Geothermal Resource Development Needs in Arizona

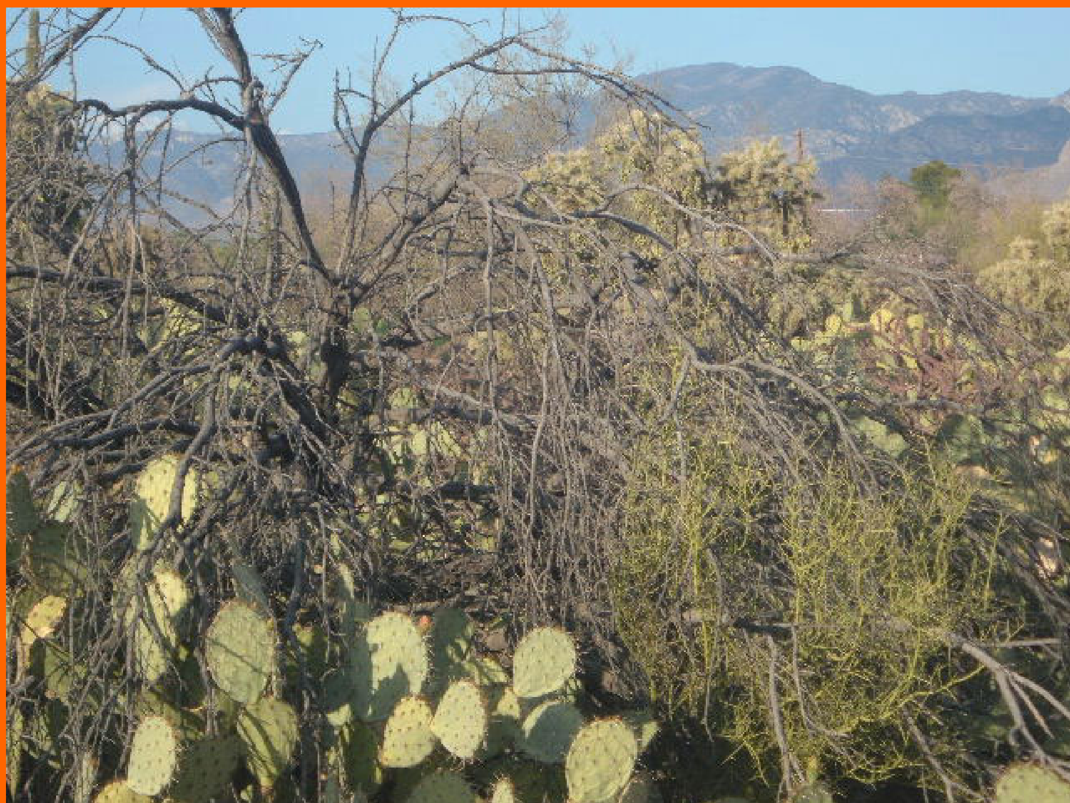

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Photo: Mount Lemmon rises above the cactus in Tucson, where direct-use heating projects have been considered. Photo by Daniel J. Fleischmann – Geothermal Energy Association

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Preface

Every state with geothermal resources faces different challenges to utilizing those resources to help meet their energy needs. The purpose of this report is to combine an analysis of relevant literature and interviews with industry stakeholders in Arizona with different perspectives, to understand what types of policies and actions public institutions can take to encourage greater development of Arizona's geothermal resources. The research has been aided by previous study done on Utah and New Mexico, and ongoing study on Idaho and Nevada, which have helped create a framework for the research on Arizona. Over the course of the research numerous experts have been interviewed that are involved with geothermal resource development. Specifically for this report, the interviews include discussion with more than 15 individuals who have been involved with geothermal development in Arizona (including geologists, developers, utilities, regulators, consultants, direct-use facility operators, clean energy advocates and university researchers).

To get a closer look at Arizona's resources, research encompassed travel from May 16 through May 18 of 2006 through New Mexico and Arizona and attendance at a one day conference in Tempe entitled "Using the Earth's Energy: Arizona Geothermal Direct Use Conference". After returning from the trip, drafts were organized for Arizona and New Mexico. In early-July of 2006 a first draft of the New Mexico report was released for review and it late-July of 2006, a first draft on Arizona was released for review.

Ultimately, after taking into consideration the broad spectrum of opinions, the findings of this report represent a general consensus or "majority viewpoint" of what various stakeholders agree are the overall needs to unlocking greater development in Arizona. The help received, whether informative, critical, or "filling in a gap" of information, was indispensable to the final product. Thank you to all who contributed time and effort to help bring this report to final publication.

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Introduction

When people think of renewable energy in Arizona, they often think of the sun. Indeed, Arizona has one of the greatest resource potentials for solar energy in the United States. However, underneath Arizona's soil rests acres and acres of clean sustainable geothermal resources that can be utilized for agriculture, industrial applications, heating homes and businesses, and in some places even powering electrical generation facilities. Arizona businesses have utilized geothermal resources for thermal uses such as space heating, aquaculture, and recreation in several locations throughout the state. Currently, there are no operating geothermal power facilities in Arizona, although Arizona residents get renewable power from geothermal power plants located in California.

Arizona's geothermal potential (both for direct thermal uses and power production) has been studied, mainly at the reconnaissance level. Between 1977 and 1982, the Geothermal Assessment team within the Arizona Bureau of Geology and Mineral Technology -- now known as the Arizona Geological Survey (AZGS) -- conducted a reconnaissance of the state's geothermal resources with attention focused mainly on the southern part of the state. A database, completed in 1995, identified 1251 thermal wells and springs above 68°F (20°C) (See Figure I) and 215 thermal wells and springs above 100°F (38°C). Some of the resources shown on the 1982 map are bottom-hole temperature (BHT) measurements performed either during geophysical logging of oil and gas exploration wells or from academic heat-flow studies[1]. After the reconnaissance was completed, the agency issued reports that evaluated the potential for Arizona's geothermal resources. Drilling in the most promising resource areas would have been the next step, however neither federal, state, nor industry funds were available to support the projects[2] as the world entered an oil-glut in 1982 that eventually lead to a market collapse in 1986[3].

In the nearly quarter-century since these initial assessments, technology has improved, conventional energy prices have increased significantly, and the state population has more than doubled[4]. According to researchers, these factors have been drivers for new research into Arizona's geothermal resource base. In January 2002, the GeoPowering the West (GPW) program of the U.S. Department of Energy (USDOE) held its first meeting of the Arizona Geothermal Working Group. At the meeting, participants discussed the steps that would be necessary to help re-evaluate resources and expand use. Soon after the establishment of the Working Group, AZGS began updating the 1995 database.

Currently, the Working Group is in the process of implementing a Strategic Plan (similar to ones developed in Idaho in 2002 and New Mexico in 2004) with a purpose of reducing barriers, identifying opportunities, and highlighting the appropriate actions necessary to address these issues. The Strategic Plan is part of an overall Action Plan that also includes:

- Identifying applicable laws and regulations that impact geothermal resource development;
- Modifying renewable portfolio standard (RPS) laws and other rules to accommodate geothermal resource development;
- Preparing general resource characterization;
- Collecting and/or developing Arizona resource materials;
- Identifying Arizona Potential; and
- Developing an education and outreach program[5].

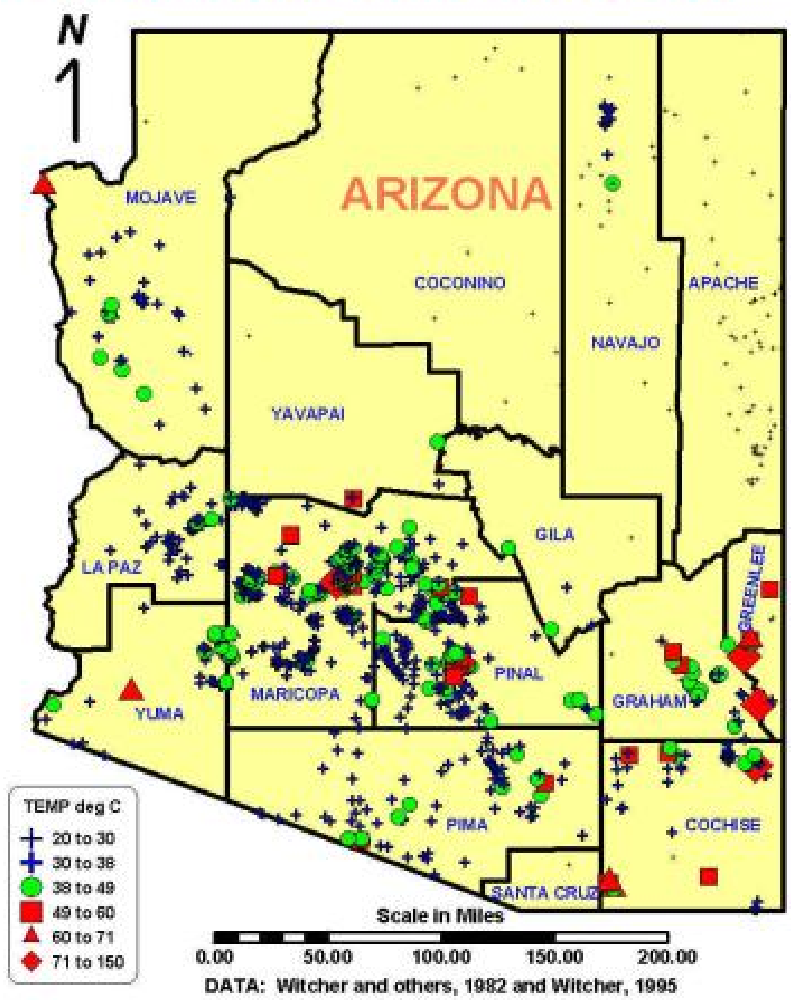


Figure I: Arizona Thermal Wells and Springs. Map courtesy of James C. Witcher of Witcher & Associates.

In pursuit of new development, the USDOE has provided assistance towards several new geothermal projects in Arizona. This includes funding in 2003 and 2004 from the Geothermal Resource Evaluation and Definition (GRED) program for a geophysical study of the eastern San Francisco Mountains in northern Arizona and exploration drilling to study the feasibility for power production near Clifton Hot Springs in Greenlee County. In FY 2006, USDOE has provided funding for a greenhouse feasibility study in Willcox. The facility is one of several greenhouses in the area heated by fossil fuel sources that could potentially utilize geothermal heating instead.

While the interviewees involved in this report agree that preparing a Strategic Plan and re-evaluating Arizona's geothermal resource base is a good first step, they also agree that the pursuit of these new developments is essential because new installations create greater visibility about the technology and demonstrate their immediate benefits to the people of Arizona.

The purpose of this report is to discuss the findings of research conducted on the needs and barriers affecting development of Arizona's geothermal resources. These findings can help determine how policymakers on the state and federal level can help meet the needs of the marketplace to propel new development. For the purposes of this document, "geothermal resources" are defined as those with temperatures sufficient for thermal uses in Arizona's climate -- generally greater than 100°F (38°C)[6]. This document focuses on both direct uses and electric power production (including power plants and distributed generation from small-scale electric units, which require temperatures above 212°F (100°C). The first part of the report focuses primarily on direct uses and second part of the report focuses primarily on power production.

This report is one of several examinations of obstacles and opportunities for geothermal energy on the state level being conducted by GEA. A final report will bring together these reports and offer cross-cutting analysis of the barriers and needs identified in different Western states.

Any opinions expressed in this report are those of the author, and do not necessarily reflect the views of the Department of Energy, the many individuals who contributed to this report, the Geothermal Energy Association or the members of GEA's Board of Directors.

Geothermal Direct-Use Production in Arizona

Perhaps the greatest promise for near-term geothermal development in Arizona rests with low-to intermediate-temperature resources that can be tapped for direct uses. At the "Using the Earth's Energy: Arizona Geothermal Direct Use Conference" in Tempe on May 18th, 2006, attendees and presenters discussed the importance of finding innovative ways to use geothermal resources to save energy, and create business opportunities. While researchers, government agencies, and interested communities and businesses in Arizona discussed a variety of direct-use applications that could thrive in Arizona, no specific sector or location emerged as the most promising.

One issue raised at the conference is that these uses are not clear because little follow up has been performed on previous reconnaissance efforts. In addition, the bulk of Arizona's population lives in Phoenix and Tucson, two of the warmest climate cities in the U.S., where heating loads are typically less of a concern than cooling.

However, experts agree that there are likely many uses where residents and businesses could benefit from geothermal resource development in Arizona. In fact, due to growth in energy demand (approximately 4% per year in Arizona[7]) and rising fossil fuel prices, there is a growing consensus that the state's geothermal resources should be more fully developed. Most agree that opening up dialogue and raising awareness about what potential uses may exist will lead lawmakers to create policies that enable new developments to come online in the immediate future.

The sections below focus on the needs that can be met through institutional changes and policies that encourage direct-use applications. These needs include:

- Regulatory Needs;
- Need to identify markets;
- Need for adequate government incentives; and
- Need to close the information gap.

For each of these needs, key barriers are identified along with proposed policy alternatives that could alleviate constraints and provide incentives to facilitate new development.

Regulatory Needs

One of the challenges facing new geothermal development in Arizona, according to experts, will be regulators' unfamiliarity with how to process requests for new projects, particularly concerning water usage and water rights issues.

Water

One of the main concerns for regulators in Arizona (both state and federal) is protecting scarce water resources. A rapidly increasing population and overproduction of aquifers by the agricultural sector have exacerbated water scarcity in Arizona. Most thermal wells or springs in the state are put to traditional water resource uses. Once water is pumped for geothermal direct-use, the water may be used for irrigation (with appropriated water rights); however, if the water is discharged to a wetland or surface body of water or injected back into the aquifer, the process will be subject to review by the Arizona Department of Environmental Quality (ADEQ), Water Quality Division. If water is pumped from a geothermal reservoir, circulated through a pipe, and then returned to the reservoir in essentially the same condition, then there are no special water regulations that should apply, except for a drilling permit. However, regulators report that because they cannot determine which specific regulatory standards apply until the details of the projects are made available, they have to be reviewed on a case-by-case basis[8].

The Arizona Department of Water Resources (ADWR) is the agency responsible for regulating all water wells, including wells used for re-injection. The Arizona Oil and Gas Conservation Commission (OGCC) regulate geothermal well drilling. The ADWR administers the rules and regulations governing groundwater withdrawals and use. State water regulations affect all land in Arizona with the exception of Native American lands in Trust. Water rights may be registered through the ADWR. The ADEQ, Water Quality Division, is responsible for administering surface disposal of wastewater, including geothermal fluids, while the Environmental Protection Agency (EPA) Region 9 has regulatory authority over injection wells (in cooperation with the OGCC and the ADEQ). The Arizona Department of Agriculture (ADA) regulates the operation of aquaculture facilities and all aquaculture facilities must obtain a license from ADA, whether they use geothermal direct-use applications or not[9].

As noted above, the major issue for regulators is the lack of experience with geothermal projects. Regulators generally agree that a routine for dealing with direct-use water issues will arise over time. However, they point out that near-term projects will likely be more practical in rural agricultural areas outside major population centers. The reason for this is that most population centers in Arizona are designated as an active management area (AMA)--which includes Phoenix, Pinal, Prescott, Santa Cruz, and Tucson—where water use regulations are more intensive for large installations. For instance, if a user in an AMA plans to use a direct-use well where more than 35 gallons per-minute (GPM) is pumped, a well impact study is required[10].

Federal lands

Roughly 42% of the total surface acreage in Arizona is federally managed (and approximately 49.2% of the total mineral acreage). In addition, 17% of Arizona's surface acreage (and over 24% of the mineral acreage) is managed by the Bureau of Land Management (BLM). 27% of Arizona is Native American land, 13% state trust land, and 18% on private land[11]. State and federal lands are the most prevalent in southeastern Arizona, where the largest concentration of geothermal resources has been identified.

According to regulators, water rights on federal lands may be contentious, depending on the location or the specific uses in the area[12], although outside of AMAs, water rights are generally less of an issue. However, during the course of interviews in both Arizona and other western states, the main concern over developing geothermal resources on federal lands for direct-use applications have not been water rights, but rather the structure of calculating royalties on federal land, which is not conducive to direct-use development. Royalties have been high in some cases, and have led to additional difficulties in other cases. For example, just across the Arizona border in Hidalgo County, New Mexico, greenhouses operated by Burgett Geothermal on federal land were required to install metering equipment that cost more than that of a geothermal well in order to determine the energy use required to calculate a royalty. In addition, the calculated royalty was more than the royalty that an electrical power plant would pay for the equivalent amount of energy use. As a result, the owner shut down all facilities that were affected by the federal lease.

There is a consensus that federal royalty regulations have been a disincentive to direct-use development for sites throughout the western U.S., and they are cited as the primary reason that there are no direct-use wells utilized on federal land in Arizona. In addressing geothermal development issues, the Energy Policy Act of 2005 (EPAct) authorized changes to these policies, although the final regulations are still under review. Considering the opportunity these technologies have for economic development -- particularly for rural, agricultural areas -- there is an urging for quick implementation.

Native American lands

On Native American land, tribes have sole authority to develop direct-use projects. Those who work with tribes in Arizona assert that tribes tend to prefer solar and wind projects, in part because the technology is more familiar. In addition, because many tribes are limited financially, tribes tend to prefer projects with lowest upfront costs. Geothermal drilling costs, which constitute the bulk of geothermal's upfront costs, may be higher than the upfront costs associated with installing solar panels or small wind turbines. Solar panels in Native American communities have been installed in the past. Many who have worked with tribes on other renewable energy projects contend that continued education and public involvement are essential (particularly to ensure regular maintenance of the facility). Without an outreach effort that highlights the viability and benefits of a community-scale direct-use project, these experts believe that development on Native American land would not be achieved.

Need to identify markets

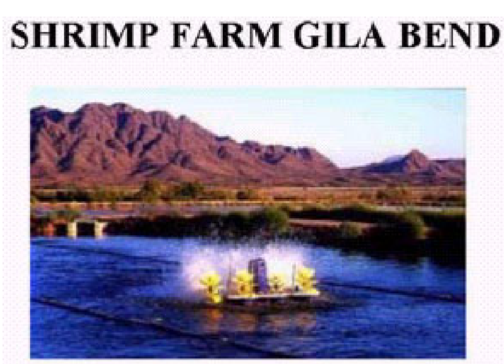
In his 1995 Report, "Geothermal Resource Data Base: Arizona", Jim Witcher suggested that there are two factors important to consider "in order to successfully develop and promote geothermal energy in Arizona." The first is that thermal wells in Arizona typically exist in warm climates "where space cooling is generally more desirable than heating." The second is that "Arizona values the thermal waters more for irrigation of field crops, municipal water supply, and industrial uses than for the heat carried by the water"[13].

Therefore, according to Witcher and others, the first step to successful development and promotion is to find areas and uses with the most "potential to enhance or create economic opportunities"[14]. Most of Arizona's thermal wells are found in the southern part of the state, south of the Colorado Plateau. While potential exists -- and, in fact, projects are being considered -- in urban parts of the state, researchers are primarily looking to develop geothermal resources in rural, agricultural areas where the economic benefits can be most immediate.

Direct-use geothermal systems replace thermal uses otherwise produced through electricity or boilers using conventional fuels. When traveling throughout the Southwest, it appears that geothermal resources have an opportunity to quell high energy prices and help spur economic development, particularly in struggling rural and agricultural areas. There are several rural and agricultural industries that researchers agree can clearly benefit from geothermal direct-use applications, such as aquaculture facilities and greenhouses. In addition, over the course of the research, it has been clear that there are other potential industries that are worth serious consideration.

Aquaculture

Arizona's aquaculture industry has utilized geothermal direct-use heating at several fish farms in different parts of the state. Two of these fish farms are located in southwest Arizona between Yuma and Gila Bend along the Gila River. In the Hyder Valley (about 40 miles east of Wellton) an aquaculture facility produces shrimp along with various types of fish, depending on the season. The farm is near Aqua Caliente (Spanish for "hot water") where hot springs once existed that have since dried up. There are several fish farmers using hot water, but only one with an installed system. The system is used to pump and pipe geothermal water for heat and then irrigates it for agricultural use. According to the facility's operator, shrimp is produced in this area primarily due to the existence of salty waters; however the geothermal heating system facilitates shrimp-producing earlier in the season, as well as providing other essential thermal energy needs throughout the year.



Aquaculture use at Hyder Valley.
Source – Arizona Public Service:
http://www.aps.com/images/PDF/renewable/GeothermalPresentation.pdf
(used by permission)

Aquaculture facility operators interviewed in the Southwest tout the advantage geothermal heat provides to lengthen breeding seasons and help them compete with foreign markets. One facility operator specifically notes that because the U.S. imports most of its shrimp and tropical fish, the use of geothermal resources can play a part in reducing the trade gap for these commodities.

Shrimp and tropical fish species can utilize geothermal heat from temperatures as low (or lower) than 100°F (38°C), and these temperatures may be present at aquaculture facilities throughout the state. However, of Arizona's numerous aquaculture facilities, only a small percentage of them use geothermal direct-use applications; regardless of whether or not they are nearby geothermal resources. Aquaculture facility operators say that geothermal direct-use applications can be a useful tool for aquaculture operators, and more should be done to reach out to their industry. They say that most in their business know little about geothermal resource development, nor how they could benefit. They are busy trying to keep their business alive, and don't have the time to pursue costly ventures without assurance that the investment will increase their profits. Furthermore, they point out that aquaculture is a complex business, and the advantage of using geothermal applications does not address challenges related to other aspects of the business. In Safford, for example, fish farms have used geothermal direct-use applications in the past, but have since shut down due to factors unrelated to issues with the resource.

Greenhouses

Currently, there is a large greenhouse industry in Arizona; however the source of their heating is almost exclusively fossil fuels (particularly natural gas).

There has been interest for several years, driven by increasing energy costs, to pursue geothermal heating for greenhouses in the southeastern part of the state where geothermal resources are most prevalent. For example, a farmer in Florence (62 miles southeast of Phoenix) has considered using a geothermal direct-use heating system for a greenhouse complex, and (as mentioned above) in FY 2006, the USDOE has provided funding to study the utilization of a geothermal direct-use heating system in Willcox at a 7½ acre tomato greenhouse complex that is planning to expand operations to 15 acres. Geothermal-heated greenhouses throughout the western U.S. have demonstrated the significant benefits and business opportunities available through direct-uses. For example, in neighboring New Mexico, a greenhouse complex near Las Cruces (Masson Radium Springs) is using an extensive geothermal direct-use heating system that saves them $46,200 per acre per year. These greenhouses employ approximately 100 workers on 16 acres, and the owner plans to expand to 40 acres in the near future (employing 4-8 workers per additional acre)[15].

If the project in Willcox is successfully demonstrated, it could raise visibility of the technology and may encourage other greenhouse businesses to consider them for their operation. For example, there are other greenhouse complexes in the Willcox area that are much larger (several hundred acres) and are heated with natural gas. Several interviewees suggest that if natural gas prices continue to climb in coming months, it would be practical to approach these and other large greenhouse complexes in Arizona about pursuing a feasibility study for installing a geothermal direct-use facility. According to experts, these systems can start small and be expanded over time, so the technology can be tested on several acres, and then, if successful, be expanded to cover a larger part of the operation.

Other uses

Throughout the years, Arizona has maintained several spas and resorts that use geothermal direct-use applications. For example, a hotel at the Buckhorn Mineral Wells utilized a direct-use geothermal system for recreation and space heating for 70 years[16]. A recent geothermal direct-use heating project is operating on private land in Tonopah at El Dorado Hot Springs (about 50 miles west of Phoenix). A space heating system was installed there in 1996 that pipes hot water from an underground well to heat buildings, showers, baths, and rental rooms, and then irrigates the water for bamboo, trees and desert plants used on the premises. According to Bill Pennington, who installed the project, the resource is used for space heating in the winter, but is used all year round for showering, bathing, dishwashing, and other thermal uses. The system is located in an AMA, but because less than 35 GPM is pumped at the site, the facility was not subject to additional regulations. According to Pennington, who recently retired and sold the hot springs, the business (which still uses the direct-use heating system) receives nearly all of its heating needs without pumping significant amounts of water. There are two geothermal wells, both several hundred feet deep, producing at temperatures of 112°F (44°C) and 119°F (48°C). Although he sold El Dorado Hot Springs, Pennington relocated next door, and uses the geothermal water there to heat buildings and provide hot water for showering, baths, and dishwashing. He plans to expand geothermal heating to at least two more buildings about 900 square feet in size[17].

While most agree that the overall lack of projects in the state is discouraging, there is optimism that new projects will abound. Experts on these issues believe that initial projects will need assistance from government programs to demonstrate their viability. In his March 2006 working group meeting in Utah, Jim Witcher notes that in order for businesses to be successful using direct-use applications, there needs to be a market to sell the product, a sound business plan, and an expert to manage the product (whether it be aquaculture, greenhouses, or other geothermal heat uses). According to the presentation, this includes the need for a good transportation route for the product and year-round product availability[18].

There is a general consensus that once geothermal resources are successfully used in one industry, it creates consideration in other industries. Agricultural industries may be one of the primary users of this technology, since these industries generally require heat and water. Some of the potential applications for geothermal direct-uses include crop and food processing and milk pasteurization. Many of Arizona's best geothermal resources lie in the Southern Basin and Range at elevations over 4,000 feet, where agricultural areas are prevalent, and where temperatures in the winter often fall below freezing overnight[19]. In fact, several interviewees point out that a number of agricultural businesses in Arizona have utilized geothermal water for irrigation to produce their crop earlier in the season; including irrigation used in greenhouses, and irrigation used for citrus products, table grapes and melons. There is a general agreement that whatever the product (be it aquaculture, greenhouses, table grapes, etc.) using geothermal resources creates a competitive advantage over foreign competitors who benefit from cheaper labor costs (especially competitors in warm climate locations, such as Latin America).

Ultimately, because Arizona has a warm climate nearby its population centers, there may be consideration of using geothermal direct-use applications for cooling purposes; although experts agree this would likely require intermediate-temperature resources. According to researchers, geothermal heat pumps can play a role in reducing these costs. However, this technology is not evaluated in this report, because heat pumps use resources as low as 50°F (10°C) without requiring the use of deep underground aquifers. Technology using direct-use applications for cooling purposes is something that is being studied, including a project in Klamath Falls, Oregon using a lithium bromide absorption chiller in combination with a geothermal direct-use heating system. In light of new developments, this technology may become more practical as technology advances. In fact, direct-use heating has been combined with geothermal heat pumps in some locations, including large buildings in downtown Boise, Idaho.

Need for adequate government incentives

Government incentives reduce risks, reduce upfront costs, and encourage investment that could help spur growth in the development of geothermal technologies. Currently, there is little, if any, incentive for farmers or communities to use geothermal direct-use and according to direct-use facility operators in Arizona they receive no financial incentive from the federal or state government for using their existing systems. While they may enjoy energy savings, they agree that without incentives, the impetus to start new projects is limited by the cost to expand or retro-fit (for existing facilities) and the risk of drilling to prove a geothermal resource (for new facilities). They suggest incentives such as loan guarantees, funding for demonstration projects, and tax credits, would likely be most effective.

Most agree that while USDOE efforts are encouraging, funding is limited, and the technology will not be widely used unless it becomes profitable to pursue on a large scale. There is a general consensus that in addition to the incentives suggested in the first paragraph of this section, the state could encourage new businesses to use direct-use facilities by adding direct-use geothermal systems in existing renewable or energy efficiency incentives (which most agree are easier to get through the political system). Current incentives focus primarily on power production; however there are efforts in Arizona to pursue incentives that reward energy efficiency and energy saving technology.

Existing state policies concerning renewable energy in Arizona have leaned towards solar energy. Arizona has several solar energy non-profit organizations and the Arizona Department of Commerce has a Solar Energy Advisory Council. Arizona provides a sales tax exemption for the sale or installation of solar energy devices (although wind electric generators and wind-powered water pumps are also included). Clean energy advocates say that government spending on direct-use facilities can create positive multipliers, such as jobs, increased revenue (taxes, royalties, etc), and model sustainable businesses. The Database of State Incentives for Renewable Energy (DSIRE) has listed several existing incentives that clean energy advocates agree could potentially expand to cover geothermal direct-use facilities. These include:

- A corporate tax credit for the commercial/industrial use of Solar & Wind technologies up to $25,000 for any one building in the same year or $50,000 in total credits in any year and equal to 10% of the installed cost of qualified "energy devices" and may be applied against corporate or personal taxes for installations serving commercial or industrial facilities in the taxpayer's trade or business located in Arizona or financed by a third-party organization;
- A personal income tax deduction for energy efficient residencies for the original owner of a new energy efficient home, condominium, or town house, with a maximum deduction up to $5,000;
- A personal tax credit for personal use of solar and wind energy systems allowed against the taxpayer's personal income tax in the amount of 25% of the cost of a solar or wind energy device, with a $1,000 maximum allowable limit, regardless of the number of energy devices installed. This includes solar thermal heating;
- A property tax exemption for solar energy if the installation adds any value to the property; and
- A 100% sales tax exemption for the retail sale of solar and wind energy devices and for installation of solar and wind energy devices by contractors, regardless of cost[20].

Of these incentives, the one that has immediate applicability for direct-use applications is the sales tax exemption. However, in addition to a sales tax exemption (as well as the other four incentives listed above that could possibly be amended to cover geothermal direct-use) there is a general agreement that modifications of the State Renewable Portfolio Standard (RPS) -- also referred to as the Environmental Portfolio Standard -- are also a prime opportunity to increase the utilization of geothermal direct-use applications.

The Arizona Corporation Commission (ACC) is currently considering raising the existing standard of 1.1% by 2007 to 15% by 2025. As proposed, the standard would include a requirement that 30% of the megawatt-hours (MWh) of renewable energy come from distributed resources. The proposed rule includes a variety of technologies: solar electric and thermal, biomass and biogas, small and large wind systems, and geothermal; including electric production, distributed generation, and direct use. Adoption of this RPS will be the first one in the country to allow a thermal geothermal process (such as aquaculture, greenhouses, space heating, and district heating) to be included[21]. This means that utilities that seek out these projects could get credits towards their RPS requirements. In discussions with those in the aquaculture and greenhouse industries, there is a general agreement that if the new RPS is adopted and direct-use applications are included, there would be an impetus for new joint projects between themselves and utilities.

In anticipation of the new standard, the ACC has been conducting a set of workshops to create an incentive program for renewable energy resources that would be identical among the regulated utilities. Called the Uniform Credit Purchase Program, the incentives developed would provide direct financial payments to those developing electric production from geothermal or using geothermal resources in direct-use applications. A vote on these rules is expected in late fall of 2006[22].

Even with potential new incentives for geothermal from an RPS, outreach and advocacy are essential to continued encouragement for geothermal technologies. In discussions with clean energy advocates in the Southwest, they report that geothermal resources are less known to the public than wind and solar, and that there is concern over the lack of a coherent direct-use industry. One challenge specific to Arizona, according to advocates, is that energy policy decisions for regulated utilities are made by the ACC, not the state legislature. In fact, the ACC is a constitutionally separate branch of government, which is largely independent of the state legislature. In Arizona, investor owned utilities (IOUs) and rural cooperatives are governed by the ACC. However, municipal utilities, such as the Salt River Project, are under the jurisdiction of the state legislature. This creates a challenge when trying to enact policy equal to all types of utilities because both venues must adopt a policy to be uniform in the state.

Need to close the information gap

Although it is clear that communities and agricultural industries in Arizona could utilize geothermal resources for direct-use applications, there is a concern that those who can benefit from these technologies may not understand how to pursue them. Although there is a general agreement that direct-use applications such as space heating are not necessarily a priority for communities without high heating loads, several interviewees suggest that it may have applicability as energy prices raise and construction is underway for communities that extend from Phoenix out into new suburban communities.

For instance, a recent well drilled in Chandler, Arizona (a large suburb of Phoenix) tapped into a hot water aquifer that has the potential to provide heating and hot water for various uses in buildings, schools, and businesses in the city, especially during winter months. Those familiar with this discovery are pursuing a grant to test the feasibility of tapping into the resource for these purposes[23].

Besides Chandler, researchers contend that there are other hot wells in Arizona that may be able to be utilized by existing or new businesses. For instance, a well located within 3 miles of Perryville (25 miles west of Phoenix) measured temperatures of 167°F (75°C) at a depth of 919 feet (280 meters). Perryville is a small community of about 20,000 with an elevation just below 1,000 feet, and to date has not utilized the geothermal resource. One of Arizona's largest prisons is located in Perryville, and researchers point out that geothermal heating for the facility might be a possibility. Geothermal space heating at prisons and other large facilities exist in other states. For example, the Utah State Prison (about 30 miles south of Salt Lake City) currently utilizes geothermal space heating for 332,665 square feet and expects to save up to $344,000 in natural gas prices in fiscal year 2006[24].

Another area worthy of consideration is Coolidge, in between Florence and Casa Grande in Pinal County. Coolidge is about 55 miles southeast of Phoenix with an elevation of just over 1,400 feet. A total of 8 geothermal wells located within 5 miles of Coolidge indicate temperatures sufficient for direct-use applications; the highest being 161.1°F (71.7°C) at 2565 feet (782 meters). However, like Perryville, the community does not use the geothermal resource. While the highest temperature was measured in a relatively deep well, there has been interest in geothermal development (including consideration of the geothermal-heated greenhouse mentioned earlier). Coolidge, Casa Grande, and Florence are home to over 50,000 people and Coolidge is home over 6,000 students attending Central Arizona College[25].

According to researchers, few land developers and business owners in these areas are aware of the hot temperatures that have been documented in these wells. Therefore, there has been little effort to test for the different types of potential uses for the resource. Can these resources be used for businesses to reduce their energy costs? Can these resources be used for new business opportunities? Can they be used to save energy for residential users? In order to determine answers to these questions, advocates argue the state government should be actively engaging these communities to seek out potential opportunities[26].

Indeed, such efforts may require additional feasibility studies, economic reports, business plans, or renewed drilling and exploration to better characterize the resource. One suggestion, repeated by numerous interviewees, is the need to invest in agricultural extension programs operated by land-grant universities, and employ staff familiar with geothermal resource development to provide a resource for farmers and ranchers. Direct-use facility operators and aquaculture professionals repeatedly express concerns that communities, businesses, and farmers are not being approached about the potential to use these technologies. Often, the only way people hear about these systems is from a neighbor or a businessman looking to develop in their area.

Although these technologies have been available for many years, geothermal has generally not been considered among the range of energy alternatives available when starting a business. For example, according to Bill Pennington, hot wells exist throughout the town of Tonopah. However, despite a general awareness of the resource in the community, he is the only one in town to have installed a direct-use system. Other businesses have chosen conventional heating sources, although several of them are located near enough to existing hot wells that they could use them for various purposes, including space heating, showers and baths, and preheating for dishwashing at restaurants[27].

Several interviewees suggest reaching out to those who have successfully developed these projects before -- including businesses, companies, consultants, and contractors -- and encouraging them to share their knowledge for new projects. In addition they suggest that state or federal agencies could contract those with such expertise to write reports on their geothermal direct-use projects that could appear in government publications and trade magazines that provide visibility about geothermal technology to a broader audience.

There is a general consensus that state efforts to increase education and information would be helpful to increase awareness and knowledge about Arizona's geothermal resource base. This includes highlighting Arizona's existing direct-use applications, and using the Internet, speaker's bureaus, and fact sheets, which can be disseminated to the public. Furthermore, the state could sponsor educational programs, workshops and symposiums to promote the uses of geothermal applications to various groups in Arizona, including businesses and local governments.

However, before education and information is dispensed, interviewees stress the importance of updating information. This includes the need to perform a reconnaissance on all of Arizona's direct-use installations that were identified in the past, and an update on any new installations installed since the last comprehensive data collection (circa 1996)[28]. Such an update might even include traveling to the locations themselves, and/or checking with regulators and local chambers of commerce to obtain updated information.

Geothermal Electrical Production in Arizona

There is a general agreement among researchers that electrical production from geothermal resources is feasible in Arizona. In fact, intermediate-temperature resources with potential for binary power production have already been identified in the state. The problem is that there are few and inadequate market drivers towards geothermal power development in Arizona. For example, most agree that the lack of major resource discoveries (as compared with other states) has limited interest in exploration. In addition, up until only a few years ago, Arizona utilities had been able to provide relatively inexpensive power from conventional fossil fuel sources. In the last several years, however, Arizona has seen significant increases in energy prices, particularly natural gas, and interest in renewables has grown markedly, bringing attention to Arizona's geothermal potential.

The analysis below identifies two specific needs for policymakers to address to greater encourage geothermal power development in Arizona. These include:

- Need for greater exploration and study of the resource; and
- Need for effective incentives and regulations.

For each of these needs, key barriers are identified along with proposed policy alternatives that could alleviate constraints and provide incentives to facilitate new development.

Need for greater exploration and study of the resource

According to Witcher's 1995 report, Arizona includes two major physiographic provinces: The Southern Basin and Range and the Colorado Plateau. According to researchers, the most promising resource areas in Arizona lie in the Southern Basin and Range.

Four subdivisions form the Southern Basin and Range: 1) the Mohave section; 2) the Mexican Highland section; 3) the Sonoran Desert section, and 4) a Transition Zone that includes in its eastern extension the Datil-Mogollon section[29]. (See Figure II) Hot springs exist in several areas while "blind" resource areas (i.e. those without apparent surface manifestations) may be present throughout a wide part of the region. According to Jim Witcher, we shouldn't be "reinventing the wheel" about resources, but using the knowledge already available to determine the best possible opportunities. Well over a century of oil and gas data, mining and mineral exploration, along with geological reports, documents, and studies are sitting in archives. These documents may show evidence of resource potential. However, if the documents' authors were not seeking geothermal resources at the time, they would not have been likely to pass on information that indicated geothermal resource potential.

Recently, AZGS was given the green light to scan all 2000+ geophysical well logs from 1100+ oil and gas wells drilled in Arizona in the files of the OGCC. While Arizona itself does not have significant oil and gas resources (In 2004 they ranked 30th for crude oil production and only had 6 producing natural gas wells[30]), researchers contend that the information in the well logs may be valuable because the information for them has not been thoroughly considered for geothermal resource potential. According to Lee Allison of AZGS, many of the wells have BHT measurements and information on circulation times of drilling fluid which allow equilibrium BHTs to be estimated. The depths of the cataloged wells range from a few hundred feet to over 18,000 feet (5,486 meters)[31]. Researchers say this will be a useful data set to better evaluate geothermal gradients across the region, and could be the basis for further research.

However, for further research to continue, it is essential that experienced researchers are available to work on these projects. A concern, brought up by numerous interviewees, is that many experienced geothermal professionals are nearing retirement. Therefore, it is crucial that these professionals share their knowledge with the next generation. The lag in geothermal resource development from the late-1980s through today has created an experience gap in the industry that highlights the importance of funding college and university programs that create a new generation of geothermal professionals. Currently, there are efforts to revitalize university programs that focus on geothermal resources at Northern Arizona University and Arizona State University. An advantage of these programs is that with new projects being pursued, they can create opportunities for experienced geothermal professionals to take students out into the field to participate in exploration tests and new drilling, using the most advanced technology.

Potential

According to the Western Governor's Association (WGA) Geothermal Taskforce Report (January 2006), there are 20 MW of identified near-term potential (i.e. by 2015) in Arizona compared with 5,568 MW in the 10 other western states discussed in the report[32]. However, evidence shows that the resource may be larger in the long-term as binary technology advances, more exploration is performed in promising areas, and deeper drilling becomes more economical.

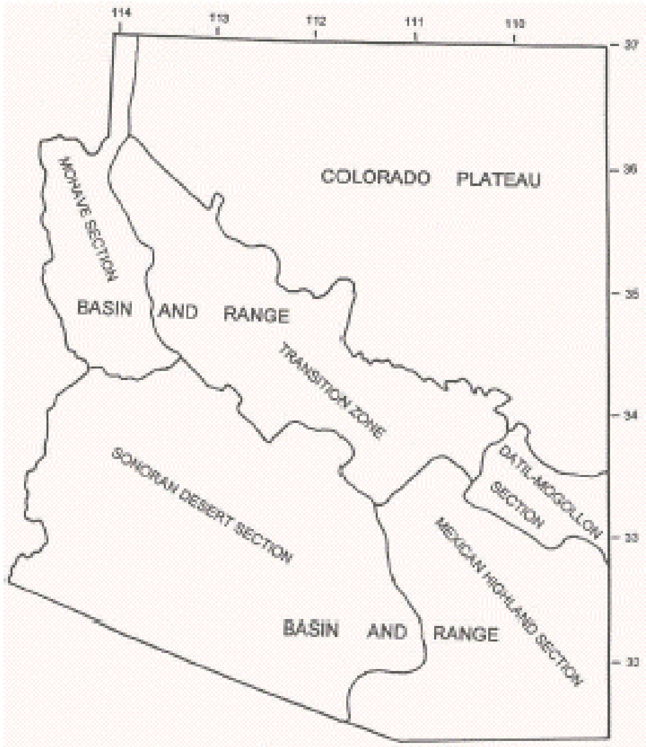


Figure II – Physiographic provinces of Arizona. James C. Witcher "Geothermal Resource Data Base: Arizona" Southwest Technology Development Institute, New Mexico State University. September 1995: Page 8.

The highest temperature known geothermal systems are located in extreme eastern Arizona adjacent the Transition Zone and Southern Basin and Range Province boundary at Gillard Hot Springs and Clifton Hot Springs near Morenci, Arizona in Greenlee County. Temperature gradients and geochemical data have indicated that potential exists in this region for intermediate-temperature convective resources ranging from 212 to 302°F (100 to 150°C)[33].

Gillard Hot Springs has measured surface temperatures of 183.2°F (84°C). The area is near transmission lines and there is industrial development located nearby. However, the springs are located on BLM land, and no exploration has been done beneath the surface. Although researchers contend that the area may have potential for small-scale power production, the area has received little interest thus far, partly due to uncertainty over whether sufficient fluid exists in the deep underground aquifer.

Clifton Hot Springs is located in Clifton, about 10 miles north of Gillard Hot Springs. Unlike Gillard Hot Springs, the area has seen exploration below the surface, and development in the vicinity of the springs is likely in the near-term. While the hot springs have a surface temperature of only 159.8°F (71°C), studies of the resource area have estimated reservoir temperatures likely capable of small-scale power production[34]. In 2005, two deep core-holes were drilled near Clifton Hot Springs, which measured promising temperature gradients (with one core-hole indicating sufficient fluid in the underground reservoir). USDOE and Arizona Public Service (APS), the state's largest IOU, have collaborated on the project, and are currently evaluating the next steps. Before a power facility can be constructed, deep exploration drilling is needed to confirm the resource. While drilling at Clifton is planned on private land, several researchers contend that BLM lands in the area also have potential, and should be examined in future exploration.

In 2004, Northern Arizona University received GRED II money to study geothermal resource potential east of the San Francisco Peaks to the north of Flagstaff. Although most of the geothermal potential in Arizona is believed to be in the southern part of the state, the volcanic geology of the San Francisco volcanic field has been considered an area with potential for high-temperatures capable of power generation. According to researchers, the San Francisco Peaks are associated with silicic eruptions as recent as 50,000 years ago. Existing geological, geophysical and geochemical data are consistent with that of a high-temperature geothermal resource and could be a major resource. Funding is being sought for deep core hole drilling in the area to determine if the temperatures are sufficiently high, and sufficient fluids exist at depth for power production.

The resource areas described above are not the only ones in Arizona with potential for power production. According to researchers, deep conductive resources may be available for production throughout southeastern Arizona (and other parts of the state) at depths exceeding 3,000 meters; depending on the permeability and availability of fluid in the reservoir. The challenge is the cost of drilling deep wells to prove these resources, although oil and gas wells in the state have been drilled to far deeper depths. In fact, deep drilling often encounters high temperatures because of the depths. For example, deep drilling has revealed high temperatures in the Albuquerque Basin, New Mexico, the Snake River Plain, Idaho, and the Basin and Range, (Northern) Utah. In Arizona, deep drilling near San Simon measured intermediate-temperatures of 273.2°F (134°C) at a depth of 6666 feet (2032 meters); however there was no additional data made available at the time, and subsequent studies have not revealed any resource of significance[35].

The quality of information is essential to determine the potential existing in deep wells. The shining example of this is Power Ranches where drilling performed in 1973 near Chandler in Maricopa County reportedly measured high-temperatures in two wells. However, no chemical or isotopic data was made available at the time, and subsequent review of the geophysical logs revealed that numbers reported were actually in Fahrenheit, not Celsius[36].

Distributed Generation

Because identified geothermal systems in Arizona are not expected to produce high temperatures suitable for large power plants, several interviewees point out that resource areas being considered for power production may be better suited for distributed generation from small-scale power units. For example, small binary power units can be used to both produce power and cascaded heat for multiple uses all in one integrated system. In neighboring New Mexico, this application was successfully demonstrated within 20 miles of the Arizona border at the Lightning Dock KGRA where three binary units (totaling 750 kW) were used to provide both power and cascaded heating for floral greenhouses.

In fact, there are two additional sites in neighboring New Mexico where there is interest in using intermediate-temperature geothermal resources for on-site power generation and cascaded heat (both generating approximately 1 MW of electrical power each). For power production to be feasible, researchers report that a geothermal resource needs temperatures at or above 212°F (100°C), along with sufficient permeability and fluid. Researchers in Arizona believe that these conditions may be possible at several locations within the state, although the potential sites require further exploration. The advantage of these projects, according to proponents, is that the projects reduce the requirements of centralized power plant development, which may require major transmission infrastructure, especially for remote resource areas. In addition, these projects avoid the necessity of securing a power purchase agreement (PPA), as well as working through an often-lengthy utility regulatory process.

Proponents also point out that because these units are used to produce a commercial product (rather than just power for the electric grid) they have the potential to provide more revenue and more jobs than a dedicated power plant of equivalent size. While those considering these projects point out that the capital costs of small power units might cost more per kilowatt-hour (kWh) than a utility would be willing to pay, they suggest that the cost might still be lower than the retail power cost the utility would charge.

In general, most agree that the range of possibilities for these technologies have not yet been fully considered or understood. Some suggest that small-scale geothermal power could be combined with concentrated solar power (CSP), used for hydrogen production, or used for alternative fuels production. In fact, the prospect for using geothermal resources for alternative-fuel production is being considered at geothermal resource areas in several western states. Those considering these projects point out that the geothermal resource needs to be nearby rail lines and/or major roads for adequate distribution capability.

As noted above, small-scale distributed generation was demonstrated in the Southwest, nearby the Arizona border in New Mexico in 1995. The operator of that facility, along with other proponents of small-scale distributed generation projects agree that what is needed are more demonstrations of these technologies to expand their visibility to attract new investors and establish new markets for the technology.

Risk

Developers in Arizona face many of the same limitations for geothermal exploration and development as developers in any other state. Exploration is a time-consuming, capital-intensive process that involves high upfront costs with risks and uncertainties that make it difficult for them to obtain financing. In addition, they generally lack the capital resources to pursue a geothermal prospect without confidence that the resource can be developed economically. According to an August 2005 report by GEA, exploration (including geological studies, drilling, and confirmation) is typically up to 1/3rd of the overall costs of a geothermal project. Drilling can be up to 1/4th of the overall costs -- considering the cost of a geothermal exploration well ranges from \$1 million to \$9 million -- depending on the depth, the type of material being used, and the current market for drilling rigs. According to the report, an average well "would probably be in the range of \$2-5 million"[37] however recent spikes in demand for steel and drilling equipment have markedly increased these costs in the past year.

Of the potential resource areas mentioned earlier, all of them require developers to take major risks if they choose to pursue development. Developers say that government programs, particularly federal programs, have been helpful in the past in other states to reduce drilling risks, thus enabling development in resource areas that might not have been pursued without government support.

Need for effective incentives and regulations

For geothermal power projects to be pursued in Arizona (whether for distributed generation or for power production) there is a general consensus that adequate incentives need to be offered. In addition, regulations need to be processed in a timely manner to enable projects to begin generating revenues to pay back the high upfront costs associated with development.

Regulatory requirements

The regulatory process for developing geothermal resources on federal land is generally more complicated than developing on state and private land. For one thing, drilling on federal land requires both state and federal permits. Although those pursuing projects in Arizona say there is less concern about these regulations because of the low volume of projects under consideration in the state, they are concerned that inexperience within regulatory agencies towards geothermal projects may complicate matters. Therefore, for more geothermal prospects in Arizona to be developed, state and federal regulators need adequate funding for a larger, more experienced staff to ensure that the resource is being both carefully developed, as well as being permitted in a timely manner to avoid project delays.

In neighboring states, where there are higher volumes of geothermal projects (such as California and Nevada) developers have expressed concern over the delays and backlogs they have encountered on federal lands considering lease applications and environmental reviews (particularly on BLM and U.S. Forest Service (USFS) land). BLM land is prevalent in areas south of and around Clifton and Gillard Hot Springs, and most prevalent in the western side of Arizona. USFS land is prevalent in areas north of Clifton and Gillard Hot Springs, as well as in areas in the San Francisco Peaks.

Due to the complications of developing resources on federal lands in these neighboring states, the U.S. Congress was compelled to amend regulations to facilitate development on these lands. In EPAct, the U.S. Congress took several actions that facilitate the BLM and the USFS in implementing new regulations addressing these issues. For instance, EPAct authorized additional funding for regulatory agencies to meet new requirements for processing leases and permits for geothermal prospects and projects and requires all future USFS and BLM resource management plans to consider geothermal leasing and development in areas with geothermal resource potential. Furthermore, new regulations changed the royalty structure for power plants to send 25% to county governments[38]. Several interviewees tout this policy because they believe it will be an effective incentive for communities throughout the western U.S. (including Arizona) to pursue geothermal projects as economic development. At the time of this writing not all these changes have been implemented or received full appropriations and there is concern, particularly from developers, that delaying these changes will limit current development and planning until full implementation is complete.

Government Incentives

Federal incentives available for power production generally target the utility sector. The most significant of these, according to developers, is the Federal Production Tax Credit (PTC). The PTC provides a subsidy of 1.9¢ per kWh. However, the Clifton project, not yet under construction, will not be completed by the expiration date of the PTC of January 1st, 2008.

Developers say that the PTC must be extended for planned geothermal power projects still in the early development stages -- like Clifton -- to be considered competitive in the near-term.

Utilities in Arizona that can take advantage of the PTC include Morenci Water & Electric Company (which provided approximately 2.5% of the retail electricity in Arizona in 2004); UniSource Energy Corporation (UNS) subsidiaries Tucson Electric Power (TEP) and UNS Electric, Inc. (which provided approximately 15.0% of the retail electricity in Arizona in 2004); and APS, the top provider of retail electricity in Arizona in 2004, providing 38.1%[39]. In fact, APS already receives 10 MW of its power capacity from a geothermal power plant in the Salton Sea, California.

While the PTC only affects IOUs in Arizona, municipal utilities and rural electric cooperatives can take advantage of the Clean Renewable Energy Bond (CREB) program that was authorized in EPAct[40]. The largest utility in Arizona that can take advantage of the CREB program is the Salt River Project (SRP). SRP is a major municipal utility that in 2004 provided approximately 35.6% of the electricity for Arizona residents (including 870,000 customers in the Phoenix Metropolitan Area). SRP has pursued renewable alternatives, offers incentives for energy-efficiency and solar installations, and is the top purchaser of geothermal power in Arizona; purchasing renewable energy credits from a 25 MW geothermal-power facility in California's Imperial Valley. Their total capacity from renewable energy is 80 MW (the generation of which makes up about 5% of their retail sales). In February of 2006, SRP set a new target of 15% of its total retail electricity sales coming from renewable resources and energy efficiency by 2025[41].

State Renewable Portfolio Standard (RPS)

Unlike the IOU's in Arizona, SRP does not face the requirements of the Arizona RPS. However, there is a general consensus that the RPS, while not technically an incentive, has created a market for geothermal power generation by setting requirements for the major utilities in the Arizona to sign power purchase agreements (PPA) for renewable power plants. Clean energy advocates agree that while the RPS gives some incentive to seek distributed resources and energy efficiency (as described earlier) the main focus is on power plant facilities. Although, several interviewees point out that because of the "distributed resource" provisions, there is potential to include geothermal-powered distributed generation projects provided utilities are able to take credit for the power-produced.

When the original RPS was established in 2001, it called for 60% of renewable sources to come from solar energy, and did not include geothermal power. However, as new regulations are finalized, that is expected to change. Geothermal should be added and the 60% solar requirement may no longer be in place. The RPS rule, as drafted, allows for utilities to purchase renewable energy resources from out of state as long as the electricity can be delivered to the utility's service territory. Developers assert that a stronger incentive to develop Arizona's geothermal resources would exist if power produced by in-state sources was given more credit in the RPS. In addition, they assert that incentives should also be geared towards peak-load production.

Ultimately the primary challenge to development is simply whether or not the resource is there. In consequence, researchers in Arizona say that because of the lack of knowledge about Arizona's geothermal resource base, past policies directed towards Arizona's utilities have had little impact on geothermal power development. This includes system benefit charges, which were authorized by the ACC for the RPS to give utilities permission for cost-recovery on renewable projects by using them to create renewable energy funds, and the Public Utility Regulatory Policies Act of 1978 (PURPA)[42]. The failure of these policies to spur development demonstrates why government funding for exploration is essential, particularly for the San Francisco Peaks study that researchers suggest has potential to be a major untapped resource.

It is clear that a market for geothermal energy exists in Arizona, whether or not the energy is produced by resources in Arizona or elsewhere. Concerns over the water usage of traditional fossil-fuel technologies such as coal, natural gas, and nuclear power; and concerns that fuel prices will affect operations and maintenance costs for fossil fuel generation are priority concerns to be addressed. For instance, APS announced in May of 2005 a Request for Proposal (RFP) for renewable energy resources of 100 MW and at least 250,000 MWh per year, including geothermal, for not less than five years beginning in 2006. According to the RFP, the renewable energy projects must be no more costly, on a levelized cost per MWh basis, than 125% of the reasonably estimated market price of conventional resource alternatives. Arizona is a net-importer of energy during the summer, and often utilities in Arizona find it cheaper to purchase out of state power than to generate it all in-state. In a separate effort, APS has proposed building transmission lines from Wyoming to northern Arizona that could tap into wind and geothermal resources in other states. Similarly, Tucson Electric Power Inc. and UNS Electric Inc. have announced RFPs for renewables, including geothermal[43].

However, renewable resources produced within the state are seeing increased prominence and interest in Arizona, even on the local level. For example, in July of 2006, the Navajo County Board of Supervisors gave their approval for the issuance of $39.25 million in solid waste disposal revenue bonds by the Industrial Development Authority of Show Low to finance a biomass electrical plant to be located next to the Abitibi paper mill near Snowflake[44]. Can something similar be done for geothermal?

Clean energy advocates working with the state legislature assert that in order for geothermal resource development (for power production, distributed generation, and direct use) to receive broader inclusion in government programs and incentives, more outreach and advocacy from the geothermal industry is essential. Geothermal resources are already at a disadvantage because they are less known to the public than wind and solar (as mentioned above, wind turbines and solar panels are more recognizable than geothermal applications), and advocates say that the geothermal industry needs a larger, more unified, advocacy presence to remain on the public and government radar. This includes working more closely with other clean energy advocacy groups on state legislative issues. Ultimately, most agree that the time is ripe to reconsider developing Arizona's geothermal resources for power production. However, the will to provide the necessary funding for new exploration will only come once the government recognizes the value of the technology. Most agree that as new development succeeds in other states, development in Arizona will follow

Web Resources with more information for Arizona

Arizona Public Service Company – "Geothermal Energy":
http://www.aps.com/images/PDF/renewable/GeothermalPresentation.pdf
Bloomquist, Gordon. "A Regulatory Guide to Geothermal Direct Use Development". Washington State University, 2003:
http://www.energy.wsu.edu/ftp-ep/pubs/renewables/arizona.pdf
Gelt, Joe. "Geothermal – Using Water to Generate Energy and Provide Heat." Arizona Water Resource. July/August 2006. V. 14, No. 6, Water Resources Research Center, University of Arizona, College of Agriculture and Life Sciences:
http://cals.arizona.edu/AZWATER/awr/julyaugust06/feature1.html
Geothermal Energy Associations (GEA):
http://www.geo-energy.org
Geo-heat Center at the Oregon Institute of Technology (OIT):
http://geoheat.oit.edu/state/az/az.htm
Geothermal-biz.com: Arizona:
http://geothermal-biz.com/States/AZ.asp
Idaho National Laboratory Arizona Geothermal Resources (Geothermal Energy Map):
http://geothermal.id.doe.gov/maps/az.pdf
Northern Arizona University:
http://geothermal.nau.edu/about/about.shtml
U.S. Department of Energy – Arizona Geothermal Working Group:
http://www.eere.energy.gov/geothermal/gpw/wkgrp_arizona.html
Water Resources Research Center, University of Arizona, College of Agriculture and Life Sciences – "Arizona has Untapped Geothermal Potential". Arizona Water Resource, Sept/Oct 2000. V. 9, No. 2:
http://ag.arizona.edu/AZWATER/awr/sep00/feature2.htm

Endnotes

[1]James C. Witcher "Geothermal Resource Data Base: Arizona" Southwest Technology Development Institute, New Mexico State University. September 1995: Page 4 & Geo-Heat Center: AZ_THRM_W_SPR.XLS

[2]Source: "Arizona has Untapped Geothermal Potential". Arizona Water Resource, September/October 2000. V. 9, No. 2, Water Resources Research Center, University of Arizona, College of Agriculture and Life Sciences*:* http://ag.arizona.edu/AZWATER/awr/sep00/feature2.htm)

[3] http://en.wikipedia.org/wiki/1980-1989_world_oil_market_chronology

[4]Population statistics
Arizona Workforce Informer:
http://www.workforce.az.gov/admin/uploadedPublications/454_census_decennials.xls & U.S. Census: http://quickfacts.census.gov/qfd/states/04000.html

[5]Source – Northern Arizona University: http://geothermal.nau.edu/working-group.shtml

[6]In Arizona's climate, direct-use facilities may likely need higher temperatures than 100°F (38°C), although in some cases temperatures below 100°F (38°C) may be used (such as in fish farms at Marana near Tucson). This document does not consider geothermal heat-pumps which can utilize temperatures as low as 50°F (10°C) without requiring the use of deep underground aquifers (although there is a general agreement by researchers that geothermal heat pumps would be useful at creating energy savings for Arizona communities, businesses, and industries).

[7]Source of 4%: 3/4/2004 – Comments of the Southwest Energy Efficiency Project (SWEEP); Environmental Portfolio Standard (EPS) Workshops, before the Arizona Corporation Commission: http://www.cc.state.az.us/utility/electric/EPS-SWEEP.pdf (page 3).

[8]See: Cason, Lori. Arizona Department of Water Resources: "Water Management Support Section Notice of Intent Unit." Presentation given on 5/18/2006 at the Using the Earth's Energy: Arizona Geothermal Direct Use Conference in Tempe, Arizona & Gelt, Joe. "Geothermal – Using Water to Generate Energy and Provide Heat." Arizona Water Resource, July/August 2006. V. 14, No. 6, Water Resources Research Center, University of Arizona, College of Agriculture and Life Sciences*:* http://cals.arizona.edu/AZWATER/awr/julyaugust06/feature1.html

[9]See: Cason, Lori. Arizona Department of Water Resources: "Water Management Support Section Notice of Intent Unit." Presentation given on 5/18/2006 at the Using the Earth's Energy: Arizona Geothermal Direct Use Conference in Tempe, Arizona & Bloomquist, Gordon. "A Regulatory Guide to Geothermal Direct Use Development." Washington State University, 2003: http://www.energy.wsu.edu/ftp-ep/pubs/renewables/arizona.pdf

[10]See: Cason, Lori. Arizona Department of Water Resources: "Water Management Support Section Notice of Intent Unit." Presentation given on 5/18/2006 at the Using the Earth's Energy: Arizona Geothermal Direct Use Conference in Tempe, Arizona & Bloomquist, Gordon. "A Regulatory Guide to Geothermal Direct Use Development." Washington State University, 2003: http://www.energy.wsu.edu/ftp-ep/pubs/renewables/arizona.pdf

[11]Sources:
1) Arizona BLM: http://www.blm.gov/az/
2) Breakdown of Arizona Land Management: Ahern, Richard. "Geothermal Leasing on Arizona State Trust Land". Arizona State Land Department. Presentation given on 5/18/2006 at the Using the Earth's Energy: Arizona Geothermal Direct Use Conference in Tempe, Arizona.
3) Total federal mineral acreage in Arizona: Bureau of Land Management (BLM) (2002): Mineral and Surface Acres Administered by the Bureau of Land Management: http://www.blm.gov/natacq/pls02/pls1-3_02.pdf#search=%22MINERAL%20AND%20SURFACE%20ACRES%20ADMINISTERED%20BY%20%22

[12]In Arizona, the Federal Government may have jurisdiction over water reserved by international or interstate compact on the Colorado River, Rio Grande River (and possibly other rivers), water reserved for tribal use under the Winters Doctrine, and reserved stream flow that protect endangered species

[13]James C. Witcher "Geothermal Resource Data Base: Arizona" Southwest Technology Development Institute, New Mexico State University. September 1995: Page 12
[14]James C. Witcher "Geothermal Resource Data Base: Arizona" Southwest Technology Development Institute, New Mexico State University. September 1995: Page 12
[15]This information was provided by Alexander Masson, of Alex R. Masson, Inc.: ram@armasson.com
[16]Buckhorn Mineral Wells recently closed its operation for reasons unrelated to the geothermal direct-use heating system or energy prices.
[17]Source: Camilla Van Sickle & Bill Pennington
Casa Blanca Hot Spring
POB 10, Tonopah, Arizona 85354
CasaBlancaHotSpring@mindspring.com
623-203-2230
[18]Source, Jim Witcher (March 2006):
http://geology.utah.gov/emp/geothermal/ugwg/workshop0306/ppt/Witcher0306_1.ppt
[19]See Netstate.com: http://www.netstate.com/states/geography/mapcom/az_mapscom.htm & http://www.netstate.com/states/geography/az_geography.htm
[20]Source – Database of State Incentives for Renewable Energy (DSIRE):
http://www.dsireusa.org/library/includes/map2.cfm?CurrentPageID=1&State=AZ&RE=1&EE=1
[21]Arizona Corporation Commission – Draft Rules 2/3/2006: http://www.cc.state.az.us/utility/electric/EPS-Rules-02-03-06.pdf
[22]For updates on the RPS rules, see the Arizona Corporation Commission:
http://www.cc.state.az.us/utility/electric/environmental.htm
[23]Source – Geothermal-biz.com: http://www.geothermal-biz.com/newsletter/Apr-2006.htm#AZ & Arizona Republic 3/16/2006: http://www.azcentral.com/community/ahwatukee/articles/0316cr-hotwater0316Z14.html
[24]Source: Greg Peay, Director of Facilities and Construction, Utah Department of Corrections – gpeay@utah.gov
[25]Well data for Coolidge and Perryville – NAU: http://geothermal.nau.edu/about/resources.shtml
[26]Temperatures are not the only indication of a resource. Permeability and flow are also critical to the sustainability of use. However, in interviews with researchers in Arizona, they indicate that the problem with the wells measured in Coolidge and Perryville is not lack of permeability or flow; rather these resources have not been subject to further exploration or testing.
[27]Source: Camilla Van Sickle & Bill Pennington
Casa Blanca Hot Spring
POB 10, Tonopah, Arizona 85354
CasaBlancaHotSpring@mindspring.com
623-203-2230
[28]This refers to research performed by the Geo-Heat Center at the Oregon Institute of Technology (OIT):
http://geoheat.oit.edu/state/az/all.htm
[29]James C. Witcher "Geothermal Resource Data Base: Arizona" Southwest Technology Development Institute, New Mexico State University. September 1995: Page 6
[30]Source – Energy Information Agency (EIA): http://tonto.eia.doe.gov/oog/info/state/az.html & http://tonto.eia.doe.gov/dnav/ng/hist/na1170_saz_8a.htm
[31]For more information, see the Arizona Geological Survey (AZGS): http://www.azgs.az.gov/
[32]Western Governor's Association Geothermal Taskforce Report (January 2006):
http://www.westgov.org/wga/initiatives/cdeac/Geothermal-full.pdf (page 64)
[33]James C. Witcher "Geothermal Resource Data Base: Arizona" Southwest Technology Development Institute, New Mexico State University. September 1995: Page 9.
[34]Temperatures for Clifton and Gillard: http://geothermal.nau.edu/about/resources.shtml
[35]In the 1978 USGS Circular 790 Report, four intermediate-temperature systems were noted including Clifton, Gillard, San Simon, and Eagle Creek, which located southwest of Clifton. Power Ranches was listed as a high-temperature resource based on previous reports of high temperatures that were not verified in subsequent testing. See USGS Circular 790 (1978) – pages 46-47 & 62-63.
San Simon information – Northern Arizona University: http://geothermal.nau.edu/about/resources.shtml

[36]The temperatures measured were supposedly 163°C (325°F) and 184°C (363°F). It turned out those numbers were Fahrenheit. Source: USGS Circular 790 (1978), pages 46-47.
According to Jim Witcher, "over the years, numerous citations and claims of high temperature resources existing near Chandler (Power Ranches) have been made. Geothermal Kinetics drilled in two deep wells to 2,800 and 3,200 m depth in 1973; however, proof of high temperatures is absent. Temperature gradients in this area do not exceed 45°C/km and temperatures taken during geophysical logging of the Geothermal Kinetics (Power Ranches) wells do not exceed 100°C."
Source: James C. Witcher "Geothermal Resource Data Base: Arizona" Southwest Technology Development Institute, New Mexico State University. September 1995: Page 9
[37]Source: Geothermal Energy Association (GEA) – August 2005: http://www.geo-energy.org/publications/reports/Factors%20Affecting%20Cost%20of%20Geothermal%20Power%20Development%20-%20August%202005.pdf (page 18)
[38]For more information on new regulations see the U.S. Department of Interior: http://www.doi.gov/iepa/2005_results.pdf (Section 222-224)
[39]% of power – Source – Energy Information Agency (EIA): http://www.eia.doe.gov/cneaf/electricity/st_profiles/arizona.pdf
[40]For more information on the CREB program, see the Environmental Law & Policy Center (ELPC) Clean Renewable Energy Bonds: http://www.elpc.org/energy/farm/crebs.php
[41]Source – Salt River Project, 2/6/06: http://www.srpnet.com/newsroom/releases/020606.aspx &
Source of 35.6% – Energy Information Agency (EIA): http://www.eia.doe.gov/cneaf/electricity/st_profiles/arizona.pdf
[42]The Public Utility Regulatory Policies Act of 1978 (PURPA) obliged utility companies to purchase energy from qualifying facilities (QF) that represent more energy-efficient and environmentally friendly commercial energy production. These QF generally represented smaller figures (below 80MW), although the limit was waived by Congress in subsequent legislation, and recent amendments have limited the scope of FERC in enforcing purchases under PURPA.
General description of PURPA: http://www.energyvortex.com/energydictionary/public_utility_regulatory_policies_act_of_1978_(purpa).html
PURPA changes: http://www.ucsusa.org/clean_energy/clean_energy_policies/energy-bill-2005.html
[43]Arizona Public Service (APS) 10/21/2005: http://www.aps.com/general_info/newsrelease/newsreleases/NewsRelease_300.html & 5/11/2005: http://www.aps.com/files/rfp/2005_Renewable_RFP_Final.pdf
Tucson Electric Power Inc. and UNS Electric Inc. (Green Power Network 7/5/06): http://www.intermountainchp.org/grants/default.htm
[44]Source: Arizona Journal. See: http://www.wte-expo.com/news.htm 7/24/2006