function of height. And the height where you see the most speedup is a function of the geometry of the hill. So there are flow models inside the Global Wind Atlas or inside WAsP that care of the calculation of the speedup. It's important to remember though that there are limits to this in the WAsP flow model. It's good for medium or simple terrain. And complex terrain tends to give overestimates of the speedup. So where the terrain is complicated and there may be low separation occurring then we experience that the WAsP flow models are overestimating speedup on hilltops.

We'll return to that point a bit later in the presentation. The other thing that the Global Wind Atlas methodology accounts for—So I should say remember the orography effects are taking account of the high resolution data we have on the surface elevation. So we also have high resolution information about the roughness lengths. And so the Global Wind Atlas methodology accounts for that too. So this diagram is showing you for a given largescale wind forcing given by—in this case we call it—the geostrophic wind.

It's the same everywhere. It's ten meter per second, largescale forcing, happening over different surfaces and depending on the surface roughness. So if we take for example Curve A is showing you what the profile looks like when you're over a rough surface with a roughness length of two meters. So you see that the wind speeds are quite low when you're moving down to the last 200 meters—lowest 200 meters in the boundary layer. Whereas you're over—for example if we take water here (D) with a roughness of .2 millimeters then for the same largescale forcing the wind speeds are higher.

This is a picture—sort of the average mean wind speed profile. And this is for a very idealistic condition. This is where there's homogeneous roughness everywhere. But of course that isn't something that happens very much. In fact what we see much more is surface roughness changes. So it could be that there's some shore, with then some water—a lake or sea for example—that then we move over a different profile. So we move over a different surface roughness length.

And the effect of that isn't immediately felt throughout the depth of the boundary layer. And this is what this diagram is showing. This is showing the profile. On the left we see the profile for winds—vertical wind speed—above a water surface. And we see for the same forcing quite high wind speeds. And then as we get to this point where zero in the X-axis we are encountering a roughness change. And now we're going to a 20 centimeter roughness. And the effect of this roughness is not, as I say, felt throughout the depth of the boundary layer straightaway.

The lower parts of the boundary layer fill this roughness change first. So we have this new low profile in the lower part. And then there's an intermediate

part—the transition profile—where it's like a mixture of the new roughness length and something left over from the old roughness length. And then above that it's as if it were still over water again. So these roughness changes actually create the development of internal boundary layers. And these can actually have quite a large influence.

As you see on the X-axis we're going 4 kilometers into the land here. So we're 4 kilometers away from the roughness change. But we actually see that the roughness around 40 or 50 meters still very much has some leftover characteristics from the roughness upstream of the roughness change. So this is an important part to get because it has a big influence on the wind resources at any location and particularly at different heights.

Okay so that was something about some of the modeling that's captured with the Global Wind Atlas. Now we say something about the atmospheric datasets. And this touches upon the question to Nicolas earlier. So we're using reanalysis datasets to give us a description of the largescale meteorology for decade over the globe. Here we list four of the reanalysis datasets that we used. In fact the ones that we're presenting in the Global Wind Atlas webpage at the moment are the mirror output.

And this is data that starts from 1979. And I think we go up to 2013. I'd have to check that. It's in the documentation. So we're talking about multi-decade periods where we find out the wind climate statistics over that long period. The thing that makes the Global Wind Atlas a possibility today or over the last few years is the growing availability of these reanalysis dataset higher and higher resolutions. So if we go back to the year 2000 then the reanalysis data we had available was on resolution around 250 kilometers.

Now we see resolution of around 50 kilometers which means that we are more comfortable making a downscale process without the meter scale. It's not perfect or anything but it's something that is more appropriate with the higher resolution of the reanalysis datasets. And then we have input datasets for the elevation and also for the land cover. And again something that makes this project possible now is the emergence and availability of high resolution data. So the elevation data, for example SRTM, has been something we've been using in wind energy circles now for some time.

They're releasing higher and higher resolution for the rest of the world now. We actually found that there were still some problems with the SRTM data in that there were some voids. And also it has limited coverage beyond 60 north and that was a problem for us. So we actually went to the viewfinder dataset which is a compilation of SRTM data and other datasets, to get a more fully-global dataset without any void problems.

And then the land cover we use the ESA—the European Space Agency GlobCover datasets. This has actually a lower resolution than the elevation datasets around 300 meters. And also there are sometimes some no data areas and for that we kind of used the MODIS data as a backup dataset of land cover classification.

One of the big challenges with the Global Wind Atlas was determination of surface roughness length. We're basing it on the GlobCover dataset and the set is European Space Agency initiative it is actually generated from one year of the kind of analysis or satellite data. It has a global resolution of 300 meters. But the crucial thing is it has 22 classes of vegetation. And this means that we have to somehow convert the 22 classes—each one of those—to a single roughness length. Well this is the way we do it now.

But we can imagine that this has implications on the accuracy because what is, for example, described as mosaic forest shrub land, 50 to 70 percent, and grassland 20 to 50 percent, just to give you an example, it's quite difficult to assign one roughness length for that classification. There are data gaps near the poles, a limited number of overpasses, and large number of cloudy images. So this is giving us some problems. But that's why we have the MODIS dataset to sort of backup where we need to.

Yeah so this is actually—I mentioned—the challenge of finding a roughness length. This is what we actually used for the microscale calculation. So this is a table showing roughness length for each GlobCover class. And you know this is something which would be interesting to get feedback from the community about whether these are appropriate or not. And then it's like a research area still do know how would the uncertainty on the roughness length kind of propagate to an uncertainty on the wind resource. There are a lot of interesting things to think about still.

Okay now I want to go through a bit about the validation that we've provided. And you can read much more about this on the webpage. So as I mentioned we have different kind of validation streams. We actually do validation over ten different countries around the world. So we make comparison of the Global Wind Atlas results with other types of data. And what I'm showing you now is a sort of selection out of those. One of the ones I mentioned was this Synthetic Aperture Radar methodology.

The limitations of this methodology are it only can be used for offshore areas. It's based don looking at the capillary, the back scatter, of radar microwaves from capillary waves on the surface of water. But this is good for us because it kind of gives a spatial picture of wind resource. How it works is you take a number of scenes—hundreds of scenes—and you make average statistics based don those hundreds of scenes. So the limitation is it is only available to use offshore validation.

Another limitation is that there can be some complication in extrapolating the wind speed from ten meters which is the standard height for Synthetic Aperture Radar retrieved winds to in this case 100 meter winds where we compared it with Global Wind Atlas output. So, on the left-hand side you see wind speed at 100 meters recovered derived from a Synthetic Aperture Radar and the methods built into software called S-WASP. And on the right-hand side you see the same area here—the detailed area of the Aegean Sea where it's the result from Global Wind Atlas.

So the picture you get is that the kind of large-scale winds are kind of similarly underestimated. But the striking thing is that the SAR is picking up the small-scale features—not microscale, but in the medium scale. So these are the mesoscale features where there is flow around islands or if you look on the west coast of Turkey here sort of between headlands and also in gaps between islands. And these mesoscale features are actually missed by the Global Wind Atlas because we go from the reanalysis data at around 50 kilometers to the microscale.

So this is definitely something you need to be aware of when you're looking the results and thinking how reliable are the results? If there are going to be a lot of mesoscale effects then the uncertainty will increase for the Global Wind Atlas. There's another example in a moment. Then we can do validation against high resolution resource maps generated from measurement-based generalized winds. And the limitations of this comparison are it's only in part based on measurement.

But it also involves a fair amount of modeling. So what I've got here is the State of Illinois—this was a result of a master's student at DTU, Munoz-Najar, who did a very nice project looking at using observational wind atlases and then putting it into the Frogfoot system. And then we have comparison on the right-hand side with the Global Wind Atlas. And what I think is quite nice about this is actually it's very difficult to see the join between the Global Wind Atlas tiled as being overlaid on top of the observational wind atlas created for Illinois.

We do see again there's the site under estimation in these areas where the highest resources are seen in Illinois. Another case is –

**Tim Reber**

Jake?

**Jake Badger**

Yes.

**Tim Reber**

Sorry Jake, this is Tim. I just wanted to jump in real quick. We do want to try and leave some time for the demo and some questions at the end.

**Jake Badger**

Yes, yes.

**Tim Reber**

If you could just try and wrap up maybe in the next five minutes or so?

Jake Badger

Yeah sure. I don't want to overrun. Of course.

**Tim Reber**

Thanks very much.

**Jake Badger**

Yeah so this is a case where we could validate against numerical wind atlas results. And this is best done where we have a numerical wind atlas result that's done and validated against measurements. So we can do that in a number of countries where we've done these studies. One, for example, is in Denmark. So we see here a comparison on the left of the numerical wind atlas and the Global Wind Atlas.

And there's another one which is from the WASA project—Wind Atlas for South Africa. There's more information out there where we've done a validation. Here the mesoscale effects are important.

Okay so I'm going to do the wrap up now quite quickly. I want to show that as Nicolas explained as the Global Wind Atlas site at DTU which is good for the modelers and those who want to get deeper into the methodology to examine. So for example here you can see what was the roughness length used? I'm zoomed in on an area I know \_\_\_\_\_ here. You can see what was the roughness length used in the modeling. You can see what the evaluation map details used in the modeling were. You can see what the orographic speedup effects were that were coming out of the modeling.

This is the orographic speedup effects for westerly winds as a function of direction. This is the aggregated mean wind speeds for each kilometer and this is looking at the top quarter—so looking at the highest 25 percent mean wind speed for the windiest sites for each of those 1 kilometer pixels. This is echoing on what we talked about earlier. We can look at the mean power density for the windiest sites with the graph looking like this.

So what we see are actually the windiest sites of a power density coming out of the Global Wind Atlas much higher than you get if you just use reanalysis alone because we are capturing the hills. This is like the key figure to look at I think when looking at resources around the world and aggregating them in areas. I just want to point out this way I think the site has a nice feature that you can look at the resources. And on top of that you can put the RIX which allows you to see the ruggedness index.

So these areas that are grayed out are areas where the model inside WAsP is sort of being pushed to its limit. We have a higher uncertainty. But everywhere where it isn't grayed out we have a higher level of confidence about the wind resources. Because we are running out of time and I probably spoke for too long about other aspects I just want to say we are very interested in collaboration on applying this data global assessment of technical potential.

And we think this dataset is very good for that because we can set out a range of test assumptions and use the data. So we can put this data—We've got enough information about the wind climate at every 250 meters to kind of put in any power curve at that grid space. So every 250 meters we can pretend we have a turbine and put the power curve information and get an annual energy production. And then we have to make some assumptions about how we thin out or how we actually deploy the wind energy.

In fact we did a study like this—like a back of an envelope calculation—based on all of this data. And we see massive amounts of resource available. And then it's a question of how do we thin —? How do we apply exclusion zones? How do we say we're only going to use like two percent of this resource? It's this strategic thinking of how to use resource is something that remains to be done. But I'll leave it there for digestion later. You can look at it from the webpage. I'll say no more about it.

So thank you very much for your attention. Here we see a list of websites. So the different maps are provided, with the methods provided. Details of the datasets are provided and there are also tutorials how to use different tools provided by the website. You can contact me with that e-mail address. I'd like to acknowledge funding from the EUDP fund, Danish Energy Agency has provided for this project. Thank you very much.

**Tim Reber**

Great. Thanks so much Jake. That was really interesting. We've even got some questions here saying, "No leave the text up," when I asked you to speed up there and apologies. But we do have quite a few questions and so I wanted to make sure we had time to get to some of those. So without any further ado let me ask some of those. We had a couple of folks asking about what exactly is considered "land?" For example is every small atoll, small island, considered land? Or is there a certain threshold? And how is that determined?

**Jake Badger**

Yeah, actually I've been looking at the Pacific Islands and atolls and they are there. So I think we cover all land, even very, very, very small atolls. I'm just trying to think how we—we used a very high resolution coastal dataset to provide us with what is land. So I'm fairly confident that most of the—all atolls—are there. The thing that we need to be clear about is above 85 north I think maybe there's no land anyway. But that is not covered by the Global Wind Atlas.

And all of Antarctica is not covered by the Global Wind Atlas. So there is some land—Antarctica. Antarctica's land is not covered by the Global Wind Atlas.

**Tim Reber**

Okay great. Good to know. The next question: is it already done or are there plans to add some other characteristics of just hourly profiles and things such as that?

**Jake Badger**

Yeah okay so this is—What we have at the moment is cycle—like biannual cycle information and annual cycle information. So we look at the reanalysis datasets and we can characterize the typical variation through the day. So this is useful for planners to see where most of the resource is occurring. Is it in the winter? Is it in the summer? How is that correlated say with rainfall or solar resources and so on? Also the daily cycle is useful information for planners.

But I know we're getting a lot of requests for people to come for us to provide information about hourly time theories data. So not just like a cycle but actually for a given year what is the time series on an hourly basis? And we don't have that now. But it's something we want to definitely work towards. We're getting a lot of people asking about that for isolated systems. They want to know in order to design an isolated power system kind of what size of battery you would need and so on, or the costing aspects. You need to have that.

Yeah we'd like to add that but it's not there yet and we'd need to have a project to start adding that. But we know it's very much of interest to people.

**Tim Reber** Great. I think that would be—Yeah certainly a couple of expressions of interest in that. It sounds like we have a few highly technical experts in the audience here and a few technical questions. Pardon me, I'm not a technical wind expert, but one person is wondering is turbulence and/or Weibull k dealt with in the generation of the power estimates. I'm not sure what Weibull k is but maybe you can speak to that.

**Jake Badger** Yeah okay so actually the output from the Frogfoot system is actually Weibull A and k for each sector. So if you can zoom into the 250 meter grid spacing calculation output you get for 12 sectors A and k. I don't think it's true to say it doesn't contain the turbulence information like at high or at very short temporal scales. But it would be similar to the ten minute average wind speeds. So what is commonly done in WASP for example is that you feed into the WASP system ten minute average winds.

And with that you can get a Weibull find for each sector. You fit Weibull A and k. So you get a Weibull distribution. And the k tells you about the variance of the wind speeds. So for a high k you have actually a lower variance. But it's not giving information about the turbulence or the turbulence intensity. That part is not given in the Global Wind Atlas.

**Tim Reber** Great. A couple more questions here and then we'll move on. With a fairly international audience, and obviously a Global Atlas here, are there plans or does it already exist—tutorials in different languages? Particularly one person was asking about whether or not a tutorial is available in Spanish.

**Jake Badger** Well we have Spanish speakers in our team so maybe we can do another version of this or make a smaller group to do it. I'd be open to that. It's true we should be trying to get as much global outreach as possible so I don't—I'd be very open to that possibility sure.

**Tim Reber** Great.

**Jake Badger** There's nothing as yet schedule.

**Tim Reber** Sure. I think there's quite a lot of opportunity for some follow up and collaboration here. For everybody in the audience we'll also try to—You can see Jake's e-mail there and we'll try and get you all in touch so you can continue some of these questions on opportunities for collaboration offline.

**Jake Badger** Okay.

**Tim Reber** Great so I think with that we should move on. And again if there's any time left at the end we can always come back to questions. Thanks very much Jake.

**Jake Badger** You're welcome.

**Tim Reber** That was fascinating. There are quite a few more questions still but we'll move on to the demo. So Abdulmalik we will go ahead and pass it over to you.

Thank you very much. Thank you Jake, also, for the very detailed presentation. So in my session I would be focusing on how users can access this wonderful dataset from the IRENA Global Atlas for Renewable Energy, how users can access some of the tools, and how you can use some of the visualization and the search and visualization functionality we have on the tools to make the best use of the dataset for discussions and for policy-type discussions.

So as Nicolas already said the IRENA Global Atlas comes in two variants: the web application which is actually the GIS where you can perform a lot of analysis—geospatial related analysis, and then the mobile platform which is the Global Atlas Pocket that enables you on the move to see where areas of high resources could be. But the presentation and demo will be focused on the web application. So to find the web application you just need to go to <http://www.irena.org/globalatlas>.

And upon launching this page from your address bar what you see is a neatly integrated map gallery which is essentially a combination of different search functionality that together helps you find relevant content on the platform basically. So the first thing you would see would be the geographic search which is basically the map and the background. You can click on your country or a number of countries and basically you would see a list of maps that are focused on the country. Some of these maps might be maps that have been created specifically for the country over thin layers that have been created specifically for the country.

Or in other cases it might be a global map such as the Global Wind Atlas where there's \_\_\_\_\_ today. When you use any of the search functionality the result you get is what looks like what you see on the screen. So you have a list of thumbnails that show up from the base. And with each \_\_\_\_\_ tool each thumbnail is basically representing a map that you can open in the GIS interface. So you have a thumbnail, a title, and a description for each map. To access the map of the GIS interface you only need to either double-click on the map or click on the open button.

And basically you will find the resulting map and the GIS interface. Before we go further I would like to introduce you to the GIS interface a bit more. On the left side you have the main menu and the layer tree which is essentially an assembly of folders with each folder tagged by a theme. So it might be solar or wind or in fact any other resource or even infrastructure. So under each folder you would find—If you see a folder tagged solar it means you would find layers. The layers you would find under this folder are actually solar layers.

Then in the center you have the map view which is essentially where you would see some of the maps that the layers that you have active in the layer tree. On the left-hand side you have the legend section. There you would also find the tools. On the legend you can use the legend threshold functionality which I will introduce to you shortly.

Okay so when you open the Global Wind Atlas from the map gallery this is basically what you would find. And as I said earlier you have on the left layer groups with the list of layers that we have for this particular map. And you can see on the map view the wind layer active. The particular wind layer that is active is the wind speed map at 200 meters' height. And then you can see the legend. The next slide basically shows you the list of datasets that we have in that map, all of which you can lose.

With this summary I would quickly go to the web platform just to give a sense of what we're talking about. Luckily I wouldn't have to do a search because we have intentionally put the Global Wind Atlas at the first map when you connect from anyplace in the world. So you don't really have to search for it. You will find it as the first map on the left. So to open it in the GIS interface you just double-click on it and you have—Okay I think I'm going to load this again because in the interim I had –

So to open the map you just double-click on the thumbnail and it opens the map neatly and the GIS interface. You can minimize the panels to have a better view, to have a full view of the map and the background. So just for a quick introduction again you have—On the left side you have the main menu. The first one takes you back to the gallery. The second one helps you create maps. The third one helps you add layers to this map that you may not find that might be in the central catalog which Nicolas referred to earlier in his presentation.

There we have over 2,000 layers that can be added to any map depending on the use case. The fourth button helps you share and the last one helps you save. On the right side you have the legend which is essentially where you see the legend for all the maps that you have active on the platform. On this legend on thing that is very interesting is that you can do some basic thresholding to take out areas that you feel are probably not within the set of what you want to look at for wind development.

And you see that takes out all the areas. I did this for up to seven meters per second. So I want to see areas with wind speeds above seven meters per second and that you can do really neatly here. From the layer tree you can basically do a lot of things. You can overlay. You might want to see the protected areas. You might want to see the same map but with respect to the protected areas. You can do some basic overlay. You can reposition datasets basically to give you a better view of maybe a base map with respect to some other parameter like the transmission lines or the elevation or indeed some other parameter.

But what is also interesting about this platform is that for every point you see on the screen there is some context relevant information which can be accessed by using the information tool at the top of the blue strip right at the top. You can click with that. You can make it active. You can click on each point to find—In this case you can find the specific value for that particular point—the wind speed value for that particular point. You can also find policies that are relevant to that point. And you can find also tools that are relevant to that point also to the ma that you're looking at.

So in this case this is the Global Wind Atlas and there is a specific tool, a statistics tool, that has been developed that can help you basically see some more details about each point or each site that you are looking at on the map. So I will quickly open that tool. On this tool what you want to do is look at an area that might be interesting. Draw a polygon over that area and you can see indeed the—hold on a second. You can indeed generate wind statistics for the area basically.

And in addition to that you can download \_\_\_\_\_ files which you would probably use on other applications like WAsP. So with this tool you're basically seeing a graph. The tool presents information about the area in quite a number of visualizations. So here you are able to see—On the first tab you're able to see a graph of wind speeds with respect to area. And this basically tells you what percentage of the area has wind speed above a second level. So if we take the example of what you see at that very controlled point you would see that indeed 44 percent of the area has wind speeds above 7.3 meters per second.

But on this tab you still have a couple more visualizations. You have the temporal histogram which some of you who are very familiar with wind statistics; it's a very popular graph. You would see the distribution of wind speeds with respect to the time. So you see how much time in a year the wind speeds are between particular ranges. So in this case it's between five and ten. And then you know that the period within the year is the integral of this function basically.

You can also see area histogram which is another visualization of what you saw previously. On the second tab you can see a wind rose which essentially gives you the direction of wind speeds around the area. So each concentric cycle in the wind rose basically represents the percentage of the time that the wind speeds are coming from a particular sector. And then finally you have the wind index which basically presents to you the moving value of the annual average.

And the annual average wind speeds and the moving monthly wind speeds. So with this you can basically see how this varies over a year. And then lastly you can download list files which you can use for analysis on other software. It's also important to note that on this tool you can basically print images or PDFs which you can use—which you can communicate. It's important to note this. And for the wind rose it's important to also note that you can download the values of the wind roses to reconstruct it and tailor on any other tool that generates this.

Without spending too much time I would like to quickly recap on one point: how do you access the platform? We go again from—This is your entry point to the Global Atlas—the IRENA Global Atlas. To find the Wind Atlas you only need to—It's been made super easy. You don't have to search. It's the first map on the left. You only need to double-click on it and you would open the Wind Atlas on a GIS platform that you can play with. And if you want to find more detailed –

After you have done an analysis, you have picked an area, and you want to know the wind statistics of the area or the policy of the area, or any other information that is very relevant to the context of the area you can find that using the information tool. Thank you very much for listening.

**Tim Reber**

Great. Well thank you so much for that demo. It looks like a very powerful tool that should be quite useful in several different applications and to broad audience. It's great for putting it together. So with that we have time to get back to answering some of the numerous questions that have come in. So I will just go ahead and jump right into them. The first question: is it possible to download some of the layers I guess to a local machine or anything like that?

**Nicolas Fichaux**

I can answer that one. So that's Nicolas. Can you hear me?

**Tim Reber**

Yep.

**Nicolas Fichaux**

Very good. So we are working on it so that you can indeed download part of the dataset—not the full dataset in one piece because each of these maps is three gigabytes. So it's a bit \_\_\_\_\_ to download directly from our server. In case we will have our admin user currently on the server. It would be very challenging. However we would allow you to download pieces of the information on specific zones. And this is a feature we would like to make available—yesterday was the deadline actually.

And it should be ready within the next ten days. It's more complicated than foreseen. And this will be inside the Global Atlas, a new feature where you would right-click on a layer and then just download and it will help you with the loading that \_\_\_\_\_. But we will have some news about that when it's ready and tested and we are sure that it's working 100 percent.

**Tim Reber**

Okay, great, thank you. Next question—and again I think at this point for any of the three of you who would like to jump in and answer, please feel free. Is there any opportunity to include wind data from existing wind masts that are installed at different locations all around the world? Or is that already **included?**

**Nicolas Fichaux**

It depends how the—What the question is precisely—So if you want to, for example, in a map of the Global Atlas—the IRENA Global Atlas in that case—if you want for example to view on the same screen. If you want to have the Global Wind Atlas and then load wind atlas of South Africa—South Africa wind atlas—or the Uruguay wind atlas or Mexico for example—you can do that. You can. You just look into the catalog of the Global Atlas from the interface.

You look for add data. And in this add data you search for Mexico wind. You will find the Wind Atlas of Mexico. You can display it inside the same window. You can do that. Jake was showing some validation that they did and you know the matching of pictures is something very interesting to look into. Maybe not the actual detailed value but how is the difference of the

viability of the wind speed in space due to the topography. And that's something you can do with the Global Wind Atlas [inaudible].

Then if you're talking about validating and using the wind atlas of Mexico in order to validate the Global Wind Atlas the question is going to Jake in that case.

**Tim Reber**

Great. And Jake I don't know if you want to touch on that?

**Abdulmalik Ali**

Yes, hello. That is a very nice feature of the IRENA Global Atlas in that you can switch in and out different sources of wind atlas. Of course the caution there is sometimes it might be a different height or a different resolution or a different temporal period. So there can be all sorts of reasons why the match may not exist. But I think as Nicolas was saying it can give a qualitative indication. I think one of the things I was trying to point out with the WASA Wind Atlas for South Africa and also the case of the Aegean Sea validation is sometimes topography can lead to some quite strong meter scale effects that are not very well represented in the Global Wind Atlas.

And these are quite often kind of enhancing wind resources where the microscale effects are not adding anything. So for example you get gap flows. So where you have say some elevated terrain to the east and then some elevated terrain to the west. And maybe there's like a 30 kilometer low terrain area. Quite often in that sort of situation you get high winds moving through that gap. And that's something that kind of requires a meter scale modeling approach. If the land is covered by a metered scale model based wind atlas you'll have an impression of what other meter scale affects you could definitely do that for the Wind Atlas for South Africa for example. Okay that's all.

**Tim Reber**

Great. Thanks so much. Moving on, still more questions. I guess this one is probably for Abdulmalik or any of you who would like to touch on it again. I'm wondering if it's possible to add your own shape file to the atlas. For example in the case if you wanted to check wind conditions within the specific town border or set of town borders?

**Nicolas Fichaux**

Yes it's possible. It's a bit specific for the moment. What you need to do is to have your shape file or GIS layer on a \_\_\_\_\_ server. So we are using map mapping services and you need to have that on a map server. You use the web mapping service link and then you go to the add data and you can add the link. Right now in the Global Atlas we don't have the capability to just open a file that you have on your computer which seems quite obvious to do with an EGIS platform. But in our case we are a web GIS platform.

And for the time being we don't have the linkage with what is happening in your computer or on your disc. This is also a feature that we are considering. It's not that easy to do but we are considering it. So to answer in short, you can do that. However you need to publish your GIS layer on a web mapping service and you just add the link to the Global Atlas. That's the way to go for the time being.

**Tim Reber**

Great, okay, thank you. An interesting question here: for those who are not experts on wind data analysis but are looking forward to using the tool in case they need technical assistance or help using the platform who exactly should they turn to for technical support and assistance?

**Nicolas Fichaux**

All right so on the IRENA side we give very regular assistance on the user of the Global Atlas. So we have users asking how to use a tool or feature. We do have that. We have users turning to us also \_\_\_\_\_ that are coming from can we download the data? So we provide assistance for that. In case you send a question on the DTU Global Atlas to us we will channel it to Jake it's about the dataset. And if you have a question about the dataset I would advise you to go directly to Jake because that's where the \_\_\_\_\_ is. If it's about the tool then we help on the tool. No problem, of course.

**Jake Badger**

Yes it's Jake here. So I completely agree. We're very happy to get questions and feedback about methodology and datasets. And if you are a modeler and want to get deeper into the methodology and to examine the other datasets that we provide on the <http://www.globalwindatlas.com> webpage you can also have a look at the tabs on the top. They give directions to different parts of the documentation. And there are also some video tutorials about how to sort of navigate and apply the tools.

But we are interested in getting feedback so please do write.

**Tim Reber**

Great. Well we still have a couple minutes and there are still more questions coming in. so we'll just keep going here. There's a question about if there are any options or plans to export files as Google Earth files or integrate with Google Earth in any way.

**Nicolas Fichaux**

You can do that. But there you need to go to our catalog. So you go to <http://www.webservice-energy.org>—the link I provided in my presentation. And you search for the layers. And then there is the possibility to open the layer because it's web mapping service. You can open it with any viewer, including Google Earth. And you can use the link in order to be able to view it in Google. So it's not something we have automated. It's something where you need to look for the link, use the link. You need to be quite comfortable with that but you can do it.

In case you are in trouble and you can't manage to find the link or you have questions we'll help you. It's no problem. It's just a feature we have not automated or promoted right now because we didn't have a request for that at all. But it's possible. It's possible.

**Tim Reber**

Great. Another question: we have somebody who works for a small wind turbine company and they're wondering about data availability for small wind turbines at the 30 meter hub height, specifically in India. But I guess more generally how about that sort of data availability.

**Jake Badger**

Okay maybe I can take that one. This is Jake from DTU. This is kind of an opportunity to say that this dataset is not intended to be used for siting. So it's not sort of that you can use this data and say, "This is where I should put a

small wind turbine." Actually the height that the wind climate is available at is 50 meters, 100 meters, and 200 meters. Having said that you know you can still use the Wind Atlas to sort of browse around and look out for what kind of microscale features may be enhancing wind. So if you were a small turbine sort of interested in that sector then you can identify features in the terrain that may be giving a higher wind resource than was hitherto considered for that area.

So I'm thinking of areas that were kind of dismissed because they seemed to be flat and had no particularly strong resource. Seen from a large-scale point of view it can be that when you look at the microscale features that you actually see say rich features that can enhance considerably the wind resource and make some potential for exploitation of wind. But then you know again it's more of a qualitative assessment rather than trying to use this to get an annual energy production.

I could say that this links actually very nicely to another project that we have going on at DTU called Online WASP. So if you're familiar with the WASP software which can be used to calculate energy production for turbines there's kind of another version of this coming out called Online WASP which is actually dedicated to smaller and medium sized wind turbines. And this is a tool that will be kind of rolled out as a global tool.

At the moment we're focusing on some countries where there are different kinds of datasets. But the idea is that you can fall back onto the Global Wind Atlas dataset to make some sort of preliminary calculations. This question I would say please look out for the Online WASP project because it might be actually more the kind of tool that you're looking for. If you want to know more please send an e-mail to me and I can put you in contact with the project leader for that.

**Tim Reber**

Great, thanks. So that's a great point. I think we have time for just one more question here. But before we do that I just want to mention that we will be— For everyone in the audience we will be sharing the unanswered questions with all the panelists and be asking them to hopefully reach out via e-mail to answer any remaining unanswered questions and follow up on some of these questions regarding opportunities for collaboration and things of that nature.

So if we didn't get to your question this time around we will do our best to make sure that it gets answered. The last question is kind of a good closing question. We've had a lot of folks asking about specifically whether or not there's data or how applicable it is in their particular country: India or Pakistan for example. Maybe you could speak briefly about sort of the global coverage and how applicable it is on an individual nation scale and if you would recommend continuing to do a sort of national scale wind assessments on top of the Global Wind Atlas.

**Jake Badger**

Okay may I take that one? This is Jake Badger from DTU Wind Energy. So yeah the Global Wind Atlas has global coverage. And therefore it's kind of very likely that everyone listening is able to go and look at the wind resource in their country. However we would still—If the Global Wind Atlas is

indicating a promising wind resource then the way to use this is to sort of—for government and policy makers and initiative takers—to say we need to push and make a national wind atlas for this country.

So what you get when you do a national wind atlas is you actually do the modeling for the wind resource in a much more dedicated specialized way for that country. So there may be some meteorological phenomena that are impacting that country and the wind resource air which needs to be adequately covered. And really what I mean by that is the mesoscale features which I've touched on before. What you also want to have in a national wind resource assessment project is a validation program.

That means you need to have numerous masts put up which are dedicated for wind resource assessment. So high masts sort of relevant height for the typical hub height of the turbines that would probably be installed following the assessment—so kind of \_\_\_\_\_ meter masts and so on. And these are used to verify the modeling that's coming out of the more specialized modeling. The Global Wind Atlas can be used to sort of prioritize which countries do we think now should be going onto a program of specialized national wind resource assessment.

The other very good thing about a national wind resource assessment is it engages the local or national stakeholders. So it's much better to be holding workshops in the country talking about the methodologies, talking about what might be specific issues for that country at the country level rather than this kind of overview that the Global Wind Atlas is providing. I think that answers hopefully.

**Nicolas Fichaux**

Can I have one minute to add?

**Tim Reber**

Yes.

**Jake Badger**

Certainly. Please do.

**Nicolas Fichaux**

Okay to add to what Jake is saying we have made use of course not the DTU dataset because it was not existing for \_\_\_\_\_ African Clean Energy Corridor that is coordinated by IRENA. We were asked to come up with some zoning exercises in order to have an idea of at the scale of Africa where our zone seems particularly suitable to prospect more in the future. And the way it was done is to consider the wind resource as accurately as possible. At the time only five kilometers was available which was already incredible only a year ago.

Five kilometers and the distance with the \_\_\_\_\_ population and city topography. And it helped a lot to have a concentration of this \_\_\_\_\_ locally on which zone could be likely to grow in the future and to think in terms of okay can we go for local validation on specific areas? In case for example the budgets are very restricted and it's not possible to cover the whole territory then it in that case it helped a lot to zero in some area and start a discussion on some location in order to have a sort of prioritization a little bit.

And this kind of dataset is helping a lot. It's been a huge progress in the last five years in terms of preservation. It helped a lot of governments to progress faster in growing renewable energy. And we're going to \_\_\_\_\_ the one kilometer. It's even more interesting because in that case you have also the local effects that can be taken into account. You cannot still rely on the actual value. That's what Jake is saying very correctly.

However you can cross that with all of the relevant information and make up your mind a little bit better than only ten years ago when we had the 100 kilometers or 50 kilometer resolution only available in the public domain. It's a huge, huge progress.

**Tim Reber**

Okay wonderful. Thank you. Thank you again all three of you. Unfortunately we're already over time here so we're going to move on to a brief survey here of the audience. If you could just go ahead and please answer the first question you see there on your screen. Great thank you and the second question. And one final question. Great thank you so much for answering the survey. Again thank you to Nicolas, Jake, and Abdulmalik. There were quite a few questions, a lot of enthusiasm and complements from the audience.

And once more, any questions that we didn't get a chance to answer here we'll give you an opportunity—give the panelists an opportunity to follow up directly via e-mail. So I'd like to thank everyone again for joining us. We certainly appreciate everyone's time. We invite you to check out the Solution Center website if you'd like to view the slides and listen to a recording of today's webinar as well as previously-held webinars.

You'll also find information on other upcoming webinars and training events on the website at the Solution Center. Additionally, we're posting the webinar recordings to the Clean Energy Solution's YouTube channel. It'll probably take about one week for the audio recording to be posted there. And you'll also find other Solution Center training materials. We invite you to inform your colleagues and those in your networks about the Solution Center resources and services including the no cost Ask-An-Expert policy support.

So with that I'd like to invite everyone to have a great rest of their day or evening as the case may be. And we hope to see you all again at future Clean Energy Solution Center events. Thank you very much. And this will conclude the webinar.