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Disclosing carbon-water-cost nexus on China's road to greener shale gas via CO_2-enhanced shale gas recovery (CO_2-ESG)

Tiancheng Ji, Peixue Jiang, Ruina Xu*

Key Laboratory of CO_2 Utilization and Reduction Technology of Beijing, Department of Energy and Power Engineering, Tsinghua University, Beijing 100084, CHINA

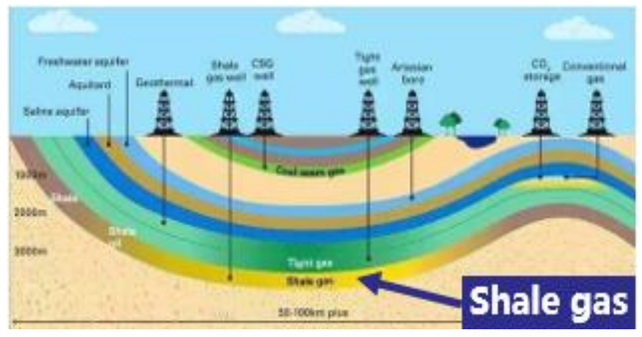
Key Laboratory for Thermal Science and Power Engineering of Ministry of Education, Beijing 100084, CHINA

Background

- Development of shale gas resources is expected to play an important role in China's projected transition to a low-carbon energy future.
- Hydraulic fracturing is mainly used for shale gas production and requires a large amount of water in a short period of time, which brings potential disadvantages including water scarcity, environmental impact and poor fracture performance.
- CO_2-enhanced shale gas recovery (CO_2-ESG) can solve these problems while increasing shale gas production and storing CO_2 to mitigate climate change, but it has cost penalties.

Motivation

- One of the most pressing issues relate to which kind of technical combinations of shale gas exploitation and utilization in China can achieve the minimum cost.
- Another question arises how to identify the carbon-water-cost interactions of shale gas supply chain networks.



Methodology

- We consider potential shale gas sites, CO_2 and water sources in Sichuan Basin and Ordos Basin.

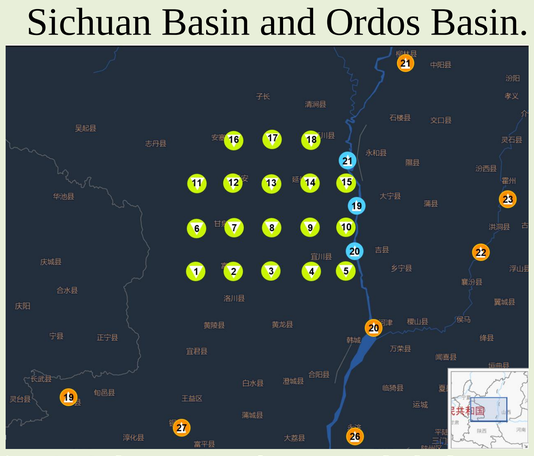


Fig. 1. Schematic of potential shale gas sources (green), water acquisition sites (blue) and CO_2 sources (orange) in Ordos Basin.

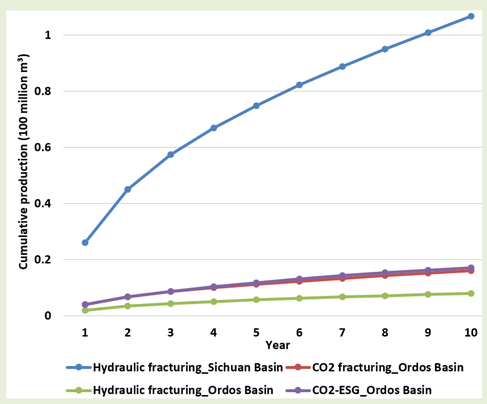


Fig. 2. Estimation of shale gas production profile in Sichuan and Ordos Basin.

Model Formulation

- We optimize the shale gas supply chain strategies to minimize the sum of water acquisition and carbon capture costs, water and CO2 transmission costs, shale well drilling, fracturing and production costs while satisfying the shale gas demand.
- We determine when, where and how much CO2 and water to acquire, where to build and connect pipelines of different sizes and when, where and how to exploit shale wells.
- The optimization problem is formulated as an mixed-integer linear programming (MILP) model.

Results and discussion

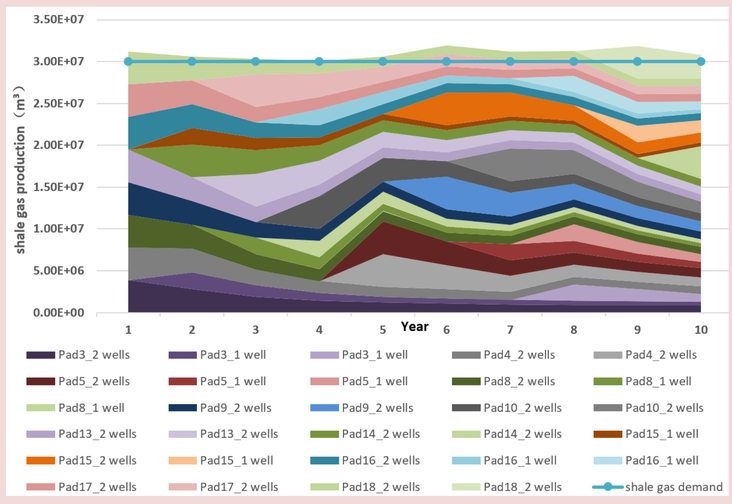
1.Optimal shale gas supply chain networks

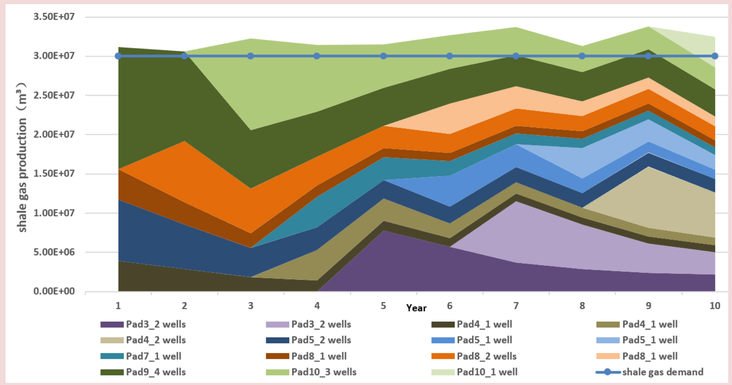
Hydraulic fracturing in Ordos Basin

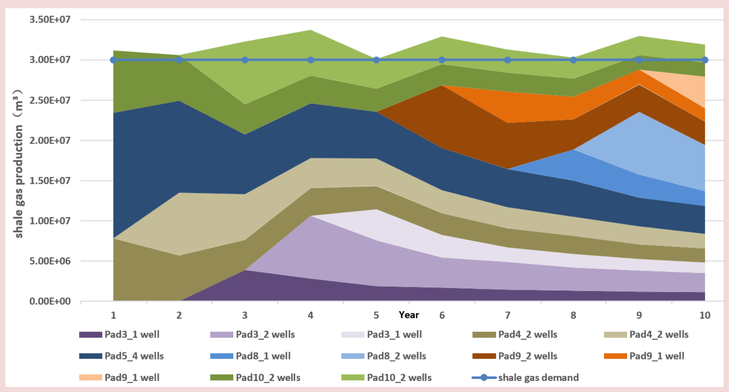
CO_2 fracturing in Ordos Basin

CO2-ESG in Ordos Basin

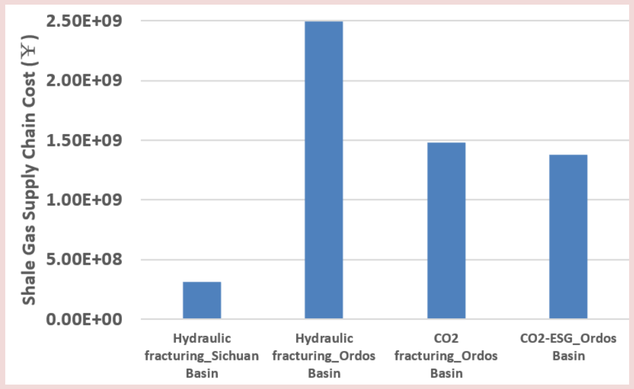
2.Optimal production schedules







3. Cost comparison



- Hydraulic fracturing in Ordos Basin results in larger water demand and more cost than that in Sichuan Basin, mainly because Ordos Basin has much lower production rate than Sichuan Basin.
- CO_2 fracturing in Ordos Basin utilizes and stores CO_2 and costs less than hydraulic fracturing, offering carbon-water-cost co-benefits.
- CO_2 fracturing and CO_2-ESG in Ordos Basin achieves notably carbon-water-cost synergies, indicating that more attention is needed to develop CO_2-ESG in Ordos Basin.

Conclusion

- Ordos Basin is suitable for CO_2 fracturing and CO_2-EOR while Sichuan Basin fits for hydraulic fracturing.
- A small increase in total cost can lead to a large reduction in water consumption and a significant increase in CO_2 sequestration, indicating water-carbon synergies.
- The technological advancement and cost reduction of CO_2 fracturing and CO_2-EOR have a great effect on reducing water consumption
- The results highlight the importance of systematic planning of shale gas supply chain and provide policy makers with insights on water cost and carbon credit.