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Kelly Franger

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In the Heat of the Law, It's Not Just Steam: Geothermal Resources and The Impacts on Thermophile Biodiversity

Donald J. Kochan*
Tiffany Grant**

Abstract

Significant research has been conducted into the utilization of geothermal resources as a green energy source.[1] However, minimal research has been conducted into geothermal resource utilization and depletion impacts on thermophile biodiversity. Thermophiles are organisms that have adapted over millions of years to extreme temperature and chemical compositions and exist in hot springs and other geothermal resources. Their ability to withstand high temperatures makes them invaluable to scientific and medical research. Current federal and California case law classifies geothermal resources as a mineral, not a water, resource. Acquisition of rights to develop a geothermal resource owned or reserved by the federal government is authorized by the Geothermal Steam Act of 1970, which was designed to promote utilization of geothermal resources. Similarly, current California law promotes the utilization of geothermal resources. While NEPA and CEQA respectively apply in federal and state geothermal resource development, thermophile biodiversity is significantly threatened due to a lack of knowledge and classification of thermophile species. California law under the Public Resources Code provides for the prevention of damage to geothermal deposits, reservoirs, and water, but not for the species that live in them. This article will examine whether current regulation in California over-utilizes

* Assistant Professor of Law, Chapman University School of Law. J.D. 1998 Cornell Law School; B.A. 1995 Western Michigan University. Former Visiting Assistant Professor of Law, George Mason University School of Law, 2002-2003; Olin Research Fellow, University of Virginia School of Law, 2003-2004.

** Environmental Project Scientist for EnviroBusiness Consulting of Burlington, Massachusetts. California EPA certified Regional Environmental Assessor. B.S. Earth Systems Science and Policy, California State University, Monterey Bay. J.D. (2006) Chapman University School of Law, Environmental, Land Use, and Real Estate Certificate.

1. Kaveh Badiei, Note, *Geothermal Energy: Is It Attractive Enough to Draw Investors for Construction of Geothermal Electric Plants?*, 7 HASTINGS WEST NORTHWEST J. ENVTL. L. & POL'Y, 109 (2001).

geothermal resources and adequately considers the threat to thermophile diversity, and whether the law sufficiently considers competing resources in order to reach optimal use of those resources.

I. Introduction and Overview

Ever heard of thermophiles? Regardless of your answer, read on. Ever cared about thermophile biodiversity? If yes, read on. If no, then still read on; you might just begin to care (or if not at least come to a decision why). One book on the subject is titled, "Thermophiles: The Keys to Molecular Evolution and the Origin of Life?"[2] The direct descendants of those early organisms are known as thermophiles. Because of their ancient origins, thermophiles may hold keys to some of the earth's most unfathomable mysteries, including how molecules evolved and how life formed on the planet.[1] As an article in the *New York Times* reports, "Many biologists believe the earth's first organisms arose in the deep sea along volcanic gashes and that microbes known as thermophiles, which thrive today in such hot regions [where earthquakes or volcanic activity create fissures that bring heat to the surface through water or otherwise], are their direct descendants."[3] Because of their ancient origins, thermophiles may hold keys to some of the earth's most unfathomable mysteries, including how molecules evolved and how life formed on the planet.

The lack of scientific knowledge and understanding of thermophiles and their geothermal environments adds to the potential for the depletion and loss of thermophile biodiversity by current geothermal uses designed to exploit the resource for energy or recreation or other uses.

Over millions of years, thermophiles have adapted to the extreme temperature and chemical compositions of each specific geothermal resource. Their ability to withstand high temperatures makes them invaluable to scientific and medical research. The economic potential of thermophiles in scientific and medical research is well known. For example, the discovery and research of a species in Yellowstone National Park resulted in a scientific process that reportedly generates approximately $100 million per year.[4] However thermophiles and their environments remain largely unstudied. Due to the isolation of geothermal resources, each geothermal resource and po-

2. *See generally* THERMOPHILES: THE KEYS TO MOLECULAR EVOLUTION AND THE ORIGIN OF LIFE? (Juergen Wiegel & Michael W. Adams eds., 1998).

3. William J. Broad, *Deadly and Yet Necessary, Quakes Renew the Planet*, N.Y. TIMES, Jan. 11, 2005, at F1.

4. Nancy S. Bryson, *The Integral Relationship Between the Federal Technology Transfer Act and Natural Resources*, 22 ENERGY & MINING LAW INST. 175, 182 (2002).

tentially each hot spring might have evolved distinct thermophile species.

Thermophile species are at a great risk for species die-off due to geothermal resource utilization, because they may only exist in one location. If that one location or geothermal resource is significantly altered or depleted, the species will become extinct. Although regulations currently exist for the monitoring and consideration of groundwater depletion and related concerns,[5] no regulations exist concerning the loss of thermophile biodiversity.

This article explains that, at the very least, there is a gap in *consideration* of whether certain geothermal resources require legal regulation in their use or exploitation. It is fundamental in policymaking to evaluate costs and benefits between the use or extraction of a resource and its preservation. The potential implications for biodiversity should at least be a metric in evaluating the use of geothermal resources where thermophiles thrive.

Federal and state laws applicable to geothermal resources are designed to promote the exploitation of geothermal energy as an environmentally sustainable, efficient, and renewable energy source. The development of geothermal resources for energy production has met considerable environmental opposition. Concerns include thermal and mineral stream pollution from plant discharge, loss of thermophile biodiversity, subsidence, seismic effects of injection, and the setting of power plants in remote and natural wildlife areas.

This article explains the scientific processes that create geothermal resources, and their categorization by economic application. Competing interests and environmental concerns are examined with an overview of applicable federal and state laws and regulations. The article illustrates that current laws and regulations applicable to geothermal resources are inadequate to preserve thermophile biodiversity for future uses such as medical and scientific research. The article remains agnostic on the issue of which competing uses should be preferred from a legal and policy standpoint. Although geothermal resources exist throughout the country, most of the analysis will use California as a case study.

The growing need for efficient renewable energy in California has led to research into green energy sources, including geothermal energy production.[6] California has a significant amount of geothermal resources, which have led to both federal and state regulations to promote geothermal energy development. In 1999 alone, the Department of Energy spent a reported $28.5 million dollars on geo-

5. CAL. PUB. RES. CODE § 3700 *et seq*. (2004).
6. Badiei, *supra* note 1.

thermal research and development.[7] The Geothermal Energy Association has reported, "In California, up to thirty percent of the state's power consumption could become dependent on geothermal energy."[8]

Although considered a green resource, development of geothermal resources for energy production has not been without environmental opposition. "Plants . . . are facing the kind of obstacle environmentalists used to reserve for oil drilling."[9]

Although federal and state regulations applicable to California have some protections for stream pollution, subsidence, and tectonic effects of injection, California lacks any regulations for the protection of thermal biodiversity. In fact, current California law promotes the utilization of geothermal resources, which in turn potentially promotes the extinction of thermophile species.

Section II explains the scientific processes that create geothermal resources and technological methods to utilize each resource. Depending on the amount of water in the surrounding rock, different types of geothermal systems form when exposed to extreme heat. In Section III, the five main types of systems are explained including dry steam, hot water, hybrid geothermal brines, hot dry rock and low temperature systems. In addition, the unique methods of extraction for each resource are discussed. Section IV concludes with an overview of the legal definitions of geothermal resources pertinent to California.

Section V discusses the competing interests and opposition to the use of geothermal resources. Competing interests and opposition to the use of geothermal resources can also be categorized by the types of geothermal resources.

Opposition is based on the nature of the utilization of the resources. Energy producing geothermal resources — dry steam, hybrid, dry rock, and hot water — require significant technology and funding to utilize, leaving development of the field to big energy companies. Low temperature resources can be used by as little as one person operating a small well, creating many small users.

The country's rapidly growing need for efficient energy, along with energy company utilization of geothermal resources — especially in California — necessarily competes with environmentalist aims to protect the environment and depletion of resources. Although considered a green energy source by energy producers, many environmental groups significantly oppose dry steam, hybrid, hot

7. *Id.* at 110.

8. *Id.* at 109.

9. Jake Wakeland, *Environmentalism's Big Lie: Renewable Energy*, INTELLECTUAL ACTIVIST, Oct. 2001, *available at* http://www.intellectualactivist.com/aboutEnvironmentalism.html.

rock, and hot water systems. Environmentalists point out that geothermal resources are still finite resources and not a renewable source of energy.[10] There is also competition among users and extractors of the resource.

Section VI explains some of the environmental concerns pertinent to geothermal resources, predominantly the potential loss of biodiversity. This section discusses energy plant discharge of heated geothermal water of high mineral concentration into surface streams, resulting in thermal and mineral stream pollution. Fish species, which survive on a very strict temperature gradient, can be subject to die-offs if the temperature or mineral composition of the stream changes significantly. Section VI also discusses the particular characteristics of thermophiles that make them susceptible to extinction, and how geothermal resource utilization threatens a significant loss of thermophile biodiversity. Section VI concludes with discussions about the lack of knowledge regarding geothermal resources, various scientific unknowns, and groundwater depletion.

The remainder of the article is devoted to an understanding of federal and California geothermal law and geothermal resource utilization. Utilization of geothermal resources under California law requires three steps: the acquisition of the right to develop a geothermal resource, compliance with environmental requirements, and compliance with development and extraction requirements. If the mineral estate and surface estate have been split, siting rights and mineral rights must be acquired. Federal and California law merge where the United States has reserved a mineral right to a geothermal field that is accessible from a state or privately owned surface estate. Section VII first discusses applicable federal acquisition statutes, including the Geothermal Steam Act and cases arising out of the classification of geothermal resources as a mineral, water, or *sui generis*. Second, federal environmental and development regulations are discussed. Section VIII then addresses the acquisition and development of geothermal resources on California state and private lands and finally, California state and environmental development requirements.

Section IX concludes the article with a discussion of the need for preservation of thermophile biodiversity for future medical and scientific research. Section IX shows that current geothermal laws applicable to California address only the development, exploitation, and depletion of the state's geothermal resources. This article contends that because of the paltry scientific knowledge concerning geothermal resources, California law should provide for the protection of

10. Attempts to make geothermal resources renewable include injecting and re-injecting water into the geothermal field. These processes will be discussed *infra*, section VI.

thermophile biodiversity to ensure that valuable resources are not destroyed before they are understood or their economic potential recognized.

Until thermophile biodiversity can be shown to co-exist with the depletion, injection, and re-injection of geothermal resources, significant precautionary measures should be instated to protect California thermophile resources for future research and uses. If it is indeed true that there is a zero-sum game between preservation of thermophiles and development of geothermal resources, legislatures should look before they leap, given the economic and medical potential of thermophile diversity.

II. Defining Types of Geothermal Resources

This section begins with an overview of the scientific processes creating and affecting geothermal resources. The majority of this section explains the functional and substantive processes of each type of system, while recognizing that definitions of geothermal resources vary between federal and state regulators. This section then concludes with the basic definitions pertinent to California geothermal resources.

The term geothermal, in its most basic sense, is simply the heat radiated from the core of the earth.[11] Geothermal resources are generally categorized by the economic application of the resource. There are five major economic applications. Dry steam systems, hot water systems, hybrid geothermal brine systems, and hot dry rock systems are each primarily utilized for energy production. Low temperature systems are used primarily for domestic applications, including direct heating and mineral spas.

A. Tectonic Relationship of Earth, Plates, Magma, and Groundwater

Although the earth is primarily composed of solid rock, the extreme heat radiated from the core causes the inner earth to take on fluid-like characteristics; the material constantly shifts and rearranges itself.[12] As mass moves away from the core and toward the surface, it begins to cool and takes on more rigid characteristics. At the surface,

11. It should be noted that many different geologic and tectonic processes cause heat production from within the earth. For a detailed discussion, *see* MICHAEL K. LINDSEY & PAUL SUPTON, GEOTHERMAL ENERGY: LEGAL PROBLEMS OF RESOURCE DEVELOPMENT 3 (1975).

12. NEIL A. CAMPBELL, BIOLOGY 485 (3d ed. 1993)

the cooled material forms into plates.[13] These plates, in essence, float on top of the lower fluid layers of the earth. However, the plates do not stay in one place. They move around and collide into each other.[14] Where two plates converge, one plate will move downwards in a process called subduction.[15] Plates can also move apart and grow when magma comes to the surface to create new plate material; that process is termed divergence. Two plates can also slide past each other, and that movement is termed "transform boundaries." It is these processes that produce geothermal resources. A geothermal resource is made up of three parts: heat, water, and minerals. Magma,[16] the molten rock that carries heat, is usually found deep below the earth's surface. However magma chambers close to the earth's surface can be found in areas of high tectonic activity, such as convergence zones along the Pacific Coast of California.[17] When the magma chamber is sufficiently close to the earth's surface, the heat from the chamber heats the surrounding groundwater.[18] The addition of high heat to water and rock causes chemical metamorphosis of minerals, some of which dissolve into the geothermal water. Thus, geothermal resources tend to have high mineral compositions. If there is a path for the groundwater to directly reach the earth's surface, the resulting flow of heated water is termed a hot spring, fumarole, or geyser, depending upon the specific characteristics of the flow.[19]

Hot springs are the most common surface manifestations of geothermal activity[20] and occur when there is a flow of water to the surface. They provide easy access to geothermal fluids and thus tend to be the most studied.[21] A fumarole occurs when less water is present, and the vent emits gases and vapor instead of liquid water. Hot

13. *Id.*

14. *Id.*

15. *Id.*

16. "[M]agma [–] [a] hot, silicate, carbonate, or sulphide melt containing dissolved volatiles and suspended crystals, which is generated by partial melting of the Earth's [sic] crust or mantle and is the raw material for all igneous processes." AILSA ALLABY & MICHAEL ALLABY, OXFORD DICTIONARY OF EARTH SCIENCES 301 (2d ed. 2003)

17. "[M]agma chamber [–] [a] region, postulated to exist below the Earth's surface, from which magma is received from a source region in the deep crust or upper mantel, stored, and from which it moves to the Earth's surface at the site of a volcano." *Id.*

18. Water other than groundwater may be present in interstitial areas, below the soil.

19. "[H]ot spring [–] [a] continuous flow of hot water through a small opening on to the Earth's [sic] surface. The water is usually groundwater heated at depth by hot rocks and recycled to the surface by convection." ALLABY, *supra* note 16. *See also* LINDSEY, *supra* note 11.

20. MARSHALL J. REED, *The Collection of Geothermal Fluid Samples for Chemical Analysis*, GEOTHERMAL PROF'L PAPERS 4 (Cal. Dep't of Conservation, Div. of Oil and Gas 1975).

21. *Id.*

springs that undergo dry periods may become fumaroles.[22] Hot springs and fumaroles can be important surface manifestations of geothermal fields, the term used to define areas of high heat concentrations and flow.[23] Much of the categorization and local regulation of geothermal resources is based on the definition of various geothermal fields.

The composition and temperature of the reservoir determines to what economic application category the geothermal resource belongs: dry stream, hot water, hybrid geothermal brine, hot dry rock, and low temperature water. Resources may also be defined by physical states: liquid, vapor, or a mixture of liquid and vapor termed "dominant phase."[24] Dominant phase resources are utilized in hybrid or "combined" systems.

B. Dry Steam Systems

When the resource emits predominantly vapor, the resource is defined as a dry steam geothermal resource.[25] Dry stream resources are the most readily usable geothermal resource for generating electricity. Basically, a well is drilled to access the geothermal dry steam in a reservoir, which in turn passes through the drilled hole to the surface. Once at the surface, the steam expands and drives a steam turbine.[26] Typically, after passing through a turbine, the steam is discharged to a condenser and mixed with cool water.[27] The heated water is then pumped to a cooling tower where most of the condensate is evaporated.[28] The water is then returned to the condenser. The excess water that does not evaporate is re-injected into the reservoir through re-injection wells.[29]

Because it produces energy directly, dry steam is easily utilized. Also, due to its vaporous nature, it has a less corrosive effect on wells

22. *Id.*

23. "Geothermal Fields – the anomalously high rate of heat flow may be due to present, or fairly recent, orogenic or magmatic activity, or to the radioactive decay of isotopes K, Th, and U where these occur at very high concentrations in crustal granites." ALLABY, *supra* note 16, at 230.

24. LINDSEY, *supra* note 11, at 5.

25. "In such a field, the porous hot zone is overlaid by an immense steam reservoir, in turn covered by impermeable rock. For this condition to exist, fluid pressures in the reservoir must be below hydrostatic. When that is the case, the steam becomes superheated." *Id.*

26. *Id.*

27. *Id.* That is the process at Geysers Field in California. *Id.* at 43. *See also* Geysers Geothermal Ass'n, *Geysers Field*, (2006), http://www.thegga.org/ (describing California's geysers).

28. LINDSEY, *supra* note 11, at 5.

29. *Id.*

and machinery used in geothermal energy plants than other methods of production.[30] However, the geological conditions that create dry steam fields are rare and only utilized in a few commercial fields globally.[31]

One such field is Geysers Field in California. Located in Napa County, Geysers Field has been operating a dry steam turbine system since 1960.[32] Four of the cases discussed later in this article, *United States v. Union Oil*,[33] *Occidental Geothermal Inc., v. Simmons*,[34] *Geothermal Kinetics, Inc v. Union Oil*,[35] and *Pariani v. State of California*,[36] involve Geysers Field.[37]

C. Hot Water Systems

Most geothermal resources consist of liquids stored in reservoirs at very high temperatures and pressures.[38] When the temperature of the water is higher than the boiling point, 212 °F, it is termed "hot water." It remains in liquid form only as long as it is subject to extreme underground pressure.[39] Hot water resources can generate electricity through flash steam or binary processes.

Flash steam energy generation is used when water temperatures exceed 350 °F. The process takes advantage of the ability of highly-pressurized geothermal liquids to "flash" into steam as they reach the surface.[40] In this system, the water is brought to the surface through a well and allowed to flash; the resulting steam drives a turbine.

Binary systems generate electricity from hot water geothermal resources with temperatures of 212°F to 350°F. In these systems, the hot water resource heats a secondary fluid, called a working fluid, which has a lower boiling point than that of water. The working fluid is heated and the vapor from the working fluid drives a turbine.[41]

30. *Id.*

31. *Id.*

32. *Id.* at 37-38. Geysers Field is a joint venture conducted by the Magma Power Company, the Thermal Power Company of San Francisco, and Pacific Gas and Electric Co.

33. *United States v. Union Oil Co.*, 549 F.2d 1271 (9th Cir. 1977).

34. *Occidental Geothermal, Inc. v. Simmons*, 543 F. Supp. 870 (N.D. Cal. 1982).

35. *Geothermal Kinetics, Inc. v. Union Oil Co.*, 141 Cal. Rptr. 879 (1977).

36. *Pariani v. State of California*, 164 Cal. Rptr. 683 (1980).

37. Ralph B. Kostant, *Summary of Geothermal Law*, THE NATURAL RESOURCES LAW MANUAL 237 (Richard J. Fink ed., 1995).

38. LINDSEY, *supra* note 11, at 5.

39. KOSTANT, *supra* note 37, at 229.

40. *Id.*

41. KOSTANT, *supra* note 37, at 229.

D. Hybrid Geothermal Brine Systems

In geothermal reservoirs with concentrated saline solutions, minerals from the surrounding rock leach into the solution.[42] These solutions are termed "geothermal brines." Some of these brines contain a mixture of hot pressurized water and natural gas.[43] Hybrid power systems are capable of generating electricity from both of the resources.

One plant that uses geothermal brines is the United States Department of Energy's Pleasant Bayou Hybrid Power System in Bayou, Texas, which started generating electricity in 1990.[44] The Bayou plant first extracts natural gas from the geothermal brines. The natural gas is then burned in a gas engine to directly generate electricity.[45] The exhaust heat from the gas engine is then combined with the geothermal brine heat to generate additional electricity.[46]

E. Hot Dry Rock Systems

Hot dry rock technology is an artificial geothermal resource. Hot dry rocks are usually granitic, found at depths of 8,000 to 20,000 feet,[47] and have high heat production.[48] To exploit the heat generated at these locations, a well is drilled and water is injected into the rock at extremely high pressures to fracture the surrounding rock, thereby creating a reservoir.[49] The injected water is subsequently heated as it flows through the rock. Secondary wells are then drilled to extract the heated water and generate electricity.[50] The water cooled from electrical generation is then recirculated and re-injected into the artificial geothermal reservoir.[51]

42. These metals are "important intermediaries in the deposition of ore deposits." ALLABY, *supra* note 16, at 230.

43. KOSTANT, *supra* note 37, at 230.

44. *Id*. *See also* U.S. Dep't of Energy, A *History of Geothermal Energy in the United States*, (Nov. 1, 2006), http://www.eere.energy.gov/geothermal/history.html.

45. KOSTANT, *supra* note 37, at 230.

46. *Id*.

47. *Id*.

48. The high heat production is a "result of the decay of radiogenic materials rather than merely residual heat." ALLABY, *supra* note 16, at 230.

49. DAVE V. DUCHANE, HOT DRY ROCK: A VERSATILE ALTERNATIVE ENERGY TECHNOLOGY 1 (Society of Petroleum Engineers 1995), *available at* http://www.ees4.lanl.gov/hdr/documents/SPE30738.pdf; *see also* KOSTANT, *supra* note 37, at 230.

50. Duchane, *supra* note 49, at 1.

51. *Id*. at 4. A hot dry rock technology study was performed by the Los Alamos National Laboratory at Fenton Hill, New Mexico, which reported a second phase water loss of seven percent. Other than the water loss, the system is basically a closed loop system. *Id*. at 1.

F. Low Temperature Water Systems

Low temperature geothermal water is any geothermal resource cooler than the boiling point of water.[52] These waters are currently incapable of efficiently generating electricity.[53] However, these resources can be used for direct heating applications.[54] Communities have utilized direct heating to heat buildings in the United States since the 1800s.[55] This resource can also be used in mineral spas and for heat in commercial applications, including greenhouses and food processing.[56]

G. California Definitions

The legal definitions of what constitute dry steam, hot water, and low temperature water inform regulatory controls. In California, for example, the Geothermal Section of the Department of Conservation Oil and Gas Division oversees geothermal resources on both state and private lands.[57] California regulations define a high temperature geothermal fluid as a "naturally heated subterranean fluid with a surface temperature equal to or higher than the boiling point of water."[58] A low temperature geothermal fluid is defined inversely as a "naturally heated subterranean fluid with a surface temperature below the boiling point of water at ambient atmospheric pressure."[59] California defines usable thermal energy as "usable heat energy contained in geothermal fluid."[60]

III. Competing Interests

Geothermal resources have different competing interests, depending upon the classification of the resources as dry steam, hot water, hybrid, and hot rock, or alternatively, low temperature water. This section first addresses competing interests and environmental

52. CAL. CODE REGS. tit. 14, § 1920.1 (2006).

53. Laura MacGregor Bettis, Comment, *In Hot Water: Can Idaho's Ground Water Laws Adequately Govern Low Temperature Geothermal Resources?*, 39 IDAHO L. REV. 113, 124 n.54 (2002).

54. *Id.* at 118, 125, 131.

55. *Id.* at 113.

56. KOSTANT, *supra* note 37, at 230.

57. CAL. DIV. OF OIL & GAS, DRILLING AND OPERATING GEOTHERMAL WELLS IN CALIFORNIA 1 (5th ed. 1990), *available at* ftp://ftp.consrv.ca.gov/pub/oil/publications/pr7s.pdf.

58. CAL. CODE REGS. tit. 14, § 1920.1 (2006).

59. *Id.*

60. *Id.*

opposition to the energy-producing geothermal resources. Although geothermal energy production is thought of as "green energy," construction of geothermal plants may nonetheless be met with environmental opposition, much like the debate over whether windmill farms harm birds.[61] Second, this section concludes with how uses of low temperature water may cause conflict.

A. Dry Steam, Hybrid, Dry Rock, and Hot Water Energy Generation

The growing need for efficient renewable energy in California and elsewhere has led to research into green energy sources such as wind, solar, and geothermal energy production.[62] This section addresses the economic limitations of geothermal resources and the environmental opposition to their use.

The expense of harnessing and transferring geothermal energy adds to the scarcity of geothermal resources, to make the industry "high-risk and capital intensive."[63] The risk means larger energy companies with sufficient capital dominate the industry. Companies have to build the plants, transfer the power once it is generated, and mitigate the effects of high mineral content and toxicity on equipment and operating staff.[64]

Geothermal resource utilization requires that the geothermal resource be used "at or very near the site of its production."[65] Geothermal resources generate electricity because of their high temperatures. Thus, any transport of water or vapor over long distances would result in significant cooling of the resource and a loss of potential electrical generation.[66] Due to the need to harness the heat energy at the nearest possible surface location, geothermal plants are usually constructed in remote areas.[67]

Once power is generated, it must be transferred through power lines to users. Power transfer from remote areas requires the "acquisition of power line easements and the installation of transmissions lines."[68] Such limitations on remote locations significantly affect the

61. Badiei, *supra* note 1, at 111.
62. *Id.* at 109.
63. *Id.* at 120 (internal quotation marks omitted).
64. *Id.*
65. KOSTANT, *supra* note 37, at 230.
66. *Id.*
67. *Id.*
68. *Id.*

cost effectiveness of geothermal power plants.[69] The remote location of the power plant also contributes to the environmental concerns.[70]

The mineral content of the water or steam also contributes to the expense of energy generation. For example, California's Salton Sea Geothermal Field "produces high temperature, high salinity water. Maximum temperatures range from 220 °C to 360 °C . . . and the concentration of dissolved solids is up to 35% by weight."[71] The combination of high temperatures and high concentrations of dissolved solids causes severe erosion of the carbon steel well casing "used to bring the resource to the surface."[72] Erosion of the well casing and related equipment can result in blowouts. Therefore, geothermal well equipment must meet blowout prevention standards, adding to the costs.[73]

Geothermal power plants are usually proposed in rural areas that for the most part remain in a natural state, and therefore they often trigger environmental opposition. Northern California groups have argued that geothermal plants will "further carve up forests" that local Native American tribes consider to "be part of their sacred lands."[74] One pro-industry article claims that environmental opposition to geothermal plants in California is "no less hostile than [the] attitude toward all other forms of man-made power. After the installation of hundreds of 'alternative' energy plants in the state . . . the greens have begun to reject one renewable power technology after another."[75] Some of the reasons for the strong environmental opposition are noted in the environmental concerns section of this article.

B. Low Temperature Uses

Low temperature geothermal water is used for many different applications including direct heating, mineral spas, and religious ceremonies and customs. For naturally-occurring hot springs, con-

69. *Id*.

70. Badiei, *supra* note 1, at 111-112.

71. REED, *supra* note 20, at 1.

72. *Id*. at 4.

73. CAL. PUB. RES. CODE § 3739 (2006).

74. Badiei, *supra* note 1, at 111.

75. Wakeland, *supra* note 9. "In 1995, the Northern Sonoma County Pollution Control District and the Sonoma County District Attorney sued Central California Power Agency over hydrogen sulfide emissions at the world's largest geothermal plants at The Geysers. They imposed a settlement payment of $150,000 . . . . Plans to build a pair of 48 MW [megawatt] geothermal plants near Medicine Lake are facing the kind of obstacles environmentalists used to reserve for oil drilling. Local environmental groups claim that the project threatens the system of lava tubes and volcanic aquifers surrounding the lake and that the Shasta crayfish, an endangered species, might be affected." *Id*.

flict arises between religious users, local users, and environmental protection interests.[76] Private property rights and tourism concerns have clashed in areas with geothermal fields capable of providing geothermal resources for mineral spas.[77]

While energy producers in the U.S. rarely heat buildings with low temperature resources, the method has the potential to be a cost effective local heat source.[78] Low temperature systems developed in Idaho in the 1800s are still in use today, heating private homes and government buildings, including the state capital building.[79] Globally, direct heat is often used in geothermal regions; for example, Iceland warms 90 percent of the buildings in its capital with direct heating.[80] Direct heating can also be used in food processing applications and in heating commercial greenhouses.[81]

In California, naturally occurring hot springs provide public enjoyment and income for private spa enterprises.[82] Conflict may arise between local users who have developed the resource by constructing bathing pools and groups exercising religious or cultural customs.[83] Many eastern cultures believe that the mineral water aids in longevity and health. To comply with health regulations, owners of hot springs used for human bathing must regularly drain and clean the pools.[84] This can result in runoff of human waste, cleaning compounds, and thermal pollution to nearby streams, thereby affecting the local ecosystem health and biodiversity. In addition, the cleaning and scrubbing of the hot spring necessarily results in the loss of thermophile species growth. Some areas, such as Yellowstone Na-

76. Badiei, *supra* note 1, at 111. "According to Felice Pace of the Klamath Forest Alliance, an environmental group challenging the construction of two geothermal projects, 'the plants will further carve up forests in Siskiyou County and [are opposed by] Indians who consider the sites to be part of their sacred lands.'" *Id.*

77. Herbert M. Atienza, *New Ordinance Brews Property-Rights Issue*, THE PRESS-ENTERPRISE (Riverside, Cal.), Aug. 11, 2004, at B01.

78. Bettis, *supra* note 53, at 114-15.

79. *Id.* at 114.

80. *Id.*

81. *Rosette v. United States*, 277 F.3d 1222, 1225 (10th Cir. 2002). Appellants utilized geothermal resources to heat greenhouses for the commercial growing of roses.

82. *See generally* MARJORIE GERSH-YOUNG, HOT SPRINGS & HOT POOLS OF THE SOUTHWEST (Aqua Thermal Access 1998), the classic tour guide.

83. Greg Cruey, *Bali: THE Southeast Asian Destination: Politics and History of Bali Tourism*, (2006), http://goasia.about.com/od/indonesia/a/balioverview_3.htm. "[T]ourism requires electricity; but generating electricity can require hard choices, as with plans for a geothermal power station at Bedugal, a sacred mountain lake. Which is more sacred: religion or the economy?" *Id.*

84. CAL. HEALTH & SAFETY CODE § 116043 (2006).

tional Park, completely forbid human bathing or soaking in natural hot springs.[85]

Conflict also arises in areas where low temperature geothermal resources are extracted from wells for use in mineral spas. For example, the City of Desert Hot Springs in southern California passed a zoning ordinance that illustrates these conflicts. The city is located directly above the Desert Hot Springs Geothermal Field, which has supported the development of a significant mineral spa tourist industry.[86] In order to further profit from the tourism and with "strong lobbying support from local spa owners,"[87] the city enacted a hot water spa district in its zoning code that strictly limits development. The zoning "essentially puts a moratorium on new home construction within the newly designated zones."[88] The zoning change has met opposition from local landowners who purchased land within the district with the intention of building single-family homes.[89] Larger developers are required to include mineral spa hotels with any new development.[90] The zoning may harm geothermal resources because it effectively requires the development, depletion, and ultimate exhaustion of the resources.

IV. Environmental Concerns

This section discusses some of the environmental impacts of geothermal resource use. Defining geothermal energy production as "green" may be misleading. Although apparently less environmentally damaging than fossil fuel and nuclear energy production, geothermal energy does have adverse environmental impacts.[91] Potential impacts include noise and air pollution associated with the construction of geothermal plants, subsequent thermal and mineral stream pollution from plant discharge, loss of thermophile biodiversity and geologic record, unknown groundwater depletion and subsidence, and tectonic effects of injection and re-injection of water into geothermal reservoirs. In addition, plant construction may conflict with the Endangered Species Act.

85. National Park Service, *Yellowstone National Park: Minimizing Your Impact on a Fragile Park*, (2006), http://www.nps.gov/yell/planyourvisit/impact.htm. "Yellowstone's thermal features are extraordinary natural wonders. Most are formed through decades or centuries of natural processes . . . . Swimming or bathing in the thermal pools or streams whose waters flow entirely from a thermal spring or pool is prohibited." *Id.*

86. Atienza, *supra* note 77.

87. *Id.*

88. *Id.*

89. *Id.*

90. *Id.*

91. Badiei, *supra* note 1, at 111.

A. Noise, Air Pollution, and Endangered Species Habitat

As noted above, the need to harness geothermal energy close to the source requires the construction of energy plants in remote areas. The geothermal plant itself can add to noise pollution,[92] which can be particularly harmful to the habitat of an endangered or threatened species. Many species, including birds, frogs, and mammals, rely on calls and sounds to mate, interact, feed their young, and warn of predators.

Although they generate significantly less pollution than a fossil fuel plant, geothermal plants can also harm air quality.[93] Geothermal plants release hydrogen sulfide and carbon dioxide into the atmosphere.[94] However, the U.S. Department of Energy reports that up to 99.9 percent of the hydrogen sulfide could be eliminated through technological processes.[95]

B. Thermal and Mineral Stream Pollution and Geothermal Brine

Thermal stream pollution occurs when heated water is added to a surface stream, increasing its temperature. Fish and other aquatic or riparian species are intolerant to significant changes in temperature, which can result in population die-offs. Even minimal temperature changes can interfere with breeding by changing the temperature of eggs. Temperature pollution can be reduced using cooling towers.[96] However, the use of local water by cooling towers can cause a "'severe strain on the available water resource[s].'"[97]

Mineral stream pollution occurs when water with a high or different mineral concentration is added to a surface stream, increasing its mineral content. The addition of geothermal brines to streams can also add to environmental degradation.[98] As discussed previously, minerals from surrounding rock leach into the solution, adding dissolved metals to the water.[99] Discharge of these minerals into streams changes the chemical and mineral composition of the stream, which affects instream species.[100]

92. *Id.*
93. *Id.* at 112.
94. *Id.*
95. *Id.* at 112 n.42.
96. *Id.* at 112.
97. *Id.*
98. *Id.*
99. ALLABY, *supra* note 16, at 230; *see* discussion *supra* Part II.D.
100. Badiei, *supra* note 1, at 112.

C. Thermal Biodiversity and the Geologic Record

Geothermal resources contain extreme temperatures and concentrated mineral compositions, making them toxic for most prokaryotic species.[101] However, certain species have adapted to live in these toxic ecosystems — hyperthermophiles and extremophiles, as well as thermophiles. "Ecological studies have shown that water-containing terrestrial, subterranean and submarine high-temperature environments harbor a great diversity of hyperthermophilic prokaryotes, growing fastest at temperatures of 80 degrees Celsius or above."[102] Geothermal resources remain one of the last sources of uncategorized biodiversity on earth. "Microbial processes in these environments are of critical importance to the biosphere, and the noncultured bacteria residing there are a valuable resource for novel genomic information."[103] Norman Pace, a molecular biologist at the University of Colorado, has noted:

> It has become clear over the past few decades that substantial microbial diversity occurs at very high temperatures. Hyperthermophilic organisms . . . promise a wealth of unknown biochemistry and biotechnological potential and challenge our comprehension of biomolecular structure. Nonetheless, relatively little is known about the diversity of life at high temperatures because of a traditional problem in microbial ecology: the inability to cultivate naturally occurring organisms.[104]

101. Sue Barns & Siegfried Burggraf, [Kingdom] Crenarchaeota, (January 1997), http://tolweb.org/Crenarchaeota/9/1997.01.01 *in* The Tree of Life Web Project, http://tolweb.org/.

102. Robert Huber, Harald Huber & Karl O. Stetter, *Towards the Ecology of Hyperthermophiles: biotopes, new isolation strategies and novel metabolic properties*, 24 FED'N OF EUR. MICROBIOLOGICAL SOCIETIES MICROBIOLOGY REVIEWS Issue 5, 615 (2000). "In their natural habitats, hyperthermophiles form complex food webs, consisting of primary producers and consumers of organic material. Their metabolic potential includes various types of aerobic and anaerobic respiration and different modes of fermentation. In hydrothermal and geothermal environments, hyperthermophiles have important ecological functions in biogeochemical processes. *Id.*

103. Cheryl R. Kuske et al., Abstract, *Detection of Noncultured Bacterial Divisions in Environmental Samples using 16S rRNA-Based Fluorescent In Situ Hybridization*, DOE MICROBIAL GENOME PROGRAM REPORT, (Sept. 2005), http://www.microbialgenome.org/2000report/19abstracts.html.

104. Norman R. Pace, Abstract, *Phylogenetic Analysis of Hyperthermophilic Natural Populations Using Ribosomal RNA Sequences*, DOE MICROBIAL GENOME PROGRAM REPORT, (Sept. 2005), http://www.microbialgenome.org/2000report/19abstracts.html.

Some argue that hyperthermophiles are the most primitive organism existing today.[105] Hyperthermophiles are prokaryotes that require temperatures above 80°C to 110°C to live,[106] functioning best at temperatures around 100 °C.[107] Some species are able to "grow at up to 113 °C and, therefore, [represent] the upper temperature border of life."[108] Cultures of some species are able to survive autoclaving,[109] making them valuable for scientific research, especially microbial research.

Bioprospecting the species can yield pharmaceutical and industrial products and applications.[110] The "enzyme *Taq polymerase* . . . was discovered through research on a thermally adapted microbe known as *Thermus aquaticus*" from sampling a hot spring in Yellowstone National Park.[111] Both the enzyme and a resulting technique used in DNA identification called the PCR process were subsequently sold for $300 million in 1991 and reportedly generate annual revenues around $100 million per year.[112]

Thermophile diversity is essential to such research. Diversity is threatened by human use of hot springs and fumaroles, and arguably bioprospecting of those resources. Loss of diversity may also occur on a subterranean level, due to depletion of groundwater sources, and injection and re-injection of non-heated water. As noted earlier, thermophiles are sensitive to changes in temperature and pressure.[113]

105. Craig Elliot, *Thermophiles Provide Unique Opportunities for Scientific Research*, YELLOWSTONE ASS'N, (2006), http://yellowstoneassociation.org/membership/discovPopup.aspx?id=22. "Some of these thermophiles are direct descendants of the earliest life forms on Earth. According to DNA analysis, the organism most closely related to the origin of life – Earth's most primitive species – lives in a hot spring in Yellowstone's Hayden Valley. During the first 3 billion years of Earth's history, scientists believe microorganisms transformed the atmosphere, which had no oxygen, into one that could support complex forms of life. Microorganisms called 'cyanobacteria' were the first to use photosynthesis to process carbon dioxide into oxygen and other byproducts. This oxygen production led to the creation of Earth's atmosphere. Other organisms tapped the energy stored in chemicals, such as iron and hydrogen sulfide, in a process known as 'chemosynthesis.' Cyanobacteria continue to be present in some of the unique bacteria mats and streamers common to Yellowstone's thermal areas. Studies have shown that cyanobacteria and other microbes make up most of the species on Earth, but less than 1 percent of them have been studied in-depth." *Id.*

106. Karl O. Stetter, *Extremophiles and Their Adaptation to Hot Environments*, 452 FED'N OF EUR. MICROBIOLOGICAL SOCIETIES MICROBIOLOGY REVIEWS 1, 22 (1999).

107. *Id.*

108. *Id.* "The chemolithoautotrophic archaeon *Pyrolobus fumarii* is able to grow at 113 °C." *Id.*

109. *Id.* "*Pyrolobus* and *Pyrodictium*." *Id.*

110. *Edmonds v. Babbit*, 93 F. Supp. 2d 63, 64 n.1 (D.D.C. 2000).

111. Bryson, *supra* note 4.

112. *Id.*

113. Stetter, *supra* note 106.

Injection of non-heated water into a geothermal reservoir can kill species if the temperature change is great enough to cool surrounding geothermal fluid, even briefly, to a temperature below tolerable levels.

In addition to adding to the advancement of science, geothermal resources may also add to the earth's geologic record by recording present fossil records. Hydrothermal springs have high rates of "microbial productivity, which often coexist with high rates of mineral precipitation, a situation generally regarded as highly favorable for microbial fossilization."[114] Microbial fossilization, biosignatures, and their applicability to scientific innovation are beyond the scope of this article,[115] but it should be noted that microfossilization of thermophiles and their biosignatures add to our scientific knowledge base, aid our understanding of evolution, and have the potential to drastically enhance medical and scientific research.

D. Unknown Replenishment Rates, Undefined Aquifers, and Unknown Chemical and Biological Compositions of Geothermal Resources.

Many unknown conditions affect the sustainability and potential environmental impacts of geothermal resources. Research on replenishment rates and aquifer definition is primarily conducted in association with a proposed or currently utilized geothermal application. The results are likely to be site or aquifer specific. The lack of scientific research and understanding of geothermal ecosystems may threaten thermophile biodiversity.

Geothermal resources have developed over tens of thousands of years, and their isolation created countless site-specific species. Separate species thrive as their environments vary in temperature and mineral composition. Species differentiate between geothermal fields and even between hot springs. Furthermore, a single pool may contain multiple species. Researchers have found different species at separate areas along the temperature gradient of a hot spring pool.[116]

In addition, little is known about the subsurface mineral composition and biodiversity of geothermal resources. Research into the

114. Jack D. Farmer, *Factors Controlling Microbial Biosignature Preservation in Hot Spring Deposits*, 36 GEOLOGICAL SOC'Y OF AM. Issue 5, 474 (2004).

115. *See* Sherry L. Cady, *Formation, Alteration, and Preservation of Hyperthermophilic Biosignatures*, (Nov. 2001), http://gsa.confex.com/gsa/2001ESP/finalprogram/abstract_6433.htm.

116. Ken Takai & Yoshihiko Sako, *A Molecular View Of Archaeal Diversity in Marine and Terrestrial Hot Water Environments*, 28 FED'N OF EUR. MICROBIOLOGICAL SOCIETIES MICROBIOLOGY REVIEWS Issue 2, 177 (1999). *See also* David B. Hedrick et al., *In Situ Microbial Ecology of Hydrothermal Vent Sediments*, 101 FED'N OF EUR. MICROBIOLOGICAL SOCIETIES MICROBIOLOGY REVIEWS 1, 1 (1992).

mineral, chemical and biological composition of subsurface geothermal resources is costly. In addition, it is difficult to maintain the integrity of the subsurface sample in collection. A report by the California Division of Oil and Gas notes:

> It is possible to completely characterize the chemical composition of a bottled sample in the laboratory, but this sample may be much different from the geothermal fluid from which it was obtained. Certain chemical species will oxidize on exposure to air, and the partitioning of species between the gas and the liquid phases will change in response to changes in physical conditions.[117]

All of these unknown factors add to the possibility of irreparable harm to the thermophile biodiversity of geothermal resources from the depletion and degradation of geothermal resources.

E. Groundwater Depletion, Land Subsidence, Injection and Re-Injection, and Tectonic Consequences

Groundwater is the water contained in interstitial areas between rock compositions on the earth's surface.[118] The use of hot or low temperature water systems inevitably requires the depletion of associated groundwater.

Groundwater carries a "considerable portion of the earth's ground load,"[119] the weight of the ground surface. "Land subsidence is 'a gradual settling or sudden sinking of the [e]arth's surface owing to subsurface movement of earth materials.' Though several different earth processes can cause subsidence, more than 80 percent of the subsidence in the United States is related to the withdrawal of groundwater."[120] Subsidence results in "damage to roads, buildings, and other structures,"[121] in addition to damaging the environment and habitat in the area of subsidence. A Geothermal Literature Assessment by Gawell & Bates notes:

> Because geothermal operations take place in areas that are very tectonically active, it is often difficult to distin-

117. REED, *supra* note 20, at 3.

118. BLACK'S LAW DICTIONARY (8th ed. 2004). *See also* CAL. WATER CODE § 60015 (2006).

119. Badiei, *supra* note 1, at 112.

120. J.R. Bartolino & W.L. Cunningham, *Ground-Water Depletion Across the Nation* 2, U. S. Geological Survey, ("U.S.G.S.") (2004), http://water.usgs.gov/pubs/fs/fs-103-03/JBartolinoFS(2.13.04).pdf.

121. *Id.* at 4.

> guish between geothermal-induced and naturally occurring events. However, geothermal energy production has been shown to at times results in land subsidence. This occurs when the withdrawal of a fluid from an underground reservoir results in a reduction of pressure, thereby causing subsidence. However, subsidence can generally be defined as any slow ground movement, whether it is horizontal movement or vertical movement. Such subsidence occurs not only in geothermal fields, but in petroleum reservoirs as well. The most serious problems have occurred outside of the U.S. and may be the result of different approaches to re-injection technology. Weakening of underground support is suspected as being the cause of massive subsidence at Wairakei geothermal field in New Zealand – the largest subsidence ever recorded[,] which is generally thought to be human-induced. It is also suspected as being responsible for the large landslide at the Zunil geothermal field in Guatemala. Re-injection has been shown to help reduce the effects of subsidence.[122]

As noted, a remedy to subsidence is to re-inject water back into the reservoir.[123] However, little is known about the geologic and tectonic effects of re-injection into hot water systems and injection of water into dry rock systems. Utilization of geothermal resources has also been noted to add to the induced seismicity of geothermal fields:

> Geothermal resources are almost always found in places that are very tectonically active, which means that these areas will be subject to a great deal of geological activity even in the absence of field development. Therefore, seismic activity in geothermal regions raises questions about whether the calamity was due to natural causes or was man-made. The literature appears to indicate that geothermal operations can indeed cause some seismic activity, but the earthquakes that are generated are extremely small and weak, and usually require sensitive instrumentation to be detected at all, even directly above the epicenter. These microearthquakes appear to be as-

122. KARL GAWELL & DIANA BATES, GEOTHERMAL LITERATURE ASSESSMENT: ENVTL. ISSUES 44, (Geothermal Energy Ass'n, May 2004), *available at* http://www.geothermal-biz.com/GeothermalLiterature.pdf.

123. Badiei, *supra* note 1, at 112.

> sociated with the subsurface pressure changes caused by production and injection operations. [124]

Although unclear and relatively unstudied, there appears to be a significant question of how utilization of geothermal resources affects tectonic activity.

V. Current California Law

Compliance with California geothermal law can be broken down into the following steps: acquisition of the right to develop a geothermal resource, meeting environmental requirements, and fulfilling development and extraction requirements.[125] Acquisition of rights to develop a geothermal resource depends on whether the geothermal resource is federal, state, or private property. It should be noted that where surface and mineral estates are split, it is necessary to acquire rights to the geothermal resource itself and to "siting" rights, the right to construct a geothermal energy plant on the land above the resource. Siting rights are particularly important on federal leases for geothermal resources, where the United States has reserved mineral rights to land received under land grants. This section addresses the acquisition of rights to develop a geothermal resource on federal lands, including applicable case law, followed by federal environmental and development requirements. It then addresses the development of geothermal resources on California's state and private lands, through state environmental and development requirements.

A. Federal Geothermal Acquisition and Siting Rights

The majority of geothermal resources in the United States are located on federal land[126] in the West. Prior to 1970, geothermal resource development was limited primarily to private lands, because federal government agencies including the Department of the Interior ("DOI") and National Forest Service under the Department of Agriculture were reluctant to dispose of geothermal resources on lands within their jurisdiction without congressional direction.[127] To reduce this restriction on geothermal resource development, President Nixon approved the Geothermal Steam Act.[128]

124. Gawell, *supra* note 122, at 42.
125. *See generally* CAL. DIV. OF OIL AND GAS, *supra* note 57.
126. Wakeland, *supra* note 9.
127. LINDSEY, *supra* note 11, at 55.
128. *Id.*

The Geothermal Steam Act ("Act") of 1970 is the basis of all federal geothermal jurisprudence.[129] With two exceptions, the Act is the only means of acquiring rights to develop geothermal resources on federal lands. According to legislative history, the purpose of the Act was to "permit exploration and development of geothermal steam and associated geothermal resources underlying certain public domain land."[130] The Act gave the Secretary of the Interior the power to issue leases to U.S. citizens for geothermal steam development[131] and utilization on public lands, including national forests, as well as on lands conveyed from the U.S. to private entities. The U.S. may reserve geothermal steam and associated resources on land it conveys.[132] The Act sets forth guidelines for leasing and royalties and states that a lessee is "entitled to use so much of the surface of the land covered by his geothermal lease to be necessary for the production, utilization, and conservation of geothermal resources."[133] Certain federal lands and Indian lands are exempt from the Act.[134]

The Act provides an exclusion clause for the development of geothermal resources within national parks when a significant thermal feature will suffer significant adverse effects. Section 1026 of the Act designates the monitoring and determination of adverse effects of proposed development within national parks, which are subject to notice and public comment.[135] Specifically, the Act provides that the Secretary "shall determine on the basis of scientific evidence if exploration, development or utilization of the lands subject to the lease application is reasonably likely to result in a significant adverse effect on a significant thermal feature within a unit of the National Park System."[136] For projects that the Secretary determines are "reasonably likely to result in a significant adverse effect on a significant thermal feature within a unit of the National Park System, the Secretary shall not issue such lease."[137]

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129. Badiei, *supra* note 1, at 113. *See* 30 U.S.C. § 1001 *et seq*. (2006).

130. Badiei, *supra* note 1, at 113 (quoting H.R. REP. NO. 91-1544, at 2 (1970), *reprinted in* 1970 U.S.C.C.A.N. 5113, 5113) (internal quotation marks omitted).

131. 30 U.S.C. § 1002 (2006). *See also id*. § 1028(a) (providing that the "Secretary of the Interior, acting through the United States Geological Survey, and in consultation with the Secretary of Energy, shall establish a . . . program with respect to hot dry rock geothermal energy resources on public lands.").

132. *Id*. § 1002.

133. *Id*. § 1013.

134. *Id*. § 1014(c).

135. *Id*. § 1026(c)(1).

136. *Id*. § 1026(c)(2).

137. *Id*. § 1026(c)(2).

Outside the Act, offshore geothermal resources may be developed under the Outer Continental Shelf Lands Act,[138] and the Department of Defense ("DOD") may develop geothermal resources on lands under its control. For example, a geothermal plant was developed at the China Lake Naval Weapons Center in Coso, California.[139] The Coso plant utilizes a steam system which, at 311°F (155 °C), generates energy to drive six turbine engines.[140] Although the Act provides that lessees shall use all reasonable precautions to prevent the waste of steam and associated resources,[141] the Act does not require the preservation of geothermal resources. The Act does provide that the Secretary shall prescribe rules for the development and conservation of geothermal and other natural resources, but does not mention conservation of geothermal organisms.

The primary question that arose from the Geothermal Steam Act was how to determine which lands conveyed by the U.S. are "subject to a [mineral] reservation of the geothermal steam and associated resources."[142] The Ninth Circuit case *United States v. Union Oil Company*[143] held that the U.S. reserved geothermal resources minerals on lands acquired under the Stock-Raising Homestead Act of 1916 ("SRHA").[144] As part of the effort to "civilize" the West, the SRHA transferred public lands to private ownership under patents subject to a reservation by the U.S. "of all the coal and other minerals."[145] The SRHA did not directly address the reservation of geothermal resources or express an intent to reserve them, because Congress "was not aware of geothermal power"[146] when it enacted the SRHA.

138. 43 U.S.C. §§ 1331, 1337 (2006).

139. Naval Air Warfare Ctr. Weapons Div., *Geothermal Power Generation at Coso Hot Springs*, (Sept. 12, 1998), https://www2.nawcwd.navy.mil/techTrans/index.cfm?map=local.ccms.view.aB&doc=paper.16.

140. *Id.* "Total electricity production from the Coso geothermal field amounts to more than 250 megawatts (250,000,000 watts). One megawatt of electricity will meet the needs of approximately 1,000 households. Assuming an average of 4 people per household, Coso output can provide enough power to serve approximately 1 million people. An important side benefit from this power source is the reduction in amount of hydrocarbons that need to be consumed. Generating 250 megawatts of electricity from geothermal for one year is equivalent to saving 3,825,000 barrels of oil or 875,000 tons of coal. A significant benefit to air quality." *Id.*

141. 30 U.S.C. § 1022(a) (2006).

142. *Id.* § 1002.

143. *Union Oil Co.*, 549 F.2d 1271 (9th Cir. 1977).

144. *Id.* at 1273-1274. *See* Stock-Raising Homestead Act, 43 U.S.C. 299 *et seq.* (2006).

145. *Id.* at 1273.

146. *Id.* "The reason is evident. Although steam from underground sources was used to generate electricity at the Larderello Field in Italy as early as 1904, the commercial potential of this resource was not generally appreciated in this county for another half century. No geothermal power plants went into production in the United States until 1960." *Id.*

In *Union Oil*, landowners in the Geysers Field argued that the term "minerals" should be given the "meaning it had in the mining industry at the time the [SRHA] was adopted,"[147] and that geothermal resources should not be considered a "mineral" under the SRHA. The court instead looked at whether it "would further Congress's purposes to interpret" geothermal resources as minerals,[148] and finding that it did, held that the mineral reservation under the SRHA included geothermal resources.

It should be noted that "nothing prevents a contrary result in a case involving private rights arising in another state,"[149] or under a statute other than the SRHA. In *Bedroc Limited*, LLC *v. United States*,[150] the Supreme Court distinguished a mineral reservation under the Pittman Act from a mineral reservation under the SRHA. The Supreme Court had construed the SRHA to include a mineral reservation of gravel where the SRHA reserved "all the coal and other minerals."[151] In *Bedroc Limited*, however, the Pittman Act reserved "all the coal and other *valuable* minerals."[152] The Supreme Court noted that at the time the Pittman Act was enacted, gravel was not a valuable mineral and therefore was not reserved to the United States.[153] Likewise, a state or another federal land grant may treat geothermal resources differently than the SRHA does. For example, a court may find that geothermal resources do not fall under the Pittman Act either, because geothermal resources were not regarded as valuable at the time of enactment.[154] The right to develop federal geothermal resources under the Geothermal Steam Act is obtained through a lease from the Bureau of Land Management ("BLM") as authorized by the DOI.[155] After rights to develop the resource are acquired, rights to construct a geothermal energy plant must be obtained.[156] The Geothermal Steam Act provides that a geothermal lessee "shall be enti-

147. *Id.* *See supra* note 27 for more information on Geysers Field.

148. *Union Oil Co.*, 549 F.2d at 1274.

149. KOSTANT, *supra* note 37, at 231. "The state of Oregon has declared as a matter of statute that geothermal resources are part of the surface estate." *Id.* However, the 10th Circuit agreed with the *Union Oil* court and held in *Rosette v.* U.S. that "geothermal resources . . . were 'minerals' with the reservations of the [SRHA] patents." *Rosette, Inc. v. United States*, 277 F.3d 1222 (10th Cir. 2002).

150. *Bedroc Limited*, L.L.C. *v. United States*, 541 U.S. 176 (2004).

151. *Id.* at 181.

152. *Id.* (emphasis added).

153. *Id.* at 185.

154. *Id.*

155. *John Rishel Geothermal Steam Act Amendments of* 2003: *Hearing on* H.R. 2772 *Before* H. *Resources Subcomm. on Energy & Mineral Resources*, 108th Cong. (2003) (statement of Patricia Morrison, Principal Deputy Assistant Sec'y for Land & Minerals Mgmt., U.S. Dep't of the Interior), *available at* http://www.blm.gov/nhp/news/legislative/pages/2003/te030722a.htm.

156. Geothermal Steam Act of 1970, 30 U.S.C. § 1022 (2006).

tled to use so much of the surface of the land as may be found by the Secretary [of the Interior] for the production and conservation of geothermal resources."[157]

Lessees under the Act do not need consent of a private landowner in order to build. In *Occidental Geothermal, Inc. v. Simmons*,[158] the holder of a DOI geothermal resources lease filed suit against two landowners who held surface rights where the U.S. had reserved mineral rights under the SRHA. Occidental sought, "among other forms of relief," declaration of its right to build and operate a geothermal plant without consent of the surface owners.[159] The court held that power plant siting rights in lands under the SRHA were reserved to the U.S. and that the Geothermal Steam Act authorized such leases. The court noted that removal of geothermal resources is inextricably connected to their utilization,[160] and to hold that geothermal lessees own the rights to geothermal resources and "yet do not have the right to exploit those resources without the consent of the owners of surface interests would reduce the holding of *Union Oil* to an empty theoretical exercise."[161]

B. Federal Environmental and Development Regulations

After acquiring rights to develop geothermal resources and siting rights, geothermal energy developers begin the actual development of the geothermal resource. According to the Department of the Interior, the "development and production of geothermal resources involves six phases: exploration, test drilling, production testing, field development, power plant and power line construction, and full-scale operations."[162]

Because the lease of federal geothermal resources requires the discretionary approval of a federal agency, geothermal resource development on federal land is subject to the National Environmental Policy Act ("NEPA").[163] NEPA was enacted to "ensure that all federal agencies consider the environmental impact of their actions"[164] through the development of an environmental impact statement

157. *Occidental Geothermal, Inc. v. Simmons*, 543 F. Supp. 870, 877 (N.D. Cal. 1982).

158. *Id.* at 878, quoting § 14 of the Geothermal Steam Act, 30 U.S.C. § 1013 (2006).

159. *Id.* at 871.

160. *Id.* at 874.

161. *Id.* at 877.

162. *Sierra Club v. Hathaway*, 579 F.2d 1162, 1165 (9th Cir. 1978) (citing DEP'T OF THE INTERIOR, FINAL ENV'TL IMPACT STATEMENT FOR THE GEOTHERMAL LEASING PROGRAM at III.2).

163. 42 U.S.C. §§ 4321-4370 (2006).

164. *Id.* § 4331.

("EIS").[165] A question arises as to which stage of geothermal resource development triggers NEPA compliance and the drafting of an EIS.[166]

The Ninth Circuit addressed this question in *Sierra Club v. Hathaway*.[167] The Sierra Club brought suit to prevent the Secretary of the Interior from executing leases to develop geothermal resources in the Alvord Desert Geothermal Area of southeastern Oregon, based on the DOI's failure to draft an EIS.[168] The court, in holding for the DOI, noted that the lease in question was only in the exploration stage and that the DOI had conducted a programmatic EIS for leasing under the Geothermal Steam Act.[169] The programmatic EIS concluded that exploration practices in the first or "casual use" stage do not significantly affect the environment, as those practices "do not ordinarily lead to any appreciable disturbance or damage to lands, resources, and improvements."[170]

The court recognized that to undertake exploration other than casual use, the lessee must submit a detailed plan of operations to the United States Geologic Survey ("USGS") with proposed measures for "protection of the environment, including but not limited to, the prevention or control of (1) fires, (2) soil erosion, (3) pollution of the surface and groundwater, (4) damage to fish and wildlife or other natural resources, (5) air and noise pollution, and (6) hazards to public health and safety during lease activities."[171] Thus, geothermal energy developers are able to postpone the NEPA process until a development plan is prepared. It should be noted that although NEPA requires an EIS, it does not require that even significant environmental impacts be mitigated or avoided.[172] In addition, it is difficult to measure the potential impacts on thermophile biodiversity because the majority of these species have not been identified, much less studied.

C. California State and Private Geothermal Acquisition

While the Ninth Circuit has found that geothermal resources on federal land are minerals,[173] states differ on the classification and

165. *Id.* § 4332(C).

166. *Sierra Club v. Hathaway*, 579 F.2d at 1166.

167. *Id.*

168. *Id.* at 1164.

169. *Id.* at 1168-1169.

170. *Id.* at 1165.

171. *Id.* (citing 30 C.F.R. § 270.34 (h)).

172. *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 350 (1989) (It "is now well settled that NEPA itself does not mandate particular results, but simply prescribes the necessary process.").

173. Badiei, *supra* note 1, at 116.

regulation of geothermal resources as minerals, water, or a *sui generis* characterization of the resource as neither minerals nor water.[174] Two California cases hold that geothermal resources are minerals on state and private lands, analogous to *Union Oil*. *Pariani v.State of California*[175] addressed whether a state patent included rights to geothermal resources while *Geothermal Kinetics v. Union Oil*[176] addressed whether a geothermal resource is part of a mineral estate in a deed to private lands. Both cases regard rights to geothermal resources within the Geysers Field.[177]

In 1980, a California Court of Appeal decided *Pariani v. State of California*, the state-law equivalent of the *Union Oil* case.[178] The plaintiffs were owners of land over geothermal resources in the Geysers Field. The lands had been granted by patent of the State of California between 1946 and 1956, with reservation to the state of "all . . . mineral deposits."[179] As in *Union Oil*, the court noted "the fact that the presence of geothermal resources may not have been known to one or both parties to the . . . conveyance is of no consequence."[180] The court identified that "[grants] for the sovereign should receive a strict construction — a construction which will support the claim of the government rather than that of the individual," and that "a grant is to be interpreted in favor of the grantee, except that a reservation in any grant, and every grant by a public officers or body, as such, to a private party is to be interpreted in favor of the grantor." [181]

Having interpreted the grant in favor of the state, the court then discussed the classification of a geothermal resource as a mineral. The court dismissed the idea that geothermal resources are heat, noting that the state's definition of geothermal resources does not limit geothermal resources to heat. The court also dismissed the

174. Bettis, *supra* note 53, at 120-125 (noting that Idaho has classified geothermal resources as *sui generis* but are "declared to be closely related to and possibly affecting and affected by water and mineral resources in many instances (citing Idaho Code § 42-4002(c)); noting that Washington attempted a more practical distinction by defining a geothermal resource as only the "'natural heat energy of the earth from which it is technologically practical to produce electricity commercially, and the medium by which such heat energy is extracted from the earth, including liquids'" (citing Wash. Rev. Code Ann. § 79.76.030); and noting that while Hawaii and Texas use a mineral classification, Wyoming and Utah treat geothermal resources as groundwater).

175. *Pariani v. State of California*, 164 Cal. Rptr. 683, 687 (1980).

176. *Geothermal Kinetics, Inc. v. Union Oil Co.*, 141 Cal. Rptr. 879 (1977).

177. *See supra* notes 27, 32-36, and accompanying text.

178. *Occidental v. Simmons*, 543 F. Supp. 870, 874 n.5 (N.D. Cal. 1982).

179. *Pariani*, 164 Cal. Rptr. at 684 n.2 (internal quotation marks omitted).

180. *Id.* at 688 (quoting *Geothermal Kinetics, Inc. v. Union Oil Co.*, 141 Cal. Rptr. at 881).

181. *Id.* (citing N. *Pac. Ry. v. Soderberg*, 188 U.S. 526, 534 (1903), and CAL. CIV. CODE § 1069) (internal quotation marks omitted).

claim that geothermal resources are water, noting that the toxic[182] condensate of the steam at the Geysers Field is not the "life-sustaining water which the courts have felt impelled to exclude from mineral grants and reservations."[183] The court concluded, "[e]ither under a constructional approach of the general intent reservation . . . or [under] the classification approach . . . geothermal resources are reserved to the patenting government."[184]

In *Geothermal Kinetics v. Union Oil*, decided by a California Court of Appeal in 1977, the court considered whether a grant of minerals included geothermal resources. Agreeing with *Union Oil* and *Pariani*, the court held that a geothermal resource is part of a mineral estate in a deed to private lands. Geothermal Kinetics claimed title from a 1951 deed of conveyance for "all minerals in, on or under" [185] the land. Union Oil, holder of an assigned lease to the geothermal resources from the surface owners, claimed that the geothermal resources were not minerals, but heat. The court noted that a functional approach to interpreting the mineral grant was warranted, instead of a mechanical approach. In addition, like *Union Oil* and *Pariani*, the court noted that the mineral does not need to be known to exist at the time of conveyance of a grant or reservation.[186]

The court recognized that the State of California placed the Geothermal Resources Act under the Oil and Gas section of the Public Resources Code, inferring that the legislature viewed geothermal resources as minerals.[187] The court went on to distinguish the geothermal resources from water, stating that unlike groundwater, the "origin of geothermal waters is not rainfall, but water present at the time of the formation of the geological structure. Because rainfall does not replenish geothermal water, it is a depletable deposit."[188] As in *Pariani*, the court also recognized that geothermal water was not a necessity of the surface estate and that the Geysers water was toxic and unusable for drinking or agricultural purposes. The court concluded that from examining both the broad purpose of the mineral conveyance, and the expectations of the interested parties, the rights to the geothermal resources are part of the mineral grant.[189]

182. *Id.* at 686. ("The minerals arsenic, boron, and ammonia are present in the steam and its condensate in such amounts as to necessitate injection of the condensate into the ground through reinjection wells to avoid detrimental impact on the surrounding area.")

183. *Id.* at 690.

184. *Id.* at 691.

185. *Id.* at 883.

186. *Id.* at 881.

187. *Id.* at 882 n.2.

188. *Id.* at 883.

189. *Id.*

Defining geothermal resources as water, mineral or a *sui generis* resource affects the ownership and regulatory oversight of geothermal resources. Federal and California cases have appropriately determined that geothermal resources are minerals. Although most geothermal resources require water to function, classifying geothermal resources as minerals instead of water accurately portrays the nature of geothermal resources as finite, where water is usually considered a replenishable resource.

D. California Environmental & Development Regulation

After acquiring either a state lease or a private grant for rights to develop geothermal resources, a developer must comply with two stages of development regulations: the California Environmental Quality Act ("CEQA") review and the acquisition of a permit from the Division of Oil and Gas.[190] This section begins with a brief overview of the purpose and process of CEQA, the California equivalent to NEPA. Then, permitting under the Division of Oil and Gas and applicable state laws and regulations is reviewed. It should be noted that the California statutory requirements for drilling and operations apply to all lands in the state, including federal, state, and private lands, while the leasing requirements under the California Public Resources Code apply only to state lands.[191] In addition, geothermal developments must comply with other applicable state regulations, including the California Coastal Act and state water laws. This section concludes with a summary of a few of the many secondary federal, state, and local laws and regulations that may impact the development of geothermal resources.

A geothermal developer must comply with the CEQA before the California Division of Oil and Gas ("DOG") will issue use permits.[192] Under CEQA, "governmental agencies must consider impacts that may result from the implementation of certain geothermal projects."[193] Similar to the result in *Sierra Club v. Hathaway*, discussed above, a full environmental impact report ("EIR") may not be needed for limited projects. A developer must first submit an application that describes the proposed project. The DOG then determines whether an exemption, negative declaration, or full EIR is warranted.[194] Unlike the federal issue in *Sierra Club*, however, exploration

190. CAL. DIV. OF OIL & GAS, *supra* note 57, at 1.
191. LINDSEY, *supra* note 11, at 72.
192. CAL. DIV. OF OIL & GAS, *supra* note 57 at 7.
193. *Id.*
194. *Id.* at 9.

is not categorically exempt.[195] Certain projects, such as repair of existing facilities and drilling, which result in minor alteration with no permanent environmental effects, are categorically exempt.[196] Parallel to NEPA, CEQA does not require the preservation of biodiversity.[197] Thermophiles are again left without legal support and run a higher risk of extinction.

The Public Resources Code governs the use of geothermal resources,[198] and regulations promulgated thereunder control the drilling and other operations of geothermal resources.[199] The DOG permitting process ensures that developers comply with state geothermal laws. The purpose of the process is to:

> Prevent, as far as possible, damage to life, health, property, and natural resources; prevent damage and waste of underground geothermal deposits; prevent loss of geothermal reservoir energy; prevent damage to underground and surface waters suitable for irrigation or domestic use; prevent other surface environmental damage, including subsidence; and encourage the wise development of geothermal resources through good conservation and engineering practices.[200]

Despite those stated purposes, state law is silent regarding geothermal biodiversity and thermophile ecosystems.

The DOG oversees the drilling of wells and injection, including collecting monthly reports on geothermal production and injection.[201] The DOG ensures compliance with state casing, blowout prevention, plugging and abandonment, and production standards. In addition, the DOG collects well fees and is responsible for subsidence detection and abatement in geothermal areas in the state.[202] Development for low temperature geothermal resources requires the same CEQA and DOG permitting procedures as high temperature wells, but those permits require different bonds, fees, and drilling practices.[203]

195. *Id.*

196. CAL. CODE REGS. tit. 14, § 1684.1 (2006).

197. *Laurel Heights Improvement Ass'n v. Regents of Univ. of Cal.*, 47 Cal. 3d 376, 393 (1988) ("a reviewing court does not pass on the correctness of the [CEQA] EIR's environmental conclusions, but only upon its sufficiency as an informative document."). *Id.* at 392 (quoting *County of Inyo* v. *Los Angeles*, 139 Cal. Rptr. 396, 399 (1977)).

198. CAL. PUB. RES. CODE § 3700 (2006).

199. CAL. CODE REGS. tit. 14, § 1900 (2006).

200. CAL. DIV. OF OIL & GAS, *supra* note 57, at 5-6.

201. *Id.* at 15.

202. CAL. CODE REGS. tit. 14, § 1970 (2006).

203. CAL. DIV. OF OIL & GAS, *supra* note 57, at 17-19.

Other agencies can exert jurisdiction over geothermal resource development within California. The Geothermal Steam Act states, "Nothing in this Act shall constitute an express or implied claim or denial on the part of the Federal Government as to its exemption from State water laws."[204] The most notable area of secondary compliance is within state water law. In cases where the geothermal plant requires a fresh water stream diversion for cooling or injection, the Water Code requires "all firms and persons diverting water from surface streams, bodies of water, including the underflow of surface streams, must have a permit, license, or domestic use registration. This includes individuals, businesses, governmental agencies, charitable organizations, etc. (i.e., all diverters), except where use is made under valid riparian or pre-1914 appropriate claim, or a stockpond claim."[205] A geothermal resource project may also require permitting from the groundwater district or regulatory authority in which it is proposed. Geothermal resource development within the coastal zone is also subject to approval from the California Coastal Commission.[206] The California Coastal Act of 1976 established the California Coastal Commission to regulate land and water in the coastal zone and to administer the Coastal Zone Management Act ("CZMA").[207] In addition to having regulatory power over all state and private lands along the coast under the CZMA, the Coastal Commission also regulates federal activities in the coastal zone.[208]

The California Regional Water Quality Control Board ("RWQCB") has jurisdiction over waste discharge to land and is responsible for issuing permits for discharging of fluids and injection of geothermal fluids under the National Pollution Discharge Elimination System ("NPDES"). In addition, the RWQCB also has authority to issue a certification for discharge to wetlands.[209]

In addition, local building and planning departments oversee use permits and building codes for construction of buildings and pipelines. If a streambed must be altered for a pipeline crossing, a permit for streambed alteration will be required from the California Department of Fish and Game. In addition, if a pipeline will cross a highway, an encroachment permit will be required from the California Department of Transportation.[210]

204. 30 U.S.C. § 1021 (2006).

205. CAL. WATER CODE § 1200 (2006). *See also* CAL. WATER CODE, Div. 2, Part 2 (2006).

206. California Coastal Act of 1976, CAL. PUB. RES. CODE § 30001 (2006).

207. Coastal Zone Management Act, 16 U.S.C. § 1451 *et seq*. (2006).

208. California Coastal Act § 30008.

209. *Id*.

210. *Id*.

VI. Current California Law's Effect on Thermophile Diversity

As noted throughout the overview of geothermal laws in California, few laws exist to conserve or preserve geothermal and thermophile biodiversity. Current geothermal laws and regulations are directed toward the development, exploitation, and depletion of California's geothermal resources. This is exemplified by the recent zoning restriction in the Desert Hot Springs community of Southern California, which prohibits the development of land in the "hot water district" unless the landowner agrees to extract the underlying geothermal resource for commercial purposes.[211] Such zoning forces landowners who would otherwise refrain from extracting the resource, to submit to geothermal pumping and extraction simply to develop their property.

This section discusses the primary reasons California should promote research into thermophile ecosystems, and should take steps to preserve thermophile biodiversity, at least until thermophile diversity can be shown to coexist with the depletion, injection, and re-injection of geothermal resources. The section first discusses how thermophile species are threatened by current uses, and continues with why thermophile diversity should be preserved or at least discussed.

A. Geothermal Depletion by Current Uses Threatens Thermophile Diversity.

The California Public Resources Code section entitled "Conservation of Geothermal Resources" does not mention geothermal organisms.[212] While remedies for groundwater depletion, such as injection and re-injection, may offset the negative environmental effects of geothermal water depletion, it is not likely that they will ensure thermal biodiversity. Thermal biodiversity is largely dependent upon specific temperature and mineral gradients, and temperature consistency.[213] Even slight changes in temperature and mineral composition can kill off thermal organisms that developed in specific temperature and mineral environments.[214] In addition, different species exist in different places along temperature and mineral gradients in geothermal resources.[215] For example, a hot spring is hottest at the source of geothermal water. The temperature of the water cools as it

211. *See supra* Part III.B.
212. CAL. PUB. RES. CODE § 3700 (2006).
213. Stetter, *supra* note 106.
214. *Id.*
215. Takai & Sako, *supra* note 116.

is subjected to air and surface temperatures. Thus, the water in the hot spring farthest from the source of the geothermal water will be coolest. The water between these two points will be of different temperatures along the gradient. Even if utilization of a geothermal resource does not result in a complete loss of thermophiles in a specific geothermal resource, it is likely that the temperature gradient of the resources will be altered. This will result in the extinction of some species along the temperature and mineral gradient.

The injection or re-injection of cooled water into a geothermal resource may drop the temperature of the thermophile environment enough to kill off entire communities of organisms. Such changes in geothermal resources can severely degrade a thermal ecosystem where thermophiles have adapted to specific temperature, chemical, and mineral compositions.

B. Medical and Scientific Potential of Thermophile Biodiversity.

Science has only recently begun to understand the importance of thermophiles and other microorganisms in the ecosystem. However, their financial addition to biomedical and scientific research for industrial process has already been documented.[216] Today, significant research is being conducted on thermophile biodiversity in ground-level geothermal springs. However, minimal research has been conducted on deep thermophile species — species which may significant contribute to scientific advancement and medical technology. Currently, geothermal resources are being exploited and depleted at significant rates solely for energy production, low temperature heating, and health spas. In many cases, such as the Geysers Field, the user of the geothermal resources is aware that the resource is finite and will soon be exhausted and destroyed.

VII. Conclusion

This article has outlined the basic mechanisms by which geothermal resources and thermophile biodiversity function. From understanding the complex web of plate tectonics, groundwater, magmatic heating, and thermophile biodiversity, we acknowledge that these incredibly specialized species of thermophiles are important to our understanding of biological life on the earth. Keeping in mind that geothermal resources are finite resources and not a renewable source of energy, the exploitation of geothermal resources without

216. Bryson, *supra* note 4.

concern for thermophile biodiversity is tantamount to allowing at least some thermophile extinction or dissolution.

Many unknowns exist concerning exploitation of geothermal resources, including unknown replenishment rates, undefined aquifers, and lack of knowledge about thermophiles and how they should be categorized. In addition, exploitation of a geothermal resource for energy production can deplete groundwater, cause land to subside, and increase the risk of earthquakes.

This article has noted the importance of the preservation of thermophile biodiversity for future medical and scientific research. Though invisible to the naked eye, thermophiles may well have value independent of, and perhaps superior to, energy production.

There is certainly much more than steam or water in geothermal resources. In the heat of the law — and the heat of the desire to develop energy resources — we need to examine and consider what might be lost in the exploitation and extraction of these age-old resources, and strengthen the laws to protect them.

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