# The McGinness Hills Geothermal Project

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***Keywords***

*Nevada, McGinness Hills, Ormat, Ormat Energy Converter, OEC, Organic Rankine Cycle, ORC, modular, geothermal, air-cooled, NV Energy, integrated two-level unit, U.S. Department of Energy, DOE, Bureau of Land Management, BLM, Nevada Division of Wildlife*

## Introduction

The McGinness Hills Geothermal Project was completed in July 2012 and provides 30 MW of base-load renewable power to the NV Energy transmission system. This project was awarded GEA Honors for environmental stewardship (nominated by the Bureau of Land Management) by the Geothermal Energy Association, signifying it as a major accomplishment for Ormat, and the geothermal industry.

Geothermal development is no easy task; discovering a geothermal resource is a difficult and risky procedure and developing the project can easily be just as difficult. In this paper we will illustrate both the unique challenges of the McGinness project along with insight on how Ormat is excelling in the art of geothermal development and developing profound technologies continually pushing the industry forward.

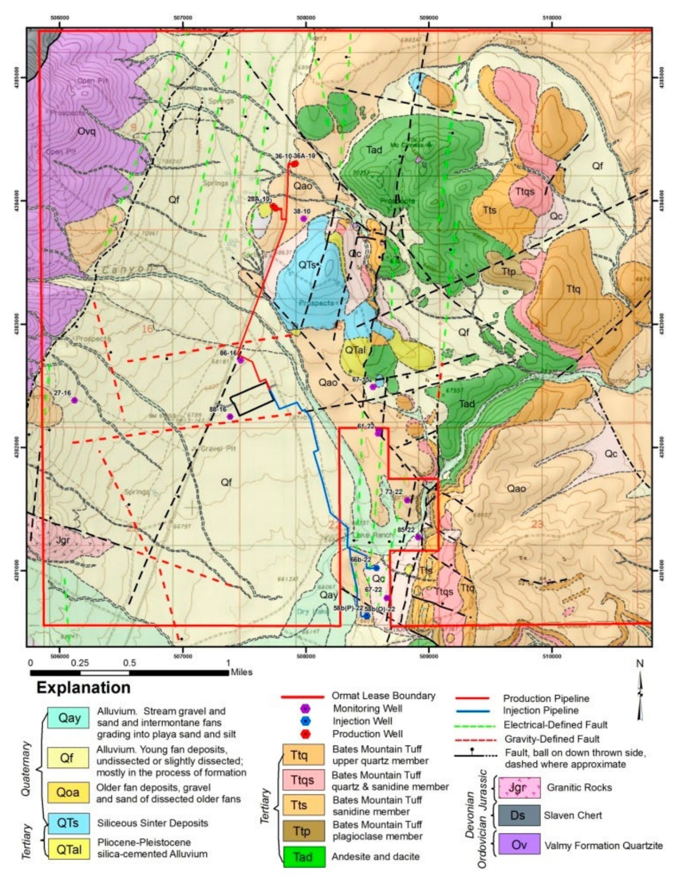

**Figure 1.** Generalized geologic map of McGinness including well locations (Geology after Stewart and Mchkee, 1969; Wendell, 1985; and Delwiche unpublished work, 2012).

## Ormat History

Ormat, now the household name in geothermal energy, began focusing on the benefits of clean, reliable energy over four decades ago. In the early 1970s Ormat commercialized the Organic Rankine Cycle technology for the application of remote power solutions, manufacturing small (in today's standards) power units in Massachusetts. This technology was adapted and well received by the then booming pipeline industry in North America. This industry was using the technology to reliably operate remotely gave valve power shelters in very remote areas and extreme environmental conditions. In the early 1980s, Ormat ventured into geothermal, commercializing low temperature geothermal power in the U.S. The first installation of the Ormat Energy Converter (OEC) in 1984, outside of Yerington, Nevada, is still in operation today proving the reliability and dependability of Ormat's technology. As low temperature geothermal power generation began to grow in the U.S. in the early 1990s and Ormat's technology was proving to be the primary choice, Ormat began to expand the application for its OEC to offshore platforms and waste heat recovery installations. In the late 1990s, Ormat expanded to owning and operating geothermal projects that generate revenue through electricity sales. Ormat's stance as a primary geothermal developer and the major supplier of ORC technology grew quickly in the new century. Today, with over 586 MW of geothermal and Recovered Energy Generation power plants, and with over 1,600 MW of installed OEC capacity worldwide, Ormat has firmly planted itself in the development and support of clean energy, and has been able to prove, where many have failed, that there is a long-term, reliable, solution for the world's energy crisis.

## The McGinness Hills Geothermal Project History

The McGinness Hills geothermal area is located approximately 11 miles northeast of Austin, NV, within the basin and range physiographic province and along the hills on the eastern flank of the Toiyabe Range (Figure 1). The Toiyabe Range consists of Paleozoic marine strata cut by thrust faults related to the Antler orogeny. Major north-northeast, northwest, and east-northeast striking faults intersect with the McGinness Hills Geothermal Project area and are related to the active geothermal system (Delwiche, 2012) (Figure 2).

A unique attribute of the McGinness Hills geothermal project area is that no modern hot springs or other thermal features exist, making it a "blind" geothermal system. However, surface evidence for a recently active geothermal system include 1) two K-Ar radiometric age determinations on the hydrothermal mineral 'adularia' of 2.2 and 3.2 m.y. (±0.4 m.y.), 2) presence of extensive sinter deposits consisting of opal and chalcedony hydrothermal silica, and 3) presence of Quaternary alluvium evidently silica-cemented by influence of thermal fluids (Casaceli et al., 1986; Delwiche, 2012).

The geology, geochemistry, and alteration of McGinness Hills were initially investigated through the course of mineral exploration during the early 1980s (Wendel, 1985; Casaceli et al., 1986). Between 1982 and 1984 the Anaconda Minerals Company and the FMC Corporation drilled 16 shallow wells. The Anaconda Minerals Company drilled four holes in 1982 and FMC Corporation drilled 12 reverse circulation holes in 1984. None of these holes encountered economic-grade precious metal deposits although hot water was found in some of the holes. More recent mineral exploration drilling by Newcrest Resources, Inc. in 2004 intercepted near boiling waters up to 190°F between 980 to 1200 ft. depths beneath the sinter mound with some geysering observed. Two fluid samples collected from the drill holes yielded silica geothermometers up to 346°F. Further studies published in 2009 focus on the mineralogical and petrographic characteristics of the sinter deposits (Ertel, 2009).

## Early Exploration Efforts

Exploration efforts of McGinness Hills included a number of studies performed prior to and following Ormat's establishment of a lease position in August 2007. Some initial background research uncovered publically available geoscientific studies including the mineral exploration thesis by Wendell (1985) and archived mineral exploration project data from the Anaconda Mining Company. These data provided significant geologic, geophysical, and geochemical data that enhanced our early understanding of the geologic controls on the hydrothermal system. A data sharing agreement was also established with Newcrest Resources Inc. who provided additional geologic and drilling data. The mineral exploration conducted prior to exploration by Ormat included 1) soil, rock, and fluid chemical analyses, 2) geologic mapping, 3) electrical surveys, 4) K/Ar radiometric dating, 5) trenching, 6) mineral exploration drilling (up to 1200 ft depth), and 7) petrogenesis studies.

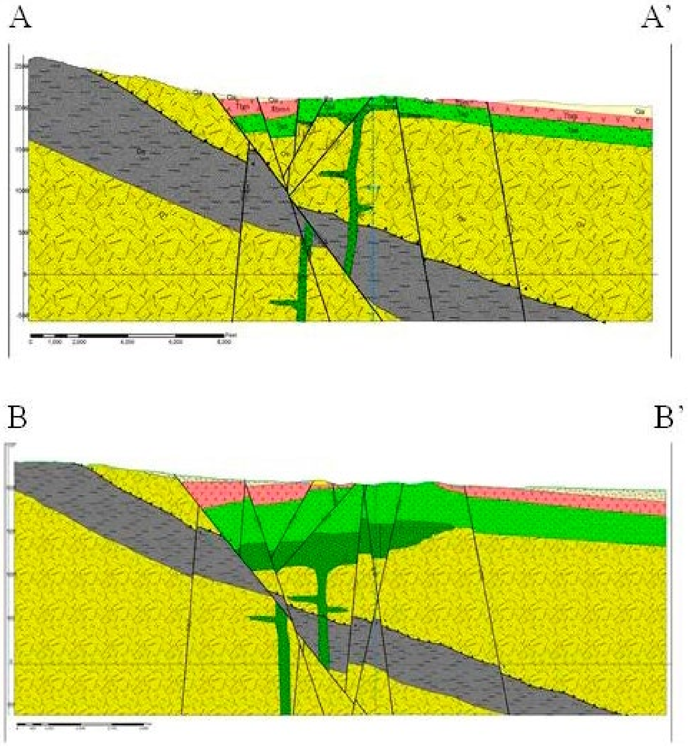

**Figure 2.** West-East cross sections of the McGinness Hills project area. Distribution of formations and faults are generalized (see figure 1 for unit descriptions).

Exploration efforts performed by Ormat included 1) water chemistry, 2) detailed geologic mapping 3) gravity survey 4) CSAMT, MT, & Schlumberger sounding electrical surveys, 5) 3D GIS modeling, 6) shallow temperature gradient core hole drilling, and 7) drilling of initial slim holes and full-size wells.

The first major development decision is where to drill the first set of exploration wells. The first well selection at the McGinness Hill project was 38-10. This well was selected to test the temperature and permeability of both WNW and ESE dipping faults inferred to exist locally (Figure 1). This well was drilled in May-June 2009 and was completed to a depth of 2,138 ft. The well flowed approximately 112 gpm with a productivity of 0.44 gpm/psi and saw maximum producing temperatures of 309°F (Figure 3). The hole was logged with a Schlumberger FMI (Formation Micro-Imager) geophysical tool and the resulting data were processed and interpreted. An assessment of these results indicated that the low productivity was likely related to: 1) silica precipitated from thermal fluids into the fracture network and 2) because the fault zone was encountered in limestone, which can deform plastically and seal fractures given adequate time and heat.

**Figure 3.** Well drilling at the McGinness Hills project.

Well 38-10 was considered a partial success. The decision was made to drill a full size well at 28-10, located approximately 830 ft. west-northwest of 38-10, to intersect the same fault zone, but 1,000 ft. deeper to see higher temperatures and permeability.

Well 28-10 was drilled from August through September 2009, and was completed to a depth of 3,400 ft. Initially, the well flowed approximately 677 gpm at a temperature of 340°F, with a productivity index of 67.7 gpm/psi. This well proved to be very productive and so 28A-10 and 28B-10 were then drilled on the same well pad.. Wells 28A-10 and 28B-10 both proved to be very productive wells with high flow rates (limited only by the pump) and commercial temperatures similar to 28-10.

While drilling 28-10, four temperature gradient holes were also drilled to a depth of approximately 500 ft. along a northeast striking fault. Temperatures encountered werefrom 175°F to 257°F and temperature gradients ranged from 25 to 35F/100 ft (Figure 3). Data from these holes were synthesized with in-house geologic data and previous mineral exploration results to identify the location for a deep test slim hole (58b(O)-22) located at the southern end of the project.

Well 58b(O)-22 was drilled from October through November 2009, and proved to be a very good production hole. The hole was completed to a depth of 2,467 ft. and produced approximately 137 gpm at 308°F, with a productivity index of 137 gpm/psi (Table 1). These successful results led to drilling of a twinned full-size well, 58B(P)-22, which was completed in March, 2010. Well 58B(P)-22 let to the selection of a second full-size well, 66b(P)-22. This well is approximately 1,300 ft. to the north and was completed in July, 2010. This well also proved to be successful by producing fluids at 317°F with a productivity index similar to the other successful full-size wells at the project.

Results of the 28-10 pad drilling led to an additional production well at 36-10, approximately 1,200 ft. north-northeast (figure 1).

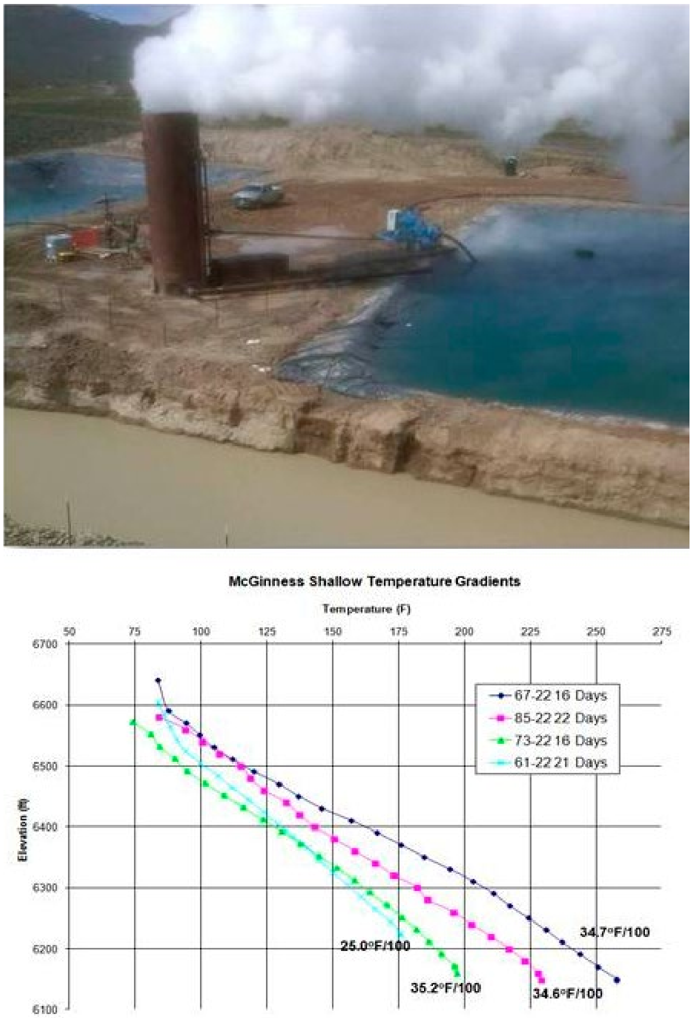

**Figure 4.** Long-term flow test and shallow temperature gradients at the McGinness Hills project.

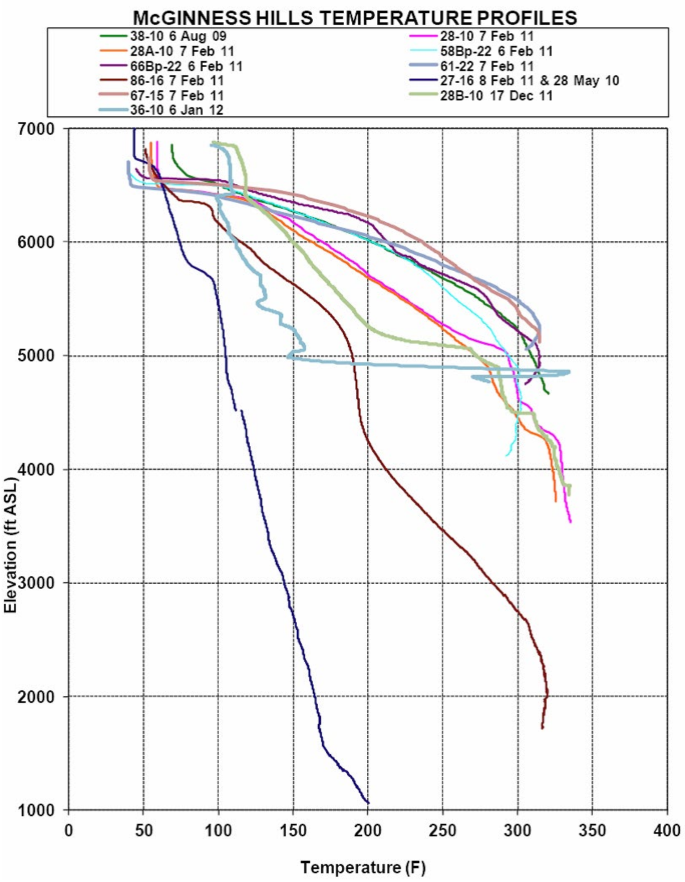

**Figure 5.** Temperature profiles of wells drilled at the McGinness Hills project.

**Table 1.** Summary of production and injection wells for the McGinness Hills project.

PRODUCTION WELLS

| Well | Pump Depth<br>(feet) | Pressure<br>(psig) | Temperature<br>(°F) | Productivity<br>(gpm/psi) | Pump Rate<br>(gpm) |
|---|---|---|---|---|---|
| 28-10 | 1500 | 472 | 328 | 67.7 | 2350 |
| 28A-10 | 1500 | 476 | 328 | 31.6 | 2350 |
| 28B-10 | 1500 | 471 | 338 | 999 | 2350 |
| 36-10 | 1500 | 482 | 335 | 250 | 2350 |
| 36A-10 drilling | 1500 | ~480 | ~335 | ~250 | 2350 |

INJECTION WELLS

| Well | Injection Depth (feet) | Injectivity (gpm/psi) | Injection Rate (gpm) |
|---|---|---|---|
| 58B-22 | 2415 | 137 | 3533 |
| 58BP-22 | 2480 | 129 | 3533 |
| 66BP-22 | 1730 | 2354 | 3533 |

This well was drilled from November through December 2011, and exhibited temperatures of 336°F and a high productivity index. Well 36A-10 was then drilled on the same pad and completed in February 2012.

A number of multi-well flow tests were performed to understand geothermal reservoir characteristics including temperature, recharge, productivity, injectivity, and interference among wells (Figure 4). These qualities are imperative to understand in order to model and maintain a long-term production and injection plan for stable power generation.

The first major test consisted of flowing 7.5 million gallons of fluid from well 58b(P)-22 and injecting the fluids into 61-22. Pressures were monitored in the wells (and other monitoring wells) for approximately one week before the test, during the test, and for two weeks after the tests. Pressure results showed a very equal response indicating a continuous production zone between wells throughout the field.

The second major test was designed to better quantify the recharge and interference of the geothermal reservoir. First, approximately 7.5 million gallons of fluid were produced from wells 66B(P)-22 and 28A-10 into large sumps. Pressures throughout the field were monitored before, during, and after the test to gauge recharge capability. After one week of pressure monitoring, the fluids were injected into 61-22 over four days. Pressures were again monitored during and after the test to understand interferences in the field. Both pressure recharge and interference results were favorable to long-term production and were integrated into the numerical model.

Many simulations were run using the numerical model to predict the production and injection response over 20 years. Results of the numerical model determined the most favorable well field configuration between production and injection to support a 30 MWe power plant.

In the end, five production wells and three injection wells were selected for the McGinness Hills geothermal project to support long-term power production (Figure 5, Table 1).

## Permitting

Permitting for any geothermal project is a lengthy and detailed effort, and can present many challenges in the project's development. Permits are required to do anything that will affect the natural state of the environment at the site. This is necessary as the site, particularly in the McGinness Hills project, is public land. The permitting process, as defined by the National Environmental Protection Agency (NEPA), is both time and resource consuming. Typically, the NEPA process will take between 12-18 months to complete a full project Environmental Assessment (EA). This is required before wells can be drilled and a power plant can be built. If the EA determines that the proposed project cannot be developed without creating significant environmental impacts, additional public and agency involvement are required in development of an Environmental Impact Statement (EIS).

**Figure 6.** The greater Sage Grouse (*Centrocercus urophasianus*).

In general, the McGinness Hills project is similar to many other geothermal projects developed in the state of Nevada. The project is located on public lands, in an area that is mostly uninhabited and un-developed. But, there was uniqueness about McGinness Hills that separated it from any other geothermal project developed in Nevada.

**Figure 7.** A Sage Grouse Lek.

The McGinness Hills project was located in Category 1 sage grouse habitat. The sage grouse (*Centrocerus urophasianus*) is a large chicken-like land bird that uses sagebrush grasslands as a habitat (Nevada Department of Wildlife, 2013)(Figure 6). Sage grouse can be found throughout Nevada, and the Department of the Interior has given sage grouse the status of "warranted but precluded" which essentially places the bird on a waiting list for federal protection. The sage grouse gather in the spring on strutting grounds called leks (Figure 7). Leks are generally found in open areas where the males can strut to attract females for mating. Their strutting performance is unique, inflating pouches in their chests that make distinct popping noises. After mating, the hens nest in sagebrush for protection against predators and elements. Chicks take approximately one month to hatch and are out of the nest and flying within weeks. Usually, by mid-August, the birds have reached adult size (Nevada Department of Wildlife, 2013).

Given the status of sage grouse and their habitat, the Bureau of Land Management (BLM) issued an interim guidance to Field Offices (Instruction Memorandum 2012-043) in 2012 to direct mitigation efforts for any development in on or near sage grouse habitat. For energy developments the Instruction Memorandum (IM) guides the BLM to closely consider a number of mitigation conditions including; noise, seasonal restrictions, minimizing habitat fragmentation, improved reclamation, siting, design, and habitat restoration.

The McGinness Hills geothermal project was the first geothermal project to be permitted fully considering the sensitive status of the sage grouse. In October 2007, the BLM issued stipulations on leases obtained by Ormat at the McGinness Hills project to avoid operations within two miles of active leks during the spring period of March 1 to May 15. This stipulation restricted the whole project from any drilling activities during this period. In 2009, the BLM authorized exploration drilling with more strict mitigation including a 0.6-mile avoidance buffer from any sage grouse populations or leks from March 1 to May 15 and avoidance of wet meadows and riparian areas identified as sage grouse nesting and brood rearing habitat from June 1 through November 1. These operational blackout periods meant that any wells drilled near sensitive habitat would require drilling during the winter months, which has a direct impact on costs for the developer.

As exploration drilling progressed, Ormat then needed to begin the permitting process for utilization of the resource, including a Site License and Commercial Use Permit. In preparing the Utilization EA, Ormat worked with the BLM and Nevada Department of Wildlife (NDOW) to develop conservation and mitigation strategies designed to avoid significant impacts and the need to prepare an EIS. Some of these strategies included studies to locate the critical habitat to be avoided, required temporal restrictions, monitoring and tracking of the existing grouse population, monitoring and study of noise impacts and mitigation, and hydrologic modeling to predict impact on existing water features.

During the NEPA process, the first significant concerns were the potential for sound levels to interfere with sage grouse lekking activities, and the potential for geothermal production and injection to affect springs and seeps critical to nesting and brood rearing. Ormat prepared detailed noise models designed to predict the maximum power plant sound levels at known lekking sites. The company also developed a hydrologic modeling and monitoring program to predict potential impact on springs and seeps. These efforts alone introduce a project cost of approximately $500,000. The results of these surveys allowed the BLM to predict no significant impacts on sound or water, but did require that the developer would implement a long-term monitoring program to demonstrate that the predictions were accurate over the long term.

Also, included in the Utilization EA were mitigation requirements for the land used by the project. The BLM applied a four-to-one habitat restoration and enhancement plan that requires four acres of land be enhanced for sage grouse habitat for every one acre of land disturbed by the project. The mitigated disturbance includes wellfield, transmission lines, roads, and of course the power plant. In total, the McGinness Hills project called for 251 acres of land to be disturbed. It was estimated that each acre of enhancement would cost $600, therefore Ormat provided a fund of over $600,000 to be used for sage grouse habitat enhancements. This fund is available to NDOW for sage grouse habitat enhancement within the same Population Management Unit (PMU) as the McGinness Hills project.

**Figure 8.** Permitting manager installing sound monitors near the McGinness Hills project.

Temporal restrictions on drilling activities remained in effect and expanded into construction activities, prohibiting construction and maintenance activities during lekking hours, defined as one hour before sunrise until 10 a.m., from March 15 through May 15 of each year. Additionally, sound level monitoring was required at the closest leks to the project in order to demonstrate that the levels experienced were within compliance (Figure 8). This monitoring program was to continue throughout the construction phase of the project and for 10 years of operation. The estimated cost for this sound monitoring plan is over $250,000.

A 10-year population monitoring plan was also required. Surveys are to be taken during the lekking season (four surveys for each lek) every year to monitor the lek population. Additionally, 24 birds must be captured and fitted with radio tracking collars each year to enable biologists to monitor sage grouse movement throughout the year. The cost for this mitigation plan is $1.6 million over the 10-year monitoring time period.

The permitting requirements for the McGinness Hills project were unique and, in many ways, some of the most expensive and resource-consuming Ormat has encountered. However, these investments are viewed as worthwhile and necessary steps given the sensitive condition of the sage grouse and other environmental considerations on public lands. In the end, it is quite an accomplishment by any developer, and here Ormat, to be able to comply with all necessary environmental regulations and concerns, and be able to fully develop and operate a geothermal project on public lands, paving the way for future projects and a long-term successful collaboration with environmental agencies.

We would like to acknowledge the BLM and the field offices, NDOW, and all other agencies that were a substantial part of making the McGinness Hills geothermal project a success.

## Power Plant Technology

In any project, once the geothermal resource parameters (temperature and flow, among other properties) can be determined with confidence (long-term flow tests), an appropriate technology can be chosen to generate the power to be sold by the project. Resource temperature is a major driver in the selection process. Higher temperature resources are viable to be flashed to produce steam, which generally is able to produce power at a higher efficiency using either a steam turbine or a condensing Organic Rankine Cycle (ORC). However, there is not an easily defined temperature limit and in many cases all the available technologies need to be considered. Lower resource temperatures almost always favor the ORC process, which can extract heat from liquid-dominated streams for power generation. At McGinness Hills, the resource temperature was estimated to be approximately 328°F. At this temperature the geothermal fluid would be kept in a liquid form as it would not produce sufficient steam for a steam turbine or condensing ORC. ORC technology was the clear choice for the McGinness Hills project.

Furthermore, given the location of the project and the strict environmental requirements, finding water to potentially be used within the power production process would be a daunting task. Because of this, the decision was made that the project would use air-cooled technology.

The choice of equipment supplier for the McGinness Hills project was also clear, as Ormat manufactures its own ORC technology, the Ormat Energy Converter (OEC). The OEC has been used in geothermal applications for decades and has been proven to be reliable and dependable, with over 1,600 MW of installed capacity worldwide. Ormat OEC's are still operating today in geothermal applications after 30 years in the field.

Ormat's OECs are designed and manufactured specifically for the geothermal resource conditions. Each is unique, implementing decades of design experience and success. Each OEC undergoes a strict thermodynamic design process to maximize the power output of the cycle while minimizing the equipment cost. As the OEC is a modular system it can be used by itself or in combination with other OECs. This modular approach also offers a unique potential to further maximize the energy output potential. Ormat is the only company today with a vertically integrated approach, that applies this level of optimization when it comes to geothermal power plants.

The design of the McGinness Hills power plant consists of three state-of-the-art Ormat air-cooled OECs. However, the OECs use the geothermal brine in a unique way to optimize the energy generation with the power plant cost. While the specific design is proprietary, the geothermal brine is passed between six separate motive fluid cycles to drive six separate turbines and three electrical generators to produce over 36 MW of net power (before well field consumption) prior to reinjecting 100% of the geothermal fluid back into the reservoir.

## Construction, Commissioning and Operation

Construction of the power plant and above ground pipelines began in mid to late 2011; first with building the power plant pad, followed by setting foundations for all major equipment at the power plant. All of the major pieces of equipment for the Ormat OEC were manufactured by Ormat in their factory. As the components (air coolers, heat exchangers, turbines) arrived on site they were set on their respective foundations (Figure 9).

Photo courtesy of Ormat Technologies, Inc.

**Figure 9.** The McGinness Hills power plant under construction, 2012.

With most or all of the major equipment unloaded at the site, the central effort of mechanical and electrical construction could commence. This process usually takes a couple of months as piping is fitted, valves and instruments installed, and then all process air and electrical connections made and tested. A project of this size requires miles of electrical cables and process air lines. There are hundreds of connections to be made, and they all must be confirmed and tested prior to start-up of the power plant.

Mechanical and electrical completion of McGinness Hills was complete in early summer 2012. The project's Commercial Operation Date (COD) was July 1, 2012 (Ormat, 2012). Since then, McGinness Hills has been producing 30 MW of clean, renewable energy to northern Nevada through the NV Energy transmission system.

## Financing

All the early exploration, permitting, interconnection and transmission efforts were completed to reach the major decision point in the project, to initiate the construction phase. The construction phase entails full release of the power plant engineering, procurement, and construction along with development drilling of the well field and design of the pipeline system. Additionally, transmission line construction, interconnection requirements, and final permitting efforts are released.

The final aspect of the project that must be realized at this stage is financing. This financing pays back the development funds used in the project and transfers that debt into a long-term arrangement in which the project can reimburse a loan and generate revenues.

Along with many other aspects of the project being unique, the financing was no different. Ormat chose to finance the McGinness Hills project, and two other projects, under a 20-year loan with John Hancock Life Insurance Company, guaranteed by the U.S. Department of Energy's (DOE) Loan Guarantee program under Section 1705 of Title XVII of the Energy Policy Act of 2005. The financing is for up to $350 million to develop the three separate geothermal projects in Nevada, including the McGinness Hills project (Ormat, 2011).

## Summary

The McGinness Hills geothermal project was a true success for Ormat, federal and state agencies, and the geothermal industry. From the beginning, it was forseen that this geothermal project would have to tackle challenges on a unique level and require a development team of an applicable caliber to conquer them.

**Figure 10.** The completed McGinness Hills power plant.

First, there was the challenge of a blind geothermal system. Very little to no surface manifestations to point at, minimal previous data to support assumptions, and a location new to geothermal development made the exploration, and justification for exploration, a careful and magical balance of resources and results.

Next, the new challenge of Category 1 sage grouse habitat lands. It was clear from the beginning that the cooperation between Ormat, the BLM, and NDOW would need to be of the highest quality in order for the project to be a success.

Then, the high risk efforts of deep geothermal exploration. Years of work drilling, testing, analyzing, and drilling again in hopes that background work would prove to support millions of dollars and hundreds of hours of resources to achieve successful geothermal field development.

**Figure 11.** Geothermal pipeline expansion loops at the McGinness Hills project.

Then, satisfying the understandably tough and thorough due diligence of the DOE in order to qualify for the Section 1705 Loan Guarantee Program for long-term project financing. Through a monumental effort between Ormat, the U.S. DOE, and John Hancock, the financing is the first of its kind in the geothermal industry showing that this high level of cooperation can bring favorable project financing to support experienced and proven geothermal developers such as Ormat.

Lastly, the completion of a five-year development timeline, a 30 MW geothermal project, on time and on budget with excellent performance to match. While on time completion and performance is something Ormat has been standing behind for decades, the McGinness Hills project proves to be no exception, no matter what challenges are faced along the way.

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