

The Third Electric Energy Transition Calls for Geothermal Energy Assurance

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Keywords

The third electric energy transition, energy security, electric power, thermal energy, the U.S. electricity grid, geothermal energy, resilience, reliability, baseload power, resilient continuous power, closed-loop geothermal energy systems (CLG), enhanced geothermal systems (EGS), advanced geothermal systems (AGS), the “heat beneath our feet,” green energy, clean energy microgrids, resilient community energy systems, climate change, global energy transition.

ABSTRACT

The third electric energy transition in the last one-hundred years is now underway in the United States. This major transition is challenging the “centralized grid” model of power generation and distribution, especially for large, energy intensive end-users. These consumers include manufacturing plants, data centers, metal smelters, refineries, chemical plants, military bases and emergency services that now consume about a third of all electric power.¹

The third transition has not been a planned evolution, but instead emerged from the disruptive combination of rapidly escalating energy demand, climate change concerns, increasing volatile energy prices, and recurring U.S. regional power outages. Consequently, traditional suppliers, typified by today’s electric and gas utilities, load serving entities (LSEs) and energy service providers (ESPs), are being supplemented and supplanted by new types of energy suppliers including Distributed Energy Resources (DERs), aggregators of demand responsive customers, microgrids, resilient community grids, Battery Energy Storage Systems (BESS), “prosumers,” and Community Choice Aggregators (CCAs). The key driver for this transition is the need for “energy assurance” – a multi-factor concept that includes the continuous availability, reliability, resilience, scalability and price stability of energy while still meeting goals for decarbonization.

Energy assurance has also become a primary concern of large organizations that consume enormous supplies of electricity and thermal energy. These organizations realize that electric energy demand is outstripping supply and that the regulated “commodity” energy market model is incapable of responding adequately. Availability is now a top priority. But even if the regulated market could generate sufficient energy to meet market demand, the ability to deliver that energy reliably is highly suspect due to aging transmission lines, line congestion, and the

prevailing vulnerability to weather related events, fire, and cyber-attacks. As a result, energy-intensive organizations are actively seeking “behind the meter” energy solutions that enable them to assure and control their energy supply.

This “behind the meter” strategy has obvious advantages, first because it avoids some costs and risks of transmission, distribution, regulatory oversight, and wholesale market coordination, and second because self or co-located generation allows energy-intensive organizations to pay for the energy attributes that most closely correspond to their needs.

The quest for energy assurance has spurred intense interest in geothermal energy. In addition to its enormous potential magnitude, geothermal energy offers a unique combination of energy assurance attributes. Geothermal energy can provide both firm, baseload electric power and direct thermal energy that is critical in many manufacturing operations. “Behind the meter” geothermal power also offers price stability and insulation from grid outages and regulatory mandates. In short, geothermal energy is moving from being an attractive energy alternative to an indispensable component of the third electric energy transition.

Introduction

In the United States a highly regulated electricity market has evolved for over 100 years as electricity consumption became ubiquitous, transmission networks proliferated, and different fuels for power generation came into use. Because the geothermal industry has failed to actively participate in drafting and influencing the laws and regulations that have structured U.S. energy markets until very recently, funding for and investment in geothermal energy has been orders of magnitude lower than that for other energy technologies.

In order to enable geothermal energy to gain essential funding and to reduce the time for projects to come online and generate revenues, it is important for industry participants to have a better understanding of the actions, events and mandates that have enabled oil, coal, natural gas, nuclear and hydro energy supplies to dominate energy markets and more recently for solar, wind, hydrogen and batteries to compete for market share.

The following sections describe the first two U.S. electric energy transitions and discuss elements of the third energy transition now in progress. The first energy transition of the electricity grid was defined by the regional electrification architecture of large-scale projects such as the Grand Coulee and Boulder dams and the Tennessee Valley Authority that made electricity available to large numbers of homes and businesses for the first time during in the 1930s. That first model comprised capital intensive infrastructure, including generating plants powered by coal and hydro-electric dams, high-capacity regional transmission lines to transport power, and local distribution systems owned and operated by utility companies.

Figure 1 below illustrates some of the major events in U.S. electricity and natural gas markets between 1875 and 1970. Significant technological advances and infrastructure development were accompanied by the creation of large companies to supply equipment, the Bonneville Power Administration and major utility companies, the initiation of state regulation, the formation of the Federal Power Commission, the National Electric Reliability Council, and the U.S. Environmental Protection Agency (EPA.) The era was characterized by ongoing significant year-over-year electric load growth and the expansion of U.S. energy systems.

Electricity and Gas Markets -- 1875 to 1970

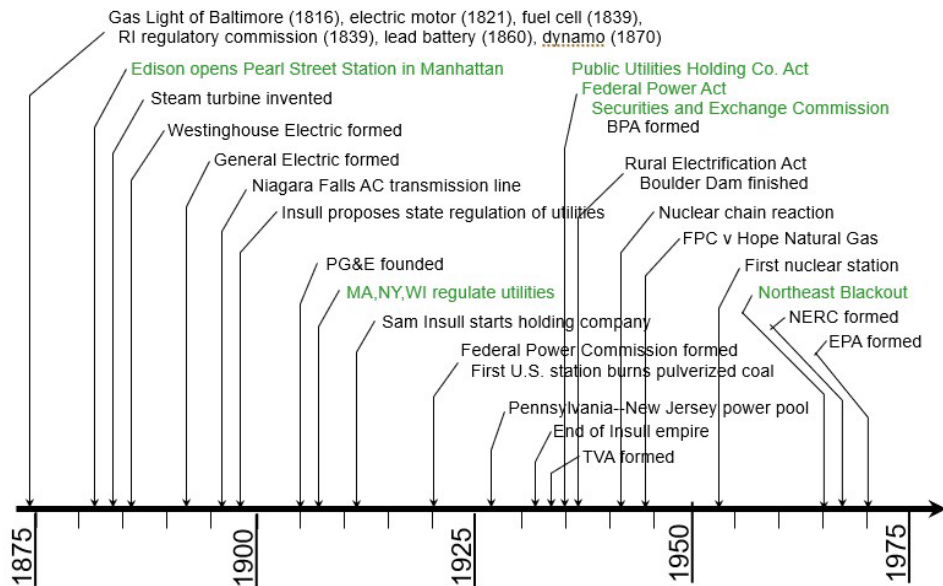


Figure 1. Key Events in U.S. Electricity and Natural Gas Markets – 1875 TO 1970

The Second Major U.S. Electric Energy Transition Began in the 1970s

The transition away from the utility-owned infrastructure model in the U.S. began in the late 1970's as governments and utilities responded to environmental and natural gas supply availability concerns by enabling power purchases at system “avoided costs,” and by mandating minimum thermal efficiencies and prohibiting new natural gas-fueled plants. One result was that independent or merchant power producers could compete on price with utility-owned generators.

Figure 2 illustrates key U.S. events between 1970 and 1990, during the “Second Electric Energy Transition,” which initiated many elements of the current market structure. Events included the formation of the U.S. Environmental Protection Agency (EPA) with accompanying clean air and clean water legislation and regulations, the founding of the Electric Power Research Institute, the OPEC oil embargo with impacts felt around the globe; PURPA, PIFUA and the NGPA legislation, and Federal Energy Regulatory Commission Orders affecting electricity, natural gas, oil and hydropower transactions, reliability standards, and the rates charged in interstate commerce.

Electricity and Gas Markets -- 1970 to 1990

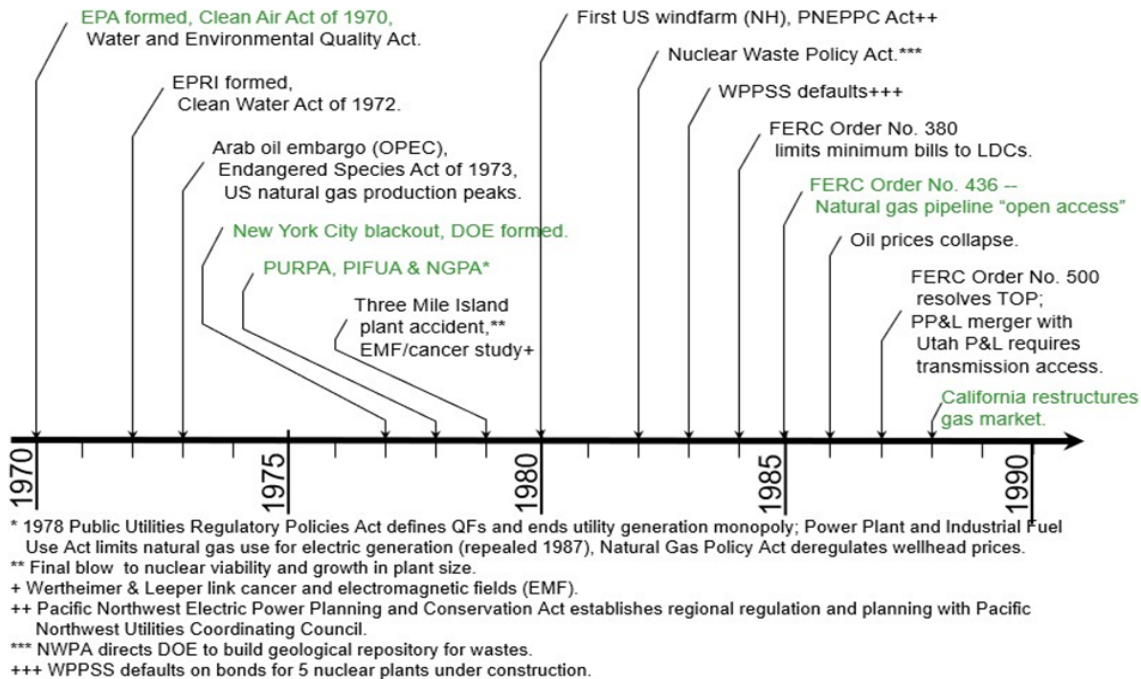


Figure 2. Key Events in U.S. Electricity and Natural Gas Markets Initiating the Second Electric Energy Transition, 1970 to 1990.

Legislation allowed more efficient energy resources, such as cogeneration, wind farms and biomass plants to be built and to create their own “learning curves.” Learning curves for advanced technologies demonstrated cost reductions and performance improvements resulting from more deployment and “learning-by-doing.” Independent System Operators (ISOs) and Regional Transmission Operators (RTOs) dispatched power plants on the basis of bids into hourly day-ahead and real-time wholesale electricity markets, paying market-clearing prices rather than costs-of-service.

During the 1990s grid operations became progressively more centralized by region. Natural gas combined cycle units became the preferred choice for capacity additions in many states. Open transmission access allowed wholesale markets to be designed and operated, and the electric utility industry was restructured.

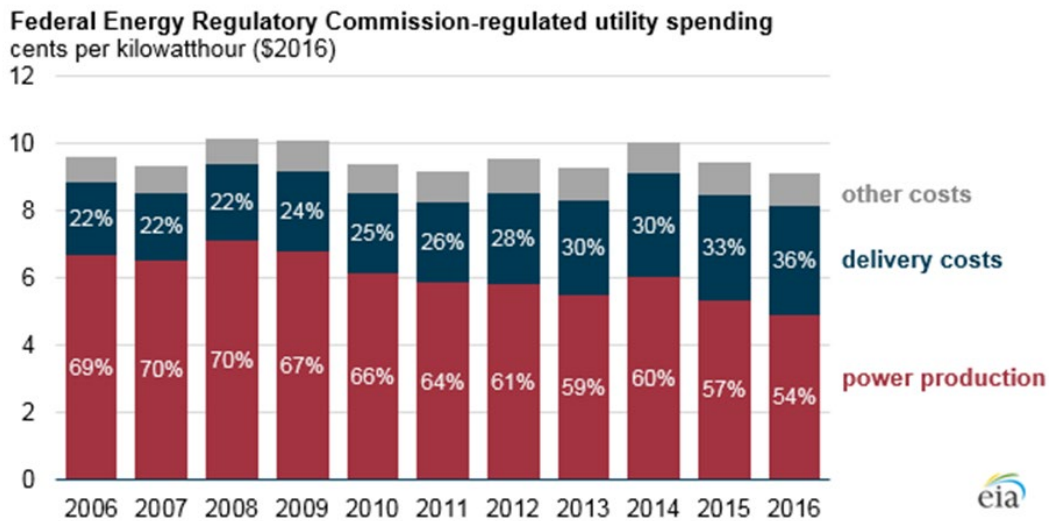
Three major regional electricity grids now operate in the U.S. and Canada. The Western Interconnect extends from the Pacific Ocean to the Rocky Mountains; the Eastern Interconnect operates east of the Rocky Mountains, and the independent Texas Interconnected system is essentially only in Texas. Interstate wholesale power transactions are regulated by the Federal Energy Regulatory Commission (FERC) and retail transactions are regulated within most states by state Public Utility Commissions.

In 2024 the core architecture for regional power systems remains in place, as utilities, merchant generators, grid operators, Electric Service Providers (ESPs) and balancing authorities dominate the generation, dispatch and distribution of electricity. There are sixty-six U.S., one Mexican and

eight Canadian control areas that maintain the reliability of the major North American interconnected grids.

In the past, new technologies took decades to be developed, penetrate, and eventually dominate electricity capacity additions. These technological advances led oil, coal, natural gas and nuclear to become the primary fuels and also spawned immense supporting infrastructure and regulatory bodies that make transitions difficult. Nevertheless, the quest to reduce costs and decarbonize the U.S. economy has resulted in the significant expansion of low-cost, just-in-time natural gas production and pipeline transport methods to fuel gas-fired applications. Together with additions of renewable, intermittent solar and wind plants, the U.S. electricity industry has been able to achieve a reduction in annual CO₂ emissions of about 28% between 1995 and 2023. Today, the combustion of natural gas for power and heating buildings produces only about 40% of the greenhouse gas emissions (GHG) that burning coal would produce to provide an equivalent amount of combustion energy. Despite these improvements, natural gas cannot enable the US to achieve its “zero carbon” goals

The cumulative result of legislative and regulatory mandates has changed cost structures and created regional grids. Today’s commodity power rates contain multiple and significant unbundled costs. Since the 1980s, electricity rates paid by end-use customers that are set by public utility commissions like the California Public Utilities Commission (CPUC) contain not only the costs of building, operating and maintaining power plants, transmission and distribution systems, but also include costs for ISO ancillary services, above-market costs of Qualifying Facilities and stranded assets, reliability must-run contracts, nuclear decommissioning and public benefits charges, among others. As a result, the relationship between the actual cost of generation and the price paid by the end-user has become increasingly decoupled. Figure 3 shows the results of this trend between 2006 and 2016, as the delivered cost of electricity rose continuously when compared to the cost of generating electricity.



Source: US Energy Information Administration, FERC Financial Reports, September 2017

Figure 3. Electricity Prices Reflect Rising Delivery Costs and Declining Production Costs

The Third Electric Energy Transition

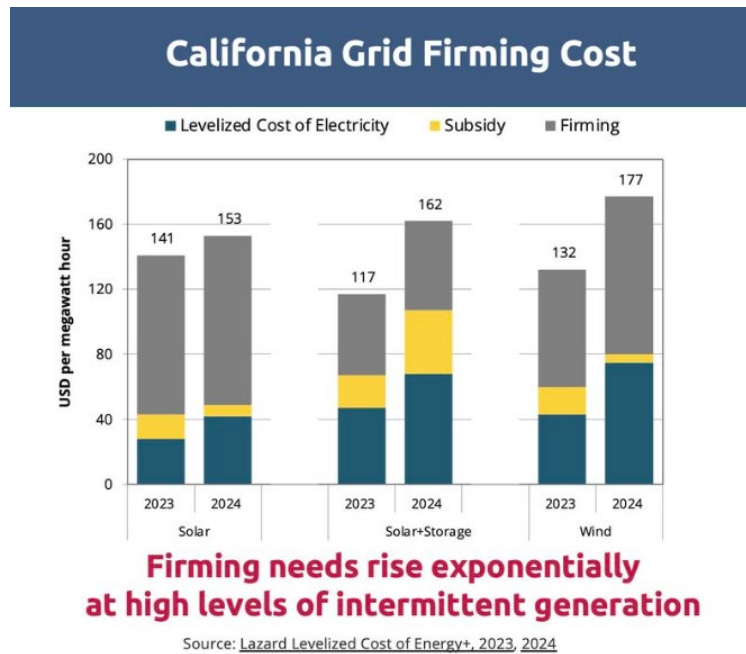
The Third Electric Energy Transition can be described as a move toward the general de-commodification of energy and, most specifically, electricity. A Megawatt-hour (MWh) is no longer just a unit of energy, but instead is energy generated and delivered with specific attributes such as price, price stability, scalability, reliability, environmental impacts, and resilience. Because participants in the energy market value these attributes differently, there is no longer one standard commodity value proposition.

Various attributes comprise the concept of energy assurance, even though each customer seeks its own balance of features. Attributes that were formerly understood as part of a standard offering of capacity and energy can now be differentiated and given separate valuations. Consequently, the Third Electric Energy Transition is spawning multiple types of solutions that enable organizations to contract for the bundle of energy attributes that best matches their specific priorities. Examples of this trend include energy efficiency, demand-side responses, distributed energy resources, microgrids, Community Choice Aggregators, resilient community grids, and self-generators.

In 2018 Sheldon Peterson, the former CEO of the National Rural Utilities Cooperative Finance Corporation, characterized the tasks facing the energy industry as Decentralization, Digitalization, Decarbonization, and Disintermediation (the 4-Ds).^{2,3} Rapid electrification and volatile markets make accomplishing the 4-Ds complex and challenging. Traditional utilities and ESPs need to raise their rates high enough to cover increasing costs but keep rates low enough to retain enough customers to provide sufficient revenues to pay for the new obligations now part of the third energy transition. However, if too many customers depart as disintermediation occurs, then the risks of a potential Death Spiral are magnified, adding instability to our interrelated energy systems.

Although solar, wind and battery technologies have become essential contributors to increased electrification and decarbonization, they are not fully capable of addressing our 4-D challenges. The risk of greater reliance on inherently intermittent solar and wind grows proportionately with its prevalence in grid-delivered electricity. Worse, we cannot eliminate all the risks that impact wind and solar energy systems including powerful storms, wildfires, widespread episodes of extreme heat, coastal flooding, and rising sea levels. For example, past volcanic and weather events like the eruption of Mt. Tambora in 1815 would, if repeated, bring about a “year-without-sun,” causing global crop failures and rendering electric grids dependent on solar and wind largely inoperable. Other risks with very high consequences, such as war or sabotage, are largely ignored but could be mitigated by having a more diverse and robust set of energy supplies.

As a result, the widely used LCOE calculation (Levelized Cost of Energy) is no longer an accurate metric for comparing the true cost of generation technologies because it does not take into account intermittency and reliability. Hence, although wind and solar appear to have a cost advantage relative to other energy sources using standard LCOE calculations, when the cost of providing necessary “firming” power is included, the actual cost is much higher. Figure 5 below demonstrates that the estimated cost of “firming” the grid to overcome the intermittency of wind and solar now costs more than the wind or solar power itself in California.

Figure 5 California Grid Firing Cost⁴

Multiple Factors Are Driving the Third Electric Energy Transition

The factors driving the Third Electric Energy Transition are fundamental, long-term, and structural.

Accelerating demand for clean energy sources

- The global demand for power has accelerated much faster than predicted, leading to shortages in many markets. For example in the United States “projections of electricity demand growth have doubled. The nationwide forecast of electricity demand growth by 2028 increased from a projection of 3.8% in 2022 to 7.8% in 2023”.⁵
- National and regional climate policies, combined with low current natural gas prices, have substantially curtailed or eliminated the use of traditional baseload energy sources, such as coal and oil.
- Availability of energy has become a potentially significant constraint on growth.
- Manufacturing, in particular, needs thermal energy in addition to reliable, clean electric power.

Price Increases and Price Instability

- After decades of relative price stability, electric power consumers are confronted with the rapid escalation of power prices along with increased price volatility

Grid Instability

- As intermittent resources, such as wind and solar power generation, comprise a greater percentage of total grid capacity, the volatility of the energy supply increases.
- Prolonged power failures (sometimes with devastating impacts, as occurred in Texas in February 2021, during a winter storm), more frequent outages, brownouts, and power rationing have become increasingly common in both developed and emerging economies.
- Much of the electric grid is comprised of aging infrastructure and has shown its vulnerability to weather, fires and other disruptions.
- Power generation has become less predictable, because baseload coal and nuclear plants are being retired and non-geothermal renewables, including hydro power to a certain extent, are weather-dependent.

Regulatory and Legal Inertia

- Utilities are burdened by a complicated regime of regulations and restrictions that make it difficult to meet rapidly mounting demands for power.
- Existing powerlines are congested and building new transmission lines can require decades of contracting with multiple parties to permit, finance, and build.
- Intermittent power sources are inherently inefficient for large capacity power lines.

Energy Assurance and Other Key Attributes Are Required by Energy Intensive Organizations

To large energy-intensive organizations, “energy assurance” comprises multiple attributes in the right combination:

- **Availability:** sufficient energy must be available to accommodate expansion and growth. For example, some major textile plants in northeastern Spain have curtailed needed plant expansions, due to draught and regulatory controls that inhibit them from obtaining additional needed power.
- **Flexibility:** because using electric power to heat materials can be prohibitively expensive, the energy mix may require both heat and electric power,
- **Reliability and Resilience:** Reliability means a high level of uptime, and Resilience means resistance to and recovery from unforeseen events, such as major weather events or purposeful attacks. To energy intensive organizations, the consequences of power shortages and power instability have been nearly existential. Disrupted operations, damage to continuous process plants, and wasted materials have become a serious business risk. Predictably, vulnerable organizations no longer view energy as a commodity with assured availability. Instead, large power consumers consider their future power needs with respect to both reliability and resilience.
- **Stable affordability:** the energy supplied must be stable and cost-effective for the intended application. Today, geothermal power purchase agreements are being signed

from \$70/MWh to \$100/MWh for greenfield projects⁶ and for \$20 to \$35/MWh for additional output from retrofits utilizing existing infrastructure.

- **Ancillary attributes:** Energy assurance alone is not sufficient. Other critical attributes sought by companies considering procuring their own energy supplies are:
 - Source: clean (ethical sourcing, reduced or no greenhouse gas emissions, limited water use & wastes),
 - Land: economical use of land and public acceptability,
 - Safety: low risks to employee and public welfare, health and safety,
 - Lifecycle costs and impacts: costs and impacts evaluated across the entire supply chain, including end-use and disposal over the project/product and its replacement’s lifetimes.

Geothermal Energy Is A Key Element of the Third Energy Transition

As discussed in prior GRC papers,^{7,8,9} geothermal energy could provide clean, carbon-free, around-the-clock, weather independent, energy secure, dispatchable, reliable, scalable and resilient power and heat in many more locations than it is used today, but only if interdisciplinary geothermal research, innovations and advances continue to achieve cost reductions and performance improvements like those occurring in recent months during 2023 and 2024.^{10,11,12,13,14}

Figure 4 shows the value proposition and attributes provided by next-generation geothermal energy systems.

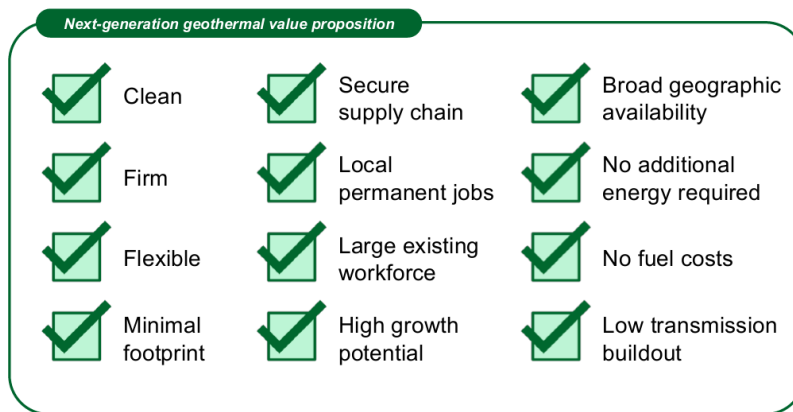


Figure 4 Features and Attributes of Next-generation geothermal projects¹⁵

Because the list of energy assurances required by consumers is comprehensive, it becomes obvious that geothermal energy is the ideal source to enable and accelerate the Third Energy Transition. No other renewable energy source provides clean energy in two forms (electrical and thermal) with high availability, reliability and resilience. Further, geothermal energy has far more global energy potential than coal, oil and gas combined, so it is inexhaustible in practical terms. In short, geothermal energy is uniquely suited to the requirements of the third energy transition.

Benefits of Co-location

These advantages can be made even more valuable by co-locating energy-intensive operations on top of or adjacent to geothermal resources. The clean, continuous, and reliable power generation from a “behind the meter” installation provides the energy assurance that energy-intensive organizations seek. They can:

- Avoid or mitigate utility price and rate increases,
- Eliminate grid vulnerabilities,
- Obtain both thermal energy and electric power,
- Meet clean energy and environmental stewardship goals,
- Reduce their energy footprint with land requirements 1/10 of solar and wind farms.

Having become aware of the significant benefits of geothermal energy, a number of industrial projects around the world are currently considering co-locating new facilities with geothermal energy operations. Such projects demonstrate the potential for geothermal to be a significant contributor to the third energy transition. Examples of such projects include:

- Data center companies that, due to the additional computing demands of artificial intelligence (A.I.) need to multiply the number of data centers by 4-fold, but can’t get the added electric power, don’t trust the grid, and want to control future prices,
- A carbon capture company that needs thermal energy to extract carbon, but knows heat is expensive and fossil energy is not low-emitting,
- Military bases that require absolute power assurance, hardened infrastructure, and resilience,
- A government-controlled power company that is directed to develop geothermal resources,
- Large textile companies that need to expand operations but cannot get additional power and are water constrained,
- Large chemical companies that need to expand operations but cannot get additional power, are water constrained and must meet GHG emission reduction goals.
- Steel manufacturing plants, which must have continuous power.
- Oil companies that need power for field operations and seek to convert depleted oil wells into geothermal power wells, thus displacing diesel generators.
- Companies mining bitcoins. It has been estimated that crypto currency operations consume 0.6% to 2.3% of all U.S. electricity demand in 2023. Of course, this electricity usage consumes resources and produces pollutants, while producing no realizable products.¹⁶

Advanced Geothermal Energy Systems Are Evolving to Match Customer Priorities

In order to realize its full energy assurance potential, geothermal power must be made more geographically available and scalable. While progress is being made across the entire spectrum of geothermal energy systems, Advanced Geothermal Systems (AGS) based on closed-loop architectures are particularly promising for third generation applications.

Closed-loop geothermal (CLG) energy systems make geothermal projects feasible in a much broader spectrum of resources than conventional hydrothermal systems and, in principle, more than Enhanced Geothermal Systems (EGS). This is because closed loops don't require the combination of large volumes of water and high subsurface permeability needed for conventional systems or the need for large-scale fracking, provided there is sufficient heat to extract. Closed-loop systems are much easier to permit because nothing is injected into the subsurface or extracted other than heat. A wide variety of CLG designs are now being developed and deployed that will provide the flexibility to use a variety of working fluids to enhance power output.

Two types of geothermal settings for “behind the meter” power projects

Organizations seeking energy assurance must evaluate many factors when deciding to co-locate a facility near a geothermal resource. However, the choice of geothermal resource will fundamentally determine the time, expense and control of the project. The key difference is whether the geothermal resource has already been at least partially developed or whether it is a “greenfield” project.

The fastest, least complicated way of providing additional geothermal energy is to work with existing projects. Such projects are in operation in many parts of the world with a combined capacity of about 16 GW. By applying closed-loop technology many of these projects can significantly expand production at an existing geothermal site. Choosing to co-locate with an existing geothermal operator has significant benefits:

- Most required permits have already been issued and additional permits should be relatively easy to acquire.
- The geothermal resource is proven, so project risk is small.
- Key infrastructure is already in place.
- Most projects have inactive wells and/or depleted permeability in fields that might be restored using closed-loop technology. Some projects also have idle electric generators that could be used.
- A contract can be executed to produce and deliver power from existing facilities or to finance and drill new wells and install additional generation.

Greenfield projects take longer to complete, but offer some advantages in terms of ownership, control, and flexibility.

- Industrial companies can do joint development of a given site to create a geothermal energy park, which is controlled by the participants.

- New projects should be able to take advantage of new forms of government subsidies and tax credits.

Increased Funding and Other Reforms Are Necessary to Continue the Third Energy Transition

The tasks required to implement the Third Energy Transition in the U.S and elsewhere are daunting and will require concerted, long-term investment by both the private and public sector.. According to the U.S. White House:

“\$3 trillion in private investments will be made over the next decade to address climate change, with 70% of these investments required to originate from utility and energy companies, clean energy developers, and financing institutions. While that may seem like a big number, it falls far short of the projections that indicate the need for annual investments to be nearly double that forecast, ranging from \$4 trillion to \$6.9 trillion just to meet the emissions reduction targets outlined in the Paris Agreement. This underscores the urgency and scale of finding clean ways to produce baseload power, and the need for substantial commitments from both the public and private sectors to drive meaningful change.”¹⁷

For decades geothermal energy has been significantly underfunded by DOE and private investors compared to other energy systems. Even in 2022, the “Inflation Reduction Act and the Bipartisan Infrastructure Law concentrated clean energy investments in solar and wind, which are great near-term solutions for decarbonization, but neglected to invest sufficiently in continuous energy solutions like geothermal energy, which are necessary to reach full decarbonization in the long term.” As also pointed out, “the increasing mix of intermittent renewable energy sources like solar and wind must be balanced by sources of clean firm power that are available around the clock in order to ensure grid reliability and reduce the need to overbuild solar, wind, and battery capacity. Geothermal power is a leading contender for addressing this issue.”¹⁸

A January 2024 Federation of American Scientists report describes how increased government support could help commercialize clean energy, including geothermal power and heat technologies.

“Next-generation geothermal technologies, such as enhanced geothermal systems (EGS), closed-loop [CLG] or advanced geothermal systems (AGS), and other novel designs, promise to allow access to a wider range of geothermal resources. Some designs can potentially also serve double duty as long-duration energy storage. Rather than tapping into existing hydrothermal reservoirs underground, these technologies drill into hot dry rock, engineer independent reservoirs using either hydraulic stimulation or extensive horizontal drilling, and then introduce new fluids to bring geothermal energy to the surface. These new technologies have benefited from advances in the oil and gas industry, resulting in lower drilling costs and higher success rates. Furthermore, some companies have been developing designs for retrofitting abandoned oil and gas wells to convert them into geothermal power plants. The commonalities between these two sectors present an opportunity not only to leverage the existing workforce, engineering expertise, and supply chain from the oil and gas industry to grow the geothermal industry

but also to support a just transition such that current workers employed by the oil and gas industry have an opportunity to help build our clean energy future.”¹⁹

“The expansion of the [worldwide] geothermal industry presents considerable employment opportunities as well, with more than 196,000 individuals employed in 2021 according to the International Renewable Energy Agency’s 2021 Annual Review. Many of these workers bring transferable skills and expertise from the oil and gas sector, facilitating a smooth transition.”²⁰

As proposed in May 2024, the 2025 federal budget promises to be instrumental in training and employing our vital future science and energy workforce.

A March 2024, New York Times article stated,

“the growth of artificial intelligence requires huge data centers to train the evolving large-language models, making proximity to users less necessary...But as more of these sites start to pop up across the United States, there are new questions on whether they can meet the demand while still operating sustainably. The carbon footprint from the construction of the centers and the racks of expensive computer equipment is substantial in itself, and their power needs have grown considerably...Just a decade ago, data centers drew 10 megawatts of power, but 100 megawatts is common today.”... “The Uptime Institute, an industry advisory group, has identified 10 supersize cloud computing campuses across North America with an average size of 621 megawatts...This growth in electricity demand comes as manufacturing in the United States is the highest in the past half-century, and the power grid is becoming increasingly strained.”²¹

“A.I. is only a small percentage of the global data center footprint. The Uptime Institute predicts A.I. will skyrocket to 10 percent of the sector’s global power use by 2025, from 2 percent today”²²

The May 5, 2024, Economist magazine cited the latest quarterly reports from Alphabet (Google’s corporate parent), Amazon and Microsoft, stating that

“the world’s cloud-computing giants—collectively invested \$40bn between January and March, most of it in data centres equipped to deal with growing artificial-intelligence (ai) workloads. Last month Meta, which does not have a cloud business but does run a data-hungry social-media empire, said its capital expenditure could reach \$40bn this year as a result of AI-related projects. That is not far off the \$50bn that Saudi Aramco, an oil colossus, is planning to splurge. Microsoft is likely to spend more.”

Artificial Intelligence (A.I.) is poised to revolutionize the energy sector, mirroring the transformative effects of the Internet and mobile communications on global economic growth, according to a recent article by Wood Mackenzie.²³ A.I. promises to raise demand for energy, drive efficiencies, support low-carbon technologies, and address climate change while boosting the global economy. A.I.'s reliance on power-intensive data centers will necessitate massive investments in geothermal power generation to deliver power “behind the meter.” As proof, tech companies are signing new power purchase agreements with early-stage geothermal companies.

And independent power producers are considering building data centers at existing generation facilities.²⁴

In November 2023, Google announced that its data center project powered by geothermal energy is now operational:

“To make the rapid progress needed to address climate change, we must accelerate a clean energy transition on a planetary scale. That’s why we set an ambitious goal to operate our data centers and office campuses on 24/7 carbon-free energy (CFE) on every grid where we operate by 2030, with the ultimate aim of accelerating the decarbonization of the world’s electricity systems.

Many industrial and commercial facilities around the world are seriously examining the feasibility of applying geothermal energy, particularly for plants operating in power systems where the costs of firm power have increased with higher penetrations of intermittent solar and wind generation. For example, Lazard’s 2023 and 2024 Cost of Energy Studies²⁵ estimate how grid firming costs increase as the levels of intermittent generation go up in California. As illustrated previously in Figure 5, firming costs in California now exceed traditional LCOE values.

The Advantages of Geothermal Energy Today

Today, geothermal energy systems offer the most reliable, resilient, 24/7, continuous power and heat with the smallest footprint and lowest lifecycle costs of all renewable resources.

Geothermal projects add more jobs, have more secure domestic supply chains, and create more environmental benefits than solar or wind. Geothermal is largely carbon free and can also displace natural gas for heating. It can help balance the grid and provide baseload power and system diversity, as well as enhancing international energy security by reducing the risks of sabotage and deliberate disruptions in energy trade across borders.

Geothermal energy is weather independent and will still be operating when events like the explosion of Mt. Tambora in 1815 obscure the sun globally for months, and solar power systems cease to function.

What do we need to do?

Reductions in permitting time for projects, increased exploration and increased RD&D will make geothermal learning curves more robust and bring down costs. Geothermal technologies can provide energy assurance to individual companies, district heating projects and to regional electricity grids.

If we are serious about global decarbonization and electrification, we need to recognize that geothermal energy is now an essential energy resource.

Conclusions

Electricity continues to expand its share of the global energy market, as the need for energy in all forms surges beyond even optimistic estimates. At the same time, recent events have impacted energy availability and electric grid reliability and stability, underscoring the essential importance of energy assurance. Consequently, energy intensive companies are prioritizing energy assurance and paying premium prices to obtain the mix of reliability, resilience, and stability they need. Among all clean energy sources, renewable geothermal energy offers a compelling value proposition that is driving intense interest in co-locating energy intensive companies near geothermal resources.

Thus, over the next several decades we must develop and deploy diverse clean technologies both upstream and behind-the-meter with essential reliability and resilience attributes. At the same time, we need to implement more workable markets, revise outdated government and regulatory policies, adapt the utility and energy supply business models, and encourage international cooperation.

To properly maintain and expand our complex electricity and energy systems, we need to evaluate the benefits of increased diversity and the role that continuous investments in RD&D must play to innovate, develop and build the future technologies we need to supply and deliver decarbonized heat and electricity in the U.S. and around the world.

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