FROM THE FIELD - EPISODE 5 - CHRISTIAN HARDWICK

Christian Hardwick: Geothermal is a resource thats, it's there, it's happening. Whether we take advantage of it or not. I mean, that's up to us. It's not something that, if we design the systems correctly, we're going to be depleting these resources. If you give it time, thermal fields are diffuse things heat up that heat is transferring from the core to the earth's surface. You design everything correctly. You do have a renewable and sustainable system.

Priya Shelly: Welcome to From the Field, a podcast logging real life scientists and their efforts to improve the world one study at a time. I'm Priya Shelly. - Beat - In this episode I speak with Christian Hardwick, a geophysicist who specializes in geothermal exploration by using gravity and electromagnetic studies.

Christian tells us how he found his passion for geothermal exploration by way of carpentry in Antarctica.

CH: I was hired to be a carpenter there, so we would go down early season, about August, which is sort of the end of winter and we'd start building things for the researchers and scientists that were going to come down for that summer season. So the scientists would show up in October, we'd have a little bit of prefabrication going on and then we'd start setting up all of their field camps and their huts. So basically, we were assigned support. They'd come in, do their science, when everything was over, they'd pack up, head out, we'd come back out to their field site, break everything down.

CH: I had taken essentially a four year break from academics. I ended up coming back to it just because I needed something more.That first semester was hard. But you know, I got back in there to get my head down, pushed pretty hard and I was able to get on top of things and math and physics, they kind of they don't necessarily come natural to me. It was something that I had to work at.

So, as I was wrapping up my work at the university, it was actually a thesis that was a collaboration with the agency that I work for now. So it was kind of a natural progression to step in that direction because they needed someone with my expertise.

PS: The agency that Christian works with is FORGE, Frontier Observatory For Research and Geothermal Energy, at a proposed field site just outside Milford, Utah. It's dedicated to researching enhanced geothermal systems, or EGS, which are manmade geothermal reservoirs. Here, Christian and his team are laying the ground work to harness the potential of geothermal energy as a renewable resource.

CH: A renewable resource is one that can be replenished at the same rate that it is extracted so that there's no depletion. So essentially, this is not a finite quantity that, once you mine it for extract it, it's done for and you, move on to the next. It's something that is continual and if you do it right, it can be sustainable. The major renewables would be solar wind and geothermal.

So the forge project, has been going for two years, I believe, maybe a little bit longer. Forge stands for Frontier Observatory for research and geothermal energy, Basically what they want to achieve is a dedicated site where scientists and engineers will be able to develop tests and accelerate breakthroughs in enhanced geothermal systems.

PS: If you go 2-10 kilometers beneath the Earth's surface, you'll find a lot of hot rocks. Fracturing and extracting this heat from the rocks would provide an immense amount of clean energy. That can only be done with an Enhanced Geothermal System. The first step is finding a suitable drilling location with an exploratory well and the funding to do so.

CH: So basically what's happening here is that DOE is putting this money forward for a handful of teams to compete and essentially say who has the best site. So there are five teams in the first phase and then going into phase two, there was a down select. Our group here, Utah, we were one of the two, the other one is a Fallon Nevada team. So we're down to two and then we're actually just wrapping up this phase currently and there will be another down select to the final site, which you know everybody's excited about.

Our site specifically, we put it in a well, I believe the final number ended up being around a four and a half, $5 million, just a little bit of pocket change. Usually that's that kind of upfront risk that investors are looking at and say hey, you're going to spend 4.5 - 5 million on a well, maybe even more depending on depth and other parameters and there's a chance that it's not going to hit a reservoir and it's going to fail. I mean thats a lot of money to just kind of throw away. With our site took us believe we were at 60 days to drill our total depth, which was, you know, down to 7,600 feet below the ground surface and that got us into our target zone, which would be our reservoir between a 175 degrees celsius and 225 degrees Celsius.

PS: 7,600 feet is about 5 empire state buildings stacked on top of each other, including the point.

CH: These are the kind of these parameters that we need to meet specifically for FORGE and it has to be within a certain depth range and it's got to be within a certain temperature range. It's sort of their sweet spot and it has to be right type of rock crystalline. So this is sort of a hot, dry rock. This is going to be an EGS system. So those are all important. My part in this, and you know, what the rest of my team is, there was a lot of work up front, you know, desktop work and then we go out in the field and do surveys to figure out, sort of what are the characteristics of the system. First of all is there a system here? What are the characteristics and what depth are we going to reach these temperatures. So we do everything just for making surface measurements, calculations on our desktops. We come back and say, ok, we think that if we drill in this spot, we're going to hit this temperature at this depth. And there's not way to confirm that until you put a hole in the ground.

Once we hit that reservoir depth and confirmed those temperatures later on, we were with in 300 hundred feet. We got down to the 7,600 feet for our reservoir, well within our reservoir, so yeah, kudos to us, yay!

PS: This was a victory for Christian and his team. In finding a suitable drilling location, the EGS has the ability to function properly at his site. EGS works by creating a closed loop injection well by injecting water into the ground and fracturing the hot rock, which then expands the amount of permeable rock. The water is heated underground by the rocks and the super hot water returns to the surface, completing the loop. The heat is then released as vapor and passes through a turbine generator to create energy.

00:59:26 CH: Yeah so we're happy with that, that we were able to hit our targets at the depth that we estimated that it would be at. Were we surprised, I mean not really. We knew that it was going to be about that about that spot because we understand the system well.

PS: The team wouldn't have been able to hit its target without Christian's collection of data. Geothermal resources are a natural commodity in the U.S. but they can't be harnessed throughout the entire Country. It's all dependent on the co-location of heat, permeability and the fluid deep within the ground. Christian uses gravity and electromagnetic fields to determine where the best areas are located within the Western part of the Country.

CH: My main role with geothermal energy is actually in the exploration stage. So we'll go out to an area measuring different properties in the field, gravitational temperature, in geophysics, we'll measure gravity, electromagnetic fields and bring that data back in with us and then we'll get to work on that, creating a model for this area to understand what is the size of the system, Once we have this volume and temperature and once we understand what the physical properties are of this potential reservoir then we can go one step further and say ok this is its potential use, whether or not it's economic, where you kind of handed over to industry at that point or anybody else who wants to dive into it and work out what the economics would be, is it going to be economic to produce electricity out here?

That's typically sort of the golden prize. But you know, one thing that's sort of overlooked is that you can use this for more than just generating electricity, you've got a lot of direct use applications of using this heat energy without having to create electricity. I think that's where the potential is.

PS: Christian explains that, while out in the field, his process and collection of data, assists him in digitally modeling a prospective area, which can reveal the characteristics of a perfect drill site.

CH: Everything that has a mass has a gravitational field, no matter the size. It's just that when we think about gravity, you're always thinking about the earth's gravity, what's holding us to the earth's surface, but that doesn't mean that you yourself, that you don't have a gravitational pull or that your cell phone to your pencil, your computer, your shoes. I mean everything that has a mass has a gravitational field. It's just that it's so small that it doesn't matter to you.

When we go out and do these surveys, the actual survey's that we're doing, there's geologic mapping of the surface which allows us to kind of see where we have fault structures, which those fault structures are important with the geometry of the subsurface or even say our bedrock, which would be our hard surface or the bottom of the basin. I don't really look at a whole lot that's on the surface. I'll look at terrain but mainly I will say, ok, through this valley we might want to do a couple of transects or where you want to measure the gravity field. Then we when we go to analyze this gravity field, we look at the relationship between the gravity field and the density of the material that's beneath your feet.

So for example a deep basin, we'll have a prominent gravity signal and that gravity signal is based on the low density fill or the low density sediments are the basin fill compared to your bedrock, which would be like your mountain. You nice big mountain ranges on the sides of it. So then what happens is whenever you have that high density, you've got larger gravity fields for acceleration due to gravity. So you have gravity highs. And then how in the middle of the basin where you have, really thick sedentary fill that's much lower density. You have gravity lows. So you have this contrast as you kind of go from one range on the site of a valley through the middle. Then on the other side, you'll have this nice kind of big gravity low. What we'll do is we'll stop that into modeling and we modeled those densities and they can work out how thick that basin fills that area. If we do that in a few places then we kind of work out a geometry and ended up getting a volume, which then ties back to sort of our, you know a geothermal system. We want to know what the resources, we want to know sort of the characteristics of it. How big is it, what's the temperature. Gravity is one way to get a it or the geometry or the structure of it.

PS: The other method Christian specializes in is electromagnetic fields, which has a slightly different approach to seeking out the best spot for harnessing energy.

CH We are making measurements on the electrical fields around say a survey site or at a station. And what those electrical fields are really telling us, sort of what are the electrical properties of the material in the subsurface, what that would actually mean or be, can further be kind of interpreted to say if you've got dry feel that's above the groundwater table.

In Utah when you have saline fluids and you've got temperature,, they're typically geothermal fluids, to geothermal fluids will have this signature in the subsurface of being conductive electrically more so than are groundwater. So we look for this, we look for those signals in those differences and that's just one other kind of a tool to better understand the system.

PS: They're like little earth clues

CH: Yes, definitely.

PS: That's amazing.

CH: Lots of earth clues.

PS: It's hard to believe what's beneath our feet. Maybe because it's something that we don't really think about everyday. Christian says he definitely manages to turn a few heads while out in the field with his equipment.

CH: When I go out to do these projects and these surveys and we run into locals out there, they're always curious to see what we're up to and what kind of science, which is great. And I'll start to explain we're out here measuring gravity and they're like, well, don't we already know gravity of the earth? Like why are you measuring it? I've learned about that in high school. 9.8 meters per second squared or 32 ft per second squared, like those are the numbers that they tell you. But what we're actually measuring, yeah ok 9.8 meters per second and now from that point divide that by a million and that's actually what we're detecting out here. We're looking at very small changes in the gravity field and that lets us know sort of what's going on underneath our feet around us which I think is really cool. But I'm a nerd in that regard. Not everybody is like, oh wow!

A couple of years ago when we were in the downtown area of the Salt Lake City here, measuring one of the street corners on the sidewalk slab and we've got our small meter set up, which just looks like an aluminum bread box about the size of a breadbox and a GPS tripod set up next to it with an antenna and all this. People walk by and kind of look at you funny. Every once in a while people will ask what you're doing and we're more than happy to explain it to them. We love science and we love doing this. One of them was particularly memorable because it comes up and he says, hey what are you guys doing here? And I turned to him and I said, we're measuring gravity and he looks at me and there was a pause and I was waiting for the question but then he just walked off. He's like you guys are like lying.

PS: Disbelief aside, Enhanced Geothermal Systems could power tens of millions of homes, businesses and public spaces without the use of fuel.

CH: That sort of leads into another point about renewable resource is that this heat, essentially, it's being transported from the center of the Earth at the core of the earth to its surface. This is known as heat flow. With that heat flow, it's going to be higher or lower and other places, depending on the physical properties of the rock, where the sediment that it's moving through or even water for that matter. But it's always there. It's always transferring to the surface and that goes into the atmosphere and then into space. So it's really an energy that's just sort of, you know you can think of a campfire that's burning. I mean you can get kind of close to this fire and warm yourself or you can get away from it but regardless that fire is still burning. And we geothermal it's sort of like, why are we not utilizing this energy source. it here. It's natural. It's not something that's going to shut off.

PS: By now, you're probably thinking what about solar and wind energy, those are renewable resources, too! And you're right, they are. But There's a key difference between solar, wind and geothermal.

CH: The main difference between geothermal and these other renewables is the geothermal is what's called a base load source. What that means is that it's always on. So with solar, solar is only working when the sun is shining. Wind, wind turbines are only spinning when the wind is blowing. When it's not, you're not producing any electricity out of these, these fields or these energy farms. But with geothermal, it doesn't care what's going on at the surface.

Nighttime, daytime, can be winter, it could be the middle of summer. You're still producing electricity. So it's always on. The thing that's important with that is say if you're trying to supply a particular load to say a large city, you've got everything that is, you know, on solar or wind, it's going to be an intermittent source and it might not line up with what you know, the city's needs are. One good example of that is what's known as the duck curve. So what happens is that sort of mid day when you have a maximum output for the solar farm is not sort of lined up with your maximum demand. Then a few hours later, once everybody starts coming home from work, the amount of solar that's being generated is actually going down because the sun is going down, but the demand ramps up.

Other thing that I should mention because a lot of the times when you're talking about solar and wind and comparing it to other resources, particularly geothermal, what typically gets mentioned is the nameplate capacity. Or also known as the installed capacity. That's because these numbers are so much larger than what would be for typical geothermal plant.

00:27:26 CH: So you've got a geothermal plant that has maybe 30 megawatts installed capacity and you have a big wind farm sitting next to that, that's over hundred megawatts. And they're like, oh wow, this is one farm is huge and then you have a solar farm that's another hundred megawatts or more. They're like oh, this is so easy to throw those up there. This is great. We're getting so much more electricity out of them. That's actually not true because if you dig into it and you actually have to look at what's being produced at these field and not just what did maximum installed capacity is, when you dig into that, we look at something that's called capacity factor. What that capacity factor is, is that it's the ratio between the amount of electricity produced in a given time period to the maximum output.

PS: Remember when Christian mentioned that geothermal never turns off? Well, that's what makes the potential for geothermal energy so immense.

CH: Capacity factor tells you how much a power plant is providing versus the installed capacity. If you look at this capacity factor in regards to geothermal, it's at 74 percent, which is only second to nuclear, at 91 percent, biomass, 68 percent, hydro 37 percent and then we look further down the line wind is at 33 percent capacity factor and solar is at 25 percent. Those are both at the bottom but everybody's like, they maximum, you know installed capacity. It's so great, it's so huge, but you know it goes back to this sun shining and the wind blowing. Solar is great, wind is great when it's working and it's cheap and so that kind of helps with getting everything out there and putting it in. But really it's not going to be a long-term solution until you're able to store all of that energy that's being produced in these infrequent cycles.

PS: Over all these years, geothermal energy in the United States, hasn't really been a main topic of conversation when it comes to renewables. Despite the US being the largest producer of geothermal power, it's sort of been existing, quietly in the background.

CH: You could go back tens of thousands of years. Geothermal has been used by people, even in just sort of the simplest of settings, with cooking , heating, sort of these basic things. It's been there, it's been used. Even some of the more primitive people are using it and yet we've got all this technology and an advanced society and we just kind of shrug it off as well, now whatever, like let's go drill a hole over here and look for oil. Let's put up a wind turbine. Let's do these different things, it just gets overlooked for whatever reason, particularly in the US because we do have a pretty good idea of how much energy we're producing and using.

Geothermal is really kind of been put in the back seat, so to speak, with respect to other energy sources for a couple reasons. Geothermal doesn't really give you as much bang for the buck, meaning that, if we compare to say a quantity called energy density, now we compare that to oil or gasoline, you get a lot more out of that than any other type of fuel. So if we're burning this to harness that energy, it's just easier to use these other types. The other thing that sets it back is that it's not a commodity that is easily sold for significant profits.

PS: There are several countries around the world that have decided to utilize this underground resource and are heading towards a cleaner future.

CH: The ones that are most popular, or might hear the most about I would say Iceland is one of the common ones. New Zealand's another one. The US being the largest producer of the geothermal power. Going from there, there would be the Phillippines, Indonesia, Mexico, New Zealand, Italy, Iceland, Turkey, Kenya and Japan. It's not something that's only in the US and it's not just a few places. It's coming up in these countries. There are also other countries that have sort of plans to put in geothermal power plants and systems. So, it's coming up, doesn't get a whole lot of you know PR but it is there.

The US as far as power potential or even if we take a step back to geothermal power plants, most of them are in the Western US and the largest one is The Geysers, which is in Northern California, that one actually started in 1962. And that's currently installed capacity is one point six gigawatts.

PS: One gigawatt alone is like having 3.1 million installed solar panels. Maybe Doc Brown should have tapped into geothermal energy to power his DeLorean.

CH: Geothermal is a resource that, it's there, it's happening, whether we take advantage of it or not, I mean that's up to us. It's not something that you know, if we design the systems correctly, that we're going to be depleting these resources. If you give it time, thermal fields are diffuse things heat up that is transferring from the core of the earth's surface. You design everything correctly. You do have a renewable and sustainable system.

PS: Christian explains that geothermal has the potential to be used for heating and cooling as well.

CH: There's a lot of direct to use and there's industrial applications.There's a large greenhouse that's in southern Utah that uses a geothermal to throw energy. The state and the state prison is actually on a heat pump system. So it uses geothermal energy to heat and cool that structure. There's, there's aqua culture, so basically either keeping ponds, warm, too, uh, breed different types of aquatic life. It doesn't really have to be focused on just producing electricity, which is what everybody thinks about. You've got all this resource that you can use for so many other things in manufacturing processes. I mean, it's just sort of endless possibilities that you could utilize it and the resource is there. It's in my backyard here, it's in the city where you are. I mean it's everywhere. It's just a matter of doing it.

The best thing for geothermal is just awareness. The first watt generated to power a light bulb you know, this was done in Italy in 1906. I mean that's not new, that's over a hundred years ago and since then that field has grown into a large geothermal plant, but you know, even here in Utah, we've got three geothermal plants that are producing electricity. The first one came online in the 1980's so it's been around almost as long as I've been alive.

I love what I do, and the main part of it is to do, it's the research that is contributing to sort of a greater need for a greater cause. So if we can figure out how to harness these things that are sustainable to clean the renewable and we're also helping to supply energy, not just to the US because then we can refine technology here. Then we'd be able to give those to other countries that might not have the same kind of resources that to more resources as in money and funding. The expertise that we have in the US we'd be able to get those to other places. And my feeling is kinda, you pay that forward and maybe that's just my perspective coming out of academia research is sort of everything is open, anything that you can kind of figure out and contribute, you give the freely and so that someone else, they might be able to come along and look at something that I didn't say hey, we can improve on this. I have an idea, and I say hey, let's go for it, you know, just keep pushing, keep pushing forward.

Since I had this interview with Christian, I found out his team progressed to the final round and will receive $140 million in research and development funding to further their advancements on bringing geothermal to the sustainable energy table. So maybe geothermal hasn't totally been forgotten after all.