Abstracts for Presentations at the Geothermal Energy Generation in Oil and Gas Settings Conference

March 13-14, 2006, Southern Methodist University

Beniot, Dick

Scaling and Corrosion Abatement

Throughout the world there are two primary scaling issues involving geothermal production. When many low to moderate temperature geothermal waters boil calcium carbonate scale is a common result. The scaling rates can vary considerably depending upon a number of factors. In the mid 1980s carbonate scale inhibition became a standard operating practice in many geothermal fields both in the United States and throughout the world. A number of chemicals have proven to be basically 100% effective in eliminating carbonate scaling. The primary difficulty in developing the carbonate scaling programs was development of reliable hardware systems for delivering 10 to 20 ml/minute of chemical below the flash point in the wells. Several types of delivery systems have now been proven to be very reliable and in most geothermal fields carbonate scale inhibition is viewed as a routine operation.

Silica scaling is a much more difficult challenge for high temperature geothermal systems where silica concentrations in the water may exceed 1000 parts per million. In the hotter fields the classical method for dealing with silica is to limit the amount of steam separated from the water, explaining why there are many single flash type power plants. Efforts involving acidification and addition of chemicals to the water have been underway for a number of years to reduce or eliminate silica scale precipitation but results to date have had limited success.

Corrosion is not typically a serious problem in geothermal fields, with the exception of the fields producing hypersaline brines or very high noncondensable gas contents. In the Salton Sea geothermal field the corrosion issue has been addressed by the use of sacrifical liners and titanium casings in the wellbores at considerable costs.

Blackwell, David

Geothermal Resources in Sedimentary Basins

The recent compilation of a Geothermal Map for North America included the use of extensive Bottom Hole Temperature (BHT) data from oil and gas exploration wells in addition to other thermal data sets. These data emphasize the extensive heat resource that occurs within drilled depths in the areas of hydrocarbon production. It is common to have hydrocarbon wells that reach temperatures of 300 to 400 °F, temperatures that are in the range considered developable for electrical energy production in the hydrothermal systems in the western US. However, many of the areas with such high well temperatures are outside of the areas in the western US typically associated with geothermal energy production. For example most of the Midwestern States and several eastern states are included in this category.

There are a number of scenarios for development. These are artificially divided into three for the purposes of discussion: coproduced fluids, geopressure fluids, and sedimentary EGS. These are briefly described and examples of development given for each case.

The category of coproduced fluids is based on the present production of water in association with hydrocarbon production. This category is very cost effective if the water is hot enough to generate electrical power (>200-225 °F). Several specific development cases will be discussed at this conference. Several thousand MW of electricity could be produced using only the present rate of waste fluid production.

There is hot water at some depth everywhere, but in the Texas Gulf Coast and East Texas for example the depths to temperatures of 300 to 400 °F are well within routine drilling ranges (10,000-18,000 ft). In the Gulf Coast the geopressure system well known and there has been a lot of additional drilling since the geothermal activity of the 1980's. In fact a 1 MW power plant was operated on fluid from a geopressured well near Houston, Texas for about 6 months in 1989-1990.

The EGS system involves introducing water into rock of limited permeability (either tight sediment or basement) in a controlled fracture setting so that this water can be withdrawn in other wells and heat extracted. An area that is very favorable is in east Texas and northern Louisiana where the low permeability tight formations of the Jurassic with temperatures over 350 °F are being exploited as tight gas systems.

The resource base for these 3 types of geothermal development has been assessed. There is not sufficient space to explain the details of the assessment, but several comments are pertinent. The first is that the resource is large. Second, the EGS resource base for Texas alone (at temperature above 150 °F and depths less than 22,000 ft) is $7.2x10^{14}$ MW-20yrs. If a recovery factor of 0.0001% is used there is still $7.2x10^{8}$ MW for 20 years available (the present installed electrical power capacity in Texas of $1.01x10^{6}$ MW). The US Geological Survey has estimated the resource in the geopressured setting in Texas and Louisiana to be $1.74x10^{14}$ MW-20yrs plus the dissolved gas. This number is essentially in addition to the EGS component of the resource. In the case of the geopressure there is also the potential for producing huge amounts of gas that would be otherwise uneconomical to produce.

Campbell, Richard

Results of the Demonstration Power Plant on the Pleasant Bayou Geopressured Resource

In the late 1980s, the Ben Holt Company designed, built, and operated a demonstration power plant on the Pleasant Bayou geopressured resource in Texas. The power plant operated successfully, and showed that electricity could be generated from geopressured resources with high reliability while using standard materials of construction. The process used a hybrid cycle where electricity was generated by burning gas in gas engines, and then heat from the gas engine exhaust was used to supplement heat from the high temperature brine to improve efficiency of a binary cycle that generated additional electricity. The project was co-funded by the U.S. Department of Energy and the Electric Power Research Institute.

Capuano, Louis - No Abstract

Creel, Prentice - No Abstract

Dicky, Halley

Small Binary ORC: Field Installations and Future Potential

Organic Rankine Cycle (ORC) power production from low to moderate temperature resources inherently and traditionally has low thermal efficiency. Low efficiency typically requires increased equipment component sizing (turbine, pump, condenser, evaporator), which become cost prohibitive, particularly in lower temperature and smaller capacity applications. Through the innovative use of mass-produced off the shelf air conditioning equipment derived into a modular packaged binary power plant, an intelligent and effective ORC solution is now available with an attractive cost structure almost a full order of magnitude smaller than that of traditional power plant equipment, with reasonable footprint and power density.

By derivitizing a low cost 200+ KW ORC power plant from traditional and well proven HVAC centrifugal water chiller technology that has enjoyed wide scale deployment for over 50 years, the PureCycle™ is both a fuel free and emission free waste heat driven power technology. Commercialized in 2004, the PureCycle™ uses low to moderate temperature waste heat sources; liquids, steam, and exhaust gas, to drive the ORC process, with liquid, evaporative, or air cooled condensing.

This paper describes a frank and provocative discussion of UTC/UTRC's past and present field demonstration projects with lessons learned, product advancements, economic analysis, and future developments as applicable to waste heat and geothermal energy generation in oil and gas settings.

Topics include natural gas-diesel-renewable fueled combustion, microturbine, waste heat, geothermal, oil and gas, off-shore drilling platform, and district heating applications, with an introduction to cascaded multi-working-fluid applications for maximum efficiency from a given geothermal heat source, and combined heat and power (CHP/cogeneration) applications utilizing ORC heat rejection.

Erdlac, Richard

Constraints And Best Use Practice: The Importance Of Texas Geothermal Electrical Energy Production

Every energy resource must be understood within the realm of its constraints and the best use practice for that energy resource. With the peaking of domestic oil and gas, and the potential near term peaking of world production as some experts predict, it is more important now to grasp this approach than ever before.

Geothermal energy has three broad variables that define all of its various constraints: natural (geological/geographical), technical, and human. The natural variable defines two categories of surface and subsurface constraints. Constraints such as landforms, geography, geology, available hear resource, reservoir characteristics, and water both storage and transfer agent of heat are defined by the natural variable. For Texas geothermal production, surface issues are not so much of a problem. Compared to surface accessibility Texas does not many areas that are extremely difficult to reach for drilling purposes. Texas also has the advantage of having access to significant subsurface information that allow detailed analyses of the heat resource, the reservoirs, and deep water availability due to the oil and gas drilling throughout the state. This is of huge advantage for geothermal development and heat extraction due to the decrease in risk when it comes to obtaining the heat. This data provides advance knowledge of the best areas to go for heat energy acquisition.

The technical variable covers constraints such as drilling techniques and patterns, heat acquisition methodologies, environmental concerns (toxic versus nontoxic materials), and data acquisition. The oil and gas industry has spent many billions of dollars over several decades to develop the technical know how to extract ever shrinking reserves of oil and gas. The O&G industry in Texas is no exception, as areas like the Permian Basin, the Gulf Coast, and the Gulf of Mexico have all played important parts within the state economy. The O&G industry has spent much time and effort developing ways to minimize water production to acquire the oil and gas. Thus the actual amount of hot water that lies deep in sedimentary basins may be unknown. However the industry has developed the techniques to extract large fluid flows from the subsurface, technologies that can also be used to move water and recover heat. Seismic data in the form of 2D, 3D, and 4D allows the O&G industry to better understand how sedimentary reservoirs work and to engineer detailed recovery systems for fluid extraction. Finally, while many areas of the world must contend with highly toxic minerals in conjunction with geothermal production, the biggest problems that the O&G industry may face our deposits of calcium, silica, and sulfide scales, problems that the industry has learned to cope with.

Finally, the human variable covers a larger number of constraints and represents the category over which we have the greatest control. These constraints include economic, perception, transmission, information and technology transfer, politics, ownership, resource management, and research, to name just a few. For the O&G industry, perception may be the principal hurdle to jump. Since the onset of the industry, hot water has been the biggest liability involved with both drilling and production. The hot temperatures have caused numerous downhole problems that compelled development of specialty steels and designs for equipment that could withstand these temperatures. High volume water production has required either a nearby injection or trucking of water to a disposal well. To develop Texas geothermal energy requires a change in attitude in the way that hot water is handled. It is the stored heat within the water that has value as it is used to generate electricity or used in other industries that require hot water.

Possibly the second most important constraint of this category involves transmission, especially as related to profit. When oil and gas is produced, these energy resources are rather easily placed within a delivery system, either a pipeline or a truck, to be shipped to the processing plant further development. Many O&G companies see their profit only at the wellhead, not in the finished product. However geothermal is different. When the hot water is produced, electricity must be produced near the wellhead so as to minimize heat loss in the pipeline. It is the electricity that is then "shipped out" to the retail or wholesale user. This is a distinct change in energy development that and O&G operator must realize. They can produce the water and they must produce the product before it is transmitted. The good news is actual transmission of the electricity may not be too difficult. For example, the Ercot grid system extends into areas of the Delaware and Val Verde Basins not only because of the wind farms that have been constructed, but also because of the need to deliver electrical power to the O&G infrastructure on the ground. Thus established electrical rights of ways that bring electricity to a producing field can also send electricity out of that field if hot water is used to generate electricity on site.

Finally, Texas geothermal energy production can help to release other energy resources presently in use for electricity production that might be better used elsewhere. For example, Matthew Simmons has indicated that natural gas has been one of the best sources of heat that we have, and finding a replacement for this energy resource is a problem. Thus the use of geothermal production for electricity generation would go a long way to free up natural gas for other industrial needs. Additionally, geothermal power plants may have the best all round availability factor of 97.5% or more of any energy resource in use.

The development of Texas geothermal energy will change the future of both the oil and gas and the geothermal energy industries. It is the Texas oil and gas industry that is best suited to take advantage of this undeveloped energy resource in its near term development. And it is the O&G infrastructure in the form of data and personnel that can make this a reality.

Erdlac, Richard

Texas Geothermal Energy: A Focus On Permian Basin And Trans-Pecos Regions

The Delaware and Val Verde Basins form the deepest parts of the Permian Basin. They represent one of 5 regions within the state that have the potential for holding vast amounts of renewable heat energy. Temperatures well in excess of 212^{o}F are present in deep wells. Using existing technology, this hot water, generally considered a liability when encountered in the O&G drilling process, holds the key for a restoration of the Texas oil and gas industry and its infrastructure for decades to come. This represents an unconventional approach to geothermal energy development.

Investigations of the Delaware and Val Verde Basins have begun by compiling a detailed database of wells within the region of study, using log headers as the source of initial information. This region presently includes Ward, Winkler, Loving, Reeves, Culberson, Pecos, Terrell, Val Verde, and parts of Crockett Counties. Two previously existing databases have recently been provided for inclusion within the new database being constructed. Initial efforts began with a focus on UT Lands but have since expanded into non-UT Lands within these counties.

Initial results in Pecos County, indicate that the mean temperature at between 20,000 and 21,000 feet is around 295^{o}F. However, a work map plotting the location of wells with temperature data in Pecos shows numerous wells at this level in the low 300^{o}F range. In fact a map at the 18,000 to 19,000 foot level also displays some wells into the low 300^{o}F range.

Reasons for this variation may be related to the complex structural nature of the basin. Local faults may be allowing hot water from various depths to penetrate to shallow depths along open conduits. Alternatively the timing of temperature recording in the well may play a large part in local temperature differences. Drilling a well will cool the annulus around the well bore. Thus a temperature reading taken immediately after drilling will record a lower temperature than if some time is allowed to pass for equilibrium to be reached. Several wells were encountered with temperature values at the same depth as low as 20^{o}F and as much as 100^{o}F different over a period of time.

The Delaware Basin covers a minimum of 5,500 sq. miles. The only Texas geothermal plant, built in Brazoria County along the Gulf Coast, was estimated to have been capable of 1.1 MW from the heat energy out of the Frio Sandstone alone. Only one zone was produced at this site originally, so this number may be low as well. Investigations in the Gulf Coast within the Brazoria, Matagorda, and Corpus Christi fairways suggested the areas, the number of plants, and the number of wells per plant that could be developed. Using information from the Brazoria geothermal power plant, where produced brine was around 277^{o}F, along with these fairway estimates, we calculated that the Delaware Basin had a minimum range of geothermal generation of 264 to 933 MW. We anticipate that these values are very much on the low side. Information from an Ormat geothermal field in an Imperial Valley sandstone suggests that production for a 50 MW plant requires around 5,000 acres for production at a temperature of 300^{o}F. Applying these figures to the Delaware Basin suggests a maximum geothermal rating of around 35,000 MW for the entire basin. The truth is likely somewhere in between these two numbers.

The Trans-Pecos region represents the only area within Texas where the geothermal potential follows more along the line of conventional geothermal development. It represents a second of the five potential regions in the state where geothermal electric power has a potential for development. In this area hot temperatures and hot water is shallower than what is found in the Delaware Basin. After being compressed during Laramide compression, the region is presently being extended due to Basin and Range tension. The region is more recently tectonically active with accompanying volcanic activity that has helped to increase the temperature at shallower depths.

In addition to local hot springs, the oil and gas industry spent time and money drilling in the Trans-Pecos looking at possible overthrust plays. Although little to no oil or gas has been successfully produced, these wells do provide an additional source of subsurface data regarding temperature and geologic strata. Just as temperature-depth data in the Delaware and Val Verde Basins demonstrate a non-linear aspect to thermal gradients, the O&G bottom hole temperature data in the Trans-Pecos also shows a similar non-linear distribution.

Conventional geothermal energy companies have yet to target deep sedimentary basins due to a lack of knowledge…knowledge of the available resource…knowledge of the subsurface geological architecture…and knowledge of the data resources developed over many decades of oil and gas production. The oil and gas industry has not taken advantage of geothermal energy because of the perceived liability of hot water within oil and gas operations. The existing O&G industry, possibly in partnership with the geothermal industry, is presently poised to take advantage of this energy resource and begin developing heat energy concurrently with oil and gas production efforts in a more consolidated energy approach.

Gosnold, Will

Geothermal Prospects in the North Central United States

Heat flow, thermal properties, and stratigraphic data have been combined to generate thermostratigraphy for sedimentary basins in the North Central United States.

Normal continental heat flow and subsurface temperatures characterize most of the region; but, in basins in North Dakota and South Dakota, the thermal blanketing effect of thick sections of shales and heat advection in regional groundwater flow systems lead to abnormally high temperatures. Temperatures of 150 °C can be found in the deeper regions of the Williston Basin and temperatures greater than 90 °C occur widely in the basin. Comparison bottom hole temperature data with equilibrium temperature measurements indicates that the BHT data are less reliable estimators of temperature than general thermostratigraphic estimates. In general, the recoverable stratabound geothermal resource in the region exceeds the energy that could be recovered from oil production.

Hays, Lance

Optimizing Separation and Power Generation from Two-Phase and Three-Phase Well Flows

A separating turbine technology to both separate and generate power from two-phase and three-phase hydrocarbon and geothermal flows has been commercialized. Additionally a power cycle based upon commercial two-phase turbines has been engineered and found to maximize power generation from separated fluid streams having sensible heat as the energy source.

Commercial and demonstration experience with the separating turbine technology will be reported for two-phase and three-phase separation and power generation for high pressure oil, gas and water flows. Results of a demonstration of the technology for power generation from a high pressure geothermal well will be reported. Results of an engineering study of a two-phase cycle using a hermetic two-phase refrigerant turbine will be discussed for a low temperature geothermal application.

A combined system to maximize the power generation from three-phase well flows while providing clean separated streams of oil, gas and water is proposed. At a well flow temperature of 330 F the system can produce separated oil and water streams with less than 20 ppmw cross contamination, a separated gas stream with less than .01% liquid carryover and a 50% more power production from the hot separated water than an organic Rankine cycle. In addition, for high pressure wells, power is produced from the separation process.

Hill, Roger

The Role of Geothermal in a Western Utility Portfolio

This paper examines how geothermal power will fit into the Western US regional utility generation portfolio. It is based on the economic analysis performed by co-author Awerbuch and expands on the geothermal aspects and implications of his work. His work examines not only the costs of generation by various types of generators, but also the risk in price by those generators. The input assumptions largely come from the Energy Information Administration (EIA), but allowances for future geothermal generation are made. This paper looks at the Awerbuch results and draws conclusions for geothermal expansion into the western portfolio. The published Awerbuch work is entitled: *The Cost of Geothermal Energy in the Western US Region: A Portfolio-Based Approach*.

The Awerbuch results are that:

- Portfolio optimization locates generating mixes with lowest-expected cost at every level of risk
  - Risk is the year-to-year variability of technology generating costs
- The EIA National Electricity Modeling System (NEMS) projected generating mixes serve as a benchmark or starting point;
  - Detailed decommissioning date assumptions using World Electricity Power Plant Database age of existing plants
- The optimal results generally indicate that compared to EIA target mixes, there exist generating mixes with larger geothermal shares at no greater expected cost or risk
  - There exist mixes with larger geothermal shares that exhibit lower expected cost and risk

Observations are made and conclusions drawn about market implications for geothermal energy.

Johnson, Doug

Regulations Applicable to the Development of Geothermal Resources in Texas

The Geothermal Resources Act of 1975 is the primary law governing the development of geothermal resources in Texas (Chapter 141 of the Natural Resources Code). The Act empowers the Railroad

Commission to regulate the exploration, development, and production of geothermal energy and associated resources for the purpose of conservation and protection of correlative rights. The Act required the Railroad Commission to adopt rules governing protection of the environment, prevention of waste, protection of the general public against injury or damage, and protection of correlative rights. This is essentially the same framework structuring regulation of oil and gas exploration and development. Accordingly, on November 3, 1975, the Railroad Commission issued Order No. 20-65,518 extending, where applicable, the existing "General Conservation Regulations of Statewide Application" (Statewide Rules) to the "regulation and control of the orderly exploration, development and production of geothermal energy and associated resources for the State of Texas." The presentation summarizes existing regulations applicable to the development of geothermal resources in Texas and some of the information resources maintained by the Railroad Commission that may be helpful to the geothermal community.

Kapner, Mark

Austin Energy's GreenChoice Program

This presentation will explain how the GreenChoice Program works to give its customers a say in increasing the utility's use of renewable energy resources in its generation mix. It will emphasize the resource procurement aspect of GreenChoice through competitive solicitations. Austin Energy has issued four Requests for Proposals, over the past seven years, for purchase of electricity from renewable resources. While Austin Energy's five power purchase contracts have been for wind and landfill methane-generated power, the procurement process is relevant to geothermal developers who hope to sell electric energy to utilities in the future.

Karl, Bernie

Chena Hot Springs Resort: Geothermal Electrical Applications in Alaska

Chena Hot Springs is located 60 miles northeast of Fairbanks, Alaska. It was officially discovered in 1905 by miners from Fairbanks. Chena quickly became a popular local destination, which it remains to this day. The springs and the 440 surrounding acres were privatized as a patented homestead in 1920, and have changed hands several times since then. The resort centered on the hot springs but fell into disrepair in the 1970's and '80's, and ultimately the owners filed bankruptcy. When the Karl's purchased the resort in 1998, they began work immediately to turn around the decline. Within the first week of owning the Resort, they drilled the first geothermal well onsite. By the first winter, they had established the district heating system still in use to heat all 30+ buildings. They also added a natural outdoor Rock Lake, which increased local visitors to the resort by 600% in the following year. Today, Chena Hot Springs Resort is the largest wintertime tourism destination in Alaska outside the Anchorage area.

While the main draw is still viewing the northern lights and soaking in the Rock Lake, the Aurora Ice Museum, the largest year-round ice structure in the world, is drawing new visitors. It boasts fantastic carvings and structures including an overview tower, jousting knights, an ice bar where martinis are served in ice glasses, a life size polar bear and giant chess set, among numerous other features. The Ice Museum is cooled primarily with the geothermal water through the use of an absorption chiller – the first of its kind ever built. With the number of visitors increasing steadily each year, Bernie and Connie have turned their attention to making Chena Hot Springs into a sustainable community. To accomplish this they have established 3 greenhouses, all geothermally heated, to provide fresh produce to the Resort restaurant. Their next project is the installation of the first geothermal power plant in Alaska, which will be installed using an ORC power plant designed and built by United Technologies. The power plant is expected to be online by May, 2006, and will dramatically reduce the power generation expenses for this remote, off-grid site.

LaSala, Raymond - No Abstract

McKenna, Jason - No Abstract

Milliken, Mark

Tea Pot Dome Case Study, Wyoming

Naval Petroleum Reserve #3 is located at Teapot Dome field in Natrona County, Wyoming. The structure is a typical Laramide asymmetrical drape fold, bounded on the west by a basement-involved blind thrust fault. Commercial oil production occurred in the early 1920s for a brief period, followed by a long shut-in period. NPR-3 was opened to full field development in 1976. An abundance of relatively fresh hot water (180° - 200° F) was produced in association with Pennsylvanian Tensleep oil from depths of about 5000 ft. Water supply wells drilled to the underlying Mississippian Madison Limestone yielded rates exceeding 20,000 BWPD flowing at formation temperatures projected to be about 230° F. Artesian flow of the Teapot Dome geothermal system is caused by forced convection resulting from recharge in the Big Horn Range located 90 miles NW. The Big Horn recharge area represents a hydraulic head of about 8000 vertical ft above the NPR-3 surface. Pumping could increase rates by factors in the range of two to four. The geothermal gradient of 25° F per 1000 ft of depth at NPR-3 is 9% higher than the average for the Southern Powder River Basin. Fractured Precambrian basement granitic rocks at depths of 7000 ft and more may yield substantially larger volumes of water at temperatures exceeding 250° F. Power potential at NPR-3 from 130 MBWPD at 220° F would be 76 MW.

Mines, Greg

Overview of Contributors to the Cost of Geothermal Power Production

There are numerous contributors to the cost of generating electricity from geothermal energy. Capital costs are incurred beginning during the exploratory phases of a project and continue through the completion of the power plant construction and well field development. Once power generation begins, the operating costs associated with both the plant and the well field will also influence the power generation cost. Factors such as the resource temperature and geothermal fluid flow rates will impact the ability to generate power, as will both the availability of water and the ambient conditions. This presentation will provide a brief overview of the various contributors to the cost of geothermal power and the factors that influence the magnitude of the various contributions. The emphasis of the presentation will be on those costs when a binary power plant is used as the energy conversion system.

Petty, Susan

U.S. 2006 Enhanced Geothermal Systems Resource Evaluation

As part of a study lead by Dr. Jefferson Tester of MIT, conducted for the U.S. Department of Energy Geothermal Technologies Program, the feasibility of developing a substantial amount of the energy needed in the future to supply electric power across the US from Enhanced Geothermal Systems. As part of this study, the amount of power production potential is being evaluated. Maps developed here at SMU by Dr. David Blackwell combined with calculations of heat in place, recoverable heat, conversion efficiency and the area with resource that can be accessed were used to determine the developable resource. The area of the US and individual states underlying parks, recreation areas, wilderness and other undevelopable areas was excluded from the study. Only a 10 temperature drop in the rock was allowed. Using very conservative estimates, this developable resource ranges from 4.3 to 43 x 10^6 MWe. The penetration of this resource into power markets was studied using project economics developed using the GETEM costing code developed for the US DOE Geothermal Technologies Program. The resource is so large that even without considering recovery of a heat mined from the reservoir, the resource can be considered sustainable. While only a small fraction of this resource might be developable in the near future at economic rates, the potential for technology improvement, including results of the Soultz project in France and the Cooper Basin project in Australia, can improve economics to allow more than 50,000 MWe to become economic over the next 40 years.

Petty, Susan

Development of Geothermal Power from the Poplar Dome Oilfield, Montana

The existence of a geothermal resource in the permeable formations of the Poplar Dome was first detected when oil wells drilled into the Madison Limestone produced hot water. The field produces about 20,000 BPD of water over 265°F (130°C), and this could be doubled if the hottest wells that were uneconomic for oil but produce hot water were recompleted. Enhancing unused high temperature wells and recompleting at the intervals with highest temperature could increase the overall temperature of the fluid to 155°C (300°F). Economics for power generation for two scenarios were calculated using the GETEM geothermal costing model developed by the DOE Geothermal Technology Program. In the first, wells of opportunity producing already at the southeast side of the oilfield are collected and used to supply a 1 MW stand alone binary power plant similar to that used at the Wendell-Amedee KGRA near Susanville, CA. The plant is assumed to run unattended with telemetry of data to a facility in Denver, CO where the performance is monitored. Oil is separated from the water in the produced fluids to improve economics and prevent fouling of the heat exchangers. In this scenario, despite the low cost for the resource, a little more than 1 MW is produced using the existing fluid at a cost of power of over 11¢/kW-hr. In the second scenario, unused wells in the high temperature part of the field are recompleted to produce the maximum amount and temperature of fluids. The wells are hydro-fraced in the high temperature water zone to improve productivity. This scenario yields a cost of just over 6.5¢/kW-hr and produces more than 3 MW.

Renner, Joel

Pleasant Bayou, Texas Geopressured-Geothermal Reservoir

The Pleasant Bayou No. 2 well was drilled in 1979 to a total depth of 16,500 feet for the U.S Department of Energy's Geopressured-Geothermal Program. Testing of the well began in 1980 and the well was flowed for 60 days at an average rate of about 12,000 barrels per day (bpd). Flow rates as high as 29,000 bpd were achieved for a short period in 1981. From September 1982 through April 1983 almost 3.5 million barrels of brine were produced at an average rate of 18,200 stock tank barrels per day (STB/d). Another long-term flow test from May 1988 to September 1992 produced 25 million STB.

Production was from the C-zone of the lower Frio sandstone in a wave-modified deltaic sequence. Production is believed to be from distributory-channel and channel-mouth bar sandstones. Growth faults provide reservoir boundaries on three sides. The reservoir boundary is not clearly located to the south.

Modeling of the reservoir by Shook (1992), based on geology and well tests, suggests that the reservoir pore volume is about 43.6×10^9 ft^3. Reservoir pressure is 10,716 psia, temperature is 306°F, salinity is about 130,000 ppm, and the methane content is about 24 standard cubic feet per STB of brine. He uses a porosity of 18% for the middle reservoir sand and 9% for the upper and lower sand units. Permeability in the production sands is believed to range from 110 to 180 milli-darcies.

Shook's modeling suggests that the reservoir is maintained by fluid recharge across a pressure-dependent fault and that the reservoir volume indicated by the 1982-1983 flow test was in communication with a larger volume in 1992. Shook estimates that Pleasant Bayou 2 is capable of producing 20,000 STB/d of brine for at least 10 years of production.

Shook, Mike

Heat Extraction from Boreholes

A series of parametric studies are presented that illustrate the potential for energy production from deep sedimentary basins. Single wellbore heat exchanger with no circulation in the formation, multi-lateral completions for single wellbore fluid circulation, and conventional multi-well circulation strategies were investigated. Our results show that power generation from sedimentary basins is possible, but requires significant fluid production rates. If the fluid volume is small, reinjection of produced fluids may be necessary to maintain reservoir pressure. Under those conditions, premature breakthrough of cooler injectate reduces energy extraction. Multi-lateral well completions work to improve fluid residence time. Either excessive overpressure or extensive sedimentary formation volume is required to sustain power production in the absence of fluid injection. Mature oil and gas fields, especially those under waterflood, are reasonable candidates for power production.

Smith, Russel - No Abstract

Smith, Tim

Overview of Renewable Energy Credit Markets

The market for Renewable Energy Credits (RECs) is growing rapidly in the United States. There are currently 21 states that have a mandate in varying stages of development for load-serving entities, and over 5 million megawatt-hours of RECs were sold to voluntary customers in 2005. RECs are a complicated concept to grasp, and this problem is magnified by a lack of any national standard. All markets, both mandatory and voluntary, are unique in their rules and definitions. REC markets are very illiquid, and there is little transparency. This makes understanding the markets and keeping up to date with them is typically difficult.

The goal of my presentation will be to give an overview of the REC markets. I will describe what a REC is, define and distinguish mandatory and voluntary markets, and discuss pricing. My focus will be on discussing markets in the Gulf States region.

Taylor, Dub - No Abstract

Thomsen, Paul

New Technologies for Modular Geothermal Power Plants in Oil and Gas Settings

Presentation discusses ORMAT's actual case histories and application information for modular geothermal power plants from 250KW to 1MW. ORMAT's field proven technology has optimized transportability, lowered installation costs, and created unmanned, automatic operation making it an ideal technology for well field settings.

Ziagos, John

Geothermal Energy in Energy Planning

Many energy projection analyses commonly focus on individual supply sectors, and as such provide little insight into the interrelationships between sectors and the total system requirements. Lawrence Livermore National Laboratory (LLNL) has published energy flowcharts based on data from the Energy Information Administration (EIA) since 1973. This allows comprehensive easily visualized charts of U.S. energy supply and use patterns. Charts have been constructed since 1973 with charts going back to 1950 (at *http://eed.llnl.gov/flow/*). Recently, we have expanded and automated the energy flowchart methodology to examine *future* scenarios of the U.S. energy system allowing investigation of end-member states under different constraints while seeking particular goals. Here, we focus on a portfolio of renewable technologies at their upper limits, including geothermal energy, coupled with significant carbon capture and storage, to support a full-blown hydrogen transportation sector, eliminating CO_2 emissions from transportation and electrical generation. In particular, possible roles for geothermal energy in a reduced carbon emissions 2050 scenario are explored.

The 2050 scenarios range from Business-as-Usual (BAU) to a dramatic renewable deployment including an optimistic geothermal energy option, a carbonless transportation system based on hydrogen with carbon reduction with capture & storage, illustrating profound consequences for the future U.S. energy system structure. For example, the 2050 BAU case demonstrates that an unacceptable level of fossil fuels will be required mainly driven by increased transportation and electrical generation demands. Also, fueling a high-efficiency U.S. 2050 light-duty fleet (80 mpg equivalent) with H_2 produced by coal gasification would require capture and sequestration of ~2 billion tons of CO_2/yr. Analysis highlights primary energy production shifts to renewables away from fossil fuels, geothermal energy's ultimate potential, CO_2 sequestration requirements, opportunities for increasing efficiency, and potential technology gaps. The closed nature of the methodology bounds supply and flow volumes quantitatively and comprehensively, prompting debate about real needs and enabling cross-sector discussions. Future analyses will explore other possibilities for geothermal energy under different assumptions and under additional constraints (e.g., economic, technical) to highlight their broader implications.