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Estimating Well Cost for Enhanced Geo System Applications

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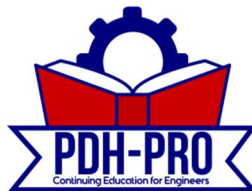
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Module 1: Introduction to EGS Cost Estimation and Drilling Economics

Learning Objectives

By the end of this section, you will be able to:

- **Evaluate** the economic trade-offs between higher fluid temperatures and escalating drilling costs at depth.
- **Apply** historical Oil & Gas drilling data as a reliable proxy for estimating Enhanced Geothermal System (EGS) project costs.
- **Select** appropriate statistical curve-fitting methods (Polynomial, Exponential, Power Series) to model cost-versus-depth relationships.

Executive Summary: The viability of Enhanced Geothermal Systems (EGS) relies on balancing the thermodynamic benefits of deep, high-temperature fluids against the exponential increase in drilling costs associated with that depth. Because the geothermal industry lacks sufficient historical data for wells deeper than 10,000 feet, you must utilize established Oil & Gas drilling datasets to build statistically reliable economic models.

Introduction

EGS reservoir performance depends on a complex interplay of parameters: reservoir characteristics, geology, drilling, well completion, plant design, and operation. To mitigate economic risk, you must identify the relative importance of these parameters.

Currently, the U.S. industry treats EGS as an emerging technology, resulting in a lack of comprehensive parametric studies. Existing literature often relies on limited datasets, potentially skewing economic projections.

The Economic Limit of Depth

Thermodynamically, the work extractable from geothermal fluid increases with temperature.

However, you must consider the opposing economic constraint:

- **Drilling Costs:** Generally increase with depth.
- **Temperature Gradients:** Linear (at best) or slightly decreasing with depth.
- **Parasitic Loads:** Pumping costs and frictional losses increase with wellbore length.

There is a specific depth where the value of increased temperature no longer justifies the incremental drilling cost.

Design Tip: Do not rely on assumed relationships found in older literature. You need precise cost-versus-depth relationships derived from statistically significant datasets to calculate the true comprehensive cost of EGS power.

Regional Drilling Costs

To determine relevant collection areas for drilling costs, this course utilizes temperature gradient data (4-km and 6-km) developed by the Southern Methodist University Geothermal Laboratory and Idaho National Laboratory.

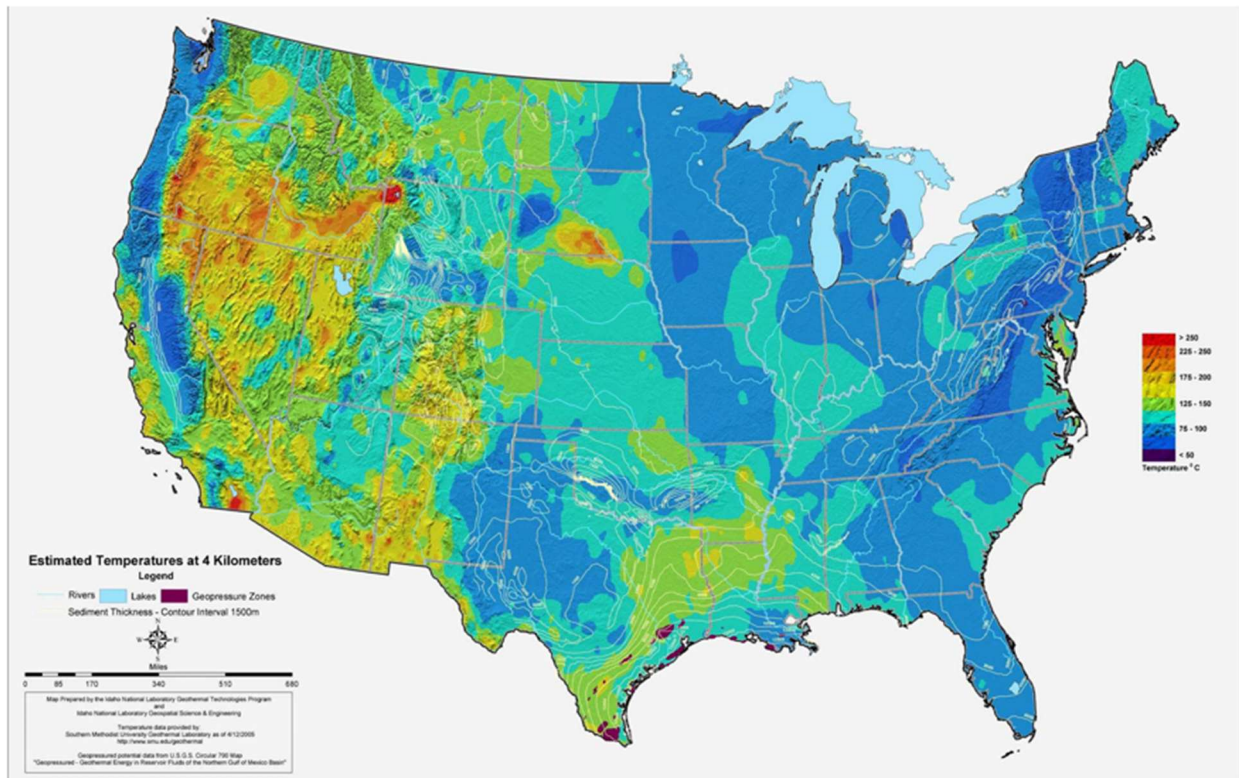


Figure 1. Estimated temperatures at 4 km [based on data from Blackwell and Richards (2004), Southern Methodist

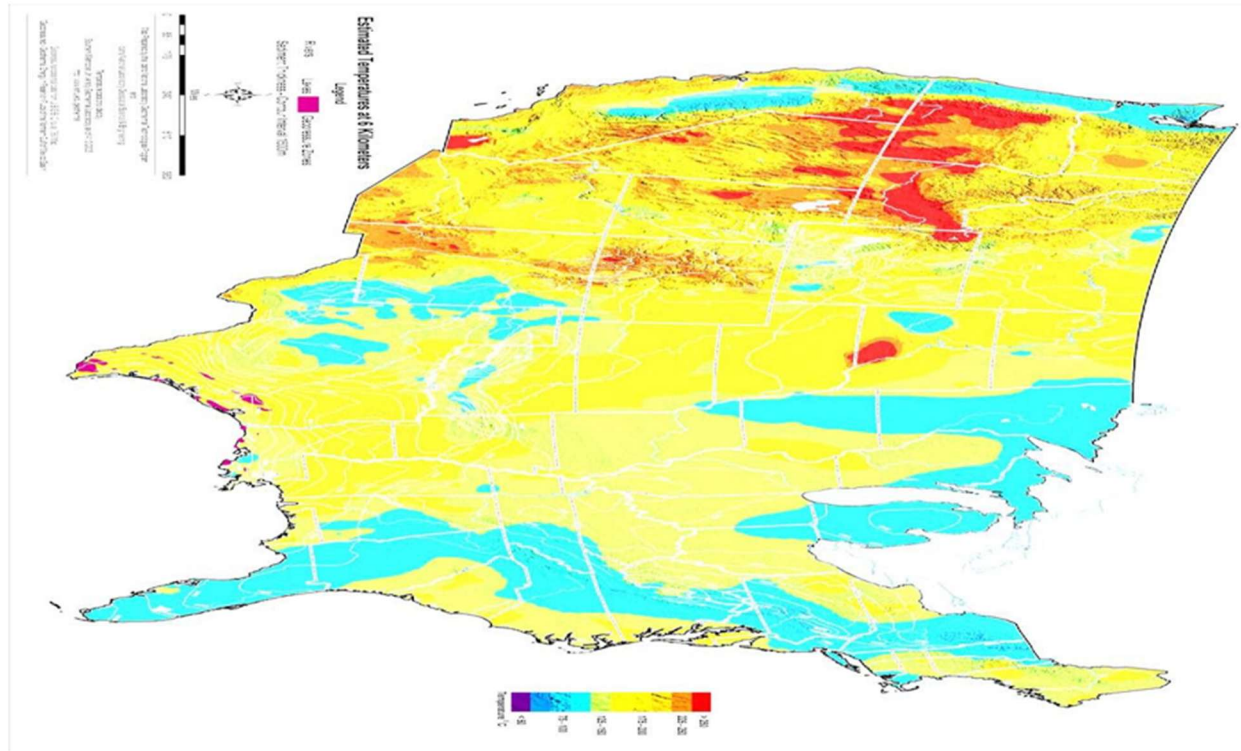


Figure 2. Estimated temperatures at 6 km [based on data from Blackwell and Richards (2004), Southern Methodist

Target Regions

Based on these thermal maps, this analysis focuses on the Western, Mid-continent, and Southern United States—regions with the highest potential for early EGS success.

Data Source Selection

- **Excluded:** Alaska and Hawaii.
- **Limitation:** Proprietary concerns limit the availability of pure geothermal operator data.
- **Solution:** This course utilizes the vast drilling dataset from the Oil & Gas industry as a proxy.

Reference Geothermal Data

While Oil & Gas data is the primary driver for deep well estimation, specific geothermal benchmarks are provided below. Table 1 summarizes costs for wells in Central America and the Azores, adjusted to July 2021 U.S. dollars.



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Table 1: Drilling costs from 1997 to 2021 for Central America and the Azores.

Depth Interval (ft)	Number of Wells	Total Footage	Total Cost (\$K)	Average Depth (ft)	Average Cost/Well (\$K)	Median Cost/Well (\$K)
0–1,249	1	679	280	679	280	280
1,250–2,499	8	15,692	10,415	1,961	1,302	1,258
2,500–3,749	0	0	0	0	0	0
3,750–4,999	5	21,535	10,857	4,307	2,171	2,148
5,000–7,499	24	139,757	65,081	5,823	2,712	2,482
7,500–9,999	20	167,065	68,834	8,353	3,442	3,453
10,000–12,499	3	32,968	11,495	10,989	3,832	3,913
12,500–14,999	0	0	0	0	0	0
15,000–17,499	0	0	0	0	0	0
17,500–19,999	0	0	0	0	0	0
20,000+	0	0	0	0	0	0
Total	61	377,696	166,962	6,192	2,737	2,577

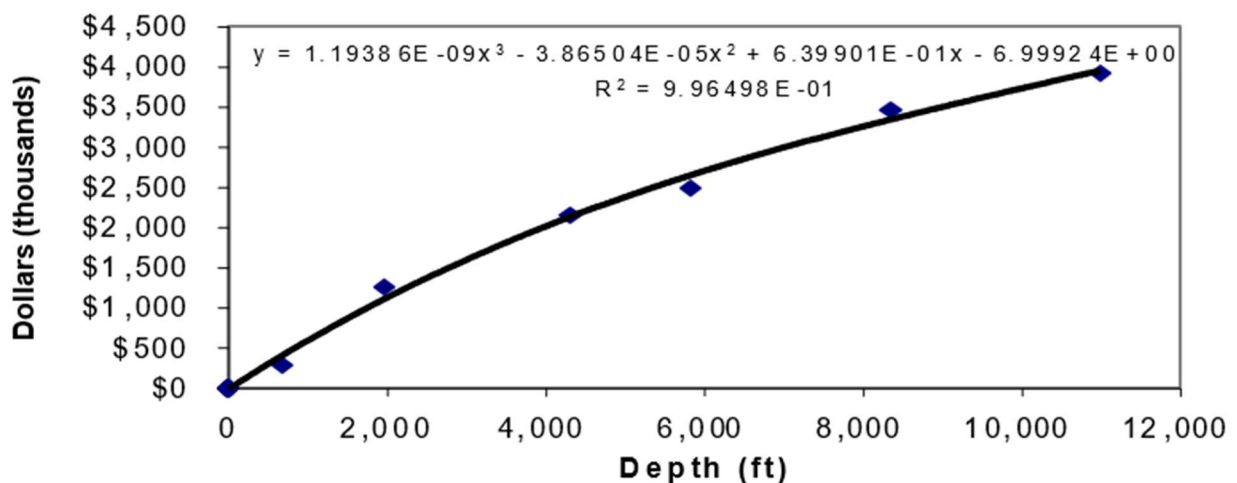


Figure 3. Average depth versus median cost from Table 1 for geothermal wells in Central America and the Azores from 1997-2021 (from Table 1 data).

Historical Geothermal Data (Sandia National Laboratory) Tables 2 and 3 present older geothermal data. Note that these combined datasets represent fewer than 100 wells, reinforcing the need to use Oil & Gas data for statistically robust deep-well estimation.



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Table 2: Geothermal drilling costs from the 1970s. (in year 2000 dollars)

Depth Interval (ft)	Number of Wells	Total Footage	Total Cost (\$K)	Average Depth (ft)	Average Cost/Well (\$K)	Median Cost/Well (\$K)
0–1,249	0	0	0	0	0	0
1,250–2,499	4	7,460	1,908	1,865	477	369
2,500–3,749	6	18,086	7,615	3,014	1,269	1,254
3,750–4,999	9	42,732	10,677	4,748	1,186	792
5,000–7,499	25	151,033	48,985	6,041	1,959	1,800
7,500–9,999	11	94,996	27,385	8,636	2,490	2,415
10,000–12,499	4	40,994	15,676	10,249	3,669	3,538
12,500–14,999	0	0	0	0	0	0
15,000–17,499	0	0	0	0	0	0
17,500–19,999	0	0	0	0	0	0
20,000+	0	0	0	0	0	0
Total	59	355,301	111,246	6,022	1,886	1,792

Table 3. Geothermal drilling costs from the mid-1980s through mid-1990s. (in year 2000 dollars)

Depth Interval (ft)	Number of Wells	Total Footage	Total Cost (\$K)	Average Depth (ft)	Average Cost/Well (\$K)	Median Cost/Well (\$K)
0–1,249	0	0	0	0	0	0
1,250–2,499	0	0	0	0	0	0
2,500–3,749	0	0	0	0	0	0
3,750–4,999	0	0	0	0	0	0
5,000–7,499	3	19,863	4,014	6,621	1,338	1,472
7,500–9,999	17	150,297	33,684	8,841	1,981	1,892
10,000–12,499	5	52,174	8,828	10,435	1,766	1,875
12,500–14,999	0	0	0	0	0	0
15,000–17,499	0	0	0	0	0	0
17,500–19,999	0	0	0	0	0	0
20,000+	0	0	0	0	0	0
Total	25	222,334	46,526	8,893	1,861	1,792



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