USE OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION

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GEOTHERMAL RESOURCES IN THE UNITED STATES

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The Earth Sciences Laboratory in Salt Lake City is a contractor to the Department of Energy. We're composed primarily of geologists, geochemists, and geophysicists who are working on both resource identification problems directly connected with the commercialization of geothermal. We interface not only with the Department of Energy and other DOE contractors but we also interface with private sector people in both the high and low temperature resource development interests. Where does a utility start if they want to look at geothermal? How do you tell whether you have any potential and how do you handle that? Well, the simplest and first place to start is to go talk with state agencies. In the folder you got from outside there is a blue brochure that has on the back of it a list of people in western and selected eastern states who are doing geothermal resource assessment. In most of these states there are also people funded to do commercialization activities and these resource assessment people can put you on to those. The commercialization people, I believe, are listed in the National Progress Monitor publication. These people have been looking primarily at the low and moderate temperature for direct heat applications but they are familiar with the resource base in each of those states for high temperature because they are also looking for low temperature resources around the margins of the high temperature resources. After talking with them and identifying whether first of all there is a likelihood of potential and whether second of all the leases in lands you might be interested in have been taken, you can then talk with geothermal producers, consultants in the geothermal field, or the people who hold the leases and see if they are interested in working with you.

In response to the question on oil wells, I'd like to point out that so far in the geothermal work that I am familiar with only once have we been drilling a 300 ft. gradient hole and hit oil. It came in at a depth of about 160 ft. One of the things that you will find as you get into the geothermal business is that there are a lot of consultants out there. And one of the problems that I think faces you as utility people is you are going to be sorting out the good consultants from the "snake oil salesmen." There are quite a few of extremely good consultants out there who can give you a great deal of help; there are also several people who are out there pushing their own particular brand of whatever. So, I just encourage you to not deal with just one consultant or involve yourself with the opinion of just one person, get multiple opinions. Talk with the people who may be interested in the resources in your state or talk with the state agencies identified in the National Progress Monitor.

When you talk with a geologist, or a geochemist, or a geophysicist, there are several different types of philophical impressions and perceptions that we bring to studying problems. One is, our concept of time is different than the concept of time I am sure from the utility and of an engineer. Where typically you hear worries about will the reservoir last for the 30-year life of the plant; that's a valid question and we are looking at it, but we are putting the 30-year life of that plant into the whole evolutionary history of the volcano if it happens to be a volcanic site and putting that into the four and one-half billion year history of the earth. So the 30 years is something that for a lot of resources becomes a very short bit of the type of perspective geologically, that we bring to a problem.

One other point that geologists bring is that resources really ultimately are going to be, perhaps with the exception of the sun, although it is due to expire in about 10-billion years, the resources are finite. So we have to do something about that. I think the best illustration of the finite nature of resources was several years ago when one of the Apollo astronauts was on a mission of circling the moon looked out the window, put his thumb against the window, and blocked out the earth. He was undergoing psychiatric care for about five years afterward, I believe. But, in terms of human civilization, geothermal resources do have the ability to be considered in effect and purpose renewable, and I'll get into that a little bit later. Geologists also tend to classify things and so I am going to give you several classifications and one of the things we do when we classify them is to put them into the most unpronounceable terms we can come up with. So you will have to get used to geologists being unpronounceable. In the geothermal business I think we may have overinherited a legacy of the Geysers and I hope that Dr. DiPippo's talk pretty well dispelled the idea that the only resources that are good are resources that are dry steam. These are very rare resources. The hot water resources are much more common and it is the hot water resources that I believe have much greater potential both in the short and longer term for meeting the electric generation needs that you face. One other thing that commonly comes up as a legacy of the Geysers is that there is a perception about every geothermal system having hydrogen sulfide problems. That will be the major environmental problem. Well, it is the vapor dominated systems, the rare ones, that tend to have the hydrogen sulfide problems. Most of the geothermal systems you deal with are much more environmentally benign that that. They will all have small problems of some nature but they are not problems of the magnitude of looking for, how do we store for a quarter of a million years nuclear waste? Or, how do we deal with the stack gases and the sulfur dioxide and the acid rain which I know is a tremendous concern to those bureaus generating from coal these days.

Rudy Black pointed out that hydrothermal resources are going to fill the gap until we get into more hot dry rock and geopressure resources coming on line. My impression is that not only can they fill the gap, but the implication of renewability says that we are dealing with a much longer term of resource. The attractive thing about hydrothermal resources is that the technology, the development is pretty much off the shelf. There is work that needs to be done but it is my feeling that it is certainly in short term and very attractive. As Randy pointed out, geothermal resources really are anomalies, especially when we get to the electric resources. They are anomalous concentrations of heat in the earth's crust, be they heat associated with Mt. St. Helens or heat associated with the East Africa Rift where the plates are pulling apart. These anomalous points are the ones that electricity will have to look for. For moderate temperature resources it becomes more attractive to look for anomalies if we get down to the realm of looking at groundwater heat pumps for direct heat applications, the numbers I've seen from the National Waterwell Association go as low as 39°F. is attractive and the only reason they don't go lower than that is they have problems handling water less than 32 when they subtract for the delta T.

So, geothermal energy to my mind is nationally attractive because it is all right here and politically attractive, especially for those of you who may be going in for rate increases because nothing is dearer to the heart of the public utility commissions these days than coming up with an alternative energy form and demonstrating that you are working on that and it's environmentally attractive because the hazards are fairly easily mitigated.

There are three components to geothermal systems. You have to have the source of the heat; you have to have permeability in the rocks to move the heat through; and you have to have a mechanism to transfer the heat from the rocks at depth to the surface where you can use it in the power plants. The source of the heat may be a volcano, the source may be as in the case of the eastern coast lower temperature resources, merely the radioactive decay of uranium, thorium and potassium, in the buried bedrock, and the source may also be just the normal thermal gradient of the earth. Typically, the earth will increase in temperature, 1°F. every 70-100 feet as you go down. In geothermal sites, the increase is often much more. The water that we get at the bottom there is most often in the geothermal systems regular meteoric or rain water that has circulated to depth and then come back up along the permeability or the fractures or stratographic horizons like sandstone beds or other aquifers that might exist in the area. Studies that have been done even in the areas as volcanically active as Yellowstone are unable to find a detectable amount of juvenile or water coming off magma. Most of the water they see there is merely groundwater circulated to death, been heated, and then rises back up.

There are these types, and here we go with a geologist classifying things. The most obvious are the Mt. St. Helens, the Yellowstone, the geothermal systems that are related to volcanic activity. We also have systems that are a circulation along faults; there are systems in the northern Great Plains for instance and along the Atlantic coastal plain, although that is the bottom kind here in detail, where the broad regional aquifers are anomously warm. There are the geopressured reservoirs such as Randy Stephens showed earlier, and there are radiogenic heat sources such as I mentioned before. In terms of short term attractiveness for the generation of electricity, it is my perception that the top two volcanic environments and fault control environments are attractive areas.

This is a drawing adapted from Don White of the Geologist U.S. Survey. Basically, what happens in a system of this sort is that a source of heat here diagrammed as magma comes up into an area -- the source of heat does not have to be magma, this could be the normal thermal gradient or an abnormally high in anomalous thermal gradient -- ground water circulates down in the side of the system is heated in the vicinity of the anomalous source of energy, and rises along fracture to become a hot spring or a geyser or something of that sort.

Production in fracture-controlled systems is most often found where you not only have one set of fractures but you have another set of intersecting fractures. So the game of exploration becomes one in environments such as this of finding these intersections as those intersections are the points where you will have the most permeability.

In a cascade type of environment in Mt. St. Helens, there are not only hot springs up high on the volcano, as in the case of the fumeroles on Mt. Hood, but there are also hot springs found very far out on the margins of the volcanoes. And it becomes an interesting exploration problem for those of you who are in the Cascades are interested in the area because you don't have to consider the areas up here on the top of the volcano that are typically now either wilderness areas or national forest or areas that have other institutional barriers, are the only places to go for geothermal resources. We see a lot of the water circulating to depth and coming up on the margins.

The vapor dominated systems have been spoken about and basically this is a geyser-type, another area that has this is mud volcano, in one of the hand-outs you have in your book it says that Old Faithful at Yellowstone is a vapor-dominated system, change that to the mud volcano area and Old Faithful at Yellowstone is a water-dominated system. Typically what you have is a deep water table that is above the source of heat and it is this deep water table that is boiling that is providing the vapor with recharge coming than from the sides to the system.

This bets to the plate tectonics and the Imperial Valley type of resource where the earth is actually moving apart; the plates are going in different directions where you get the heat being concentrated in permeable sediments and then a capping layer above them you can get this brine up to 300°C.

So, the geologic environments where the resources are found are the volcanic belts, the extentional environments; this for instance would include the entire basin and range and the Great Plains as a lower temperature, the northern Gulf of Mexico, as the geopressured and the Atlantic coastal plain as the radiogenic.

If we look at the volcanic sites, this is after the U.S. Geological Survey circular 790, the red dots are the systems such as Coso and the Geysers where they find a very great amount of thermal energy left. The blue dots are volcanic systems that have according to their calculations lesser amounts. You can see that there is a fairly wide distribution but there are not all that many prime volcanic areas for looking at. A lot of this territory remains by and large unexplored in detail. There are prime targets for looking for service areas in these vicinities, probably somebody has leased this, go talk with them and get them interested.

So, if we look at the physiographic map of the western U.S. and where the resources are likely to be out here again the entire basin and range, especially the north-western part over here, as a fairly high anomalous amount of heat flow or absolute amount of heat coming from the earth, and there are a fair number of sites that are of interest. The Cascade Mountains are of interest; down here in the Imperial Valley, the southern part of the basin range in Arizona, and the Rio Grande Rift coming up through the central part of New Mexico and perhaps this should be continuing up here into the southern part of Wyoming and there is geologic discussion as to whether or not it does, and the margins of the Snake River plain become attractive areas in terms of known environment.

Randy Stephens mentioned that DOE has been cost sharing exploration with industry. These are just some of the sites in Nevada where the cost sharing projects have gone on. The Cove-Fort and Roosevelt hot springs areas in Utah were also included in this program and as was mentioned, the program is now in a state of limbo waiting to see whether or not it will be reinstituted or whether or not the tax incentives that have been proposed by the government are sufficient to spur private sector interest. Maybe we can get their developers to talk about that tomorrow morning.

In terms of geothermal exploration there are basically two things that control what you can do. One is how much money you have and the other is that you can do things in Nevada that you can't do in downtown San Diego. So the techniques that you apply in terms of exploration will vary.

There are geological, geochemical and geophysical steps that can be taken that then lead to the ultimate step of drilling the reservoir and doing a reservoir production test. The easiest thing to do if you are looking for hot water resource is to look for hot water. And, by inventory, not only the springs and wells in the area but looking for springs that may have dried up for some reason or another. A case in point where a spring dried up is Roosevelt Hot Springs in Utah where they decided that because a spring was dried up there was no energy at depth, they would have been significantly misled. Fortunately, they didn't. A look in volcanic areas such as I outlined previously and then proceed with geologic mapping, both at regional and local scales, looking for what units are there and the geologically structured relationship between the various units. Where are the faults? Where are you going to find the permeability? Geochemically, the thing that is done most commonly is to look at the waters through a chemical analysis of them and then apply what is called the geothermometers. Another thing you can do is look at the rocks -- the way rocks are altered will often be a response to thermal events and you can also look at the distribution of trace elements.

The common geothermometers are the silacageothermometers and the sodium potassium calcium and magnesium geothermometers. You'll see a lot of numbers reported in the literature on these and on the next slide I have outlined some of the things that have to have happened if the number you see is to be considered a good number. And I'd like to point out that a lot of people use the numbers, do the calculations and then do not look back and see whether or not all of these conditions have been met. If any one of these conditions has not been met, or there is not a way to chemically deal with conditions not having been met, the number you see can be a misleading number. This is one place where sometimes wrong numbers will slip into the literature.

Geophysically, we are looking for the quantity of heat. You can test for that. The gravity and magnetic patterns of the earth will change. You can look for geologic structures and the electric patterns you see in the earth will change, all as a result of thermal input and all as a result of hot water being in the area. This seismic one looks primarily for geological structures. None of these directly tell you whether or not you have hot water but they tend when you put together to compile and indicate that you might have that.

I'd like to very quickly conclude here with the slides by going through a brief case history of Coso KGRA where the Navy is looking as part of the DOE effort at geothermal energy. The lesson to be learned from this is that it is much more cost effective to do more exploration in the beginning. If we talk about a full bore explanation program we are talking in the very broad ball park of two to ten million, four to eight might be a better number, but if you start with a little bit of information it can be misleading about where to drill. In Devils Kitchen in Coso Hot Springs, the drill hole that was drilled was up here. If we look at this, the geology of the area in general has north-south faults in the vicinity; there is also an east-west trend and there is another thing we look for which is nice to find but not absolutely required and that's young volcanic activity. If you look at the places here in green where hydrothermal alteration has taken place you can see that there is a general north-south trend and there is some indication of a trend that is northeast-southwest If we look at the temperatures at a depth of two meters we have temperatures of 30 degrees C. at that shallow a point. And again, they concentrate in the vicinity of Coso Hot Springs, Devil's Kitchen and there is some sort of indication coming off in this direction. The aeromagnetic contours were one of the things that can give you a magnetic relatively low response is the fact that the rock may be altered by thermal events or the rocks may be heated up. In this case, we see again the north-south and the northeast-southwest trend. If we put all that together we end up with everything concentrated in this area along that trend and along that trend but here is a drill hole that is right in the center of the first two sets of data they used.

I'd like to close with a couple of quick comments, one of which is that as utilities you will be funding this 4-8 million dollar ballpark of resource exploration but you are going to be funding that indirectly. There will be other companies, the resource producers that you will be talking with and hearing from tomorrow who will probably be the people who are actually out there and doing the work. But as managers, you may have to be dealing individually as well with other consultants and I encourage you to read Ron DiPippo's books. They are both very good in terms of outlining the types of things and in terms of expanding the funds. We really have just begun to scratch the surface of the geothermal resource base that is there. We are movning now beyond the point the oil industry was in when they were looking for oil seeps and drilling there. We've been looking at Hot Springs and drilling there. We are now in the sophisticated stage of being able to build beyond having to see something at the surface.

Question: Do you have any estimate of how hot the water is in Yellowstone? The maximum?

Answer: The maximum is apparently about 360 degrees C. That is a reservoir that has not been tapped and there has only been very shallow research drilling done in Yellowstone. It looks like that is about the maximum derived from some of the geochemical thermometers.

Question: Do you feel like that there is a mixture of the Island Park caldera in the Yellowstone caldera water?

Answer: Yes and no. There are some very good geological indicators and the Island Park caldera is overall geological environment where you would expect to find high temperature resources. There are also some things that the Island Park caldera may be slightly too old to have an electric quality resource associated with it. It certainly does have not springs in it and it has very large flow ones. If you look at the regional hydrology of the area you find that Yellowstone is, on a regional basis, a higher area than Island Park. And so the regional flow patterns would suggest that rather than having water flowing from Island Park to Yellowstone, you have water flowing from Yellowstone ti Island Park. But that would be the surfact hydrology. What the subsurface hydrology and what the hydrology at a depth of six to ten thousand feet would indicate, we don't know without drilling. There are places where we see water at depth going against the surface head in the Yellowstone area. I know that the National Park Service is also interested in exploring this. They have been conducting an inventory this summer on the western side of the Park to see what is it. Maybe you can get some of the resource developers to talk about this tomorrow.

So the answer is yes and no. There are indications saying that it should be good and some saying that it should not be good. There are cases you can build that would say yes, there is interference and cases you can build that say, no there isn't.