Methanation of By-product Gases from Integrated Steelworks

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Methanation and Second Generation Fuels

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Approaches for CO_2-reduction

Steel Industry

	Circular Economy		
Pathways	**Smart Carbon use (SCU)** **Process Integration with reduced use of carbon + CCS**	**Smart Carbon use (SCU)** **Carbon Capture and Usage (CCU)**	**Carbon Direct Avoidance (CDA)** Hydrogen, Electricity
Description	Process Integration with reduced use of carbon	Using CO/CO_2 from steel mill as raw material (chemical conversion of CO/CO_2)	Renewable electricity in basic steelmaking, e.g. production of H_2 to replace carbon
Projects/ initiatives	HISARNA, TGR-BF-Plasma, PEM, STEPWISE	Steelanol, **i³upgrade**, **RenewableSteelGases**, Carbon4Pur, Carbon2Chem, FReSMe	**H2Future**, **SuSteel**, HYBRIT, GrInHy, SALCOS, Siderwin

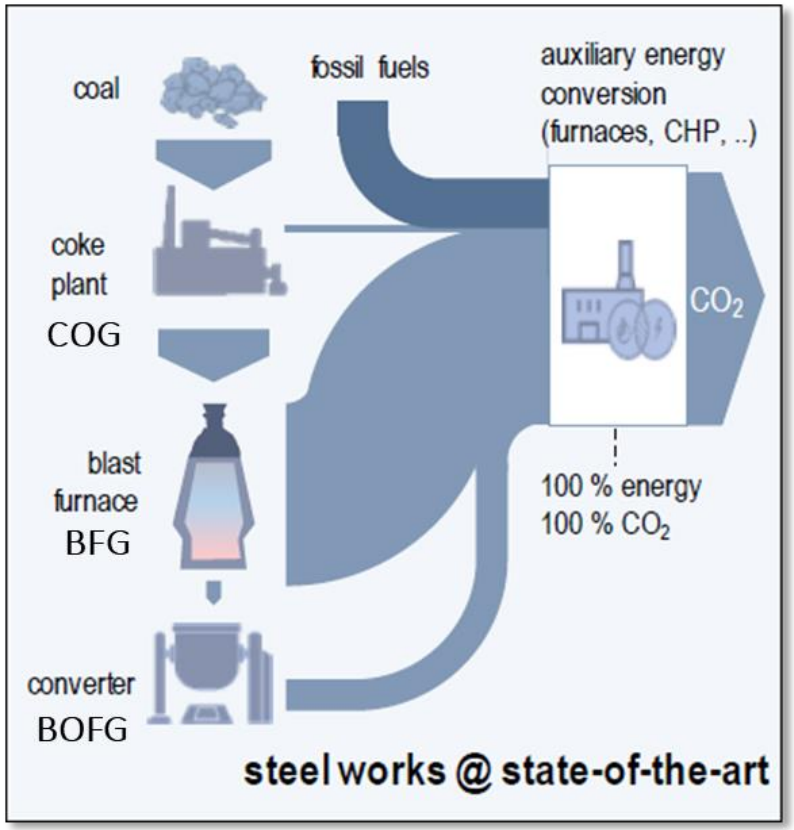
Smart Carbon Usage (SCU)

- Chemical conversion of CO_2 to hydrocarbons using H_2 (CCU)
- Utilization of CO_2 as raw material
- Capture of CO_2 and geological storage (CCS)
- Optimisation of BF/BOF route

Carbon Direct Avoidance (CDA)

- Complete avoidance of CO_2
- Direct use of H_2 and renewables for reduction of iron ores
- Electrolysis of iron oxides
- Breakthrough-technologies

By-product gases of integrated steelworks



COG ~ 65,000 Nm³/h
BFG ~ 800,000 Nm³/h
BOFG ~ 75,000 Nm³/h

Coke Oven Gas (COG):

- Blast furnace stoves
- Reheating furnaces hot strip mills
- Under firing of the coke oven
- As alternative reducing agent in BF
- Power plant

Blast Furnace Gas (BFG):

- Hot blast stoves
- Under firing of the coke oven
- Power plant

Basic Oxygen Furnace Gas (BOFG):

- Rolling mill
- Power plant

	COG		BFG		BOFG
[Vol.-%]	Min	Max	Min	Max	Mean
CO_2	1	5.4	16	26	17.2
CO	3.4	5.8	19	27	60.9
H_2	36.1	61.7	1	8	4.3
N_2	1.5	6	44	58	15.5
CH_4	15.7	27	-	-	0.1
C_nH_m	1.4	2.4	-	-	-

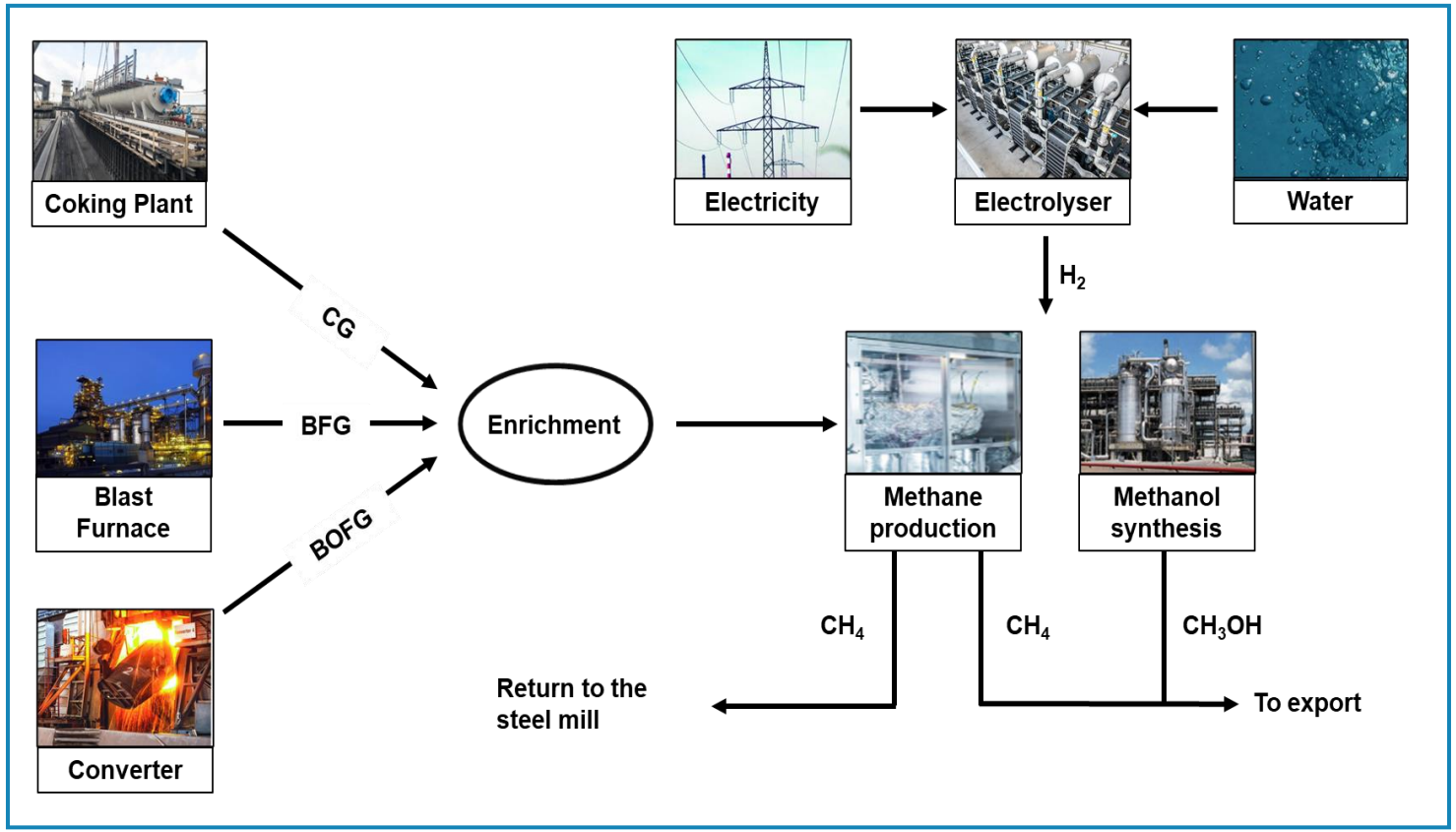
* Best Available Techniques (BAT) Reference Document for Iron and Steel Production, Industrial Emissions Directive 2010/75/EU Integrated Pollution Prevention and Control, 2013

✓ High C-content in BFG & BOFG

✓ Source for hydrogen-intensified methane & methanol syntheses

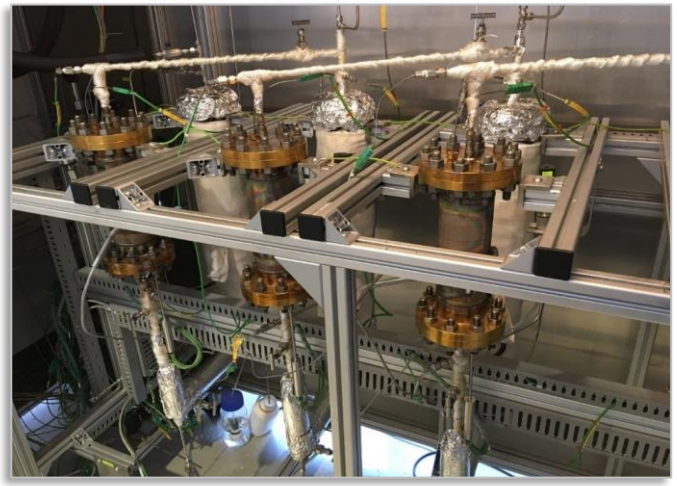
The project i³upgrade

intelligent and integrated upgrade of carbon sources in steel industries

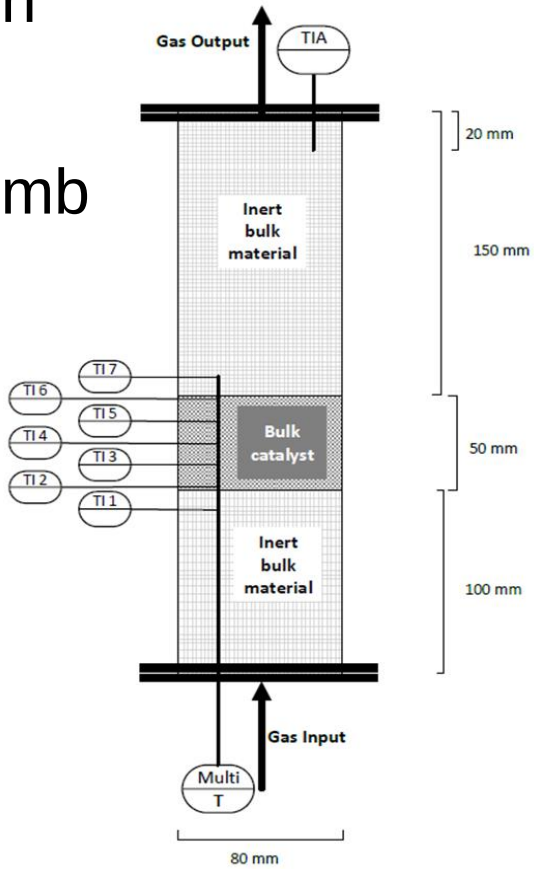


- Direct methanation and methanol synthesis of by-product gases in integrated steel works under transient conditions
- Integration of renewable energy sources in the steelmaking process through the addition of renewable hydrogen
- Partly substitution of fossil fuels for the energy supply via the upgraded carbonaceous streams
- Reduction of CO_2 emissions

Methanation test rig setup (MUL)



- 3 fixed-bed reactors in series
- Q_{max} = 50 NL/min
- p = 1 - 20 bar
- Bulk or honeycomb catalyst



Sabatier reactions

- $CO + 3\,H_2 \leftrightarrow CH_4 + H_2O$ ΔH^0 = -206 kJ/mol
- $CO_2 + 4\,H_2 \leftrightarrow CH_4 + 2\,H_2O$ ΔH^0 = -164 kJ/mol

Reverse water-gas shift reaction

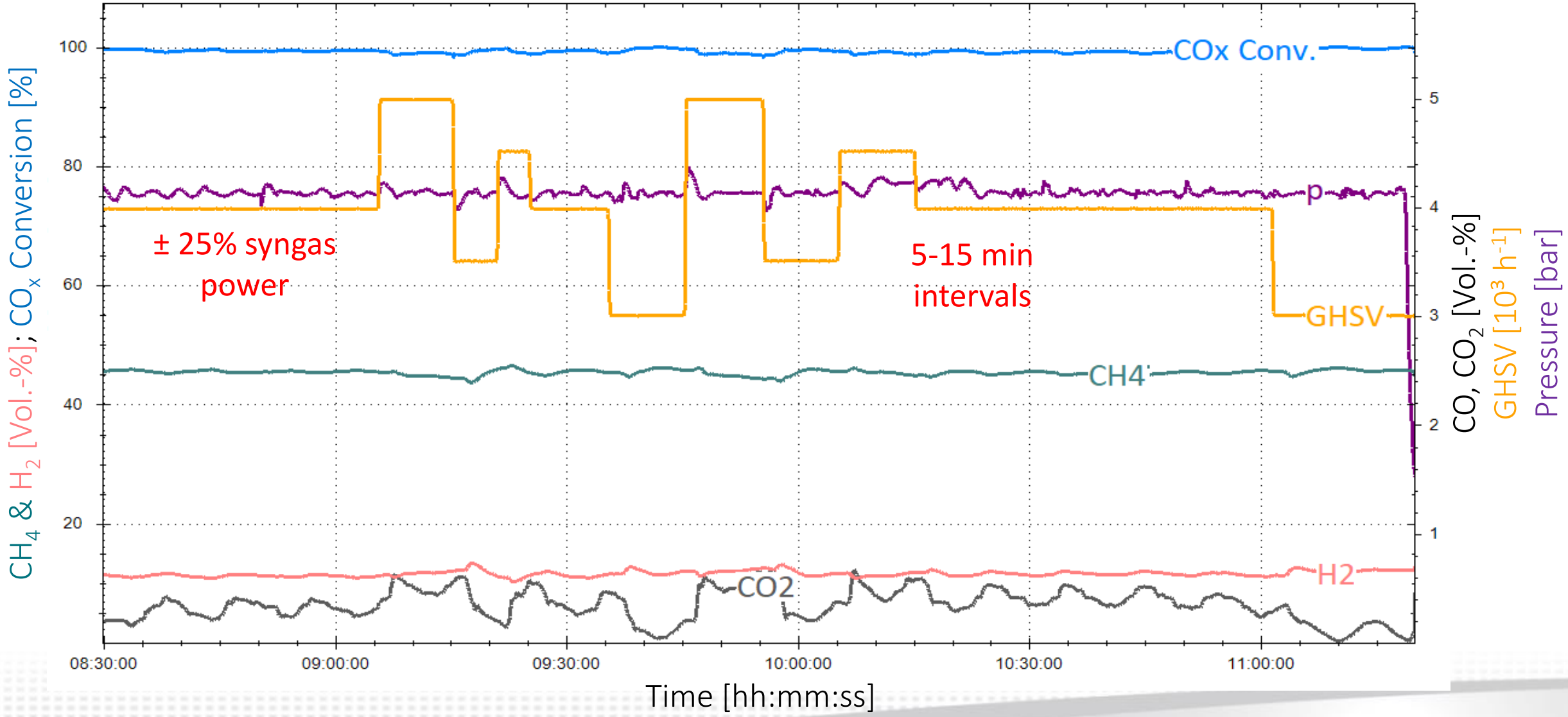
- $CO_2 + H_2 \leftrightarrow CO + H_2O$ ΔH^0 = -41 kJ/moL

Boudouard equilibrium

- $2\,CO \leftrightarrow CO_2 + C$ ΔH^0 = -172 kJ/mol

Dynamic experiments with BFG

4 bar, GHSV variation, 4% H_2 excess rate



Summary and conclusion

Dynamic methanation

- High load changes in the range of seconds to minutes
- Dynamic parameter: H_2-variation → depending on electricity price
- Full/high CO_x conversion for BFG & BOFG w/ 5% H_2 excess rate
- Only minor changes in CO_x conversion & product gas composition
- Temperature control essential for optimal conversion rate

Thank you! Questions?

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