Enhanced Geothermal Shot

Frequently Asked Questions

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Introduction to geothermal and enhanced geothermal systems

What is geothermal energy? What is it used for? Where is it found? What are its benefits?

- Geothermal is a renewable source of energy found beneath the Earth's surface. Wells can be drilled deep into the earth to tap naturally-occurring steam and hot water that can be drawn to the surface to generate electricity and heat and cool buildings, and for other uses.
- Geothermal energy can benefit all communities nationwide by providing clean power and heat to millions of homes and businesses without generating emissions or waste. It is a stable, resilient electricity resource that can be turned on and off as needed, which can help integrate more variable forms of renewable power onto the grid. In addition, geothermal energy used directly to heat and cool homes and buildings provides a method to mitigate a major emissions source and reduce the use of fossil fuels.
- Geothermal resources naturally occur everywhere on Earth; however, variability in rock temperature, rock permeability (ability for fluid to flow through rock), and other geologic conditions influence the cost-effectiveness of the resource.

What are enhanced geothermal systems (EGS)?

- When found together and in sufficient amounts, heat, water, and permeability (ability for fluid to flow through rock)—the principal elements needed to capture geothermal energy—can support cost-competitive rates of energy extraction. While heat exists everywhere on Earth, some locations lack adequate water and/or permeability to make it accessible.
- Enhanced Geothermal Systems (EGS) create man-made geothermal reservoirs in places where naturally favorable amounts of permeability and/or water are lacking. EGS reservoirs are created by first drilling wells and then pumping water to create permeability. The new reservoir then has the three principal elements necessary for water to be circulated continuously and be used for electricity production or direct use.
- While there are technically over five terawatts of geothermal energy potential in the United States (enough to meet the electricity needs of the entire world many times over), most is in areas accessible only via new humanmade geothermal reservoirs such as EGS.

What are the key challenges to scaling up EGS?

- EGS deployment faces both technical and economic challenges, but current R&D to overcome these challenges is promising.
- The first technical barrier to EGS, as well as currently-existing conventional geothermal energy, is simply visibility: geothermal is a "hidden" resource. Because we can see the sun, we easily know how much solar power is available for use; understanding the heat and other conditions below the surface of the Earth is much more challenging. Often, sufficient heat for EGS reservoirs is very deep (2 miles deep, or more). We currently can't "see" what is that far below the subsurface, but advancements to sensor technologies and high-performance computing are promising and are already being used in other subsurface technologies.

- The second technical barrier to EGS is the unique extreme environments found at great depths. EGS reservoirs often must be created in extremely hard rock—10–20 times harder than sidewalks—which can rapidly destroy drilling equipment. These environments can also be highly corrosive, which can further impact tools, electronics, and wellbore durability. Advances in the development of new resistant materials are beginning to overcome these challenges.
- These technical challenges mean that EGS is not currently cost-competitive other forms of electricity. With technology improvements, though, EGS could be engineered cost effectively wherever there is hot rock at accessible depths, enabling economic capture of EGS potential nationwide.

Why do we need an EGS Energy Earthshot?

- EGS is a realistic pathway to a constant, renewable, waste-free resource. These qualities are a necessary complement to the intermittent electricity generated from solar PV and wind turbines, and critical for achieving President Biden's goal of a fully-decarbonized electric grid by 2035.
- EGS holds great promise. As mentioned above, the Earth has a virtually inexhaustible heat resource; with technology improvements and economies of scale, EGS could provide clean, dependable power and heat anywhere in the United States. This would open opportunities for gigawatt-scale geothermal energy deployment and greatly increase opportunities for geothermal heating and cooling solutions nationwide.
- DOE's Enhanced Geothermal Shot enables a cost reduction of more than 90% to less than $40/MWh across the United States.

How will DOE work to achieve the Enhanced Geothermal Shot goals?

- Striving towards the goals of the Enhanced Geothermal Shot will require significant research, development, and demonstration in EGS systems.
- DOE is supporting this work through multiple initiatives, including its flagship Frontier Observatory for Research in Geothermal Energy (FORGE)—which recently announced $44 million in new R&D funding—and its Geothermal Energy from Oil and gas Demonstrated Engineering (GEODE) initiative, which will provide up to $155 million to transfer best practices and workforce from the oil and gas industry to geothermal energy. DOE will also support $84 million in funding for four new EGS demonstration projects under the Bipartisan Infrastructure Law.

How do we know EGS works?

- Over the last decade, new understanding, philosophical shifts, technological advances both adapted from the shale revolution and from high-performance computing, and successes within the DOE Geothermal Technologies Office (GTO) research portfolio, place EGS on the cusp of commercialization in the United States.
- Transformational advances 3-D modeling, for example, have changed the way we design projects, drill wells, and create reservoirs, increasing the chance of project success.

- Technology and workflow advances adapted from oil and gas have expanded our ability to precisely direct fluid flow below ground; this capability has been critical for successful oil and gas extraction, and is similarly critical for efficient mining of geothermal heat. These advances have also improved our ability to site wells in the optimal places to ensure successful results.
- EGS is in the same technological place today that shale gas was twenty years ago—theoretically robust, practically feasible, but so-far-unproven. Over the last two decades, trial-and-error improvements on over 500 wells took shale gas technology from theoretical to exceedingly profitable (see Hovey, 2010). To date, less than 20 EGS demonstrations have been tried, but with this Energy Earthshot, we intend to drive a large increase in the number of EGS deployments, and in doing so, realize similar dramatic advances in cost and performance
- EGS advances are now being demonstrated worldwide, both in the public and private sectors.
- In the United States, DOE currently funds a major EGS demonstration in Milford, Utah, called Frontiers of Research in Geothermal Engineering (FORGE) that has demonstrated order-of-magnitude improvements in drilling rates and successful rock stimulation.
- DOE also has successfully funded two EGS demonstration in areas near existing conventional geothermal power plants:
    - Desert Peak, Nevada. Ormat Technologies stimulated a non-commercial well on the periphery of its operating conventional geothermal system at Desert Peak with the goal to evaluate characterization tools and methodologies, stimulation technologies, and—ultimately—improve the permeability enough to connect the well to the existing power plant. Following the successful result of a 1.7MW increase at Desert Peak, a permanent pipeline was built to Desert Peak 27-15 and has been in use since project completion.
    - The Geysers in northern California. The Geysers project reopened and deepened two previously abandoned wells as an injection and production well pair, respectively, to stimulate and produce from beneath the normal Geysers reservoir. The steam contributed by the two production wells within the EGS produce an additional ~5.8 MW of power.
- In the private sector, companies such as Fervo Energy have raised the necessary funds to successfully drill and stimulate EGS reservoirs.
- Internationally, France has had a commercial EGS system for some time. The deep EGS project at Soultz-sous-Forêts in Alsace has provided clean energy to France's grid since 2011. In 2016, France also inaugurated the Rittershoffen deep geothermal power plant, which provides heat to local industrial plants using EGS technologies.

How do EGS investments impact the buildings sector?

- Advancing EGS technologies can also expand access to geothermal energy for us in the heating and cooling sector.
    - Geothermal heat pumps (GHPs) can be deployed in 28 million U.S. households by 2050, serving close to 25% of the entire U.S. heating and cooling market (Liu et al. 2019). GHPs represent a deployment-ready technology that offers a crucial pathway to decarbonize heating and cooling for single family homes, campuses, and cities across the United States.

  - Geothermal district heating (GDH), where geothermal energy heats buildings through a distribution pipeline network, has the promise to offset fossil fuel used for heating individual, commercial, and industrial buildings. By 2050, up to 17,500 GDH systems can be deployed in population centers along the U.S. Eastern Seaboard, the Ohio Valley, Texas, and portions of the Southwest, serving 45 million households (McCabe et al. 2019).

- However, these significant deployment opportunities will not happen without technology development and investment. If geothermal develops along a "business as usual" pathway, only minimal growth and market share by 2050 will be realized—less than 1% in the electric sector and 7% in heating and cooling.

Workforce Development, Climate, Health Benefits and Environmental Justice

How will EGS support a just transition to a clean energy workforce?

- The goal of this Enhanced Geothermal Shot is to expand geothermal as a clean energy industry, and we have an opportunity to do so in an equitable, responsible way. Expanding EGS deployment—and geothermal in general—can offer a seamless transition to the hundreds of thousands of oil and gas workers as they seek new roles in a clean energy industry, using the skills they already have.
- The oil and gas and geothermal industries have numerous similarities that provide new opportunities for geothermal expansion—from advances in drilling and well construction to retrofit possibilities of abandoned oil and gas wells.
- The Geothermal Technologies Office has announced $165 million for the creation of a consortium to address technology and knowledge gaps in geothermal energy, based on best practices used within the oil and gas industry. Accessing the expertise, technologies, and experience of the larger domestic oil and gas industry can help overcome barriers and encourage private investment in geothermal energy.

What impact will scaling up geothermal energy have on greenhouse gas emissions?

- DOE's *GeoVision* analysis found that, by 2050, deployment of low-carbon geothermal energy can help address the climate change crisis by offsetting more than 500 million metric tons (MMT) of greenhouse gases in the electric sector and more than 1,250 MMT in the heating and cooling sector—the equivalent of removing 26 million cars from the road every year (U.S. DOE 2019).

What impact will scaling up geothermal energy have on air pollution?

- Expanding geothermal will also help reduce air pollution by reducing demand for fossil fuel generated electricity and heating. Specifically, *GeoVision* also found that, by 2050, deployment of low-carbon geothermal energy could lead to a reduction of 279,000 metric tons of sulfur dioxide (SO2), 417,000 metric tons of nitrogen oxides (NOx) pollution, and 54,000 metric tons of PM 2.5, also known as soot. These pollution reductions will be present across the country, but especially in Texas and the southwestern United States.

How will working toward the Enhanced Geothermal Shot goal advance environmental justice?

- In addition to reducing greenhouse gas emissions and air pollution, which disproportionately impact underserved, overburdened, and frontline communities, DOE is working to ensure that communities historically left behind in federal programs and spending are able to access the benefits of the energy transition. Specifically, all DOE funding opportunities conducted under the Enhanced Geothermal Shot will seek to drive 40% of the overall benefits to these communities, as established by President Biden's Justice40 initiative. Learn more about DOE's commitment to Justice40.

Environmental and land concerns

Is induced seismicity a concern with EGS?

- While movement of fluids into or out of any well (water, oil and gas, geothermal) can induce or trigger some level of seismic or microseismic activity, a National Research Council study, "Induced Seismicity Potential in Energy Technologies," found that geothermal does not pose a high risk for inducing felt seismic events because fluid that is introduced into the subsurface is removed from the subsurface.
- DOE has proactively addressed potential concerns about EGS including seismicity by developing best practices and protocols identifying issues and parameters that can help industry and regulators evaluate and mitigate any adverse effects of induced seismicity. All DOE-funded EGS projects are required to follow these best practices and protocols.
- In recent years, the geothermal industry has also made great strides in technologies that allow practitioners and scientists to target their efforts underground during EGS reservoir creation (e.g., zonal isolation technologies). Being able to surgically target specific areas underground reduces the uncertainty of location and magnitude of certain impacts, such as induced seismicity.
- DOE also recently announced the Geophone Prize, which will provide $3.65 million in prizes and incentives for innovations related to downhole seismic sensors, or geophones. These sensors help researchers and industry professionals better understand and track changes in the subsurface during EGS stimulation.

Is well construction and integrity a concern for geothermal and EGS wells?

- Well construction techniques and practices can impact the public's health and welfare in significant ways. That is why ensuring the safe, responsible, and transparent construction, use, and abandonment of all types of wells, including EGS wells, will continue to be a priority for the Department of Energy.
- Well construction and integrity is significant when assessing geothermal project cost, however. DOE is currently identifying the R&D opportunities that could lower the costs of well construction. These opportunities could include lowering production costs of well cement, more efficient casing and deployment methods, or advanced casing systems.

Does EGS contaminate water? How do these risks compare to those of oil & gas (fracking)? Do geothermal power plants dispose of nasty fluids to surface water or groundwater?

- Water contamination risks due to EGS reservoirs are low for two reasons: 1) EGS reservoirs are generally much deeper than oil and gas reservoirs, which means they are disconnected hydrologically from any groundwater or near-surface drinking water supplies both through natural geology and well casing; and 2) geothermal power plants do not release any water on the surface; rather, all water is reinjected into the same underground reservoir from which it was drawn, again and again.
- This design is essential to protect aquifers as well as to ensure continuous operation of geothermal power plants because they rely on sufficient fluid to bring geothermal heat to the surface.

What kind of water does geothermal use to create reservoirs and generate electricity? What research is being done to reduce their environmental impact?

- EGS requires water to create reservoirs and generate electricity; however, that water does not need to be drinkable. For example, The Geysers Geothermal Field in Northern California uses secondary treated wastewater for geothermal injection activities.
- Fluid used for EGS can range from potable to waters that are useless to municipalities and farmers because they contain high total dissolved solids and can never be released into drinking water streams. Local and national permits and regulations that ensure safe water quality must be adhered to with any federally funded EGS project.
- DOE funds research that can reduce or replace the need for water in EGS reservoir creation. This includes projects that develop novel and/or improved technologies to enhance permeability in geothermal wells utilizing stimulation methods that do not require the use of water, with an emphasis on eliminating fresh water sources as a primary source of the fracturing fluid.

Is the quantity of water used a concern with geothermal energy, and EGS in particular?

- Significant increases in deployment should not materially impact the water needs of the wider electric system. DOE analysis indicates that almost all of the geothermal energy growth we envision could be supported by non-freshwater resources, such as municipal wastewater and brackish water. This means that geothermal deployment growth could be supported even where access to freshwater is limited.
- Conventional geothermal energy is water efficient, using 1.4 to 4 gallons of water per kilowatt-hour of electricity (source: Union of Concerned Scientists), compared to 13 gallons for traditional power generation (source: EIA).
- EGS has a small water use impact relative to its opportunity to provide energy. EGS can potentially provide 8.5% of total electricity generation in the United States, but only withdraw 1.1% of the water needed for the power sector.

- Continued innovation in EGS technologies and making EGS development activities more efficient can help further reduce water use as deployment expands.

What kind of environmental reviews do geothermal projects go through?

- Any project either funded with Federal dollars or occurring on Federal lands triggers a review under the National Environmental Policy Act (NEPA), where DOE and permitting agencies work together to explore the potential environmental effects of the project.

- If a project is found to NOT have a categorical exclusion (CX) or a Finding Of No Significant Impact (FONSI), DOE will prepare, review, and make decisions based upon the findings in an Environmental Assessment (EA) or Environmental Impact Statement (EIS), the latter of which includes public input and more data and analysis. An EIS is a lengthier process and requires more data, information, and stakeholder buy-in.
- An EIS analyzes the environmental impacts of a proposed project, any impacts that cannot be avoided should the project move forward, alternatives to the proposed project, and the irreversibility of those impacts. In addition, an EIS requires agencies to analyze the project's human health, economic, and social effects, specifically within minority and low-income populations.
- The responsible agency will review the completed EA or EIS and decide whether to move forward.
- All NEPA-related documents, including the EA or EIS and the Records of Decision, are available to public officials and citizens before any actions are taken.