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Review Article

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Solar-Powered Oil Recovery (SeOR)

Alperen Sahinoglu[1]*

[1]Nigde Omer Halisdemir University, Nigde, Turkiye

INFORMATION

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Contact
*Alperen Sahinoglu
alperensahinoglu@ohu.edu.tr

ABSTRACT

Heavy oil production, which comprises 70% of the world's remaining reserves, is becoming increasingly important for oil companies. While heavy oil is abundant, its thick, tar-like consistency makes it challenging to extract. The primary method for its extraction is steam injection, a thermal-enhanced oil recovery (EOR) technique. This process involves injecting steam into a reservoir to heat the oil, reducing its viscosity and enabling it to be pumped to the surface more efficiently. Steam injections can enhance well productivity by up to 300% but requires significant energy. Traditionally, the steam for EOR is generated by burning large amounts of natural gas, a scarce and valuable resource in many oil-producing regions. Solar EOR offers a sustainable alternative by replacing natural gas with concentrated solar power to generate steam. Solar energy can supply up to 80% of the steam needs of an oilfield, dramatically reducing natural gas consumption. During the day, solar-generated steam is used, while natural gas-generated steam is utilized at night to ensure continuous injection. Solar EOR employs an enclosed trough technology designed specifically for the oil industry. This system uses curved mirrors inside a glasshouse to track the sun, focusing its heat onto water pipes. The concentrated sunlight heats the water, producing steam. The glasshouse structure protects the mirrors from environmental factors like wind, dust, and sand. Utilizing solar energy redirects the natural gas saved to higher-value applications such as power generation or industrial projects, thereby supporting local economies and generating employment opportunities. Solar EOR (SeOR) also produces steam without emissions, contributing to a more sustainable approach to meeting global energy demands. This review explores the interconnections between solar-powered systems and oil production, discussing various aspects of heavy oil, extraction methods, and solar energy.

1. Introduction

Heavy oil fields account for 70% of the world's proven reserves, yet much of this resource remains inaccessible using conventional production technologies. Oil companies are investing significant efforts in developing new extraction methods to increase the proportion of recoverable heavy oil. These heavy oil fields are extensively distributed globally but present considerable challenges in bringing the oil to the surface due to its viscous and tar-like nature (Fig. 1).

The primary technique for extracting heavy oil is steam injection, a thermal-enhanced oil recovery (EOR) method. This process involves injecting steam into the reservoir using surface pumps to heat the oil, reducing its viscosity and facilitating its extraction (Figs. 2–3).

Steam injection can potentially enhance well productivity by over 300%, making it an effective method. However, the process is highly energy-intensive, requiring substantial energy input for steam generation.

2. Solar-Powered Oil Recovery (SeOR)

Enhanced oil recovery (EOR) has consistently been an effective method for extracting oil from challenging reservoirs. Traditionally, this process has depended on burning natural gas to generate steam. However, solar-powered oil production is increasingly considered a practical alternative to this conventional approach.

Advanced oil recovery is not new; it was developed as early as the 1950s. For instance, oil production in California relies heavily on subsurface rocks for steam generation, primarily powered by natural gas. While natural gas is currently cost-effective, it is projected to become more expensive. Furthermore, although it burns cleaner than other fossil fuels, it still contributes to the carbon footprint associated with oil production.

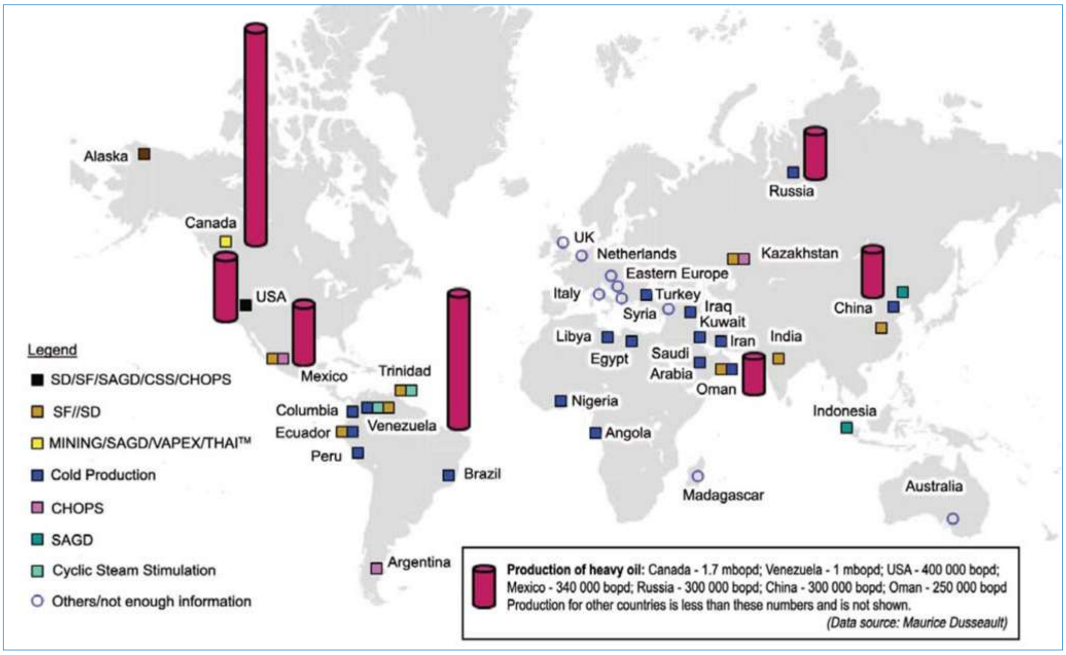

Fig. 1. Distribution of heavy oil around the world (Chopra and Lines, 2008)

Fig. 2. Oil production with solar energy (https://energiesmedia.com/how-solar-energy-is-revolutionizing-oil-and-gas-production/)

Solar-powered oil production, or solar-enhanced oil recovery (SeOR), involves installing an affordable greenhouse structure with solar mirrors near oil fields. This innovative approach reduces oil production's carbon emissions and generates steam at a significantly lower cost than natural gas (Abd et al., 2022 and their references) (Fig. 4).

One example is a solar steam generation system that operates in a 100-year-old oilfield in California. A half-acre greenhouse houses solar reflective mirrors suspended from cables attached to the ceiling. Motors adjust the mirrors' position throughout the day to capture maximum sunlight. The focused sunlight heats water-filled pipes suspended within the greenhouse, boiling the water into steam. This steam is continuously injected deep into wells, reducing crude oil viscosity and enhancing oil recovery.

Advocates of SeOR highlight its economic benefits. For instance, this method's estimated cost of producing steam is approximately USD 3.78 per million British thermal units (Btu), compared to USD 5.79 per million Btu for gas-generated steam.

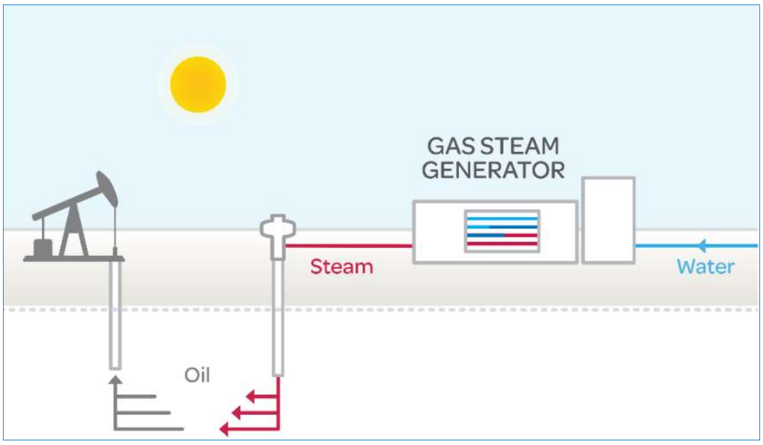

Fig. 3. EOR method (www.glasspoint.com)

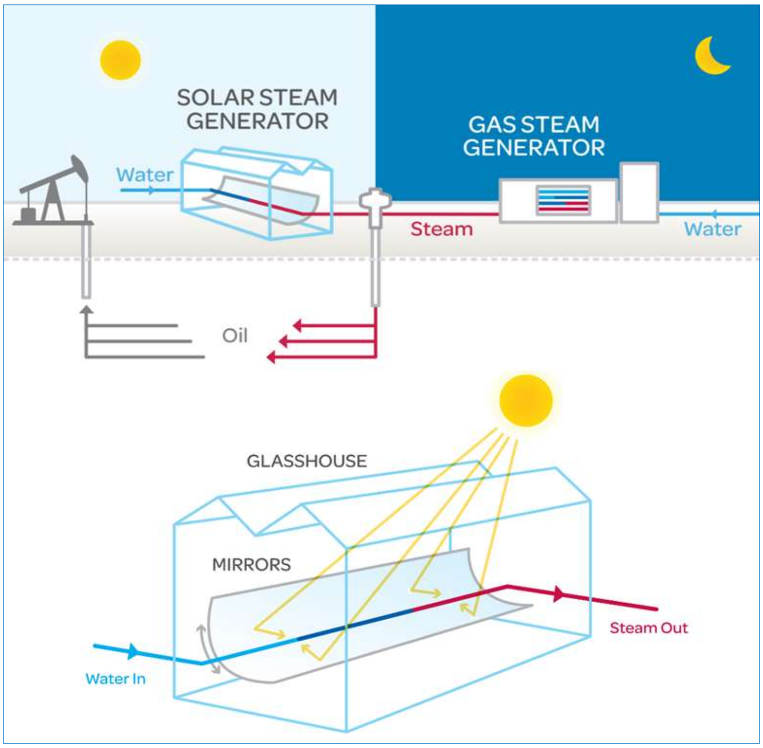

Fig. 4. Solar-powered oil production (SeOR) (www.glasspoint.com)

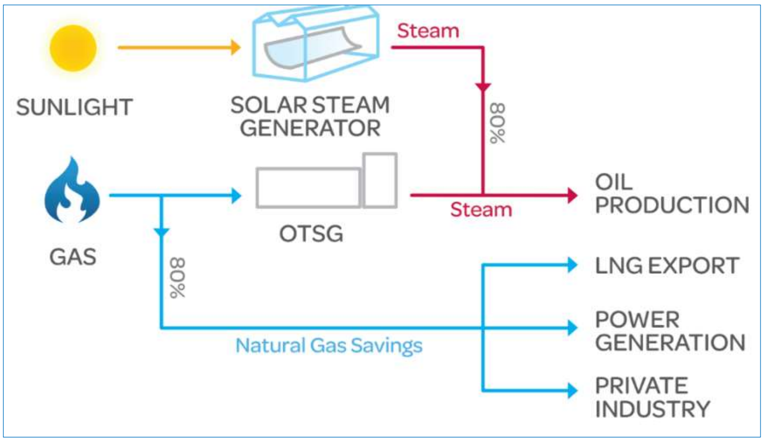

Fig. 5. Advanced solar-powered oil production method with LNG export terminal (www.glasspoint.com)

Additionally, greenhouses are easy to procure, install, and maintain. Their enclosed design protects the mirrors from wind, allowing for higher operational temperatures and preventing dust accumulation due to exposure to moisture (Abd et al., 2022 and their references).

Despite its advantages, SeOR faces challenges. A standard oilfield would require approximately 100 acres of greenhouse structures to meet its daily steam requirements, with larger fields demanding even more space. Moreover, when solar energy is unavailable, natural gas remains essential for nighttime steam production.

SeOR's most significant potential lies in regions like the Middle East, where natural gas, previously reserved for export, is increasingly retained for domestic use to support local economic development. For instance, Oman once relied on its LNG export terminal and redirected some of its gas reserves toward oil production after its output peaked in 2000. Other countries in the region may confront similar challenges (Fig. 5).

3. Conclusion

This study underscores the growing importance of innovative technologies, such as SeOR, in addressing the challenges associated with heavy oil production. While effective, traditional methods like steam injection are energy-intensive and heavily reliant on natural gas, which raises economic and environmental concerns. SeOR offers a sustainable alternative, leveraging solar power to reduce natural gas consumption, operational costs, and the carbon footprint of oil extraction. Integrating solar technology into oil production demonstrates significant potential in regions with abundant sunlight and a pressing need for economic diversification, such as the Middle East. By redirecting saved natural gas to higher-value applications, SeOR enhances the efficiency of oilfield operations and supports local economies and industrial development. However, the scalability of SeOR remains challenging, requiring substantial infrastructure investments, including expansive greenhouse systems, to meet the steam needs of larger oilfields. While SeOR is still in its early stages, its adoption represents a critical step towards more sustainable and economically viable oil production practices. Future research should focus on optimizing SeOR systems to further improve their efficiency and cost-effectiveness. Additionally, collaboration between industry stakeholders and policymakers will be essential to promote the widespread implementation of this promising technology and to address the global demand for energy in an environmentally responsible manner.

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