US Dept of Agriculture - NRCS | Solar-powered Water for Grazing Operations

Today's webinar moderator is Kevin Ogles. Kevin is the grazing lands specialist here at our center. Now Kevin, the floor is yours.

Thanks, Holli. I just want to introduce our first speaker here in just a minute. But we're so glad everybody could join in today. And we just wanted to make a couple of the caveats to our presentations today.

This is geared towards the eastern United States with high rainfall, humid climate. I want to make sure you note that. And also, our target audience for these presentations are NRCS planners-- what they need to consider when they might be looking at the alternative of solar water energy to provide the watering system for grazing livestock.

So with that, we're going to get right into it here. We are very fortunate to have Rob DeClue with us from New York. Rob's done a lot of work with infrastructure of grazing systems including watering systems, and he has some experience with solar. And so we're going to have him join us today. So Rob, I'm going to let you go ahead and get started.

Thank you, Kevin. I am sure that most of us have heard a lot of interest among farmers on solar-powered facilities, in particular water pumping for livestock on pasture. There are a variety of reasons which may compel a farmer to explore and pursue photovoltaic powered watering pumping. Economics are most commonly the driving issue, but not always. Cost break point was about a third to one-half mile from the grid, back in 2004, for New York State.

Depending on what the prevailing electric rates of the local utility that serves your farmers, the capital expense of conventional pumping or gravity feed options, and the cost of solar-powered alternative, a cost analysis can reveal the economics of that particular option. There are a number of key points that I want to make right at the beginning. First of all, like so many other alternative ways of providing water to livestock, but particularly with solar, it's much more costly than traditional approaches.

Also, in particular solar, we only have a relatively brief window of opportunity in which to capture that energy and make use of it. So with the cost and some of the other challenges that face solar, would it be worthwhile to explore the more traditional options where they can provide livestock to water on at least some of the acreage in the grazing system, and reduce the need for solar as much as possible.

Because solar is heavy on the technology, there's always things that can go wrong. And with that in mind, just as with other problems on our grazing system-- like drought, or flooding, or stuff like that-- having a contingency plan when the system is down, so to speak, is certainly worthwhile. And Kevin will get into this in more detail, but recognize that the type of grazing management that is practiced really impacts the design, component capacity required, and the overall cost of the solar option.

Trying to find a suitable site for a photovoltaic array takes a lot of things into consideration. Perhaps the most important is finding a spot that's on unobstructed to the south horizon. And when I say that, obviously shade above the photovoltaic array is a major problem. Whenever there's some shadow that's cast on the surface of the array, that reduces the overall output.

Another issue to consider is what the exposure or the amount of wind that might be expected at that site, because wind on the array puts a lot of mechanical stress, which leads to premature failure due to fatigue. In addition to that, the distance between the array siting as compared to where the actual pump is placed is also important, due to avoiding voltage drop in the wires. Most of the time, it's a DC powered motor, and with DC applications, voltage drop is a major consideration.

Unfortunately, due to the required exposure and prominence of photovoltaic arrays, they become easy targets for foul play. Finally, the photovoltaic array mounts mandate solid foundation to keep proper orientation to the sun. So soil characteristics like depth of bedrock or other restrictive layers can make this problematic.

As far as positioning the array, you want to try to have the surface of the array perpendicular to the sun as much as possible, and as consistently as possible. And so there's two considerations there. One is the elevation-- sometimes called the tilt or altitude. The other is the azimuth or the compass bearing.

There are various ways to basically position it. Most commonly used is the fixed frame, either on a post, a ground mount, sometimes on roofs-- those are some of the ways that it's actually placed and fixed to a solid foundation. The angle on a fixed frame usually is adjustable-- manually, that is. And in the summer for our part of the country, it basically is equal to the latitude minus 15 degrees. In the winter, then you basically would add 15 degrees to the latitude.

This is the least expensive approach to positioning or to basically mounting the panels, but it also is buffeted from winds because of the solid setting. There are the opportunities to have trackers installed onto the array that will potentially increase the output of the array somewhere between 40 and 45%. So the amount of modules that need to be procured to drive the pump may be reduced accordingly.

They're not as beneficial in the winter months as they are in the summer months. There are two types. Passive is probably the most common. That's what's shown in the photo. The other option is active, either single axis or double axis. They basically have servomotors that basically change the orientation of the panel relative to the sun. Again, you get into a lot more components there, potential for things to go wrong, as well as, obviously, the increased cost and that capital expense. The biggest thing with the trackers is they are vulnerable to wind damage, basically going out of alignment if there's a gust, in particular.

Again, I mentioned earlier about solar having a limited window of opportunity. A couple terms here to help understand this graph-- solar radiation is light power at the Earth's surface, and is measured in units of kilowatt per square meter. Solar irradiance, however, is light power intercepted by an object of a particular area. And it's also expressed as kilowatts per square meter. Solar insulation is the amount of solar irradiance over a given period of time.

Normally it is quantified as peak sun hours, which equates to the hours at an even solar irradiance of 1 kilowatt per square meter. Thus it represents solar energy for that period of time. The average for most of New York State and northern parts of Pennsylvania is only a scant two and a half hours in the winter for this peak sun period. During the summer, it lengthens out to 5.5 hours. On average, it's four hours for the year.

This graph basically illustrates some other concepts that need to be taken into account. At any given location, the amount of solar energy reaching the ground of a photovoltaic array on a sunny day varies uniformly in a predictable diurnal pattern. Under these conditions, maximum solar radiation is received.

However, when continuous and uniform cloud cover-- what would be considered overcast-- filters out the full sunshine, significantly reduced radiation is received in a pattern mimicking clear days, but reduced output. On days when intermittent or scattered cloud exists, sunshine at the ground level is highly variable in intensity and duration.

The different approaches basically used have some bearing on the total project-- recognizing the limitations of solar pumping. Again, electric power is only generated for a small portion of the day at best. And at a minimum, many hours separate each generating period due to the diurnal nature of sunlight. Cloud cover can further diminish daily accumulated energy reaching the photovoltaic array.

There's two basic approaches that bridge that gap between demand and service. The battery option is one. It has the potential, of course, to reduce the size of the photovoltaic array and pump capacity that may be needed. However, it has many down sides. First of all is the high maintenance issue. There are possibilities of safety due to the hazardous fluids and explosive gases under certain circumstances. A charge controller or regulator is an additional component that is required in that situation, as well as a low-voltage disconnect item. And overall, this results in a significantly expensive option.

The option or approach that is used more commonly in grazing situations is to establish a gravity-feed storage tank. And that basically requires that that storage or reservoir be positioned on the landscape very high, especially relative to where the dispensing points in the pasture are for offering water to the livestock. That may require significantly more pipe, basically going up to the storage and then out to the distribution to the various paddocks where water is provided.

Another issue with storage is if sunlight can get through the tank itself, like this polyethylene unit that's shown here. Then that may create some algae, which obviously reduces water quality and may have some health concerns, as well as maybe plug up the float valves. However, with all that being taken into account, this is a significantly lower cost alternative if the terrain permits. In a few instances when there hasn't been a lot of difference in elevation, the farmers and contractors have actually created a mound to slightly elevate the tank, just to get this particular option working.

The duration of service has another bearing, a significant bearing, on the design as well the construction of a livestock watering system, no matter what it be-- photovoltaic array or even a more conventionally pumped scenario. The most common, of course, is one that serves the livestock only during the growing season. That's simplistic. It allows pipelines to be placed on top of the ground where they're not subject to physical damage.

However, a lot of graziers are actually trying to extend the grazing season, both at the early portion as well as at the tail end of the growing season, and that may require some extensive or extra techniques in order to get by those colder days. The most challenging scenario is basically when water is required to livestock 12 months of the year, maybe not so much in the south, but in the north where we have freezing weather as well as snowfall and other issues like that. There are different ways and components in which to basically activate the pump-- turn it on or off as is necessary.

Perhaps the most common one is the float switch, especially when there's water storage. It's a very simple device, and it basically will send a signal back to the pump controller when the storage tank needs to be refilled or recharged. Another alternative is more traditionally used in grid-powered pumping systems. That's the combination of a pressure switch and a pressure tank.

Some terms to help familiarize you with some of the components in the industry-- the smallest unit of generating electricity for photovoltaic arrays is the individual cells. Then those cells are combined into a flat, rigid-- usually rigid-- surface called a module. A number of modules may be combined in order to form a panel. And then ultimately, multiple panels may generate or create the actual array.

The different types of actual photovoltaic materials that are out there are basically in three categories. There's a fourth, but it's a combination of two of them. The first one is the monocrystalline. Chris That one is most important because it is the most efficient-- 15% efficient, which doesn't seem like much, but compared to the other ones, it's much higher.

Multicrystalline is a little less efficient. And then we get down to the amorphous or thin film, which is less than half of the others. So other components that you should be aware of-- the pump controller, sometimes called a linear current booster or LCB by the contractors and installers. It's basically an electronic interface between the photovoltaic array and the pump. And what it does is it matches very precisely the output of the photovoltaic array in terms of voltage and current to the pump, to actually make it work most efficiently.

Other items you may see at a photovoltaic pumping station is a disconnect box. It's basically the switch that isolates the output of the photovoltaic array from the controller and the pump. And then a surge suppressor, and you'll see that right over here at the bottom of that particular disconnect box.

There's two classifications of motors. Alternating current or AC motors are the more commonly known type of motors in grid applications. They're also known as induction motors. They are characterized by a very high start-up power when it's at a standstill, and then you flip the switch.

It also normally requires a very stable voltage in order to operate without damage to the motor itself.

They're generally of low efficiency, at least for AC applications, and the mindset of the manufacturers is that normally there's unlimited power that is able to be provided to the motor. So efficiency isn't normally a big concern.

When AC type motors are used in photovoltaic situations, an inverter is needed to basically convert the DC to an AC source. A newer technology has come on the market in recent years, is what they call a 3-phase version of the AC motor, where it couples the motor to the array through a variable-frequency controller. And it allows it to be much more efficient than even would normally be the case.

The more traditional motors used in photovoltaic pumps is a direct current type motor. And it's characterized by a low start-up power. And operates under varying voltage to produce different speeds of the shaft rotation-- much, much higher efficiency. There are basically two versions of that-- brush, which requires a higher maintenance to replace them when they start to wear down, and the brushless style, which is perhaps the more common in the components these days.

The pump environment is basically categorized in two situations. You can have a surface-mounted pump, where it obviously has fairly easy access for both installation as well as maintenance and repair. However, depending on where it's actually situated, it may be more vulnerable to freezing damage if it is not protected, and you actually are exposed to that kind of a climate.

It also requires protection from livestock as well as wildlife and the elements. In that situation, they when it basically draws water to the intake port, the suction is limited to basically 22 feet maximum. Submersible pumps, however, are immersed in a column of water. And so in those cases, getting to the unit, both for installation maintenance and repair is more involved. However, it's generally protected from freezing if that's a consideration or a concern, as well as protected from the other things like wildlife, weather, and livestock. Suction is not an issue, of course there, because it's right in the column of water.

As far as pump classifications and types, there's two categories-- positive displacement as with centrifugal-- and you can see the different pumps that come in through that. We're going to go through those very quickly. For a photovoltaic array situations that basically are pumping water, a diaphragm pump is perhaps the simplest set up there. It's of moderate cost, and one of the major drawbacks is the diaphragm-- because there's a lot of fatigue on that particular component-- it has to be replaced. And so you have to rebuild that portion of that pump very often, normally from one to two years.

Piston pump is another option for positive displacement pumps. These are significantly higher cost than the prior option I mentioned. However, they are very, very durable and reliable-- have a great track record. They also are very tolerant of dirty water. And of all the pumps available, they are the most efficient in terms of moving one gallon of water with a set amount of energy.

Vane pumps have the characteristics, unfortunately, of very low flow. Fairly high lift, however, and one of the major other drawbacks is it absolutely requires filtration. It is extremely intolerant of contaminants, sediments, particulates-- so filtration is necessary. On the positive side, it can operate on very, very low power when you have a cloudy or overcast day.

Helical rotor pumps are kind of unusual for normal pumping situations when you're connected to the grid, but they're actually fairly common in photovoltaic situations. They allow for very high lift, pretty good flow. They're tolerant of dirty water, and they most traditionally are offered in submersible versions.

Centrifugal pumps-- they are moderate to high cost. They have fairly good lift, but one of the things where they shine is very, very high flow. Unfortunately on the flip side, they're fairly low in efficiency in moving water relative to the amount of power that's provided.

Lastly, cannot overemphasize O and M aspects of any conservation practice, but in particular for photovoltaic pumping stations. There are some extra features to consider. One is, of course, again trying to avoid reduction of sunlight getting to the photovoltaic array. And so when you have accumulation of dust, foliage, or any other debris on the surface, over time that is going to dramatically impact and lower the output of that array. So consistently cleaning that is ultra important, in addition to inspecting all the wires and cables for any potential damage, and then making sure all the bolts and other fasteners are tight on the frame itself or the tracker, because if they're not, due to, say, wind or some other impact, then the unit is not operating at top performance.

OK, thank you, Rob. That's very informative. And remember that our handouts, and Jeff in a little while will talk about some of the references that we have to help explain some of this so you can go back over it. Rob, we had a few questions come in. One was about the passive trackers, how they work. And then also, kind of related to that, was tilt-- when do you need a fixed tilt and does that change during the growing season, or just from summer to winter, that kind of thing? So you want to take a stab at those questions?

OK if I can go back for some slides that show the trackers. The question, if I understand correctly, is basically the passive track, how it works, is these kind of look like wings on either side of the mount for the array. And behind that, you can see maybe a little bit over here, and a little bit just below the wing, it's cylinders. And they're filled with a fluid.

And they're basically plumbed and oriented in such a way that as the sun basically shines on them-- they're usually a black surface, so sunlight hitting a dark surface, it's changes wavelength, and then it heats up that container of fluid. And then as it basically heats up and expands, it moves through the plumbing to shift, basically, the weight of the array from one side to another, and automatically tracks the sun. That, however, is a single-axis type of tracking. It's not double axis. It only basically will track the sun throughout the day, from sunrise to sunset.

The other question was what, Kevin?

The tilt of the orienting that to the sun in summer versus winter, or would you want to vary the tilt during the growing season. That would certainly optimize the amount of capturing of sunlight onto the array, depending on the particular array. On a fixed mount, it can be somewhat involved, but the more that you could do that-- maybe every month would be beneficial-- but at the very minimum, either end of the season, so that would be a minimum.

OK a couple more questions here-- actually have had a lot of questions come in, but trying to pick out some ones here that are kind of connected. So when you talked about the number of hours per day that you could count on the sunlight producing enough energy by creating electricity through those PVs, if you had a fixed array, would that give you less hours of operation versus one where you could vary the tilt, even during the growing season?

Maybe not so much hours that it would pump. It's the output of the pump itself, because early on in the day and late in the day, when the angle that the sunlight is striking the surface of the array-- if it's in a fixed mount position-- it's obviously not going to be as great as it is during noontime. And so yes, the panel will produce some amount of output, but it won't produce anywhere near as you have at high noon. And so the pump will operate, but it will obviously not operate at full capacity. So that's why tracking usually increases the total output during the day versus a fixed mount set up.

OK, great, great. So how far-- you talked about-- another question dealt with the PVs being near your pump. If you were in a situation, let's say for some reason it couldn't happen, so getting farther away from the pump, what does that cause in inefficiency, or what are the concerns there?

The big concern is the photovoltaic array is basically your generator. That's your power source. And then the pump is the device that is basically creating the demand.

And so it's the hookup between the generator and the device drawing that electricity and going through-- it goes through, of course, the pump control. But still, those cables, the longer they are, especially for DC motors, there's what is known as voltage drop in the conductors. And the further away that those two units are, the greater the voltage drop would be.

And normally they don't like to see a voltage drop of anywhere higher than, say, 2% or 3% at maximum. So the only way you can overcome that is increasing the gauge or the diameter of the conductors, which significantly increases the cost. It gets to a point where if those two units are too far away from each other, it's probably not cost effective.

OK, great, great. Well, you can see why we had Rob talk about this. He's very knowledgeable about this. I think we're going to go on. We've got a lot of great questions, and we try to keep all the questions so that we try to get them answered as best as we can.

We've got a lot of great stuff to present-- especially Jeff's going to go through a neat little exercise with us. So let's move on here. So we have had webinars previously, as Holli stated at the beginning. So most of these slides you're going to see that I'm showing you have been shown in one webinar. Most of them have been shown in two webinars previous.

So I'm just going to highlight things about solar energy watering system, as well some things that are important regardless of the energy source. And just to let you know, there's not a whole lot of research out there. I'm going to be quoting some that we do have from Missouri, North Carolina State, Virginia Tech. And there were some great GLCI funded studies in New York and Indiana that helped us out with this. But what information we do have is on cattle-- usually on beef instead of dairy. But we know that water's very essential, because if it's inadequate amounts or low quality, then it really affects intake, animal health, and several other things.

So determining need-- this was also covered-- how much, how fast, under what climatic conditions, and what kind of animal behavior management do we need to be aware of, because these definitely affect designing the system. This is what we're trying to do, is supply water that the livestock need. So this is a very famous study that was done at University of Missouri by Jim Gerrish and some of his colleagues there. And it's also been backed up by North Carolina State and some other land grant university since he did this.

So we know that during a grazing event, utilization of the forage in that paddock greatly goes down the farther away those animals are from water. Are around the 700 to 900 feet category is when that begins to drop off in utilization. In fact, there's also some studies done on dairy with some of these GLCI funds that showed that those impacts with lactating dairy cows, that distance is probably much shorter-- in the 400 or 500 feet range, since those animals need a lot of water. So those are really important facts that we need to keep in mind as planners when we're going to be doing some design work.

So if we stay within these distances or less, 2% to 5% of the herd's going to come at a time. And we can calculate that, and Jeff's going to go through an example in a little bit. And then if we're greater than those distances, we're going to have a lot more of the herd coming at one time. And there's been documented cases where you get far enough away, the whole herd's going to come to the drinking water source. So obviously, how many animals are going to be drinking at a time is a big impact on our design.

So here's, again, some facts we've shown before. So we can figure about 6 gallons per drinking event. We want to stay on the high side in our calculations. And there's two to five drinking events per day, so we might have 30 gallons per head per day that we would need to supply water.

We've shown these in past slides, also. You just want to make sure you take into account all of the water that the animals are getting, and that it's not unusual for them to get quite a bit through the graze forage. There was actually a study done where we showed that the animals got as much as 12 gallons per head per day just from the forage.

And there were actually days in May and June that certain individual animals never came to the water tank to get a drink, because they were getting plenty of water otherwise. So we just need to take into account all the water. Unfortunately, it gets critical when we're in a dry time, and then those forages don't have as much water in them.

We also are just going to touch on this thermal heat index, as I said earlier-- how much heat stress those animals are under. It's really important when we begin to design things. If we're in the northern climate, for instance Michigan where I spent a lot of my career, there's only a few days of the growing season per year that those animals-- with 50 years of weather records-- are in heat stress from temperature and humidity, versus going into central Alabama, looking at that area-- over 25% of the growing season those animals are in heat stress from temperature and humidity. So obviously, that's a big factor when we're getting ready to design, which I'll show you here in a second.

I've been asked where that line is from north to south. And it's not that simple. It's not simply saying, well, here's the latitude line. North of here there's not much heat stress, so just work on a contingency plan for those hot days versus south of here you just need to incorporate it into your design. So there's too many factors-- elevation, closeness to the large water bodies, and other things.

So here's information from the University of Missouri did. If you look at this during July, these were dairy heifers. Look at the difference in the air temperatures that those animals took in per day-- that far right column. So 80 degrees at typical July humidity for Missouri, those animals took in about 10 gallons of water per day.

That's in the very mild stress. We wouldn't consider that something where we had to worry yet about supplying shade or keeping those animals cool. Versus the 90 to 95 degree Fahrenheit, with typically humidity is very high at that time, too. You can see that the gallons of water those animals need per day more than doubled-- so very important factor on how often those animals are going to be in heat stress.

This has also been shown in and past webinars. This is a slide or a table from the prescribed grazing and feeding management for lactating dairy cows out of New York, of which Rob DeClue is one of the authors, as well as Karen Hoffman and Darrell Emmick. And just emphasizing that if we're going to have a large tank, we can have some reserve in that, and we can have a little slower recovery time, and that-- as you'll hear Jeff go through in a minute-- that helps with some of our solar systems, versus a small tank.

Then we need to have a rapid recovery so as to be able to refill quickly. And it won't have hardly any reserve. And so we have to be able to put a lot of gallons per minute in that tank quickly. So that's a factor when we think about solar.

So this is just a small tank that would have to have a quick refill, versus a large tank that we would typically see, permanent tanks. And in this situation, just want to point out that regardless of what our energy source is, when we do large, permanent tanks, we really need to be aware about what's going on out here around, off the pad, if there is a pad. Any time we go to bare earth, whether this pad is three feet wide or 10 feet wide, we usually have this. And so now we've created a resource concern where we may not have had one earlier-- so important consideration in planning.

So these facts have been repeated before. You can read them. There's conflicting data on what the preferred temperature of the water is for cattle, but the important thing to remember is that we provide some head space and the height of these tanks. Here's a tank where six or seven animals can water at a time. And if that's what our design was based on, then that's great.

You can see here there is a electric fence line there, so this tank is running parallel to that. And they probably want to protect it because of the hose here providing the water. And so that's how they had it set up that way-- nothing wrong with that, if that's what they plan for and design. If they planned on 15 head drinking at a time around this tank, why then we have problems with our design by the way we set up the tank, or the size of the tank.

An important consideration here-- it's OK if we plan on this tank being cut in half to supply water to two different paddocks. That's fine, just as long as we plan for that in our design. Sometimes that gets overlooked. Kevin Kaija sent me this picture from Vermont NRCS. I appreciate him giving me that picture. This is just showing a dairy operation.

Again, if this is designed this way for just a couple cows to drink at a time, that's fine. If it wasn't designed that way, then we need to figure out what are we going to do. We're going to push this tank further in, or do we have to get a different tank to supply what those animals need?

Same thing here with this operation. We could slide that tank further into one paddock versus the other if for some reason it wasn't planned on just a few animals drinking at a time. And same thing here with round tanks-- just an important consideration.

We see this sometimes where a permanent tank's been put in and going to a four-paddock system, which is great. That's good livestock management. But when we do that, we just have to make sure-- OK, now when these animals are in one of these paddocks, they only have a quarter of that tank, the perimeter area to drink from. And so is that what we planned on for that system?

Greg Brann sent me this from Tennessee NRCS just showing that here's a good system. It takes a lot of good things into consideration. Four animals can drink at a time. The paddocks are sized so the management's been set up so that those animals aren't waiting for a drink due to the distance to the water.

Another system-- this system is from Michigan. I'm very familiar with this picture. Tom Adams sent me this. And so these animals are doing fine. They're moved every three days, so this is not a problem. If these animals stayed here for 10 days, we've got too many things that they love to just hang out here. We've got shade, the water, salt and mineral and the fly rub up, here so they would hang out there a lot.

So management decides if we're going to be able to meet the livestock's needs. So if management determines that, so as planners we have to make sure do we have the kind of management to be able to provide the water that those animals need? So we need to consider all those things we've talked about-- distance, how much room they've got to drink, temperature of the water. We can help with that to some degree depending on what the actual water source is-- what are we pumping from-- a well or another source. And so we also need to make sure that we don't make the drinking area a resource concern.

So some consequences if we don't consider things-- just some examples-- this is actually a picture from Rob DeClue. We can denude the area, and then nutrients will pile up here as they hang around the water tank. And then right down below here, you can see the stream. So we could be causing a real resource concern there by our management of not moving those animals often enough.

Here's a good situation-- quick rotation. These animals just came out of this paddock. Again this came from Rob DeClue. And so we know that this is going to recover. When these animals come back around here again, we won't be able to see that spot, and the tank will be put in a different position in the paddock. If we do not plan things correctly, we can have algae buildup. Rob talked about that a little bit. And that can have bad effects on the livestock. So we've misdesigned here. The management's off, because that shouldn't be happening if we've got that drawdown, refill, drawdown, refill cycle going on the way it should.

OK, we want to get to Jeff. He's got some good information to share. And Jeff, feel free to cover everything you need to here. I'm going to turn it over to Jeff Porter, one of our engineers here at the East Tech Center. And he's actually manure management team leader. So Jeff, go ahead and take it.

All right, well, thanks, Kevin. I appreciate that. We've heard a lot of great information today dealing with this issue of solar-powered livestock watering system. And what I'd like to do during this very short segment is to build upon some of the concepts that have already been discussed, and hopefully try to address some of the questions that have already been asked today. And then I will try to bring it all together by going through a very short example. I want to touch again on why it's so important to plan in all aspects of the work that we do within NRCS. But why it's also very important in planning for livestock water systems-- especially when we're dealing with these alternative energy sources like solar.

I want to cover just a little bit on the importance of evaluating a solar system and the proper configuration to maximize the performance. And then I want to touch briefly on the hydraulics, as one has to balance between the PV system, and the pump, and the piping system. Just to give note, we mentioned this about some other webinars that have been done on watering facilities. If you were to go onto the conservation webinar's dot net website, you could look up these systems webinars if you're interested in getting additional information on various types of different livestock watering systems.

So why do we plan? Well, number one, as an agency, that's who we are. We are planners. And there's so many aspects that have to be considered when dealing with systems, and in particular alternative technologies such as this. And it's so important to get out into the field. It's important to meet with the landowner. It's important to get to know what that person desires out of the system that they're trying to get. We need to gather all the information that we possibly can, so we can get a good plan, so we can be developed to meet those needs of the landowner.

Now, probably the biggest factor that the landowner must consider, as Rob alluded to earlier, was that financial obligation. Even though that's not always the final deciding factor, it's still very important factor. And this may or it may not limit what can actually be done. So we need to be looking at these when we're installing practice or technology. But we also need to realize that by not doing a certain practice, we need to take that into consideration, and see what kind of impacts that may have from a financial standpoint as well.

Now as one needs to understand the limits of a system such as this, here we see the average annual daily solar resource data that we have here in the United States. One of the things to be noted here is that as one moves to the Northeast, the amount of solar energy that's available on an annual basis decreases. And this makes it more difficult to configure a PV system in this area, especially if one desires to do it year round, or at least to extend the periods of time that they want to use it.

Here it just shows in a few cities across the US to give you an understanding of how the energy varies, not only between different parts of the country, but also how it varies from month to month within a given area. Take for example Syracuse, New York, which is the last one I have listed on here. The number varies from 2.1 in December up to 5.7 in May. It would likely be very difficult to operate a system year round in this location. But it would likely be more feasible to look at a PV system that functions, say, from April to September, or maybe stretching it from March through October.

Now let's look at the same information graphically. I think that'll help to clarify things a little bit better. I know this busy with all these lines, but I wanted to take the tabular data and show it in this graphical display, because I believe that you can see some of the difficulties in putting together a good PV design, especially in the Northeast and also in the Northwestern corner of the US.

As we see from this graph, on the average from April through September, the insulation values don't very as much as throughout the rest of the year. And this really shows the importance of planning. Now, there are some things that we can do to help improve the performance. And let me just show you one of those. And I know that Rob touched on this as well.

This is looking at the angle-- the tilt-- of your panel that you're working with. Again, I've taken Syracuse, New York, and I've manipulated the fixed panel by changing the tilt angle. And as it has been mentioned, a good starting point for the tilt angle is to set it at the location's latitude. And in this case, it's 43 degrees. So you initially set it at 43 degrees, because that's the latitude at Syracuse, New York.

Now notice by decreasing the angle by 15 degrees, which is the red line, the solar insolation actually increases during the summer months. So you're going to get more usable energy by making this change. But you're going to lose some of that efficiency during the winter months. Now consequently, you could increase the tilt angle by 15 degrees-- which is the green line-- for the winter months. And you'll see there's an increase that occurs during the winter months. But then you also lose efficiency during the summer months.

We also talked about some of the solar tracking. We could incorporate that, but these add expense. And they also add additional operation maintenance issues.

So once we get an idea of the solar values and the time intervals that we'll will be working with, then we can move to the area of hydraulics-- looking at the pump and the pipe sizings. And to tackle this, we need to look at the pressure requirements for the system's operation. And one of the things we need to determine is a term that I'm going to call the total dynamic head. And I'll get into that as we continue throughout some of these slides. Hopefully, you'll understand all of this.

So basically, this is looking at what it takes to move water from point A to point B. And the four items that we have listed here-- looking at the elevation-- what kind of elevation rise are we dealing with? How long is the pipe that we're having to focus in on? What are the pressures within the system? Is it pressurized or is it not pressurized? What kind of frictions do we have within the system, and also looking at some of the other losses that could take place within the system.

Now, the presentation that was done by Bill Reck and Kevin Ogles back in 2013 covers this information in much greater detail. And I would encourage you to take a look at that if you're interested in some of those design features.

Now again, looking at the elevation distance-- this just kind of gives you a brief summary of what we're looking for. How much rise do we have in an elevation? And then also how long is the pipe to meet the requirements for the particular system?

When we're looking at the frictional losses, basically what kind of impacts are we having on the velocity within the pipe? We had different factors we had to look at-- how big is that pipe? The larger the pipe, the lower the losses. What type of material is actually being used?

How long is the pipe? The longer the pipe, the more losses and more friction we have within there. We're also dealing with such things like fittings and valves which introduce additional losses within the system. And those have to be taken into consideration when designing these systems.

Now from animal water requirements, flow rates can be determined. And we're going to be looking at, again, an example here in just a few moments. Once one knows the flow rates, and once one can determine the total dynamic head, you can use pumping curves such as these to determine which pump will work best for the system. So here now we've got the basics. What do we do with it?

It's a good question, so let's just kind of take a look at this example. Now for this example here, we have a 100 head beef cattle operation. The cattle have currently been using the stream for their water source. The landowner wants to get the cattle out of the stream. This is located in Syracuse.

The landowner would also like to see if there's a possibility that once you get the water into a storage tank, could gravity feed be used? And then also can we do the majority of the design handling a solar system? And that's what we're going to take a look at in this short example.

Here we have the site. And this shows the location of the water source. It shows the location of the storage tank and two of the watering troughs.

Now information obtained from a diagram like this is just invaluable from a planning standpoint, especially when we're doing these livestock watering systems. It just gives us a good visual, and gives us an idea of some of these links, elevation, some of those types of things. I would strongly encourage that you diagram out your systems.

Now it was determined by the landowner for this operation that these are the water requirements that were determined for these animals. Now I want you to notice the differences between the water requirements from July and November. I also want you to note the water intake requirements for very hot and humid days.

All those are going to come into play when we actually do our designs. We can't just take one number and run with it. We have to look at all these other things. And so we have to consider everything on here when we are looking to prepare a design.

Also notice that one of the things that they try to get from, I guess, a conservation standpoint is we want to have three days of storage. Just in case the system would happen to be down, we would have an additional storage. So in this case, we're going to have to have a 4,000 gallon tank to store that additional water that's going to be needed.

Note that the flow rate requirements here for November are actually greater than July, even though the water usage is less than one-half of that that's required in July. And that's because of the limited amount of solar radiation that's available for energy generation. Now these higher flow rates may have an impact on the type of pump that can be used for this operation. And I would prefer that you go back to what Rob was talking about as to what kind of pump you might want to actually look at for your particular case and situation.

Now let's look at these pump requirements. Using the previously computed flow rate for July-- and we're going to be looking at a system that will be used just during the growing season-- and when we use the other parameters, we can determine what the total dynamic head would be. And then we could select the pump.

We have these numbers, and I know some of you are getting glazed over with the numbers. But basically, if you go through the process, you'll begin to understand how this works. So we find out what the elevation is where the tank is station, and it's an elevation 248. We need to add the elevation of the height of the tank. So that's another 11 feet. And then we subtract from that the elevation of where the water is, and that's 226. So when we do that math, we come up with 33 feet.

Now we need to determine are we going to pressurize the system? For simplicity reasons, we're not going to pressurize this system and so that will be zero for that part of the total dynamic head. Then we need to look at our friction. We're going to estimate we have about 200 feet of pipe. We're going to add 10% for minor losses. Again from just a simplicity standpoint, we're going to estimate 10% additional losses.

We go into our appropriate tables, and we can figure out what our friction loss would be. In this case, it's 5.2 feet. So we would add the three numbers. So in this case we had 33, 0, and then also 5.2. We get just over 38, and I said, let's use 40 feet.

So now we know the flow rate that's required, and we also know the total dynamic head. Based on that information, you can then go into your pump curves, and you can evaluate and estimate what type of power requirements would be needed to run your PV system. And in this particular case, the system would require about 170 watts to run the system.

One of the recommendations, though, is that due to environmental factors such as dust-- when we also have wear over time-- they recommend adding about 25% so that the system will perform over a longer period of time. And when you do that, that's going to raise the PV requirements up to about 215 watts. Based on this, then the landowner needs to work with a supplier to find the array that would then meet this configuration and the pump requirements for this particular system. So now what we've done--

we've actually designed the system from the water source up to the storage tank. That's where the PV system has now been designed.

Now, since this tank is located on a hill, the landowner want to check and see could the water be distributed to the troughs by gravity, or are we going to have to add a pump? Are we going to have to add additional PV arrays to get the water to the facilities? And this is going to have to be evaluated.

Now another thing that the landowner said with the high temperatures and humidity during July, the landowner wanted to make sure that during the peak water usage events that these cattle would deal with-- they consume about 60 gallons of water-- he wanted to make sure that they could replenish that 60 gallons of water in about 30 minutes. So that sets another limiting factor on here.

So we can't just look at 6 gallons per minute for the entire system. We now have to get this water and replenish that amount within 30 minutes. Another item to take into account is that when you have a float, many of those floats require some type of a pressure to make sure that they're operating properly. And for the floats that are going to be used for this system, they're going to require 2 psi. Now when you convert psi two feet-- and that's what we generally work in, is feet-- you multiply that number by 2.31. In this case, we're just going to round it to 4.6.

The calculation on this slide, I know, are very busy. But again, I'm using this information here to help us understand the process that one would go through when designing a system. Now to make sure that we meet the requirements of the 60 gallons in 30 minutes, we're going to need to get two gallons per minute. That's the replacement rate. The flow pressure is 2 psi.

So we set up our equation just like we had before. And this would be the equation, similar to the total dynamic head types of things. And you would determine the pipe size that would basically go from the storage tank down to, in this case, the most distant watering trough.

What we've done here is I've assumed that the large tank is nearly empty. So that's where the half foot comes into play, where I have elevation 248. That's the elevation of the ground at the tank. At a half a foot-- that's a very conservative number saying the tank is almost empty-- and that is going to equal the elevation of the watering trough, plus the pressure at the watering trough, plus the friction losses within the pipeline.

Now that pressure of the trough-- that's what we're trying to find. That number needs to be greater than

4.6. And if it is, then our system will function. I evaluated both a 3/4 inch pipe and a one-inch pipe for this. Because of the smaller pipe, it had too high of a friction loss, which was much larger than 3.4, and because of that we could not use a 3/4 inch pipe and we had to use a one-inch pipe to meet the two gallon per minute requirement.

Now if we were going to say, well, we could get by with 60 gallons per hour, or one gallon per minute, we could then make an adjustment to the system. As you can see here in the second part of the equations, we could then use a 3/4 inch pipe. So again, in planning, it's so important to know what is going on within the system, and then doing the proper calculations.

And one of the things we need to understand here is that there's much more planning required then just doing the PV system. That's just a small part of the system. And if you want to know more about this process, I would encourage you to read this document-- one of those that's attached. It's entitled "Design a Small, Photovoltaic Solar-powered Water Pump Systems." And that's included in your handouts. And I really encourage you to take a look at that, to see if that can help you understand the process a little bit more, because I jump through this really, really fast.

Another thing-- I just wanted to mention a couple references that you might look at. There's a program called AgPipe. And if you're within our CS, you're going to need to have your IT folks help you to download the software. If you're a non-governmental individual, then you can download this directly at the web link that is provided.

I also know that many states have spreadsheets for designing pipelines, so I would encourage you to look at those, get a good understanding of those. Also in the engineering field tools, eventually we're going to have a pipeline component that will be added to that piece of software. But as of today, we're waiting for funding to complete that work. So it'll be a little bit of time before that actually comes out in the engineering field tools.

Now the other one I wanted to mention was this PV watts, the calculator. I used a lot of that information to show what kind of solar insolation you have at various locations. And you can input that data in there, and it will give you that information. So it's really a very good tool.

So as I bring this presentation to close, I'd just like to summarize some of the things that we've covered-- planning, planning, planning. That is so important for us to get a good system out there, whether it's a

PV system or another type of livestock watering system, or anything that we do within the agency. We need to make sure we plan well.

Also, we need to understand that for these systems, generally you're going to get less than six hours of energy to run your pumps, so you've got a very limited amount of time. So you need to make sure that you design these properly, and you design them well. We need to make sure that we link the flow requirements of the pumps, the piping, with the PV system as well.

And then a key point that Rob touched on here is that operation maintenance should never be overlooked. This is so important to keep these systems running properly, especially your PV arrays. You need to go out there and periodically clean those, because they will accumulate dust, other types of things, to make sure that they are running properly.

So Kevin, with that, I'll return control back to you.

OK, well, we've got a bunch of questions. We probably can't get through all of them. But one, I guess for all three of us-- whoever would like to answer this-- do you know of a solar watering system that's been working for years, for a long time? I don't know one right off hand. All the ones I've visited, I haven't had contact with since I was there.

Rob of Jeff, do you know of one that's been going for quite awhile?

Yeah, some of the systems I've been familiar with, either upon initial installation or subsequent follow-up, there's set-ups that I've been aware of that have been operational for 10, 15 years at least.

OK, OK. There's lots of questions about pressure. And maybe we can take a try this one. There's questions about shut-off switches. Does code require that-- a shut-off switch from the pump controller?

Partly it's a safety issue, which mostly your building codes-- that's the basis for them. It's also for servicing the units. I mean, just think of this-- if you had to work on the pump, or whatever, or the controller-- if it's during the daylight, which most people are going to do at that point in time, the photovoltaic array is going to keep on pumping electricity out.

So if nothing else for safety reasons, you need to disconnect. As well as if there's some problems on the devices, you want to de-energize or at least have that capability. And I believe it is part of the code.

OK.

And I would also throw in there that you need to check with your state to see what their requirements are. They may have more stringent requirements from one state to another.

OK, good. Here's another one that we probably should address-- if the pump is a quarter mile from the tank, do they need to run a wire to the flow to shut off the pump and not just the water? Or is there a bypass? What would be best?

That has to do with the control, the turning on and off of the pump. And if I think as the person is alluding to, if the distance between the storage reservoir is significant from where the pumping station is, yes, normally there is what they call a signal wire or cable that goes from the pump controller out to the storage vessel. And then that's where the float switch is basically deployed.

Normally, even with significant distance, even though there will be voltage drop, the level of electricity or the amount of electricity that needs to go through that part of the circuit is very low. So it still can operate fairly well even over a reasonable distance. However, if it goes too far-- that's maybe one of the questions, too-- then the pressure tank, pressure switch option may be a more viable way to control the pump itself.

Right, OK, great, great. Just a couple more-- we've got lots more, and we want everybody to know that's listening that we're going to do our best. We've got all these questions. We're going to do our best to answer these. And also take a look at those handouts, because those are going to answer a lot of those questions.

Jeff kind of went through sizing in that example-- how he came up with what he needed. But there's some more questions here, Jeff, about sizing the panels, and where you can get information on lists of arrays and pumps. Is that in some of the handout information, Jeff?

There is some information on some of the locations, but I would just encourage going online, doing some online searches. Also, your information is going to be different within states, because you can have different providers. I would just check with your local NRCS person to see if they have that contact information. But you can get some general information from the handout material.

OK, OK, one more question, then maybe just a couple wrap-up comments by each of you-- so the question came up about the animals need less water in the winter. So wouldn't that be better? And you touched on that in your example, Jeff, but you could you just address that? What's the problem, especially in the Northeast, with using solar in the wintertime?

Sure, there are actually a couple issues. Number one, you've got freeze up, so you've got to make sure that you have some way of dealing with freeze up of the systems. Also, the type of array that you're using-- definitely during the winter, you probably want a fixed array because, again, of the freeze up, some of the weather conditions that you're dealing with. You're also going to have to keep the array cleaned off if you've got the snow, ice, those types of things.

But probably the biggest thing is that you have a limited amount of solar energy that's actually reaching the array. So you may only have two hours worth of energy coming onto the system, or getting energy for two hours during a given day. With that being the case, you may actually have higher flow rate requirements for the winter months then you would during the summer months. So there are actually several things that you've got to take into consideration when you're looking at using a system during the winter.

OK, with that-- and again, we're going to do our best to address all questions that you folks have sent in. There's lots of good ones. Just a final comment, Rob, and and then we'll go to Jeff. And then I'll make just a final comment.

Well, I guess to wrap it up from my perspective, the photovoltaic pumping option is viable. I mean, it may not have been utilized in every area of the East as long as other areas, but it is a proven technology. The other aspect of it-- because it is technology, there are always innovations and improvements in products and devices. So be aware of those advances in the industry. And where appropriate, capitalize on those in future projects.

OK, good. Thanks, Rob. Jeff?

I guess I'm still going to harp on the same thing. We've got to make sure we plan well. Meet with the landowner. Find out what the landowner's objectives are. Work within those objectives. And develop the best system you possibly can. And it may or may not be a PV system, but what we just need to make sure we give the landowner what's going to meet those objectives for that landowner.

Thank you, Jeff. And I'm just going to kind of tag on to that, too. We really need to explore every avenue. Rob talked about the expensiveness of these solar systems and the maintenance. And so any time we can find another route to go instead of depending on solar-- I realize there are remote pastures even in the East, where that may be our only choice.

But don't be afraid to be innovative. There's people that are renting water from a neighbor whose pump is closer to those pastures. And so that's how they supply water to those animals when they're in those particular remote pastures.

So it's always good to be innovative, but as Rob says, sometimes solar is the only option you've got. So then you need to work with that. But don't be afraid to look at all the other avenues, and if you can use the grid, that's always less expensive and more dependable than a lot of these solar systems can be.

So with that, Holli, I'm all done. And I think we've had a great presentation by Rob and Jeff today.

We certainly have. So thank you, Rob, Kevin, and Jeff for your time and effort to make this presentation today. And thanks to all participants for joining in. We had more than 430 people join today's webinar-- a very popular topic. So participants, if you selected to earn CEUs for this webinar, please return to your open browser window to continue the process offered by Step Two at ConservationWebinars.net. And with that, this concludes our webinar presentation.