ESTIMATING SMALL WIND TURBINE ENERGY OUTPUT AND ECONOMIC PERFORMANCE WEBINAR

November 4, 2010

Coordinator: Welcome and thank you all very much for standing by today. All participants are going to be in a listen-only mode until the question and answer session. As a reminder, this call is being recorded. If you have any objections to the recording, you may disconnect.

I would now like to turn the call over to Ms. Trudy Forsyth. You may begin.

Trudy Forsyth: Thank you (Michele). So this is Trudy Forsyth and I am the - one of the co-Chairs of the ASES Small Wind Technology Division. And we have been having Webinars every other month. And this year's Webinar will be presented by colleague Tony Jimenez.

Just a brief background on Tony. He's got a Bachelors of Science and Engineering Physics from CU, a Masters of Science in Mechanical Engineering from CSU and has been an NREL employee as a student and as a full time equivalent for 14 years.

He is my colleague in many distributed wind - small wind projects. He has a specialty in understanding small wind economics. And besides that, Tony was in Iraq for a short period of time, 18 months, through the Army National Guard, which we're very proud of him for doing that.

So Tony, I've probably given more information that you would, but this is your opportunity to cut me off and start the presentation.

Tony Jimenez: All right. Well, thank you Trudy. My name is Tony Jimenez. And I'm going to - the presentation is really going to focus on to estimate wind turbine output and then how to examine the economics. And I call it Managing Expectations because people put in a turbine, they have some - usually have some expectation if not on the economics, at least how much energy they're going to get and those sort of are related. So I'm going to kind of go step by step.

So without any further ado, say the overview of the presentation. I'm going to spend some time talking about the wind energy - wind itself and how we characterize it, how much energy is in the wind because that's the, you know, you can only get the energy that's there.

Then I'll talk a little bit about sources of wind data and the good news is that it's a lot - there's a lot of information out there. A lot more than there was say ten years ago. Then I'll get into the nuts and bolts of estimating turbine energy production and looking at wind turbine economic analysis.

Now if you look at this presentation, it's 51 slides. I'm actually going to go through about 40 of them. The remaining ten or so are kind of additional information that I don't think I have time to go through for this Webinar. But if you want to download the slides and look at it, basically it looks at sizing the turbine to a specific load. So it's related to estimating turbine energy production.

The first section is wind characteristics and energy potential. And just a, you know, why do we care about this? Why do we care about trying to get a good wind resource estimate? And the reason we care is that's the basis for any other analysis you're going to do with a wind turbine.

I mean unless you just want to install it and see what you get, you’re going to need a wind resource estimate to have some idea of the energy production. And the energy production in turn will dictate the economics of the project.

(Like to) spend a little bit talking about energy and power. The terms are often used interchangeably even by those who should know better. And but there is a distinction between them and it’s good to understand that. Think of energy as a quantity equivalent to say an amount of water, number of gallons of water. And when we’re talking about electrical energy being the standard unit of measurement is the kilowatt-hour. Again, think of it as a quantity.

Power is energy divided by time and so it’s a rate. So we just divide out the hours and we get kilowatts. And again, going back to our water analogy, you could think of a bathtub being filled and you can turn the water all the way - turn the spigot all the way on and have the - have a high flow rate, that'd be analogous to a high power. Or you can turn it down to where you’re just getting a little bit of a trickle, go into the bathtub and you have a low power.

But it’s basically the quantity or it’s basically you consider it a rate. And so you can have the same amount of energy created by a high power for a short period of time or low power by a long period of time. And they go from kilowatts to kilowatt-hours simply by multiplying by time.

So for example, if you had a 100-watt light bulb and you ran it for five hours, that'd be 500 watt hours or half of a kilowatt hour. And the other units we use are megawatts and megawatt hours; a megawatt being 1000 kilowatts and a megawatt hour being 1000 kilowatt hours. So bottom line, energy is a quantity. Power is a rate.

And the reason most electrical equipment is sized in kilowatts is because it's sized based on the maximum amount of energy that it can create or handle. And so you want to know that so you don't overload it.

Let's talk about power in the wind. And this formula top - if you take away nothing else, excuse me. If you take away nothing else from this presentation, this formula is what you ought to take or the contents behind it. If we imagine a straw of wind moving across the landscape, the power in that wind is this formula. It's .5 times rho -- that's that funny - that's that funny P looking character -- times A times V cubed. But what does that mean?

So the .5 is just a constant. Rho is the density of the air. And if you want to keep consistent units, it'll be in kilograms per meters cubed with a meter being a little bit longer than a yard. And so not much you can do about the air density. It pretty much is what it is. It's going to be a little bit higher at sea level and a little bit, you know, a little bit lower if you go up where I am at say in Colorado or even lower if you go up into the mountains. So you need to account for it but there's - at a given location it's going to be what it is.

A is the swept area of your rotor. And it's important that it's not just the area of the blades but if you turn that, it's that, you know, assuming you have a horizontal axis machine, that whole circle created by rotating those blades. And so if you want more - if you want to extract more energy or more power from the wind, one way to do it is to make your - go with a bigger swept area, i.e., longer rotors.

So that's something you do have control of. And typically if you have two turbines, the one with - regardless of their power ratings, the one with the bigger swept area is generally going to give you more energy production.

The final one in red and it’s red because it’s the most important one and the most sensitive on is the philosophy of the wind. And what this is saying is the velocity - is the power in the wind is proportioned the cube of the velocity. So that’s the velocity times the velocity times the velocity. It’s very sensitive.

If you double the velocity, there’s eight times more power in that wind, two times two times two, which makes it very sensitive if you - if you increase your speed by a mere 10%, that’s a 30% change in power.

And this is why all but the big wind farm developers are always looking for the very best - the very windiest sites to put up their wind turbines because they get, you know, even a small change in the average wind speed means a bit change in energy output.

With the small wind, you don't quite have that flexibility or you’re probably trying to power a load and so you’re more likely just trying to figure out what the wind resource is at your location.

If we divide out by A, we get what’s called the power density. So this is the power per unit area of wind moving over the landscape. And for kind of historical reasons, we've developed a series of wind power classes. And this - and the power density is given in watts per meter squared. And you can kind of see what the different wind classes are.

Large wind turbines - large wind farms typically Class 4 and above, you might dip into the high Class 3. Your community scale projects say several - say 100 kilowatts to a couple megawatts probably be Class 3, maybe high Class 2. For most people doing small wind, below 100 kilowatts, are probably looking at Class 2 or below. Most people if you look at the maps, you know, where people live and where the winds are, most people live in Class 1 or Class 2 areas. It's not very pleasant.

For most people living in a really windy area and for other reasons such as sources of water and stuff, people live in the areas that aren't quite as windy as the really good wind sites. So when you're talking small wind, you're probably talking Class 1, Class 2, maybe Class 3 for a few folks.

One thing. Because of the cubic relationship between wind speed and power is in addition to knowing the average wind speed, you need to know how those wind speeds are distributed to get a better idea of the average wind power density.

And so I'm going to step you through this slide to not so you really understand the nuts and bolts but you can see what the difference is between different wind speeds or different average wind speeds and different wind speed distributions.

Let's first - let's see if this works. Let's look at this blue solid line. That represents a wind speed distribution of five meters per second with a shape factor of two. We've done is we've used a mathematical relationship that has two parameters. One is the average or it's to the average. And the other is kind of how peaky the peak is. And those two parameters describe this curve.

KF2 is very common distribution for an inland site. And if you look at this and this has a power density of 146 watts per meter squared or about 150 watts. That's what I want you to focus on.

And let's look now at the dotted blue line. This is the same average wind speed, five meters per second, but a different shape factor, a KF3. This would be for an island site. And you can see that the power density is much lower. It's 108 watts per meter squared. So the same average wind speed and we have a 30% difference in power density.

So you can kind of see - so this - we want to show you the importance of knowing the wind speed distribution. This is especially important for the utility scale projects where a small change in power density can mean millions of dollars over the life of the project.

The last thing to look at is the red line. This is an average wind speed of six meters per second and a K of two. So compare the red line with - the solid red line with the solid blue line. And you can see the power density is a little over 250 watts per meter squared.

So we went up from five to six meters per second. You know, basically a 20% change in average wind speed and the power density increased by 2/3. Again, just hammering home the concept that the power density is very, very sensitive to the average wind speed.

Another way - another aspect of wind is how fast the wind changes with height above the ground. Typically the higher you go above the ground, the faster the wind blows. And we - that concept is called sheer and this just kind of graphically shows that. And I'm going to talk about sheer for the next slide or two.

So how is it usually described? This is one common way of describing it, this formula up top. If you have - if you know the wind speed at Height 1, we call it our reference height, and you want to estimate the wind speed at Height 2, this is the formula you use where H1 is your reference high to H2 is the height at which you want to know the wind speed. V1 is the wind - is the reference wind speed and V2 is the wind speed we're trying to estimate.

And this alpha, this exponent here is called the wind sheer exponent. Commonly it ranges from .1 to .3. If the world was a billiards ball, it'd be .24 according to the fluid (dynamisis). But since the surface of the earth is bumpy, the exponent changes.

And then a few caveats to using this. The wind sheer will vary from location to location. Even at the same location will vary by time of day, by season, by wind direction and by height. What I mean by height is that you may have a different sheer going from say 10 to 20 meters than you do from 40 to 50 meters. So you can - it's something you back - you really have to back out.

Also this equation or this relationship breaks down at what I'll call the line of ground clutter. This is kind of the tops of the trees and the houses and what not. Basically what happens at that line is the sheer gets very high and as you go below the ground clutter, your wind speed is going to go down very, very quickly.

Just give you an example. Let's say at, you know, at 20 meters above the ground level, the wind is blowing at five meters per second. If you know the wind sheer is .14, what's the wind speed at 40 meters above the ground? Well, we plug it in, you see the relationship and it's about 5.5.

So kind of very generic rule of thumb would be if you, you know, if you have kind of a standard wind sheer, if you double the height above the ground, you're going to get about 10% bump up in wind speed and that equates to about a 30% increase in power density (so) wind sheer.

The thing we need to know about the wind is where does it come from. What are the prevailing wind directions? And so here in this slide I have on the left a wind rho is in orange and then an energy row is in purple. The wind rho shows the - where the wind comes from, what are the prevailing wind directions.

And so in this case you can see the wind basically comes in the quadrant from the Southwest. You know, going extending a little bit North of West and a little bit East of South. But if you look at the winds that give you - the winds that have the most energetic, i.e., the directions where when the wind is coming from that direction, it's blowing hard, the energy row shows that basically it's two directions; a little bit North of West and a little bit East of South are your direction where - that provide the majority of the wind energy.

And so what this tells us is you want to have - you want to ensure you have good exposure, if you can, to the winds that give - that provide most of the energy.

Turbulence. What is turbulence? One kind of consider it gustiness. If you remember the last time you looked at a stream or something, there are parts of the stream where the water is (relamider) where it was kind of flowing smoothly. And then where it's going over rocks and stuff it tumbled and there are lots of bubbles and it was frothing. That's kind of what turbulence is.

And the effects of turbulence is basically less energy production and more wear and tear on your turbine and therefore possibly increased (onum) expenses. So from a turbine energy output point of view, turbulence is bad. Turbulence effects are hard to quantify in advance. It's hard to say, you know, how much a particular side is going to be turbulent. You know, they vary between say your garage and you house how turbulent it’s going to be and what the affect is. But you can know it’s going to be bad.

What causes turbulence? Well, basically two things. One is terrain. If you have very complicated terrain like mountains and valleys and what not, you’re going to have turbulence due to that terrain. Not much you can do about that.

The other is ground clutter. Houses, trees, that sort of thing create turbulence - create turbulence as well. And, you know, about the only thing you can do is try to avoid ground clutter as much as possible or get a - use a high enough tower that you’re above the ground clutter.

How do you minimize the turbulence? One rule of thumb is to have the lowest portion of the swept area at least 30 feet higher than anything within, you know, 3 to 500 meters or 3 to 500 yards. So your turbine should really be the tallest thing in the immediate area. And if you do that, then you’re minimizing turbulence.

If you can't do that, then know that your energy production is - will take a hit. It will not be as great as it would be if it was above the turbulence zone. And this just kind of shows it graphically. If you have an obstacle of Height H, in this case a house, you’re going to have a disturbed region about 20 H downwind. And the peak actually goes 2H up. So again, you want your - if you can, site you turbines above this turbulent region.

And sources of wind data. There’s lots of sources online of at least general quality. A good place to look is the state wind maps you can access through the Wind Powering American Web site. These are static and we have them for most states for both 50 and 80 meters. This is not quite as useful for small wind where you’re probably looking at the resource at 20 or 30 meters above the ground. But it gives you a sense of where the good winds are.

There are a couple of companies that have Google Maps based wind maps, (three tier and 8W) is true wind. They’re kind of generic and I'll show you what I mean by that a little bit later. But, you know, at least for what they offer for free is pretty generic. And you have the option of paying to get more detailed information about a particular location. And that may or may not be worthwhile for you. It’s certainly cheaper than putting up a met tower.

There’s the Renewable Energy Atlas of the West. It’s kind of a GIS based server. It covers the Western part of the United States. Some states have additional data and you can try - you usually access by looking at the Web site of your state energy office. And they may have sites that the state’s been measuring or for which the state has collected data.

Sources of all called real data or, you know, time serious data is local airports. Be advised that the data quality will vary. Typically it’s low to - it’s really low to the ground. And the instruments may be mounted on the side of, you know, a building, something like that. So the usefulness may, you know, may be questionable although it will give you a sense of kind of long, you know, kind of the long term resource.

Now what - when should you monitor onsite? That’s a really tough question. Traditionally said, you should think about it if you’re project is 100 kilowatts or larger. But I have, you know, good friends who do projects much larger than that.

You know, do single turbine projects of the megawatt size and they try to avoid putting up a met tower just because it adds so much time and expense.

So, you know, somewhere between 100 kilowatts and a megawatt depending on how much uncertainty you can tolerate.

Some cautions regarding the wind maps. The wind maps, you know, people develop them. We try to - we try to use real data to validate the wind maps but it’s modeled wind data. And then it’s basically - it'll be vetted as much as possible.

But the, you know, it could be off - easily be off by a wind class at any location especially if you’re in complex terrain. And the value is typically assumed good exposure to the wind. So an open field, not the space between your house and your garage.

So that’s sources of wind data. And here’s a couple of examples. This is the South Dakota wind map. South Dakota’s a pretty windy state. And in this case it’s - the wind looks pretty useful because the - for the most part the areas of the same wind class are large. You can see a lot of purple here, a lot of yellow here.

If you’re here in the Black Hills where it’s very complex terrain and you can see the average wind speed changes a lot, it’s a little harder to figure out exactly which pixel you’re in. So it’s a little less useful but still helpful.

Next one is from the first look. They used to actually give an estimate of the wind speed but they've gone to a global wind rank. I guess they decided they were giving away too much by giving out the wind speed. But they’re still worth looking at kind of get a relative sense of the windiness. And again, you have the option of buying more detailed information for a given location.

So at this point I'm going to stop for a few minutes and (Michele) if there's any - if there's any questions about wind energy, I can take a few questions at this point before moving on.

Coordinator: Thank you sir. If you would like to ask a question, you may do so by pressing star 1 on your touch-tone phone. You will be prompted to record your name. Please un-mute your phone when doing so. One moment please for our first question.

One moment please.

Our first question comes from (Chris Weir).

(Chris Weir): Yes. I was curious about using wind data from the local airport. How do you gather that data over time? I've been able to look at it just at a, you know, instantaneously but that doesn't seem that useful to me.

Tony Jimenez: Okay. The question is how do you use - how do you get the data from the local airport over time. The only thing I can suggest is call the airport manager. They - and it depends on whether the airport stores that data or not. A lot of them do, some don't. And if the manager doesn't know, he should be able to point you in the - for who would know. So it's just kind of asking questions and following up with people as best you can.

(Chris Weir): Okay.

Coordinator: Our next question comes from (Heather Roseweaver).

(Heather Rhodes-Weaver): Hi. Can you hear me?

Tony Jimenez: Yes.

(Heather Rhodes-Weaver): Okay. Hi Tony. I typed this in also. Just thinking about the, you know, publicly available sources of wind data that you showed some of the maps, some of our subscriptions and thinking about, you know, NREL has this really excellent program for solar called PVWatts that is a lot, you know, higher level I guess for solar than for people wanting to do small wind.

And this was discussed last week at a meeting with you - we in Denver. I'm just wondering if you have any updates on the timing of some of those recommendations that came out of the meeting if they're going to be acted upon or what the kind of next steps would be for getting some better tools out there for small wind.

Tony Jimenez: At this point I don't have any update from last week. It's going to take a little bit of time for DOE to digest the results of the meeting and give NREL any guidance. Trudy, do you have anything further to add?

Trudy Forsyth: No. I think you've got that categorized or characterized correctly Tony. My recollection from the meeting is that DOE said that they were going to put out a draft of the notes and ask the attendees to comment. So that's what I know.

(Heather Rhodes-Weaver): Okay. And if you can still hear me, kind of a - I guess an unrelated question but yesterday Wind Powering America had a Webinar and I noticed they talked about a new workforce roadmap and I'm wondering how we can make sure that distributed wind, you know, job opportunities for small wind applications get included into that roadmap.

Tony Jimenez: I don't have a - I don't have an immediate answer to that. I mean I guess just make sure that the people involved in developing the roadmap include some small wind representatives would be the only thing I could say.

Trudy Forsyth: Yeah. And my advice (Heather) would be to send an email to (Ian). I assume it was him on the Webinar. I don't really know. But if it wasn't (Ian), whoever was on it and ask that question.

(Heather Rhodes Weaver): Okay. And is there - yeah, is there anybody at AWEA that's working on that?

Trudy Forsyth: I really don't know.

(Heather Rhodes-Weaver): Okay. Okay. Sorry. Go back to your topic here.

Coordinator: There are no further questions sir.

Tony Jimenez: Okay. I'll keep going then. And we'll have plenty of time for questions at the end.

Okay. I'm having to shift gears and actually talk about wind turbines now and essentially how to calculate your wind turbine energy production. And I just want to say here, you know, even for people who may not particularly care about the economics, you know, if they're - they just want to be green and even if they - even if they crunch the numbers and it looks like they're going to pay more than if - with business as usual.

Even the people who may not care a whole - care that it's going to pencil out to be a great investment, they still have - at least probably have some sort of expectations as far as the energy production. And so I'm going to talk about the energy production because that’s a key intermediate step to discuss in the economics.

So if you look at this top equation, if you eliminate the first C sub P, it’s basically our old friend 1/2 rho AV cubed again. And thinking the same. And this new thing is the C sub P is basically the efficiency or basically how much of the energy from the wind that the turbine is actually extracting. And the - for small turbines for their - and their sweet spots, the C sub P ranges from about .2 to .45 with a theoretical max of .59 or 59%.

Note that the C sub P is going to - even for the same turbine is going to vary with wind speed. They'll usually try to have the C sub P be maximized at the most common wind speeds. And as the wind speeds get higher, the efficiency is actually going to get lower but that’s intentional because if the turbine - at really high wind speeds the turbine needs to be shedding energy, not trying to extract it or it will be damaged.

So this is the formula we use to do that. And if you want a sense of how much energy you can get out of wind, anywhere from 20 to 45%, probably the long term average is probably closer to 205 overall.

So here’s your step-by-step process for calculating turbine output. Get your - whatever research data you have. At a minimum you need an average wind speed ideally the wind speed distribution. But if you don't know, you know, if you’re inland assume two for your K factor and you'll probably be in pretty good shape.

You next want to scale to the wind turbine to your turbine up high from whatever the - whatever reference height. So if your wind resource data is 20 meters and you’re considering using a turbine at 30 meters, you can just scale that data up using our wind sheer calculation. Again, if you don't know what the wind sheer is, you know, I would suggest using .14. That's usually a bit on the conservative side that when you're going up.

You then multiply the wind speed distribution by the wind turbine power curve. What do I mean by that? I'll show you that in the next slide. You then adjust for elevation and then you - since Murphy is out there at all times, you'll then de-rate by anywhere from 8 to 15% to account for real world losses. You know, availability, (ya) losses, blade soiling, electrical losses, all those little things that add up.

All right. Well probably your second - this middle one here. So let's look at that in a little more detail. I mean by multiplying the power curve by the distribution is you do it by bins. And so if we look at the dotted blue line here, this is a wind speed distribution. It's basically saying how many hours per year you can expect to find the wind blowing at a particular speed or more accurately within a particular bin.

This dotted black line is the power - is the wind turbine power curve for a particular turbine. And all the power curve does is it says when the - it relates wind speed to power output. So at ten meters per second, you can expect about 40 kilowatts out of this turbine.

Distribution. For the distribution look on the left here in terms of number of hours. So for example, you expect the wind blows at, you know, meter or five meters per second about 1200 hours a year. And so what you do is you simply multiply your power curve, so in this case the black, by the blue and you get the red.

Do that for this particular bin and then you - that gives you your energy - your annual energy production at that particular wind speed and then you just add up the area underneath this red line. And so you know the unit in tens of kilowatt-hours.

So in this case we have 40 kilowatts times about 950 hours and we get a total energy production from that bin of about 1500 kilowatt hours per year. And then you just do the same for every bin. It's really easy to do in Excel, which you'll see on the next slide. And that gives you again the area under this red line is your annual energy production.

And a few things to note. For one thing, the annual energy production does not peak either at the peak of your wind speed distribution or at the peak of the power curve but rather in between. And particularly in the modest wind regimes in which most people live, this is almost universally true. Your bread and butter wind speeds are really these intermediate wind speeds before the wind turbine reaches max power and when the distribution is on its way down.

What happens here at the very low end speeds is the wind blows at that speed a lot but there's just so little energy, you know, the turbine doesn't even kick in until about four meters per second that you're not getting much if any energy production.

And out here, the high wind speeds yeah, the turbine produces a lot but you have so few hours at those high wind speeds that - and again, you don't get much energy production over the course of a year from those wind speeds. So there's really these middle wind speeds that count.

And so that has a - you know, when you're looking at a particular wind turbine that ought to inform your decision, you know, several wind turbines will brag that they kick in at really low wind speeds, that's fine. But there's so little energy in those low wind speeds it doesn't really matter.

Or they might, you know, say we produce a lot at 20 meters per second or 50 miles an hour. But you don't have many hours where your 20 meters per second. And so again, that really doesn't matter. It's what's happening her in the middle that really counts.

This next slide just shows everything in tabular format. So we have our wind speed here going up to 25 meters per second. These are our bins. We have our wind turbine power curve here showing what the power is at each particular wind speed. So you can see it kicks in at about four meters per second.

This is the wind speed distribution in percent. And so you can see it doesn't quite add up to one due to rounding errors but it's really close. And I multiply this percent by 8760 to get the number of hours per year at that wind speed. And so it should add up to 8760 but again, due to rounding errors, we're a little bit off.

And so all we do, say let's look at eight. We have 26 at the bin surrounding eight meters per second. Our energy output is 26 kilowatts. We have 613 hours per year on average where the wind blows at that speed. And so that bin produces just under 16,000 kilowatt-hours per year. And then we just add up all these and this is our total gross annual energy production, which is in this case about 92,000 kilowatt-hours per year.

And again, I want to specify this is - want to say this is gross energy production. We'll then have to de-rate due to elevation and due to any other losses. But this is basically how it's done.

And one thing you may hear - one term you may hear a lot is called - is capacity factor. And it’s basically the - it doesn't apply just to turbines but anything that produces power. It’s basically the energy production over the - typically over the course of a year. Can be over any arbitrary period. But typically over the course of the year divided by what it would produce if it produced at rated power all the time.

And so this shows what it is. It’s useful to do the economics. And capacity is for all types of wind turbines typically range from about 10 to 40%. For small wind typically 9 to maybe a little over 20. And the reason the small wind has the less capacity factors are they’re on the shortest towers and they’re in the locations with the more modest wind speeds typically.

For distributed wind, this is say between 100 kilowatts and one or two megawatts. We’re looking at 15 to 30% because they’re - if you’re going to spend - if it’s a bigger project, it’s going to spend that much money, you’re going to - you’re going to make sure you’re put in a better wind regime. Also they tend to be on slightly taller towers so that helps as well.

The wind farms, it’s all about the money. They’re going to look for the very best locations where, you know, they can have good wind, good transmission, et cetera. They don't have to worry about owning the land. They'll just do a lease with whoever owns it. And so wind farms typically have the highest capacity factors in the U.S., you know, typically from the high 20s going into the low 40s.

So as an example production estimate, you know, for a particular scenario assuming differ tower heights and different average wind speeds. Typically you'll probably know your wind speed to within, you know, plus or minus, you know, 10 or 20%. So in this case, you know, our average is five, that’s kind of our best guess. But it could be as low as 4.1 or as high as six. And we’re looking at several different tower heights, 20, 30 and 37.

So this middle one 16,500 is kind of our base estimate. But these numbers show how much that aspect can vary based on what the - based on uncertainties in the wind resource and also different tower heights. And so if we look at a particular, you know, any given height, we’re looking at a factor of almost three in terms of the energy production between the low wind speed scenario and the high wind speed scenario.

If we look at going from the short tower to the tall tower, we’re looking at, you know, 20, 25% change in energy production going form a short tower to a tall tower. So you can see how all these uncertainties create a big uncertainty in your energy production estimate but at least it gives you, you know, a little bit better than order of magnitude which for small wind projects is probably is far along as it’s worth going in most cases because it’s real expensive to try to - to try to reduce that uncertainty much further than this.

All right. So I've walked you through the process of estimating energy - of estimating wind turbine energy production. So now I'm going to talk about wind turbine economics and different ways of evaluating the economics.

I'm going to talk about four methods. One is first cost and I'll say up front, this is a very poor method but it’s commonly used and I'll try to explain why you shouldn't use it. Talk about simple payback, talk about cost of energy and then talk about the more sophisticated cash flow analysis using tools that are available - generally available to download and use or mostly a spreadsheet based.

So first costs. The all in costs we'll say of a small wind turbine is typically between 4 and $8000 per rated kilowatt. Simply it’s the turbine, the tower, any sort of civil works and insulation. So for example, a three-kilowatt turbine would cost between about 12 and $24,000.

And that’s a fair chunk of change and people are looking for ways to save money. So things that will lower the cost of a turbine. One is using a lower quality turbine, using a shorter tower, using a guide tower. I'm going to argue that two of those three things are not good. Higher things that lead to higher costs are higher quality turbine, taller tower or freestanding tower.

Let’s talk about turbine quality. If you saw a turbine, it’s going to be up there, it’s going to be spinning several thousand hours per year and then unless you've chose a really poor wind regime area.

And let’s think about that. This is a mechanical device operating thousands of hours per year. If you drove your car thousands of hours per year, you’re mileage on it would be between 100 and 200,000 miles per year which is about ten, you know, then times more than most people drive.

And the O&M effort you want to make is maybe you want to do an occasional oil change. You know, that’s about how much maintenance effort most people would like to put into wind turbines. You know, most people are like me. They want to install it and forget about it. You know, if you’re going to operate a mechanical device that much, you probably want high quality or it’s just not going to last that long.

The next way to lower cost is go with the shorter tower. Well I've, you know, shown you the effects of short towers versus tall towers and I have to balance that over the cost. But again, if you go below the - you know, if your turbine is shorter than - or your tower is shorter than if there are any trees and houses, your energy production is going to be very, very low and you're not going to get much energy out of you turbine.

Third method is to use a guide tower. This basically uses guides to help keep up the tower. This is mostly an aesthetic issue. It will not affect you turbine energy production and is a - you know, if you have the room for the guides and it doesn't both you, it's certainly a legitimate way to lower costs.

Talking about higher costs, you know, higher quality turbine, you know, probably pay for itself in the long run in terms of producing more energy. A taller tower up to a point, you'll get more energy production that may - will probably offset the cost of the turbine at least until you get above everything else. And, you know, if you prefer the look of a freestanding tower and want to pay for it, that's fine.

And again, first cost is a poor method for economic analysis. Now again, there may be limits as to how much available money you're willing to apply towards a wind turbine. If you need to get a smaller wind turbine, go with the higher quality, smaller turbine than a lower quality larger turbine. That's about the only thing I can say about that.

All right. Simple payback. How do we define that? Basically when you're savings, presumably the turbine is producing electricity that you would otherwise buy from the utility and so you're eventually looking for how long the turbine savings - how long will it take for the savings to pay back the cost of the turbine?

And so I define it as turbine capital cost divided by your net savings. And what I mean by net savings, that's the value of the wind energy minus any

O&M costs. Some people will not account for O&M because it is kind of a second order affect but in this case I do.

What is O&M? Varies all over the map. I kind of peg it as a problem arranging or from half cent to two cents a kilowatt-hour. And it just really varies all over the map. You'll hear testimonial saying I've had my turbine for 20 years and, you know, paid 50 bucks to do some minor repair. And that's great. And you'll have other people who've had a lot of trouble with their turbine. So it's a broad range, you know, even with the same turbine. I typically use the penny a kilowatt-hour just to kind of benchmark it.

And so we have our fictitious turbine, the AE1200, the airbrush engineer 1200 or 12-kilowatt turbine. Capital cost $60,000. And let's assume you're paying 12 cents a kilowatt-hour for your energy. With a value of the energy every year, the 16,500 -- I'm just going from my previous example -- times 12 cents or about $2000 a year worth of energy. Our O&M $165 a year. We plug it into the formula. We get a payback of 33 years, which probably doesn't look all that promising in this case.

Couple notes about simple payback. Does not account for the escalation in electricity prices so you're probably going to not pay 12 cents for 30 years. It'll probably go up. And so that should reduce your payback time. This method does not account for the time value of money.

And what I mean from that is that if you have a choice between paying $10,000 now or $1000 over the next ten years, most people would choose to pay the $1000 over the next ten years because they're delaying the day of reckoning. So these two things you could argue that they kind of balance out at least to a first approximation.

Let’s look at cost of energy. Another way to look at it is what’s the cost of energy produced by the turbine. And so this is going to be your turbine capital cost plus your O&M plus any interest costs you incur. In this case I'm assuming you’re paying cash divided by your total lifetime production.

So let’s assume a 20-year lifetime. So again, we have a $60,000 capital cost. Our lifetime O&M is 16,500-kilowatt hours per year times a penny a kilowatt-hour times 20 years or $3300. And our lifetime energy production 16,500-kilowatt hours per year times 20 years, 330,000 kilowatt-hours. So we plug that all in. We get about 19 cents a kilowatt-hour is the cost of energy from this turbine.

Again, significantly higher than the 12 cents you’re paying now but you'd have to look and see how - what you think the escalation rate for your electricity costs are going to be to make a real accurate comparison.

When doing cost of energy calculations, it’s very sensitive to the lifetime of the turbine. If we assume you baby the turbine and it lasts 30 years, you’re basically amortizing the $60,000 over an additional ten years and the cost of energy drops to 13 cents a kilowatt hour which is very close to the, you know, your current 12 cents.

One important note if you’re financing any part of this, they needed to be added to the cost and that will increase the cost of energy. But kind of another way to look - so that’s another way to look at it.

Final way is to use a lot of the cash flow models that are available. You can - they’re usually based - Excel spreadsheet based. You can download them, plug in your numbers and have at it. They'll calculate additional things like net present value and rates of return. It can account for the time value of money so you can put your discount rate there.

They can show tax effects, which can be very important. You can put in your - you can escalate your grid electricity costs and O&M costs if you want to. Easy to run multiple scenarios. One thing to be aware of is any sort of implicit assumptions that may not be valid and a very common one is that all electricity produced by the turbine is valued at retail rate.

If you’re not in a net metering situation, that may not be true. And what I mean is that the turbine is producing more energy than you’re using at a given time. The excess energy is going to go out to the grid. And if you’re on - in a non-net metering situation, you know, that energy (set down), you may not be valued at the 12 cent that you pay. You know, maybe it'll be a voided cost. You know, it might be four cents.

And so if your turbine is producing - if you’re turbine’s big and it’s producing anywhere near your - say your annual load, a lot of that energy is going to go off site. And so if you’re not - and if you’re not net metering, then you need to be careful to - you may be careful it may not - the economics may not be as good as these cashable models show.

Let’s go through an example. Current electricity costs 12 cents a kilowatt-hour escalating at 4% per year. Some people may think that’s a bit aggressive. Install costs $60,000, O&M a penny a kilowatt-hour and our annual energy production is 16,500 kilowatt hours per year.

And this particular model is available from the NREL Web site. I'm certainly not saying it’s the best model out there. It’s just one that I'm familiar with.

One nice feature of this is that you can have multiple scenarios and then use the radio button to choose that one. So you don't have to reenter information.

So in this case I'm going to assume a mortgage so it's tax-deductible interest payments. Make a 10% down payment. Borrowed 5.5% effective marginal tax rate of 30% and I'm going to borrow for the lifetime of the turbine, 20 years. So kind of a long loan. So that's that piece of it.

The next are the site characteristics. So the first is basically your wind resource. So you have your average wind speed. You have your anemometer height or your reference height, your wind sheer exponent, your (allowable) K and your site elevation. So you just put that information in and the model does the work. And then the other is basically what you're currently paying. So in this case I'm using this scenario out there, 12 cents a kilowatt-hour and I'm assuming it escalates at 4% per year.

Final piece of information is turbine information. So I'm using the AE1200. I'm putting in cost. I know this is a little hard to see. O&M costs. Let's see. I'm escalating those at 3%. Physical characteristics rated power, rotor hub height, availability and I just assume 10% overall losses.

And then down here we have the wind turbine power curve. And so you input all this information, you hit the menu button or it just updates automatically. And you get graphs and information.

In this case I'm showing the nominal dollar cash flow and this is, you know, this probably doesn't look all that great. You're making you $6000 down payment. You're paying over the next 20 years. And then once you finish making your debt payments, you then go cash flow positive. And so in this case paybacks about year 26. And the overall - you know, assuming the turbine lasts 30 years, you know, we do have a positive net present value, which is good.

This is kind of the bad news. No incentives. One nice thing is that there are very generous federal incentives out there. There is a 30% investment tax credit available to homeowners. And so - actually available to anybody. And so you can deduct 30% of the cost of your system off your income taxes. So you'll get that within, you know, a year or so depending on what time of year you install your turbine. And it has a very good affect on the economics.

For one thing basically you still - you make a smaller down payment that is 10% of the - what remains after the 30%. You’re borrowing less and so you’re - basically your savings are about paying off your loan. So that’s good. And then, you know, you have your savings at the end.

So you go much less negative and your paybacks basically in year 21. So a much better scenario. And the overall net present value over 30 years is $50,000. So a much better economic scenario arguably.

So just to wrap up, I looked at - we looked at wind characteristics and energy potential particularly the focusing on the cubic power law. We looked at sources of wind data. There’s a lot out there. It’s not - the precision may not be as much as you'd like but it’s still a lot better than what’s available - what was available ten years ago.

We went through how turbine energy production is - you know, how you estimate turbine energy production. And probably that’s the big takeaway there is the method of bins and lots of uncertainties. And just we went to look in the economics. Don't focus on first costs and don't sacrifice quality would be my main themes there.

Resources on the Web. There's lots and lots of good resources on the Web. There's - these first few are wind specific and then there's sites that are more general renewable energy sites. American Wind Energy Association is the Wind Industry Trade Group mostly focused on small - on large wind but they do have a good small wind section.

And I'd particularly recommend the writings of Mick Sagrillo. He has - a lot of his stuff is archived there and he can be a lot more explicit than I can at NREL and he's a good and entertaining read.

The Distributed Wind Energy Association is a new organization. I went to their Web site a couple days ago and it's basically one page. It says we're working on more content. My understanding is that it's basically an amicable separation from AWEA. It was decided that there needed to be a group that focused on the specific policy needs of small and distributed wind. And so DWEA formed with that purpose in mind.

There's a Wind Powering America Web site. WPA focuses on all levels of wind but it does have a good small wind section with some good information. Windustry focuses on community wind. They're based out of Minnesota. And if you're doing projects, you know, say a single utilize sized turbine project or a couple of utility sized turbines, they're a good place to go.

These remaining sites are more generic or ecumenical renewable energy. There's the American Solar Energy Society, ASES and despite their name, they're - they do devote some time and attention to small wind. They're sponsoring this Webinar so thank you to ASES for that.

There's the Home Power Web site, which complements their magazine. If you're considering doing small wind and want to research prices, it's well worth getting a few back issues. They typically include a small wind installation. Each issue with a lot of detailed cost information. So you can see what's involved in putting up a small wind turbine.

And the last is the Interstate Renewable Energy Council that does a lot of small and distributed renewable energy policy analysis. And finally the various manufacture Web sites often have very good information as well.

So with that, carpe ventum, seize the wind and we'll take questions.

Coordinator: Thank you. Once again, to ask a question, please press star then 1. One moment.

One moment please.

And once again, to ask a question, please press star 1 and then record your name. One moment please.

Our first question comes from (Heather Roseweaver). Your line's open.

(Heather Rhodes-Weaver): Okay. Since nobody else jumped up; Tony, I might have missed it but could you give us the Web link for where to find that cash flow model for NREL. And while you're thinking about that, the other thing I want to mention is of course another Web link.

The Small Wind Certification Council which is smallwindcertification.org in the next few months here is going to be posting certified power curves from turbines that have gone through that process. So that is obviously a better data source for the power curves.

Tony Jimenez: Great. Thank you for reminding me about SWCC. As far as the calculator, go to the Wind Powering America Web site, go to the small wind section and it should be parked in that section there for download.

(Heather Rhodes-Weaver): Okay. I'll look for it. Thanks.

Tony Jimenez: Okay.

Coordinator: Our next question comes from (Chris Weir).

(Chris Weir): Yes. I have a question about the advertised power curves that typically come with the turbines. Are they very reliable at all or is it typically better off to do the like a rotor sweep power estranged from that you were talking about previously?

Tony Jimenez: That’s a good question. Some power curves are pretty accurate, some are not. And the nice thing about SWCC is that as part of their - as part of the certification process there'll be a third party validated power curve that will be available for use. So that should eliminate that source of uncertainty. Certainly another way to estimate energy output would be just, you know, look at your average power density and multiply by, you know, by 20% or so and, you know, times the swept area of the rotor. That’s certainly another way to do it.

(Chris Weir): Okay. Thank you.

Tony Jimenez: You bet.

Coordinator: And our next question comes from (Radcliff Percy).

(Radcliff Percy): Yeah. What was that Web site again that are going to have the power curves on it?

Tony Jimenez: Google Small Wind Certification Council. Actually it can...

Trudy Forsyth: I think it’s smallwindcertification.org, O-R-G. I'm going to check that now that I said that. (Heather) knows exactly where it is.

Tony Jimenez: Smallwindcertification.org. Yeah. Trudy’s correct.

Trudy Forsyth: Okay.

(Radcliff Percy): Thank you.

Tony Jimenez: One word. You bet.

Trudy Forsyth: And other question I've seen is whether we’re going to post you presentation. And I think we posted other presentations in a PDF format under our Wind Powering America small wind site. So that’s where I'd proposed to put Tony’s presentation today.

Tony Jimenez: Yeah. I'm not sure. It’s sponsored by ASES. So I don't know the mechanics of where it’s going to be - where it’s going to be posted.

Trudy Forsyth: That’s why I think we just handle it ourselves.

Tony Jimenez: Okay.

Trudy Forsyth: Under something we can control which is the windpoweringamerica.gov.

Tony Jimenez: Okay.

Trudy Forsyth: And there’s a tab that’s small wind. And we'll put it there.

Coordinator: We have two more questions. Would you like to take them?

Tony Jimenez: Yes.

Coordinator: Okay. One moment please. Our next question comes from (Lisa).

(Lisa): Hi. I am - I have a modeling system but there’s obviously an error. You showed how you take the (ybel) shape and plug it in to those bins. My (ybel) shape is messed up and it comes up to multi thousands of hours a year rather than the 8760. I'm wondering if you could guide me on how to correct that.

Tony Jimenez: Basically the - without knowing the details, I would say you’re (ybel) is going to give - gives a percent initially and then I multiply by 8760 to convert those percentages into hours per year. The only thing I can think of off hand would be your binning - is how you’re doing the binning. And that’s the only thing I can think of without know the specifics of what you’re trying to do.

(Lisa): I'm sure it’s coming from that and I just can't figure out how to correct it.

Tony Jimenez: Without knowing exactly what you’re doing, I can't give you - I can't give you any more detailed guidance than what I've already said.

(Lisa): Thanks.

Coordinator: Our next question comes from (Chris Weir).

(Chris Weir): Yes. I have a question about the state wind data maps. They list a (ybel) value typically on the lower left hand corner. And it's pretty much always point to I think but is that the correct (YO) value to use then if you're predicting your wind speeds using that data or is it - I guess any input on that is appreciated.

Tony Jimenez: It's kind of a default shape factor is - are you talking about the (ybel) - the (ybel) shape factor or the sheer factor?

(Chris Weir): The (ybel) shape factor.

Tony Jimenez: Well (ybel) typically two is the common default. If you have the actual bin data, then you can back out something more accurate. Typically the wind maps assume two just for convenience sake.

(Chris Weir): Okay. The second question I had about the wind maps is I overlaid the wind maps in Google Earth and then just kind of stretched them around the match up, you know, the lines so they kind of fit in there. And that's a methodology that I've used to help me figure out where I'm at on the map with a specific site and I was...

Tony Jimenez: That's a good idea.

(Chris Weir): ...if anyone else has anything else like that that they were trying.

Tony Jimenez: I've not heard of anybody doing that before but I'll, you know, certainly it's a good idea. And if other people want to try it, they should certainly go for it.

(Chris Weir): Sure.

Tony Jimenez: Thank you.

(Chris Weir): You bet.

Coordinator: Our next question comes from (Radcliff Percy).

(Radcliff Percy): Hey. Second question. I was trying to find the power curve for any of these turbines. Where could I get that information from?

Tony Jimenez: Typically the manufacturer's Web sites is the place to get power curves. They should have a - go to the Web site. You should have some sort of spec sheet and the spec sheets usually include power curve. Now maybe, you know, something very small at the bottom, you know, at the bottom corner of one of the pages. But that's - if it's not on the manufacturer Web site, it probably doesn't exist.

(Radcliff Percy): Okay. So the (unintelligible) of them is so smart it can't really get a...

Tony Jimenez: Exactly.

(Radcliff Percy): ...estimation of what they really do. So like plug into the formula like you had. Right now the manufacturer is about - I think it had some of that on the NREL site. But that's about the only place that would have other than the manufacturers?

Tony Jimenez: Yeah. We do - at the wind site we've done certification testing and so we have for just a bare handful of machines, you know, you can download the reports and get the power curves from there as well. But it's only for like three or four machines.

(Radcliff Percy): Okay. Thank you.

Tony Jimenez: You bet.

Trudy Forsyth: Just to follow up on that Tony, it's under www.nrel.gov/wind and then you'll see something about projects. And if you look under small wind research, you'll see, as Tony rightly says, the limited number of power curves we have. We only have it for a few turbines. But that's where it is.

Coordinator: At this time sir I show no further questions.

Tony Jimenez: Okay. I guess we'll take one last go around. If there's no more questions, we'll stop.

Coordinator: There are no questions.

Tony Jimenez: Okay. Thank you everybody.

Trudy Forsyth: Thank you very much Tony and thank you to our audience for learning more about the economics of small wind. I will send out a notice to the ASES Small Wind Division when the - when this presentation is posted and give that link. Thank you.

Coordinator: This does conclude today's conference. You may disconnect your line at this time. Thank you for your participation today.

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