Gambling for the Planet

Part 1: Funding a Clean-Energy Backup Plan

How city governments, state programs, and local utilities can fund new technologies that prevent global warming

Energy is the ultimate "just-in-time" service, with delivery essential at the moment (microsecond) of use. Electric generation sources must be "dispatchable" when they are needed, bedeviling advocates of a clean-energy future to prevent climate change.

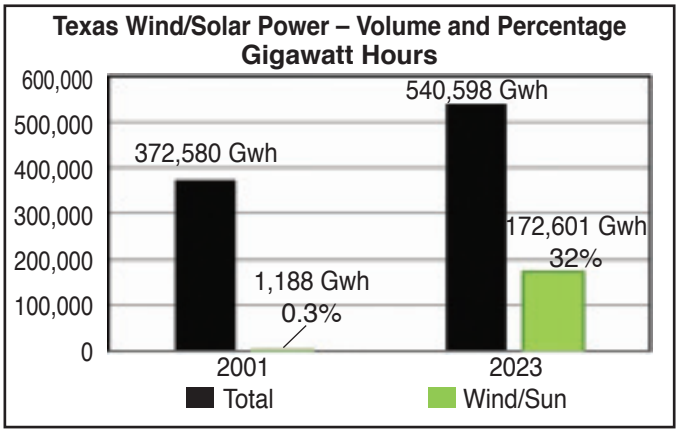
Globally, intermittent renewable wind and solar electricity growth has soared. Generation in 2022 was over 5 times the 2012 baseline, and represented almost 12% of the world's electricity generation. Dispatchable renewables such as hydroelectricity extended clean energy sources to 29%. **(1)** *Still, dangerous fossil or fissile fuels produce over two-thirds of the world's electricity. New technologies to fill this gap are urgently needed.*

If the City of Austin began funding clean-energy research to reduce global warming, critics would complain that it was gambling with the public's money. However, exercising fiscal discipline while watching the world melt down due to global warming is an emotionally-challenging proposition. This article explores one idea to fund clean energy development at the local level: repurposing of Austin's GreenChoice program.

Clean, Safe, Carbon-Free...and Finicky

Energy storage and alternative forms of dispatchable renewable energy have become the Holy Grail…or desperate gambit…of climate hawks. Below is a charted example of the dilemma.

In 2023, Texas generated more combined wind and solar than any other state in the U.S. It only received 0.3% of its power from renewable wind and solar in 2001. By 2023, it was 32%. Wind and Solar Increased 145 Times Since 2001. **(2)**



Data From U.S. Energy Information Agency

In the month of August 2023, Texas received 31% of its power from a combination of wind and solar cells.

This progress at the state and local levels may seem dramatic, but it is also self-limiting. There is no practical way to have a grid running on completely renewable energy in Austin or Texas without dispatchable power or energy stor-

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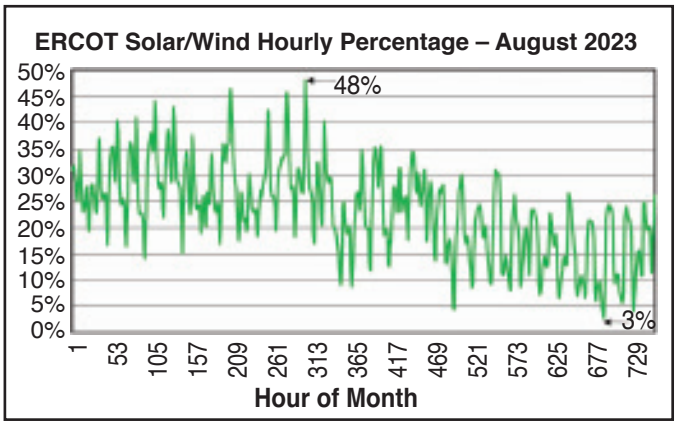
age when intermittent solar and wind are not producing.

The graph below shows the combined percentage of solar and wind for each hour on the Texas ERCOT electric grid in August 2023, soaring to a high of 48%, while plummeting to as low as 3%. (ERCOT, the Electricity Reliability Council of Texas, serves 90% of the state.) Meanwhile, dispatchable renewables, hydroelectricity and biomass, provided far less than 1% of ERCOT's power needs. Natural gas, coal, and nuclear supplied the polluting but dependable balance.



From U.S. Energy Information Administration

Combined wind and solar power percentage on the ERCOT grid in every hour of August 2023.

Energy Storage and Dispatchable Generation

The technologies to get to zero carbon emissions are essential to stop the worst ravages of global warming, and by extension, the long-term survival of most of the world's human (and many other animal and plant) populations. That does not mean they will succeed.

Many of the technologies that will allow a post-carbon future at a price people can tolerate are only commercially available for niche markets, or are being tested in small pilot projects, or only exist in a laboratory.

One need only look at lithium storage batteries used in utilities. They are the common denominator that many climate hawks, ardent opponents of climate change, turn to when pointing the direction for a different energy future. Despite the installed cost having fallen as much as 70% between 2015 and 2025, unsubsidized battery prices are way too high to compete with electricity other than in niche markets.

And the lithium default option has several other liabilities. Some lithium chemistries are vulnerable to fire, raising installed costs for fire prevention. Most of the metals are imported from countries outside the U.S. Due to the competing use of lithium batteries in electric vehicles, demand is relatively high, which drives up costs. They are extremely vulnerable to degradation; they lose capacity if they are deep-cycled (from 100% to 0% charge) too often. And they need to be heated or air conditioned, depending on the season, for dependable performance, driving down their overall "round-trip efficiency."

The avenues for the average person to affect a change in energy technology seem limited. Most readers of this article do not work for energy utilities, are not venture capitalists, and do not direct national research laboratories. If a person is extremely motivated, and they have the economic latitude to have the time to lobby their national representatives, they might have some positive, but abstract effect, on technological development.

A number of promising alternatives are being researched, developed, or actually built on the promise they will be cheaper:

- batteries made of salt, zinc, compressed air, and electrically charged liquids;
- thermal batteries that can charge with intermittent renewable electricity or industrial waste heat to provide industrial process heat and electricity;
- new types of geothermal energy that offer more electricity generation potential.

These technologies are highlighted on pages 61 to 69.

There are also a number of innovative energy-efficiency technologies being developed that reduce the need for energy consumption altogether. Just a few of these include:

- Vacuum Insulated Panel (VIP) insulation and glass;
- Heat pumps that heat in sub-zero weather;
- Metallic film that reradiates heat already retained in roofs and buildings back into the atmosphere;
- Flexible LED lighting panels.

At Austin's electric utility, Austin Energy, there is a similar listlessness: to wait patiently while inventors, investors, and national government laboratories do the work. This is in contrast to state governments such as California, Connecticut, and New York, which have collectively invested several billion dollars in clean-energy product development. This state money has in turn leveraged many times its orignal value from private investors. These state-funded clean-energy technologies programs, and some of the innovations they are developing, are highlighted on pages 70 to 74.

A Local Solution: Repurposing the GreenChoice Program

One way Austin can start investment in a clean-energy future is to repurpose its existing GreenChoice program. Many utilities, including Austin Energy (the City's municipal utility), have voluntary programs that allow consumers the option to pay into a fund that specifically purchases clean energy. This extra funding is intended to purchase intermittent wind and solar energy.

Like Texas, Austin's share of renewable energy grew from almost nothing in 2000, to 51% in 2023 as the cost of intermittent renewable energy fell.**(3)** It is projected to

hit at least 75% by 2035 due to environmental goals set in response to popular citizen demands. However, nothing close to 75% can be achieved in the real world with only wind and solar.

The program, begun in 2001, allowed the utility the latitude to buy more wind power, and it won national awards for its success. However, as renewable energy grew in Texas, and the cost came down, the Austin City Council set goals for increasing percentages of it. GreenChoice is no longer instrumental to increase renewable energy. Today, it is more of a symbolic effort than a catalyst for change. The current way that it operates is obsolete.

Proposal: In 2022, about 28,000 (6% of total) customers subscribed to GreenChoice, resulting in 984 million kwh, about 7% of total Austin Energy consumption. It increased the total average Residential bill of subscribers by about 6%.

In a normal year, GreenChoice would have resulted in about $7.4 million in increased revenues. This money, leveraged with private investors (including the technology provider); grants from federal, state, city, and non-profit entities, and other utility companies; would be a springboard to invest in new dispatchable technologies.

Investment would be directed to companies selling energy storage different from conventional lithium technology, or dispatchable renewable technologies that are suitable in Texas (such as enhanced geothermal energy). These products may currently be more expensive than the lithium benchmark, but would have the potential in the long-term to be less expensive.

Business Model: There are a number of different ways that this reinvigorated program can be structured. It can be kept as an increased customer contribution to the greater good as it is today (with new investments being much more relevant to the current situation with renewable energy).

However, some GreenChoice investments might actually make money. Consider a newer battery technology that stores overnight power in the summer at 1.5¢/kwh but sells during the highest peak for 50¢. If enough events like this occurred, it could either lower the customer premium or even make a profit, all-the-while creating greater economies of scale for the product and lowering its future costs.

Andrey_Popov/Shutterstock.com

Arbitrage

1.5¢ Overnight Power ⟷ 50¢ Peak Demand 5 PM

Marketing: GreenChoice has a brand loyalty. To ensure a successful transition, polling of subscribers and the general public should take place to gauge acceptance for the new direction, as well as new reasons that would motivate more participation.

Public events and public hearings would also become a forum to explain the new technologies that hold the most potential for the repurposed program, as well as get public and expert input on which technologies to pursue.

Governance: The program would continue to be administered by Austin Energy. The strategy on which technologies to invest in would need careful technical and economic evaluations. An academic partner or partners would be an asset to this effort.

Social Equity: While this idea is largely directed at increasing renewable energy supplies for all customers, there might be a way to locate some of the research in underprivileged areas of the city. If, for example, an energy storage unit for buildings is selected as a project, it might be located in libraries, recreation centers, or health facilities that primarily serve low-income citizens. (One of Austin's first city buildings to mount solar cells on its roof was the Carver Library in East Austin.)

The Bigger Wager

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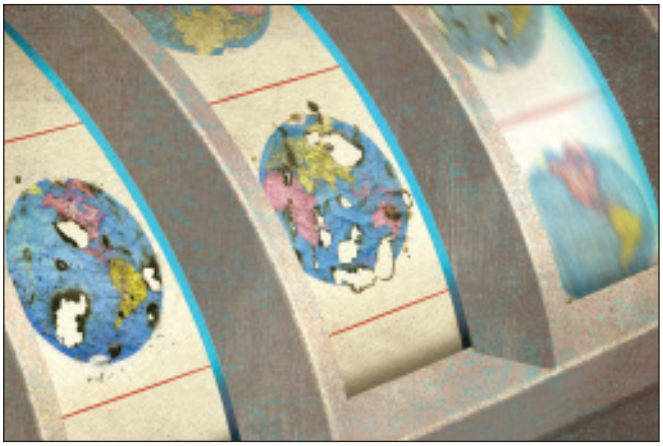
The climate dice are loaded.

-- Climate scientist Dr. Jim Hansen

City governments often avoid financial risks to ratepayers. However, exercising fiscal discipline while watching the world melt down due to global warming is an emotionally-challenging proposition. Reducing the idea of repurposing Austin's GreenChoice program to a parable about gambling risks cliché. But the analogy here fits. (See "I Don't Like the Odds," p. 58.)

NARRATIVE CONTINUED ON PAGE 60

GLOBAL WARMING: I DON'T LIKE THE ODDS



Jon Krause

I long ago came to the conclusion that all life is 6 to 5 against.
--Damon Runyon

Critics complain that carbon hawks are gambling with public money spent on clean-energy research to reduce global warming. It would therefore be useful to briefly review the risks of doing nothing.

Temperatures: The top 10 annual average temperatures for the Earth's surface since 1880 (when detailed global weather records began) all occurred between 2015 and 2024 (with 2024 being the hottest).**(1, this sidebar)** It has already risen by 2˚F, with predictions of a further 2 to 9˚F rise by 2100, depending on the level of greenhouse gas emissions.**(2)**

A 2024 analysis of mortality caused by higher temperatures in the U.S. from the University of Pennsylvania estimated that between a recent benchmark climate period (2008-2019) and mid-century (2036-2065), an additional 11,100 and 18,325 deaths would occur annually.**(3)**

Another analysis conducted by the Atlantic Council think tank estimated 51,500 increased annual deaths from heat-associated incidents in the U.S. by 2050 over the baseline period (1986-2005) at the highest level of carbon emissions.**(4)** There would also be a nearly 4-fold increase in heat-related occupational injuries, 450,000 compared to 120,000, in the same time period. And it would also result in $400 billion in lost labor productivity.

A study to quantify global temperature effects conducted by scientists at the University of Pennsylvania and Purdue calculates that under a high carbon-emissions scenario, many cities will become so hot as to be uninhabitable outdoors during the day, with people compensating by staying indoors or with air conditioning indoors.**(5)** The local environment would become rife for heat stroke and other related illnesses. Some of these cities, particularly in the Middle East, Africa, and South and East Asia, could experience these conditions for weeks or months at a time. A few Middle Eastern cities could experience such conditions throughout most days of the year. Even North American cities would be affected a few days of the year.

Central Texas currently experiences about 29 days a year with peak temperatures over 100˚F; by 2100, it is predicted to suffer between 37 and 110 days, depending on how severe carbon emissions become. **(6)**

Escalating temperature will obviously create a greater demand for cooling. In Austin's climate, for example, without increased energy-efficiency measures, it could lead to Residential air conditioning consumption at least 23 to 100% higher, as well as shorter life of the appliance due to mechanical stress.**(7)** (If it is any consolation, heating costs will be lower, though global warming will likely lead to more extreme cold periods when they occur.)

Weather-Related Disasters and Insurance: Worldwide, there was a 432% net increase in annual disasters not related to earthquakes between 1970 (71) and 2023 (378), including extreme weather, extreme temperatures, flooding, and wildfires.**(8)**

These weather events are a direct contributor to high insurance costs. In the U.S., for example, there were 3 average billion-dollar weather disasters between 1980 and 1989 causing average damages of $20.5 billion/year. By 2022, this rose to 18 disasters a year causing damages of $165 billion.**(9)** These weather events, combined with increased rebuilding costs, and rebuilding in regions more predisposed to weather-related disasters, has raised the cost of damages to the point that many insurance companies are refusing to serve people living in areas of high risk for floods, wind storms, and fire. And for those that can still purchase insurance, it will become increasingly unaffordable.

Using fire damage as an example, in 2010, there were only about 3,000 homes destroyed in the U.S. by fire. Due to increased droughts and temperature increases influenced by global warming, and more homes built near rural areas, this rose to over 17,000 in 2023. The associated damages were about $14 billion. The situation is so precarious that between 2015 and 2021, insurance cancellations in fire-prone areas of California rose 800%.**(10)**

By 2053 (30 years after 2023), extrapolations are for a doubling to about 34,000 homes destroyed annually by fire, with damages of about $24 billion. **(11)**

U.S. federally-offered flood insurance has also risen dramatically, so much so that premiums more than doubled in 12 states, likely influencing the contraction in the number of homes opting to pay for it by 21% (5.7 million homes in 2009 reduced to 4.7 million in 2023).**(12)** Despite the increases, the program was under water (pun intended) by $20.5 billion in 2022 because it has paid out more claims than it could actuarily support. Taxpayers were paying $280 million in interest a year on the debt.**(13)**

Texas homeowners insurance rose by a net 124% between 2012 and 2023, compared to inflation at 35%.**(14)**

Food: According to a 2016 University of Oxford study, by 2050, 529,000 deaths a year could occur stemming from a 3.2% decrease in agricultural production.**(15)** In a high emission scenario, 10% of the world's agricultural land

will be unsuitable by 2050, and 30% by 2100. Even with low (but increasing) emissions, close to 8% of the world's land will be unsuitable by 2100.**(16)** Food shortages and increasing population will lead to higher prices, malnutrition, and shorter life expectancies in economically challenged populations.

In 2024, a study partially funded by the European Central Bank calculated global warming would raise the cost of food and inflation by 0.9-3.2% per year by 2035.**(17)** It concluded that for every 1°C temperature increase per month, food prices would increase about 0.2% the following year.

Sea Level Rise: In 2022, 11% of the world's population, about 900 million people, lived near the world's coasts directly exposed to flooding hazards.**(18)**

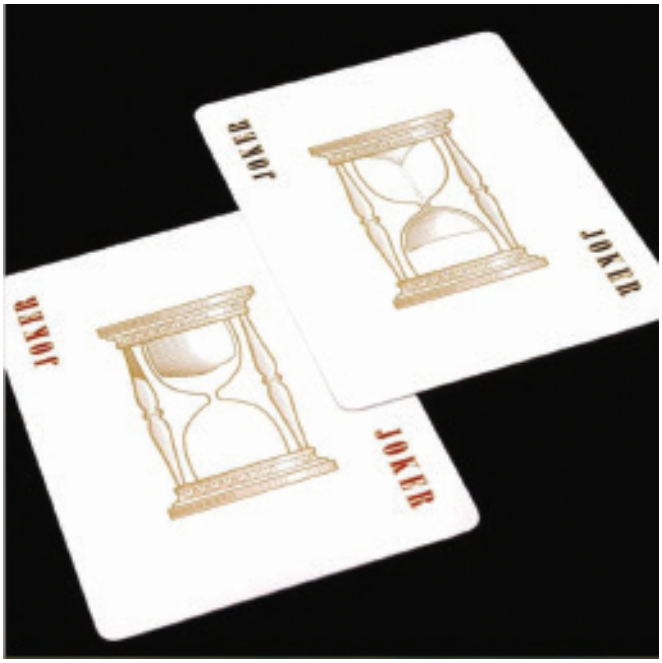
The oceans have risen 7 inches since 1924, and are set to rise another 10 to 12 inches by 2050.**(19)** When combined with sinking coastal land (due to building weight and subsidence caused by water and oil drilling) and storm surge, as many as 536 square miles in 32 major U.S. coastal cities are threatened, affecting as many as 273,000 people and 171,000 properties.

Worldwide, by 2050, more than a billion people will be located in at-risk coastal areas. Between $7 and $14 trillion (2022 dollars) in coastal infrastructure will be in danger.**(20)**

Parasitic Inflation: Global warming will act like a constant drain on the world's economy. Money that could go for necessities, education, and a better quality of life will be diverted to: rebuilding after natural disasters; increased heat-related illness; increased energy cost to mitigate increased heat-related illness; increased labor costs due to heat-related illness; increased food costs; sea level rise and loss of developed real estate; and migration forced by climate events and situations.

A 2024 study by the Potsdam Institute for Climate Impact Research predicted the economic drain would be equivalent to a worldwide average loss in income of 19% by 2050, and could rise to as much as 60% with extremely heavy emissions by 2100.**(21)**

An even more pessimistic analysis by economists at the National Bureau of Economic Research linked a 1°C rise in global temperature to as much as a 12% lower world GDP, which does not fully revert even if the temperature subsides after 10 years. Since global temperatures have already risen by over 1°C since 1960, world GDP per capita would be 18% higher today had no warming occurred between 1960 and 2019. A further temperature rise of 2°C implies the permanent loss of economic activity comparable to the Great Depression of 1929. **(22)**



Courtesy JP Games Ltd

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Maybe we will beat the odds waiting for technology that might be developed, waiting for private investment to come to our rescue. Or maybe we should create our own luck by joining the technology development process.

In this particular proposal, the risk is not placed on all customers, only on those who choose to play. Moreover, it can be leveraged with other types of public, private, and non-profit development.

This investment may or may not break even. However, at a minimum, an investment program for product development will result in delivered assets that save, or store, or produce, energy. And even if it does not break even, the investment will likely contribute to economies of scale to lower costs in the future.

In a better outcome, some of the storage or energy production actually makes the utility money. If it is set up as a kind of stock, the GreenChoice investment might actually make the participating customers money. Again, the investment will probably help with more volume production.

Local employment and business development might be enhanced by this new program if the new technologies are installed and operated in the Central Texas region. Such commitment to renewable development might contribute to a business climate conducive to clean-energy firms locating in Austin.

GreenChoice is no longer instrumental to increase renewable energy. Today, it is more of a symbolic effort than a catalyst for change. The current way that it operates is obsolete.

Another benefit of Austin's GreenChoice repurposing will be to "leverage enthusiasm" – to inspire other utilities, cities, and local governments to start their own similar programs. Since Austin is larger than several individual U.S. state populations, it is hardly the only jurisdiction large enough to adopt this strategy.

Austin has been a role model to the country in the past with several of its environmental and resource management programs, including leadership in energy and water efficiency, green building, and wildland management. Austin cannot rest on its past record at this critical moment.

Relying on the same clean-energy GreenChoice program model developed a quarter-century ago will not do much to advance the ultimate goal of a completely renewable energy future. Most innovative companies change with the times.

Why should Austin be any different?

Baruch Eremeev / Shutterstock.com

Focus on Technologies and State Programs

The balance of this article focuses on two subjects.

Pages 61 thru 69 summarize some of the new technologies that can potentially replace dangerous fossil and fissile fuel dispatchable electric generation. This includes storage batteries with alternative chemistries that have the potential to lower costs compared to more commonly-used standard lithium batteries. It details thermal batteries that store heat generated from renewable energy or waste heat from industry. And it discusses advanced geothermal energy technologies that employ advanced oil drilling technologies to access fossil-free heat from the Earth's core.

Pages 70 thru 74 explain how three U.S. states, New York, Connecticut, and California, fund clean-energy research, development, and capital financing. The article provides specific examples of innovative technologies and companies that these states are backing.

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Part 2: New Technology
Alternatives to Lithium Batteries

The majority of batteries used for energy storage in electric utilities and transportation today are based on some type of lithium chemistry. Built with the lightest solid element in the periodic table, lithium batteries were developed as an alternative to heavy lead-acid batteries commonly used in early electric vehicles (EVs).

Lead batteries store 40 watts per kilogram (w/kg), compared to gasoline at 12,200 w/kg.**(1)** Lithium commonly used in EVs today is often rated at 150 w/kg, though some go up to 275 w/kg.**(2)** The most advanced commercial products being made, solid-state lithium batteries, are estimated at 400-500 w/kg.**(3)** For all the bad things you can say about gasoline, it is an extremely compact fuel.

The average expense of lithium batteries can be more tolerable when competing with gasoline (or diesel) in transportation, since these liquid fuels are higher cost than fuels used in electric utilities.

While lightness is necessary for overland travel, in most cases compactness is not necessary for battery storage for electric utilities and buildings. Despite the installed cost plummeting 70% between 2015 and 2025, lithium storage prices are still too high to compete with electricity other than in niche markets such as displacing very high-cost peak demand (limited to a small number of days per year) and back-up power for use during unexpected outages.**(4)**

In 2024, the average unsubsidized cost of lithium batteries was about 11¢/kwh on top of the electricity used to charge them. **(5)** Costs need to fall at least 74% for them to become more widely accepted for everyday power prices for Long Duration Energy Storage of over 4 hours at a time.**(6)**

In addition, lithium has other liabilities.

• Safety: Under the wrong circumstances, lithium batteries can catch fire. This translates into increased monetary costs for fire prevention and added insurance. In 2023, there were 7 fires at utility-scale lithium battery sites in the U.S. out of about 377 storage plants.**(7)** Experience has taught operators how to reduce these incidents, but they still continue to be a (smaller) occupational hazard.

• **Lifetime:** The assumed 20-year lifetime of batteries is shortened when lithium and lead batteries experience repeated deep discharge cycles (from 100% of rated capacity to 0%). When enduring this abuse, capacity will fade to the point that battery sites will need to be supplemented with new units to maintain the originally-installed peak energy storage.

• **Material Supply Problems:** Lithium, as well as other essential battery metals for lithium chemistry such as cobalt and nickel, are usually sourced from countries outside of the U.S., though domestic lithium mining is slowly growing. Moreover, the largest producer of the world's cobalt is the Democratic Republic of the Congo, renowned for its abusive and unsafe treatment of workers, including child labor, as well as environmental degradation at mining sites.

• **Efficiency:** There is an old saying that you will not drive a fossil-fueled car from Austin to Dallas to fill it up with gas. Utility systems work the same way.

All power generation and storage units suffer from "parasitic losses." These include control facilities, software-related energy, and security lighting. However, lithium batteries also require air conditioning and heating to operate at expected levels. There is also energy lost in the charging/discharging process. These losses can greatly harm the net or "round-trip" efficiency, which in turn hurts cost effectiveness.

In 2023, the average losses for lithium batteries used for utility storage in the U.S. were about 15%, and they only dispatched electricity about 5% of the time.**(8)**

SODIUM BATTERIES

Batteries made with salt (similar to common table salt) are one of the most widely pursued alternatives to lithium. The manufacturing process is similar to lithium; some sodium batteries are actually made in repurposed lithium-battery factories.

Some sodium products are currently similar in weight efficiency (watt hours per kilogram) to lithium iron phosphate (LFP) batteries used in most EVs, though some sodium batteries can take up more space (watt hours per liter). Several current products currently operate at about 140 to 160 Wh/kg; new generations will come close to or meet performance of 200 Wh/kg. Cycle life in several of these products is below the 5,000-10,000 cycles expected for LFP batteries, though this too is expected to improve.**(9)**

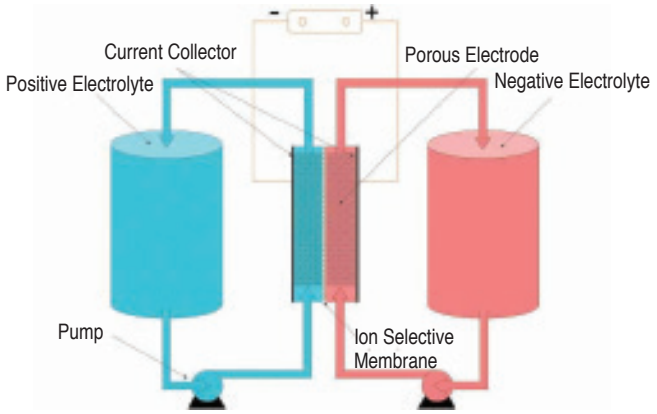
Sodium's ability to operate at low temperatures at least partially compensates for its lower weight efficiency. (The range of electric vehicles can fall by 41% in cold weather.) **(10)** At least 3 sodium-battery products can operate at -40˚F, well below LFP. The power density that can be supplied at peak demand is superior to LFP. Costs are on par with LFP, though about 30% less than more efficient Nickel Magnesium Cobalt lithium batteries.**(11)** It is hoped with mass production and less expensive materials, sodium batteries will decrease about 50% in the 2030 decade.**(12)**

In the near term, sodium batteries have potential to gain a noticeable share of the utility and building stationary energy storage market. They may also make increments in the EV market due to better cold-weather capability.

In 2024, there were about 25 companies working on sodium batteries, with at least 8 actually manufacturing them. In 2024, Hina Battery (China) was building the largest sodium battery project in the world: 50MW/100MWh for a data center installation.**(13)** This was expected to double in size. Chinese EV manufacturers began using sodium batteries in niche applications in 2023, with sodium battery use expected to expand greatly in 2025.**(14)**

Also among the leading sodium-battery companies is the U.S.-based Natron Energy. It commissioned a 600 MW/year manufacturing plant in Holland, MI, in 2024 to make storage for data centers, critical power, forklifts, and EV fast-charging markets. (Storage can allow charging stations to purchase inexpensive off-peak power.) While Natron products only store energy at about 70 Wh/kg, they have an incredible life of 50,000 cycles.**(15)**

FLOW BATTERIES



Flow batteries use a liquid electrolyte charged with ions using various metal particles. The charged ions move through a porous membrane to create a current. At least 21 companies are currently using various chemistries, the most common being vanadium saturated in sulfuric acid.

Unlike conventional batteries enclosed in compact cells or boxes, flow batteries require large volumes of charged liquid stored in tanks to be pumped to the membrane. While too bulky for transportation, the strategy of flow batteries is to add inexpensive electrolyte in tanks without scaling up the peak power of the unit. (If you want to drive a car twice as far, you need a bigger gas tank, not 2 engines.)

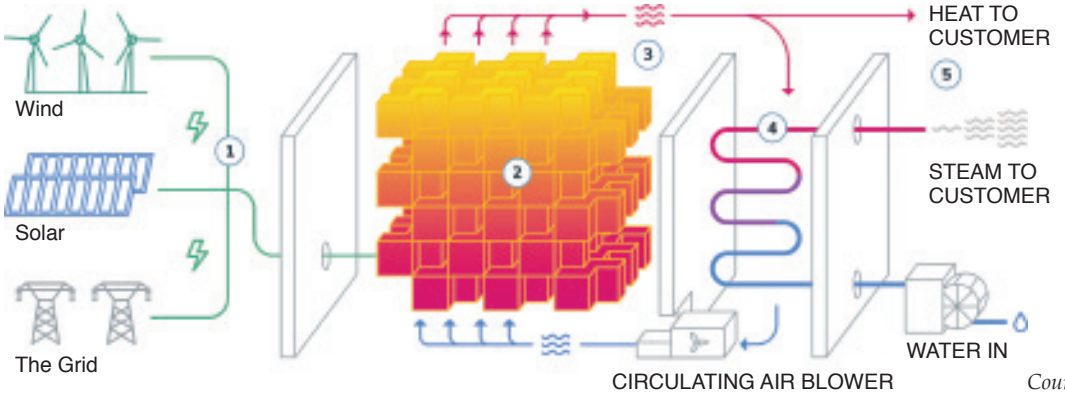
Though each company's technology is different, they generally have an efficiency of 60-85%. The hardiest can work in temperatures as low as -40˚F and as high as 120˚F. They are expected to have much longer lives than lithium, as much as 25,000 cycles, and can repeatedly be discharged to 0% of their capacity without degradation. Most vanadium batteries have 75-85% round trip efficiency.**(16)**

In 2024, there were at least 27 companies in some phase of commercialization or research of this technology.**(17)** Globally, at least 4,800 Mwh of flow-batteries have been installed or are under contract by at least 10 of these.**(18)**

The world's largest vanadium flow battery, with 400 Mwh of storage, was built by Rongke Power in China in 2022.**(19)** Canadian manufacturer Invinity had more than 190 MWh of systems deployed, contracted for delivery or awarded across more than 90 sites in 17 countries by 2024.**(20)** VRB, another Canadian firm, had 750 Mwh installed and 500 MWh under development in 2025.**(21)**

Vanadium, however, has price and supply constraints that encourage alternative approaches. ESS Inc., an iron-salt flow battery manufacturer based in Oregon, has at least 2,500 Mwh of products on order by 2030.**(22)** EOS, located in an abandoned manufacturing plant near Pittsburgh, PA, had $682 million of backorders in 2024 for its zinc bromide chemistry.**(23)**

Thermal Batteries



Courtesy Rondo Energy

Electric resistance (bare-wire) heating is used in almost every U.S. home in some fashion: from toasters to cook bread; to space heaters to heat air in buildings; to water heaters for hot showers. It isn't far-fetched to heat ceramic bricks, rocks, minerals, and sand to store heat created from renewable or low-cost off-peak electricity for later electric production and industrial manufacturing. This technology can also duct and store industrial waste heat. And stored heat can be used in conventional electric generation.

Heat from the bare wires is conveyed into storage through air channels and ducts, or directly through radiation, then harvested when needed for use through these same ducts. These storage mechanisms are enclosed in a heavily insulated container for extremely minimal daily heat losses. They generally have 90-98% round-trip efficiency.

Depending on the storage medium, this technique can harvest heat ranging from less than 200˚F for industrial uses such as food processing to as high as 4,500˚F, which is sufficient to melt most metals and manufacture cement. (This latter temperature is almost half the temperature on the surface of the sun.)

About 18% of the world's energy use in 2022 was for industrial process heat, including food processing, metal smelting and fabrication, chemicals, oil refining, paper, agriculture/forestry, and manufacturing. And a quarter of this industrial heat is at or below the temperature of boiling water (212˚F).**(1)**

The two biggest advantages of thermal batteries over conventional lithium storage batteries are lower cost and ability to be used for industrial heat.

Utility-scale lithium batteries, which store electric energy, cost about $400 per stored kilowatt hour in 2022, which is roughly 8 to 80 times more than thermal batteries that store energy in the form of heat.

The biggest disadvantage is also, paradoxically, cost. While thermal storage itself is inexpensive, the electric fuel that is stored can be expensive compared to natural gas. However, industrial facilities throughout the country operate with different heat requirements, efficiencies, and fuel costs. Under various conditions, commercialized thermal batteries can compete with natural gas without environmental taxes or subsidies.

Strategies to Enhance Cost Effectiveness

There are several ways to allow thermal batteries to better compete in the market place. Not all of them involve subsidies.

• **Electric Price Arbitrage:** In many power markets, including ERCOT, buying wind power at 5 PM on a hot summer day can cost more than 100 times the power generated at 2 AM on a spring morning. (In some cases, there is actually negative pricing, where consumers are being paid to take it.) Summer peak demand can literally be twice as high as a spring morning. Thermal battery storage has the advantage of buying strategically to use any time of day.

• **Electric Cost Averaging:** No retail electric customer pays 7 different bills for each fuel (solar, wind, hydro, biomass, gas, coal, nuclear). They pay an average cost. In some cases, electricity from thermal batteries can be 2 or 3 times as much as renewables. But by blending the high costs with the low ones, a more economic bottom line is reached.

• **Onsite Power Generation:** Onsite "behind the meter" electric production from solar and wind power can escape transmission costs that are sometimes charged, as well as transmission line losses that can be 5% and more.

• **Using Stored Heat More Efficiently:** Obviously, the more efficiently a product is used, the lower its effective cost. In the energy industry, this can be accomplished several ways.

One example is power plants. Old-school "simple-cycle" turbines lose about 2/3 of their primary energy to the surrounding air or cooling water. Some renewable energy pioneers dream of repurposing old coal plants with thermal batteries. But the tremendous heat loss can treble the price. "Combined cycle" power plants can double plant efficiency by using combustion turbines (driven by hot air) and reusing the lower-grade exhaust heat to drive a simple-cycle plant at the same time.

Combustion turbines would require much higher heat than a coal plant, and engineering challenges that have not been surmounted yet. But once these adjustments are made, the economic advantages are much better.

Combined cycle plants are similar to cogeneration, used since the 19th century, where primary heat from power plants recycles waste heat for industrial use.

• **Industrial Heat Pumps** – Another efficiency option is heat pumps that can produce steam for industrial purposes. These machines can produce as much as 3 times the energy they are supplied with; thermal batteries can enhance their efficiency. The maximum heat this technology can produce is currently about 400˚F. Work is ongoing to increase temperature limits.

• **Direct Use Guided By Location** – Many states in the U.S. and many countries in the world, have relatively expensive natural gas, but relatively inexpensive renewable energy. While Texas has cheaper fossil fuel because of its extensive gas production, California and Japan do not have large resources and must import it. In these examples, and many others, thermal batteries are a better option.

• **Taxes and Subsidies** – As of early 2024, 52 countries in the world and 14 states in the U.S. levied taxes on fossil-fuel carbon emissions or implemented some type of carbon-pricing program. These ranged from pure symbolism to a substantial cost. Sweden, as example, levied $114 per ton in 2023, which would add $6.03 for each (MCF) unit of natural gas for fuel uses covered by this tax.**(2)** (The average gas cost for industrial use in Texas in 2023 was $4.59.)

In most U.S. states, however, federal and state subsidies are more the norm: tax credits, grants, loans, and loan guarantees. One example is a recently enacted federal tax credit bestowing $45 per kilowatt hour of thermal battery capacity, which can sometimes be more than the equipment cost.

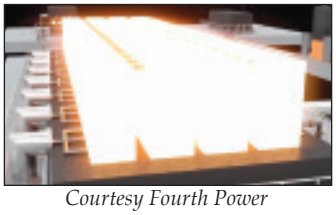
In early 2024, there were over 30 companies manufacturing or developing thermal batteries. At least 11 were in the U.S. A few are discussed here.

Rondo Energy

Courtesy Rondo Energy

The California company uses refractory bricks (with uses such as lining kilns and fireplaces) made of alumina, silica, and oxygen, which can retain heat from 170 up to 2,700˚F. Its first commercialized installation was the Calgen ethanol fuel manufacturing plant in 2023 (seen above). In early 2024, the company announced a partnership with EDP, a global energy company specializing in renewable energy. They plan to offer heat as a service option for industrial processes and cogeneration.

Antora Energy and Fourth Power

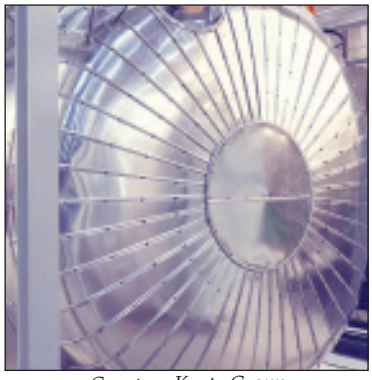


Courtesy Fourth Power

Antora, a California-based company, employs graphite as the storage material, which can store temperatures as high as 4,500˚F. At certain temperatures, it can be used for extremely high-heat applications such as melting certain metals. But at high temperatures, it also glows, allowing thermophotovoltaic solar cells to produce electricity. Antora is already manufacturing products for installation in 2025.

Fourth Power, in Cambridge, MA, uses 4400˚F liquid tin to convey heat to graphite through tubes embedded in them. It also uses thermophotovoltaics to convert heat to electricity. A demonstration plant is expected by 2026.

Kyoto Group



Courtesy Kyoto Group

Located in Norway, the company's batteries store temperatures of around 900˚F in vessels filled with molten salt. This material has decades of use in nighttime heat storage for concentrating solar power generators. The company commissioned its first commercial installation in 2023: a 4 MW, 18 Mwh unit at a coal-fueled district heating plant in Denmark. There are 8 pending industrial orders, including a pet and aquafeed manufacturer.

Brenmiller Energy

Courtesy of Enel Green Power

This company has developed storage units based on crushed volcanic rock heated to 1,400˚F. By 2024, it had installed 4 commercial projects: a 24 MWh standby unit for a power plant in Italy (seen in photo); a 1 MWh unit for a district heating plant at a university in New York; a 1 MWh unit at a plastic production plant in Brazil; and a 1 MWh unit at a military site. In early 2024, it planned to provide an Israeli hospital a "heat as service" option, with all upfront costs paid by the company.

Using Hell as a Power Plant

Geothermal Energy from the Earth's Core and Earth Pressure

The intense heat at the core of the Earth registers 9,752°F, almost rivaling the surface of the sun. The pressure is 3.6 million atmospheres. This heat originated from the Earth's creation 4.5 billion years ago, as well as from radioactive decay of elements.

It is not possible to drill wells anywhere remotely close to this depth to access this heat, and if it were, the access would be prohibitively expensive. The world's deepest oil well to date made it 7.7 miles down. **(1)** The Earth's inner core is 3,220 to 4,000 miles deep. However, some of this heat migrates towards the Earth's surface at lower temperatures, especially in regions prone to volcanic activity. Some of this heat creates hot water or steam that flows with natural pressure or from drilling under the Earth's surface.

Using heat from humanly-modified geology beneath the ground to displace fossil fuels has attracted renewed interest as another strategy to generate and/or store energy as a foundation for a completely renewable electric grid. And geothermal energy can also provide direct heat for buildings and industries.

The theoretical power of the Earth's self-generated heat is only rivaled by the sun. By one estimate, there is enough geothermal power in the U.S. to provide all of its energy for 136,000 years if economic technologies could be developed to harvest it.**(2)**

Not a New Idea

People have been making use of geothermal energy at some level for millennia. According to the World Geothermal Congress, in 2019, direct use of geothermal energy was employed in 88 countries on 6 continents. Uses included heating in district energy utilities and individual buildings, electricity generation, bathing and swimming, greenhouses, crop drying, aquaculture, industrial process heat, and minor uses such as snow melting and (absorption) air conditioning. It has even been used to raise greenhouse bananas in Iceland, greenhouse mangos in Northern Japan, and alligators in Colorado. In 2024, it powered about 13,911 MW of electric power.**(3)**

To date, however, it is only a niche in the world's energy supply, providing only about 0.17% of the world's total in 2020 for heat and electricity.**(4)** Still, in countries where close-to-the-surface resources are available, it provides huge benefits. At least 7 countries obtain more than 10% of their electric generation through geothermal plants.**(5)**

A brief review of some of the countries that employ geothermal heat hints at its future potential.**(6)**

Italy: During the Roman Empire, baths fed with hot-springs were established in Rome and other parts of Italy, as well as the conquered territories that are now France, Germany, Austria, and England. While this practice waned after Rome's decline, the use of Italian hot springs and muds for medicinal purposes became popular again in the 12th century.

But as interesting and colorful is the country's use of geothermally-heated water for mineral production, in particular boron, which was, and is still, used for pharmaceuticals. In the 11th century, this mineral was imported to Europe from the Middle East. Due to naval conflicts that occurred over a period of centuries, imports were disrupted and local production became necessary. Hydrothermal water mining in the Tuscany region began during this period.

Not only did the springs yield boron, but also sulfur

(medicines, wool bleach, and after the 13th century, gun powder), alum (wool processing), "Cyprian (green) vitriol" or ferrous sulfate heptahydrate (medicines and dyes); and "Roman (blue) vitriol" or copper sulfate pentahydrate (medicines and colorants).

This mining was so important and lucrative that a state of war for ownership of the hydrothermal region occurred, beginning in the 12th century and lasting until 1472. When hostilities were settled, the region's wool guild purchased the chemicals without duties, which allowed such a competitive advantage that it held a near monopoly on the Italian textile industry that lasted more than a century.

Eventually this mineral production declined, while Europe still required expensive imports of boric acid from the Middle East. Reconstituting Italian hydrothermal production began in the early 19th century. A partnership co-owned by French exiles began in 1818, using firewood to evaporate hydrothermal water to obtain the dried minerals. When the operation became challenged because of overexploitation of forests, one of the partners, Francesco Larderel, bought out his other 2 partners in about 1827 and began using geothermal steam and energy as the heat source for evaporation.

Use of this heat, coupled with new drilling technologies that could access more water with higher mineral content, caused production to explode from about 50 tons in 1818 to 2,000 tons by 1860. Because of the distance between the production area and existing cities, the small town of Larderello was created to service the company's machinery and production. The company expanded to the point that it now markets chemicals (including boric acid) and fertilizers in at least 10 different countries around the world, including the U.S., and still includes factories in the original region where it began.

Courtesy of Enel Green Power

Larderello, 1916. Holes feeding power plant open for measurement.

The company began experimenting with geothermal steam to generate electricity, and established 2-20 KW generators, one in 1905 and a second in 1908, that provided power to the town's most important industrial plants and main residential buildings. In 1913, it established a larger 250-KW plant. Growth continued to the point that by 1943, there were 132 MW of geothermal electricity in the region. While all operating geothermal electric stations were destroyed during W.W.II, the geothermal fleet was rebuilt and expanded throughout the country to the point that today there are 870 MW of capacity that provided 2.4% of the Italy's electricity in 2023.**(7)** Italy was the world's only country to employ geothermal electricity until 1958, when New Zealand built its first geothermal power plant.**(8)**

Iceland: The country has never possessed a domestic supply of peat, coal, oil, or natural gas, and only had a limited supply of wood. However, due to geology, it has over 600 hot springs and at least 35 active volcanoes. Eruptions have occurred as recently as 2024.

Chrispo/Shutterstock.com

Geothermal power plant near Krafka volcano in Iceland

While harnessing geothermal energy was not widespread until the 20th century, hot-springs bathing goes back as far as the 10th century, where a historic site revealed water conveyed in stone-lined ditches to a bath made of stones 400 feet away.

In 1,000 A.D., when the Norse religions were abandoned for national conversion to Christianity, Icelandic converts refused to be baptized with cold water, and instead demanded the water of geothermal springs.

An 18th century travel book described using geothermal hot water for bathing, washing clothes, and food preparation. Hot spring water was also diverted to potato and cabbage crops to increase yields. In the latter part of the 18th century, geothermal energy was used to dehydrate seawater for salt export.

Using geothermal heating domestically began in the early part of the 20th century. As early as 1908, a farmhouse imported hot springs water through a steel pipe a third of a mile away. The first geothermal district heating system was built in 1930. In 2020, about 90% of the country's 131,000 homes were heated with about 30 geothermal district heating networks in towns and villages and about 200 small rural systems.

There are 140 geothermal outdoor and indoor swimming pools and sites in the country. In 2019, geothermal water was used to melt snow from almost half a square mile of sidewalks and parking spaces, and to heat 49 acres of greenhouses that produce about 18,000 metric tons of vegetables annually. It was also used in food production to dehydrate both seawater (to obtain salt) and raw kelp.

Since 1969, the country has successfully harnessed geothermal for electricity production, growing to 29% of its (2022) consumption supplied by 763 MW of capacity.**(9)**

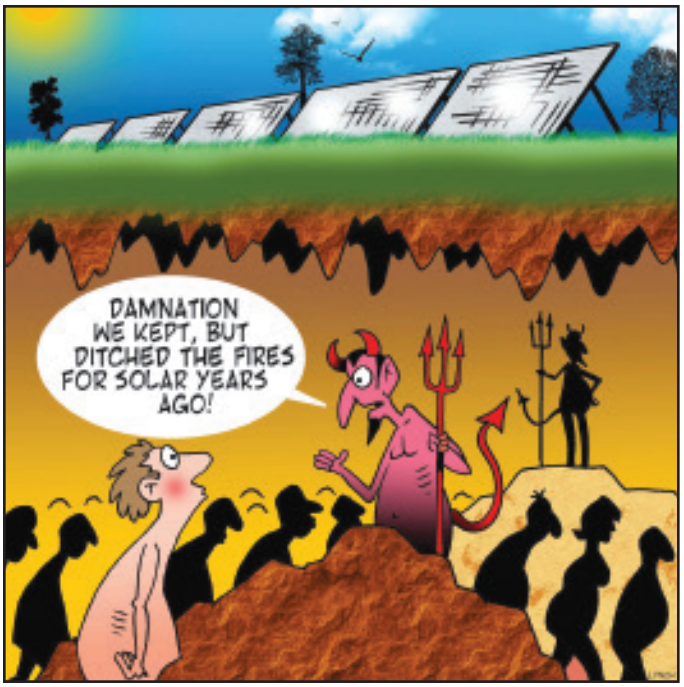
France: The village of Chaudes-Aigues (translated to English as "Hot Waters") in Southern France has been using geothermal energy since at least the year 1334. There are about 30 hot springs in or near its vicinity.

Until the 1950s, the spring waters were transported from springs in the village through underground pine wood pipes, and they currently provide heat to an estimated 150 village homes. By the 19th century, there were over 3.1 miles of the network. The pipes have been replaced with modern plumbing materials.

In the past, pipes set under the floors provided radiant domestic heating. Springs also provided hot water for private and public baths, a public laundry, and onsite public cooking and baking. Currently, some homes use central heating or non-radiant methods to distribute the heat.

Between the 15th and 19th centuries, this hot spring water was also used by textile mills to process wool. This included reused hot water from the residences. Public baths were enjoyed by tourists for health and recreational purposes, off and on, for centuries. In 1972, a well was drilled to provide increased volume for this purpose.

While this historic example is colorful, it is just a shadow of the country's geothermal resources. According to one estimate, as much as 97% of the country has economically accessible geothermal energy below the surface. Since the latter part of the 20th century, geothermal has been employed in a number of cities and sites, going back to at least 1963 when Radio France in the Paris area used it for building heat.**(10)** Actual drilling began in Melun in 1969. **(11)** By 2019, 46 district heating loops provided geothermal heat to about 700,000 people in the greater area of Paris.**(12)** Overall, there were 72 such systems in France, as well as systems for crop drying, aquaculture, and greenhouses.**(13)**



Cartoon by Mark Lynch © CartoonStock

By 2023, an additional 34,166 household equivalent units planned or under construction were expected to be online.

Some of the most innovative future geothermal proposals include co-production of hot water saturated with lithium brine located in various regions of the country, which are intended to extract the metal for raw materials in electric batteries in addition to providing heat.

China: There are 2,334 hot springs located in China, which has a recorded history of using geothermal water for medical and recreational purposes going back 3,000 years.

The country has almost no geothermal electricity. However, China has 7 large direct use geothermal district heating systems serving 58 square miles of buildings; this is the largest use of direct geothermal heating of any nation in the world. (The heat in 2019 was equivalent to the average use of about 2 million Texas Residential gas customers.)**(14)**

China also operates about 1,600 geothermal public baths and pools, and uses geothermal water to heat 2.1 square miles of aquaculture fish farms.

United States: Almost every major hot spring in the U.S. and Canada had a history of use by Indians. The U.S. Parks Service has estimated that the site of Hot Springs, AR, had been used by Native Americans for 10,000 years. Springs were used for warmth, cooking, bathing, and medicinal purposes. The Geysers in California were known to them 12,000 years ago. Warring tribes often considered such springs common ground. It has been speculated that the "Fountain of Youth" sought by Spanish explorer Ponce De Léon was really a hot spring.

The oldest geothermal district heating utility in the U.S was created in Boise, ID by 1891 to power 200 homes, businesses, and a recreation center.**(15)** Today it serves 300 buildings.**(16)** But the city has 3 other much larger systems. The City of Boise created a downtown system with 20 miles of pipe serving about 90 downtown buildings with 6 million square feet of space, most of it commercial buildings. **(17)** Geothermal serves 22 buildings with 436,000 square feet in a U.S. Veterans Affairs complex.**(18)** Still another system heats the State Capitol complex of 1.5 million square feet.**(19)** And there are about 79 other geothermal heating, commercial, and recreational systems in Idaho.**(20)**

There are at least 12 other geothermal district heating utilities in the states of California, Colorado, New Mexico, Nevada, and Oregon.**(21)**

In the U.S., use of geothermal heating for individual buildings or sites (not part of a district heating network) doubles the total use for geothermal building heat.

Courtesy Northern California Power Association

The Geysers power station in Northern California

Yet building heat made up only 28% of direct use geothermal heat used in the U.S. Some 29% of geothermal heat was used for bathing; 31% was used for fish farming, and 12% was used for agriculture (most of it in greenhouses).**(22)**

Regarding electric production, the U.S. has the largest fleet of geothermal generation in the world, with 4,047 MW from 67 units.**(23)** Still, these close-to-the surface resources are limited, and their output only amounted to 4/10ths of 1% of the electricity generated in the U.S. in 2023.**(24)**

Earthshot

The U.S. Department of Energy funds the Enhanced Geothermal Shot research program, part of the agency's advanced renewable energy "Earthshot" initiatives. (This is a word play on the space-race accomplishments of NASA in the 1960s that led to the "moonshot.")

The Advanced Geothermal Shot initiative aims for a 90% reduction in costs – 4.5¢/kwh (in 2019 dollars) by 2035, which was less than the average lifecycle cost of a baseload plant fueled by natural gas. Further, by 2050, there would be 90,000 MW of capacity, up from about 4,000 MW currently.**(25)**

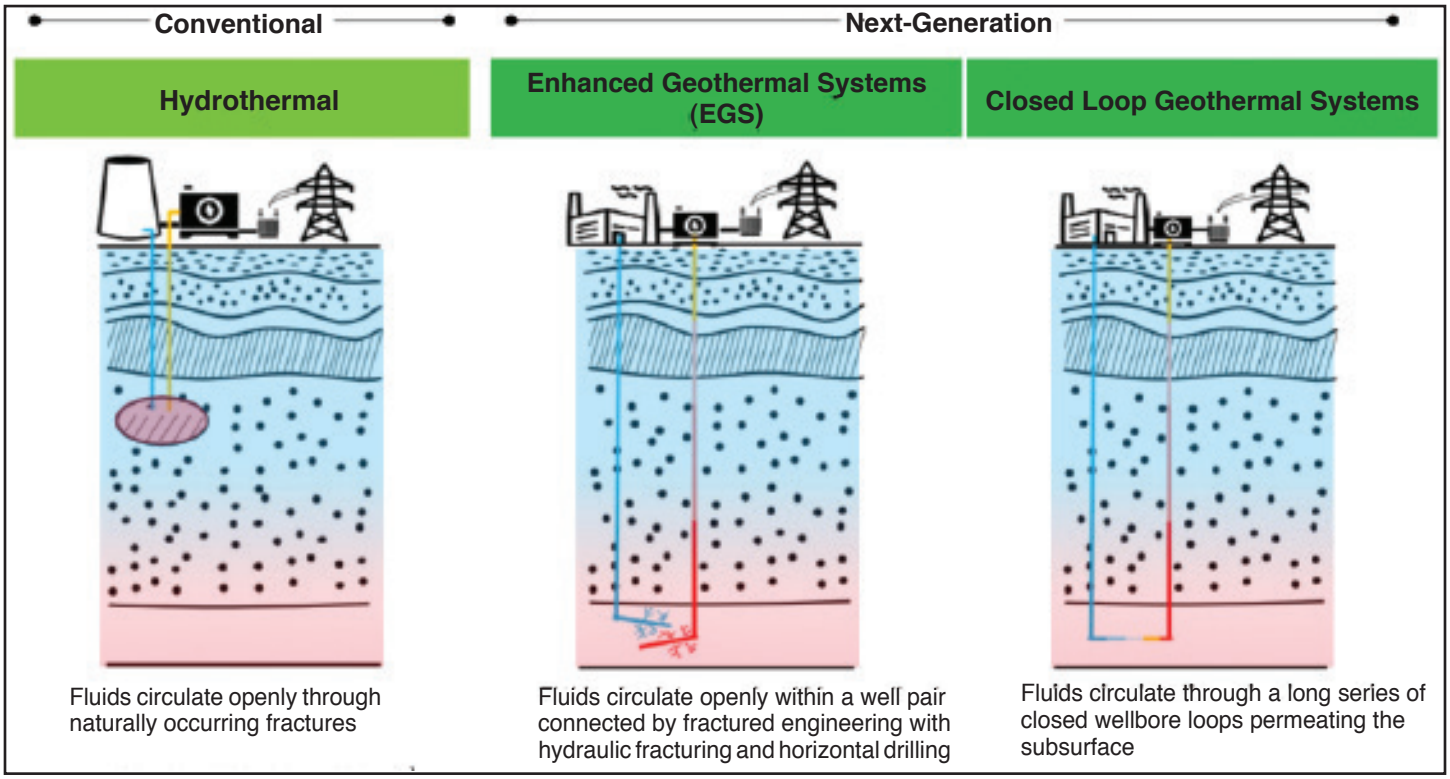
Virtually the entire current global fleet of geothermal electric stations use hydrothermal resources, which employ hot water or steam close to the earth's surface. New approaches to expand this are based on technology developed for fracking oil and gas. Drilling costs have fallen by about 90% since the more frequent use of the technique began in 2008. Though there are variations, there are 2 main approaches to next-generation power plants.

Enhanced Geothermal Systems (EGS) fractures hot dry (non-hydrothermal) underground rock, pumps cold water down one deep hole to absorb heat from the fracked earth, and draws the hot water up to spin turbines. The cold- and hot-water pipes never come in direct contact with the boiling fluid of the generator. Instead, the geothermal heat travels through a heat exchanger.

Closed-Loop Systems have a single pipe where cold water is sent down to deep hot dry (non-hydrothermal) rock, flowing back up to the generator at the surface to convey heat. Again, the water never comes into direct contact with the generator fluid, but is transferred in a heat exchanger.

Both these approaches search for heat more than a mile, and often several miles, below the surface, where heat to power turbines can be as high as 500˚F.

Ironically, many of the companies developing these technologies that can potentially produce carbon-free energy have their origins in the oil and gas industry.



Courtesy of BloombergNEF

ENHANCED GEOTHERMAL SYSTEMS

EGS systems drill vertically into the earth to reach hot dry rock, and then use horizontal drilling techniques to establish fissures. Water is piped into these fissure zones to harvest heat, returning to the surface to run generation, and then recirculated back for another cycle. Two Houston, TX, based companies directed by veterans of the petroleum drilling industry are leading the way.

Sage Geosystems "Heat Root" approach drills vertical wells and then creates tangential reservoirs at the well bottom. After sending water down the wells to these reservoirs, electricity generation can be powered in 3 ways: 1) accessing geothermal heat; 2) using water pressure; 3) using both heat and water pressure.

Sage will build a first of its kind commercial pressure-driven "EarthStore" system near the San Miguel Electric Cooperative lignite plant close to Christine, TX, about 50 miles south of San Antonio. Beginning construction in late 2024, the plant will produce 3 MW for 6 to 10 hours a day with a hydropower turbine, providing merchant power to the Texas ERCOT grid at a levelized cost below 10¢/kwh. Sage expects 70-75% round-trip efficiency, with water losses less than 2%. Similar to other well sites that use fracking, the same pad can be expanded without greatly expanding the footprint to produce as much as 50 MW.

In the summer of 2024, Sage also announced an agreement with Meta (Facebook) to supply 150 MW of geothermal electricity for a data center by 2027.

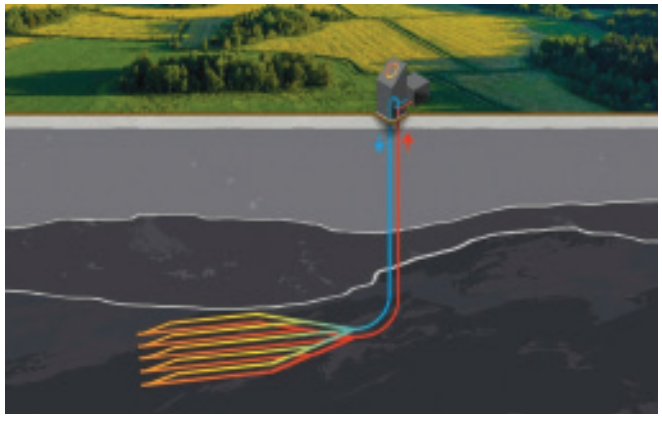
Fervo Energy's EGS systems more resemble horizontal drilling, sending vertical wells to a depth of about 8,500 feet, and then attaching lateral extensions 3,000 to 4,700 feet long, with temperatures of about 347 to 383°F.**(26)**

In late 2023, Fervo commissioned a small 3.5 MW commercial plant in Northern Nevada that will provide power to a Google data center as a step towards the company's zero-carbon goal. This pales, though, to the 400 MW Cape Station plant now under construction near Milford, Utah; 320 MW of this has been contracted to Southern California Edison. Another 53 MW are contracted to community choice aggregators that bundle wholesale purchases to participating cities as a way to lower costs. The first 70-MW increment will come online in 2026, with the balance intended for completion in 2028.

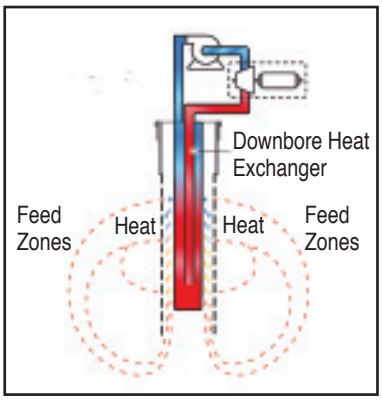
Both companies use organic Rankine cycle turbines, which use fluids with a lower boiling point than water (such as air conditioning refrigerants) to power the turbine blades. These have lower efficiency than steam turbines, but can access lower-grade heat.

CLOSED LOOP GEOTHERMAL

Eavor (pronounced "Ever") Technologies is headquartered in the oil-producing province of Alberta, Canada. The company's technology harvests geothermal heat by moving a "cold" non-water fluid down a vertical well and then through an elaborate whisker-shaped radiator drilled into rock. The radiator is sealed to keep the heat transfer fluid from leaking. The ground-heated fluid is thermosiphoned through this sealed loop and up a second "hot" vertical well to provide electricity and domestic or industrial heating. The fluid is never directly exposed to the ground or the surface environment.



Its first commercial installation near Geretsried, Germany (about 20 miles south of Munich) began construction in 2023, with partial commercial operation set to begin in 2024 and complete operation in 2026. Upon completion, it will rate at 8.2 MW of electric capacity and 64 MW for district heating. The project will be 14,800 feet deep, with 2 wells (moving a non-water fluid from cold to hot with a continuous thermosiphon) through 12 underground loops 16,400 feet long each.



California-based GreenFire Energy has a closed loop "tube-in-tube" system based on a unitary loop. Rather than 2 separate well bores that are connected, a single well is drilled. Colder water or alternative fluid (carbon dioxide) is sent down one channel to collect geothermal heat, and the hot fluid is collected through an insulated channel rising back to the surface.

Following a 2019 grant from the state of California to test a pilot well, the company received another grant to develop a commercial facility at a well at the Geysers, the largest geothermal plant in the world. In 2024, there were also signed agreements to evaluate or install its technology in Kenya, the Philippines, and Taiwan.

Part 3: U.S. State Research and Development

New York State Energy Research and Development Authority (NYSERDA)

NYSERDA is a multifaceted organzation established in 1975. In conjunction with utility-funded efficiency incentives and renewable energy purchases, the authority is charged with significant responsibilities for achieving a 40% carbon-free electricity system by 2030, and achieving 85% by 2050, from 1990 levels.

Included in its program menu is R&D "Innovation and Research." Its 2022 budget for clean energy product development was about $60 million out of a total budget of $1.76 billion in 2023. Of the $60 million, approximately $50 million was funded as part of a surcharge on the state's electric utility sales, specifically amounting to about 2/10ths of 1% of gross utility revenues.

"Climatetech" and "carbontech" product categories include: renewable energy; high efficiency furnaces and heat pumps; advanced lighting; non-lithium energy storage; and hybrid electric buses.

By year's end 2022, NYSERDA's technology and business development investments had impressive results of more than 656 new and improved clean energy products in the market (including 77 new products added in 2022).

In addition to the goal of developing new clean energy products, NYSERDA, in collaboration with other state agencies and the private sector, is creating jobs in design, manufacturing, and installation of these products. The state employs an array of strategies to accomplish this.

• As of 2022, NYSERDA's cleantech incubator program, which supported 6 cleantech incubators across the State, assisted 384 clients and helped these startups raise more than $2.3 billion in private and non-NYSERDA public investment, while generating and retaining 3,400 jobs and bringing dozens of new clean energy and clean technology products to the market.

• Leveraging investment capital from the public and private sectors goes beyond the businesses in its incubator program. NYSERDA's investment leveraged $1.2 billion in 2022 alone, with a total of $3.5 billion through the end of calendar year 2022.

• NYSERDA also scouts for customers that could be an anchor market for new products, suggests solutions for market barriers, and helps navigate regulatory barriers.

• It assists with workforce training, legal assistance, marketing, access to qualified employees, mentorship, and peer networks to growing companies.

• It also aids with production ramp up, including matching with relevant manufacturers, supply-chain management, and scaleup logistics.

By 2022, annual product sales developed with NYSERDA exceeded $2.5 billion.

Following are a few examples of the authority's initiatives in creating new products and businesses.

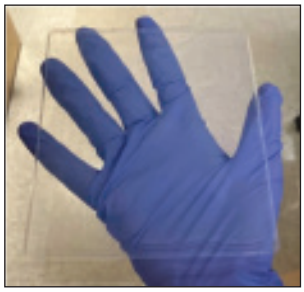
CLEAN HEAT FOR ALL CHALLENGE

To assist with the energy costs in low-income housing while lowering carbon emissions, NYSERDA, in cooperation with the New York City Housing Authority and the New York Power Authority, has funded development of cold-temperature, quiet-running heat pump window units. These will replace fossil-fuel heating and can operate efficiently at down to at least 15˚F below zero, as well as provide efficient AC in summer months. These operate on standard wall-plugs, with no need for additional wiring costs.

This R&D funding is part of a larger budget of $13 million for development of this technology. In 2023, 2 companies provided a total of 72 units to be tested in apartments. If testing is successful, this will eventually lead to investment of $70 million to install 30,000 Housing Authority units.

EFFICIENT BUILDINGS

Lighting: NYSERDA began investing in development of LEDs for general use as far back as the 1990s, at least a decade before the first commercial products. It has also advanced research in OLEDs (LEDs on plastic panels), and occupancy sensors that automatically turn off lights when people leave an area.



Clear aerogel window insert

Windows: The agency funded development of smart windows that screen out sunlight when the sun increases air conditioning loads. While some of these products are electrically controlled and carry a large premium, one is a lower-cost window coating that passively adapts to sunlight. Another product is a clear aerogel insulation insert that fits inside double-pane glass.

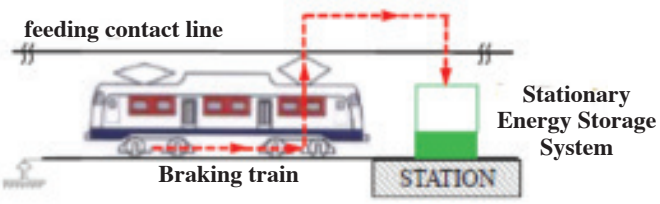
HVAC: NYSERDA collaborated with other states to research Residential efficiency HVAC upgrades that could be transferred into federal requirements or best-practice installation standards for contractors. It also funded a company that lowered the cost of geothermal heat pumps, and another manufacturing a "fisonic" device to greatly reduce steam heating in commercial buildings.

ENERGY STORAGE

R&D grants have been issued to both improve the efficiency of conventional lithium ion batteries as well as create alternative battery chemistries.

Conventional battery research dealt with improvements such as anodes made of different materials and engineering batteries to operate at higher temperatures. Alternative battery types include zinc and sodium. These are considered safer than lithium due to reduced fire risk and have longer life when completely discharged. Moreover, these metals are commonly found in the U.S. and are less expensive. There is also a "paper battery" being researched, which is extremely thin, to supply power to devices constrained by shape.

An interesting direction for NYSERDA battery research concerns reclaiming and storing energy from regenerative braking in the electric powered subways and railways that serve a large portion of the state's population and consume a considerable amount of electricity.



RENEWABLE ENERGY

At least 77 solar and wind power research projects have been funded by NYSERDA. Some of this was incorporated into locally manufactured products.

These include "passive tracking" bifacial solar cells that boost production, solar panels that preheat air for winter space heating, and building integrated photovoltaics like the solar fence above. Wind power products included automatic and wireless wind turbine monitoring to determine likely problems and plan preventative maintenance.

One of the more innovative projects (at this point uncommercialized) was solar-powered fiber optic traffic lights whose light source was at ground level to reduce maintenance costs.

Connecticut Innovations

Connecticut has been using state money to provide venture capital to create businesses and resulting jobs in the state since 1972. The most current agency managing this is Connecticut Innovations, established in 2012. Funded with state bonds, it invests or loans money to prospective companies in the directions of: Climatetech; Consumer products; Healthcare; Technology; and other venture-capital funds.

The ClimateTech Fund is a discrete part of the program. As of 2024, it had $100 million invested in capital and strategic support in companies in the following areas: energy; transportation; food/agriculture; water; climate-related software; waste/circular economy; advanced materials/manufacturing; and carbon removal/sequestration. The fund invests between $150,000 and $5 million per company and requires a co-investment.

Bond payments, future investments, and administrative operations are paid through the "profit" made on successful company exits, where participants were acquired by other companies or graduated to Initial Public (stock) Offerings. By May 2024, there had been 74 successful enterprises.

In addition, the organization seeks to leverage its investments with private capital. One method is the state's "Angel Investor" state tax credit of 25% of invested funds (at least $25,000 in qualifying companies).

As of the end of the 2023 fiscal year, the company had about $290 million in assets, with over half being portfolio investments and loan repayments. In the first 3 quarters of 2024, Connecticut Innovations: invested $39 million in 79 transactions, including $8.5 million in 17 Climatetech-related companies; received $32 million from investments to cover administration and to spend on new investments; leveraged $661 million in its investments from private capital, including $12 million from the Angel Investor program.

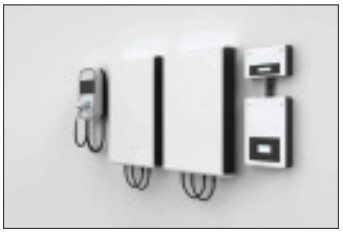
BUDDERFLY, INC.

This energy service company funds energy-saving equipment upfront, such as efficient air conditioners, lighting, and refrigeration controls. Its follow-through equipment management and monitoring optimizes bill savings and environmental goals across thousands of buildings.

CADENZA INNOVATION

This is a Connecticut manufacturer of lithium-ion battery cells, modules, cell housing, racks, EV-packs for use in utility substations, renewable energy generation, transportation, UPS, and onsite low-footprint and weather-sealed building energy storage. These batteries have cloud-enabled monitoring allowing for utility demand response.

TANTALUS



Tantalus helps utilities modernize their distribution grids by harnessing the power of data across all their devices and systems throughout the entire distribution grid. Their platform can use any protocol to acquire and serve data, thus enabling control of: distributed energy resources; peak management; time-of-use rates; outage management; data analysis; transformer monitoring; voltage reduction; distribution system preparation for natural disasters; theft; and meter-tampering prevention.

ROUNDTRIP EV SOLUTIONS INC.

Electric vehicles lower energy use, air pollution, carbon emissions, and noise. Specializing in waste-hauling, this company provides electric waste truck fleet funding and management for the waste hauling industry. It pays for the trucks and chargers upfront while also providing vehicle maintenance and energy management. Waste haulers pay for this as a monthly service.

California Utility Research and Development

Since 2012, the State of California Energy Commission has administered the Electric Program Investment Charge (EPIC) initiative funded with a small percentage bill increase from the state's three large Investor-Owned Utilities. In 2022, the program's budget was equal to about 1/3 of 1% of collective gross revenues. As of May 2024, it had spent over $1.4 billion on 620 projects, while leveraging private investment of $10.1 billion.

Some of the research included: microgrids; advanced electric storage batteries; 3D printing of wind-turbine towers (to save money on transportation of materials); wildfire mitigation (to prevent outages caused by powerlines in forested areas); window-unit heat pumps; radiative cooling for commercial refrigeration systems; exterior retrofit insulation panels for multifamily buildings; photovoltaic window coatings; and creation of chemicals from carbon dioxide instead of hydrocarbons.

Since 2000, a similar program has been funded by the state's four private gas utilities. In 2020, the program's budget was equal to about 1/4 of 1% of collective gross revenues. Between 2004 and 2023, the program spent at least $319 million on 301 projects, while leveraging private investment of $6.1 billion.

Some of the research included: smart shut-off technology that turns off gas service when detecting fires, leaks, natural disasters, and operational errors; waste heat capture in industrial facilities; real-time monitors to detect leakage from utility-supply gas storage sites; commercial building boiler and air volume retrofit demonstration to reduce gas consumption by 60%; commercial gas-powered heat pumps; raising combustion efficiency of gas wall heaters and space heaters; and low-cost solar industrial heat collection.

Following are a few examples of the agency's initiatives in creating new products and businesses.

BATTERIES

By May 2024, EPIC had spent over $49 million on 17 projects related to unconventional battery storage. These included batteries with zinc chemistry, and flow batteries, which charge and pump large volumes of positive and negative liquid electrolytes to separate tanks to create an electric current.

While having less electric density than lithium batteries used for vehicles, they can be used for electric utility storage that is not restricted by weight. These technologies use less expensive materials, are not nearly as vulnerable to fires, have longer life, and can be fully discharged multiple times with low capacity fading.

LIGHTING

Self-dimming "electrochromatic" windows

EPIC-funded development of cutting-edge lighting technologies include: better design of conventional LEDs; an ultra-thin and flexible LED lighting panel (to take the place of lamps and fixtures); an electronically adjustable LED fixture that reduces glare and improves energy-efficiency; and automatic shading devices (such as self-dimming windows) to save money on lighting and air conditioning.

Flexible LED lighting panel replaces conventional lamps and fixtures

RETROFITS FOR MULTIFAMILY HOMES

One of the largest challenges to affordable energy for multifamily and low-income housing is the excessive labor cost. EPIC is investing in standardizing materials and installation techniques. Outer-wall insulation panels, including vacuum insulated panels with unsurpassed efficiency, are being developed for the outside of buildings. Small drop-in packaged units for heating, cooling, and water heating are also being tested.

EPIC-funded energy-efficient window-unit heat pumps for cold climates are being tested with advanced polymer heat exchangers and low-global-warming refrigerant. The first 72 units were installed for testing in specific New York City Housing Authority apartments in the winter of 2023/2024. Successful operation is expected to lead to eventual installation in 30,000 apartments.

REFRIGERATION, COOLING, AND HEATING

EPIC is researching all manner of strategies and devices being used to lower cooling and heating costs, both in the building shell as well as the equipment.

One innovative technology, radiative film, rejects heat to make roofs, air conditioning, and refrigeration more efficient. It not only rejects the sun's heat, but reradiates heat already retained in roofs and buildings back into the atmosphere. It can be used both as a radiant barrier, or used in front of fluid loops to transfer cooler temperatures to HVAC equipment.

Building-shell projects include less-expensive energy-efficient aluminum windows, and less expensive methods to seal and insulate attics for up to 15-25% HVAC savings. Equipment-related projects include: testing energy savings from inverter technology; newly designed evaporative cooling; and an advanced heat exchanger that alternates between air and water cooling, depending on the temperature, to save water and energy in commercial buildings.

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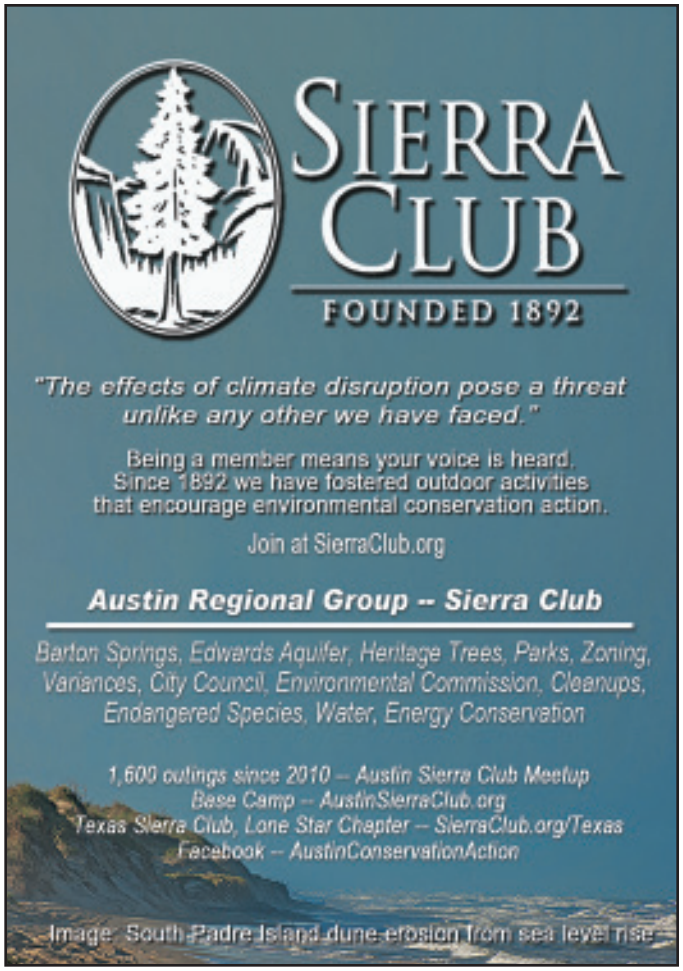

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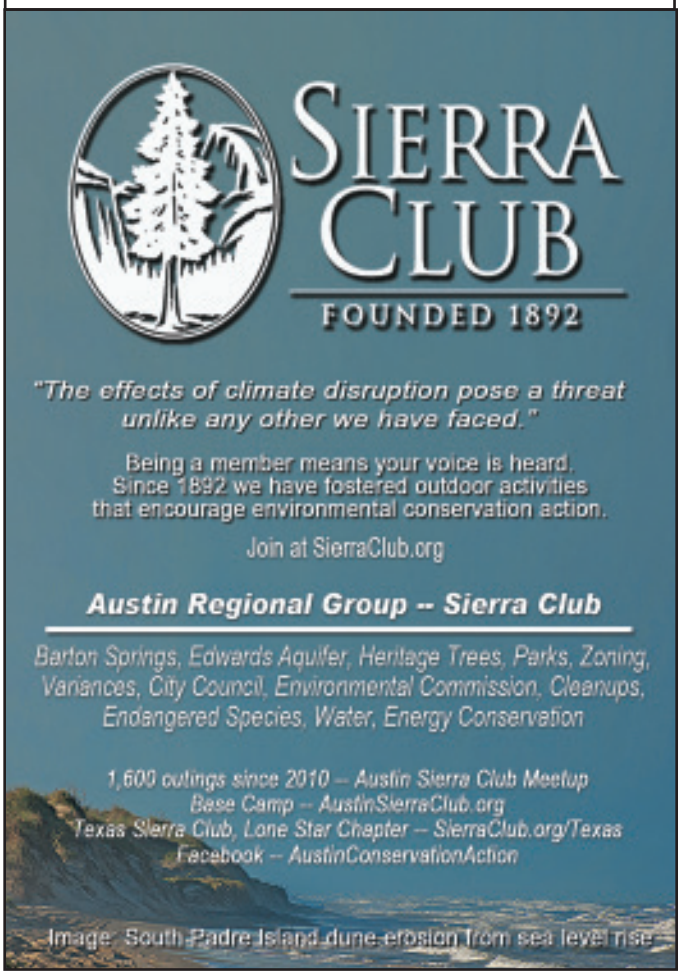
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