

The Silent Killer of Geothermal Projects: Long Term Resource Risk

Hezy Ram

540 President St. Brooklyn NY, 11215

hram@greenmaxcap.com

Keywords: Geothermal Resource, Production Risk, Mitigation

ABSTRACT

The exploration risk associated with geothermal resources is well known as a major hindrance to the development of geothermal capacity. Various public and private sector approaches and technical and financial mechanisms have been established to address this issue. This article will provide a critical review of instruments such as the Geothermal Risk Mitigation Facility (GRMF) and Munich Reinsurance's exploration risk insurance product. All available products address only short-term exploration risk.

Long-term geothermal resource risk, however, is often less understood and tends not to receive the attention that is warranted. Remarkably, this is a common problem in the industry and has caused serious damage to multiple projects in both developed and emerging countries. This article will discuss case studies of operating power plants that experienced adversity when the associated geothermal resources collapsed at once or over time. Some of these projects went bankrupt, causing significant losses to lenders and investors. This paper will discuss the outcomes of each scenario.

The nature of long-term resource risk, as well as steps that can be taken to address these risks, will be analyzed. These steps encompass careful planning and execution and implementation of financial solutions.

As the geothermal industry matures, it has become increasingly vital to understand the short-term and long-term risks of geothermal project development, and more importantly, the measures that can be taken to mitigate these risks.

1. INTRODUCTION

The real estate sector is all about location. Similarly, the geothermal plants are all about the geothermal resource. The rationale here is as clear as daylight – the geothermal resource is the ONLY source of “fuel” a geothermal plant needs to operate. The geothermal resource cannot be replaced or moved around (but for short distance). Moreover, the quality of the geothermal resource cannot be improved. In other words, the essential parameters of the geothermal resource being temperature, pressure, and enthalpy will never improve over time, i.e., the temperature and pressure of a resource tend to decline over time. Other parameters may change for the better (enthalpy, which indicates the steam fraction, comes to mind), but these are a short-term phenomenon.

Hence, the geothermal resource should be at the center of any planning for a new project; i.e., Planning for how to find it and how to exploit it on a sustainable basis over time should be the top priority.

Naturally, we tend to focus on the short-term: When we consider a new plant, we spend more of our attention on the CAPEX even though the OPEX element is the one that will come back to bite us if not dealt with respect. Similarly, a considerable effort is dedicated to the first stages of resource development: exploration and production drilling. This effort is justified as only 50% of the initial drilling operations in geothermal Greenfields prove successful. But once the exploration is successful, a lot of attention needs to be paid to the long-term as well. Long-term resource risk is the focus of this article.

2. THE FALLACY OF THE GEOTHERMAL VALLEY OF DEATH

Figure 1 is a graph that has been used extensively in discussions that center around the subject of geothermal risk. However, it only tells half the story: While the exploration risk is immense and many companies are unable to cross the “Death Valley,” as is accurately represented by the figure, getting to the other side is not definitively indicative of a successful project. Once the project has proven the existence of the resource, it has been “de-risked”; hence, the construction of the plant can now move forward and more importantly, financing is now within reach.

The problem that is missed by many when reviewing geothermal projects is the long-term resource risk that exists between the start of operations until the end of the project's life. Geothermal projects require a substantial initial investment, which needs to be amortized over 20-30 years. During this period, the power plant needs a continuous supply of steam/hot water to convert into electrical power, that can be sold to pay for the significant up-front investment (and O&M costs). Any interruption in the supply of thermal energy means fewer revenues and thus hardship for the investors and lenders to the project.

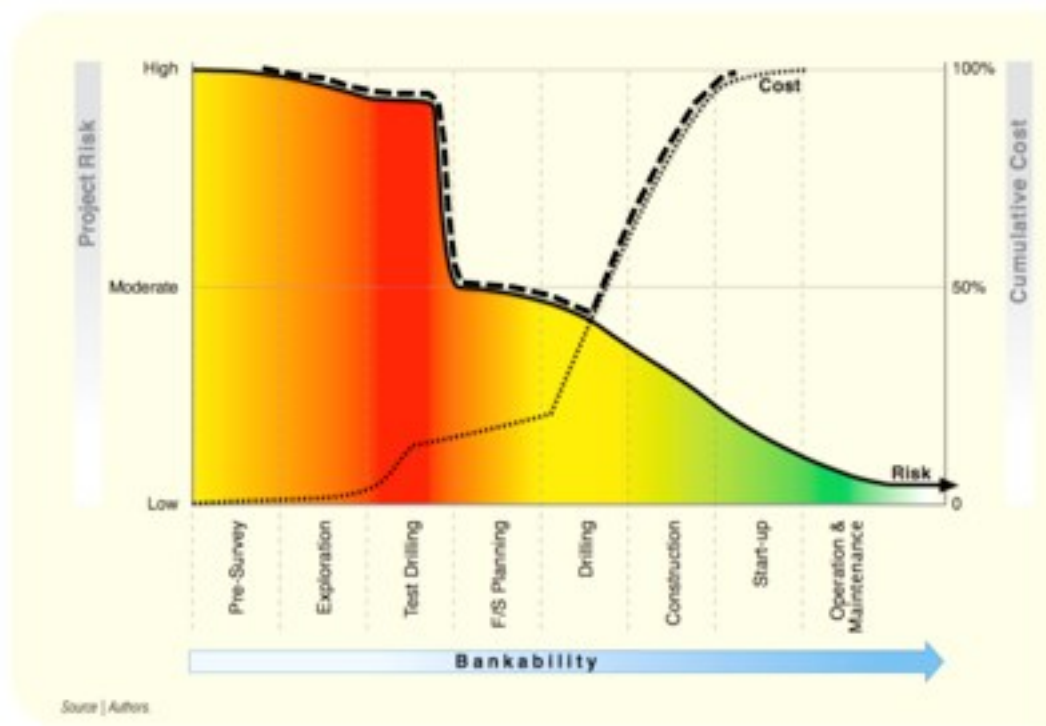


Figure 1: The Geothermal Valley of Death. Gehring et al (2012, p. 4)

3. LONG TERM GEOTHERMAL RISK

Geothermal resources provide thermal energy in the form of steam, hot water, or a combination of both. The quality of the thermal energy relies on the resource temperature (which roughly reflects the enthalpy associated with the resource being the accurate measure of energy content), pressure, and flow rate. In flash (condensing steam turbines) systems, the pressure is a good indicator for the flow rate, but this is not the case when lower temperature (usually pumped) geothermal resources are involved. Therefore, they will use flow rate and temperature as the two underlined factors in the analysis. The operation of the geothermal power plant will fall short if either one is deficient.

Generally speaking, resource deficiency can occur due to one of or both of the following two principal reasons:

- Skin Damage: This phenomenon occurs following a problem during the drilling or completion of the well. In turn, the construction errors may restrict the flow of the resource into the well. The chemistry of the well may incur additional issues. Adverse chemistry may cause scaling on both the production and injection wells. The “good news,” is that it is possible to resolve any problems associated with drilling or operating of geothermal wells. This article will not focus on any of the numerous mitigation measures. Nonetheless, close monitoring and a qualified team can solve any well-related issue without risking a long-term decline in the performance of the project.
- Geothermal Resource Related Issues: These problems may ruin geothermal projects that are otherwise perfectly designed and constructed. In essence, we experience issues with the two parameters mentioned below. Interestingly, the type of resource (Steam or hot water) and the technology in place determines the severity of the problem.
 - Reduced Flow Rate/Pressure: This phenomenon is typical to vapor (steam) dominated resources whereby the resources are either pure (dry) steam, or dual phase and artesian. Usually, the cause of this issue is a disparity in the speed of the natural recharge of the fluid and the rate of consumption of the resource. The technology most commonly used for this type of resource is single, double, or triple flash. In extreme circumstances (dry steam), no flashing is required. In any event, the operation of the power plant involves the consumption of a great deal of the resource as part of the cooling process. Anywhere between 30%-80% of the resource is lost, and thus a permanent deficit of the liquid grows. Some geothermal resources benefit from a robust natural recharge, so the impact of partial reinjection may only be felt after a very long time. The industry, however, has experienced quite a few situations whereby the depleted reservoir limited power production. This will be demonstrated later on with actual examples.
 - Plummeting Resource Temperature: This phenomenon characterizes the liquid-dominated resources, which usually reinject close to 100% of the resource that is pumped out, thus eliminating potentially reduced production. Consequently, the issue is founded in the mining of heat from the rocks and its subsequent recovery. The biggest challenge is typically the delicate balance between spudding the production and injection wells. If the injection well is too close to the production area, the cooler injection fluid will inevitably reduce the temperature of the

resource. On the other hand, placing the injection wells too far from the production zone will lead to a loss in pressure support, which means a more significant drawdown.

4. REAL LIFE EXAMPLES

The following are three instances where a long-term risk management approach would have helped the management.

4.1 The Geysers Story: The rise, the fall and the rise again

The US Geothermal industry began with an 11 MW project in 1960. It happened in The Geysers after the discovery of a large dry steam reservoir. In the following 25 years, many power plants were developed at the site of The Geysers by numerous developers. Pacific Gas and Electric (PG&E) happily purchased the output to feed San Francisco with clean (and cheap) energy. At the height of this development, The Geysers field, which remains the single largest geothermal field in the world, had an operational capacity of 2,000 MW. Unfortunately, by the mid-1990s, something changed. Production declined rapidly, and within a few years, the same field could not deliver more than 1,000 MW. The power extraction process had left a depleted reservoir as the liquid level had dropped annually for roughly 30 years. It was a classic case of the tragedy of the commons, as there was no one entity in charge and the institutions utilizing the resource exploited it without any consideration for each other. Only 20% of the produced steam was reinvested into the reservoir. Consequently, the field was running out of media to bring heat up to the surface. Initial measures, such as better use of cooling towers, increased the percentage of reinjection to 33%, but it was clear that this was not enough.

Fortunately, those who truly cared about the fate of The Geysers took action to save it. First, the various players and leaseholders consolidated under two players: one entity, Calpine now owned 17 of the 19 power stations and the associated resource. NCPA owned and operated the balance. Second, and more importantly, two major pipelines from Lake and Sonoma counties were built to provide a continuous supply of treated wastewater to The Geysers (Appendix A), supplementing the injections from the power plant. This exercise took place roughly 15 years ago and proved to be a real success. Operations stabilized, and The Geysers will continue to supply clean, reliable, and dependable power for the next 50 years.

4.2 Blue Mountain: The cost of greed

The Blue Mountain geothermal project is located in Eastern Nevada. From the time of the initial exploration, it was engineered to use the Organic Rankine Cycle (binary) technology. This technology is best suited for a medium temperature resource, which requires pumping. Originally designed as a 25 MW project, the exploration and production drilling continued in parallel to the construction of the power plant. However, the geothermal field had not been fully developed and tested (including the injection strategy) when the decision to build the power plant was made.

Incidentally, higher temperatures and increased production were discovered during the development of the geothermal field. This gave rise to unchecked optimism as a result of an expectation that a greater resource was discovered. In such a case, there are two strategies of construction: 1) Go slowly and build the project in phases over time and 2) Build all at once. The first approach (see Steamboat in NV which went from 5 MW to 70 MW over 20 years without any significant issues) is slow and less profitable than the more aggressive approach which takes considerable risks to get a marginally better financial reward. The banks (and their commissioned based agent) wanted to lend more, so they pushed for a larger project and exacerbated the problem. Hence, the fateful decision was made to go for a 50 MW project.

The article “Stimulating Geothermal Power” (Kryzanowski, 2010) discusses the entire story of the project. In 2009, the project went online and delivered 45 MW for a short time. The euphoria was short-lived, and within 6 months, both the temperature and production of the resource dropped drastically, as indicated in the graph (Appendix B).

Numerous resolutions were applied, but they all proved unsuccessful. The result was unfortunate as:

- The developer of this project, Nevada Geothermal, lost all the investment it had made and went out of business.
- The subordinated lender (The senior lender is the DOE), had to write off over \$100 million.

Recently, the project was operating at 25 MW. It was acquired by another geothermal player, which continues to try to improve its operation.

4.3 COSO Geothermal: The musical chairs game – multiple losers

Coso Geothermal was developed during the 1980s in California; It generated about 240 MW from 8 different power plants which were built over time. In other words, only when it was clear that the resource could support additional development was a new plant designed.

This strategy worked for a while, and consequently, this project made a lot of money. There was always an investor who was willing to buy into the project. Initially developed by the Bishop family in partnership with CalEnergy (currently, BHE), the family bought Calenergy’s share for what seemed to be a considerable sum of money at that time. In turn, the family refinanced their position with public bonds to the tune of \$626 million (Appendix C). Debt was raised based on the fact that the generation of this project would not only stay on track but increase to about 270 MW (Appendix D). Additionally, in a sale-leaseback transaction, a large insurance company and Citi raised close to \$100 million.

Later on, the family sold its portfolio of projects, including Coso to a private equity fund that had no experience in the geothermal space. When reality finally caught up with the project, and the depletion rate rose dramatically, two things were missing:

Ram

- Expertise: The local team tried to take a page from Calpine's books and ink a deal with a local ranch to procure its water rights. They built a pipeline from Hay Ranch and pumped a substantial amount of water into the field. Unfortunately, the team did not study the Calpine success story in full, and the water injection plan backfired. The project finally stabilized at about 160 MW and could not be prompted to perform at a higher level.
- Money: The project rotated through many owners and, in the process, was leveraged to the tilt based on unrealistic assumptions. As a result, any hiccup created severe problems for the financing partners. Also, no funds were set aside for a "rainy day."

Moody's summarized the outcome in the report as follows (Appendix E):

- The project went bankrupt as it was not able to service the public debt
- The private equity fund lost its position
- The lessor which tried to support the project financially finally lost hope and threw in the towel and wrote off its investment as well
- The bondholders took over the project in return for a major "hair cut" to the value of their holdings.

5. CONCLUSION

Geothermal resources can be capricious and should be dealt with cautiously. A few lessons to take from the examples aforementioned and others:

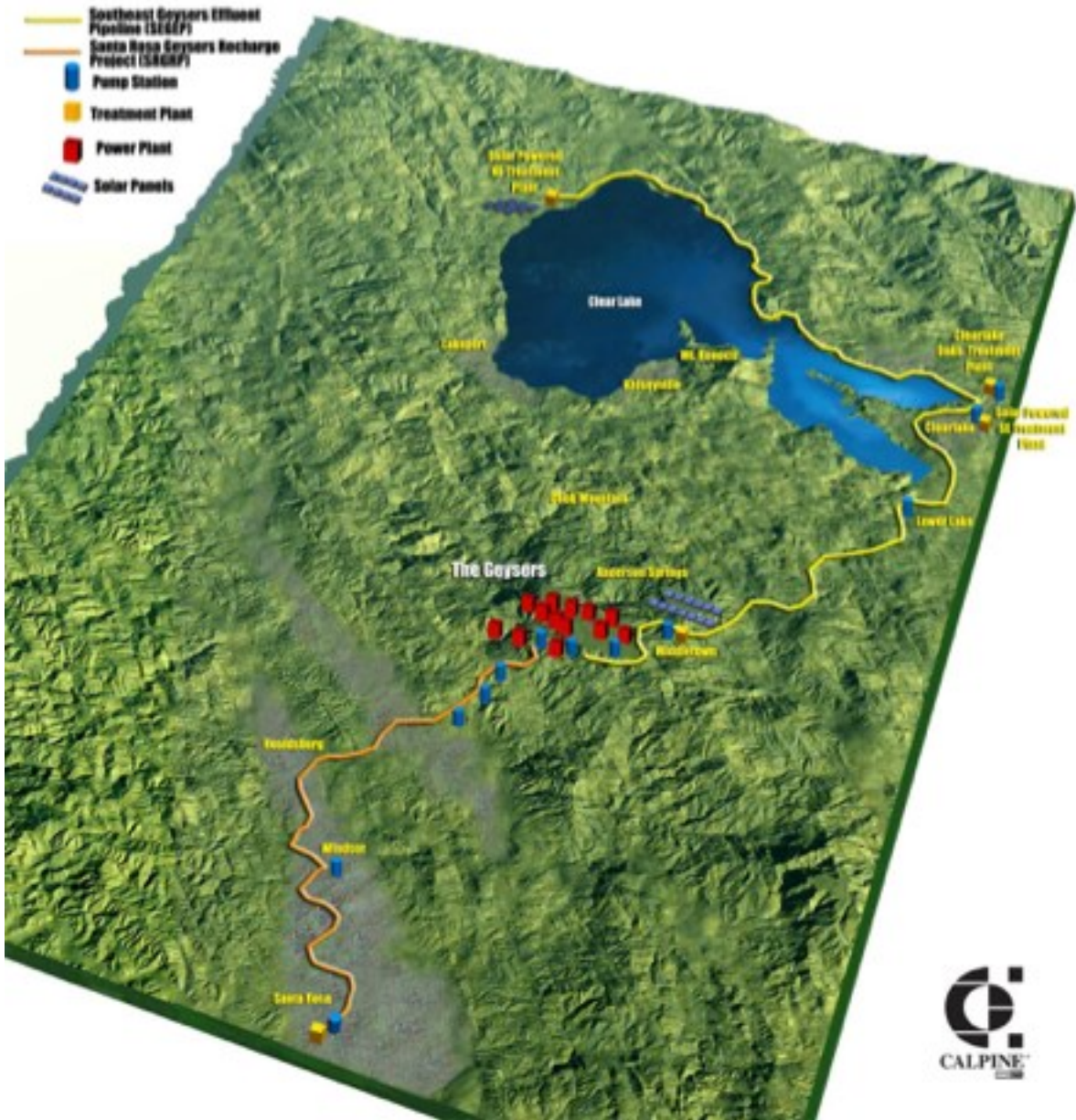
- Always assume the worst. Believe that the resource will decline in the long-term. Both the temperature and the flow rate may drop. The earlier a potential problem is detected, the higher the chances that the issue can be dealt with timely.
- Monitoring and analysis need to be a priority expense. A numerical model is a must, and it should be maintained and updated by the best talent the company can afford.
- Proper human resources and equipment need to be in place to address contingencies head-on.
- Phased development, albeit slower and more expensive, is the best strategy. Frankly, there is no other strategy.
- It is best not to try and squeeze every last cent from a project by charging hefty fees and over-leveraging. It is a tried and tested recipe to lose the project. Consequently, an appropriately sized war chest should be kept aside for contingencies. They will likely happen sometime during the lifetime of the project.
- Pray if you believe it can help. One needs a fair amount of luck in this business.

REFERENCES

Gehring, Magnus; Loksha, Victor. 2012. Geothermal Handbook : Planning and Financing Power Generation. ESMAP technical report;no. 002/12. World Bank, Washington, DC. © World Bank. License: CC BY 3.0 IGO.

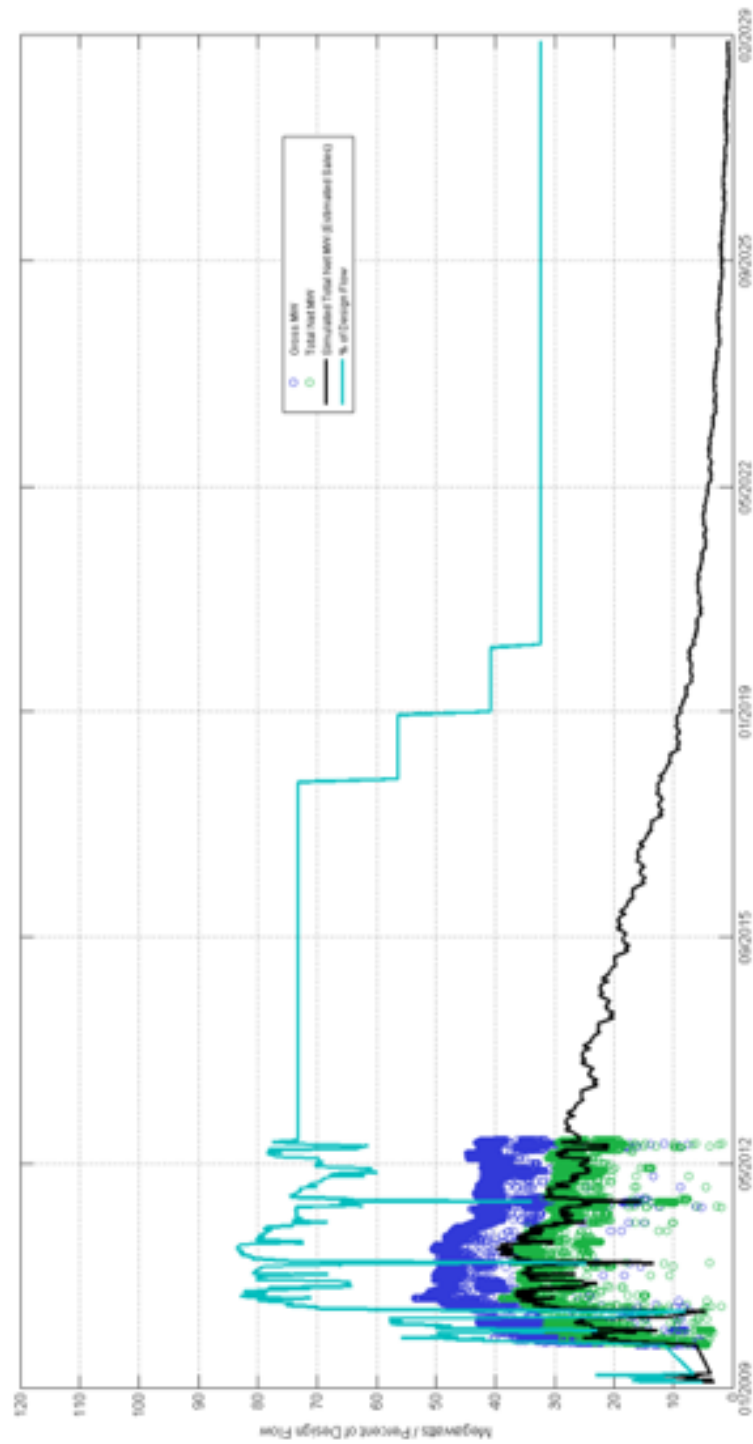
Kyrzanowski, Tony. "Stimulating Geothermal Power." *EnerG: Alternative Sources Magazine*, EnerG Magazine, 2009. Online.

APPENDIX A: THE GEYSER WASTEWATER RECHARGE PROJECTS

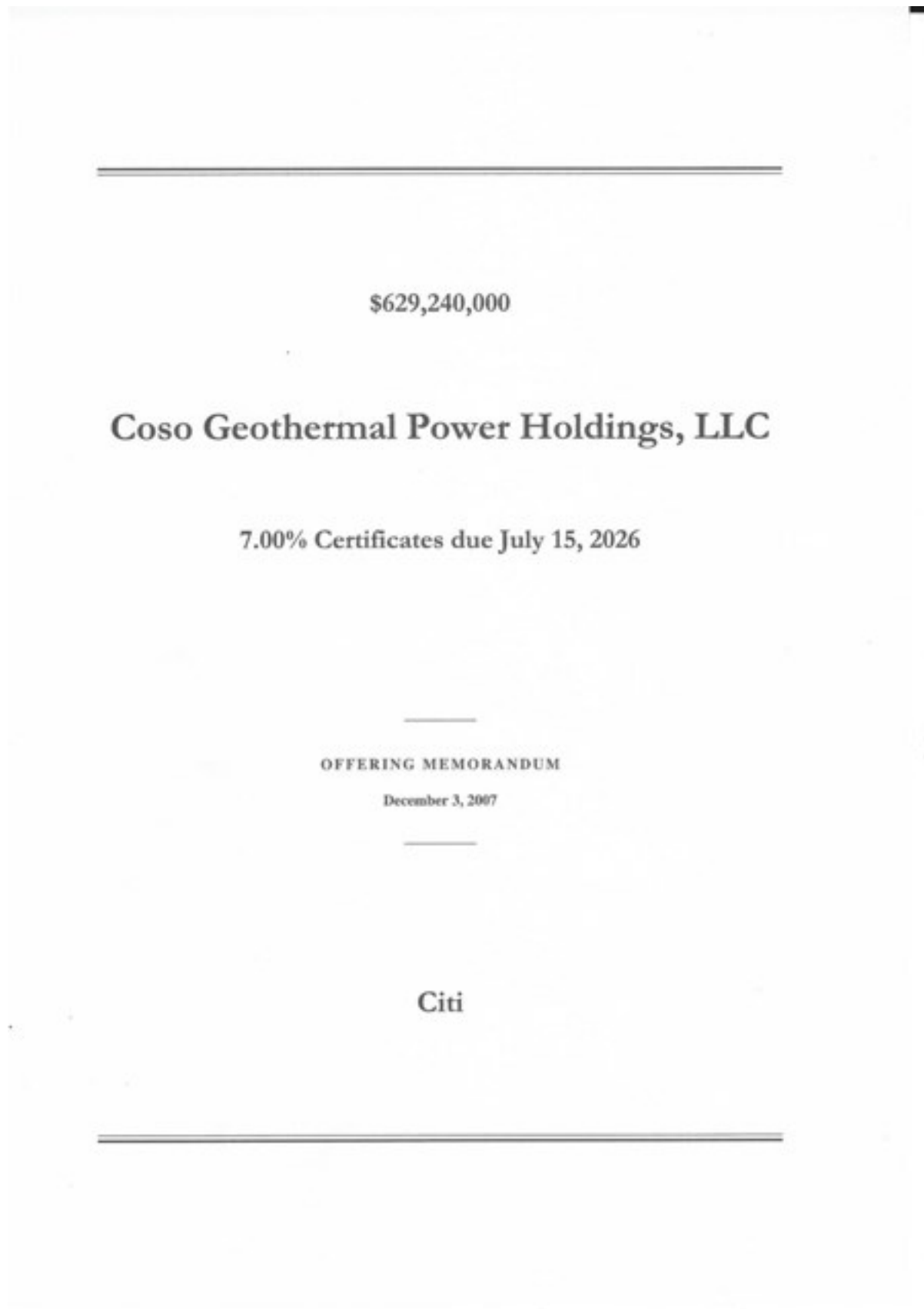


Calpine Corporation 2012 annual report

APPENDIX B: RESOURCE TEMPERATURE OF THE BLUE MOUNTAIN GEOTHERMAL PROJECT

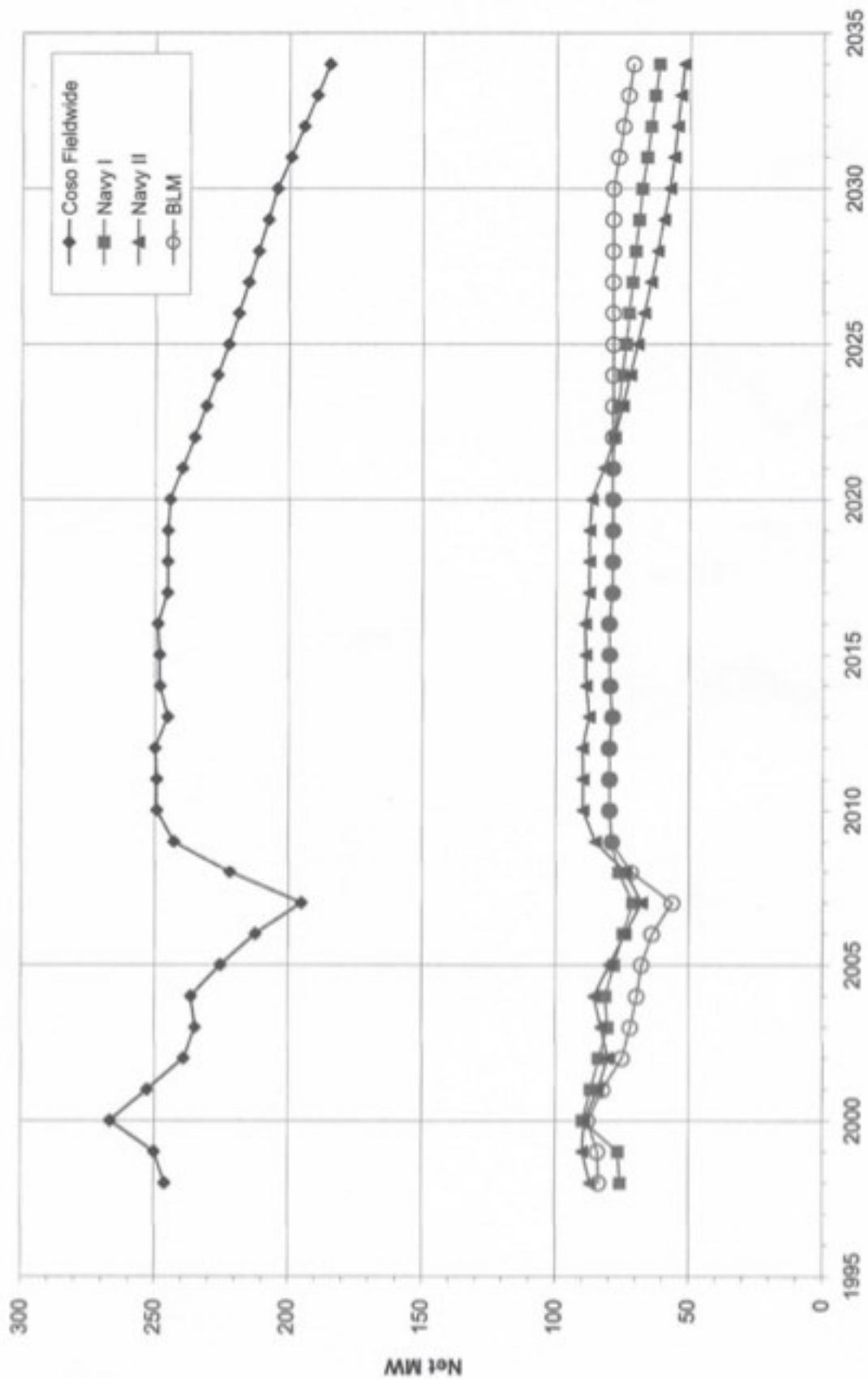


APPENDIX C: VALUE OF COSO GEOTHERMAL PUBLIC BOND TRANSACTION



CITI – Coso Geothermal, \$629,240,000 offering memorandum – Dec 2007

APPENDIX D: FORECASTED GENERATION FOR THE COSO GEOTHERMAL PROJECT



CITI – Coso Geothermal, \$629,240,000 offering memorandum – Dec 2007

APPENDIX E: MOODY'S ADVISORY REPORT FOLLOWING DEBT RESTRUCTURING



Rating Action: **Moody's withdraws Coso Geothermal's rating and outlook following debt restructuring**

22 Feb 2017

Approximately \$400 million of rated debt previously outstanding

New York, February 22, 2017 --

Moody's Investors Service ("Moody's") has withdrawn Coso Geothermal Power Holdings LLC ("Coso") Ca rating and stable outlook following the completion of the issuer's debt restructuring earlier this month.

RATINGS RATIONALE

The rating action reflects Coso's debt restructuring that we understand occurred on February 16, 2017. The terms of the debt restructuring have not been publicly disclosed, although we understand that the previously rated instruments are no longer outstanding.

Please refer to the Moody's Investors Service's Policy for Withdrawal of Credit Ratings, available on its website, www.moody's.com.

Coso is a special purpose company formed as part of a sale-leaseback transaction of geothermal facilities totaling a gross 302 MW and located in California.

REGULATORY DISCLOSURES

For any affected securities or rated entities receiving direct credit support from the primary entity(ies) of this credit rating action, and whose ratings may change as a result of this credit rating action, the associated regulatory disclosures will be those of the guarantor entity. Exceptions to this approach exist for the following disclosures, if applicable to jurisdiction: Ancillary Services, Disclosure to rated entity, Disclosure from rated entity.

Regulatory disclosures contained in this press release apply to the credit rating and, if applicable, the related rating outlook or rating review.

Please see www.moody's.com for any updates on changes to the lead rating analyst and to the Moody's legal entity that has issued the rating.

Please see the ratings tab on the issuer/entity page on www.moody's.com for additional regulatory disclosures for each credit rating.

Clifford J Kim
Vice President - Senior Analyst
Project Finance Group
Moody's Investors Service, Inc.
250 Greenwich Street
New York, NY 10007
U.S.A.
JOURNALISTS: 212-553-0376
SUBSCRIBERS: 212-553-1653

A.J. Sabatelle
Associate Managing Director
Project Finance Group
JOURNALISTS: 212-553-0376
SUBSCRIBERS: 212-553-1653

Releasing Office:

Moody's Investors Service, Inc.
250 Greenwich Street
New York, NY 10007
U.S.A.
JOURNALISTS: 212-553-0376
SUBSCRIBERS: 212-553-1653



© 2018 Moody's Corporation, Moody's Investors Service, Inc., Moody's Analytics, Inc. and/or their licensors and affiliates (collectively, "MOODY'S"). All rights reserved.

CREDIT RATINGS ISSUED BY MOODY'S INVESTORS SERVICE, INC. AND ITS RATINGS AFFILIATES ("MIS") ARE MOODY'S CURRENT OPINIONS OF THE RELATIVE FUTURE CREDIT RISK OF ENTITIES, CREDIT COMMITMENTS, OR DEBT OR DEBT-LIKE SECURITIES, AND MOODY'S PUBLICATIONS MAY INCLUDE MOODY'S CURRENT OPINIONS OF THE RELATIVE FUTURE CREDIT RISK OF ENTITIES, CREDIT COMMITMENTS, OR DEBT OR DEBT-LIKE SECURITIES. MOODY'S DEFINES CREDIT RISK AS THE RISK THAT AN ENTITY MAY NOT MEET ITS CONTRACTUAL, FINANCIAL OBLIGATIONS AS THEY COME DUE AND ANY ESTIMATED FINANCIAL LOSS IN THE EVENT OF DEFAULT. CREDIT RATINGS DO NOT ADDRESS ANY OTHER RISK, INCLUDING BUT NOT LIMITED TO: LIQUIDITY RISK, MARKET VALUE RISK, OR PRICE VOLATILITY. CREDIT RATINGS AND MOODY'S OPINIONS INCLUDED IN MOODY'S PUBLICATIONS ARE NOT STATEMENTS OF CURRENT OR HISTORICAL FACT. MOODY'S PUBLICATIONS MAY ALSO INCLUDE QUANTITATIVE MODEL-BASED ESTIMATES OF CREDIT RISK AND RELATED OPINIONS OR COMMENTARY PUBLISHED BY MOODY'S ANALYTICS, INC. CREDIT RATINGS AND MOODY'S PUBLICATIONS DO NOT CONSTITUTE OR PROVIDE INVESTMENT OR FINANCIAL ADVICE, AND CREDIT RATINGS AND MOODY'S PUBLICATIONS ARE NOT AND DO NOT PROVIDE RECOMMENDATIONS TO PURCHASE, SELL, OR HOLD PARTICULAR SECURITIES. NEITHER CREDIT RATINGS NOR MOODY'S PUBLICATIONS COMMENT ON THE SUITABILITY OF AN INVESTMENT FOR ANY PARTICULAR INVESTOR. MOODY'S ISSUES ITS CREDIT RATINGS AND PUBLISHES MOODY'S PUBLICATIONS WITH THE EXPECTATION AND UNDERSTANDING THAT EACH INVESTOR WILL, WITH DUE CARE, MAKE ITS OWN STUDY AND EVALUATION OF EACH SECURITY THAT IS UNDER CONSIDERATION FOR PURCHASE, HOLDING, OR SALE.

MOODY'S CREDIT RATINGS AND MOODY'S PUBLICATIONS ARE NOT INTENDED FOR USE BY RETAIL INVESTORS AND IT WOULD BE RECKLESS AND INAPPROPRIATE FOR RETAIL INVESTORS TO USE MOODY'S CREDIT RATINGS OR MOODY'S PUBLICATIONS WHEN MAKING AN INVESTMENT DECISION. IF IN DOUBT YOU SHOULD CONTACT YOUR FINANCIAL OR OTHER PROFESSIONAL ADVISER.

ALL INFORMATION CONTAINED HEREIN IS PROTECTED BY LAW, INCLUDING BUT NOT LIMITED TO, COPYRIGHT LAW, AND NONE OF SUCH INFORMATION MAY BE COPIED OR OTHERWISE REPRODUCED, REPACKAGED, FURTHER TRANSMITTED, TRANSFERRED, DISSEMINATED, REDISTRIBUTED OR RESOLD, OR STORED FOR SUBSEQUENT USE FOR ANY SUCH PURPOSE, IN WHOLE OR IN PART, IN ANY FORM OR MANNER OR BY ANY MEANS WHATSOEVER, BY ANY PERSON WITHOUT MOODY'S PRIOR WRITTEN CONSENT.

CREDIT RATINGS AND MOODY'S PUBLICATIONS ARE NOT INTENDED FOR USE BY ANY PERSON AS A BENCHMARK AS THAT TERM IS DEFINED FOR REGULATORY PURPOSES AND MUST NOT BE USED IN ANY WAY THAT COULD RESULT IN THEM BEING CONSIDERED A BENCHMARK.

All information contained herein is obtained by MOODY'S from sources believed by it to be accurate and reliable. Because of the possibility of human or mechanical error as well as other factors, however, all information contained herein is provided "AS IS" without warranty of any kind. MOODY'S adopts all necessary measures so that the information it uses in assigning a credit rating is of sufficient quality and from sources MOODY'S considers to be reliable including, when appropriate, independent third-party sources. However, MOODY'S is not an auditor and cannot in every instance independently verify or validate information received in the rating process or in preparing the Moody's publications.

MJKK and MSFJ also maintain policies and procedures to address Japanese regulatory requirements.