Pathways to Commercial Liftoff:

Next-Generation Geothermal Power

Fireside Chat

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Pathways to Commercial Liftoff:

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Report Overview

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Top-Line Messages

Next-generation geothermal is poised to be a key contributor to a secure, domestic, decarbonized power generation in the US.

- Emerging technology **vastly expands the total resource available for geothermal power generation**
- **Significant and unique starting advantages:** transferrable technology, supply chains, and workforces from the oil & gas sector
- Industry is **on track to the Enhanced Geothermal Shot** target (national average LCOE of $45/MWh by 2035).
- Deployment could reach **90+ GW by 2050,** and potentially up to 300GW

Achieving liftoff will require 2-5 GW across 4-6 states and $20-25B of investment by 2030

- Achieving scale requires an additional 90-130GW of deployment $225-250 billion in investment by 2050

5 challenges to achieve liftoff and scale (potential solutions offered in report):

- High up-front costs & risks constraining development capital and limiting geographic reach
- Perceived & actual operability risk for deployments
- Long and unpredictable development lifecycles driven by permitting and interconnection
- Existing business models undervaluing the potential of next-generation geothermal
- Community opposition in some instances

U.S. DEPARTMENT OF ENERGY

Chapter 1: Overview & Value Propositions

Next-generation geothermal technologies **create their own reservoirs** from ubiquitous hot rock, which expands the availability of geothermal resources in the United States from 40 GW to over 5,000 GW.

Next-generation geothermal can **economically provide 90 GW of the 700 – 900 GW of clean, firm power** needed for a decarbonized economy by 2050, and technical and market factors such as limited land available for other renewables and the rate that other key technologies develop can triple expected deployment to over **300 GW.**

Rapidly increasing projections of electricity demand are driving increased need for clean firm power, which already commands a price premium in some cases; PPAs today are signed between **$70-100/MWh**, $20-50/MWh more than the average solar PPA in North America.

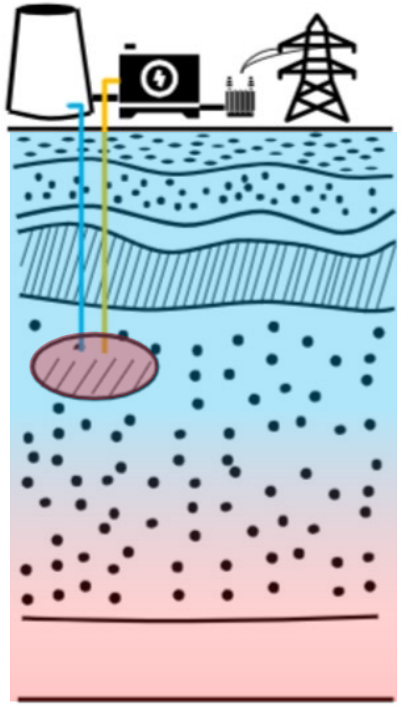
Next-generation geothermal technologies can store energy in the subsurface over long durations, increasing the value proposition of the technology. The economic deployment **of next-generation geothermal doubles** if this capacity is pursued.

The next-generation geothermal industry can leverage **large and existing workforces and supply chains**, reducing key commercial and political adoption barriers to, enable faster uptake.

Next-generation geothermal technologies engineer their own resources

Conventional

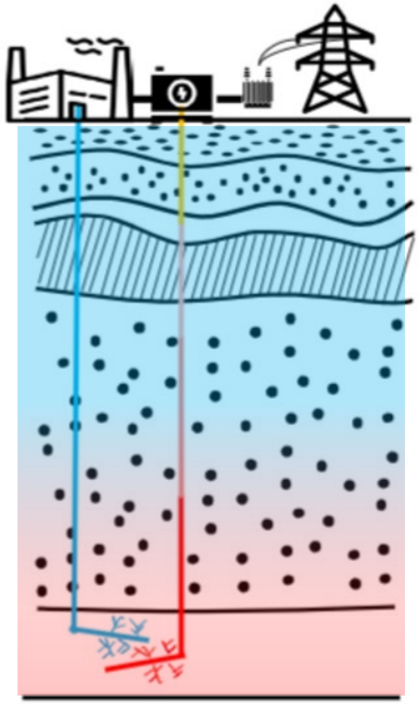
Hydrothermal



- Fluids circulate openly through naturally occurring fractures
- Limited estimated total resource (~40 GW)
- ~4 GW on the grid today

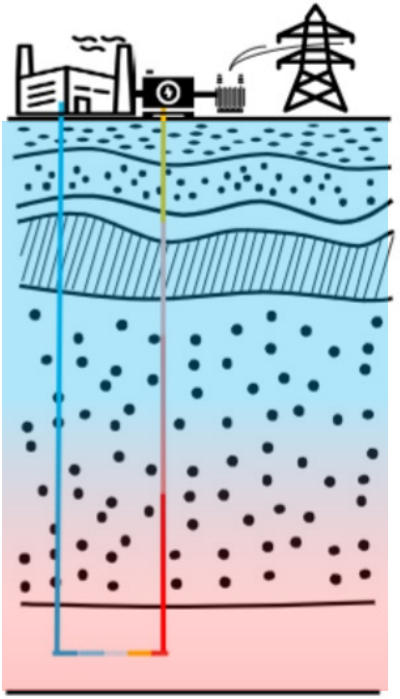
Next-Generation

Enhanced Geothermal Systems (EGS)



- Fluids circulate openly within a well pair connected by fractures engineered with hydraulic fracturing & horizontal drilling
- Large estimated total resource (5+ TW all next-generation geothermal)
- Scales through modular deployment of many well pairs

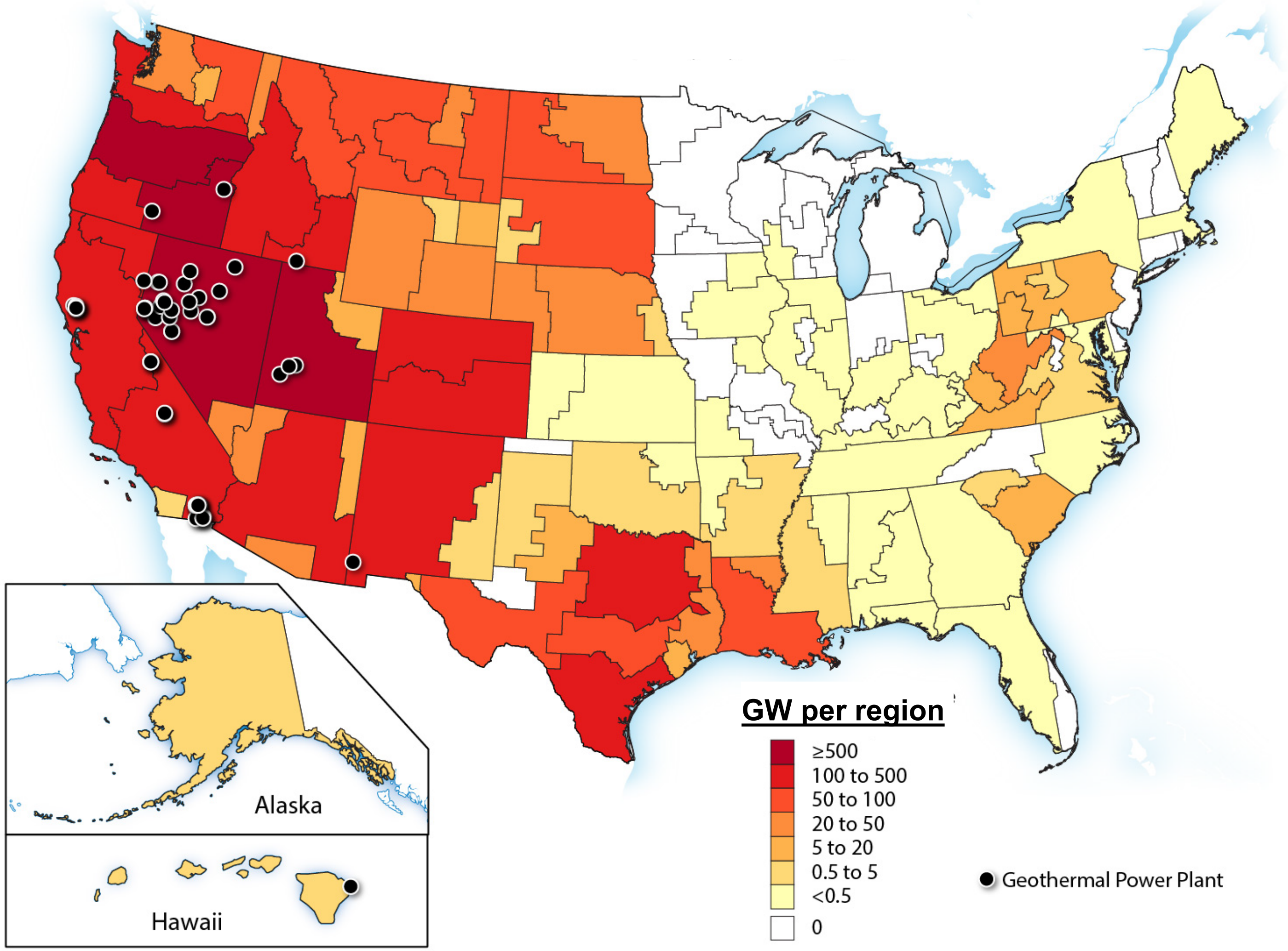
Closed Loop Geothermal Systems

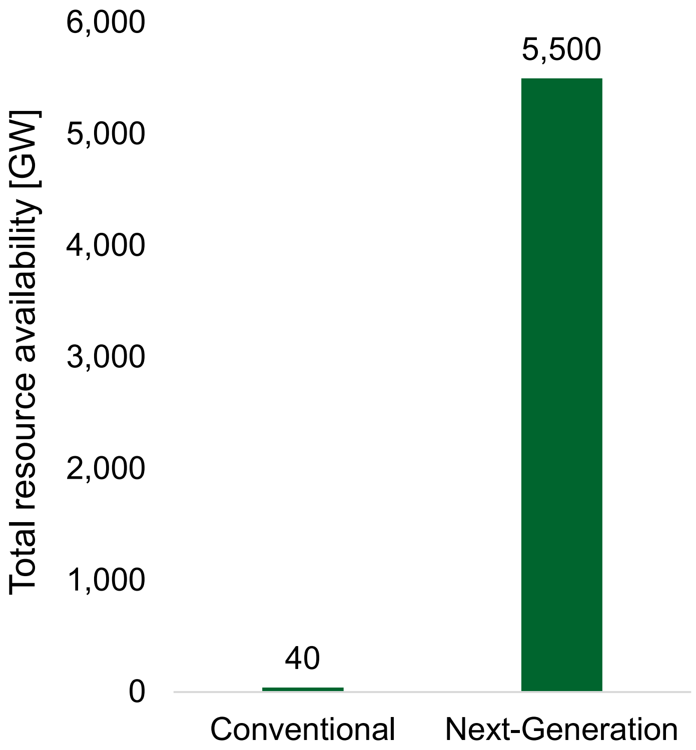


- Fluids circulate through a long series of closed wellbore loops permeating the subsurface
- Large estimated total resource (5+ TW all next-generation geothermal)
- Scales through modular deployment and increasing wellbore lengths

Next-generation technologies dramatically expand available geothermal resources

Next-generation and conventional geothermal resource estimates





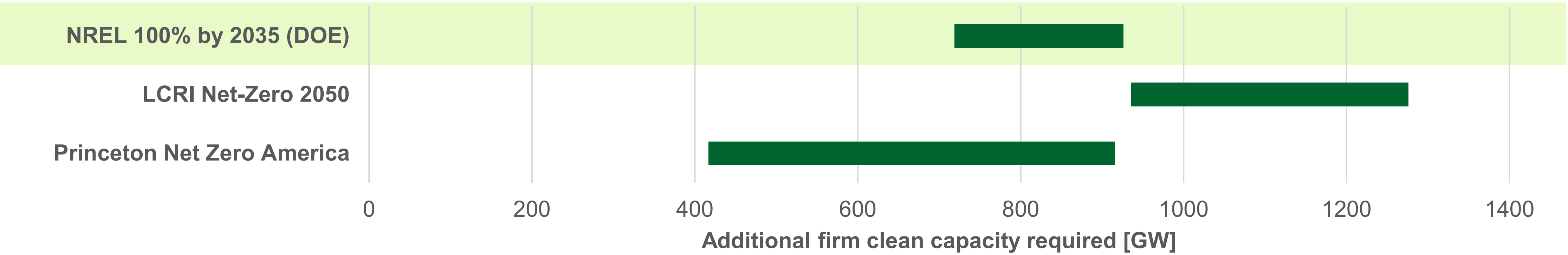
Next-generation geothermal has a strong and varied value proposition that position it to be a key technology for a decarbonized grid

Next-generation geothermal value proposition

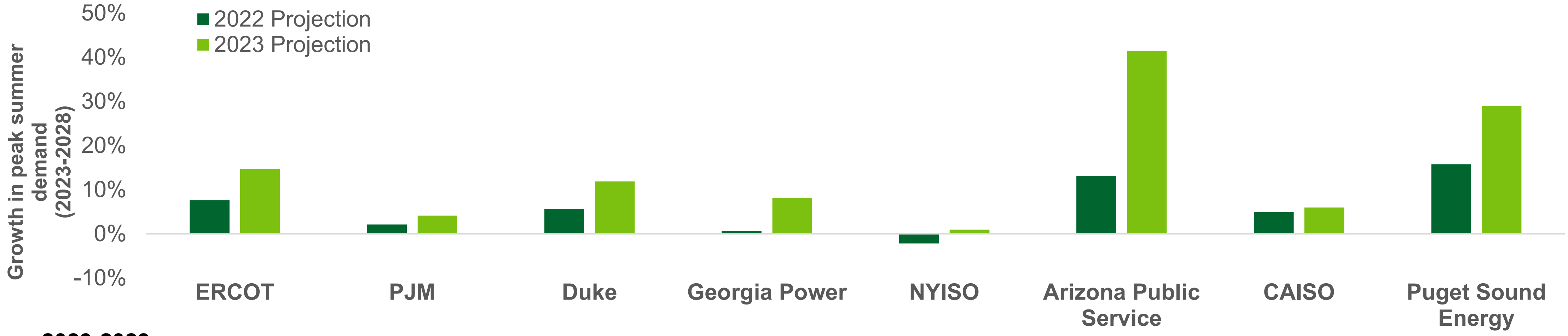
- Clean
- Firm
- Flexible
- Minimal footprint
- Secure supply chain
- Local permanent jobs
- Large existing workforce
- High growth potential
- Broad geographic availability
- No additional energy required
- No fuel costs
- Low transmission buildout

Firm clean power demand is large and increasing

Projected range of additional need for clean firm power in multiple net-zero scenarios from 2023 to 2050



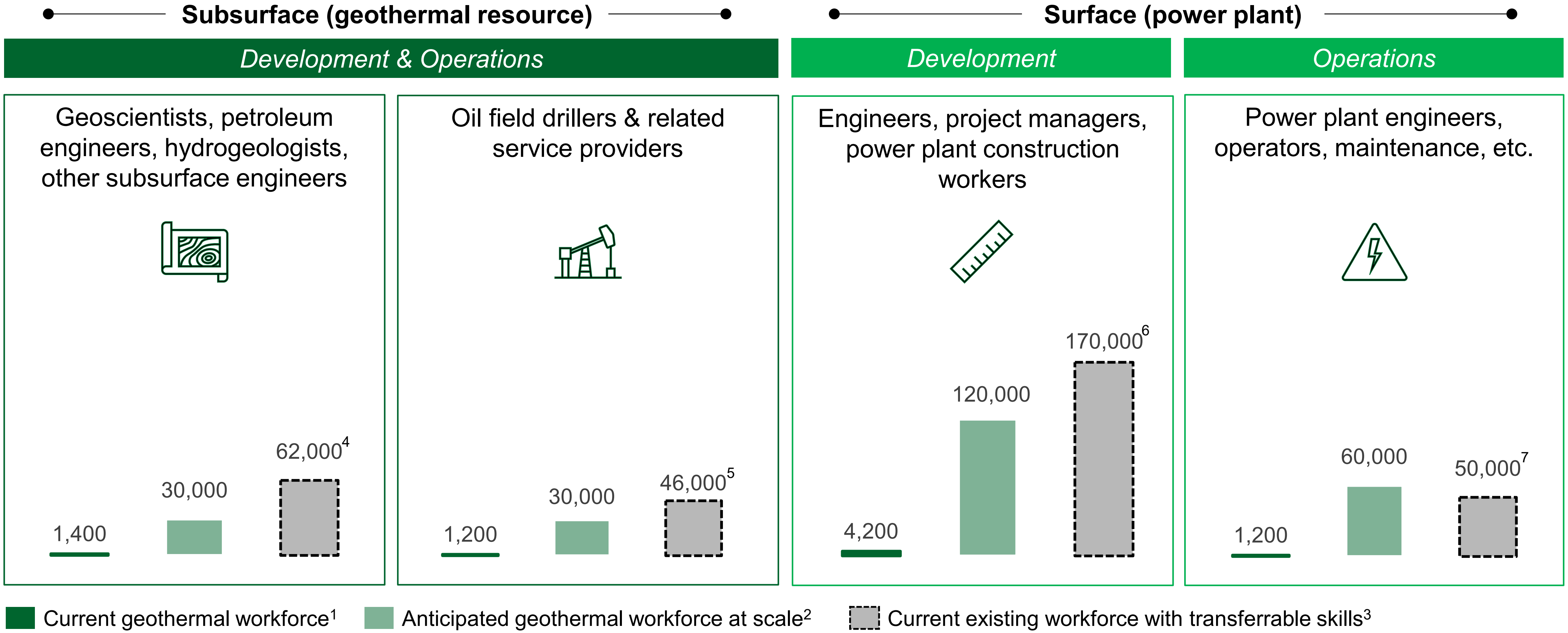
Total peak summer demand change expected from 2023 to 2028, % change from 2023



2023-2028 growth (GW):	11 GW	7 GW	4 GW	1 GW	1 GW	1.9 GW	3 GW	1 GW

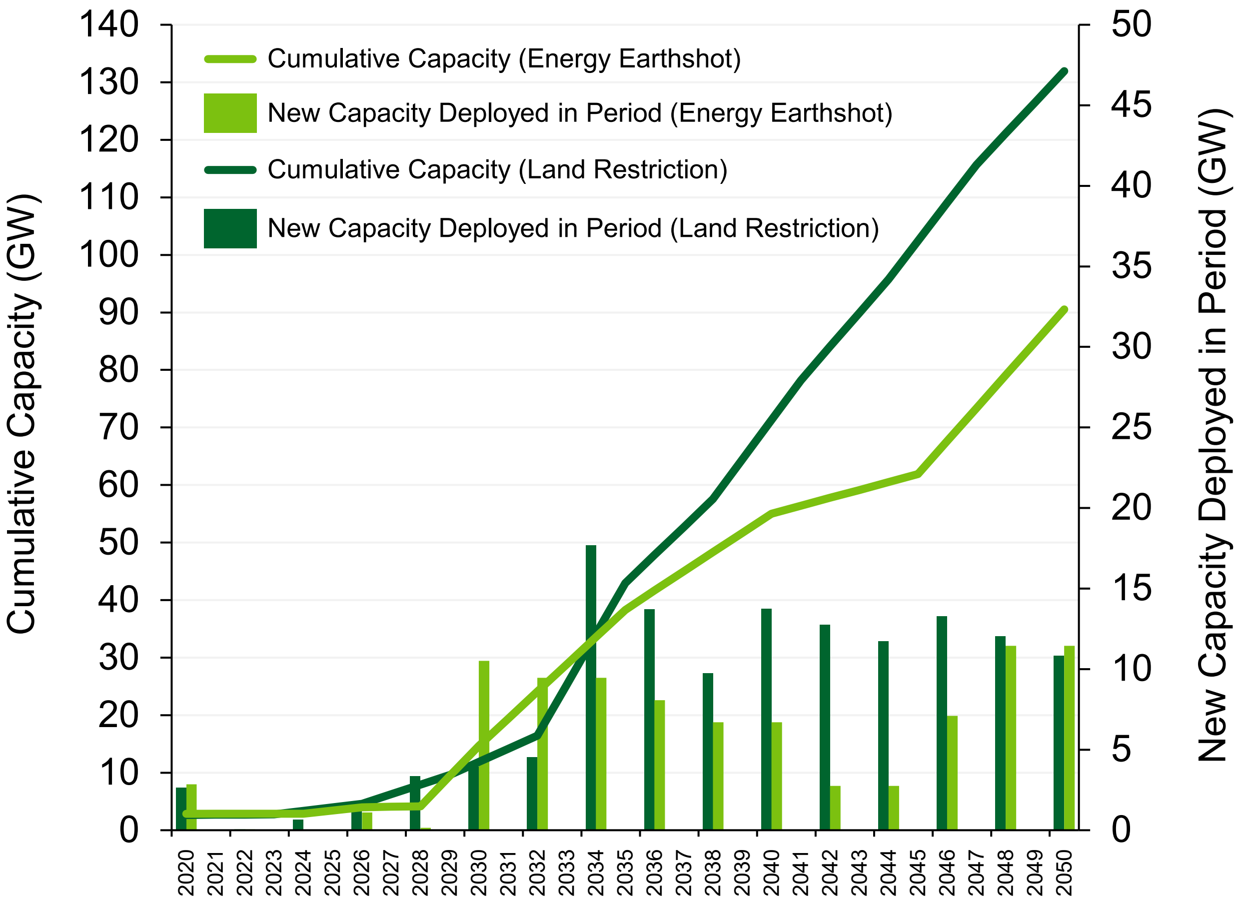
A sufficient existing workforce is a major starting advantage for next-gen geothermal

Existing and anticipated geothermal workforce at scale

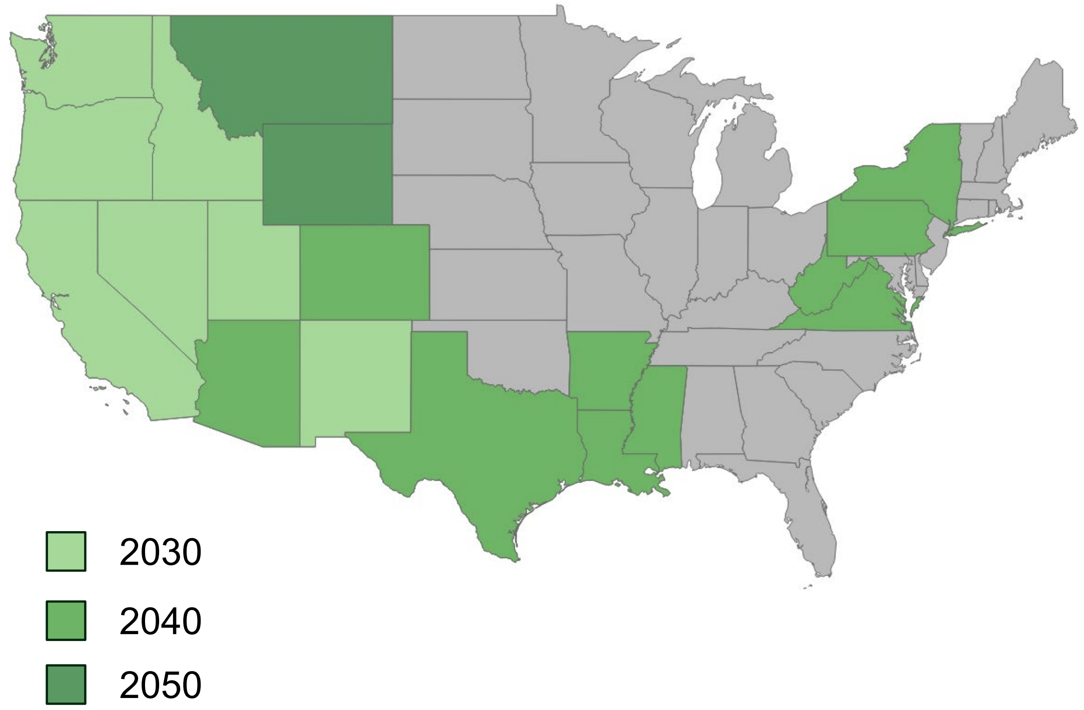


Next-gen geothermal could economically deploy 90-130GW across much of the US by 2050

Estimated next-generation geothermal deployment potential

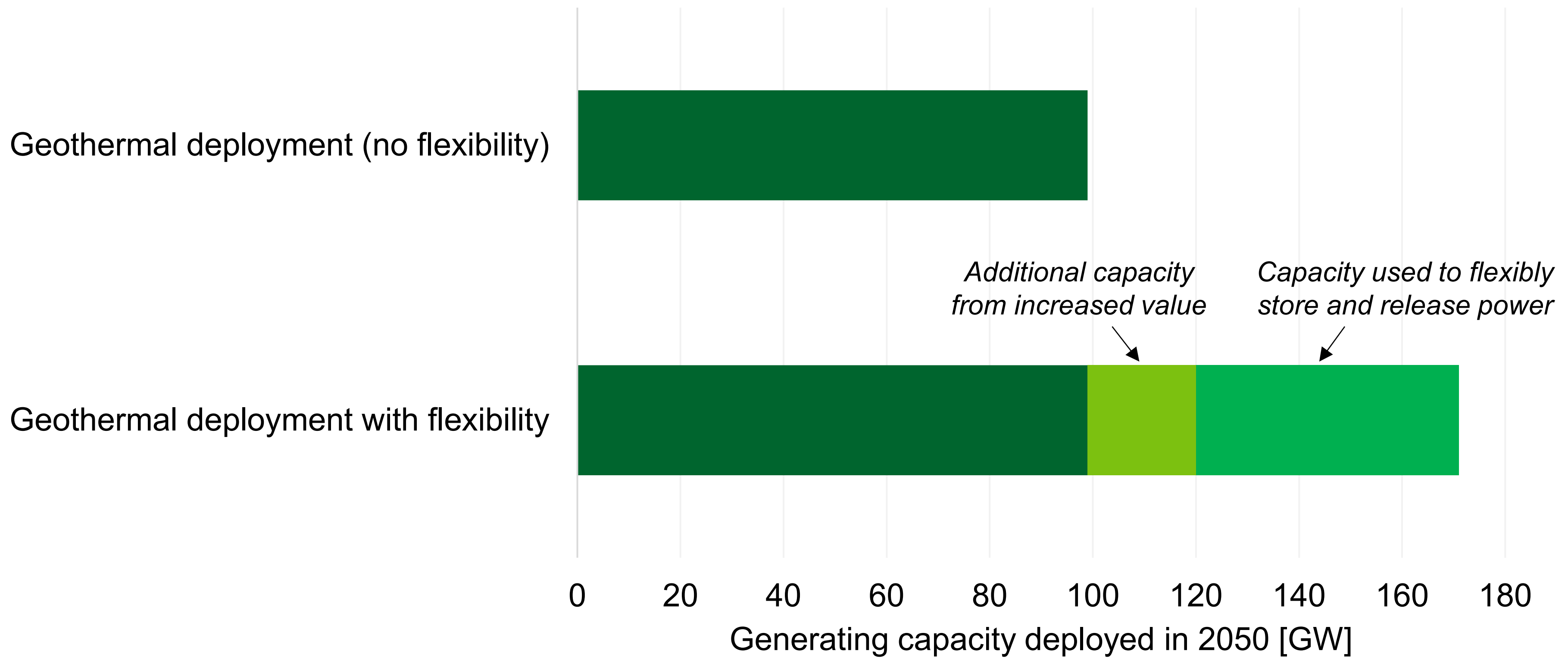


Potential geographic extent of next-generation geothermal



Long-duration storage capabilities enabled through flexibility increase geothermal value and deployment

Increased 2050 next-generation deployment when flexible generation is enabled



Chapter 2: Next-Generation Technology & Market

Despite cost-competitiveness, conventional geothermal project development is constrained by a **limited resource base, risk of incorrect resource characterization, inconsistent repeatability, long project lifecycles**, and investment perceptions shaped by **select project failures**.

Next-generation geothermal technologies **transfer risk from resource identification to engineering capabilities**, creating the potential to sidestep issues that have traditionally held back the geothermal industry.

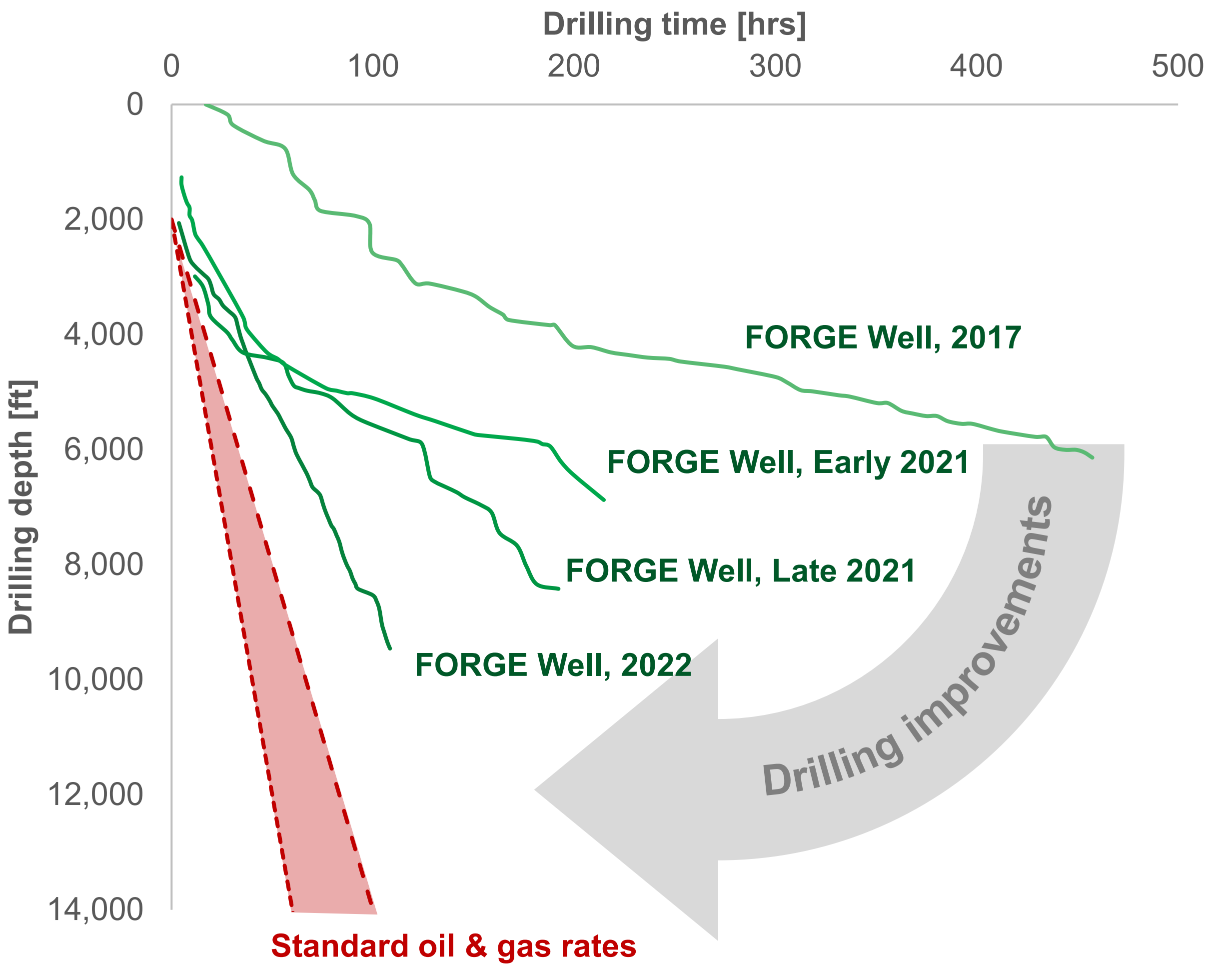
Iterative improvements enabled by modularity in drilling operations have **cut next-generation drilling costs in half over the last year**.

DOE's EGS Energy Earthshot target of $45/MWh is achievable, making EGS cost-competitive with other clean firm energy technologies by 2035.

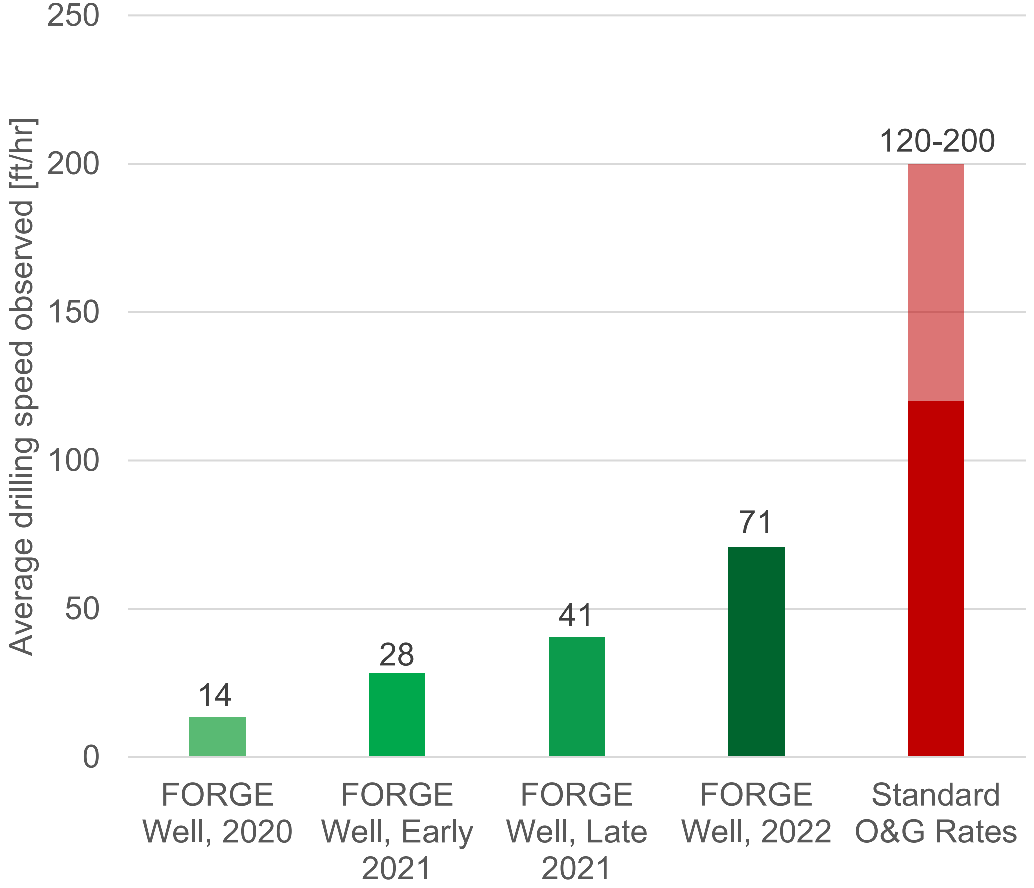
Recent advances have catalyzed substantial recent momentum in the next-generation geothermal market

Drilling timelines have shown remarkable improvement in 3 years, driving cost reductions

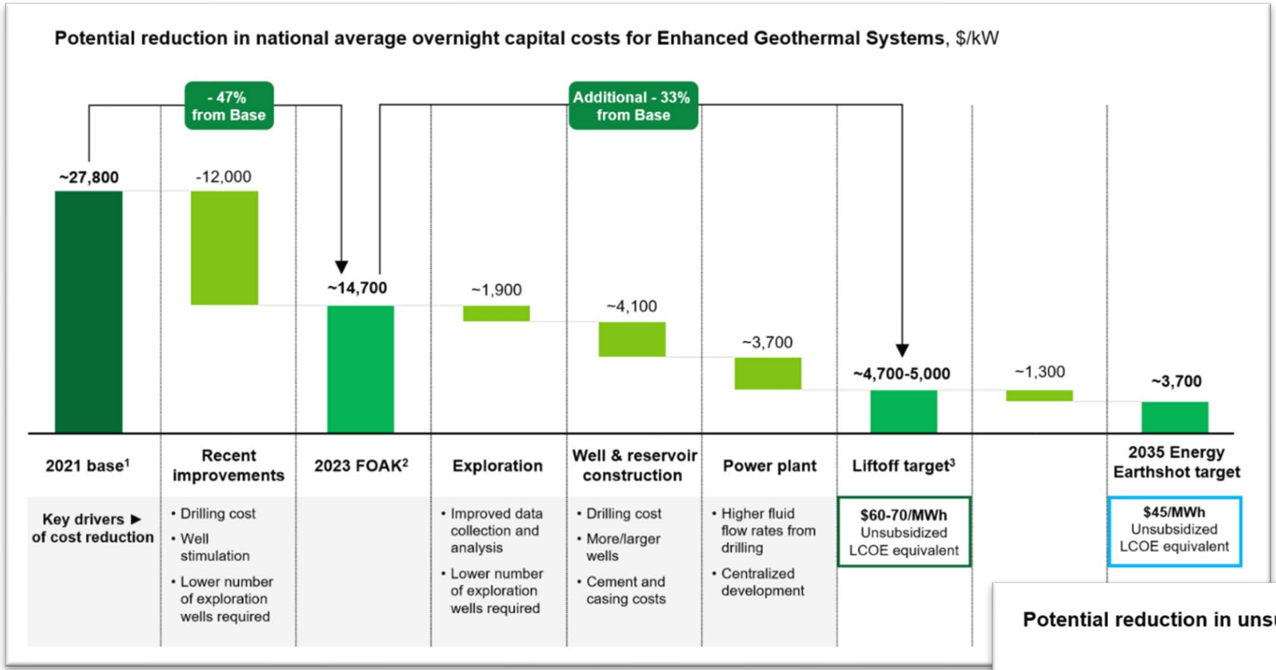
Drilling timelines at DOE FORGE demonstration site

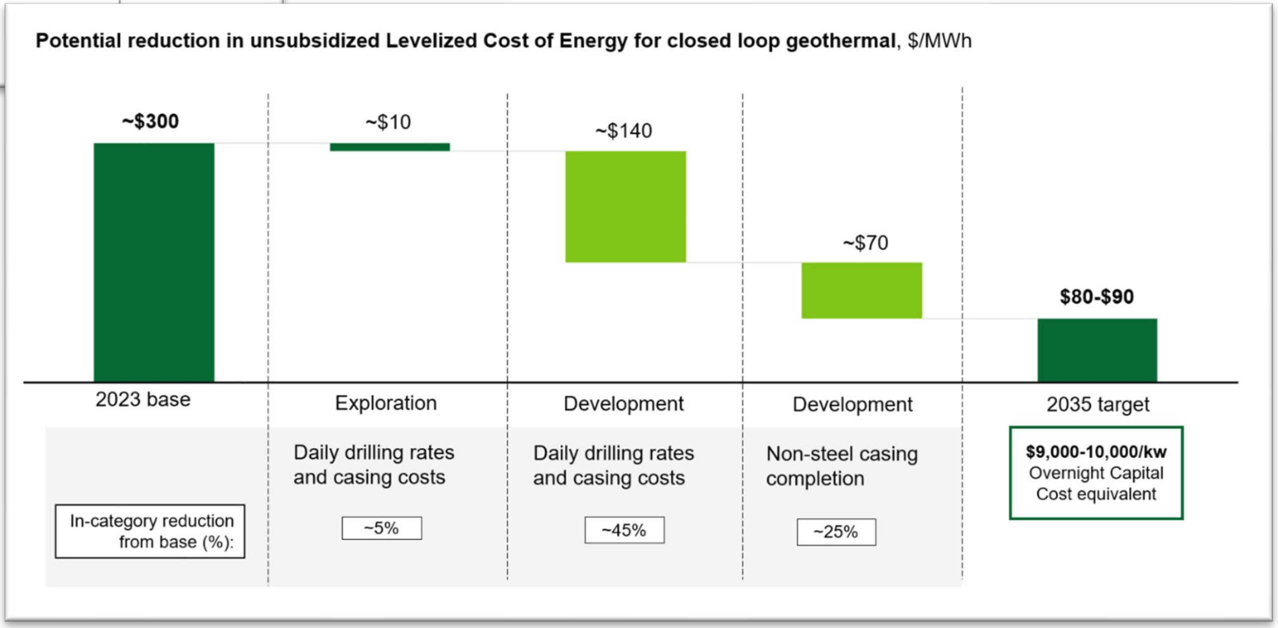


Average drilling times at DOE FORGE demonstration site



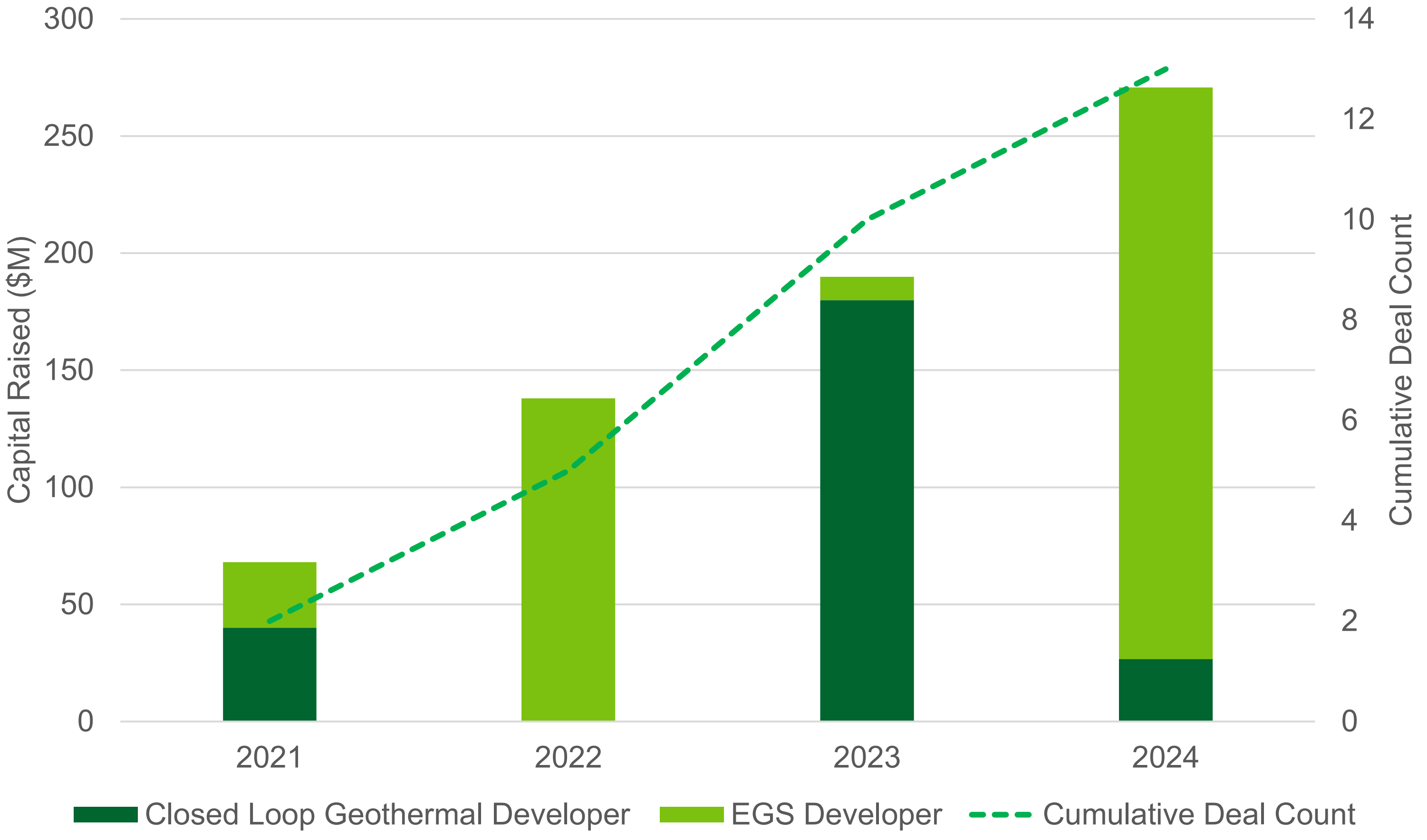
Next-Generation Geothermal costs are on their way to Liftoff and Earthshot targets





Next-generation geothermal market is showing strong recent momentum

Capital raised and cumulative deal count in next-generation geothermal, 2021-2024



Chapter 3: Pathway to Liftoff

The next-generation geothermal industry is characterized by a combination of **unusually high up-front costs**, plus a maturation timeline that includes not only reductions in key risk, but also a resource base that increases mainly as new projects are developed

Demonstration in **5-10 separate geologic settings** can reduce risk and verify resource availability, catalyzing **commercial liftoff in the U.S. by 2030**. This corresponds to 100+ developments, **2 to 5 GW** of overall deployment, and **$20-25B** of investment before 2030.

To reach scale by 2050, next-generation geothermal will require an **additional $225-250B** in investment, driven by a new ecosystem of developers, investors, utilities, and other offtakers, and leveraging existing workforces and supply chains.

RD&D and iteration within drilling and hydraulic fracturing will drive cost reductions as was observed in the oil & gas industry throughout market maturation, and **breakthroughs in drilling and resource characterization** can further expand potential.

At different market maturities, different development models apply. At low maturity, equity investors dominate, but as maturity increases, **a wider array of developer classes leveraging project finance could dominate.**

The pathway to Liftoff and scale for next-generation geothermal can proceed in two stages with increasing geographic reach

Reaching Liftoff

2-5 GW ($20-25B)

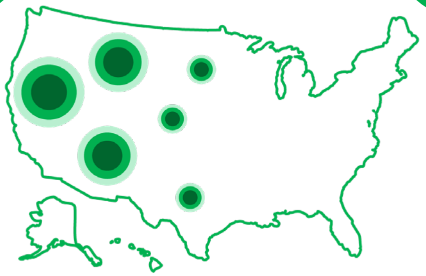
- Prove and document engineering capabilities
- Unlock access to low-risk financing and larger capital pool

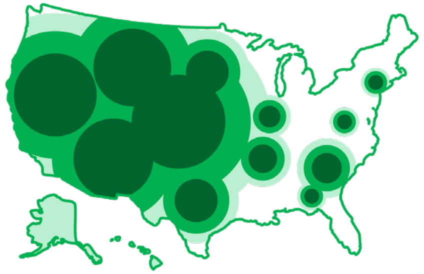
Achieving Scale

88-125 GW ($225-250B)

- Mobilize new ecosystem of developers, investors, utilities, and other offtakers
- Rapidly increase inventory of economic resources
- Reduce cost with iterative improvements and implementation of new RD&D
- Industrialize repeatable development process, leveraging existing oil & gas workforce and supply chain

Today — 2030 — 2040 — 2050





1. Prove market opportunity

Deployments covering 5-10 different geologic settings

2. Expand viability of geothermal resources in competitive regions

Order and deliver projects, capitalizing on existing workforce and supply chain in competitive regions

3. Expand geothermal footprint to entire United States

Order and deliver projects across entire United States

Pursue breakthrough RD&D *Advances in drilling techniques and resource identification reduce costs and increase deployments*

Four key enablers can help next-generation geothermal achieve Liftoff conditions

Liftoff Conditions

5 - 10
geologic conditions

- Validation suite of deployments to prove low enough risk for debt during construction
- **4-6 States** with multiple in-state deployments

2 - 5GW
deployment

- Total next-generation geothermal deployment to cover sufficient geological conditions
- **1,300-3,300 wells drilled** at ~3 MW/well

$20 - 25B
investment

- Total capital expenditure required for deployment
- **~60% cost reduction** from 2023 estimate

Key Enablers

Cost reductions

Cost reduced to $60-70/MWh National average LCOE ($40-50 in competitive regions)

- Iterative cost improvements and the impact of directed R&D drive competitiveness in key early regions

Large-scale demonstrations

30+MW scale demonstration projects

- Data supporting repeatably consistent and maintained power production proves down technology risk

High-value PPAs

Prices that reflect clean firm value proposition

- Offtake agreements with utilities or off-grid demand sources (e.g., industrial users or data centers) supports new projects

Community-informed siting

Site selection and development in partnership with communities

- Leveraging tools to locate and co-develop next-generation geothermal developments with benefits in mind and in partnership with communities

A fully mature geothermal industry could develop projects using project finance

Developer classes, investment sources, and development models available at different levels of industry maturity

Industry Maturity	***FOAK***	→	***NOAK*** →
Risks (High / Medium / Low)	Technology (High) Resource (Medium)	Technology (Medium) Resource (Medium)	Technology (Low) Resource (Low)
Appropriate developer class	• Early stage (e.g., start-ups; internal innovation teams)	• Maturing early-stage entities • Upstream oil & gas; mining	• Established renewables developers • Upstream oil & gas; mining
Potential sources of investment	• Corporate equity (early-stage) • Philanthropy and public grants • Strategic investor-offtakers	• Corporate equity • Private equity • High-cost debt • Strategic investor-offtakers	• Infrastructure investors • Corporate equity • Project equity • Low-cost debt
Project stage at debt entry	n/a	Surface construction	Subsurface development (after first well)
Development model *Up-front equity[1]* *(hurdle rate)*	***Unlevered equity*** *~$450M* *(loss leader)*	***High-risk financing strategies*** *~$180M* *(20+%)*	***Low-risk financing strategies*** *~$5-10M* *(5-10%)*
	Demonstration Projects →	**“Farm-Down”** →	**Project Finance** →

Chapter 4: Challenges & Opportunities

High up-front costs & risks constraining development capital and limiting geographic reach.

- About $5 billion out of the $20-25 billion of capital formation in the liftoff phase to finance the validation suite of first-of-a-kind (FOAK) developments in varied geologies, sourced from governments, equity investments, corporate venture or strategic investor-offtakers, or oil & gas
- Market signals, such as high-valued PPAs, to motivate investment in initial loss-leaders
- In-field testing and innovation at active geothermal developments through RD&D spending
- New financial products to reduce drilling costs, such as public/private cost-share agreements and drilling insurance programs

Perceived & actual operability risk for deployments constraining demand and investor appetite

- Strategic demonstration siting and data dissemination from 10+ early deployments to show sustained power production

Long and unpredictable development lifecycles driven by permitting and interconnection

- Allowing for combining and streamlining of specific steps in permitting process, where authorized.
- Technology changes that allow certain steps to occur in tandem
- Continued and increased support for permitting agency capacity, where authorized.

Existing business models undervaluing the potential of next-generation geothermal

- Planning policies that incentivize higher-cost, higher-value power
- Leverage flexible geothermal operations to capture highest-value power
- New offtake models, e.g. subsurface developers providing heat for multiple purposes

Community opposition in some instances

- Adherence to long-established induced seismicity and environmental monitoring best practices
- Early, frequent, and transparent community engagement

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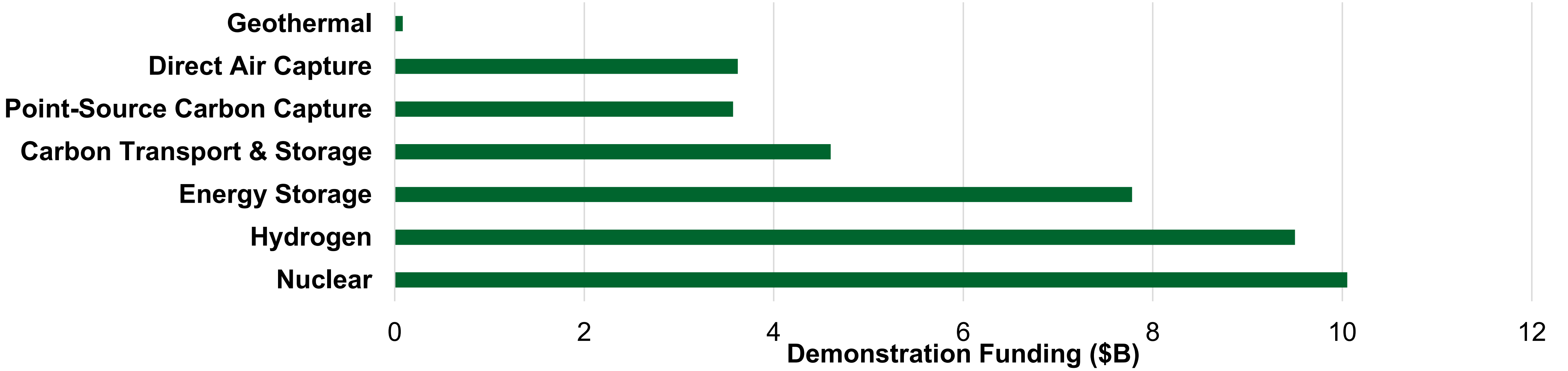
Funding allocated for large-scale demonstrations, manufacturing and supply chains, and supportive infrastructure
Bipartisan Infrastructure Law and Inflation Reduction Act



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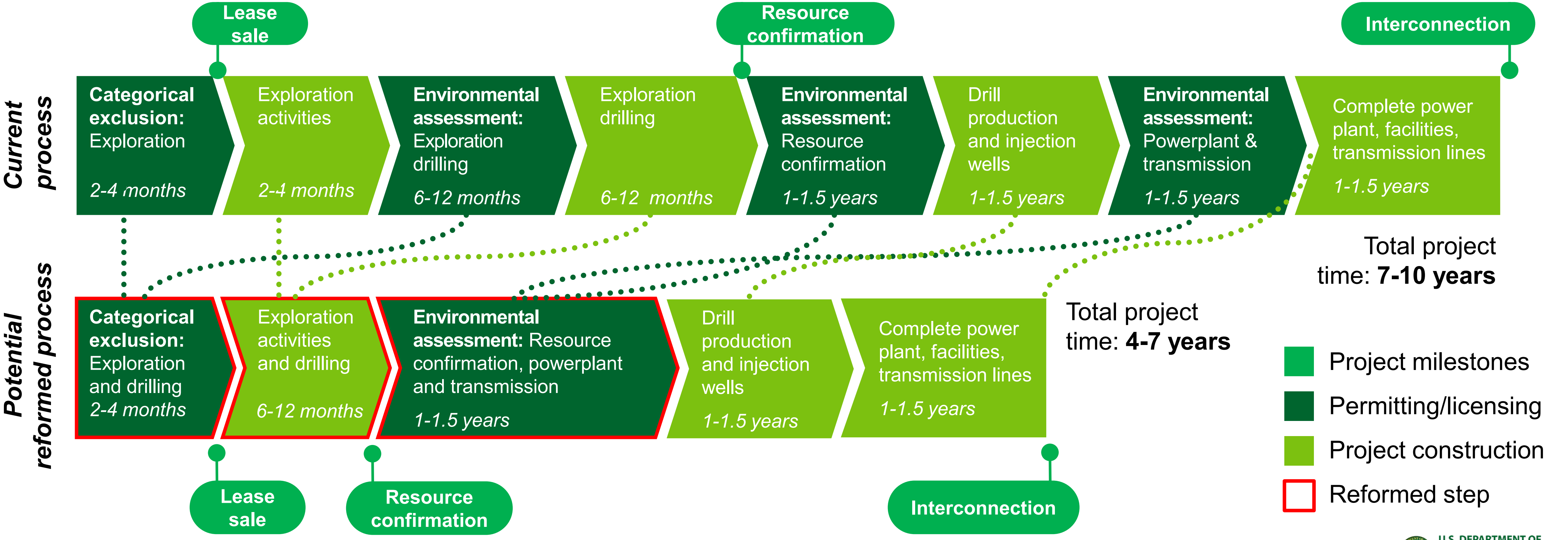

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Thank you!

We want to hear from you!
To help inform future Liftoffs, please submit feedback at:

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