CO₂ LOAD IN THE PROCESS OF HYDROGEN PRODUCTION BY COAL GASIFICATION AND PYROLYSIS

Tomasz Chmielniak
Scope of the presentation

1. General assumption
2. Technological variants – scope of analysis
3. Results of analysis
4. Conclusions and recommendations
Assumption: General

1. The main goal of the study is an analysis and assessment of potential technological options for hydrogen production from coal - under domestic - Polish conditions, with particular focus on the CO₂ emission
2. Gasification and pyrolysis (coke oven gas)
3. Complete technological cycle for hydrogen production: extraction, transport, and coal conversion to hydrogen
4. Direct (technological) and indirect (related to consumption/production of heat and power) CO₂ emissions
5. Production and transport of coal – real operational data from Polish coal mines and Polish railways
6. Coal processing – results of calculations: detailed process model
Assumption: Feedstock selection

- **Gasification process**
  - Hard and brown coal
  - Coals selected as potential fuels for the power sector in the long term perspective (proven large coal resources)

- **Coking process (typical feedstock used in Poland)**

<table>
<thead>
<tr>
<th>Component</th>
<th>Unit</th>
<th>Hard coal, gasification</th>
<th>Hard coal, coke making</th>
<th>Brown coal, gasification</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>%</td>
<td>47,8</td>
<td>77,4</td>
<td>32,3</td>
</tr>
<tr>
<td>H</td>
<td>%</td>
<td>3,6</td>
<td>4,2</td>
<td>2,5</td>
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<td>N</td>
<td>%</td>
<td>0,8</td>
<td>1,2</td>
<td>0,5</td>
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<td>S_{total}</td>
<td>%</td>
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<td>0,5</td>
<td>0,4</td>
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<td>O</td>
<td>%</td>
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<td>2,4</td>
<td>8,0</td>
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<tr>
<td>W_{total}</td>
<td>%</td>
<td>19,1</td>
<td>8,2</td>
<td>50,0</td>
</tr>
<tr>
<td>A</td>
<td>%</td>
<td>17,5</td>
<td>6,1</td>
<td>6,3</td>
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</table>
Technological variants: Coal gasification (1): New technologies

1. Pressurized CFB reactor: in-house design
2. CO\textsubscript{2} as gasification agent – oxygen and carbon carrier, increase in the gasification efficiency
3. Own calculation models based on experimental data from atmospheric reactor of 200 kg\textsubscript{coal}/h and 8 t/h capacity
4. New pressurized unit (100 kg\textsubscript{coal}/h) after start-up and first tests
Technological variants: Coal gasification (2): System configuration - New technologies

Integration with HTR reactor:
- Variant 7: coal drying, coal heating, CO₂ heating
- Variant 8: coal drying, CO₂ heating, heat for gasification process – 50% of required heat for coal pyrolysis
Technological variants: Coal pyrolysis (1):

- Hydrogen production unit is an integral part of the coke plant.
- Steam produced in the gas reforming unit is exported to the power plant (coke plant or independent plant).
- The system is supplied (from outside) with boiler water (steam production), low pressure steam and electricity (to cover the needs of hydrogen plant).
- The CO$_2$ emissions associated with the consumption of heat and electricity in the coke making plant and resulting from combustion of coke gas were also taken into account.
Technological variants: Coal pyrolysis (2): System configuration

Clean gas processing:

- Not fundamental changes in plant configuration
- Easier to implement

Raw gas processing:

- Change in coke production plants configuration
- No units for removal of tars and benzene.
Results (1): Process efficiency

Media and raw materials consumption

Reduction of the relative consumption of
- **coal by 14%**,  
- **oxygen by 25%**  
  (in case of CFB gasification consumption of oxygen for gasification and gas conversion),  
- **electricity by 28%**  
  (without CO₂ compression)

Average values obtained for entrained flow reactors vs. results for the fluidized-bed gasification technology – without integration
Results (2): Process efficiency

Production efficiency

![Graph showing hydrogen production efficiency for different variants and coal types.](image-url)
Results (3): CO₂ emission without CCS

Production cycle: mining, transport and conversion

- Technological emission: 96-98%
- Coal mining and transport: 2-4%
- The lowest CO₂ emission rates - hydrogen production from coke-oven gas. Emission reduce by 18-42% in comparison to entrained flow and fluidized-bed gasifiers.
Results (4): CO\textsubscript{2} emission with CCS

*Production cycle: mining, transport and conversion*

- Hydrogen production based on coke-oven gas are characterized by the highest emission – high share of the indirect emission.
- The best results – entrained flow, slurry feeding reactor followed by CFB technology.
Results (5): \( \text{CO}_2 \) emission without CCS

Structure of \( \text{CO}_2 \) emission

Indirect emissions associated with production or consumption of energy carriers could exert a significant impact on the obtained overall carbon dioxide emission rates.
Results (6): **CO$_2$ emission with CCS**

Structure of CO$_2$ emission

<table>
<thead>
<tr>
<th>Variant</th>
<th>Hard coal</th>
<th>Hard coal</th>
<th>Brown coal</th>
<th>Hard coal</th>
<th>Hard coal</th>
<th>Hard coal</th>
<th>Hard coal</th>
<th>CCOG</th>
<th>RCOG</th>
<th>RCOG</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>GEE/Texaco</td>
<td>Shell</td>
<td>Shell</td>
<td>CFB/CO2</td>
<td>HTR1</td>
<td>HTR/reaktor</td>
<td>CPOX</td>
<td></td>
<td></td>
<td></td>
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<td>4 364</td>
<td>3 949</td>
<td>3 949</td>
<td>4 364</td>
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<td>-584</td>
<td>-3658</td>
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<tr>
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<td>1 078</td>
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<tr>
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<td>1 122</td>
<td>1 286</td>
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<td>3 949</td>
<td>3 949</td>
<td>4 364</td>
<td>0</td>
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<tr>
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<tr>
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<td>3 949</td>
<td>4 364</td>
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<td>-584</td>
<td>-3658</td>
</tr>
</tbody>
</table>

Influence of the indirect emission is especially important in the case of hydrogen production from coke oven gas and CO$_2$ compression.
Results (7): CO₂ emission

**CH₄ emission impact**

- **Direct CH₄ emission** - when analyzing the Global Warming Potential (GMP) – lead to a considerable increase in equivalent CO₂ emission.

- Considering only the CH₄ emission in ventilation air, an increase of more than 4 times in terms of the equivalent CO₂ emission in the coal production process is observed.

- Consequently, CO₂ emission rises in the full cycle of hydrogen production (with the average increase of 11%).
Conclusion / Recomendation

- High hydrogen production efficiency combined with the lowest relative CO$_2$ emission make the hydrogen production scenarios based on coke-oven gas recommendable in the first instance for hydrogen acquisition in an industrial scale. The foregoing is also supported by the existing domestic-Polish potential for coke-oven gas production.

- The development of the hydrogen production potential should be simultaneously conducted through implementation of the coal gasification technology.

- In case of commercially available gasification technologies, the more advantageous solution is the use of reactors with dry fuel feed. This choice is most definitely reinforced by its higher hydrogen production efficiency and capacity, as well as lower rates of direct technological CO$_2$ emission. Nevertheless, the final choice of the technological option should follow a detailed analysis of technical and economic aspects.
Conclusion/recommendation

- Interesting results have been obtained in case of system based on coal gasification under CO₂ atmosphere. Results of process calculation show high efficiencies combined with the lowest hydrogen production-related CO₂ emission as well as raw material and media consumption rates among all the gasification technologies. Decisive for the future development of the technology would be the confirmation of its efficiency in a pilot scale.

- For lignite drying, steam-based coal drying technology is recommended (e.g. WTA). It seems that its application could significantly increase the attractiveness of lignite utilization in the gasification process.

- The obtained results could be used for a preliminary choice of technologies and their configurations in an investment process. CO₂ emission rates provide valid information, particularly useful when making investment decisions, since they are directly linked with costs which may have significant affect the hydrogen production costs when an increase in the CO₂ emission allowance price is expected.
Acknowledgments

Thank you for your attention

The task of research, "Development of coal gasification technology for high production of fuels and electricity" funded by the National Center for Research and Development within the strategic program of research and development: "Advanced energy generation technologies".