

2021 Geothermal Rising Conference

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The Benefits of Geothermal Power, Evolution of the U.S. Electricity Grid, and the Need for Geothermal Research and Development



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SCD ENERGY SOLUTIONS

BLADE ENERGY PARTNERS

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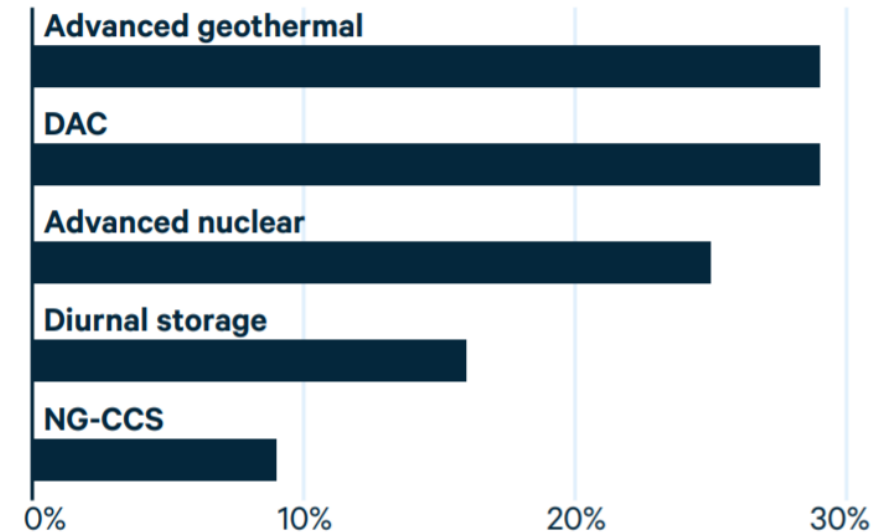
Presentation Topics

- The Benefits of Geothermal Power Compared to Advanced Technologies
 - Benefit/Cost Ratios & Estimated Cost Reductions from U.S. RD&D Funding
 - Uncertainty Ranges for Levelized Costs with & without U.S. RD&D Funding
- The Evolution of Power Technologies & U.S. Electricity Markets
 - Leading Power Generating Technologies Since 1950 – Geothermal Is Next Up
 - California: Where More Geothermal Capacity Would Avoid Future Blackouts
- Sustained RD&D is Needed for EGS and CLG Geothermal Technologies
 - Investment to Date in Geothermal Energy Systems Has Been Low
 - Critical RD&D Areas Include:
 - Improved Drilling, Completion, Monitoring and Analytics of Geothermal Wells,
 - Expanded Geothermal Resource Exploration, and
 - Demonstration Projects in Steam Dominated Resources, Two-Phase Reservoirs and in Deeper, Hotter Dry Rock Systems

Estimated Benefits of 10-Year U.S. RD&D Funding

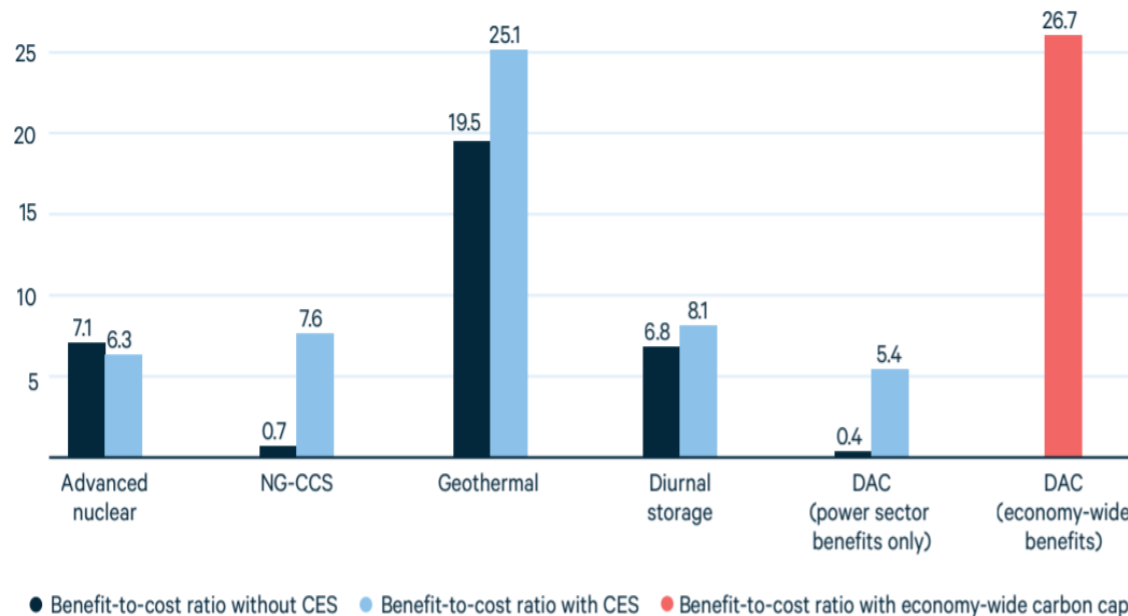
Resources for the Future, “The Value of Advanced Energy Funding: Projected Effects of Proposed US Funding for Advanced Energy Technologies, April 2021. <https://www.rff.org/publications/issue-briefs/projected-effects-of-proposed-funding-for-advanced-energy-technologies/>

Estimated Average Cost Reductions in 2035 Due to 10-Year RD&D Funding

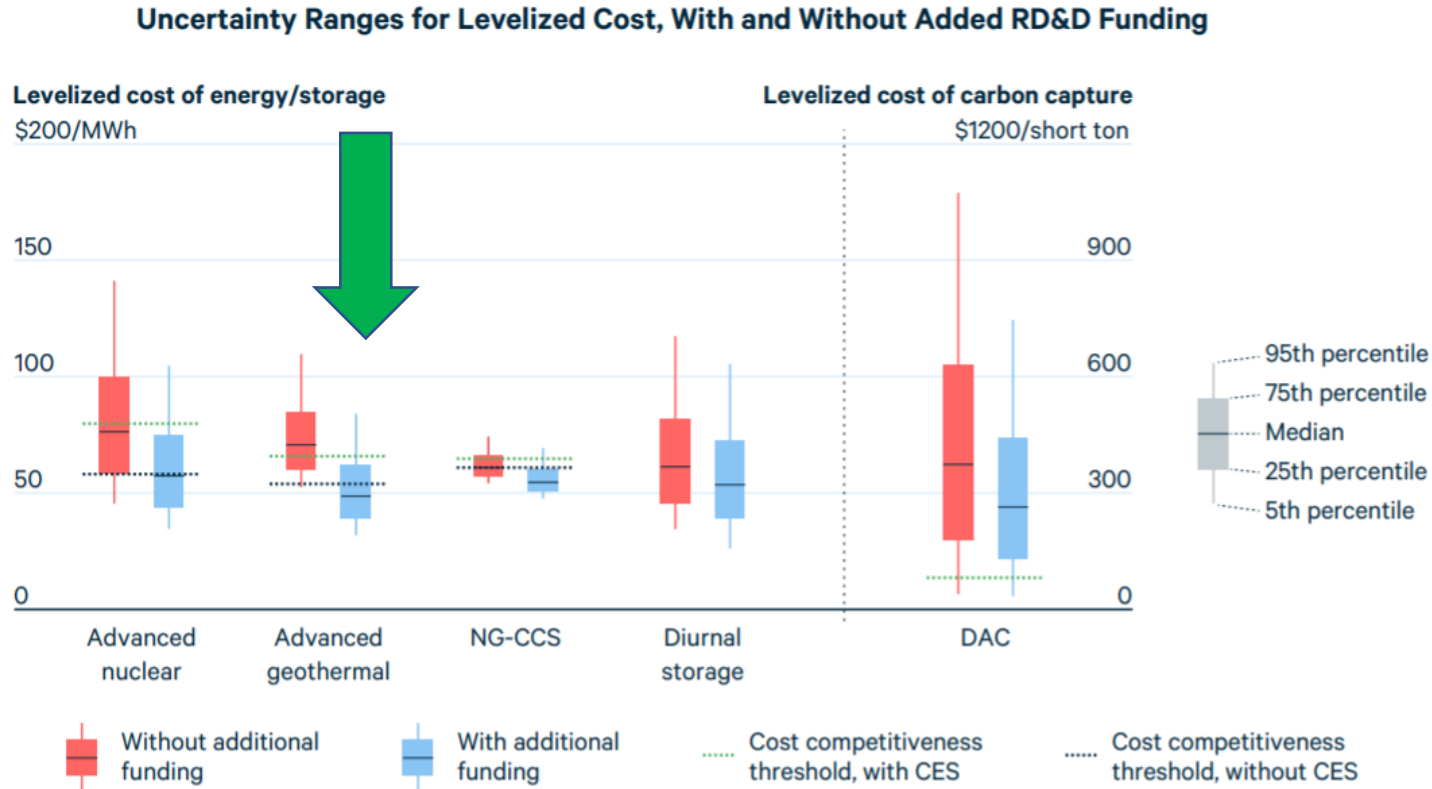


Advanced Geothermal
 Direct Air Carbon Capture (DAC)
 Advanced Nuclear Power
 Diurnal Energy Storage
 Natural Gas – Carbon Capture & Sequestration
 CES: a U.S. national Clean Energy Standard – 94 percent clean power by 2050.)

Estimated Benefit-to-Cost Ratios from 10 Years of RD&D Funding

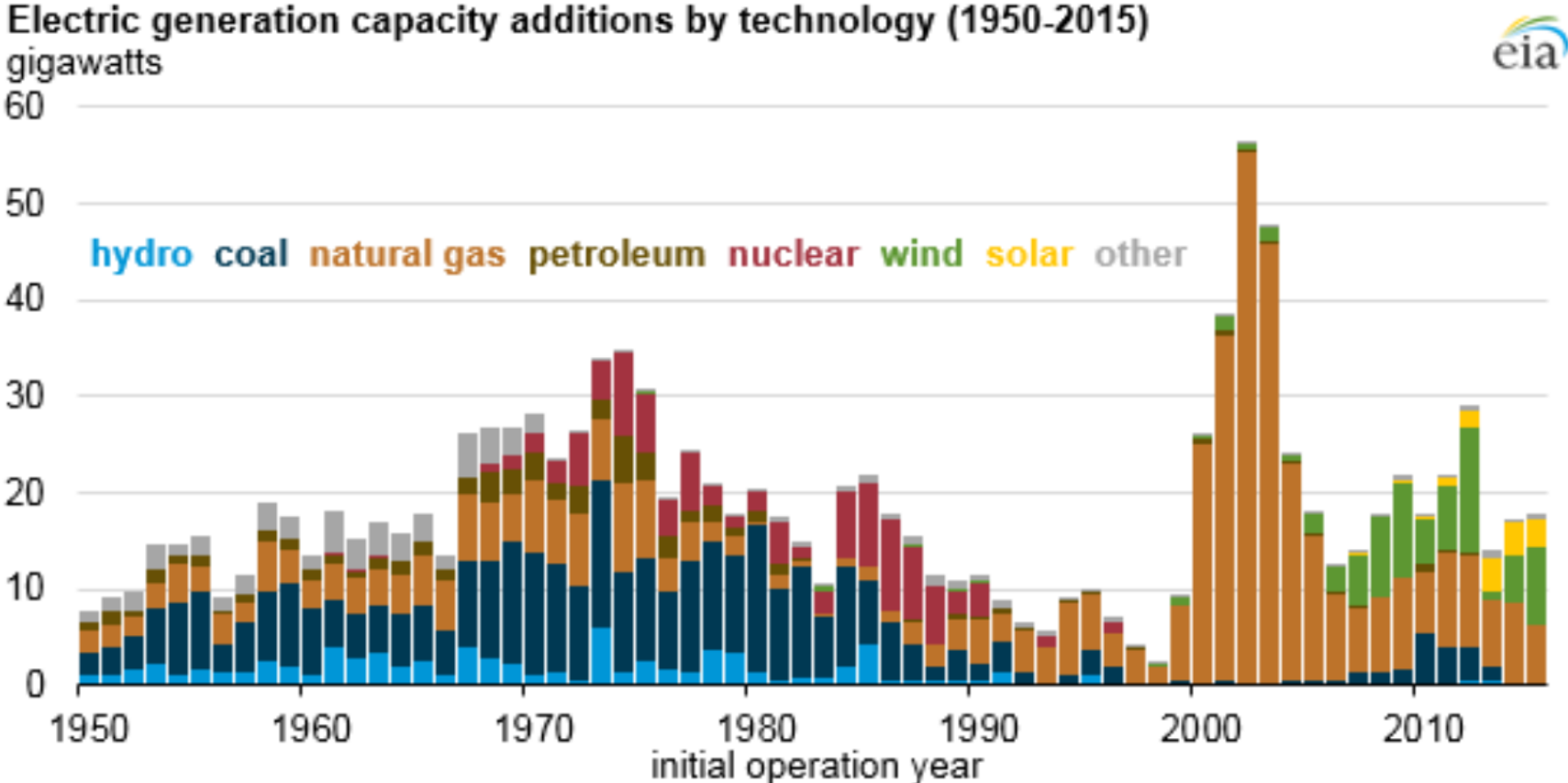


Levelized Cost Ranges With & Without 10-Year U.S. RD&D Funding for Advanced Energy Technologies



Resources for the Future, “The Value of Advanced Energy Funding: Projected Effects of Proposed US Funding for Advanced Energy Technologies, April 2021. (NG-CCS: Natural Gas-fired Generation with Carbon Capture & Sequestration, DAC: direct from-air capture of CO₂, CES: a national Clean Energy Standard that requires 94 percent clean power by 2050.)

The Preferred Electric Generation Technology Has Changed in Each Era

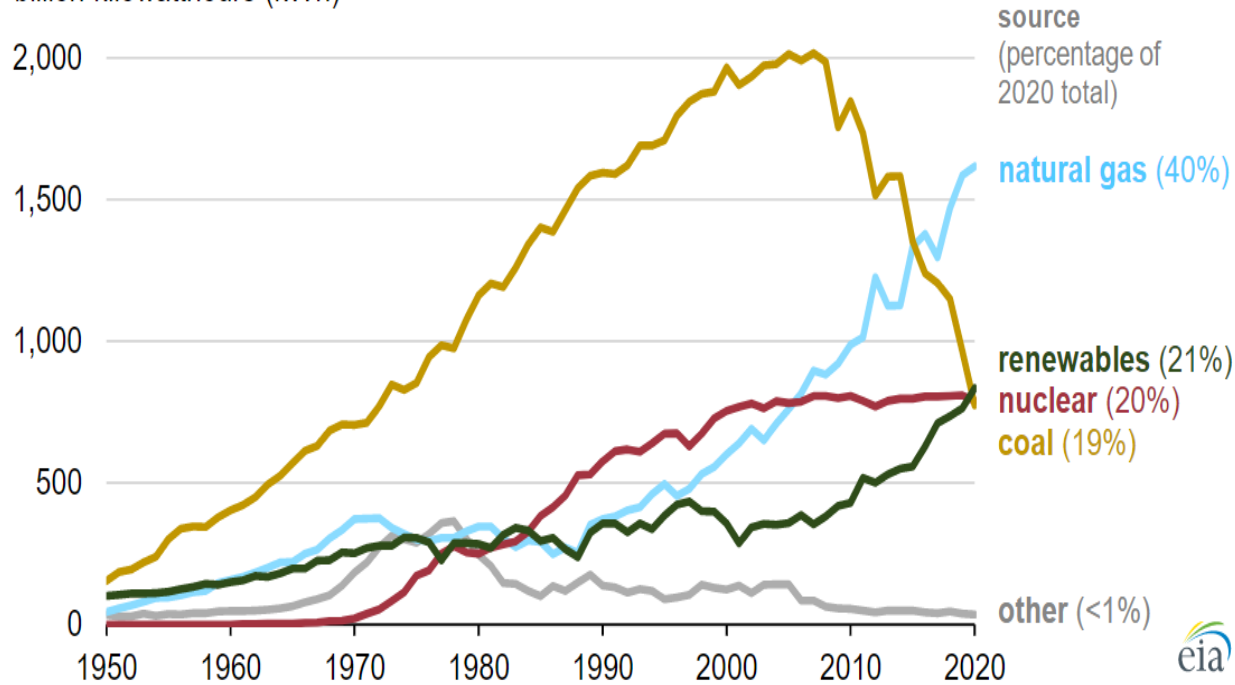


Source: U.S. Energy Information Administration, *Monthly Electric Generator Inventory*, and Platts Electric Capacity Database

Renewable Power Now Leads the Way Forward

Annual U.S. electricity generation from all sectors (1950–2020)

billion kilowatthours (kWh)

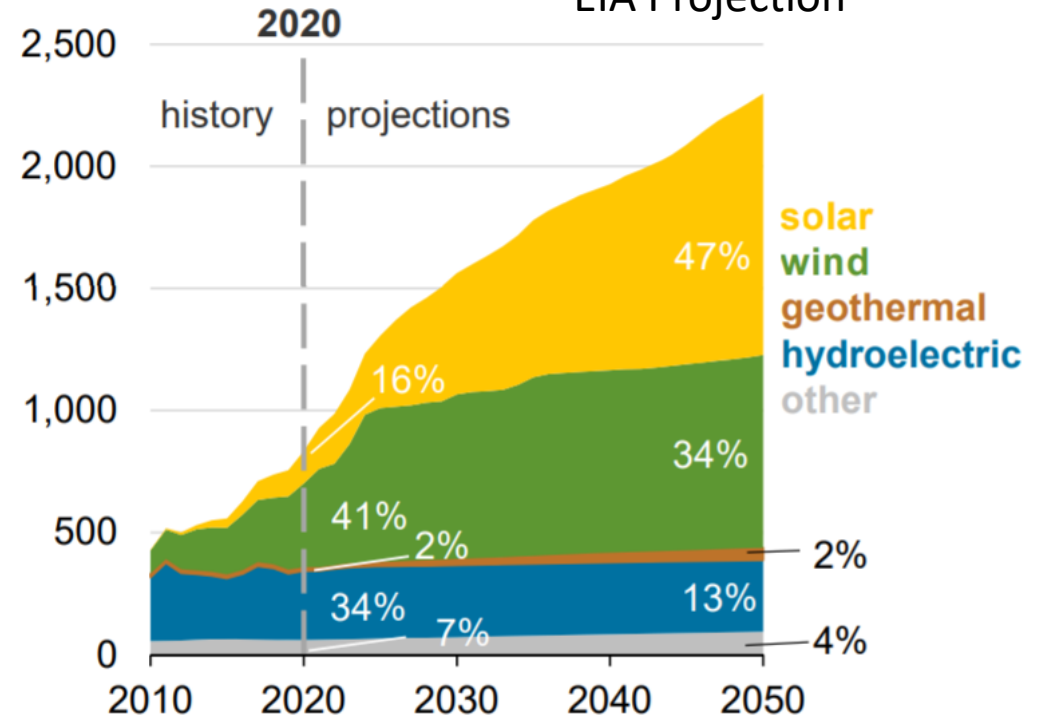


Source: U.S. Energy Information Administration (EIA), *Monthly Energy Review*

Note: This graph shows electricity net generation in all sectors (electric power, industrial, commercial, and residential) and includes both utility-scale and small-scale (customer-sited, less than 1 megawatt) solar.

U.S. renewable electricity generation, including end use AEO2021 Reference case

billion kilowatthours



Geothermal Energy Should Become the Preferred Renewable Technology Due to Its Better Attributes

Why Geothermal Energy Is Preferable

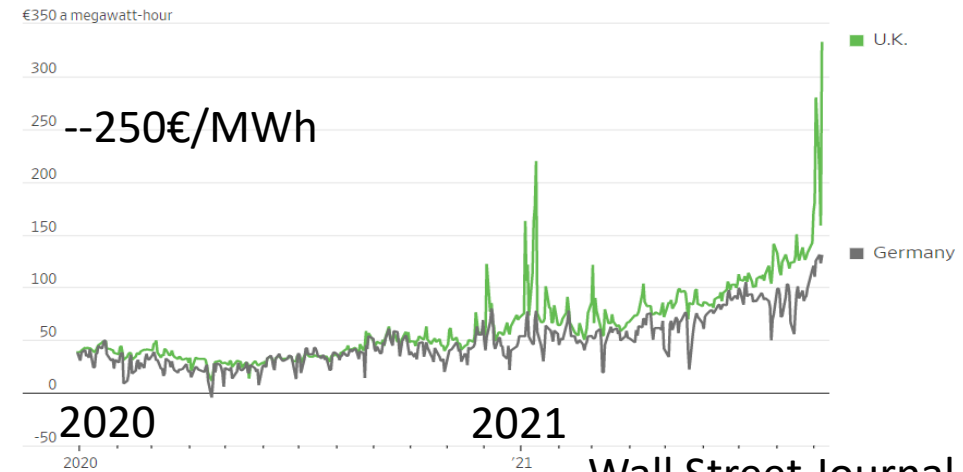
- The Earth's battery is an inexhaustible resource
- Power plant availabilities are over 90% - Always On, Secure Fuel
- Baseload & Dispatchable power from a Much Smaller Footprint
- More cost-competitive than solar and wind, even with storage
- Lower Lifecycle Impacts & Costs

Geothermal Energy Complements Intermittent Wind & Solar, Yet Does More

- “Lack of Wind Is Blow to Europe”

- https://www.wsj.com/articles/energy-prices-in-europe-hit-records-after-wind-stops-blowing-11631528258?mod=searchresults_pos1&page=1

Wholesale day-ahead power prices since 2019



Note: €1 = \$1.18
Source: ICIS

Wall Street Journal
September 13, 2021

Why Closed Loop Geothermal (CLG) Systems Are Becoming a Preferred Geothermal Technology

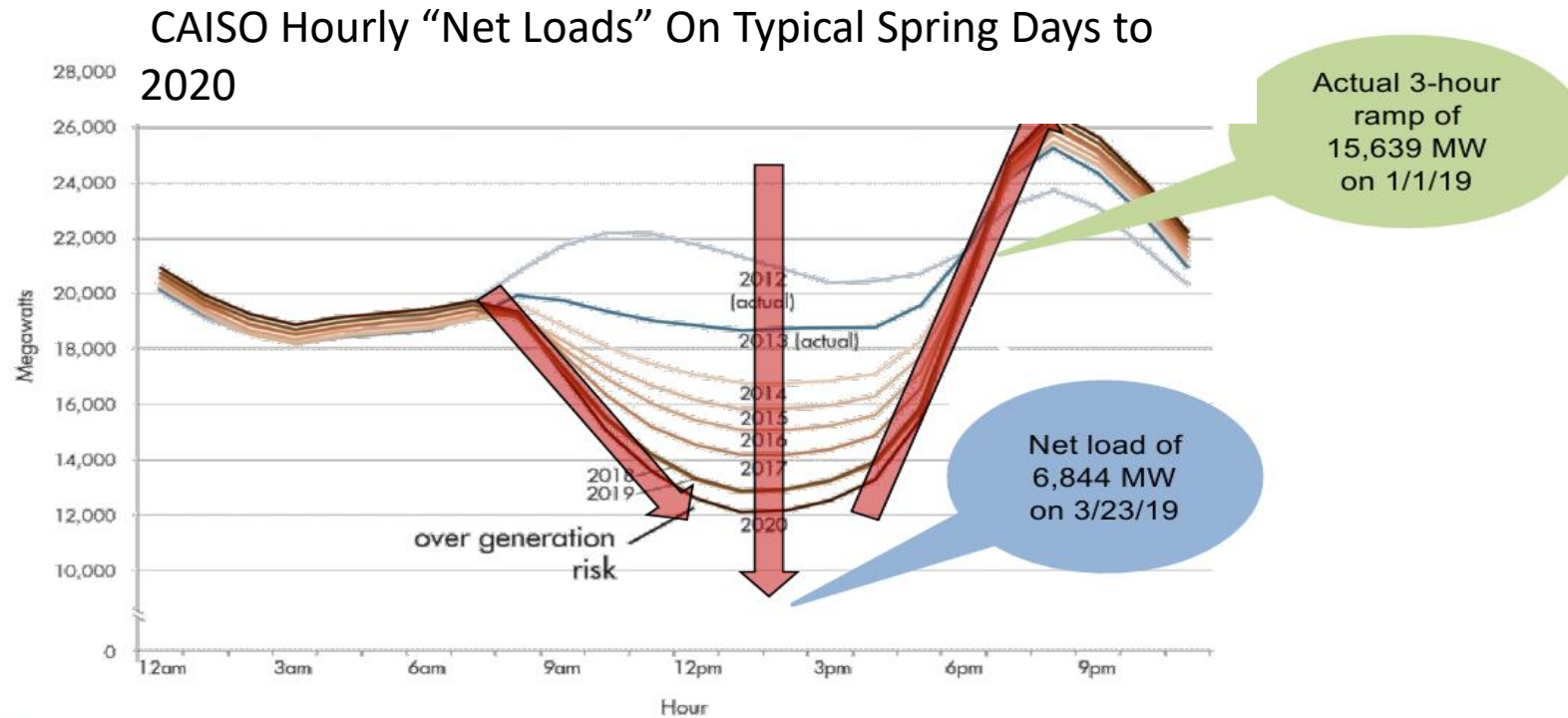
Enhanced Geothermal Systems (EGS)

- EGS are open systems that require geofluid/water flowing within a hot reservoir.
- Permeability is needed, which may be enhanced by GeoFracking.
- Brine pumping, treatment & re-injection need parasitic power.
- Water consumption is continuous.
- More permitting requirements and longer lead times to revenue.
- Provides 24/7 reliable renewable baseload electric power.

Closed Loop Geothermal (CLG)

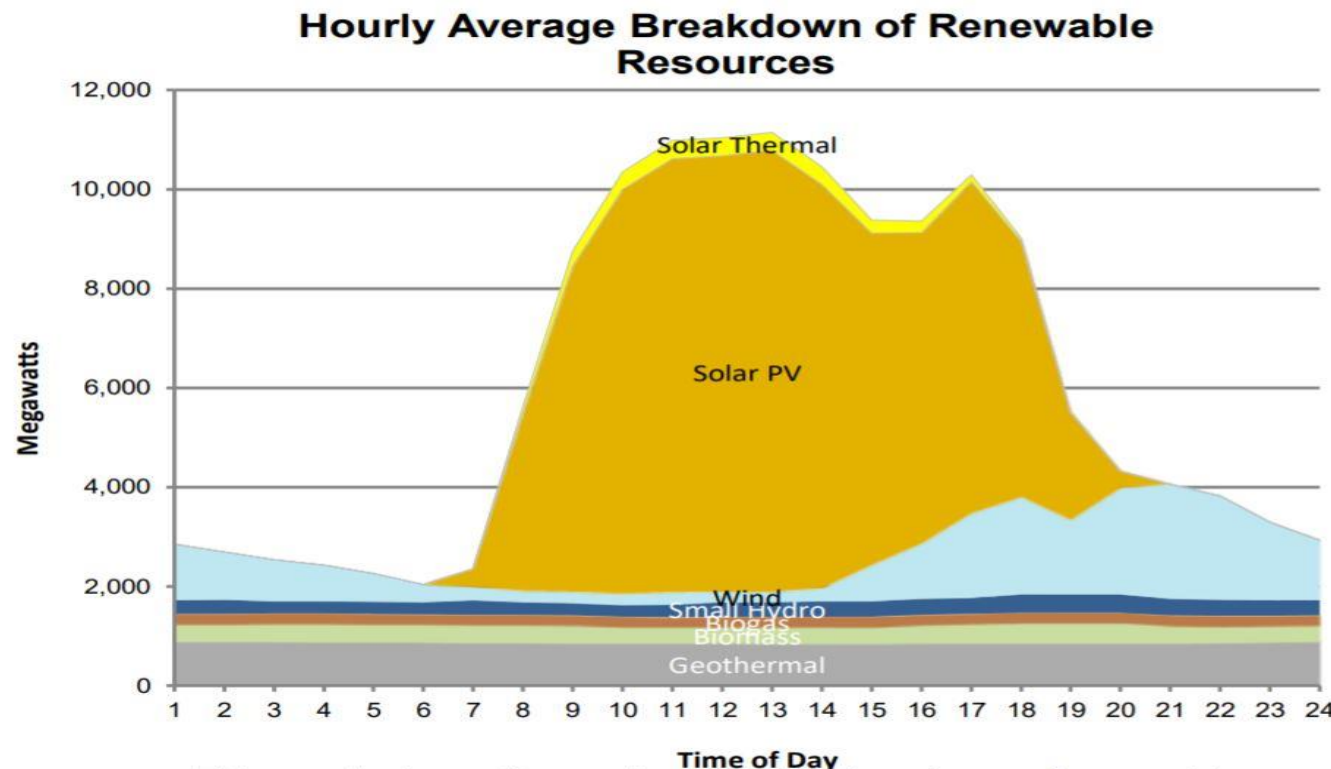
- CLG uses selected working fluids circulating within a closed system of wells & pipes.
- CLG operates in more types of hot rock – permeability is not required.
- No geofluid is injected or withdrawn – no fracking required nor induced seismicity.
- Emissions are carbon-free. Lifecycle impacts and costs are lower.
- Provides weather independent supply diversity and 24/7 baseload and dispatchable renewable power for grid reliability, grid balancing and stability.

California Illustrates Critical Grid Reliability Issues



California's Rolling Outages Were Avoidable

- August 15, 2020, Showed Why Additional Geothermal Capacity Is Needed.



This graph shows the production of various types of renewable generation across the day.

CAISO Hourly Average Renewable Generation on August 15, 2020.
http://content.caiso.com/green/renewrpt/20200815_DailyRenewablesWatch.pdf

Sustained RD&D Will Continue to Improve EGS and CLG Geothermal Technologies

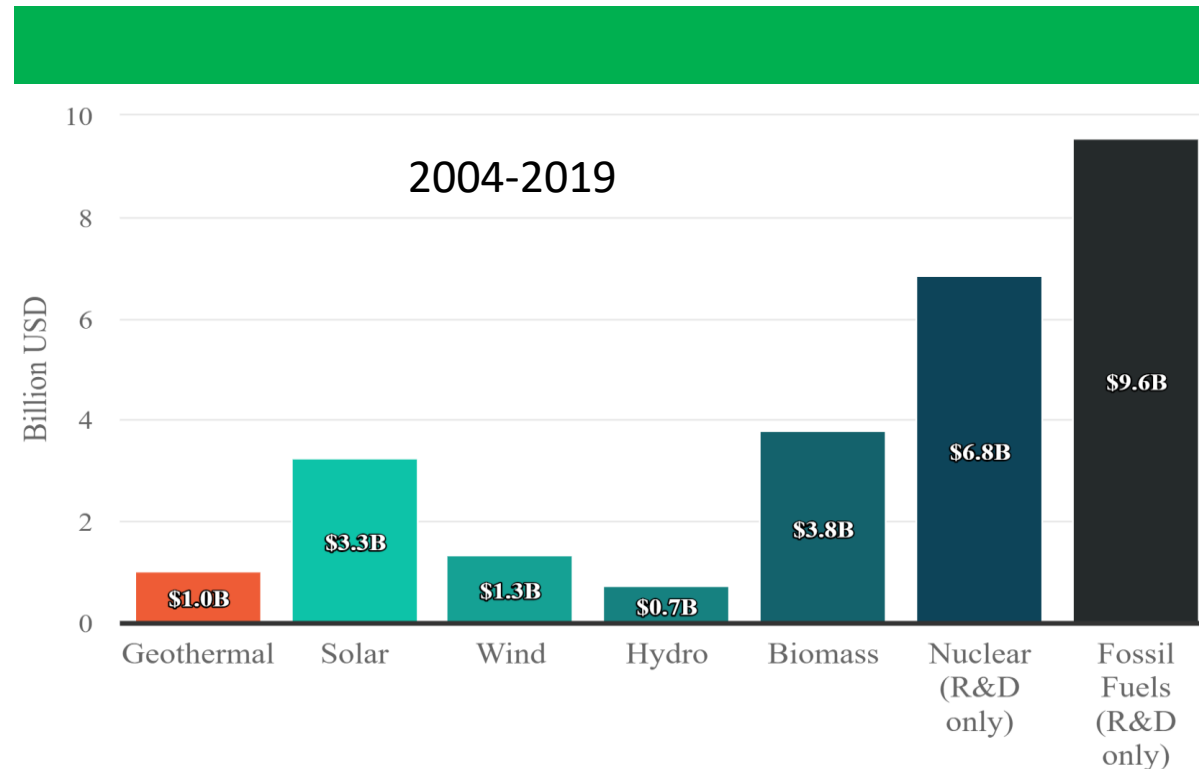
- Cumulative DOE Investment in Geothermal Technologies Has Been Low (2004-2019)

Olsen, E. “It’s Time to Take Geothermal Energy Seriously.” (2020). Online report, accessed 05/26/2021,

<https://thebreakthrough.org/issues/energy/take-geothermal-seriously>

- In 2020 global renewable energy investment was \$303.5 billion; < \$6 billion on geothermal energy.

- BloombergNEF, January 2021.





Major Advances Can
Be Made, If
Significant RD&D
Funding
Commitments Are
Made and Kept

Innovation and Advances can occur in many areas affecting geothermal technologies and project cost and performance, including:

- Resource exploration and characterization,
- Refinement of geothermal workflows and data integration,
- Well drilling, monitoring, operation, and evaluation,
- Heat transfer and thermodynamic modeling and system design,
- Downhole heat exchangers and downhole electricity production,
- Topside conversion of hot water/steam/brine/refrigerants into heat and power.

Critical RD&D for Drilling, Completion, Monitoring and Analysis of Geothermal Wells

- Research is needed to improve key well drilling and design parameters and materials, including managed pressure drilling/operation (MPD/MPO) technology, Vacuum Insulated Tubing (VIT), along with drilling, well completion, and AI methods
- Improved drills, sensors and electronics are needed for use in high pressure, high temperature (HPHT) rock formations $> 220^{\circ}\text{C}$.
- FORGE: Milford, Utah is a DOE site for developing, testing and optimizing innovative tools and stimulation techniques for EGS reservoirs by extending existing technologies and demonstrating advanced technologies.

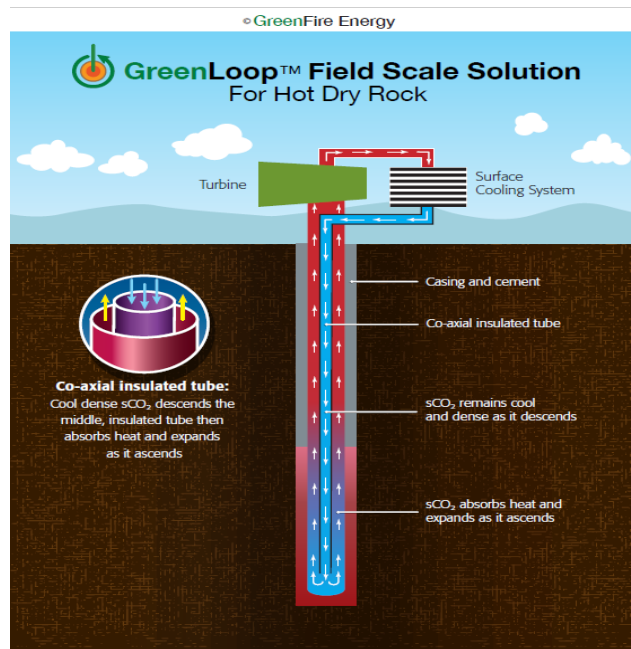


Critical RD&D for Expanded Resource Exploration

- Targeted RD&D to improve geological and geophysical (G&G) methods will reduce geothermal exploration, well drilling and production risks.
- The exploration of subsurface geothermal reservoirs can make better use of 2D and 3D imaging developed by the oil and gas industries to discover and exploit deep reservoirs of extractable geothermal heat.
- Subsurface heat maps are being compiled by USGS, SMU, UT, and Cornell. However, today's drilling technologies can go deeper than current maps, so better, deeper maps are needed.
- “Ring-of-fire” countries, tectonic plate zones and volcanic areas have excellent sites. Today, useful geothermal resources can be identified and developed, even in areas not known for geothermal heat.

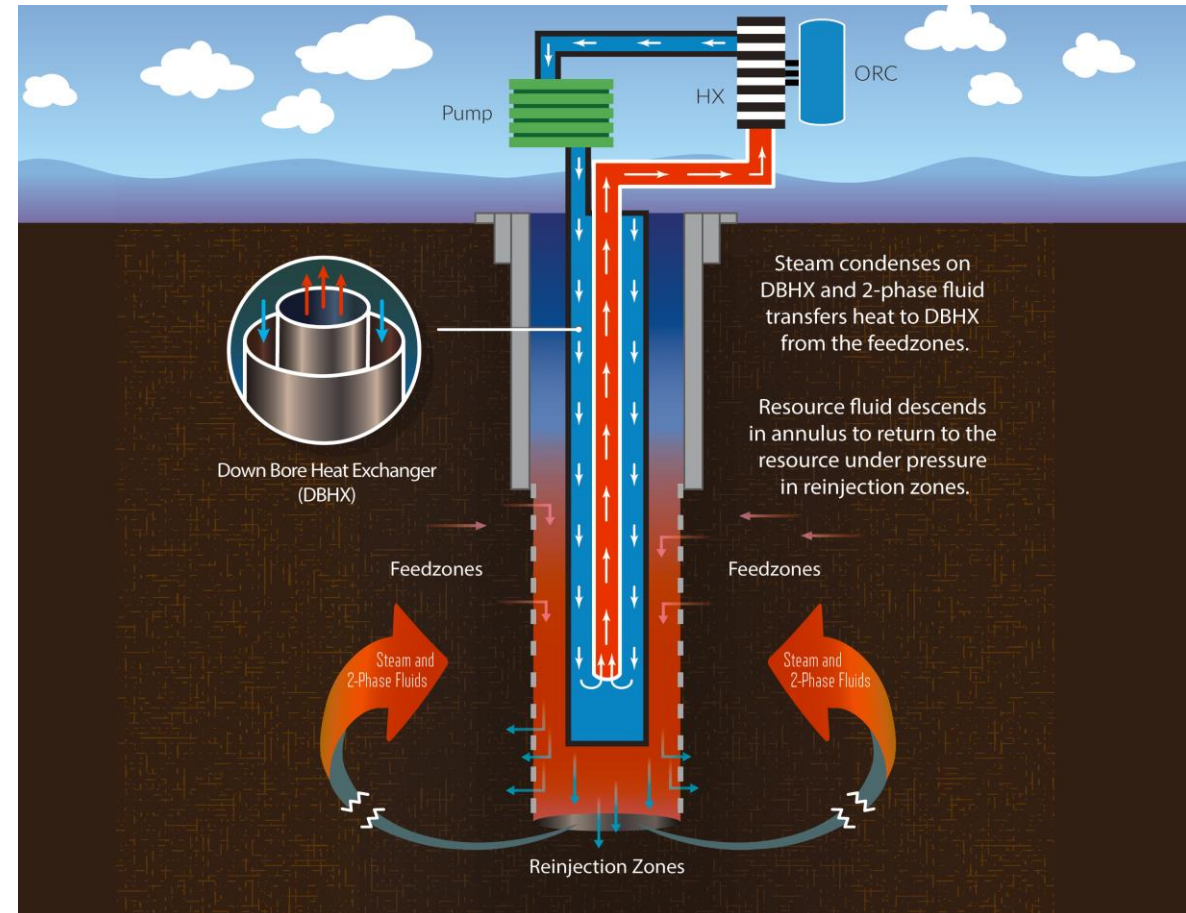
Critical RD&D via Demonstrations and Scale-up

- Demonstration Projects Will Help Advance Commercial Systems in –
 - Deep, Hot Dry Rock,
 - Steam Dominated Resources, and Two-Phase Reservoirs.



October 3 - 6, 2021

CLG Systems: GreenFire Energy's "GreenLoop" Designs for Preserving & Expanding Steam Dominated Reservoirs



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Conclusions

- Innovations & major cost reductions in Energy Technologies are spurred by Research, Development and Demonstration funding.
- Intermittent solar and wind with unproven batteries have reduced grid stability and grid balancing capabilities. What happens when smoke or global volcanic eruptions reduce their output for days or weeks?
- Climate imperatives, grid reliability and diversity, and the Global Energy Transition require carbon-free, renewable, dispatchable, fuel-secure, always available, and resilient geothermal energy technologies.
- Sustained RD&D funding for Enhanced Geothermal Systems (EGS) and Closed Loop Geothermal (CLG) will help expand the global delivery of even more reliable, resilient, economic power and heat from a broad range of global resources operating with the lowest lifecycle costs.



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- To Philip Ball, Ph.D., MBA for providing his comprehensive and informative published articles,
- To Don Winslow, formerly of Chevron, for helpful comments,
- To the California Energy Commission, EPRI, J-Power, the Shell GameChanger Program, the Coso Operating Company and the U.S. Navy for supporting the first Closed Loop Geothermal (CLG) demonstration project at Coso, California in 2018 and 2019.
- To the geothermal community for developing and deploying renewable, carbon-free, 24/7 reliable, resilient, compact technologies for electric power and heat delivery around the world.