Capture and Reduction of CO_2-rich Waste Gases Emissions to Maximize Circularity in the Steelmaking Process

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Project Background

Blast furnace steel production generates 3 main off-gases; Blast Furnace Gas (BFG), Coke-Oven Gas (COG), and Basic Oxygen Furnace Gas (BOFG). CO & CO_2-rich by-product gases emitted from the BF or BOF are of particular interest as they contain valuable reactive compounds with high calorific values. This research focusses on making synthetic natural gas to substitute for natural gas by in situ reaction of real steelworks gases, i.e., direct carbon capture and utilization using BFG and BOFG as a C source.

Steelworks Gas composition

Table 1 shows dry composition of steel off-gas plant (ca. 6Mt/year). Direct carbon capture and utilization will use BFG, or BOFG COG as different feedstock alternatives to fossil fuel. The aim is to develop a novel processes which can reach high yields of valuable products to avoid CO_2 emissions whilst off-setting or exceeding production costs.

Table 1: Dry composition of steel off-gases.

%-vol	CO	CO_2	H_2	N_2	CH_4	O_2	CV (MJ/m^3)
BFG	22	23	5	50	-	-	4.2
COG	6	-	65	4	25	-	17
BOFG	75	19	-	5	-	1	9.5

Project goals

Process evaluation

- Thermodynamic feasibility investigation: Extracting thermodynamic data (Temp, Pressure, ΔG) for main and by-products reactions by HSC-Chemistry simulation.
- Parametric and lab aging studies: Flow rate, and feed gas composition for conceptual process optimization and process design

Catalyst material development, production, and testing

- Manufacturing poison resistant and high activity catalysts for CCUS reactions.
- Evaluating a highly efficient synthesis method for manufacturing at tonnage scale.
- Laboratory apparatus set up.

Transformation of CO_2 into fuels

Some of the products that can be acquired from CO &CO_2-rich waste gases can make this process highly feasible for the steel industry . Fig .1 shows the Gibbs free energy versus temperature for different reactions of towards CO &CO_2 utilization; syngas production, methanation, methanol synthesis and water gas shift reaction.

Fig. 1 shows how the Gibbs Free energy changes with temperature for different reactions. The aim is to reduce GHG emissions and substitute the need for fossil fuels by displacing raw materials.

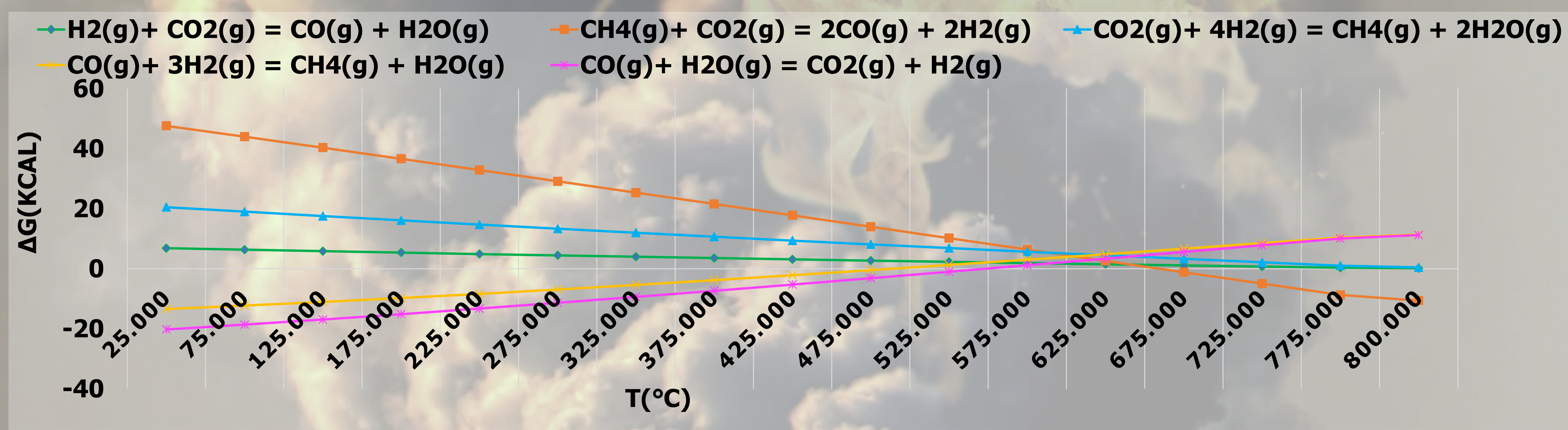


Fig .1: Reactions towards CO_2 utilization; ΔG VS Temperature-extracted by HSC-Chemistry.

CCUS reaction testing

All catalytic tests will carry out on a test rig set up at the Swansea University, SINTEC Lab (Fig. 2 below). The apparatus is designed to work at temperatures up to 450 °C and pressures up to 2 MPa.

- One or two reactors will be set up to take input gas feed and convert it into new products which will be analyzed by online GC

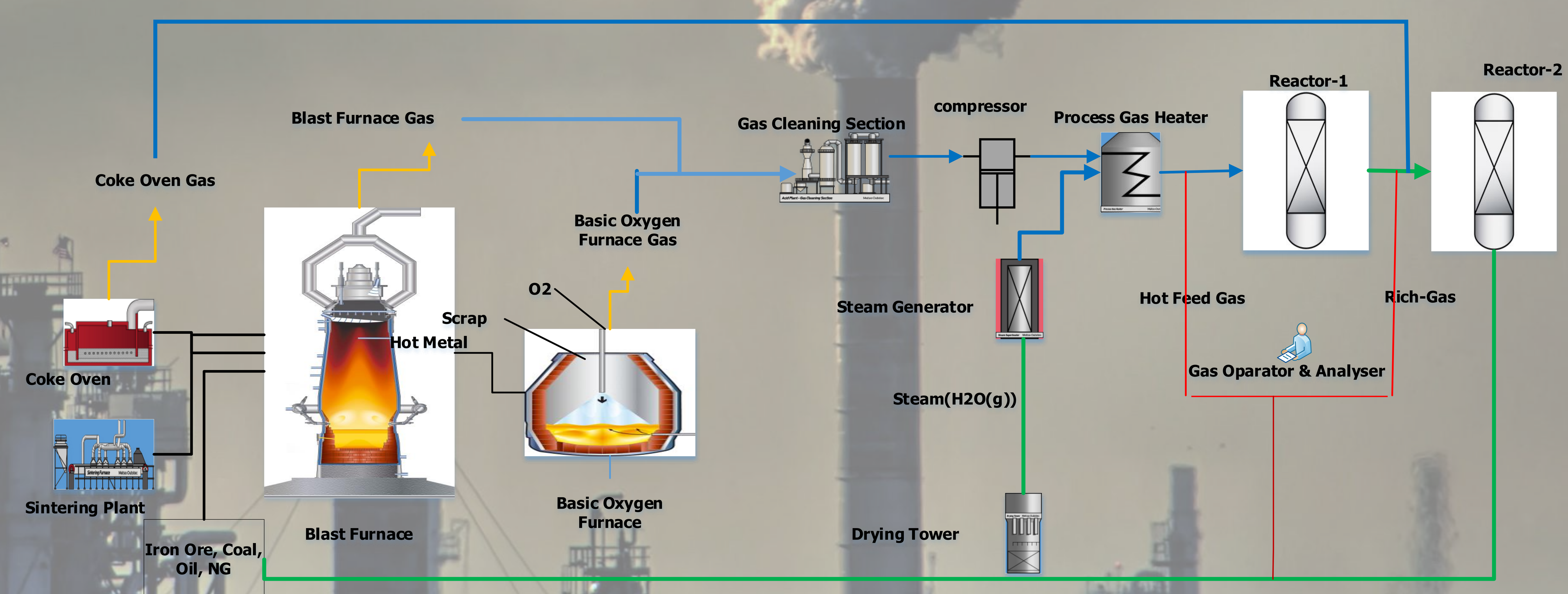
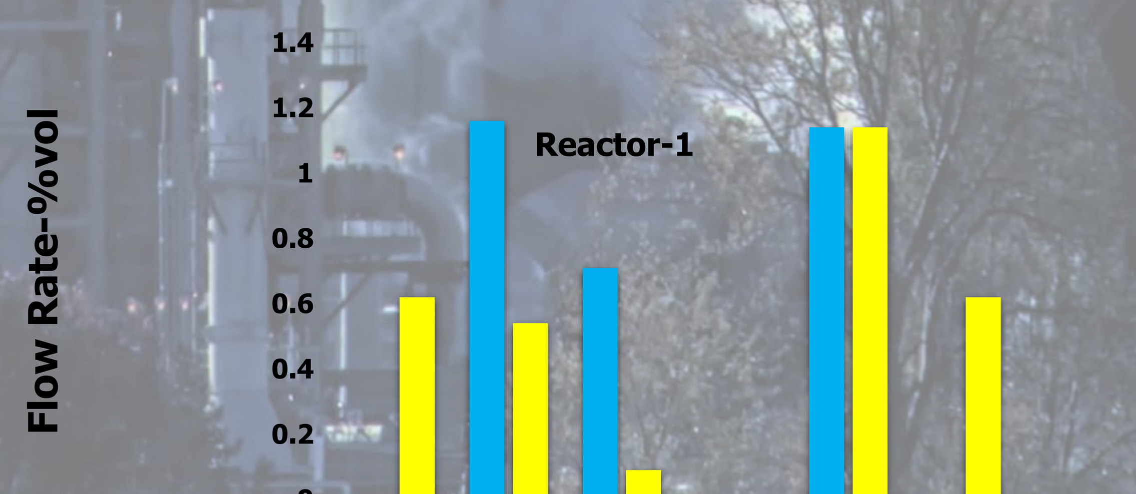


Fig .2: Possible reactor set up for CCUS testing.

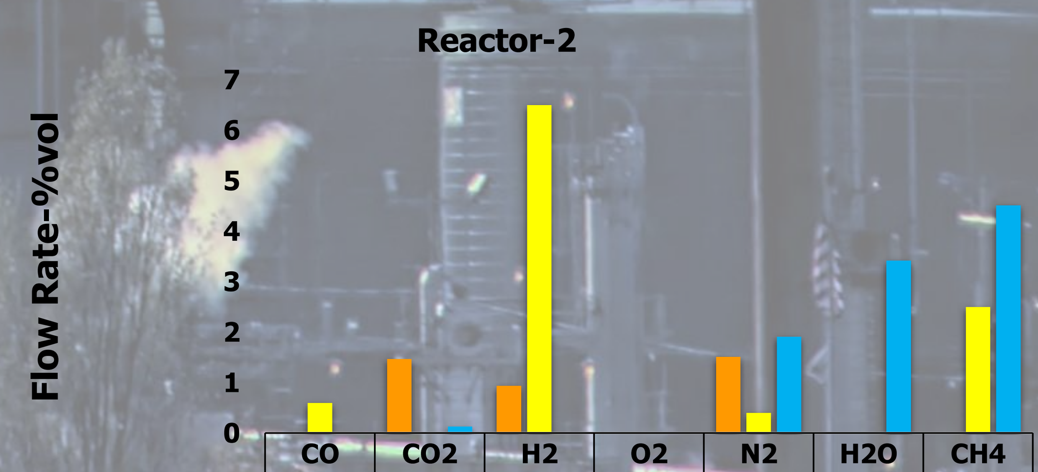
DATA Simulation by HSC-Chemistry

HSC-Chemistry software is a powerful simulation tool to calculate proposed reactor input and output gas composition for CCUS testing.



	CO	CO2	H2	O2	N2	H2O	CH4
Process Gas-1	0	1.16	0.71	0	1.14	0	0
Input Gas-1	0.62	0.54	0.09	0.001	1.14	0.62	0

Chart 1: Gas Composition for reactor 1



	CO	CO2	H2	O2	N2	H2O	CH4
Input Gas-2		1.47	0.94	0	1.51	0	0
Input Gas-3	0.6	0	6.5	0	0.4	0	2.5
Process Gas-2	0	0.13	0	0	1.91	3.42	4.51

Chart 2: Simulated Gas Composition for Reactor 2

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