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Coal Gasification

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Overview

- Coal gasification is a high-temperature process (1,000°-1,500°C) that converts coal into syngas - a mixture of hydrogen, carbon monoxide, and carbon dioxide. Hydrogen is then extracted through water-gas shift reactions and purified, with carbon capture and storage (CCS) reducing emissions.
- Combined with carbon capture technologies, coal gasification can reduce emissions by up to 90% while producing 3-4 kg of hydrogen per kg of coal. It accounts for 25% of global hydrogen production.

Source: (Chfii et al., 2024).

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Cost Structure

- Hydrogen from coal gasification costs \$1.40 to \$2.50 per kg, depending on coal prices, energy requirements, and the cost of carbon capture, utilization, and storage (CCUS).
 - Coal accounts for 40–50% of production costs.
 - Advanced carbon capture increases capital costs but can cut lifecycle emissions by up to 60%.
 - Countries with abundant coal reserves (e.g., China, India) benefit from lower costs due to stable domestic supply.

Source: (Ang et al. 2022), (Liao et al., 2021).

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Technology Readiness

- Coal gasification is currently at Technology Readiness Level (TRL) 8-9, meaning it is commercially deployed but undergoing continued cost and efficiency improvements.
 - It produces 50 million metric tons of hydrogen annually worldwide.
 - Ongoing process innovations aim to reduce costs by 15-20%, particularly in combination with CCUS.

Research & Innovation

- Emissions Reduction - Life cycle emissions from coal gasification with CCUS can be cut by 60-90%.
- IEA Projections - The International Energy Agency (IEA) forecasts that coal gasification will contribute 20% of the global hydrogen supply by 2030, assuming further CCUS deployment.
- Challenges - Scaling CCUS remains economically difficult due to high costs.

Lifecycle Stage

- Coal gasification is in the Maturity Stage of the hydrogen market, contributing 25% of global hydrogen production, primarily for energy-intensive industries.
- Future improvements focus on:
 - Integrating renewable energy to reduce emissions.
 - Advancing CCUS technology to improve carbon reduction.

Key Process Steps

1. Coal reacts with oxygen and steam at 1,000°–1,500°C, forming syngas.
2. Water-gas shift reaction converts carbon monoxide into hydrogen and CO₂.
3. Hydrogen is purified using pressure swing adsorption (PSA).
4. Carbon dioxide is captured to reduce emissions by 60–90%.

Challenges

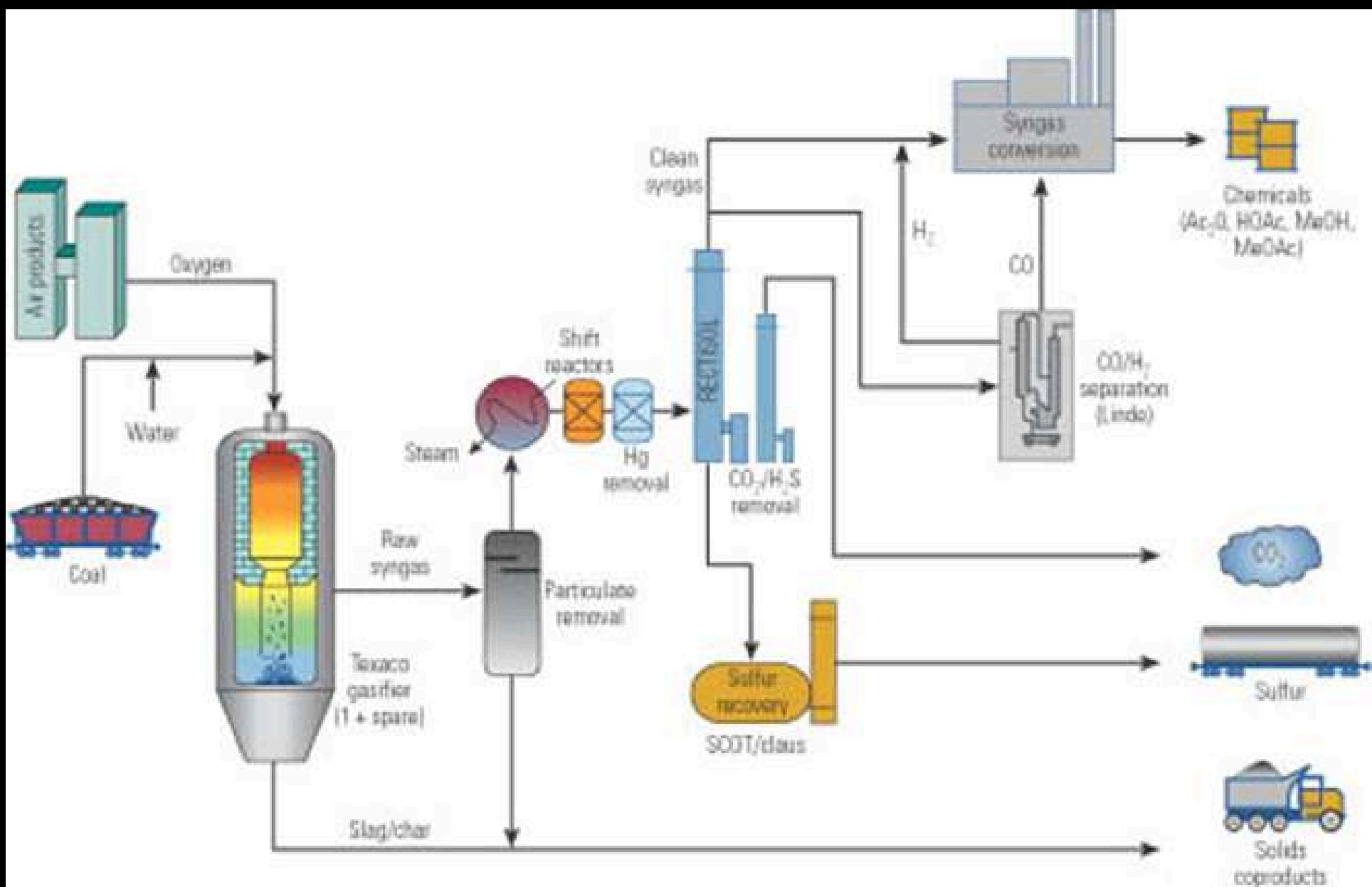
- High Energy Demand - 40-50% of production costs stem from electricity and thermal energy consumption.
- Emissions Without CCUS - Coal gasification produces 8-10 kg CO₂ per kg of hydrogen, making it among the highest-emission hydrogen production methods unless CCUS is applied.
- Capital Costs - High reactor and CCUS investment costs limit adoption in lower-income economies, driving research into cost reduction and carbon management.

Example Applications

- Ammonia & Methanol Production - Over 50% of hydrogen from coal gasification is used in the chemical industry.
- Synthetic Fuels & Energy - Syngas supports clean hydrogen applications and alternative fuels.
- Industrial Decarbonisation - Essential for coal-dependent industries seeking lower-carbon solutions.

Flow diagram

- Flow diagram of coal gasification process, including syngas production, hydrogen separation, and carbon capture.



Source: (Hao, 2023)

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Summary

- Coal gasification supplies 25% of global hydrogen production.
- When paired with CCUS, emissions can be cut by up to 90%.
- The technology remains cost-competitive in coal-rich regions and continues to improve in efficiency and sustainability.
- As a transition technology, coal gasification will remain relevant in regions where renewable energy is not yet feasible.

Source: (Hao, 2023)

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