DOE Office of Indian Energy Foundational Courses Renewable Energy Technologies: Solar Webinar (text version)

Below is the text version of the Webinar titled “DOE Office of Indian Energy Foundational Courses Renewable Energy Technologies: Solar”.

Amy Hollander:

Hello, I’m Amy Hollander with the energy department’s National Renewable Energy Laboratory. Welcome to today’s webinar on solar as a renewable energy sponsored by DOE’s Office of Indian Energy Policy and Programs. This webinar is being recorded from DOE’s National Renewable Energy Laboratory’s brand new state-of-the-art net zero energy research support facility in Golden, Colorado.

Our solar energy presentation today is one of nine foundational webinars in a series from the DOE Office of Indian Energy education initiative designed to assist tribes with energy planning and development.

The course outlining for this webinar will cover the DOE Office of Indian Energy education initiative, a course introduction, resource map and project scales, technology overviews with siting and cost information, successful project examples, and policies relevant to project development. At the end there will also be a list of information and resources.

The DOE Office of Indian Energy is responsible for assisting tribes with energy planning and development, infrastructure, energy cost, and electrification of Indian lands and homes. As part of this commitment, and on behalf of the U.S. Department of Energy, Indian energy is leading education in capacity building efforts in Indian country.

The foundational courses were created to give tribal leaders and professionals background information on renewable energy development that presents foundational information on strategic energy planning, grid basics, and renewable energy technologies that breaks down the components of the project development process on the commercial and community scale. And that explains how the various financing structures can be practical for projects on tribal lands.

Now I’d like to introduce today’s speaker, Otto Van Geet. Mr. Van Geet is a principle engineer at the National Renewable Energy Laboratory. Mr. Van Geet has been involved in the design, construction, and operation of energy efficient research facilities as well as office and general use facilities. His experience also includes passive solar building design, PV system design for off grid applications, energy audits, and minimizing energy use.

Mr. Van Geet is the author of many technical reports and conference papers, and has been recognized with many awards including the 2007 Presidential award for leadership in Federal energy management.

On a personal note, he and his family live in an off-the-grid passive solar house with a PV and wind hybrid power system, and solar hot water heating that he designed and built fourteen years ago. Mr. Van Geet is a registered professional engineer, a certified energy manager, a LEED accredited professional, and a project management professional. And with that I will turn it over to Mr. Van Geet.

Otto Van Geet:
This course will cover resource maps and project scales. We'll have a technology overview, including siting and costs, and give some successful project examples, and we'll have policy discussion for relative to project development, and then we'll finish with additional resources and information.

The purpose of this course is to define different solar technologies, applications, costs, and performance. Some of the key takeaways are that solar technologies work in all parts of the United States. The economics of solar are dependent on the first cost, including incentives, the solar resource, and the cost of the energy being displaced.

Like all renewables, we want to start with the resource maps. In this case, we have several resource maps that the link listed for both photovoltaic's and concentrating solar power, or CSP. And on the next slide I'll cover the photovoltaic map.

So this is a map of the solar resources in the United States. You can see down at the bottom of the map is the scale. The brighter the color, the higher the available energy production. The energy is listed in kilowatt hours per meter squared per day. This would be the average. You can the most is as you'd expect in the desert southwest with the number somewhere around 6.8 kilowatt hours per meter squared per day. And the least would be in the northwest, say in the Seattle area, and it'd be maybe 3.5 kilowatt hours per meter squared per day.

The key take-away from this is from the best part in the country to the worst part is only a factor of two difference, so again photovoltaics will work in all parts of the country. Just the energy production will vary depending on the location.

This is a map of PV solar resources in the southwest, and overlaid on the solar resource is tribal lands. This is an example of where the tribal land sits primarily in New Mexico and Arizona in this case, with the solar resources. This is an example of what can be done through technical assistance using NREL's GIS maps.

So following the outline, we'll now talk about siting and costs, a simple direct PV system. This is a nice simple example. The sun is shining on the photovoltaic panels, the PV panels. The PV panels make DC, direct current, electricity, and that DC energy can be used to power a simple load such as a pump in this picture. This was one of the first applications of PV, and still a very good one. As you get full sun, you get full power, half sun, half power, et cetera.

This is an example of an off grid photovoltaic system. Again, the sun shining on the PV panels creates DC energy. That DC energy goes through a charge controller. That charge controller controls the amount of energy going into the batteries. The energy coming off the batteries or the charge controller could be used to power a DC load directly, a T.V. in this example, or it could go into an inverter and create AC energy, alternating current energy, like is normally used in houses.

This is a really important example for remote tribal lands. These kinds of systems are very cost effective. In my house in the mountains outside of Denver, Colorado, I've had a system like this for fifteen years, and it continues to work very well.

The main focus of this course is going to be on grid-tied photovoltaics. In this case, similar parts, but you see that the sun shining on a panel goes to a grid-tied inverter. There is no batteries. The inverter has all solid state electronics so there's no moving parts. All PV modules come with at least a twenty-year warranty. A twenty-five-year warranty is more common. And what these twenty-five-year warranties say is that at the end of twenty-five years the panels are guaranteed to produce at least 80% of the rated life. Here at NREL we actually have panels that are over fifty years old and that are still working well.

The panels are then wired in series and in parallel to meet the voltage and current requirements of the inverter. The last part of this diagram is once the energy leaves the inverter, it would typically go through a meter, and then either be fed to the grid, or fed to an on-side load such as the house in this example.

So what is a photovoltaic panel? As you can see in this diagram, a panel consists of a cover, usually glass, an adhesive, and an antireflective coating, and then semiconductor devices. The N-type which is on top in this example produces an electron when the sun hits it. The electron leaves through the front contacts in this example shown in blue, produces electrical currents going to do useful work, a light bulb in this example. And then you complete the circuit going back to the P-type semiconductor on the bottom.

Of more importance is solar cells are all rated with what's called standard test conditions, or STC. Those test conditions are 1,000 watts per meter squared. That'd be how much energy is hitting a square meter of area. And with the panels operating at 25°C, which is the same as 77°F. Typical efficiency of crystalline solar PV is about 15%. And what efficiency means is how much energy you get out compared to the energy that hits the panel. As you can see in the box at the bottom of the slide, the power output times 100% divided by the area in meters squared, times 1,000 watts per meter squared is how you'd figure the efficiency.

To make it real simple, 10% efficiency would mean that you'd have 100 watts per meter squared with 1,000 watts per meter squared hitting it. And that would also give you a panel with an efficiency conversion of ten watts per square foot roughly.

PV is very modular. Cells are assembled into modules. Starting in the left-hand side you can see a typical cell. Cells are put together in series and paralleled to make a module in the middle of the slide. And then modules are wired into arrays. Those arrays, you can see that there is ten of them in this example. Those ten modules make the array. The arrays are then wired together to inverters to produce the AC energy that's fed to the grid.

Since we've talked about PV panels, now we want to talk about entire PV systems. In this example, starting in the upper left is an example from Dangling Rope in Utah. And this would be an example of a fixed tilt PV. These are the most common. And what this means is that the panels are tilted all at the same tilt, typically something like 20° on a rack, and the panels stay in that fixed position year round. For most small systems, that's what you'd want to go with. For larger systems, you might end up going to tracking type PV. In the bottom right-hand corner is an example from Alamosa, Colorado, and these are panels on what's called the zero tilt single axis tracking. And if you look closely, there's a shaft that the panels are mounted to that rotates and has the panels follow the sun across the sky.

Another example is in the upper right-hand portion of the slide. This is from Arizona Public Service in Arizona. The long rows which are running north/south are the same zero tilt single axis tracking. Again, those follow the sun across the sky. In the bottom right of that picture is a tilted single axis tracking. So it's similar, but it's mounted at a tilt, normally about 25°. And then the upper part of that picture, the big squares are what's called concentrating photovoltaics, or CPV. CPV, those modules are very large, 60-80 kilowatts, and mounted on a large pipe, and they're an up-and-coming technology for places where you have very good solar insulation, like in Arizona.

To follow on the previous slide, single axis tracking PV, this is a close-up of the panels mounted to that shaft, and again, the shaft turns by the gears in this picture and follows the sun across the sky. The reason you might do this is you end up increasing the output per panel by about 20%. This would only be done – tracking would only be done for large PV systems, typically about 300 kilowatts or larger.

So how much area is required for PV? It does vary by the technology, the tilt and the location for building-mounted photovoltaics. If it's mounted directly to a sloped roof, you might get somewhere in the order of eleven watts for each square foot of panel, of available area. For flat roofs where you'd use a ballasted mount, and I'll talk about that next, you might get eight watts per square foot. Or for large ground mounts, depending on the technology, that's shown in the box at the bottom of the slide, the most common would be the crystalline silicon. You get about four watts per square foot if it's fixed tilt, or about 3.3 watts if it's tracking.

Just to put this in perspective, a typical home system is about three kilowatts, which is 3,000 watts. And if you assume you have a power density of ten watts per square foot, that would mean that you would need 300 square feet to produce that 3,000 watts or three kilowatts. Again, that would be a typical home system.

There's several good tools that NREL and others have come up with for calculating the yield for PV, and again, this would calculate the yield based on your location. In this slide is a screenshot from one of the NREL tools called In My Backyard. The links are shown in the bottom of this slide. But in the IMBY tool, what you do is you enter your address and then you hit "find" and it'll go to that location, and then you can actually draw the area available – again, say the rooftop. And then IMBY assumes that same ten watts per square foot, then will calculate the energy production from that system that you drew for your location.

Another very good, simple and easy to use tool is PV watts. The link is shown for that also, or either one of these tools you can simply go to Google and type in PV watts or In My Backyard.

So we've talked about what solar is. We've talked about how to estimate the production. Now we want to talk about where to install solar. So this is a slide on the priorities. The first priority would be on the built environment. That would be, for example, on existing building roofs that have an expected life of at least fifteen years. Twenty or more years is even better. And very importantly, roofs that can accept the added load. This added load is typically two to four pounds per square foot of panel.

Some of the good news is the panels will reduce the solar loading on the building. For all new buildings, they should be built to be solar ready, meaning that they have electrical interconnections designed to handle the additional two to four pounds per square foot, et cetera. And there's a document that I've highlighted there that provides additional information. Other good areas on the built environment are things like parking lots, pedestrian paths, et cetera. And here the PV would serve as a nice amenity for providing shade and protection from the rain, et cetera.

In addition to the built environment, the next on the list would be in compromised lands. This would be lands like landfills, brown fields, et cetera. If you don't install it in either of those locations, if you install it in a green field, then you want to minimize the site disturbance, plant native low-growth, low-height vegetation, and locate as close to the grid as possible.

Here's an example of a flat roof system. And as we discussed earlier, the flat roof system is held on the roof by what's called the ballasted racking system. This happens to be an example from the V.A. in Loma Linda, California of a 309-kilowatt system. This is the example where the ballasts and the PV and the racking would be about four pounds per square foot, and the advantage of this is that there's no roof penetration so the system literally lays on the roof and the weight holds it on the roof. There's additional information on the slide related to this system that you can read.

So as you're getting ready to look at installing a PV system, you want to do an assessment. Turns out that PV is very sensitive to shade, so you want to make sure you're installing it in spots that have very little or no shade. On this slide is a picture of one of the instruments you can use for determining shade anytime of the year. This one happens to be called the Solmetric SunEye. There's others that are equivalent that are made. What you're looking for once you've figured out the estimated size, then with the tools we talked about, like In My Backyard, or PV watts, you can estimate the annual production. We'll talk about cost coming up, and based on cost you can do some economic analysis.

So we've been talking mostly about the PV modules, but those need to be connected to a system, and then connected to the grid. This is an example of the modules being mounted on a roof, in a ballasted system in this case. The modules, each group of modules called a string or a bank here, is wired together into a combiner box. So each string, you can see the smaller wires there goes to a combiner box. Larger wires go down and into the vocation for the inverter. First they'll go through a DC disconnect, as you can see in this picture. Then there would be the inverter that would produce AC electricity. Typically 240 volts AC, although it could be 208 three-phase. Then there'd be an AC disconnect shown on the weaving side of the inverter. A transformer if needed to step up to higher voltage. And then tying into an electrical distribution panel.

On the electrical distribution panel, you need to figure out how you're going to interconnect that. In this picture is a typical house panel. A typical house panel is probably 200 amps, 240 volts. What you can do is actually run the PV and back feed a breaker, and then what the national electric code tells you is that the sum of the source circuits, meaning the main breaker and the PV breaker, cannot exceed the rating of the panel for residential, or cannot be larger than 120% of the rating of the panel for commercial.

Just as an example, if we put in that 3,000 watt, that three kilowatt PV system into a 240 volt panel, that would only require about 12.5 amps. So a fifteen or twenty-amp breaker is all that's required. If you're putting in a very large PV, and you cannot find panels to tie into, you might be able to reduce the main breaker size so you don't exceed the panel rating. You might put in a new panel that's a few hundred for a home typically. Or you could do what's called the line side tap, and that's tapping the wires that come into the panel. If it's a very large system, then you'd need to upgrade the electrical service to the building. That of course, is quite expensive and normally you wouldn't do that.

So this is a graph of the price of PV systems. Not shown on this graph is that in the past thirty-five or so years the price of PV modules have come down by about thirty times, meaning that in 1975 it was about $30 a watt, now it's $1 a watt. But the important thing is the path forward. The DOE Sun Shot program has the goals shown on this slide. Currently in 2010 the price of residential scale solar was $5.71 a watt broken down by inverter, ballasting system, and modules as shown. By reductions in each of those – again, inverter, ballasting system, and modules – the goal was that by 2020 the installed price of PV at a residential scale will be $1.50 a watt.

This is an installed cost today for PV systems. And as we saw in the previous slide, for residential scale about $4.39 a watt. Utility scale systems, meaning systems a megawatt or more are on the order of $3.50 a watt installed.

Here's another example of a large ground-mounted system. This one happens to be at NREL here in Colorado. This is a picture of the 720-kilowatt single axis tracking, meaning it follows the sun, that'll produce about 1,200 megawatt hours per year. This is how most large systems go in, and this is an example of a power purchase agreement, or a PPA. And what this is, is a third party will come in, design, own and operate the PV, collect any incentives, and then sell the energy to the customer, NREL in this case. The advantage of this approach obviously is that there's no money required upfront from the owner.

So we've talked about PV, and that's the most likely for most tribal locations. However, if you're located in the desert southwest where you have a very good solar resource as we discussed, and you have a large utility grid close by, you can consider what's called concentrating solar, or CSP. And this is a diagram of the different types of CSP. Starting in the upper left is the most common. That's called the parabolic trough. And this parabolic trough has an absorber tube that runs down the middle of it. That tube carries a fluid that goes to a power cycle that I'll talk about in the next slide.

The upper right is something similar, but is linear Fresnel lens, and these lenses which are basically curved mirrors, focus the light on an absorber tube also. The bottom right is a less common type, but it's a dish engine type, and the dish will focus the light on an engine at the receiver point. And then in the bottom right is another fairly common type called the central receiver. The central receiver as you can see in that diagram has a receiver up on the tower surrounded by a field of mirrors or heliostats. Those heliostats track the sun and reflect the sun up onto the solar central receiver.

This is the same CSP technology. Starting in the upper left is an example of a parabolic trough plant. Upper right, linear Fresnel. Lower left a dish engine plant. And bottom right, a tower type, central power tower. You can see the power tower up on top, and all the heliostats reflecting the light up onto the tower.

CSP is unique in the renewables world because it can generate dispatchable energy, or energy when you want it is another way. And in this diagram we're seeing in yellow the typical solar resource. You can see how it peaks at solar noon as you guess. And then what often happens is there's – from the grid you want energy later than the solar peak. A lot of times the grid peak is somewhere in the late afternoon, because of air conditioning, et cetera. So what you can do is take the solar resource and store it in thermal storage, typically a molten salt, and then that thermal storage can produce dispatchable power, meaning power whenever you want it. Typical storage times are on the order of six hours, so you can run the solar for say six hours after the sun sets. And this produces a much higher value to the CSP plants.

Some additional advantages of CSP is it can be easily integrated into a thermal plant, meaning a typical fossil fuel plant for say coal or natural gas, because you're just generating steam for a power cycle, and I'll talk about that in an upcoming slide.

Another advantage is it's not affected by abrupt changes such as a cloud passing, which large PV plants are affected by. Some of the disadvantages, first it will only work in the desert southwest in areas that receive very good direct solar. Another big disadvantage is that it will require at least some water for the cooling towers. That can be an issue in the southwest. You can do a lot of the cooling with dry cooling if you need to, but the last stage will require some water. And then the other one that I talked about, it's only viable for very large plants. Meaning plants that you're going to sell to the grid. Typically fifty megawatts or larger.

So this is a schematic of a typical CSP system. You can see a solar field on the left-hand side, parabolic troughs in this picture, but it could be a central tower or a linear Fresnel. Heating up a fluid. The fluid would go up, following to the upper right. It could go into the thermal storage shown in red and yellow here, or it could go directly into a boiler. In the boiler, the water will be circulating on the other side of the heat exchanger. The water gets vaporized and runs into a normal power cycle with a steam turbine, or it could be run through an industrial process, or a combination of both.

Then leaving the heat exchanger, the heat transfer fluid simply makes a loop by pumps, back around. If there is thermal storage, you can see there's a pump dedicated to it, and you could continue to produce thermal energy and electricity after the sun sets. Parabolic troughs and CSP in general have been around for a long time. They've been operating in the deserts of California for almost thirty years. And the plants that have been operating there, they're called the SEGS plants, and you can see SEGS one through nine listed here. But they're large plants that continue to operate today, and operate very well. As you can see on the far right-hand side, there is a dispatch ability built into some of the plants. Some of them have thermal energy storage. Some of them have onsite gas boilers or heaters built in also. In addition to this several plants, several CSP plants are under construction currently in the desert southwest.

Back to the course outline. We've talked about the technologies. Now I want to talk about policies. So what will help the economics is if there's financial incentives, and the best place to look for financial incentives is in the database of state incentives for renewable and efficiency, or the DSIRE site. The link is shown there as DSIREusa.org. And it's all types of incentives listed there. And I won't read them all to you, but all incentives are shown and you should go to that site whenever you're investigating the feasibility of solar for your location.

This is a screenshot of one of the resources from the DSIRE site, and this is a screenshot of what's called net metering. What net metering means is that it allows the meter to spin backwards. So you get credit for energy that's produced in excess of what you're using onsite. And these net metering laws are available in forty-three states plus the District of Columbia and Puerto Rico.

For example, New Mexico has a net metering law of 80,000 kilowatts, or eighty megawatts. Another example is Colorado above has a 2,000 kilowatt net metering law, et cetera. Most states again have it, but some – if you see, there's no color that means there is no net metering laws. So we're almost done.

And the next couple of slides we'll talk about additional resources and information. Here's some useful resources. The first one and the place you should start is NREL. There's a group called First Look that can also provide resource data. And then in the middle of the slide is several tools that can be used for solar. We haven't talked about the system advisory model, but that's a slightly more detailed modeling tool. For off grid, like the example that I've shown, the HOMER tool is a very good one. We did talk about PV watts and In My Backyard. And then another nice international tool is called RETScreen. The links for all of those are shown here. And again, for incentives, it's DSIREusa.org.

That concludes our presentation. Again, for additional information you can go to the Indian energy links, and then again the NREL technology sites, and this is Otto Van Geet. My email is again listed there, and please feel free to email me with questions.

Operator:
I now want to turn your attention to information on the curriculum program, and offerings of the DOE Office of Indian Energy education program. There are two series in the program. The foundational courses, and the leadership or professional courses. The foundational courses give basic information on renewable energy technologies, strategic energy planning, and grid basics. The leadership and professional courses cover more detail on the components of the project development process, and existing project financing structures.

The foundational courses are divided into energy basics and renewable energy technologies. Energy basics include assessing energy needs and resources based on a tribe's location and available resources. Electricity grid basics review the types of the utility grids in the United States, and resources of how tribes can tie into or be independent of existing power grids. Strategic energy planning teaches the steps to take when setting up renewables.

The renewable technology webinars give basic information on the types of renewables that are successfully used in today's world. Be sure to visit the DOE Office of Indian Energy website to find these webinars and other tools. And that concludes our webinar. Thank you for your attendance.

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