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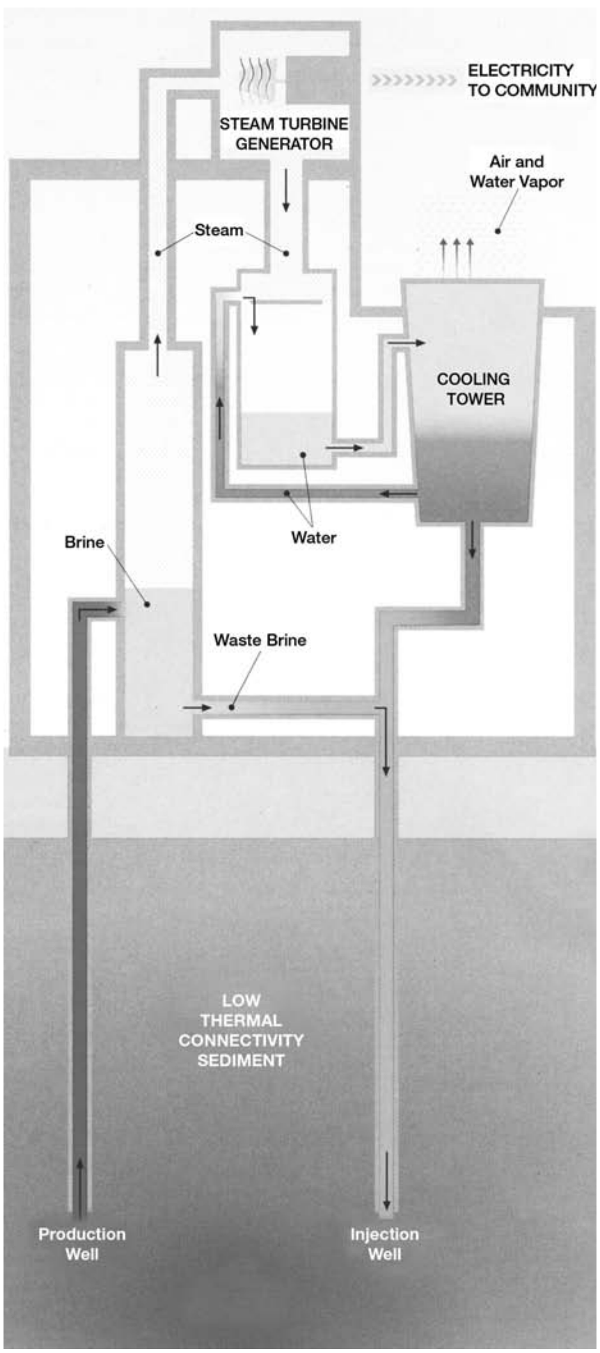
PRACTICE GEOTHERMAL DEVELOPMENT

Planning and Zoning for Geothermal Energy

By Erica Heller, AICP

This diagram shows the basic components of a geothermal power plant.



American Planning Association

According to the Union of Concerned Scientists, the United States has more geothermal power generation capacity than any other country.

Recent research by the U.S. Geological Survey identified geothermal resources in several hundred communities in 13 western states that could be developed for utility-scale power generation or industrial applications. These include Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. The vast majority of this potential has not yet been developed. In addition, geothermal industry experts are quick to point out that many geothermal resources are yet to be discovered; deep resources exist in locations where no surface signs indicate their presence. These are often identified only during unrelated drilling or mining activities.

The steam heat from the hottest geothermal resources can be used to drive turbines for electricity production, while cooler resources can provide heat for commercial and industrial applications such as breweries, aquaculture farms, industrial drying, heating districts, and pools and recreation facilities (known collectively as "direct use"). The passage of renewable portfolio standards in several western states with known geothermal resources has spurred a recent surge in geothermal resource development. Advances in technology can be expected to improve our ability to use a wider range of geothermal resources in the future. For planners, this means that more communities need to understand geothermal development as a land use.

The term "geothermal development" includes both geothermal power plants and direct uses. Planners interested in how to regulate geothermal development will benefit from understanding the character of both of these land uses. All geothermal developments have two major components: (1) the area where wells are drilled into the ground from which the heat is drawn and (2) the surface use. The surface use may be a direct use that uses the heat in some direct application or a power plant that uses steam to turn turbines and produce electricity.

Geothermal power plants produce clean, non-carbon-based electricity. Emissions from geothermal power plants are primarily water vapor, with trace amounts of other nontoxic gases. Geothermal energy generates continuous "base load" power, unlike the intermittent nature of solar or wind energy. Construction of geothermal power plants, including drilling down to the geothermal resource, creates hundreds of jobs, while operation of the plants creates smaller numbers of permanent jobs. Once a geothermal power plant is constructed, no fuel needs to be mined or transported to the site, unlike for coal-powered plants.

There are several challenges to increasing geothermal as part of the U.S. power mix. The deep drilling required to tap into a geothermal resource is expensive. Although geothermal energy is comparable in cost to other energy sources over time, the vast majority of the expense of geothermal power production is front-loaded in exploration (finding where to tap the resource) and development (drilling the geothermal wellfield). For this reason, geothermal power plants are most often privately owned, profit-making businesses that sell energy to public utilities.

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About the Author
Erica Heller, AICP, is a land-use planner with eight years of experience in planning and zoning. She has worked with client communities to draft sustainable zoning code standards. Heller has spoken about and published on the topics of zoning regulations for wind energy, local renewable energy, and neighborhood involvement strategies.

The lifetime of a geothermal power plant is somewhat uncertain, and depends in part on the quality and extent of the geothermal resource and whether the water vapor is reinjected. Because of the expense of research and development, geothermal energy developers are careful to develop resources where scientific data indicates that the resource is likely to be strong and stable over at least 30 years. However, there is always uncertainty about what may occur deep below the earth's crust that could shorten or extend the predicted lifetime or require retooling the plant or drilling new wells.

CHARACTERISTICS AND IMPACTS OF GEOTHERMAL DEVELOPMENT

Footprint

According to the U.S. Department of Energy, geothermal electricity generation requires one to eight acres per megawatt (MW) versus five to 10 acres per MW for nuclear operations and 19 acres per MW for coal power plants. A typical geothermal power plant often sits on five to 10 acres owned by the energy company.

A wellfield for a geothermal power plant can easily span 2,000 acres. The wellfield subsurface rights are typically leased by the energy company, while land ownership remains in private or public hands. Aboveground structures in the wellfield associated with the power plant are generally quite limited, consisting primarily of insulated pipes that conduct the heat to the power plant. Generally, wellfields that tap high-temperature, utility-grade geothermal resources are compatible with agricultural and other low-intensity uses. However, uses such as residential development, which would concentrate people near the pipes, create concern about possible tampering or unlikely accidents such as blow-outs that could potentially create hazards. For this reason, rural areas developed with high-temperature wellfields generally should not be converted to more urbanized uses until or unless the wellfield is no longer productive.

A geothermal direct use typically relies on one or more wells located on the same property as the surface use. These uses have footprints that are comparable to similar uses that use other heat sources.

Courtesy DOE/NREL; credit: USGS

The Geysers geothermal power plant in northern California is the largest electricity-generating geothermal development in the world.

Emissions and Effluent

While there is a range of technologies in use in geothermal power plants (including flash, dry steam, and binary), all geothermal power plants emit some amount of water vapor and many emit trace amounts of other gases. In some cases, the vapor emitted by the plant may have a sulfurous "rotten egg" or other noticeable odor caused by gases such as hydrogen sulfide. Mitigation of such odors and the substances that cause them may fall under state or federal air quality standards or may need to be regulated at the local level. As the steam is used for electricity generation or a direct use, it cools into liquid water. Many geothermal plants reinject such effluent, which can help prolong the life of the geothermal resource. Otherwise, the discharged water, which is warmer than surface waters and may contain higher concentrations of dissolved minerals, may have environmental and habitat impacts on surface waters into which it may be discharged.

Geothermal direct uses also use steam that cools into liquid water and must be reinjected or discharged. Reinjection typically prolongs the life of the resource and is a hedge against subsidence (See the discussion below.) However, because injection wells, like production wells, may cost as much as a million dollars to drill, geothermal direct uses may not be financially feasible if reinjection is required.

Noise

During development, drilling noise in the geothermal wellfield area is considerable and can last for months to years, depending on the number of wells and rate of development. Effects on both human and wildlife populations in the vicinity can be negative during this period. Anecdotal evidence from installed plants suggests that within a few years after drilling is completed, all or most species of wildlife return. Steam emissions from an operating geothermal plant or direct use creates constant, hissing "white noise" at a level comparable to other industrial uses. Drilling for direct uses is similar, but because these uses often require only one well, the duration of drilling is much shorter. Most geothermal surface uses (i.e., both power plants and direct uses) are readily able to comply, through a combination of technology or land acquisition, with typical noise standards of 65 to 60 decibels as measured at the property line.

Other Attributes and Land-Use Impacts

Several other typical attributes of geothermal development warrant brief mention. The transfer of hot vapor and fluid from a geothermal wellfield to the end use involves miles of pipes that can be quite hot. Although insulated, the pipes could pose a hazard to anyone that would tamper with them. Also, warmth from the pipes can create microclimates that are atypical of the surrounding area. The impact of this warmth on wildlife may be positive or negative. Some species congregate near warm geothermal infrastructure during winter months.

A concern often voiced by local residents is that geothermal resource development and use will increase seismic activity. While the fear that geothermal exploration may trigger an earthquake is unfounded, it is possible that seismic activity may be induced by drilling or removal of geothermal fluids. According to the U.S. Department of Energy, such activity is of such small magnitude (less than 2.5 on the Richter scale) and duration that it cannot be felt at the surface. However, some residents near geothermal development report noticing increased seismicity.

In communities with surface geothermal features such as hot springs, geothermal development may raise concerns about possible impacts on these features. Most often, surface features do not coincide with the best areas to drill wells, and utilization of deep resources will not affect surface features. However, it is often difficult to say with absolute certainty if and how geothermal resources may be linked below the ground, or to rule out all possibility of changes to surface resources. When use of the surface resources underpins the local economy, such as in Pagosa Springs, Colorado, the community is typically very cautious about embracing geothermal development.

In some cases, geothermal energy development may require additional transmission lines. Although land-use impacts of transmission are not addressed in this article because they are not unique to geothermal development, transmission lines may be an important consideration in local geothermal permitting decisions.

Finally, land subsidence—where an area of land sinks—is another possible impact of geothermal development due to the removal of fluid and gas from the underground geothermal reservoir. Subsidence that is detectable on the surface is rarely a result of geothermal development, is generally very limited, and can be minimized by reinjecting fluid back into the reservoir.

> Local communities with geothermal resources often recognize that the resource has the potential to offer clean energy and economic development benefits that align with community goals.

PLANNING TOOLS FOR GEOTHERMAL DEVELOPMENT

The permitting process for geothermal power plants and direct uses is multilayered and time-consuming. Geothermal well drilling and production emissions are subject to state and federal regulations for well drilling, air quality, and water quality. Many geothermal resources are located on public lands controlled by agencies with their own study and reporting requirements. And, like other power plants, the use is subject to some regulations in the Homeland Security Act, such as being fully enclosed within fencing that is secure and allows for visibility of any approaching potential threat. Local regulations and permitting processes are in addition to these other permitting requirements.

Local communities with geothermal resources often recognize that the resource has the potential to offer clean energy and economic development benefits that align with community goals. Thus, they seek to use planning tools to encourage safe development of geothermal resources, and to maintain the resource for potential future development. The remainder of this article describes some of the common tools and approaches that local governments are using to address geothermal development.

Comprehensive Plans

Some communities with identified geothermal resources are using comprehensive planning to set policy for potential geothermal development. Comprehensive plans can help indicate the desire of the community with regard to geothermal resource development and lay the groundwork for codified regulations. Most comprehensive plans ad-

Courtesy DOE/NREL; credit: J.L. Renner—INEEL

The Soda Lake Power Plant 2 in Soda Lake, Nevada, has a 12 MW capacity.

GEOEXCHANGE HEATING AND COOLING SYSTEMS

In contrast to geothermal power generation and direct use, geothermal heating and cooling systems, (also known as ground source heat pumps or geoexchange systems) can be installed in any community. They rely on the constant temperature of the earth below 10 feet in depth. Water (with antifreeze in cold climates) is passed through coils of tubing underground, bringing it from air temperature to approximately 50 degrees. The water preheats or cools air or water in the building heating system.

According to the U.S. Department of Energy, geoexchange systems are 25 to 50 percent more efficient in their use of electricity than traditional heating and cooling systems. They are more expensive to install, but energy savings typically pay back the initial expense within five to 10 years. The indoor equipment has a 25-year lifespan, while the underground coils can be expected to last 50 years or more.

Tens of thousands of geothermal heat pump systems have been installed in homes, institutions, and businesses in the United States. Geoexchange systems are subject to the building code, which ensures that the coils are encased to prevent collapse or leakage. But in some circumstances, there may be reason to regulate geoexchange systems using zoning tools, as well. For example, some communities specify setbacks for underground coils from property lines, rights-of-way, and surface waters. In other communities where artesian aquifers are present, it may be important to establish the maximum allowed depth of the underground coils.

dress geothermal in an energy element or stand-alone geothermal element. Inclusion in a natural resources element is also common. However, Churchill County, Nevada, includes development of industrial geothermal in the Economic Development section of the Master Plan. In communities where hot springs are a significant aspect of the local economy, such as in Calistoga, California, general plan policies often seek to balance utilization of deep geothermal resources for direct use or energy generation with ensuring the ongoing quality of near-surface hot water resources.

The extent and detail of comprehensive planning around geothermal varies widely, even among communities with significant resources. The geothermal element for Imperial County, California, is more than 80 pages long and provides extensive geothermal data as well as discussion of transmission limitations and expansion potential. Most communities' geothermal policies are much more modest—perhaps a few pages to a few paragraphs. One excellent example of thorough, yet succinct, treatment in a comprehensive plan is the geothermal element of the Lake County, California, 2007 general plan. In addition to definitions, it contains five major sections that address research and development, environmental protection, resource utilization, collaboration with other agencies and public outreach, and implementation measures.

For many communities, the best geothermal resources occur on federal lands where local government has limited jurisdiction. Adoption of detailed zoning regulations may be unwarranted in these communities, as local review—if it occurs—is advisory only. In these areas, comprehensive plan policies may be the best way to establish local preferences for geothermal development, including policies that seek local consultation during permitting. For example, the Mammoth Lakes, California, general plan includes a policy that seeks to annex any national forest lands on which future geothermal development occurs.

Mapping

One difference among communities with geothermal potential that affects the types of tools and degree of protection the community applies to the geothermal resource is the degree of detail known about the location of the geothermal resources. Known geothermal resource areas (KGRAs) are mapped in some communities, but many geothermal resources remain unmapped. Furthermore, pinpointing the precise location(s) to most effectively tap into a known geothermal resource can be expensive and time-consuming. In a limited number of communities, a federal research agency or other entity may have determined the location of the best drilling sites. Without such information, local planners may know only that geothermal development may be possible within a large, generalized area. As a general rule, the larger and less certain the extent and location of the geothermal resource, the less likely it is that the community will be willing adopt protective regulations for the geothermal resource. It is difficult to justify regulations that would preclude potentially incompatible uses when the level of uncertainty about the potential and location of future geothermal development is high.

Zoning Regulations

Allowed/Conditional Use. Most jurisdictions with KGRAs and some communities with unmapped geothermal potential specify geothermal uses in lists of allowed uses by zoning district. In most communities, geothermal development is allowed as a conditional or special use. A few communities, including the Town of Vale and Malheur County in Oregon, allow geothermal direct uses by right in heavy industrial zones. Where geothermal resources are adequate for energy production, most communities group all geothermal development as one use type, allowing direct and energy uses in the same pattern of zoning district. However some, such as Malheur County and Sonoma County, California, distinguish between the two, allowing direct uses in some zoning districts and energy production in others. Other communities distinguish between wellfields and surface uses. For example, the zoning regulations in the Town of Mammoth Lakes allow exploratory drilling for geothermal in all zoning districts by right, while "geothermal production" may be conditionally allowed in two zoning districts. Production drilling for wellfield or direct use is not regulated by zoning, but rather is subject to discretionary permits from the public works department.

Definitions. It is important that zoning regulations define geothermal uses so that they can be regulated with similar uses. For example, many codes include geothermal power plants within the general definition of a power plant. Others include geothermal exploration and drilling alongside other exploratory drilling activities. Given the ownership structure for geothermal plants—which are typically owned by pri-

Courtesy DOE/NREL; credit: Courtesy Studio 804

After a tornado devastated Greensburg, Kansas, in May 2007, the town turned disaster into opportunity by rebuilding as a model "green" community. This new school building incorporates a ground source geothermal system.

vate entities—it may be necessary to define the use as being within the definition of a "utility." Otherwise, special permitting may be required to allow geothermal pipelines to be located within or cross a right-of-way.

Use Standards. Many—but not all—communities that have some zoning provisions for geothermal codify a range of use standards for geothermal development. Examples of communities that have adopted use standards include Washoe County, Nevada; Harney County, Oregon; and Imperial County, California. Communities that allow geothermal uses in use lists but do not set out specific use standards include Beaver County, Utah, and Mammoth Lakes and El Centro, California.

Many of the typical use standards are listed below:

- Road improvement requirements and standards to minimize the total linear feet of new access roads and resulting disturbance and erosion
- Emergency standards that include requirements for submittal of contingency plans, on-site posting of emergency contact information, and coordination with 911 and fire departments
- Dust abatement requirements during drilling and construction
- Noise standards for both drilling and operations
- Abandonment provisions, such as requirements to restore and revegetate after drilling
- Access protection requirements for fencing or other deterrents to public access
- Air quality protection requirements that typically consist of references to state and federal standards
- Ground or surface water protection standards, which typically reference state and federal standards but may also elaborate separation standards from existing wellheads
- Historic and cultural resources and habitat protection requirements
- Separation requirements from other uses, particularly noise-sensitive uses such as schools, hospitals, and—most commonly—single-family residences
- Pipeline standards for road crossings that minimize visual and traffic impacts
- Subsidence standards that are generally stated to require mitigation of any subsidence that may occur

In communities that have not codified specific standards, permit approvals may be conditioned based on similar considerations as needed.

Some local jurisdictions' geothermal regulations include provisions that are redundant to or simply reference state or federal regulations. In general, such redundancy is unnecessary. However, some jurisdictions codify these provisions locally so that, in the event that another agency's enforcement is slow or lax, local code enforcement tools such as permit revocation may be brought to bear.

Overlay District. Geothermal overlay districts, whether mapped or unmapped, are used in a number of communities both to regulate and to protect geothermal resources development. Imperial County has adopted and mapped energy zones around its KGRAs that protect them from development that could impede future geothermal development. Klamath County, Oregon, which has the potential for direct use applications of geothermal but not energy development, has adopted a geothermal overlay zone that is not mapped. Geothermal development in the county requires rezoning to the geothermal overlay district, which adds

Courtesy DOE/NREL; credit: Geothermal Heat Pump Consortium (GHPC)

The homes in the Hillside Oaks development in East Dallas, Texas, include ground source geothermal systems and structural insulated panels that dramatically reduce heating and cooling costs as compared to similar homes with conventional HVAC and insulation.

additional application submittal standards as well as development standards. The overlay district also allows for a concept plan approval to give certainty to prospective geothermal developers. The city of Klamath Falls, Oregon, has adopted a yet another flavor of geothermal overlay zone; it covers the entire city. Within the overlay zone district, geothermal direct uses are reviewed by the planning department for consistency with the zone district designation, while the geothermal aspects of the project are subject to approval of the city's public works department. Hawaii County, Hawaii, has several geothermal "subzones" that may be designated based on criteria set by the state legislature. They have been mapped on parcels where geothermal development appears imminent.

Incentives

Hawaii County has adopted several incentives for geothermal energy development. The planning department in Hawaii County administers a geothermal relocation and community benefit revolving fund. The funds benefit residents who wish to be relocated from the area around geothermal "subzones" surrounding the Puna geothermal power plant. The county has also adopted a property tax exemption for the value of alternative energy production improvements, including geothermal energy.

Zoning regulations that protect geothermal resource areas from incompatible development can also serve as a very important incentive to prospective geothermal developers. As noted above, geothermal development costs are front-loaded. Unexpected degradation of the resource can reduce or eliminate profitability of a geothermal venture. Over time, some agricultural and rural areas where wellfields are developed may face development pressure for other uses. Energy companies typically lease, not own outright, wellfields, and leases of subsurface rights may be held independently of surface rights. Surface property owners may pursue land development opportunities that are not compatible with wellfields, such as residential development. It is important that local communities understand that a geothermal wellfield permit has long-term implications for land development opportunities. Communities with policies that signal such understanding or that have regulations that make a commitment to protecting geothermal development are very desirable locations for geothermal developers.

The Imperial County energy zones mentioned above were proposed in the county's comprehensive plan for the explicit purpose of maximizing geothermal energy development and protecting existing plants from urbanization that would create use conflicts. Lakeview, Oregon, has adopted a protective overlay zone that applies when a geothermal resource is identified. It prohibits degradation of a geothermal resource and development of any surface use that would preclude future use of the geothermal resource. A similar concept is used in Malheur County, where uses in the M-2 manufacturing zone that are within a geothermal resource area must be reviewed to ensure that they will not "seriously interfere" with future geothermal resource use and development.

SUMMARY

Communities with known or potential geothermal resources have employed a range of local planning strategies to allow, encourage, and protect geothermal resource development for direct use and energy production. These include comprehensive plan goals and policies, and zoning tools such as conditional use permits, use standards, and overlay zone districts. Comprehensive plans are important for setting local priorities for geothermal development, even when geothermal resources are on lands that are not under local regulation authority.

Geothermal power plants and direct uses are still relatively rare in the U.S. and each geothermal resource offers unique opportunities and challenges.
Most planners and industry officials find that the conditional use permit process is the most appropriate procedure for working out the challenges, concerns, and constraints of a specific proposed geothermal energy development to maximize the potential benefits. Permitting of direct use geothermal can be somewhat more standardized than geothermal energy development. Some communities with experience now allow geothermal direct uses as by-right uses.

At this time, there are a substantial number of local governments with permitting experience and thoughtful regulations for geothermal development. These communities will serve as models for the next generation of communities that grapple with geothermal development as the use of this beneficial resource increases in the United States.

CORRECTION . . .

Mary-Margaret Jenior, AICP, author of the April 2010 issue of *Zoning Practice*, has identified a number of corrections and clarifications to her article on solar access.

We have posted her comments online at www.planning.org/zoning practice. Reminder: Jenior will be available for an online "Ask the Author" forum May 10 to 21. Readers may submit specific questions for her there.

The Heber Second Imperial Geothermal Power Plant in Heber, California, is part of a large geothermal development that produces over 80 MW of electricity. Courtesy DOE/NREL; credit: Warren Gretz. Design concept by Lisa Barton.

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5