SPINNING UP; NOT OUT

Enabling Next-Generation Turbomachinery for Rapid Geothermal Deployment

WE ARE WORKING ON A REPORT TO DRAW INNOVATION, INVESTMENT AND POLICY FOCUS TO TURBOMACHINERY

New System Ventures

project innerspace™

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New System Ventures is a **venture capital fund** investing in hardware and software inflection technologies in energy, heavy industry, and transportation

Project InnerSpace is a **global nonprofit** accelerating the deployment of geothermal energy through advanced subsurface mapping, data infrastructure, and ecosystem-building

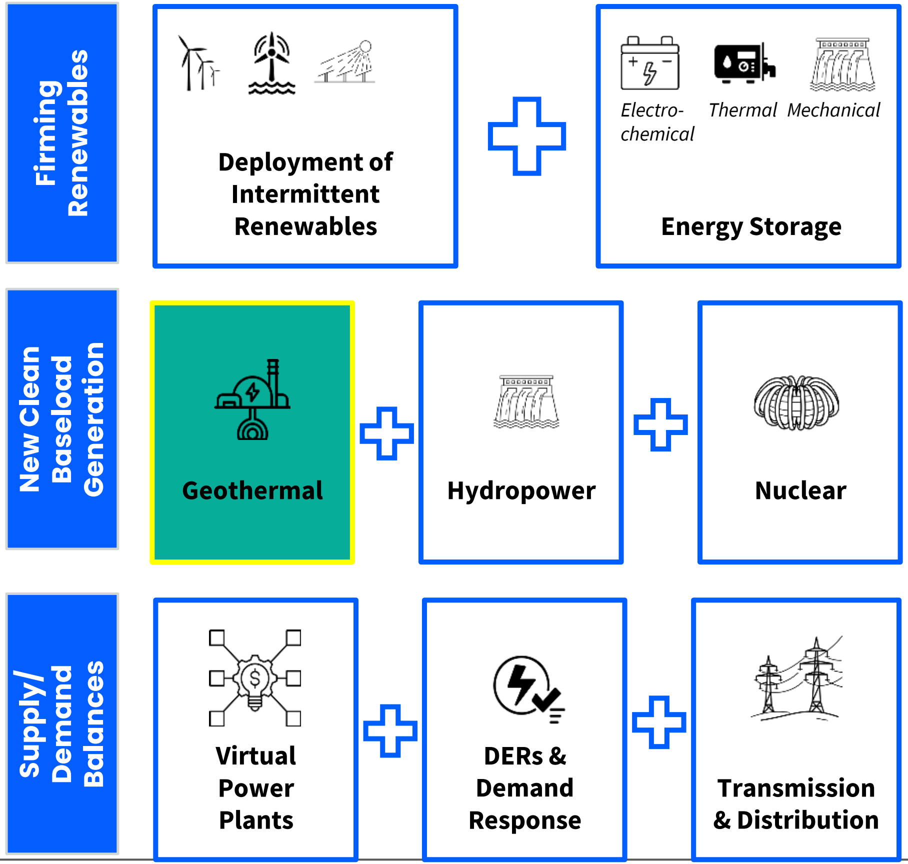
SwRI is an independent applied **R&D institute** providing deep engineering, testing, and validation capabilities across turbomachinery, energy systems, and advanced industrial technologies

THE **BACKSTORY** THAT WE ALL KNOW AND LOVE.

SYSTEMS-LEVEL RESEARCH: 24x7 CARBON FREE ENERGY PATHWAYS

Our grid must **move away** from paying for clean generation **at times and places that are disconnected from demand**.

This transition is enabled through virtual power purchase agreements (PPAs), firming of renewables, and increasing the availability of **clean firm baseload energy** tailored to when and where it is needed - **even if the sun isn't shining.**



WE NEED MORE POWER AND THE PRIORITY IS TIME-TO-POWER

How has power procurement changed?

Baseload energy matters, but the true constraint for near-term decarbonization is **time-to-power** the ability to deliver capacity **quickly, reliably,** and **at scale.**

Geothermal provides a credible path to clean, domestic baseload power that meets the urgency of the AI era.

Hyperscalers are continuing to explore behind-the-meter configurations to bypass interconnection delays, favoring baseload tech.

Demand Pull: AI and Hyperscale Data Centers

AI Infrastructure Drives Demand: Goldman Sachs Research projects global data center power demand will **surge 165% by 2030**. Multi-hundred-billion-dollar investments like OpenAI's **"Stargate Project"** signal a buildout at unprecedented scale and speed.

Time-to-Power is the New Metric: The White House's **"Speed to Power Initiative"** reflects a fundamental shift: schedule-driven NPV now trumps traditional LCOE. A higher-cost power source delivered 12-24 months earlier delivers higher value.

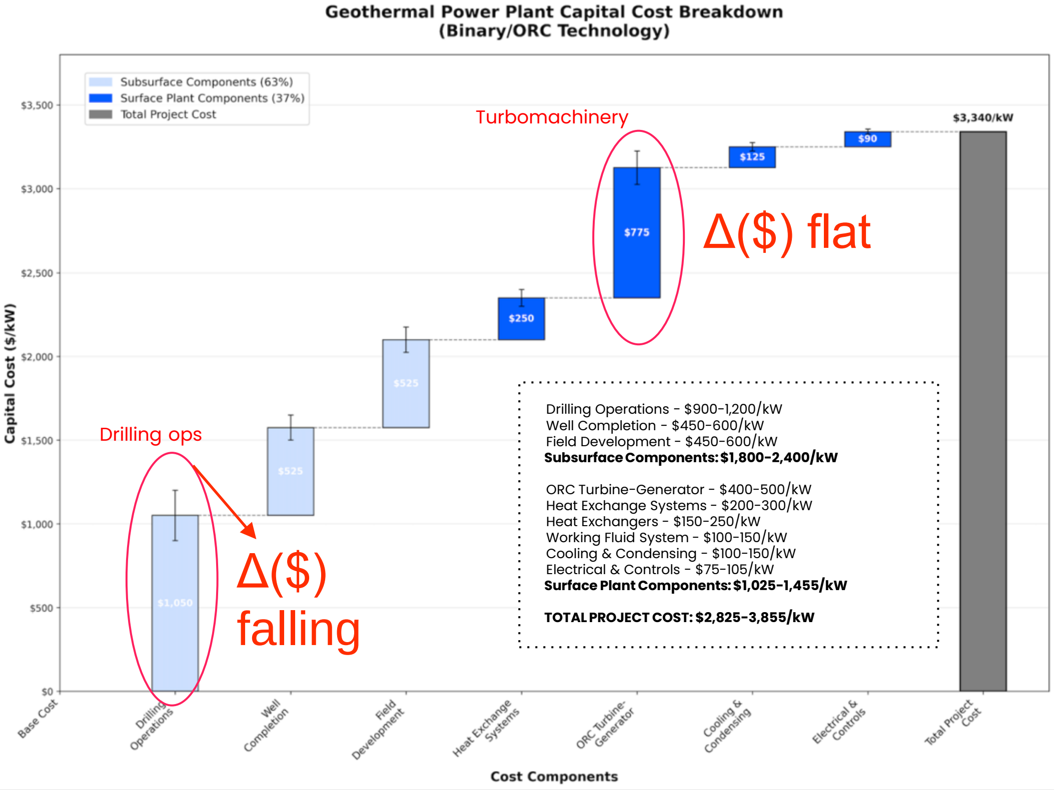
Behind-the-Meter Advantage: The urgency of AI/Data Center demand has shifted priority from **lowest LCOE to fastest deployment**. This demand prioritizes speed and **interconnection certainty.**

DRILLING COSTS ARE FALLING, THE NEXT FRONTIER IS TURBOMACHINERY

Fervo's Cape Station wells have so far been drilled at a rate of **$4.6M/well**, vs. the historical average of $17M/well for all prior EGS wells

This statistic represents drilling costs that have fallen by **70% compared to historical drilling** costs

Turbomachinery components have not benefited from the same technological transfer or industrialization as drilling



Note: Based on Binary/ORC systems, **assuming 10-25 MW project scale, costs in 2024 USD with a lower-temperature resource (110-200°C)** vs Flash Steam (>200°C).

Sources: NREL Annual Technology Baseline 2024 (atb.nrel.gov), IRENA Global Geothermal Assessment 2024 (irena.org), DOE GeoVision Analysis 2019 (doi.org/10.2172/1524768), Soultz-sous-Forêts Project; Akindipe & Witter;

WE'RE FACING A TURBOMACHINERY SCALE UP CHALLENGE

Global next-generation geothermal capacity will reach between 30 GW (medium-cost case) and 120 GW (low-cost case); **representing several thousand new systems** needed over the next decade.

Production Scale Up

Today we produce dozens of turbines

- Flash Steam: ~10-15 units/year
- sCO_2: <5 demonstration units/year
- ORC: ~40-50 units/year

We will need a lot more

- Geothermal growth projections show 100+ GW by 2050
- Translates to 100s to 1,000s of turbines/year
- **10-100x** scale-up required

Critical challenges

#1: LEAD TIMES

- 12-18+ months door-to-door for turbines due to **customization**
- Heavy hardware and large pressure vessels drive fabrication timelines
- International logistics add 2-3 months

#2: MANUFACTURING CAPACITY

- Market dominated by few OEMs (Israel, Italy, China)
- Custom manufacturing model prevents standardization
- Unpredictable demand = underinvestment in capacity

#3: OPTIMIZATION OPTIONS

- What turbine is suited for what conditions?
- What thermal efficiency options exist on the R&D frontier?
- What well and flow factors dictate the right power plant site design?

THE DATA GAP PROBLEM.

THE GEOTHERMAL POWER CONVERSION DATA IS... DATED.

Most of the techno-economic models we're using are based on research from the 2010s

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2017

Title	Global Value Chain and Manufacturing Analysis on Geothermal Power Plant Turbines
Author	Akar, Sertac; Augustine, Chad; Kurup, Parthiv; Mann, Margaret
Affiliation	National Renewable Energy Laboratory
PDF	yes - click here!
Volume Title	Geothermal Energy: Power to Do More
Journal	Geothermal Resources Council Transactions
Volume	41
Pages	2384-2400
Year	2017

CEMAC Clean Energy Manufacturing Analysis Center

2018

Global Value Chain and Manufacturing Analysis on Geothermal Power Plant Turbines

Sertaç Akar, Chad Augustine, Parthiv Kurup, and Margaret Mann

National Renewable Energy Laboratory

Internal geophysics

Integral modeling and financial impact of the geothermal situation and power plant at Soultz-sous-Forêts

Presented by: Written on invitation of the Editorial Board

...sue: On the way to the exploitation of deep geothermal resources in naturally fractured...

... Géoscience, Vers l'exploitation des ressources géothermiques profondes des systèm...

...eux naturellement fracturés, Volume 342 (2010) no. 7-8, pp. 626-635

2010

Cost of electricity from enhanced geothermal system...

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2010

Published	2010 / 02
Summary	This paper presents the results of an analysis of the cost of electric power from Enhanced Geothermal Systems (EGS), specifically, reservoirs with sub-commercial permeability enhanced by hydraulic stimulation
Keywords	drilling costs, cooling rate, geothermal energy, well depth, prediction, outlook, EGS, enhanced geothermal system
File name	Stanford_2007_COST OF ELECTRICITY FROM ENHANCED GEOTHERMAL SYSTEMS.pdf

Thermodynamic Analysis and Optimization of Geothermal Power Plants

2021, Pages 17-41

Chapter 2 - Global value chain and manufacturing analysis on geothermal power plant turbines

Sertaç Akar, Chad Augustine, Parthiv Kurup

2021

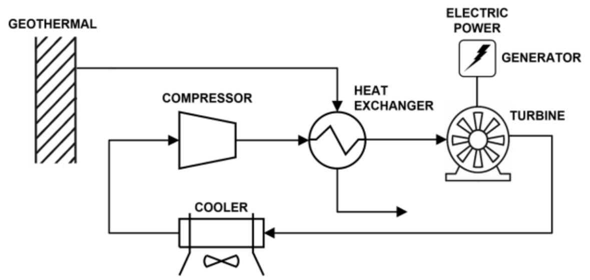
BETTER DATA = TIGHTER CONFIDENCE INTERVALS = LOWER COST OF CAPITAL = MORE PROJECTS FINANCED

THE OPEN QUESTIONS WE'RE TRYING TO ANSWER

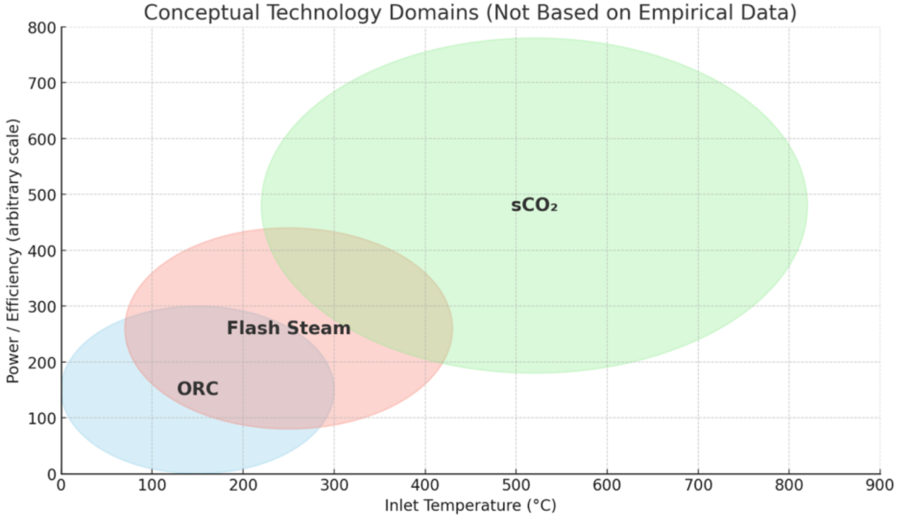
RESOURCE TO TECHNOLOGY MATCHING:
- At what temperature & pressure does sCO_2 beat ORC? Flash steam?
- How does brine chemistry change the answer?
- Where do modular ORCs fit into the value chain?

TECHNICAL PERFORMANCE:
- What efficiencies are happening in the field?
- What's the degradation curve over time?
- Where can we get the biggest step-change?
    - Compressors? Heat exchangers? Parasitic load? Air-cooled condensers?

CAPEX & LEAD TIMES:
- What lead times are you being quoted? What are the actual lead times to delivery?
- Which components are the long poles?
- Where's the bottleneck: engineering capacity, manufacturing slots, or materials?



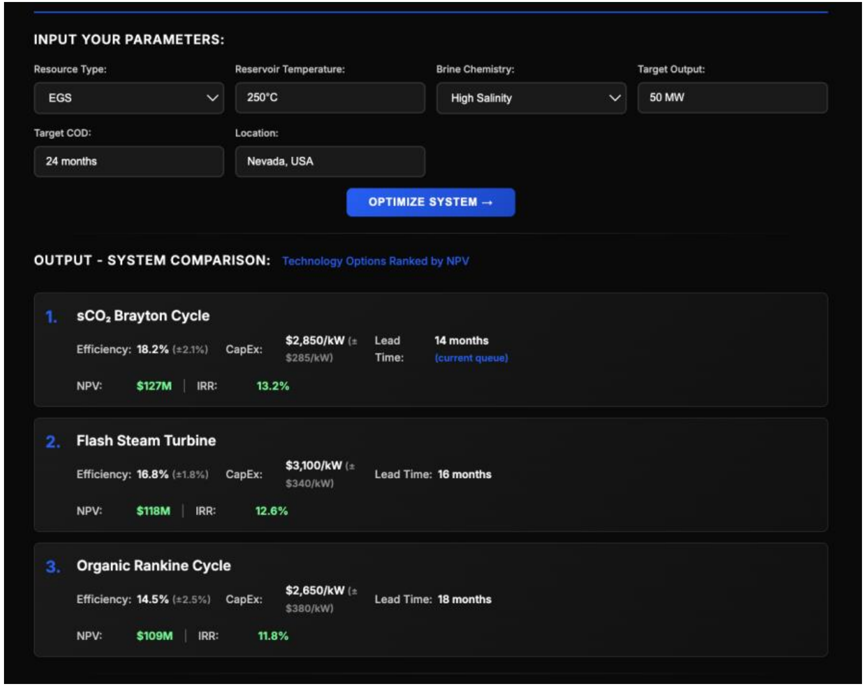
Δ (theoretical vs actual)



Note: This visualization is conceptual only and does not represent measured or validated performance data.

WHEN WE FIX THE DATA GAP, PROJECTS GET FINANCED AND INNOVATION ACCELERATES

Decisions can be made, and sites can be designed, for maximum site-specific thermal output, where 1% efficiency improvement can translates to tens of millions in LTV from increased energy production



Example application showing site inputs to target outputs, inclusive of lead times, NPV, and efficiency curves.
Source: NSV Asset

…AND PARTIAL DIS-INTEGRATION BECOMES POSSIBLE

Stage 1:

At first developers must:

- Design the wells
- Drill the wells
- Design the surface system
- Operate the system

Stage 2: Commercial Scale-Up

As technology matures:

- Drilling & reservoir simulation becomes repeatable
- **ORC/skid components are commoditized**
- EPC partners can take on more responsibility

Stage 3: Mature Industry?

Industry could resemble:

- Oil & gas (subsurface expertise concentrated in service companies)
- Wind (OEMs + developers separated)
- Solar (fully modular)

TO CONSIDER: HOW INTEGRATED WILL NEXT-GEN GEOTHERMAL COMPANIES BE?

THE IDEAS WE'RE TESTING.

For Incumbent Manufacturers

Leverage Existing Capacity	Strategically co-locate ORC production within existing turbine campuses to leverage infrastructure, skilled labor, and established quality systems, working on reducing time-to-market
Create "Fast-Lane" ORC Packages	Develop standardized, pre-engineered ORC power blocks with guaranteed delivery clocks and interfaces. This directly addresses the market's "time-to-power" imperative and creates a scalable, repeatable product

For Start-Ups

Design for Velocity	Startups should focus on modular designs and additive manufacturing to reduce component complexity, shorten lead times, and create a competitive advantage based on speed and hardware economics. Get cycle times on the board as quickly as possible and look for entry opportunities (e.g. cycling over test wells or as a bottom cycle at a natural gas plant)
Explore Multimodal Pricing Models	In addition to hardware purchase and leasing agreements, consider adding customization, automation software and analytics sold on a recurring basis to stabilize forecasted revenue

For Innovators and R&D Leaders

EGS and SHR means moving to higher temps	Re-examine the project unit economics for surface systems that can take full advantage of the higher production temps - justifying the case for an industry wide move to topside designs that break out of the Organic Rankine Cycle default assumption (e.g. sCO_2)
Solve the Parasitic Load hurdle	Focus R&D on the primary technical challenges for improving round-trip thermal efficiencies and novel topside tech for geothermal applications
Solve the Ambient Derate Challenge	Ambient derate reduces summer production considerably. If geothermal operators want to develop 100% geothermal behind-the-meter projects, they'll need to tackle ambient derate. ORC designs are optimized for average rather than extreme temperatures which experience 10-30% losses.

For Investors

Fund the Gaps	Target investments in companies that address specific, high-value supply chain gaps, where customizability will remain a key differentiator and additive manufacturing can materially shorten the time to delivery
Changing the assumptions around bankability	There's been a sense of tradition that needs to be broken around ORCs; develop metrics of risk that are inclusive of the urgency and supply chain of the moment - we're in a fundamentally different age of rapid experimentation and rapid deployment

For Policy Makers

Federal funding for turbomachinery R&D	DOE and ARPA-E for research and development; utilization of levers such as the infrastructure and production tax credits (ITC / PTC) for buyers to offset the costs for geothermal power production investments and encourage domestic manufacturing
Build Secure Supply Chains with Partners	Use strategic trade and finance agreements (via EXIM, DFC) to build secure supply chains for critical components with trusted partners like India, South Korea, Japan, and key European allies to make up the gaps
Deploy Targeted Industrial Policy	Utilize the Defense Production Act (DPA) and DOE Title 17 Loan Programs to provide grants and financing for retooling existing U.S. factories for ORC and sCO_2 turbomachinery production

SURELY WE CAN DO BETTER THAN STRAPPING CONCRETE BLOCKS TO JET ENGINES

ProEnergy repurposes jet engines to power data centers amid gas turbine shortages - report

Retrofits old CF6-80C2 jet engines into 48MW power generators

October 22, 2025 By: Zachary Skidmore Have your say

US energy solutions provider ProEnergy is repurposing jet engines to power data centers.

As first reported by IEEE Spectrum, the company revealed that two data center operators are using its repurposed gas turbines to power facilities during construction and in the first few years of operation.

The PE6000 gas turbines are made through retrofitting old CF6-80C2 jet engine cores and matching them with newly manufactured aero-derivative parts made by ProEnergy or its partners.

– ProEnergy

To make jet engines suitable for use as power generators, they are modified with an expanded turbine section to convert engine thrust into shaft power, a series of struts and supports to mount them on a concrete deck or steel frame, and new controls. Following assembly, the engines can supply 48MW of capacity.