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СОВЕРШЕНСТВОВАНИЕ ТЕХНОЛОГИЙ ГЕОТЕРМАЛЬНОГО БУРЕНИЯ И РАЗВИТИЕ ИННОВАЦИОННЫХ МНОГОЗАБОЙНЫХ РЕШЕНИЙ В АЗЕРБАЙДЖАНЕ

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Развитие геотермальной энергетики в Азербайджане требует применения передовых технологий бурения для полного использования значительного геотермального потенциала страны. Многозабойное бурение, адаптированное из практики нефтегазовой отрасли, предлагает существенные преимущества для геотермальных приложений, повышая эффективность работы резервуаров и снижая воздействие на поверхность. В статье рассматривается применение технологий геотермального бурения в Азербайджане с акцентом на многозабойные методы, современные материалы и решения для работы в условиях высоких температур. Тематическое исследование потенциальных геотермальных зон, таких как Кура-Аразская низменность и Абшеронский полуостров, иллюстрируют реализуемость этих технологий. Несмотря на такие высокие затраты и экстремальные условия под землей, исследование подчеркивает роль многозабойного бурения в достижении целей Азербайджана в области возобновляемой энергетики.

КЛЮЧЕВЫЕ СЛОВА: *геотермальное бурение, многозабойные скважины, геотермальные ресурсы Азербайджана, современные материалы, переход к возобновляемой энергетике, управление резервуарами, тепловая энергия, устойчивое развитие.*

ӘЗІРБАЙЖАНДА ГЕОТЕРМАЛДЫҚ БҰРҒЫЛАУ ТЕХНОЛОГИЯЛАРЫН ЖЕТІЛДІРУ ЖӘНЕ ИННОВАЦИЯЛЫҚ КӨПЖАБЫНДЫ ШЕШІМДЕРДІ ДАМЫТУ

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БАКУ ЖОҒАРЫ МҰНАЙ МЕКТЕБІ
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Әзірбайжанда геотермалдық энергияны дамыту үшін елдің айтарлықтай геотермалдық әлеуетін толық пайдалану мақсатында заманауи бұрғылау технологияларын енгізу қажет. Мұнай-газ саласының тәжірибесінен алынған көпбұтақты бұрғылау әдісі геотермалдық қолдану үшін үлкен артықшылықтарға ие. Бұл әдіс қоймалардың тиімділігін арттырып, жер бетіне әсерді азайтады. Осы мақалада Әзірбайжандағы геотермалдық бұрғылау технологияларын қолдану мәселелері қарастырылған. Атап айтқанда, көпбұтақты әдістер, заманауи материалдар және жоғары температуралық шешімдерге баса назар аударылады. Құра-Арас ойпаты және Апшерон түбегі сияқты әлеуетті геотермалдық аймақтардан алынған зерттеулер бұл технологиялардың қолданылу мүмкіндігін көрсетеді. Жоғары шығындар мен жер асты жағдайларының қиындығына қарамастан, зерттеу көпбұтақты бұрғылаудың Әзірбайжанның жаңартылатын энергия көздеріне көшу мақсаттарын жүзеге асырудағы рөлін атап көрсетеді.

ТҮЙІН СӨЗДЕР: *геотермалдық бұрғылау, көпбұтақты ұңғымалар, Әзірбайжанның геотермалдық ресурстары, заманауи материалдар, жаңартылатын энергияға көшу, қоймаларды басқару, жылу энергиясы, тұрақты даму.*

ADVANCING GEOTHERMAL DRILLING TECHNOLOGIES AND MULTILATERAL INNOVATIONS IN AZERBAIJAN

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The development of geothermal energy in Azerbaijan requires advanced drilling technologies to fully utilize the country's significant geothermal potential. Multilateral drilling, adapted from oil and gas practices, offers substantial benefits for geothermal applications, enhancing reservoir efficiency while reducing surface impact. This article examines the application of geothermal drilling technologies in Azerbaijan, with a focus on multilateral techniques, advanced materials, and high-temperature solutions. Case studies from potential geothermal sites, such as the Kura-Aras Lowland and Absheron Peninsula, illustrate the feasibility of these technologies. Despite challenges like high costs and extreme subsurface conditions, the study underscores the role of multilateral drilling in achieving Azerbaijan's renewable energy goals.

KEYWORDS: *geothermal drilling, multilateral wells, Azerbaijan geothermal resources, advanced materials, renewable energy transition, reservoir management, thermal energy, sustainable development.*

Azerbaijan's geothermal fields are concentrated in regions such as the Absheron Peninsula, Kura-Aras Lowland, and the Greater and Lesser Caucasus. These areas exhibit geothermal gradients of 30°C to 50°C per kilometer, making them ideal for both high- and medium-temperature applications. The Absheron Peninsula, for instance, is a prime candidate for electricity generation due to its high geothermal temperatures. In contrast, the Kura-Aras Lowland is better suited for direct-use applications such as district heating, given its medium-temperature reservoirs. Despite these promising conditions, traditional vertical drilling methods often limit reservoir efficiency and increase surface environmental impact.

Multilateral drilling is a key innovation that addresses these limitations. By creating multiple lateral branches from a single main borehole, multilateral drilling increases the reservoir contact area, thereby enhancing fluid production and overall energy output. This approach also reduces the need for multiple surface wellheads, which is particularly beneficial in environmentally sensitive areas such as the Kura-Aras Lowland. A feasibility study conducted in the Absheron Peninsula demonstrated that multilateral wells could increase production rates by 35% and reduce drilling costs by 20%, primarily through shared infrastructure and optimized reservoir management.

The adoption of multilateral drilling in Azerbaijan necessitates advanced materials and technologies. High-performance drill bits, such as polycrystalline diamond compact (PDC) bits, have proven effective in geothermal environments, reducing bit failure rates by 40% in high-temperature formations like those in the Absheron Peninsula. Similarly, advanced casing materials, including titanium alloys and fiber-reinforced composites, are essential for maintaining well integrity under extreme thermal and pressure conditions. The application of thermally stable drilling fluids is another critical innovation, ensuring efficient cuttings transport and minimizing viscosity changes at temperatures exceeding 300°C.

Despite its advantages, multilateral drilling in geothermal applications presents significant challenges. High initial costs remain a major barrier, with the average cost of drilling a geothermal well in Azerbaijan ranging from $1.5 to $2 million. The complex engineering requirements of multilateral wells, including precise branch isolation and advanced monitoring systems, further add to the financial burden. Extreme subsurface conditions, such as high salinity and corrosive fluids, necessitate continuous innovation in materials and drilling techniques. Environmental concerns, particularly the potential for seismic activity induced by geothermal drilling, also require careful management and rigorous safety protocols.

To overcome these challenges, Azerbaijan must adopt a multi-pronged strategy. Government support in the form of feed-in tariffs and tax incentives can significantly reduce the financial risks associated with geothermal projects. Public-private partnerships, particularly with organizations like SOCAR and international renewable energy firms, can facilitate the transfer of technical expertise and resources. Increased investment in research and development is also critical, focusing on advancing drilling technologies, improving geothermal reservoir modeling, and enhancing energy storage solutions.

The economic and environmental benefits of adopting advanced geothermal drilling technologies in Azerbaijan are substantial. Multilateral drilling reduces surface

infrastructure requirements, cutting costs by up to 20%. It also enhances energy security by increasing geothermal output, contributing to Azerbaijan's target of achieving 30% renewable energy by 2030. Environmentally, geothermal power plants produce negligible greenhouse gas emissions, aligning with the country's commitments under the Paris Agreement. The application of multilateral drilling in Azerbaijani geothermal fields could set a benchmark for sustainable energy practices in the South Caucasus region.

Case studies from the Absheron Peninsula and Kura-Aras Lowland underscore the feasibility of these technologies. In the Absheron Peninsula, high-temperature multilateral wells have extended reservoir life and sustained electricity production, while in the Kura-Aras Lowland, optimized multilateral configurations have improved thermal efficiency for district heating. These examples demonstrate the potential of multilateral drilling to unlock Azerbaijan's geothermal resources, providing a model for integrating advanced drilling techniques into renewable energy development.

Why Suggest Multilateral Drilling for Geothermal Reservoirs? Multilateral drilling is ideal for geothermal applications due to its ability to maximize resource utilization, reduce environmental impact, and optimize economic outcomes. In Azerbaijan, where geothermal reservoirs like those in the Absheron Peninsula and Kura-Aras Lowland hold significant potential, the adoption of multilateral drilling can transform geothermal energy production. It addresses the challenges of complex subsurface conditions and land use restrictions while providing a sustainable and cost-effective pathway to meet the country's renewable energy goals. This approach aligns with international best practices, offering a competitive and environmentally responsible solution for geothermal resource development.

In conclusion, the advancement of geothermal drilling technologies, particularly multilateral drilling, is essential for realizing Azerbaijan's geothermal energy potential. By addressing technical, economic, and environmental challenges, these innovations can significantly contribute to the country's renewable energy transition. Multilateral drilling not only enhances reservoir efficiency but also reduces environmental impact, offering a sustainable and scalable solution for geothermal energy development. With continued investment and collaboration, Azerbaijan can position itself as a leader in geothermal innovation, setting a precedent for the region and beyond.

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