**An Economic Assessment of the Geothermal Resources Available at Buena Vista, Colorado**

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A WHITE PAPER

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**Executive Summary**

Buena Vista is situated in a region that has access to geothermal energy. Previous research has found that it is possible that the temperature profile of the geothermal resource near Mt. Princeton, in Chaffee County, will support electric power generation. Additionally, there are a range of direct use applications for the hot water that could be implemented to facilitate economic development in nearby Buena Vista. The purpose of this White Paper is to suggest several direct-use geothermal applications that are technically feasible given the estimated temperature of the resource and highlight the economic feasibility of these applications. This White Paper identifies three specific potential geothermal direct use projects that are consistent with Chaffee County’s Master Development Plan circa 2010.

# Introduction

Buena Vista is located in central Colorado in Chaffee County, roughly midway between [Salida](https://en.wikipedia.org/wiki/Salida,_Colorado) and [Leadville](https://en.wikipedia.org/wiki/Leadville,_Colorado) in the Upper [Arkansas River](https://en.wikipedia.org/wiki/Arkansas_River) Valley (UARV) at an elevation of 7,965 feet (2,428 m). The Arkansas River Valley and the area of what would become Buena Vista was first settled in 1864 by settlers drawn to the area by the plentiful water which made the land suitable for agriculture. By 1894, Buena Vista had electricity, telephone service, street lights, parks, cemeteries, and schools. Travelers, speculators, and miners traveling up the Arkansas Valley towards Leadville made Buena Vista a popular stagecoach stop, and railroad depot following the 1890s. While certainly experiencing economic ups and downs, the valley's agricultural economy, tourism and the penitentiary have made the area more resistant to the 'boom, bust' cycle of mining towns.

Buena Vista’s spirit is strong and the town continues to imagine ways to reinvent itself in the new economy. There is a thriving artist community in the town, and there is a major focus on outdoor recreation. In addition to a strong spirit and loyal citizens, Chaffee County is also home to a geothermal resource that has been known to the area since it was inhabited by the Ute Indians over a hundred years ago. Deep below the earth’s surface, the presence of hot water may be the pathway to the re-invigoration of this small mountain town. Preliminary analysis of the geothermal resource in the Buena Vista area indicates that power generation is possible, raising the possibility of sharing the resource to support a variety of direct uses, which could provide the town with opportunities for economic development and growth.

This goal of this White Paper is to highlight, from both technical and economic standpoints, the potential uses of the geothermal resource by the Town of Buena Vista in particular, and Chaffee County in general. It will begin by providing a brief technical overview of the geothermal resources available in the Chaffee County region. Next, the White Paper will introduce a variety of direct use applications of geothermal energy that may be appropriate for development in the Buena Vista area.

**Community Attitudes**

Chaffee County’s economic development plan (2010 CEDS) indicates the goals, resources, significant problems, needs and policies regarding the four economic sectors important to the region: agriculture, manufacturing, tourism and mining. Of these sectors, the irrigated agriculture sector has limited potential, but the opportunities for continuing livestock grazing are better. The stated policy is to protect the existing agricultural area. Tourism, mining and manufacturing are all considered to have excellent potential for growth and economic development. The policy stipulates the desire to encourage greater development in these sectors. At the same time, the plan emphasizes that the environment must be protected so that the beauty and the healthfulness of the region will be maintained. Therefore, industry of a non-polluting sort and environmentally sound mining techniques are to be encouraged in the region. Geothermal power is specifically referenced as having a significant opportunity for Chaffee County to pursue. Chaffee County’s goal at that time was to become the first self-sufficient [energy] area in Colorado.

# Geothermal Resources in Chaffee County

In the 1970s three exploration firms—Occidental Oil, AMAX, and Petro-Lewis—began surveying the Mount Princeton Hot Springs area for the purpose of geothermal resource assessment. These activities included deep and shallow temperature gradient measurement, geologic mapping, and geophysical surveys. AMAX Exploration drilled 31 temperature gradient wells in the area, but reconnaissance activity in the area stagnated significantly due to complications in obtaining geothermal leases from the Forest Service. Global declines in oil prices also contributed substantially to a reduction in interest and investments in renewable energy sources.

Academic field work conducted between 2008 and 2010 for a geophysics field camp in the UARV consisted of several geophysical reconnaissance studies. The surveys, which were the collaborative efforts of the Colorado School of Mines, Boise State University, and Imperial College-London, characterize the geological, hydrogeological, and geothermal conditions of the Mount Princeton Hot Springs geothermal area. Two-dimensional deep seismic reflection surveys conducted in a transect through the Mount Princeton Hot Springs geothermal area yielded results that validate previously inferred stratigraphic and structural characteristics of the UARV.

In 2009 Mt. Princeton Geothermal, LLC drilled five temperature gradient holes in the Mount Princeton Hot Springs area, delineating the western margin of the temperature anomaly. Magnetotelluric (MT) surveys were conducted by Dewhurst Group, LLC in 2011 and 2012 in conjunction with the exploratory efforts of Mt. Princeton Geothermal, LLC. These surveys yielded results indicative of 150 °C waters at depths of 760-1,070 m. Groundwater studies estimate the hot reservoir temperature in the range of 300 to 3900F, the highest in the state. The heat flow is estimated at 650 mW/m2 or about 8 times’ normal measurement, also the highest in Colorado.

# Direct Use Applications of Geothermal Energy

Worldwide, space and district-heating systems are second only to bathing and swimming in terms of installed capacity. District-heating systems distribute hydrothermal water through pipes to houses and buildings. There are 21 geothermal district-heating systems in the United States13. One of the largest districts is Boise, Idaho, which has 58 buildings on its system. Space heating of individual buildings generally uses one well per structure heated. It is estimated that over 2,000 buildings across 17 states utilize space heating, with over 600 buildings in Klamath Falls, Oregon utilizing this technique. Directly using geothermal energy in homes and commercial operations is much less expensive than using traditional fuels. Savings can be as much as 80 percent over fossil fuels. It is also very clean, producing only a small percentage (and in many cases none) of the air pollutants emitted by burning fossil fuels.

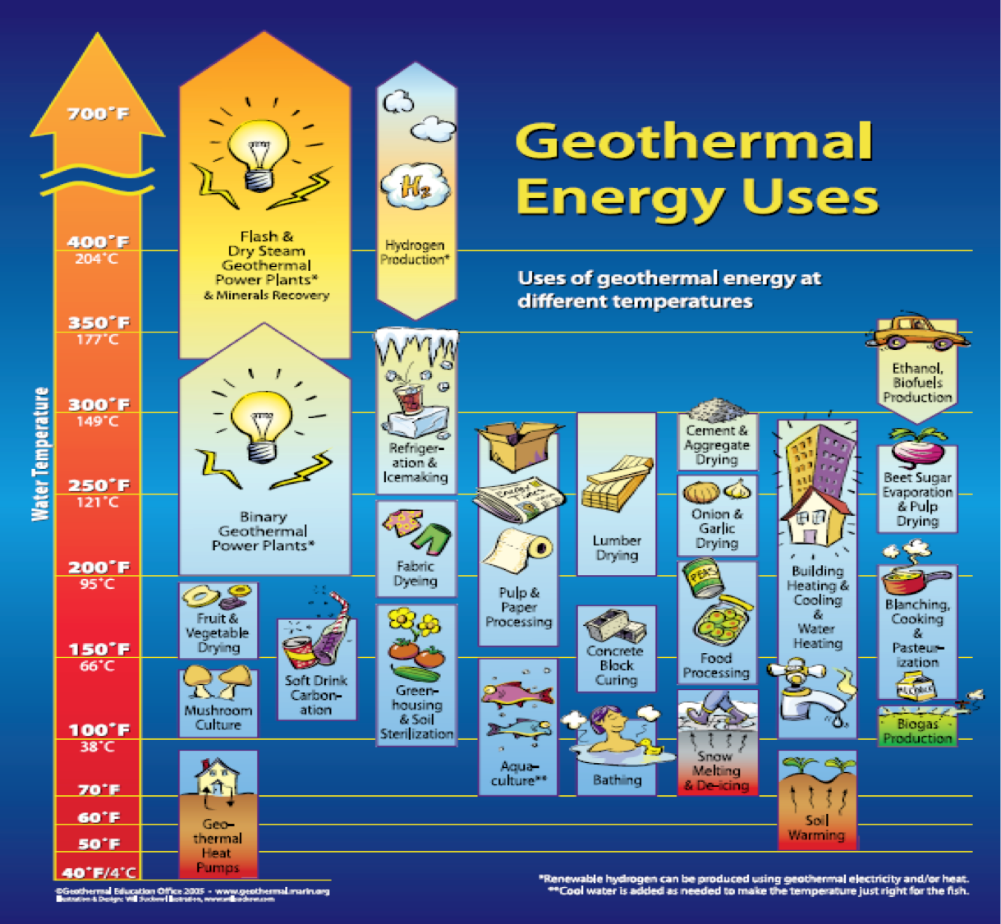
Geothermal energy is traditionally used in two distinct modes. The first mode is electrical power generation in which geothermal steam or hot water, flashed to steam, is used to drive a turbine which then rotates a generator. For electricity production, temperatures of at least 150°C (300°F) are generally required1. Past research at the area near Mt. Princeton has explored the potential for electricity generation. However, further study and exploration are needed to provide a complete evaluation of the technical and market feasibility of electric power generation in the region. The second mode is direct use, in which the heat from geothermal energy is used directly in a variety of applications. Given the available information on the temperatures of the geothermal resources in the Mt. Princeton area, several direct use approaches which work well with the known low to moderate observed temperatures may be implemented more immediately.

Direct uses of geothermal energy involve using the heat in the water directly for projects such as heating of buildings, industrial processes, greenhouses, fish farming, and bathing (Figure 1). Direct use projects typically require resource temperatures between 38°C (100°F) to 150°C (300°F). More information on a wide variety of direct uses of geothermal energy can be found in a report from the Colorado School of Mines produced in 2009.

Space and district-heating systems reduce costs of heating by eliminating the need for conventional heating energy such as propane or firewood as well as eliminating the need for equipment such as boilers and gas vents. Geothermal heating districts have been shown to save customers 30 to 50 percent in heating bills compared to conventional fuels. Water temperatures for space and district-heating range from 26°C (79°F) to 166°C (330°F). Due to the significant costs associated with developing a communitywide district-level heating system, this analysis will focus on space heating two facilities in Buena Vista, with the opportunity to connect additional buildings.

We will suggest the technical and economic feasibility of using the geothermal resources to provide energy to power the retrofit the Buena Vista Correctional Facility (BVCF), from a fossil fuel boiler/steam system to geothermal energy, and to provide thermal energy for a Buena Vista middle/high school (BVHS) building currently in the planning stages. These buildings represent >200,000 ft2 of space-conditioned area and the BVCF alone has over 102,000 MMBtu of space heating demand.

The expected 150°C geothermal resource in the UARV Basin is of sufficient grade to serve many types of energy demands. A typical Lindal diagram (Figure 1.) illustrates that harnessing geothermal energy from this resource is suitable for a host of end-use applications including: (1) steam heating, (2) direct-use space hot water heating, (3) space cooling, and (4) power generation. We propose to investigate the feasibility of harnessing this deep-well geothermal resource to economically serve the combined cooling, heating, and power demands of the Buena Vista Correctional Facility (BVCF), and planned Buena Vista Middle/High School (BVHS), and possibly a new state-employee/staff housing project.



**Figure 1. Lindal diagram showing temperatures for different uses for geothermal resources.**

The target reduction in fossil energy consumption for the proposed work is 60-80%, which represents a *doubling* of savings compared to typical commercial geothermal heating applications along with >95% reductions in local emissions, such as SOx, NOx, and greenhouse gases.



**Fig. 4. Conceptual schematic of cascading-geothermal energy**

**utilization to serve large-scale commercial buildings**

New construction in state employee/staff housing and the high school offer additional innovative application areas for direct use-geothermal energy via tight building energy system integration. The integration concepts to be explored in these buildings are: (1) low temperature, highly efficient radiant heating and cooling systems, and (2) increased use of fresh outdoor (makeup) air in the building through direct-use air preheating, as done in many sustainable (LEED) buildings. Radiant systems use thermally activated walls/ceilings/roofs to change the mean radiant indoor temperature and thereby, achieve thermal comfort. They represent an excellent application of low-end thermally cascaded geothermal resources.

Since the state employee/staff housing would be of new construction, significant attention will be paid to designing geothermal energy systems that can provide heating, cooling, and power (trigeneration), including dual-mode groundwater-coupled heat pumps, direct cooling/heating using radiant panels, thermal storage, and indoor air quality improvement via high percentage outdoor air use throughout the year.

Home and business heating expenses are substantial in Chaffee County where, natural gas, propane and wood dominate heating expenditure. At a district level, heating could reduce the heating bill for whole blocks in Buena Vista, allowing owners to exploit lower heating costs and invest in other ventures. District-level heating may also provide greater opportunity for tenants in the cheaply heated buildings. It is the intention that the geothermal heated buildings would be used to provide more public events and increase visitation to Buena Vista that otherwise would not occur.

**Other Direct-Use Applications**

Direct use geothermal energy has a variety of other applications. Within the agricultural sector, potential geothermal market demand is in production of crops, especially for heating and cooling greenhouses, and also in soil warming to extend growing seasons. Agricultural production of livestock is another potential use, for warming feedlots and livestock water and feed, for warming barns, lambing and calving pens and pig farrowing pens, for nurseries and for poultry houses. Geothermal fluid is also ideally suited to clean-up of dairy barns and equipment and animal shelters.

Aquaculture is another possible agricultural use of geothermal energy, including warming water for fish hatcheries and raceways. Production of alcohol from farm produce is another possible use for geothermal heat, one that has gained considerable attention over the past several years.

Crops can be grown using geothermal energy in a variety of ways. Greenhouses can be easily heated with geothermal energy. Geothermal heating systems are not unlike conventional types of space heating systems, using either water or air as a heating medium.

**Industrial Applications.**

The industrial potential of geothermal energy in Colorado has been little

discussed, in the past, probably because Colorado's major industrial area along

the Front Range apparently has no geothermal sites with elevated temperatures.

The emphasis in prior discussions of potential demand for geothermal energy has been primarily upon space heating of commercial and residential buildings. Industrial use is, however, an attractive prospect for both consumers and producers/distributors of geothermal energy. The heat load of the industrial consumer is usually relatively high and is often stable year-round. Rising energy bills eat into profits, stimulating the search for ways to reduce those bills. The energy producer/distributor can more economically supply energy to one or a few major geothermal energy consumers than to numerous small users, because of the cost of distribution and heating systems. Furthermore, he stands to receive a greater return in a shorter time because industrial consumption is relatively steady, compared to more seasonal commercial and residential consumption.

Numerous manufacturing processes could use geothermal energy. There may also be a significant market for geothermal energy among manufacturing plants not now located near geothermal sites. Replacement plants and expansions may for a variety of reasons be located at new sites. As a matter of policy, the State of Colorado is encouraging additional value-added for products originating in the State before they leave the State. That is, agricultural or timber products, for example, could be processed more extensively in Colorado prior to export. Whether new manufacturing plants are established near geothermal sites depends

upon the site location criteria of the particular process and firm. Several

factors determine the suitability of a particular location for a particular

manufacturer.

Some industries require highly-populated urban area locations. For efficient,

effective operation, they may need a large or highly-trained labor force, large

local market, major research and educational institutions and/or a wide range

of transportation modes including jet air and rail. Some new manufacturing plants will be established in more sparsely-populated areas, however, including those with geothermal energy. As population grows in western Colorado, new market-oriented industries will be needed. Some industries will decentralize, opening small plants in new locations. Certain industrial categories are more likely to be attracted to such areas than others.

Of those that most commonly require process heat temperatures within the range of geothermal energy are food processing and lumber. Additionally, most

chemical manufacturing requires low temperatures as do several specific stone,

clay and concrete categories. These include structural clay, concrete products

and ready-mix and gypsum, stone and asbestos products. Of these categories that are potential markets, food processing, chemicals and stone, clay and concrete have the highest total energy requirements and those three plus lumber have the highest percentages of non-metro energy requirements.

In summary, a potential market demand is found in the manufacturing sector, both among those manufacturing types now co-located with geothermal energy and among those that will expand or relocate in the future. For demand among co-located manufacturing to materialize depends largely upon the extent to

which geothermal energy is made available and can reduce production costs. For

plants to locate where they can use geothermal energy depends both upon those

criteria and the satisfaction of other site location criteria. Where there is

a match, both the geothermal producer and the manufacturer stand to benefit.*e*

Following is a “Hypothetical Report” illustrating the development potential for geothermally-related businesses in Chaffee County.

**WARNING**

**This following is a hypothetical report of what could be done in Chaffee County to coordinate and develop the geothermal energy potential available to its residents. It is loosely based on the reported successes of other communities in creating a geothermal energy development district by creating the necessary zoning and development regulations required to attract such geothermal energy businesses.**

Chaffee County, located in south central mountains of Colorado, is abound in natural resources, agriculture activities, geothermal resources, and forest by-products that provide opportunities for the region to be a leader in geothermal energy. As part of its regional economic strategy, the Chaffee County Economic Development Corporation (CCEDC) has established a sustainable energy base to provide a solid foundation of related job opportunities and industry development, using our resources to promote geothermal energy allows for economic diversification, creation of jobs, and reduction of major health risks. The strategy also affects land use in a positive manner, thereby improving the environmental future of our county.

The region has a unique opportunity to diversify its economy by focusing on its geothermal energy resources. Specific strategies and priorities for maximizing the use of these resources are being developed. There are a number of different projects in Chaffee County centered around geothermal. The proposed geothermal industrial park is currently in the planning stage and is progressing into a prominent future economic development opportunity. There is also a proposed heating district for Salida, Buena Vista and Poncha Springs that is in the conceptual stages of development and if implemented would offer a number of residents and businesses energy at a reasonable cost.

**Chaffee County Economic Development Corporation**- Several geothermal energy projects have resulted from the work of CCEDC and its partners. Following is a summary of these projects:

* **Geothermal Ag Industrial Park Development**– CCEDC is working with \_\_\_\_\_\_\_\_\_\_\_ to expand the geothermal operation to include about 40 to 50 acres of marginal farm ground. The farms geothermal heated water already serves multiple purposes. A biodiesel plant uses geothermal heat for processing canola seeds. Spent water from a greenhouse operation also warms about 28 small ponds to 85 degrees F., where aquaculture experts raise freshwater tropical fish. Using Funds from the US Department of Energy and the Natural Resources Conservation Service, CCEDC has hired engineering consultants to design the next phase of the park which includes installation of a reinjection well.
* **Geothermal Energy Project Financing Assistance –** CCEDC has assisted several projects that utilize geothermal heat to offset their cost of doing business. These include:

1. **ABC Brewing Company**—Economic Development Administration Revolving Loan funds financed a geothermal supported brewing company that created 40 new jobs.
2. **Greenfuels of Colorado –** CCEDC staff assisted the biodiesel company in packaging a loan request which was funded by the Regional Investment Board Revolving Loan Fund and the CCEDC. The company uses canola seed and used restaurant oil as their feedstock. The geothermal water available on the site is used to help in the reaction process of making the Biodiesel.
3. **BioControls** - Expanding into Chaffee County and utilizing geothermal water to heat the greenhouses helped lower their utilities and eliminate the high expense of propane. A financing package was completed which, in addition to debt financing through the Chaffee County Economic Development Corporation and the State of Colorado, included another $135,895 in grant funding from Climate Trust for the Carbon offsets. The funding package enabled BiotControls to move its operations to Chaffee County, Colorado. The company currently employees eleven fulltime workers utilizing 70,000 square feet of existing greenhouses. Future plans to build an additional 130,000 square feet.
4. **Organic Growers, LLC**– Joint loan financing from the State of Colorado and grants from the Climate Trust and the US Department of Agriculture, have allowed Organic Growers to occupying greenhouses in the geothermal agriculture industrial park located near Buena Vista to take advantage of the county’s geothermal heat. The business produces biocontrols used as an alternative to toxic pesticides and will employ 32 local employees within the first two years, providing livable wages and health benefits.
5. **Demonstration Center** – with funding from the U.S. Department of Commerce, Economic Development Administration, CCEDC funded the staff expertise and capacity needed for Chaffee County to actively partner with potential private and public investors. In conjunction with the Colorado Energy Office, the CCEDC has set up a Geothermal Energy demonstration center at the Chaffee County Fairgrounds.

In April 2018 it was announced that CCEDC received funding from USDA Rural Community Development Initiative to assist with building collaborative partnerships in Chaffee County, to develop alternative energy resources. CCEDC will provide staffing and institutional support.

**SUCCESS STORIES**

1. Workers in Salida collect the spider mites' eggs and ship them to a lab in Denver that uses them as feed for the predator mites it is raising. The company, BioControl, Inc., then releases predator mites on strawberry patches, almond orchards, mint fields and other crops, where they happily munch spider mites, reducing or eliminating the need for pesticides.
2. Chaffee County Brewing Co., which uses geothermal heat to brew its beer, was selected one of Colorado's sustainable small businesses of the year for 2019. The pub operates out of a former creamery in downtown Salida and is part of a geothermal district that circulates heat to two dozen downtown buildings -- and melts snow off the sidewalks.
3. “**Gone Fishing” Farms** uses the waste water from local greenhouses to grow tropic fish for aquariums and tilapia for the food market. Geothermal water quickly mixes with the cold pond water to provide 80°F (27"C), which is ideal for the fish. The owner raises more than 100 varieties of fish and sells to markets in the Denver –metro Area — trucking about a 1,000 fish each week. CCEDC funded a loan *to* Gone Fishing for working capital and equipment to begin processing Tilapia at their property. This working capital allows Gone Fishing to process up to 300,000 pounds of Tilapia per year which equates to $450,000 in annual sales.
4. [Geothermal technology project gets $100 million loan guarantee. Company officials](http://www.eereblogs.energy.gov/geothermaltechnologies/post/neal_hot_springs_loan_guarantee.aspx)  recently announced that the Barclays Bank finalized a $100 million Recovery Act supported loan guarantee for Mt. Princeton Geothermal, LLC, to construct a 10 megawatt (net) geothermal power project in Chaffee County, in south central Colorado.

The Colorado Office of Economic Development and International Trade estimates that the project will create approximately 150 construction jobs, more than a dozen permanent jobs and even more supply chain jobs across several states, including Colorado, California and Texas. The company anticipates about 95 percent of the power plant's infrastructure and parts will be supplied by U.S.-based manufacturers. In addition, the project's total output will be sold to Sangre De Cristo REA under a long-term power purchase agreement. With the 25-year agreement in place, the project is well positioned to accommodate anticipated population growth and geothermal energy demand in the region.

1. The Mt. Princeton Hot Springs Resort has been welcoming guests for more than a hundred years. By the 1920s, a sizable five-acre garden provided much of the food served to hotel guests. Today, Mt. Princeton staff carry on these traditions. The geothermally heated greenhouse, built in 2019, produces fresh herbs, flowers, and vegetables year around. Outdoors, a large vegetable garden produces a wide variety of fresh treats for guests. Dining room chefs demand high-quality, fresh foods with superior flavor. For that reason, gardeners use only organic methods of fertilization and pest control. Mt. Princeton is starting a new tradition of sustainable agriculture as a means to provide guests with memories of good food in a gorgeous mountain setting.

The resort also uses geothermal water from the hot springs to heat offices and outlying buildings. Low-flow faucets and fixtures help reduce water use. Gardener \_\_\_\_\_\_\_\_\_\_\_hopes to install a new geothermal system in the fall. "I would like to run the greenhouse's hot-water out-flow through tubing, warming two or three of the garden beds outside the greenhouse," she said "This, combined with cold frames, will allow us to grow and harvest cold-weather crops throughout the winter."

1. **Economic Impacts of an Onion Drying Facility near Poncha Springs**

Geothermal heat can be used to dehydrate fruits and vegetables. An onion drying facility is proposed near Poncha Springs, Colorado (Chaffee County). The facility would create $12.2 million in annual sales, $7.4 million in value-added, $3.4 million in earnings, 151 jobs, and $814 thousand in indirect business taxes annually. The construction impacts would create $8.98 million in short-run sales impacts, $9.2 million in value added, $2.6 million in earnings, 112 jobs, and $0.214 million in indirect business taxes. These are short-run transitory economic impact on the local economy.

1. **Geothermal Water Keeps School Warm**

When sub-zero temperatures hit Colorado...the cost of heating always seems to sky rocket. But one school in the south central part of the state never gets a heating bill. The Buena Vista school district relies on Mother Nature to heat it's classrooms.  
  
With the cost to heat buildings climbing, Colorado school districts are having to pinch pennies to pay the bills. But a system put in place 2 years ago in Buena Vista keeps heating costs low. Back in 2018, the Town of Buena Vista decided to harness the earth's energy by drilling a well to tap into a hot underground water source. It's the water from the aquifer that keeps the buildings warm.  
  
The temperature coming into the building right now, the temperature of the water is reading 150 degrees. It gets pumped through the six inch line and it goes all the way out throughout the building to each individual classroom. Each classroom has a radiated heater hooked up to the geothermal water pipes; the hot water flows through the pipes to each of the 27 heaters. The heat from that water just heats up and then it's got the fans that turn on and off with the thermostat settings and it just blows in the warm air into the building.

1. The Buena Vista Correction Facility is operated by the Colorado Department of Corrections. The facility was converted to geothermal heating in 2016. The facility houses around 900 minimum custody inmates and some 400 custodial and support staff at the 112- acre site. Geothermal heat is used for 50 to 80% of the prison’s space and domestic water heating, as well as for a medium-sized greenhouse. It is supplemented by the existing natural gas system.
2. REACH, Inc. is located just outside the Salida city limits. REACH has found a niche in the specialty area of the selective and environmentally-friendly removal of juniper and also finding uses for the entire tree. After a tree has been cut, it must go through a drying process to prevent warping later on. The sap in a piece of lumber sets at 1350F to 1400F, a temperature easily achieved using geothermal steam

The company is currently planning on expanding operations in the building such as adding two drying kilns. The 50,000 sq ft building was constructed in 2019. About a third of their gross income is from mill work and a third from the juniper products.

1. Colorado Trail Mushrooms is located on the east edge of the Town of Poncha Springs, in Chaffee County. Elevation is about 7,000 ft. Winter temperatures reach -20oF and summer temperatures of 90oF. The mushroom plant construction was financed through the USDOE Loan Guarantee Program and began production in 2018. Initially, 2,500 tons of white button mushrooms were produced annually. Production now includes other varieties and has increased to 4,000 tons annually. There are 130 employees year round.
2. At Mt. Princeton, Colorado, a company called ColoCulture Inc. is one of the largest domestic suppliers of tilapia fingerlings in the US. Tilapia fingerlings are the

early stage of the fish’s life cycle. ColoCulture produces between four and seven

million fingerlings annually, and then ships them all over the country. These fingerlings are sold to growers and researchers who then grow them to full size before use. Their utilization of geothermal energy provides a plethora of advantages. Their facilities are heated at a much lower cost, compared to the use of propane or electricity. Also, the tilapias have an accelerated growth rate due to the above average temperature of their environment. This further increases the energy savings of the company.