



# NCPA at The Geysers

**Northern California Power Agency Benefits the Public and Its Member/Owners with Reliable, Renewable Geothermal Power**

**By Murray Grande – NCPA Acting Assistant General Manager for Generation Services; and NCPA Geothermal Staff – Steve Eney, Bill Smith, John Council, and Steve Jones**

In the late-1970s, the Northern California Power Agency (NCPA)—serving the public as a non-profit agency—searched for a reliable, renewable power source to benefit both its electricity consumers and the environment. After thoughtful consideration of the long-term advantages of geothermal energy, the municipal utility decided to develop two power plants at The Geysers Geothermal Field in northern California.

The success of these operations showcases the deep commitment that NCPA has made to developing “green power” and meeting its market and technical challenges. That success is exemplified by one of NCPA’s Member/Owners, Alameda Power and Telecom, which in 2004 earned the distinguished American Public Power Association Award for Community Service. The award is given to public power utilities that have shown a commitment to enhancing the quality of life in their communities.

The City of Alameda owns 17 percent of NCPA’s geothermal operations, which provide more than half of the community’s electricity demand. To further the cause of renewable power, Alameda established a public education and outreach program, which has prompted more than 700 citizens to tour NCPA geothermal power facilities at The Geysers during the last two years.

## **NCPA Background and Early Geysers Development**

Established in 1968, the Northern California Power Agency (NCPA) is a non-profit California Joint Action Agency. For nearly three decades, NCPA has been devoted to the purchase, generation, transmission, pooling and conservation of electrical energy and capacity for its members.

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*NCPA Power Plant #2, rated at 110 megawatts, has been online at The Geysers in northern California since 1985.*

## NCPA Steamfield 1998 History and Forecast

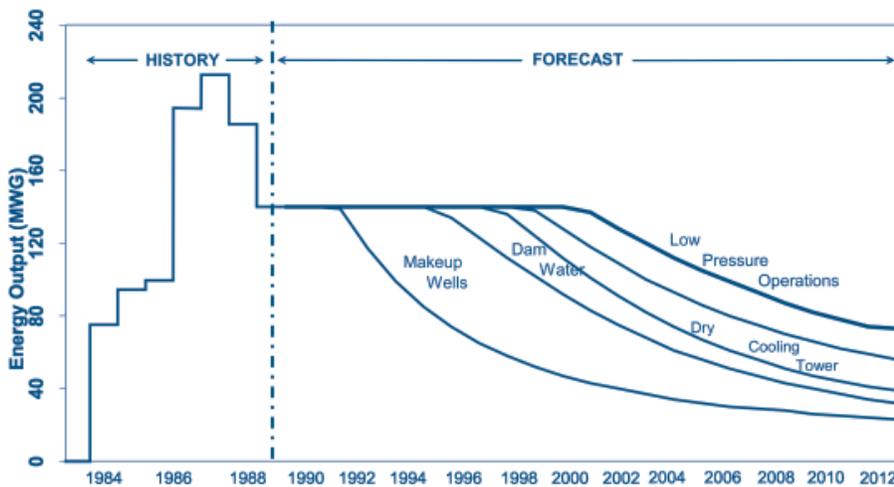


Figure 1 - NCPA's 1988 vision of potential benefit of enhanced generation projects including completion of makeup wells, augmented injection from two different water sources, and low-pressure operations. Shown is average annual gross generation from 1983 to 1987, and anticipated generation with and without NCPA steam enhancement projects.

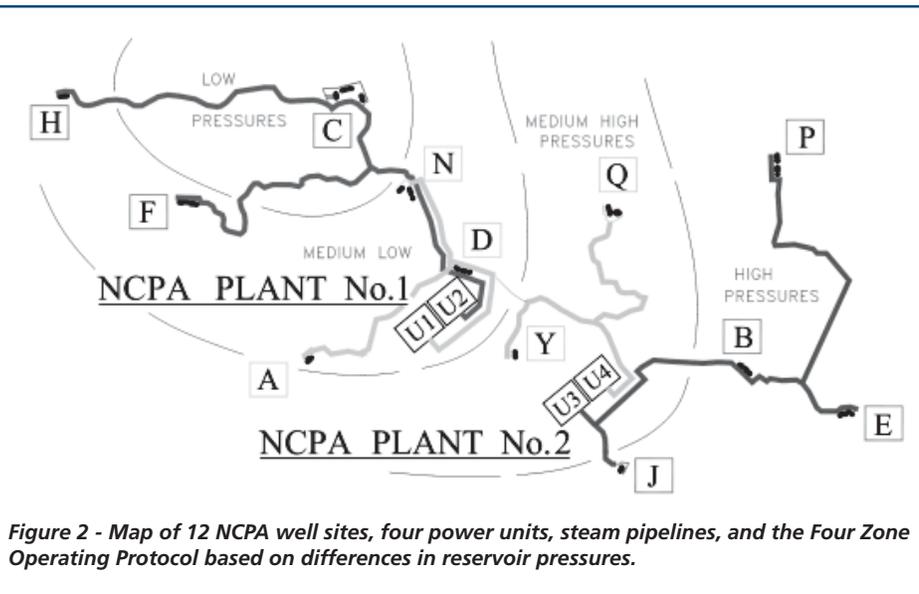


Figure 2 - Map of 12 NCPA well sites, four power units, steam pipelines, and the Four Zone Operating Protocol based on differences in reservoir pressures.

With the onset of electric utility restructuring in California, NCPA has become a primary supplier of power scheduling and interchange management services to power marketers and public agencies.

In addition to its geothermal power facilities at The Geysers, NCPA owns and operates five dual-fuel, quick-response natural gas combustion turbines and a 49-megawatt (MW) steam-injected gas turbine. The units are located in the cities of Alameda, Roseville, and Lodi, providing reserve capacity, spinning reserves, and peaking energy. NCPA's North Fork Stanislaus River Hydroelectric Development Project generates 250 MW.

NCPA membership is open to municipalities, rural electric cooperatives (REC), irrigation districts (ID) and other publicly owned entities interested in the purchase, aggregation, scheduling and management of electrical energy. NCPA Member/Owners participating in The Geysers geothermal energy project include the cities of Alameda, Biggs, Gridley, Healdsburg, Lodi, Lompoc, Roseville, Santa Clara and Ukiah, as well as the Plumas-Sierra REC and the Turlock ID.

NCPA's formal interest in developing geothermal power generation started in 1977 with a Shell Oil Co. contract for an exclusive right to purchase steam from two U.S. Bureau of Land Management (BLM) geothermal leases spanning 4,077 acres in the southeast Geysers Geothermal Field. Rated at 110 MW, NCPA Geothermal Plant No. 1 started operation in January 1983, and is the first publicly owned power plant to operate at The Geysers. NCPA Geothermal Plant No. 2 began operation in September 1985, and reached its rated capacity of 110 MW in April 1986.

In 1985, NCPA bought the steam wells, associated steamfield production facilities, and all rights for further development within the original Shell BLM leaseholds. By combining power plant and steamfield operations under single ownership, NCPA was the first major geothermal developer at The Geysers to create a coordinated and integrated approach to future development and enhancements that would improve the long-term efficiency of its power facilities.

The NCPA geothermal project at The Geysers has achieved an outstanding record of reliability, logging 21 years of power generation that has produced more than 27 million megawatt-hours (MWh) of electricity for its 11 Member/Owners.

The project currently consists of 77 geothermal wells, two 110-MW power plants (with two 55-MW generating units each), associated steam pipeline facilities, and part-ownership of the 26-mile Southeast Geysers Effluent Pipeline from nearby Lake County.

NCPA steam wells are located on 12 sites spaced across approximately 1,200 acres. The wells are connected to the utility's power plants by 7.6 miles of steam pipelines up to 48 inches in diameter. The geothermal steam delivered by this system fuels four generating units that currently generate about 135 MW (gross).

## NCPA Successful Response to Declining Reservoir Pressures

NCPA generally maintained 220-MW baseload electrical generation levels from its Geysers operations until 1988, when a field-wide decline in steam reservoir pressure threatened future operations. At that time, an extensive reservoir performance analysis indicated insufficient steam was available to operate NCPA's geothermal power plants at full load for their 30-year project lives. Forecasts from that study are shown in Figure 1.

To maintain a satisfactory level of future generation, it was concluded that specific operations enhancements had to be identified and successfully implemented. To maximize future geothermal electrical generation, several enhancements were targeted in 1988 for potential development, including low-pressure operations, augmented injection, and advanced drilling technologies.

NCPA deemed it necessary to: 1) modify the steam-gathering pipelines and power plant turbines to more efficiently operate at lower turbine inlet pressures; 2) acquire additional sources of water for increased injection by increasing recovery from cooling towers and by possibly building a dam; and 3) drill a series of makeup steam production wells. Enhancements that were ultimately implemented are described below, and though they were somewhat changed from NCPA's original assumptions, reservoir response has far exceeded expectations set forth by the 1988 reservoir performance analysis and forecasts.

At the end of 2003, NCPA's Geysers generation capacity was 142 MW (gross), compared to the 120 MW anticipated by the 1988 model. And since that time, the utility has amply demonstrated the reliability of geothermal power. NCPA generated approximately 1.2 million MWh of geothermal electricity during the last 15 years. Monthly average generation has always been greater than 100 MW since 1985, following startup of the facility's third generating unit. Load flexibility was always available, and variation in monthly generation ranged from a low of 116 MW (gross) to a high of 141 MW. More recently, average annual generation was 135.8 MW (gross) in 2003, compared to 136 MW in 2002, for a statistically minor 0.7-percent decline.



*Top: NCPA 110-MW low-pressure turbine deck at NCPA Plant #1. Bottom: NCPA Team Leader Jerry Stasik (right) and Operator Martin Trujillo (left) keep watch over system operations at the facility's integrated plant and steam field control room.*

### Enhancement #1 Low Pressure Operations

Load following started in 1988, and can be considered as the first step to enhance the value of electrical generation from NCPA's Geysers operations. An apt analogy is that of a "once through"

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hydroelectric facility. As with a hydro project, the geothermal fuel source is limited and is scheduled for periods when it is most needed by the NCPA Member/Owners.

NCPA was the first power plant operator at The Geysers to change to load-following operations, with an average daily load of 140 to 150 MW. Rate changes were conducted up to 20 times per day. This paradigm shift from a 220-MW baseload operation was brought about by detailed reservoir and economic analysis from NCPA's Geothermal and Power Management groups and a com-

mitment by the NCPA Member/Owners to enhance the environmental and economic benefits of its geothermal facilities. An added benefit to NCPA Member/Owners was planned "banking" of steam for periods when generation would be of greatest value.

With that strategy, NCPA maintained approximately 150 MW of geothermal generation for 11 more years. Load following continued from 1988 to 1999, when gradual steamfield pressure decline forced a return to a full, four-unit baseload operation with a capacity near 140 MW (gross). If needed, however, the utility's

Power Dispatch Group can still utilize the geothermal facilities to trim load in response to NCPA Member/Owner needs.

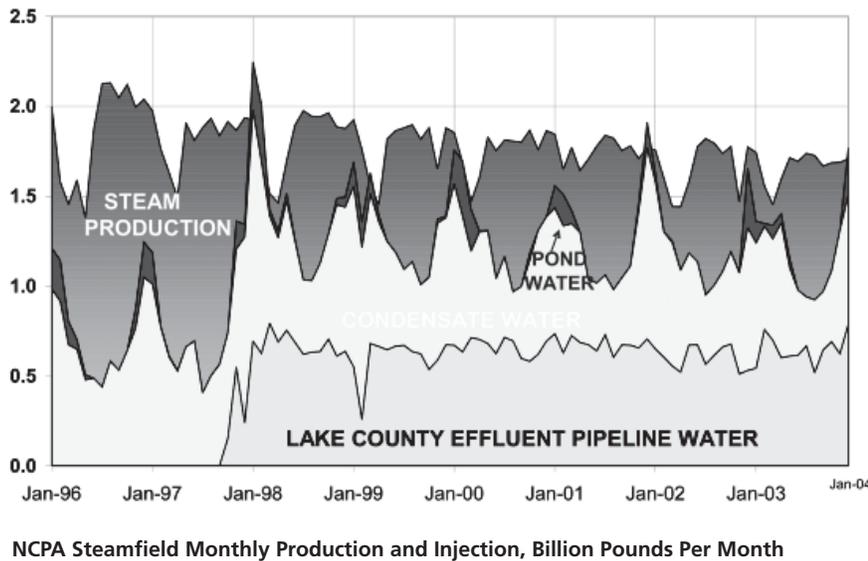
The 12 NCPA Geysers well sites (Fig. 2) are grouped into four different steam gathering pipelines that separately deliver steam to each of four power generating units, based on the distribution of differences in reservoir pressures. The four areas are known as zones. A Geothermal Operating Plan approved by the NCPA Commission in December 1999 established the number of zones and generation levels for the geothermal power plants. The Four Zone Operating Protocol was designed to mitigate the impact of reservoir pressure decline.

NCPA's first low-pressure (LP) turbine has completed its eighth full year of operation, resulting in higher flow rates of steam from the lowest pressure areas of the reservoir. To allow even lower operating pressures for Unit 2, well D-8 delivers steam for the unit's gas ejectors, which have a higher operating pressure. Based upon observed benefits of the first LP turbine, NCPA installed a second LP turbine for Plant 1 in April 2002. The Four Zone Operating Protocol resulted in reduced operating pressures in Zone 3 of the steam field, providing increased steam production from that area and improving overall reservoir management. Because of the decline in reservoir pressure, NCPA modified its B-Site gathering system, generating unit steam strainers, and other pipeline facilities to allow for reduced system pressure.

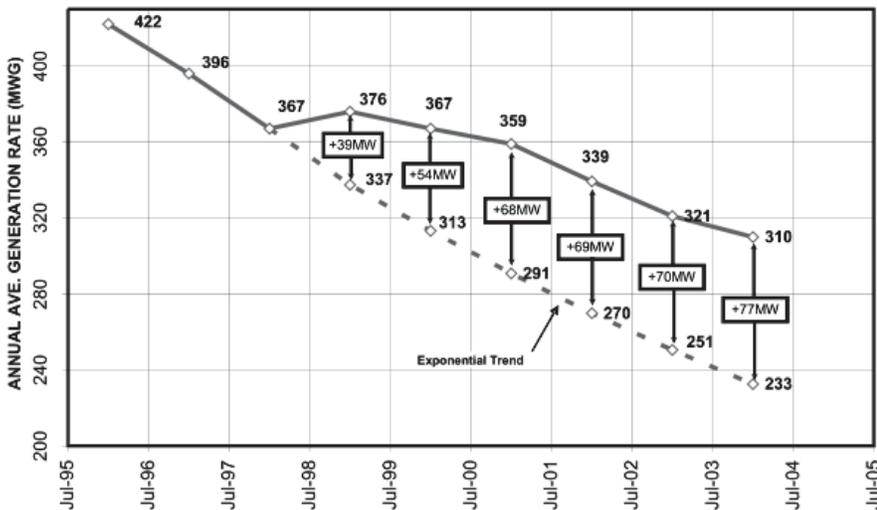
## Enhancement #2 Augmented Injection

NCPA began augmenting condensate injection in 1991 with the construction of a pond system that captured excess rainwater. Today, there are three sources of injectate at the facility, including steam condensate (43%), the rainwater ponds (4%), and fluid from the Southeast Geysers Effluent Pipe-

**Figure 3 - In 2003, 73% of the mass of steam produced at The Geysers by NCPA was replaced with injectate.**



**Figure 4 - Effect of SEGEP effluent injection on power generation in the Southeast Geysers.**



**NCPA Power Plants 1 & 2, and Calpine Units 13, 16, and 18**

line Project (SEGEP) (53%). Monthly steam production, injection, and injectate sources are shown in Figure 3. As a result of the augmented injection program, mass replacement of steam in the NCPA reservoir increased from 33 percent in 1988 to 73 percent in 2003.

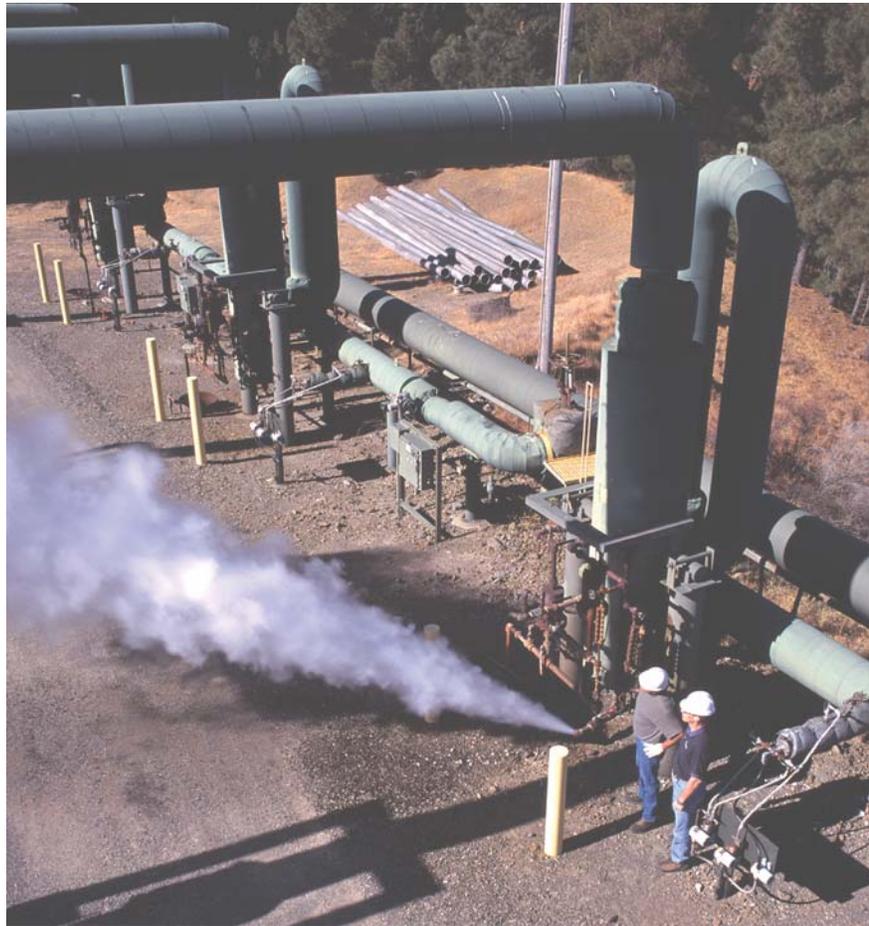
SEGEP began delivering water to The Geysers steam field from Lake County on Sept. 25, 1997. Daily deliveries throughout early 1998 peaked at about 9.5 million gallon per day, or 6,600 gallons per minute (gpm). Maximum capacity declined to about 5,500 gpm by the end of 2002. In March 2003, NCPA began to develop agreements with the other geothermal power plant operator at the steam field, Calpine Corp., that would increase NCPA's ownership interest in The Geysers portion of SEGEP from a third to 50 percent, and provide a significantly larger percentage of effluent for injection when the pipeline is operated at ~5,400 gpm.

NCPA also agreed to improve system operations to at least 6,400 gpm. As a result of these Basin 2000 Upgrades, NCPA expects to receive an additional 700 to 900 gpm of effluent, for a 50-percent increase over the previous delivery rate. It is anticipated that all additional pumps will be installed by the end of 2004. At that time, NCPA will be replacing essentially 80 percent of the steam it produces with injected water from all sources, rather than approximately 20 percent of the steam prior to augmented injection.

Geochemical tracer recovery tests and thermodynamic data indicate that the reservoir continues to benefit from augmented injection. Since the start of SEGEP in 1997, project participants as of June 2004 have injected over 18 billion gallons of effluent into the Southeast Geysers. The increase in electricity generation attributed to this additional injection is now over 77 MW (Fig. 4) for both project participants. Of that, NCPA has gained over 25 MW, which is more than a 15 percent increase in electrical generation for its Member/Owners.

During 2003, NCPA's water injection management program was further modified to distribute increased injectate from SEGEP with 11 injection wells. As a result, the injection water is now distributed over a wider expanse of the reservoir than in the past. This is especially true throughout the lower pressure (drier) portions of the field. The amount of injection into each well is varied, depending on the different reservoir characteristics that change with time. NCPA continues to operate the steam field to both optimize the use of available injectate—with the goal of improving reservoir performance—and to minimize the occurrence of microseismic activity.

Increases in microseismic events observed at The Geysers have been accompanied by increased awareness and concern by those who live nearby, especially in Anderson Springs. NCPA is cooperating with affected parties, and is considering meaningful approaches to assist in mitigating the microseismic issue for the community.



*Top: Clean geothermal steam vented from wellhead separator by Operator Martin Truillo and Operations Supervisor Brian Crothers. Bottom: NCPA Geothermal Chemist Jeff Furst takes steam well sample to help quantify steam derived from injectate.*



Photos: TJC / GRC

**NCPA Electrician Greg Bentley and Steam Field Superintendent Steve Enedy with 500-HP Gould pumps at the site's Southeast Geysers Effluent Pipeline (SEGEP) pump station.**

### Enhancement #3 Advanced Drilling Technology

As geothermal power development progressed at The Geysers and mass withdrawal from the reservoir increased, average steam flow rates from rig tests across the field declined from between 150 to 250 thousand pounds per hour (kph) to between 50 to 100 kph. To help counter the situation, NCPA developed an innovative drilling technique, whereby production from a marginal or subcommercial leg can be combined with production from a second leg in a forked completion. NCPA has completed 12 such wells. The technique has been most effectively utilized near the edges of the geothermal reservoir, successfully expanding its commercially productive area by about 1,200 acres.

In response to the need to better distribute injectate to enhance recovery of injection-derived steam, NCPA drilled the first near-horizontal geothermal injection well at The Geysers in 2003. Well N-7 was drilled with the assistance of a \$1.6 million grant from the California Energy Commission. As shown in Figure 5, the well was directionally drilled to a near-horizontal orientation at the intended injection intervals. In this way, more near-vertical fractures have been intersected, allowing wider distribution of injectate for more rapid boiling and faster recovery of injection-derived steam.

### Summary and Conclusion

Since the mid-1980s, NCPA has operated two geothermal power plants at The Geysers Geothermal Field in northern California. The NCPA geothermal project at The Geysers has logged

21 years of power generation that has produced more than 27 million megawatt-hours (MWh) of electricity for its 11 Member/Owners. The project currently consists of 77 geothermal wells, two 110-MW power plants (with two 55-MW generating units each), associated steam pipeline facilities, and part-ownership of the 26-mile Southeast Geysers Effluent Pipeline from nearby Lake County.

The success of these operations showcases the deep commitment that NCPA has made to developing “green power” and meeting its market and technical challenges. The utility produced 419 billion pounds of geothermal steam and generated more than 27 million megawatt hours from the start of operations in January 1983 through December 2003. In response to a field-wide decline in reservoir pressure at The Geysers, NCPA implemented a resource management program starting in 1988, which included three highly successful enhancements: 1) Low Pressure Operations, 2) Augmented Injection, and 3) Advanced Drilling Technologies.

The annual decline in average well flow rate has been reduced by about 77 percent

*Geothermal enhancements implemented by NCPA.*

Enhancement 1 Low Pressure Operations	Enhancement 2 Augmented Injection	Enhancement 3 Advanced Drilling Technologies
1988 - Load Following Initiated	1989 - Modify Cooling Tower Operation	1987 – Developed Forked Hole Technology
1993 - Two Zone Operation	1991 - Construct Rain Water Pond 1	1992 – Developed 77 Wells, 1,200 ac, and a total of 110 drilled miles
1994 - Three Zone Operation	1993 - Construct Rain Water Pond 2	1993 – 2003 Well Cleanouts: D-7, D-8, J-2, J-3, P-3, B-6, B-3, C-7, D-1, etc.
1996 – Unit 2 New Turbine Installed	1997 - Startup of Lake County Effluent Pipeline Project (EPP)	2003 Near-Horizontal Drilling of Injection Well N-7
1999 - Four Zone Operation	2003 - Construct Basin 2000 Upgrades for EPP	
2000 - Economic Loading		
2002 – Unit 1 New Turbine Installed		

since 1988. Improved reservoir performance is a direct result of NCPA steam field enhancements, especially augmented injection that has increased average mass replacement from 33 to 73 percent. As a result, the total amount of remaining steam capable of being produced by NCPA through the year 2030 is currently estimated at 399 billion pounds. This represents 95 percent of the steam produced since the start of the project. NCPA forecasts an additional 24 million MWh of electrical generation from its geothermal power operations at The Geysers.

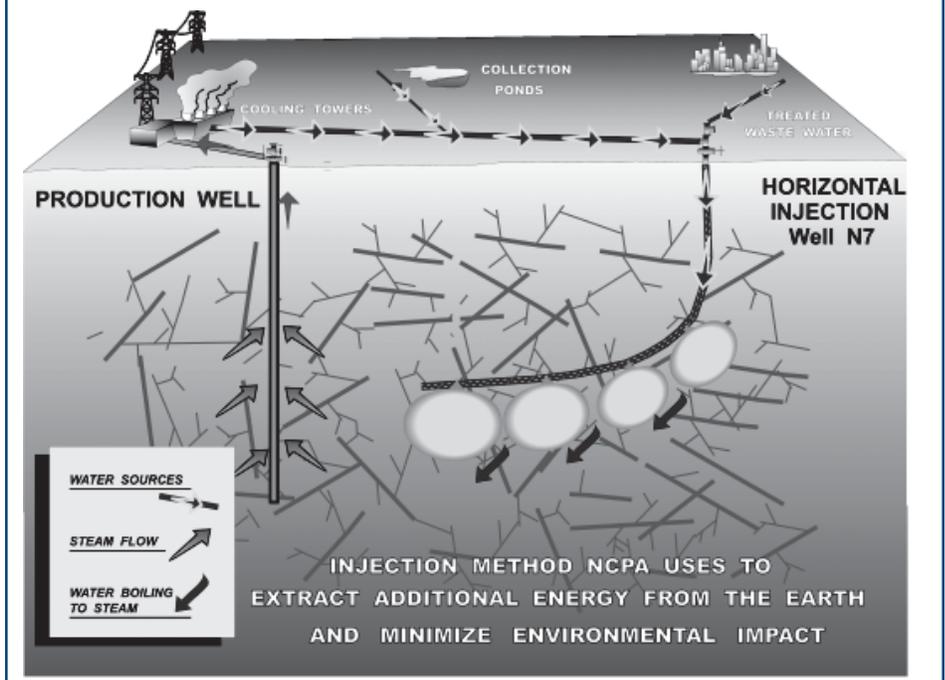
## Acknowledgments

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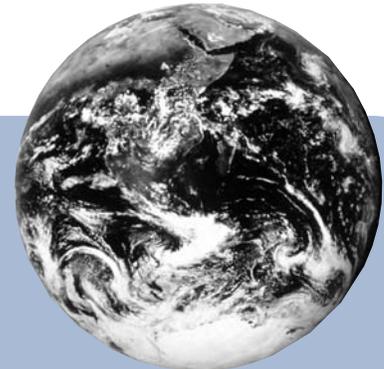
Figure 5 - NCPA's new near-horizontal injection method.



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