Geosciences and Engineering, Vol. 14, No. 1 (2026), pp. 74–84.
https://doi.org/10.33030/geosciences.2026.01.006

TECHNO-ECONOMIC FEASIBILITY OF GEOTHERMAL WELL REPURPOSING IN SYRIA

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Abstract: The Euphrates Graben in northeastern Syria offers strong potential for geothermal energy through repurposing decommissioned hydrocarbon wells. This study evaluates technical and economic feasibility based on temperature, depth, and well integrity. Results show wells (2400–3100 m, 120–150°C) can generate 3–5 MW using binary cycle systems. Economic analysis indicates competitive costs (LCOE: $0.08–0.12/kWh). Repurposing reduces drilling needs, emissions, and costs while supporting sustainable energy development, making it a practical solution for enhancing energy security and renewable integration in Syria.

***Keywords**: Geothermal energy, Repurposed wells, Euphrates Graben, Binary cycle systems, Techno-economic analysis*

1. INTRODUCTION

Syria's energy sector has historically relied heavily on conventional hydrocarbon resources, including oil and natural gas, which have served as the backbone of the national economy and electricity generation infrastructure (Al-Kubaisi et al., 2020). However, ongoing conflict, infrastructure degradation, declining hydrocarbon production, and fluctuating global oil prices have exposed the vulnerabilities of a hydrocarbon-dependent energy system. These challenges highlight the urgent need to diversify the national energy portfolio by integrating renewable energy sources that are locally available, sustainable, and cost-effective. Among the potential renewable alternatives, geothermal energy offers a unique opportunity to provide stable, baseload power that is less dependent on weather conditions compared to solar or wind energy.

The Euphrates Graben, a prominent tectonic depression in northeastern Syria, extends over approximately 300 km in length and 50–70 km in width, and represents a rift-related sedimentary basin with complex geological structures (Jassim and Goff, 2006). The graben is filled with Cenozoic and Mesozoic sediments and hosts multiple hydrocarbon reservoirs that were extensively explored and produced during the late 20th century. Many of the hydrocarbon wells in this region have been decommissioned or abandoned due to declining production rates, technical difficulties, or operational hazards. These wells, however, still penetrate deep geothermal gradients and offer a significant opportunity for repurposing into geothermal energy production wells.

Globally, the concept of repurposing hydrocarbon wells for geothermal electricity has gained attention over the past two decades. Studies in Europe, North America, and Asia have demonstrated that abandoned oil and gas wells can be converted into medium- to high-temperature geothermal systems, with significant reductions in drilling costs and development timelines compared to conventional geothermal projects (Tester et al., 2006; Bertani, 2016; DiPippo, 2015). Binary cycle geothermal plants, in particular, are well-suited for medium-temperature resources (100–180°C) typically encountered in sedimentary basins, enabling electricity generation with high efficiency and minimal environmental impact.

Despite its potential, geothermal development in Syria remains limited due to a lack of systematic resource assessment, technical feasibility studies, and economic evaluations. Few studies have addressed the potential of repurposing existing hydrocarbon wells, and most regional energy planning continues to prioritize fossil fuels. Leveraging abandoned wells in the Euphrates Graben could accelerate renewable energy deployment while reducing the environmental footprint associated with new drilling operations.

This study aims to fill this research gap by providing a comprehensive techno-economic assessment of repurposing decommissioned hydrocarbon wells in the Euphrates Graben for geothermal electricity production. Specific objectives include:

- Geological and thermal assessment: Evaluating subsurface temperatures, well depths, and reservoir characteristics to identify wells suitable for binary cycle geothermal conversion.
- Technical feasibility analysis: Assessing well integrity, flow capacity, and the potential energy output of selected wells.
- Economic evaluation: Estimating CAPEX, OPEX, and LCOE to determine the financial viability of geothermal repurposing in the region.
- Strategic recommendations: Providing guidelines for pilot implementation, regulatory frameworks, and operational optimization to facilitate large-scale deployment.

By integrating geological, technical, and economic perspectives, this study seeks to demonstrate that repurposing hydrocarbon wells in the Euphrates Graben is not only feasible but also offers a practical pathway toward sustainable and resilient energy development in Syria.

2. MATERIALS AND METHODS

2.1. Study Area

The Euphrates Graben extends across northeastern Syria, bordered by the Palmyra fold belt to the west and the Arabian Shield to the east (Fig. 1). Average well depths range from 2,000 to 3,500 m, with bottom-hole temperatures of 100–160°C (Jassim and Goff, 2006). These thermal conditions are suitable for medium-temperature geothermal applications such as electricity production via binary cycle plants.

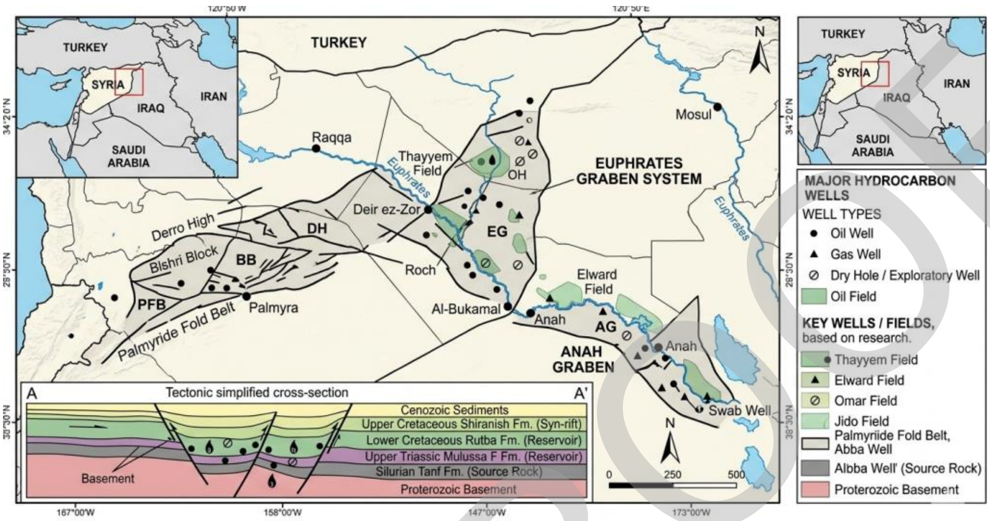

Figure 1

Location map of the Euphrates Graben and major hydrocarbon wells

2.2. Overall Research Framework

The methodological workflow consists of four sequential stages. The first stage involves data collection and screening, comprising the compilation of geological, thermal, and well data from hydrocarbon fields. The second stage covers technical feasibility assessment, including evaluation of reservoir temperature, well integrity, and flow capacity. In the third stage, power generation potential is estimated using thermodynamic equations. The fourth and final stage consists of an economic evaluation, in which CAPEX, OPEX, and LCOE are analyzed to assess financial viability.

2.3. Data Collection and Well Selection

A dataset of 50 decommissioned hydrocarbon wells in the Euphrates Graben was analyzed. Wells were included in the study only if they met the following selection criteria: a depth of at least 2,000 m, a reservoir temperature of at least 120°C, the availability of well logs covering temperature, pressure, and casing condition, and a structural integrity deemed suitable for re-entry. Data were compiled from three main sources: well logs provided by the Syrian Petroleum Company (SPC), regional geological surveys, and published geothermal datasets (Bertani, 2016). Of the 50 wells examined, 28 met the temperature threshold, 18 subsequently passed integrity checks, 10 were shortlisted for detailed analysis, and 4 were ultimately selected as representative case studies (Table 1).

Table 1

Selected Wells for Geothermal Conversion

Well ID	Depth (m)	Temp (°C)	Flow rate (m³/h)	Potential Power (MW)
EG-01	2,400	130	60	3.2
EG-07	2,800	145	70	4.5
EG-12	3,100	150	80	5.0
EG-19	2,500	125	55	3.5

2.4. Geological and Thermal Modeling

The geothermal gradient in the Euphrates Graben was estimated using bottom-hole temperature (BHT) data:

$$Geothermal\ Gradient = \frac{Tbh - Tsurface}{Depth} \tag{1}$$

where T_{ah} denotes the bottom-hole temperature (°C) and $T_{sui}^{\varphi ace}$ is the average surface temperature (≈ 20°C). The average geothermal gradient measured across the study area ranges from 30 to 40°C/km, yielding reservoir temperatures between 120 and 150°C. These values confirm the suitability of the area for medium-temperature geothermal systems, particularly binary cycle plants. These values indicate suitability for medium-temperature geothermal systems, particularly binary cycle plants.

2.5. Well Integrity Assessment

Well integrity is critical for safe geothermal conversion. Each candidate well was evaluated against four key parameters: casing condition (assessed for corrosion and deformation), cement bonding quality (examined for adequate zonal isolation), well-head stability, and potential leakage risks. Each parameter was scored on a 0–5 scale, and only wells achieving satisfactory scores across all criteria were advanced to the power generation modeling stage.

2.6. Flow Rate Estimation

Flow rates were estimated using analog geothermal reservoirs and Darcy's Law:

$$Q = \frac{kA(P1 - P2)}{\mu l} \tag{2}$$

where Q is the flow rate, k is the permeability, A is the cross-sectional area, $(P_1 - P_2)$ the pressure differential, μ is the fluid viscosity and L is the flow length. Based on analogous geothermal reservoirs in comparable sedimentary basins, the flow rate was estimated in the range of 50–90 m³/h, with moderate reservoir permeability assumed throughout. Reinjection wells are considered available and necessary for long-term reservoir sustainability.

2.7. Power Generation Modeling

Electricity generation potential was calculated using thermal energy balance:

$$P = m^{\cdot} \cdot Cp \cdot (Tres - Trein) \cdot \eta \tag{3}$$

where $\dot{f}$ is the mass flow rate (kg/s), C_p is the specific heat capacity (4.18 kJ/kg·°C), T_{res} is the reservoir temperature, T_{rein} is the reinjection temperature (≈ 70°C), and η is the thermodynamic conversion efficiency (10–15%). The selected technology for electricity generation is the Binary Cycle Power Plant based on the Organic Rankine Cycle (ORC), which is well suited for medium-temperature resources in the 100–180°C range. Key advantages of this closed-loop system include efficient electricity generation from moderate-temperature resources and low environmental emissions, making it particularly compatible with sedimentary basin geothermal systems such as those found in the Euphrates Graben.

2.8. Economic Evaluation

2.8.1. Capital Expenditure (CAPEX)

The total CAPEX is expressed as CAPEX = Cq_{ell} + $C_{sui}{}^{\varphi ace}$ + $C_{pl}{}^{a}{}_{nt}$ (Eq. 4), where the three components represent well re-entry and rehabilitation costs (including downhole pumps and casing repair), surface infrastructure, and binary cycle power plant installation (heat exchangers and turbine system), respectively. For the selected wells, CAPEX ranges from $2.0–2.3 million for shallower wells (~2400 m) to $2.8–3.2 million for deeper wells (~3100 m), reflecting the increase in technical complexity with depth

$$CAPEX = C_{well} + C_{surface} + C_{plant} \tag{4}$$

2.8.2. Operational Expenditure (OPEX)

Annual OPEX covers three main categories: routine maintenance, pump electricity consumption, and chemical treatment (primarily anti-scaling and anti-corrosion measures). In aggregate, OPEX is estimated at approximately 4–6% of CAPEX per year, expressed as OPEX ≈ 4–6% of CAPEX annually, consistent with benchmarks reported for comparable binary cycle installations (Tester et al., 2006).

2.8.3. Levelized Cost of Electricity (LCOE)

The LCOE was calculated according to Eq. (5),

$$LCOE = \frac{\sum(It+Ot+Ft)}{\sum ET} \quad (5)$$

where I_t is investment costs, O_t is operation and maintenance costs, F_t is fuel costs (≈ 0 for geothermal) and E_t is the total electricity generated. The calculation assumes a project lifetime of 20 years, a discount rate of 8%, and a capacity factor of 85–90%. The resulting LCOE values are compared against solar photovoltaic and natural gas in Fig. 2, illustrating the competitive position of geothermal energy for the region.

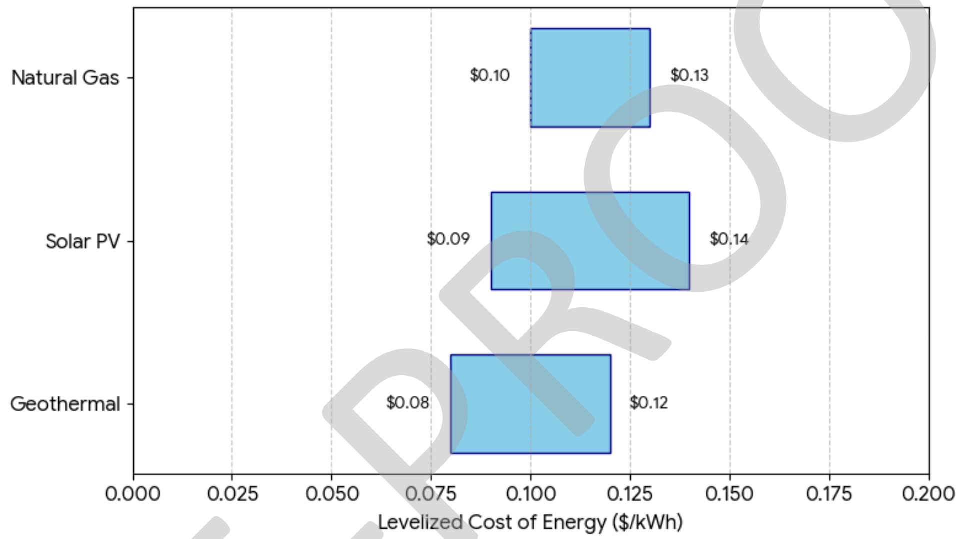

Figure 2

LCOE comparison between geothermal, solar PV, and natural gas

3. RESULTS

3.1. Geothermal Resource Potential

The analysis of 50 decommissioned hydrocarbon wells in the Euphrates Graben revealed that approximately 56% of the wells exhibit reservoir temperatures exceeding 120°C, which is considered the minimum threshold for efficient electricity generation using binary cycle geothermal systems. The geothermal gradient across the study area ranges between 30 and 40°C/km, consistent with rift-related sedimentary basins.

The selected wells demonstrate favorable thermal and hydraulic conditions. Reservoir temperatures range from 125°C to 150°C, with corresponding flow rates between 55 and 80 m^3/h. These parameters are sufficient to sustain continuous geothermal energy extraction with minimal thermal depletion when reinjection is properly managed.

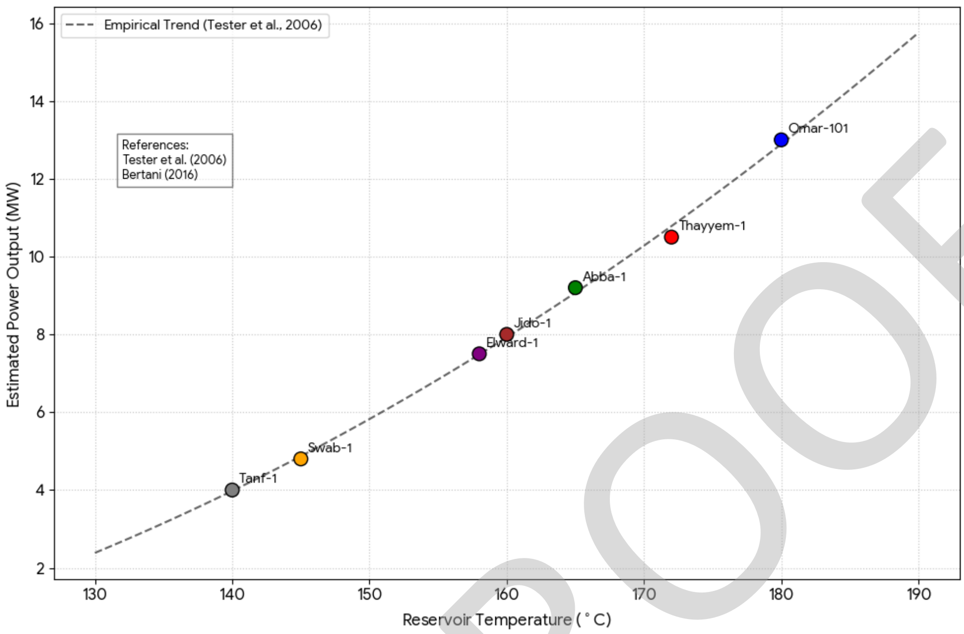

Figure 3.
Reservoir temperature versus estimated power output for selected wells (Tester et al., 2006; Bertani, 2016)

As shown in Fig. 3, power output increases with reservoir temperature due to higher thermal energy availability. For instance, well EG-12, with a reservoir temperature of 150°C, achieves an estimated power output of 5 MW, while well EG-19 at 125°C produces approximately 3.5 MW. This trend confirms that temperature is the most critical parameter influencing geothermal energy production.

3.2. Power Generation Potential

Using the thermodynamic model described in the methodology, the estimated power generation capacity for each well ranges from 3 to 5 MW. Assuming a conservative capacity factor of 85%, the annual energy production per well is calculated as:

Using the thermodynamic model described in the methodology, the estimated power generation capacity for each well ranges from 3 to 5 MW. Assuming a conservative capacity factor of 85%, the annual energy production per well (Table 2) is calculated as:

$$E = P \times CF \times 8760 \quad (6)$$

where P is power output (MW), CF is a capacity factor (0.85) and constant 8760 is given in hours per year.

Table 2.
Estimated Annual Energy Output

Well ID	Power (MW)	Annual Energy (GWh/year)
EG-01	3.2	23.8
EG-07	4.5	33.5
EG-12	5.0	37.2
EG-19	3.5	26.0

3.3. Economic Evaluation and CAPEX Analysis

The economic feasibility analysis demonstrates that repurposing existing wells significantly reduces upfront investment compared to drilling new geothermal wells.

Capital costs increase with depth due to higher technical complexity. This relationship is presented in Fig. 4.

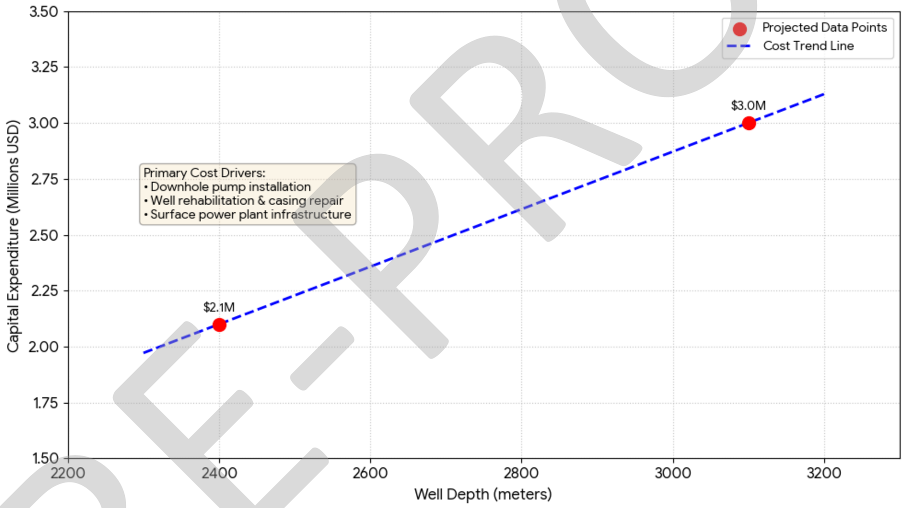

Figure 4.
Capital expenditure (CAPEX) versus well depth for geothermal conversion

As shown in Fig. 4, CAPEX ranges from approximately $2.1 million for shallower wells (~2400 m) to $3.0 million for deeper wells (~3100 m). The primary cost drivers include:

- Downhole pump installation,
- Well rehabilitation and casing repair,
- Surface power plant infrastructure.

4. DISCUSSION

The results demonstrate that repurposing decommissioned hydrocarbon wells in the Euphrates Graben is both technically viable and economically competitive. The geothermal gradients observed in the region are sufficient to support binary cycle power generation, which is particularly suitable for medium-temperature resources.

A key advantage of this approach is the significant reduction in capital costs due to the reuse of existing wells. Drilling new geothermal wells typically accounts for 40–60% of total project costs; therefore, repurposing existing wells can reduce overall CAPEX by up to 50% (Tester et al., 2006).

From a technical perspective, reservoir temperature is the dominant factor influencing power output, as demonstrated in Fig. 3. Wells with temperatures above 140°C exhibit substantially higher efficiency and energy generation capacity. Flow rate also plays a critical role, as insufficient fluid circulation can limit heat extraction.

However, several challenges must be addressed:

- Well Integrity Issues: Aging wells may suffer from casing corrosion or cement degradation.
- Scaling and Corrosion: Mineral deposition can reduce system efficiency over time.
- Reservoir Sustainability: Long-term heat extraction must be balanced with reinjection strategies.

Economically, the LCOE results indicate that geothermal energy is competitive with solar and natural gas, while offering the advantage of continuous baseload power. Unlike solar PV, geothermal energy is not dependent on weather conditions, making it more reliable for grid stability.

In the Syrian context, geothermal development could play a critical role in energy recovery and infrastructure rebuilding. However, political instability, lack of investment, and regulatory barriers may limit immediate implementation.

5. CONCLUSIONS

This study evaluated the techno-economic feasibility of repurposing decommissioned hydrocarbon wells in the Euphrates Graben for geothermal energy production. The key conclusions are:

- The region exhibits favorable geothermal conditions, with temperatures between 120°C and 150°C suitable for binary cycle power generation.
- Repurposed wells can generate between 3 and 5 MW of electricity per well.
- The estimated LCOE of $0.08–0.12/kWh is competitive with other energy sources in the region.
- Reusing existing wells significantly reduces capital costs and project development time.
- Geothermal energy provides a reliable and sustainable energy source that can enhance Syria’s energy security.

Based on the findings of this study, the following recommendations are proposed.
Technical Recommendations:

- Conduct detailed well integrity assessments before conversion.
- Implement corrosion-resistant materials and scaling mitigation techniques.

- Optimize reinjection strategies to ensure long-term reservoir sustainability.

Economic Recommendations:

- Develop financial incentives to attract private investment in geothermal energy.
- Explore public-private partnerships to fund pilot projects.

Policy Recommendations:

- Establish regulatory frameworks for geothermal energy development.
- Integrate geothermal energy into national energy planning strategies.

Future Research:

- Conduct field-scale pilot projects to validate modeling results.
- Investigate hybrid renewable systems combining geothermal and solar energy.
- Perform detailed reservoir simulations for long-term performance assessment.

ACKNOWLEDGMENTS

The authors thank the University of Miskolc (Institute of Mining and Energy) for academic support and appreciate the constructive feedback from the managing editor and reviewers.

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