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

Below is the text version of the Webinar titled "DOE Office of Indian Energy Foundational Courses Renewable Energy Technologies: Hydroelectric."

Amy Hollander:

Hello. I'm Amy Hollander with the National Renewable Energy Laboratory. Welcome to today's webinar on hydroelectricity as a renewable energy, sponsored by the U.S. Department of Energy 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 hydroelectricity presentation today is one of nine foundational webinars in the series from the DOE Office of Indian Energy Education Initiative, designed to assist tribes with energy planning and development.

The course outline for today's webinar will cover who the DOE Office of Indian Energy is and what is this initiative: the course introduction, resource maps and project scales, technology overviews with siting and cost information, successful project examples, policies relevant to project development, and additional information and resources.

The DOE Office of Indian Energy is responsible for assisting tribes with energy planning and development, infrastructure, energy costs, 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 and 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 then explains how the various financing structures can be practical for projects on tribal lands.

And with that, I'd like to introduce today's speaker, Mr. Owen Roberts. Mr. Roberts graduated with a masters of science in mechanical engineering from the Worcester Polytechnic Institute in 2007, and first worked on wind farm construction and development as a field engineer.

In 2009, he began his career at the National Renewable Energy Lab with modeling optimization, wind, solar, and hydropower technologies. Mr. Roberts also provides international technical systems for energy development for rural populations, including the design, analysis, and implementation of remote power systems. And with that, I'd like to turn it over to Mr. Roberts.

Dr. Owen Roberts:

Thank you for the introduction, Amy. We will start with the resource maps and project scales. I personally became interested in hydroelectricity as a child, when I lived in Tennessee and was exposed to the Tennessee Valley infrastructure of dams and pump storage facilities. I was captivated by the amount of power potential in water.

In college, I worked with refurbishing some of the oldest hydroelectric projects in Massachusetts, as there was opportunity for power generation and utilization of existing, but old dams and power generation equipment. Projects are not necessarily only resource driven, but it is a combination of site suitability – such as environmental and land use issues, resource, technology, ownership, financing, available capital, financing costs, and need for returns on investment.

Also, the incentives available and ownership of the project can drive the project feasibility. Native American entities cannot take advantage of federal tax incentives. But their stakeholders may have the unique perspective of making longer-term investments due to this fact. As such, hydroelectric may be a more attractive option, since the investors are not as constrained by typical private sector needs for faster returns on investment.

The scale of hydroelectric power plants can be broken down into three groups. Macro hydropower is very large hydroelectric projects. Think of the Hoover Dam. And these can cost millions or billions of dollars. Small hydropower can cost a couple of million dollars to tens of millions of dollars. And this would be the scale of potentially a very small community or even very large casino or a very large building.

Micro hydropower, which is defined as less than 100 kilowatts, is mostly applicable to remote communities, but also smaller community centers or utilization of what we would think of as smaller streams. The utilization of existing dams or impoundments, such as some irrigation drops, is typically utilized, since they reduce the cost of these projects.

There are many examples of grids – connected and non-grid connected micro and small hydro projects throughout North America. Types of hydroelectric power include water wheels, which we may conventionally think of as a large wooden wheel that provided mechanical power to grind grain. And these were used for hundreds of years to power mills and then machinery.

This later evolved into hydroelectric, where a more efficient water wheel, then called a "turbine" was connected to an electric generator. And that then was used to supply electricity, again, to mainly industrial customers. A subset of hydroelectric can be called "damless hydro," which we will also call "run of the river hydro." And this typically would not involve a large dam, but would redirect some of the flow of a stream or river into a turbine.

Title power and marine hydrokinetics are also an evolving technology. These capture mechanical energy from the waves or tides, and then release the water or use the movement of the turbine itself to create electricity. Now marine hydrokinetics and title power are not explicitly in the same category as hydroelectric for our definition purposes. Because they are an evolving technology and not widely deployed on a commercial scale yet.

The U.S. Department of Energy has created some potential resources for siting small and micro hydropower projects. This virtual hydropower prospector web interface tool, provided by the Idaho National Lab, breaks down the nation into hydraulic regions, and has outlined the hydroelectric potential.

Of these, we can see that conventional hydroelectric has a very large potential – upwards of 60,000 megawatts throughout the nation, with wave energy and hydrokinetic having large potentials as well. But these technologies are not as proven. Here we see a pie chart of the electricity generation mix in the United States currently.

The majority of energy generated in the United States is still based on fossil fuels. This process takes fossil fuels and combusts them or burns them and creates, typically, steam – which turns a similar kind of turbine to a hydroelectric turbine. This then is connected to a generator and converts the mechanical energy into electrical energy. We can see here that nuclear also makes up a fairly large portion of the United States generation mix at 19 percent.

And hydro, in and of itself, makes up a fairly large portion, due to the large government installations around the 1900s and 1930s. As you can see here, hydroelectric is not necessarily included as a renewable form of energy. But many definitions include hydroelectric.

Next, we're going to provide an overview of the technologies and talk about system siting, as well as capital and operating costs and the economies of scale associated with hydroelectric, as well as some successful Native American projects. The basics of hydroelectric is essentially capturing the kinetic energy and the potential energy that water contains when there are two bodies of water at different altitudes.

Basic Newtonian physics shows us that potential energy, or that of water being above another elevation, is the product of mass and height. And the rate of flow is proportional to the kinetic energy, and this is just the potential energy per unit time. So of this, what we need to consider, when you're looking at a potential project, is not only the height difference between where you can take in water and where you can release the water, but also the flow rate of this water.

Now the considerations that need to go into siting a project must include the fact that turbines cannot produce very efficient power at a very, very wide range of flows. The turbines can maintain a reasonable efficiency curve, depending on the design, with the flow fluctuating by roughly a factor of two. Run-of-the-river installations are unique. Because as flow increases, the head can decrease, which actually reduces energy output. Turbine selection depends heavily on the seasonality and the fluctuations of the flow. And these are some of the preliminary screening criteria for looking at a potential project.

Hydroelectric generation is simply the harnessing of the water cycle. So as the sun heats the surface of the earth, water evaporates and is redeposited at higher elevations in the form of precipitation, be that snow or rain. Harnessing this new potential energy form and converting it to electricity is hydroelectric generation.

Large fluctuations in a specific site resource can occur due to the seasonal annual snowfall or the seasonal precipitation patterns and, also, temperature fluctuations. It is best to look at many years of data for a specific stream flow and try to capture the impacts of seasonal and annual variations when sizing a system.

The components that make up a hydroelectric system include the intake, the canal, the forebay or settling pond, the penstock, the powerhouse, and the tailrace. This illustrates a run-of-the-river system, where some of the flow is diverted from a river or stream. The water comes in through the canal into the forebay.

The precipitous, such as sand or small particles, can fall out of the water, and the water can flow through the penstock. This is important because sand and other aggregate can wear on the turbine itself. And so separating the sand from the water is fairly important for the longevity of the project. Once the water goes through the turbine in the powerhouse and out the tailrace, it is reintroduced to the river.

It differs from an impoundment dam, which we will see on the next slide. Impoundment is typically what we think of, when we think of hydroelectric, that being a very large dam that holds back a lake or a large body of water. This is the most common type of hydroelectric plant. These installations are typically much larger electrical nameplate capacities because of the larger capital cost associated with siting and installing a major dam.

The dams are used to store water in a reservoir. This actually has the advantage of damping out some of the fluctuations that you may see from a seasonal flow difference, be it from rainfall or from snowmelt. These installations also have the advantage of being able to assist with flood control. Water released from the reservoir flows through the turbine, which spins it and produces electricity.

Water can be released either to meet changing electricity needs or to maintain a constant reservoir level or, as we said, to control flooding or for environmental purposes – for fish habitat. These installations can typically have large impacts on fish and land area, and introduce the potential for issues such as dam safety.

These installations also have very high constraints in seismic areas, as obviously the implications behind a dam failure can be fairly large. There have been no significant installations in the past 50 years in the United States due to not only regulatory constraints, but also because of increased environmental awareness in the past.

In the United States around the turn of the century, as well as in the 1930s, there were many large government projects which looked to harness some of the very large potential hydroelectric resources, especially in the East, and large installations in the West, such as Hoover Dam.

Here are some examples of diversion hydroelectric – and this is sometimes called run-of-the-river. This channels a portion of the river through a canal or penstock. It typically does not require the use of a dam, although some diversion installations do require small dams.

There are typically no storage opportunities, as with impoundment, and this can potentially lower the capital costs, due to the lack of the need for a dam. But it also leaves the potential resource potentially more volatile due to the lack of storage.

These types of installations also create fewer concerns for fish and land area, as they will not create large areas of impact from flooding. Typical costs for hydroelectric can vary widely, depending on the scale of the plant, be it macro hydro or large hydro, all the way down to micro hydro.

One of the main advantages of hydroelectric is that it typically has a very low maintenance cost. That also argues the fact that the capital cost for the equipment is much higher than other forms of generation. So the financing and the availability is a much higher consideration to take into account.

Typical cost of energy for very, very large installations can be on the order of only 1 to 2 cents per kilowatt hour. Whereas micro hydro installations can really only compete in areas where there is a high cost of energy or very high incentives. And that cost of energy may be on the order of 10 or 15 cents a kilowatt hour.

Here we see the Wapato Irrigation Project, which is an example of a Native American hydroelectric installation. These turbines were initially installed in 2008. This was a retrofit project from a previously disused hydroelectric project. The potential generation for this system is about 1 megawatt. And this system actually took advantage of some very large irrigation channels that supply water to the Yakama Reservation.

This project is based on irrigation channels which were created by man, and has losses of elevation which allow the harnessing of hydroelectric energy. In the pictures, you can see the turbines themselves, as well as the output from the turbines, on the lower right-hand corner.

This project was actually partially funded by the Department of Energy, as well as the Confederated Tribes and Bands of the Yakama Nation. Here you can see a very busy flow chart of all of the negotiations and coordination that was required to execute this project. Obviously there are many considerations in terms of water rights: who the off-taker of the electricity was, who assisted with the balancing of the grid – since this was a grid-connected project, the ownership of the actual project, and who provided, obviously, the capital cost, and who would provide the maintenance cost.

The metering transmission, balancing, and power sales all had to be negotiated, and there had to be many understandings between the tribes – the Confederated Tribes and Bands, the public utility, as well as the Bonneville Power Administration. So overall, this can be a very complicated process. But there are resources from the Department of Energy, as well as others, to assist with projects on this scale.

In 2008, the Wapato Irrigation and Power Generation Station was, sadly, destroyed by volcanic ash. This system was refurbished in 2009, and these are some pictures of their celebration upon that reopening. Here we can see some more pictures of the commissioning of the Wapato Irrigation Project. It's amazing to see any project get to this point, since it is such a complicated process.

One note about hydroelectric equipment is that the capital costs are high, but the typical lifetime of hydroelectric projects, depending on the scale, can be upwards of decades or even hundreds of years. There are installations – large installations – that have lasted more than 100 years.

And, obviously, the maintenance is much more costly as the project ages. But the large pieces, such as the turbines themselves, have been known to last for decades or even hundreds of years. Thus, the initial investment is high. But it can be a very good long-term investment.

Here are some pictures from the Wapato Irrigation Project. Again, these were the old turbines – pictured here. And these had functioned since the late 1930s and early 1940s. There are many resources for hydropower information. The National Hydrography Database and the PRISM Precipitation model are both very good resources to try to look at potential hydroelectric resources in your area or on your lands. These resources will be able to summarize stream flows - or the average stream flows – of the streams and rivers in your areas.

Also, the Yakama Power Project – they have some additional information on their site. And then DOE and EERE have several tribal energy examples. Now we come to an interesting piece of hydroelectricity, which are the policies relevant to project development.

Policies that affect hydroelectric projects include the review by the Federal Energy Regulatory Commission (FERC). The commission's responsibilities include the issuance of licenses for new projects, the issuance of licenses for continuances of existing projects, and the oversight of ongoing project operations, including safety and environmental monitoring.

FERC has jurisdiction for tribes, as well as for private generation. The Bonneville Power Authority and the Tennessee Valley Authority are somewhat different. But FERC permits construction and considers environmental impacts, as well as operational impacts on the electrical grid and the environment.

The hydroelectric plant pictured here allows fish habitat uninterrupted spawning cycles. Constraints such as these can have a very large impact on project performance, as the turbines may need to be shut down to allow fish to travel. Or additions, such as fish ladders, may be required. These additional costs should be considered when planning a project.

When considering a hydroelectric project, initial conversations with FERC should be one of the first and primary investments of time when looking at the feasibility of a project. This will allow utilization of FERC, as they have vast experience with this – with hydroelectric obviously. But, also, it would be very cost ineffective to invest time and development into a project when there are outstanding environmental or other impacts that FERC will later investigate.

Here we have a couple of additional resources for information on hydroelectricity. These resources include the NREL Geographic Information System maps, as well as the Virtual Hydropower Prospector at Idaho National Labs, as well as the Federal Energy Regulatory Commission website. Thank you for your attention and time.

If you have any other questions, please feel free to contact me. For larger technical requests or for a speedier response, please contact the IndianEnergy@HQ.DOE.gov address, which is the first address on this list. Thank you. And now I'll turn it back over to Amy Hollander, who will describe the DOE Indian Energy Education Series.

Amy Hollander:
Thank you, Mr. Roberts, for that interesting webinar on hydroelectricity. There are two series in the program – the foundational courses and the leadership or professional course. 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 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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