

Improving Sustainability of Oil Industry via Integration with Geothermal Energy: Analysis of Strategies

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In this research, we reviewed the types of geothermal and oil wells as well as their drilling methods. The existing research background has yielded positive results toward increasing sustainability in line with use of abandoned oil wells to utilize geothermal energy. Also, with an emphasis on Iran's fourth and fifth development plans for sustainability and stressing this issue in the oil industry, we conducted the "SWOT" analysis in this regard. This analysis clarifies four categories of Strengths, Weaknesses, Opportunities, and Threats, also includes a variety of strategies that can be applied in Iran's oil industry by means of these categories, including the SO strategy, whereby the increase in the use of new energy resources as renewables will lead to increases the positive social attention towards Iran's oil industry. Also, we conducted the WO strategy in which, investing in research and development can optimize the conversion of abandoned oil wells for geothermal energy production, reducing the high conversion costs and increasing the potential capacity of geothermal energy production. In addition, ST strategy can be functional where increasing attractiveness of the oil industry due to sustainable development among other countries can attract foreign capital. Finally, the WT strategy that a small number of companies that can be linked to cooperate with each other can reduce the risk of the threat of disagreement between managers and organization heads. © 2023 Journal of Energy Management and Technology

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1. INTRODUCTION

Nowadays, in many countries around the world, the use of geothermal energy has made significant progress. The utilization rate of geothermal energy varies based on factors such as the number and quality of the hot underground aquifer [1]. Besides, the lack of proper plans in the policy system has led to hesitation from those who hold the stake in focusing on geothermal energy from a strategic view [2]. In general, the environmental impacts of geothermal electricity production and also the direct use of it are controllable, or inconsequential. In this regard, the environmental regulations, which may vary from country to country, must be fully considered and concerned [3].

There have been many studies conducted on integrating geothermal energy in the oil and gas industry, Kai Wang et al. [4], investigated the geothermal resources available in oilfields and their utilization, including the unique characteristics of geothermal energy extraction in oilfields, current developments, challenges, and potential solutions. It has been concluded that utilizing geothermal resources in oilfields can be a beneficial option for offsetting operational costs, reducing CO₂ emissions,

and extending the economic lifespan of wells and infrastructure. It has highlighted the significant benefits that geothermal energy can provide to the petroleum industry and society. Finally, while certain obstacles remain that limit the development of geothermal resources in oilfields, significant growth in direct use and power generation is anticipated in the future due to the emergence of new technologies and research breakthroughs.

Also, Wight and Bennett [5] proposed and evaluated an approach that utilizes water as the wellbore fluid, in combination with abandoned wells and a closed wellbore, to generate electricity through a binary cycle plant while reducing contamination risks associated with conventional organic working fluids, they obtained that by using the approach of a binary cycle power plant with a multistage heat exchanger, 109 kW to 630 kW figure of power can be reached and also when using abandoned oil or gas wells as for producing energy with the means of water as the wellbore circulating fluid, this approach will have not any dependence on the fluid of geothermal.

However, Cano et al. [6], by referring to different synergies between the geothermal and oil and gas industries, indicated

that there is a huge need to conduct pilot tests to demonstrate the proper feasibility of this type of project and gain the practical experience that will show skeptics that this technology is as beneficial as the large body of literature suggested.

Local heating using geothermal energy resources can be a very good choice, especially for shallow abandoned wells [7]. As the Y. Le Nian and W. L. Cheng [8] estimated, if a geothermal well with the relevant features such as a depth of 3000 m and a depth well temperature of 125 °C is available, it would be enough to keep a building with a 10,000 m² heating area at around 26 °C. However, a thermo-economic analysis should also be performed before practical and engineering applications. Based on A. Mehmood et al. [9], It can be seen that both hot water and electricity can be obtained from abandoned wells. Also, the results show that the distance between two wells should not be less than 40 meters to avoid interference between them. In addition, X. Bu et al. [10], concluded that the financial revenue of electricity generation is 36,833.26 US\$ per annum for one retrofitted well. By referring to F. Asadi et al. [11], in the case of using geothermal electricity, it has been said that if the price of fuel is liberalized, it can have a significant effect on reducing the costs of geothermal electricity production, so that this power plant becomes one of the most economic power plants in Iran after the combined cycle power plants. Geothermal energy, unlike other renewable energy resources, is not limited to seasons, time, and conditions and can be exploited without interruption. Also, the cost of electricity in geothermal power plants is competitive with electricity produced by other conventional (fossil) power plants and is even cheaper than other types of new energy resources [12]. Geothermal wells are varied based on their special features and they are the wells that are used to produce geothermal energy. These wells are divided into several types including self-discharging wells [13, 14], pumped wells, airlift wells [15], and abandoned oil wells [16]. Abandoned oil wells can be easily retrofitted as geothermal wells by sealing the bottom of the well and insulating it [16]. Abandoned oil and gas well based on geothermal systems are different from conventional geothermal systems. In geothermal systems based on oil and gas wells, the circulating fluid does not directly contact the rocks as in a two-tube heat exchanger, so only heat transfer occurs without mass transfer. While in conventional geothermal systems, fluid is extracted from rock or porous soil [8]. The monitoring wells are used to evaluate the exploited well and measure their characteristics, such as reservoir pressure, water, and oil levels, water and oil ratio, etc.

In line with the importance of this topic, it is enough to know that in the 4th and 5th development plans of the Iran government, there have been serious discussions in the direction of sustainable development, and this topic is greatly important until the year 2025 [17].

The integration of geothermal energy with the oil industry has been explored in various studies, some of which are mentioned above. However, there are some potential gaps and novelties in the literature on this topic that this current research has tried to cover them. For first and foremost, there is limited use of SWOT analysis, while some studies have explored the potential benefits of integrating geothermal energy with the oil industry, few have conducted a SWOT analysis to assess the strengths, weaknesses, opportunities, and threats associated with this integration. Additionally, the "Lack of focus on sustainability" is recognizable in the previous study, there are few which have focused specifically on improving the sustainability of the oil industry through this integration. Thus, highlighting the sus-

tainability aspect in the introduction and throughout the paper can be novel and significant.

Also, economic aspects and potential for economic growth, such as potential cost savings or additional revenue, and return on investment are very important. There is insufficient attention to economic aspects in previous literature such as potential cost savings or additional revenue. Besides, there is limited attention to implementation challenges. There are just a few which have addressed the challenges associated with implementing this integration. Identifying implementation challenges and how to overcome them, and can be a valuable addition to the literature.

2. METHODOLOGY

Considering the importance of sustainability and the issue of this research, we examine the SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis method to study the use of geothermal energy in Iran's oil industry in order to understand how we can increase sustainability in this way [18]. Researchers have been always enthusiastic about understanding the companies' competitive advantages. In supervising organizations for better performance, SWOT analysis states that to struggle favorably in the market, organizations must simultaneously consider internal and external factors some of them may be favorable to the organization while others may not. In a SWOT analysis, the first group of factors that the company's performance is generally driven through them, classified into strengths and weaknesses [19].

Businesses derive their strengths from higher levels of skills and tangible and intangible resources that help them outperform in the marketplace and win the competition. Weaknesses are the limitations that prevent the company from performing perfectly or succeeding in the market. SWOT analysis also emphasizes the identification of relevant factors that affects the company's fulfillment and interprets them as opportunities, in addition, it classifies the threats [20]. Although SWOT analysis was conceptualized more than four decades ago, it is still popular among executives due to its simplicity to use. It is useful because it provides business owners with a simple framework for how they understand their organization and business environment. However, some researchers feel that the open-ended and not well-structured nature of the SWOT analysis approach provides managers little guidance on where to look for variables or what to do once they have identified the outputs, and it is likely to consider too many factors that have less effect on the performance of the company [21].

A. The Geographical Location of oil basins in Iran

The SWOT analysis in the integration of geothermal energy and the oil industry has been done based on Iran's oil industry and its conditions in the country's policy and regulation. This approach would need to be adapted and customized based on the specific characteristics and circumstances of different geographical locations. Some differences could include variations in the geothermal potential, the level of oil production, regulatory and policy frameworks, infrastructure availability, and social and environmental factors.

For example, in regions with high oil production but limited geothermal potential, the analysis would need to focus on the feasibility and potential benefits of importing geothermal energy from other regions. Similarly, in areas with low oil production but significant geothermal resources, the analysis would need to evaluate the potential for integrating geothermal energy into

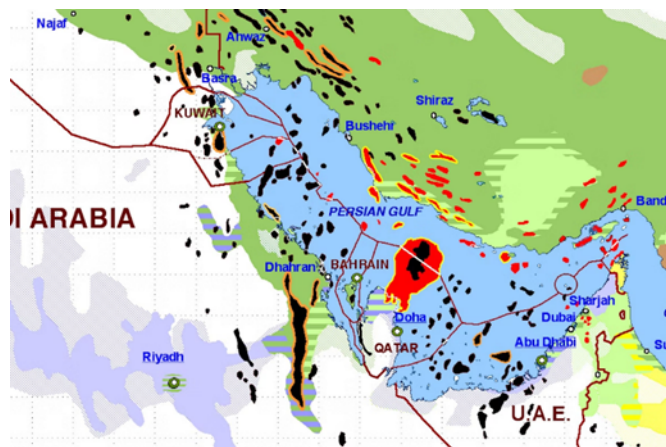


Fig. 1. Active oil basin areas map in south of Iran [22]

other industries, such as mining or agriculture, since Iran has a considerable amount of fossil fuels and oilfields, this study seemed beneficial to conduct and investigate.

However, there may also be commonalities across different regions in terms of the challenges and opportunities associated with integrating geothermal energy and the oil industry. These could include issues related to technological compatibility and investment costs since these challenges would be more important to focus on in Iran because of sanctions, public perception, and acceptance. Potential environmental impacts will be other points that need to be addressed. Overall, while the SWOT analysis in the integration of geothermal energy and oil industry approach can provide valuable insights and guidance, it would need to be tailored to the specific context and characteristics of each geographical location.

B. Data analysis

To analyze this issue, it is good to consider related geological maps along with other required information. It is observable from Figure 1. The target location of this research is obtained since we need active basins of oil and gas wells to overlap them to places that can organize geothermal systems too.

As it can be seen, a moderate amount of Iran's geothermal and oil and gas fields are shared, which can be used for increasing sustainability.

We have conducted SWOT analysis in this research due to several factors. SWOT analysis can help to ensure that the strategies developed are sustainable over the long term. By considering both internal and external factors, SWOT analysis can help stakeholders to identify potential risks and challenges to the sustainability of their strategies and develop mitigation plans. Also, its simplicity and flexibility make it an adequate analysis to extract strategies for improving sustainability in the oil industry through geothermal energy integration.

When using SWOT analysis for this issue, to avoid using specific points in more than one category of strength, weakness, opportunities and threats, we prioritize the most relevant category. While an attribute may fit into multiple categories, there is usually one category that is more relevant than the others. Prioritize that category when deciding where to place the attribute.

Another approach is to use a more detailed framework that allows for a more nuanced analysis of each attribute. For example, we use the PESTLE framework that can be used to analyze

political, economic, social, technological, legal, and environmental factors that may impact a business or organization. This can help to identify more specific areas of strength, weakness, opportunity, and threat, provide a more comprehensive view of the overall situation, and overcome the obstacle overlapping between points in different categories.

In the light of mentioned facts, SWOT analysis and related strategies can be presented in the Table 1 in areas of strength, weakness, opportunity, and threat.

Strengths. First, we explain the strengths of this strategy:

- According to the discussion presented before, it can be seen that the geothermal energy potential in Iran is at an acceptable level and Iran has a lot of geothermal energy resources.

- In addition, it can be mentioned that the environmental effects regarding lands and etc. of geothermal energy are small or controllable and negligible, and this is very small compared to the environmental effects of fossil energy exploitation [3].

- Also, there is water in the underground aquifers in the oil fields, and this can be understood from the fact that when a well is being drilled, some water is also extracted during the extraction of oil which can be used to generate geothermal energy.

- The produced water will be suitable for reuse in the geothermal industry after needed treatments because the deeper oil wells have a higher temperature, and most oil wells in Iran are deep and exploratory, so the water in them is suitable for use in the geothermal industry due to their temperature.

- Abandoned oil wells can be recovered.

- Because of those oil wells which are not used anymore, some lands remain unusable and practically lost, through this strategy of reuse theme, they will be recovered too.

- Oil wells and geothermal wells, as stated in the introduction, are very similar to each other, and even there is a type of Geothermal Wells called abandoned oil and gas wells, which are used for geothermal wells.

- Also, the methods of drilling oil and gas wells and geothermal wells are very similar to each other, and in the shared reservoirs of geothermal energy and oil, additional work and energy and human resources will be avoided.

- Moreover, this approach increases the rate of using renewable energy resources in the country.

- This strategy will be increased the public popularity of oil and gas companies in Iran. This means that if the oil industry uses geothermal energy as a type of renewable energy for providing an amount of needed energy for refining as well as drilling equipment, this will lead to sustainability and increase the public popularity of the oil industry and renewable energy organizations.

- The number of areas that can be used for both extracting oil and gas energy and geothermal energy is significant, and this can be a case of promoting sustainability in these areas.

- If there are several oil wells in a shared basin of oil or gas and geothermal energy, after the engineers recognize that there is a well that is not efficient anymore, it can be used to provide the required energy for the drilling equipment of other wells in that basin by using geothermal energy extracted from, which is led to save a higher amount of energy.

- Abandoned oil wells have existing infrastructure such as pipelines and access roads, which can be used for geothermal energy production, reducing the costs associated with building new infrastructure. Also, geothermal energy is a renewable energy source that produces no greenhouse gas emissions, reducing the environmental impact and pollution of the oil industry [23].

Table 1. A quick review of SWOT analysis

Strengths (S)	Weaknesses (W)	Opportunities (O)	Threats (T)
The significant potential of geothermal energy in Iran and economic growth that will bring for Iran's energy sector.	Increase the number of underground equipment due to the need for additional equipment for exploiting geothermal energy	Bright future of renewable energy market and increase the share of renewable energy in country's energy mix.	Environmental threats such as earthquakes.
Low rate of environmental effects of geothermal energy.	Human interventions in nature.	Cooperation opportunities for different companies and energy organizations in Iran.	Danger to the flora and fauna of the project areas.
Accessibility to underground aquifers via oil wells.	Lack of suitable tools for reliability and risk analysis assessment for the project.	Opportunity to produce the required energy for drilling equipment from geothermal potential.	Competition from other renewable energy sources such as solar and wind power can create a crowded market.
Oil extraction comes with some water.	Lack of enough information in this area.	Opportunity for new progress in related fields and technologies in long term based on earned experiences.	Unexperienced employees threaten this process, also, other employees.
Suitability of co-extracted water in oil basins for geothermal heating after needed treatment.	The lack of huge capital from Iran's oil company to advertise this issue is a good measure to raise sustainability and to spread this approach around the world.	Creating motivation for attracting investment.	Limited opportunity for absorbing foreign investments at first.
Abandoned oil wells will be recovered.	Potential public dissatisfaction.	Opportunity for providing heat for people in offshore oil stations from the waste heat resulting from integrating geothermal technology in a related area. [24]	Disagreements among managers of oil and renewable organizations.
Abandoned lands can be used for new goals again.	Lack of enough budget for extensive investment due to additional equipment.	Providing required heat and electricity for people's houses near the basin.	The inability to strategically plan for the company toward this issue that may cause a financial deficit.
Similarity between oil and geothermal wells.	Lack of enough technology and knowledge to identify some shared areas so they will be undetected and not used.	Positive social attention toward Iran's oil company.	Due to the lack of sufficient experience the safety risk to the employees as well as the investments can be a threat.
Similarity between the drilling approaches of oil and geothermal wells.	Lack of experienced experts in scaling formulations to handle huge systems are conducted in both the oil and geothermal industry [25].	Profit-making for Iran's oil industry by selling electricity to local people or National Power Organization.	Inconsistent regulatory approach due to the monopoly of the oil industry
Increasing the rate of using renewable energy in the country.	Geothermal potential of abandoned oil wells may be limited due to special geothermal wells factors.	Creating entrepreneurship and recruiting unemployed in the site of the project based on their abilities.	
Increasing the popularity of oil and gas companies.	Causing Soil erosion because of the long-term use of equipment.	Decreasing the costs of the total energy for equipment.	
Common and overlapped basins for generating both types of energy (oil and geothermal).	The high conversion costs of an abandoned oil well to a geothermal one.	Iran will have the potential to export clean geothermal energy to neighboring countries.	

• The issue raised in this research is an almost new issue that has recently been investigated.

Weaknesses. This topic also has some specific weaknesses, and the following can be mentioned:

• The production of geothermal energy and its exploitation requires more pieces of equipment than drilling, which will increase the number of underground equipment.

• Also, the increase of human interventions as well as the technologies in nature due to operations being carried out, will be another negative factor in this process.

• The calculation of reliability and risk analysis related to this issue should be taken into consideration because of the impossibility to predict correctly what risks await the equipment and people who are working in that area, and this is due to the lack of sufficient tools which may cause special threats too.

• The lack of sufficient knowledge in this field because of not (or rarely) conducting this strategy before, is one of the other weaknesses [24].

• Also, the lack of large capital in this part of the industry will form an obstacle to spread this issue as an important measure for raising sustainability and using all available resources for encouraging other countries to go through this approach.

• This issue may also cause public dissatisfaction due to the extra noise in their hometown. For instance, In the USA, the prices of houses around the cities where refineries, oil rigs, and oil wells are located will fall sharply, and this has harmed the residents. So this issue may lead to public dissatisfaction and the people of that area will oppose this issue if this well, which is related to both oil and gas and geothermal, is close to their places [25].

• The oil industry may face to lack of funds for high investment in this area because the cost of converting abandoned oil wells for geothermal energy production may be high, as it requires drilling deeper and installing different equipment than traditional oil wells.

• Also, due to the newness of this subject, lack of experienced experts to scaling formulations to handle huge systems conducted in both oil and geothermal industry will be another weakness.

• The geothermal potential of abandoned oil wells may be limited, depending on factors such as the temperature and flow rate of the geothermal resource

• Another thing that can be mentioned as a weakness is the increase in surface destruction due to the additional use of equipment that was not utilized before.

• Also, considering the long-term use of land for this technology, it may cause soil erosion or landscape damage [26].

• Also, the high conversion costs of an abandoned oil well to a geothermal one may be another weakness regarding this issue.

• There are few companies to collaborate with conducting this strategy.

• Also, lack of partnership between financial institutions and investors can be a weakness for the project.

Opportunities. In the following, we will examine the opportunities of this issue and use both of these technologies together to increase the sustainability of the oil industry in Iran.

• Using abandoned oil wells for geothermal energy production can help Iran reduce its dependence on fossil fuels and increase the share of renewable energy in its energy mix.

• Creating an opportunity for cooperation between the Oil Company and renewable companies such as "MAPNA" and consequently increasing the investment capacity is important and must be considered as an opportunity.

• The generated electricity from geothermal resources can be used to supply the energy required for drilling and mining equipment, thus reducing related costs.

• After a while, by entering to sustainable development market and using oil and gas technology and geothermal energy technology together, there will be improvements in technology by earning related experience, and this will lead to the overall development of new technologies in the country.

• Considering that this topic is very new, after a while it can increase the scientific per capita of the country through the publication of new articles in this field, which will be the result of the technical and experimental knowledge has been enhanced by engineers [27].

• Creating a forwarding motivation and suitable platform for further research in the direction of using geothermal energy in oil rigs and stations and offshore oil wells.

• If this issue, which was mentioned in the above line, becomes possible, the heat produced by the geothermal wells can be used to provide electricity and heat to people who are working in offshore and near oil stations.

• Also, this topic can be used in areas that are close to other people's houses to provide heat to their houses.

• Due to the use of new energy resources and initiatives, positive social attention will be increased to the oil industry from investors and environment activists.

• Iran will have the potential to export geothermal energy to neighboring countries, which can help to increase its foreign exchange earnings.

• Geothermal sourced electricity can be sold to the National Power Organization. This organization purchase the renewable electricity in higher tariffs from renewable power plants due to the new policies to encourage investors to invest in renewable industries that can make a great deal of profit for stakeholders.

• Workers can receive the necessary training and be added to this workspace for monitoring or repair and related actions, which will lead to creating job opportunities.

• Some investment opportunities that did not exist before can be created for the oil industry, which can become a positive point and an opportunity to attract foreign investment to help the country to deal with economic and political sanctions.

Threats. In this area, we can also mention some threats:

• The possibility of an earthquake occurring at the drilling site of oil wells is very high. In order to use oil wells to produce geothermal energy, we may have to use those wells that are already out of service for more energy efficiency or dig them in order to get to deeper height and this will cause environmental threats such as earthquakes [28].

• After an oil well turns into an abandoned one, after a while the damage caused by operations and erosion of the soil and flora and fauna of that area will be repaired, but if these wells are used again for geothermal goals, due to related equipment, the vegetation may be damaged again. And the animals' environment in these areas are threatened and endangered too.

• The development of geothermal energy may face competition from other renewable energy sources such as solar and wind power. This can create a crowded market and reduce the competitiveness of geothermal energy.

• In light of the fact that this is a new issue, inexperienced employees may threaten this process, also, other employees.

• There are limited opportunities at first, to attract foreign capital due to sanctions in Iran.

• If there is a cooperation between renewable and oil companies, disagreements between managers may cause work disruption.

tions.

- Because this type of cooperation has not been used in our country before, the organization may lack the ability for strategic planning and risk analysis that can threaten equipment and economic aspect of the project.

- Sudden changes in regulations can hurt this process and predetermined plans and investments as tax changes for related company

- Due to the lack of sufficient experience, the risk will be towards the employees as well as the investments [29]. Safety problems, as mentioned earlier, can be an important threat [17].

3. RESULTS AND DISCUSSION

In Table 2 the SWOT strategies have been conducted based on opportunities, threats, strengths, and weaknesses which are mentioned in Table 1. In Table 2 each category of SWOT analysis are mentioned, and the blank block of each potential strategies are filled that explain with each point of strengths or weakness we can form SO, ST, WO or WT strategies.

The first type of strategy which is derived from SWOT analysis is the SO strategy by the means of this approach, the increase in the use of renewable energy resources increases the positive social attention toward Iran's oil industry. In addition, the recovery of failed oil wells will lead to use them to generate electricity for the drilling equipment, and considering that this is a new topic, it encourages and requires research in this field. Additionally, due to the similarity of drilling methods of oil and geothermal wells, this can reduce energy costs for the oil industry. Additionally, leveraging existing infrastructure and expertise in the oil industry can develop geothermal energy production capacity, diversifying Iran's energy mix and supporting sustainability goals. And explore the potential to export geothermal energy to neighboring countries will create new revenue and contribute to economic growth.

The second type of strategy is the WO strategy which we can benefit from due to the fact that using two industries and two technologies together increases investment and this may partially compensate for the lack of funds in the oil industry. Furthermore, providing heat to some nearby houses may reduce public dissatisfaction. And increasing the income of the oil industry can lead to the development of undeveloped technologies by investing on them. Also, entrepreneurship opportunities can partially justify the increase in human interventions in the nature. Eventually, cooperation between two industries and the use of engineers in a more specialized field may partially compensate for the lack of sufficient knowledge. In addition, invest in research and development to optimize the conversion of abandoned oil wells for geothermal energy production will reduce the high conversion costs and increasing the potential capacity of geothermal energy production.

Another type of strategy that can be formed from SWOT analysis is ST strategies which we can obtain that, since the environmental effects of geothermal energy are small and can be ignored, the flora and fauna will not be overly damaged. Also, due to the novelty of the subject and the need for more investigation, during this research, the risks of extraction can be reduced by reaching new points and functional results by examining new methods. And increasing popularity of the oil industry due to sustainable development among other countries can attract foreign capital. This analysis will be finished by conducting the last sort of strategies that is WT strategies. The small number of companies that can be linked for cooperation can reduce the threat

of disagreement between managers. Additionally, changes in regulations may sometimes be in the direction of reducing taxes, which will result in additional profit for the organization, especially in Iran which the new policies are recently conducted to overcome obstacles for renewable energy usage in industry. Also, develop partnerships with financial institutions and investors will lead to secure funding and reduce the financial risks associated with geothermal energy production.

4. CONCLUSION

In this study, we used SWOT analysis to increase the sustainability of Iran's oil industry by integrating geothermal energy based on various potential in this area. Based on Iran's geographical condition and numerous oilfields and abandon oil wells in oil and gas extraction stations, and by concerning this country situation in geothermal resources overlapped in oil and gas basins, several strategies has been obtained based on SWOT analysis to overcome challenges and boost opportunities to build a sustainable oil and gas industry. As it can be seen through this analysis there are different types of strategies that can be applied in Iran's oil industry to achieve the goals that are mentioned in the development plan of Iran to meet an acceptable level of sustainability. In addition, by utilizing of mentioned SWOT strategies, the worries of agents toward some issues like investment and costs, etc. will be reduced. Finally, by using this strategy that can be functioned in other geographical conditions by considering the specific features and policy conditions, a huge range of benefits in economic, environment and energy sectors will be provided.

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