Optimization of Sorption-Enhanced WGS for use with Basic Oxygen Furnace Gas from the steel plant

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Valorisation of steel off-gases to enable economic viable CO_2 storage and utilization

- Presence of diluted energy containing streams: unique feature of current steel making processes

Gas type	CO_2	CO	N_2	H_2	CH_4	LHV (MJ/Nm^3)
BFG	22	22	49	4	--	3.2
BOFG	14	57	14	3	--	7.5
COG	2	5	7	62	24	15.3

BFG – Blast Furnace Gas
BOFG – Basic Oxygen Furnace gas
COG – Cokes Oven gas

10Mt/year Iron&Steel Mill, see IEAGHG report on Iron&Steel, http://www.ieaghg.org/docs/General_Docs/Reports/2013-04.pdf

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VALORIZE THE ENERGY IN THE RESIDUAL STREAM

CO => H2

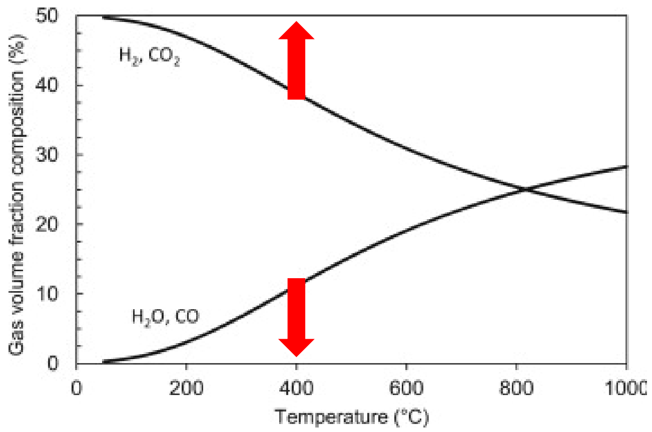
How to transform CO to H_2?

➢ Add steam and do the water gas shift!

- Water gas shift reaction at 400^{o}C is thermodynamically limited
- Combine the Water-Gas-Shift reaction with sorbent material to simultaneously produce H_2 at high temperature whilst also capturing CO_2

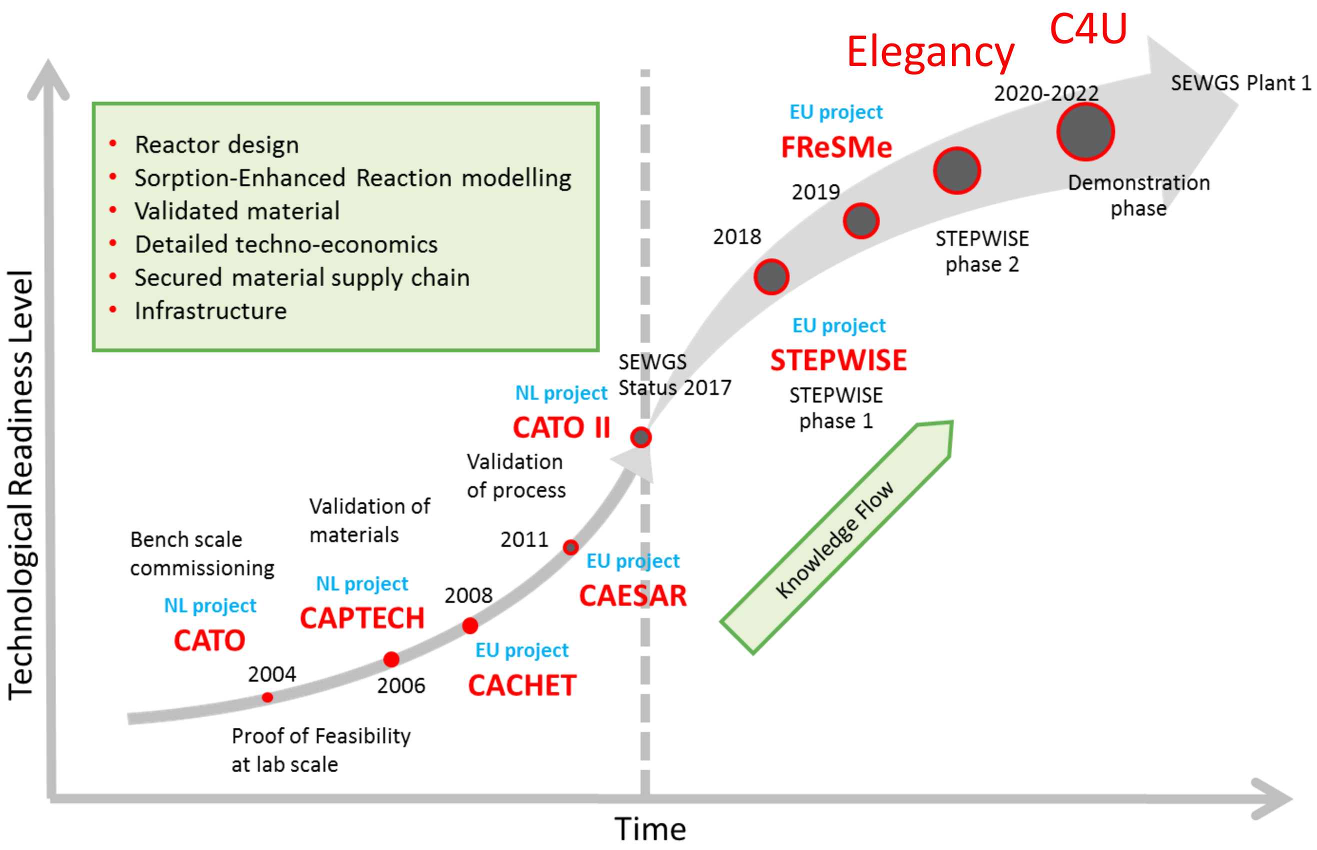
$$CO + H_2O \leftrightarrow \boxed{CO_2} + H_2 \qquad \Delta H = -41\ kJ/mol$$

In situ removal



Sorption-Enhanced WGS development

- *From power production to also H_2 production environment*



Residual gas streams in the steel industry

- Presence of diluted energy containing streams: unique feature of current steel making processes

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Elegancy:
1) **BOFG**
2) BOFG + BFG

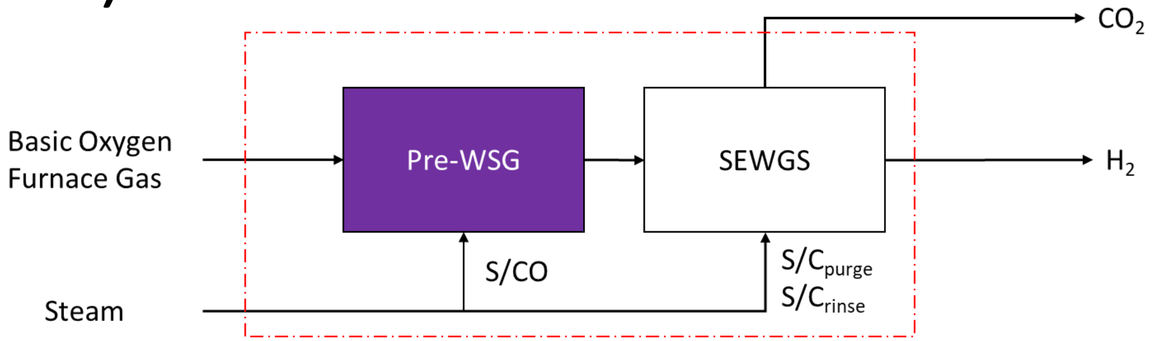
Objectives SEWGS (scope of Elegancy)

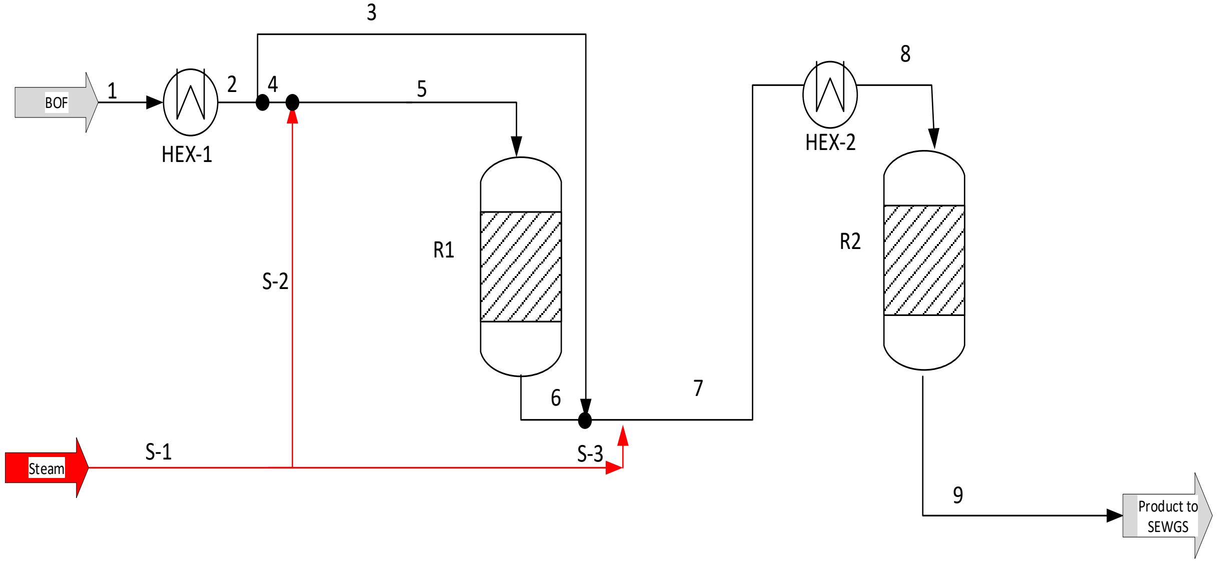
1. Prove the ability of water gas shift catalysts to operate in the presence of high carbon content and contaminants
   - For very high CO content gases, **the SEWGS system requires a pre-shift section** with associated catalyst

2. Extend the SEWGS model to steel works gases

3. Prepare the ground for the TRL7 deployment of the SEWGS process in high CO content steelworks gases.

1) Pre-shift



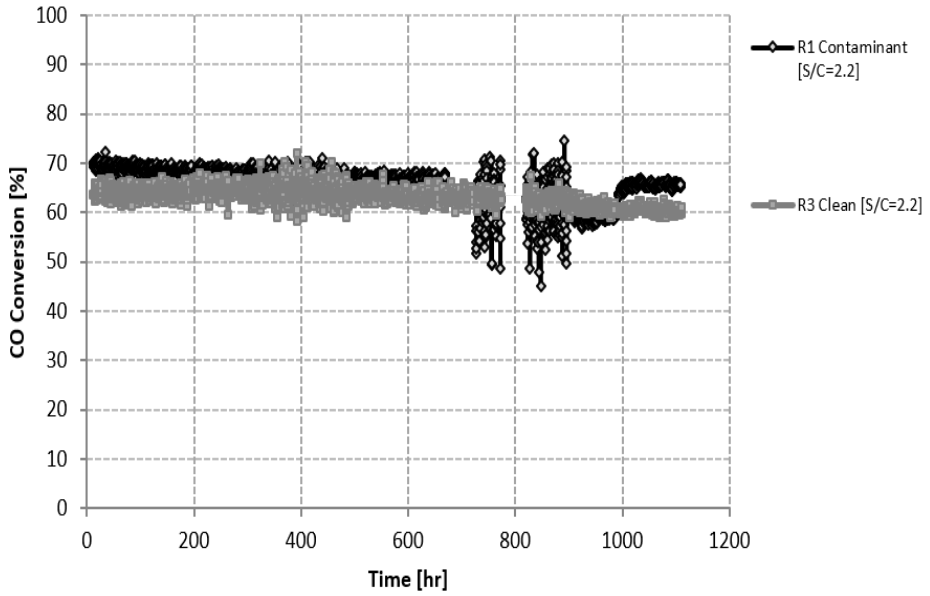


- To save steam, a split-flow configuration for the pre-shift section

1000+ hr testing BOFG

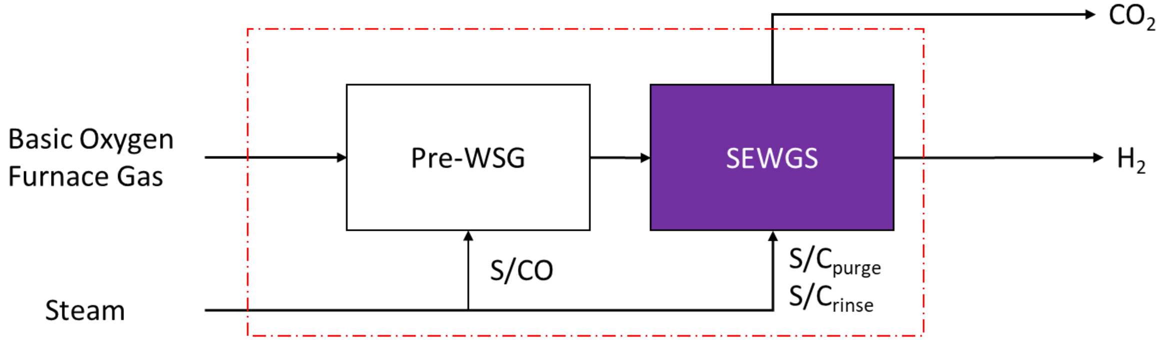
Commercial Catalyst (state-of the art)

Contaminant: **55 ppm NO_2 and 5 ppm SO_2**



- Effect of contaminants insignificant

2) SEWGS



- Multiple reactive separation columns
- Operated dynamically according to defined cycle

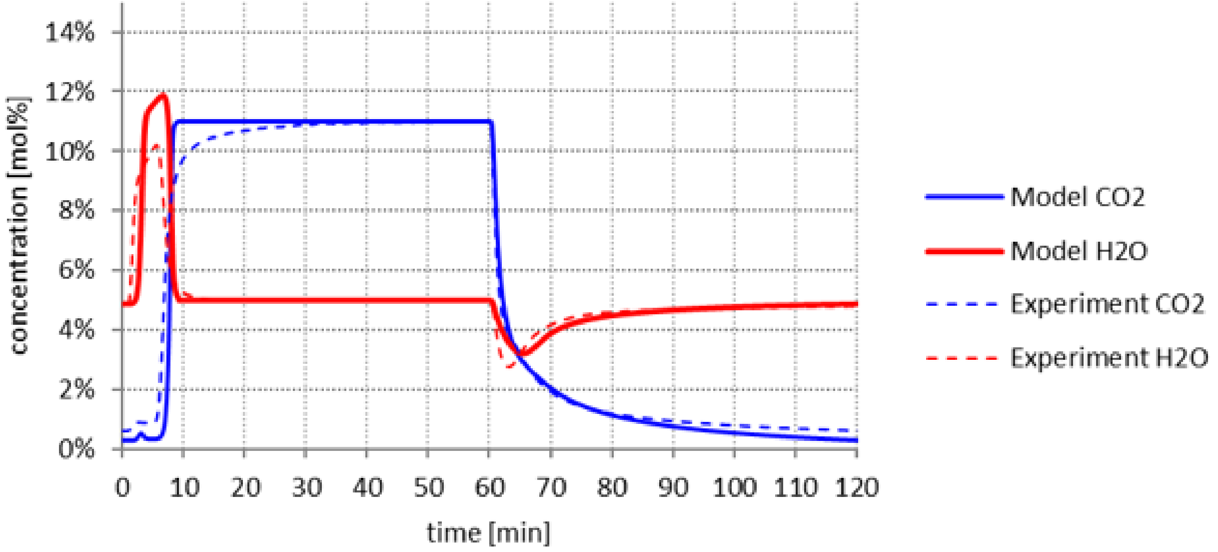
	1	2	3	4	5	6	7	8	9	10	11	12
Column 1	A		R		PE1	PE2	BD	P		PE2	PE1	RP
Column 2	PE1	RP	A		R		PE1	PE2	BD	P		PE2
Column 3	P	PE2	PE1	RP	A		R		PE1	PE2	BD	P
Column 4	BD	P		PE2	PE1	RP	A		R		PE1	PE2
Column 5	PE1	PE2	BD	P		PE2	PE1	RP	A		R	
Column 6	R		PE1	PE2	BD	P		PE2	PE1	RP	A	

- A (adsorption) R (Rinse) PE (pressure equilization) BD (Blow down) P (Purge) RP (Repress)

➢ High CO2 purity & high Hydrogen recovery

Multi column (6 x 6m)
Cyclic steady-state
Up to 30 bar(a)

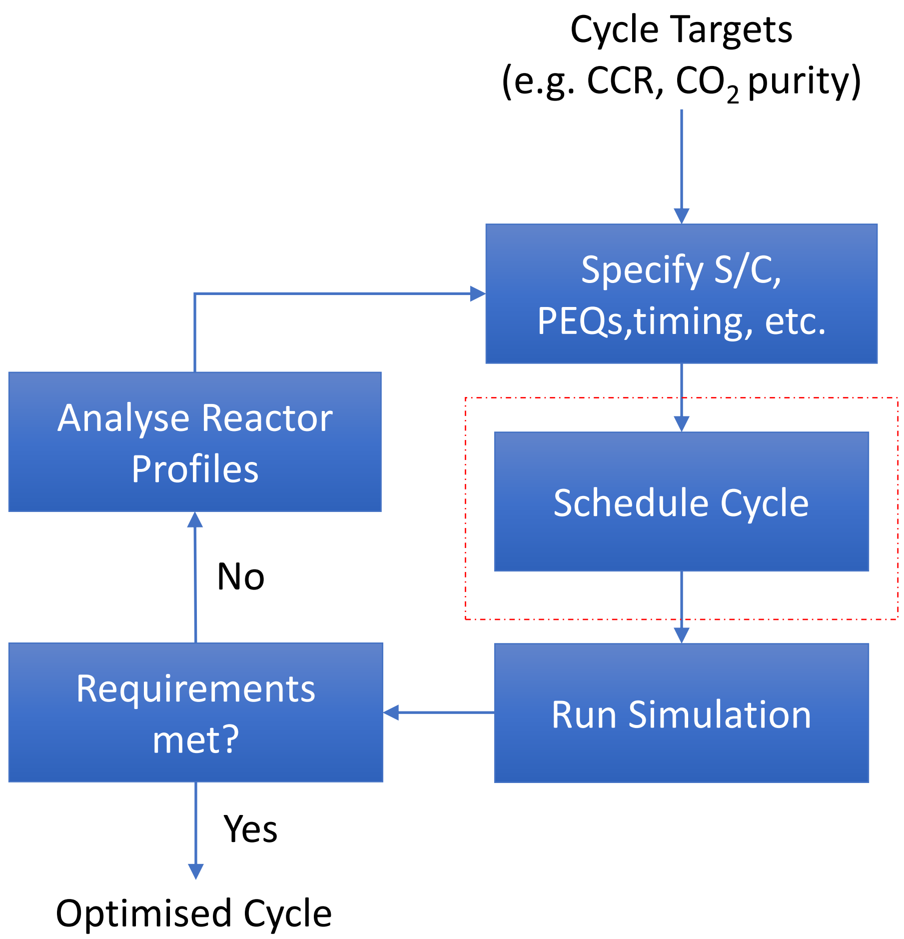
SEWGS modeling is essential for design



Simulations of the CO_2 and steam transients during a CO_2 step in- and decrease to a steam containing feed. The solid lines represent the model, while the dashed lines the experimental observations.

The updated model is capable of predicting cycle performances accurately.

Cycle Design and optimization



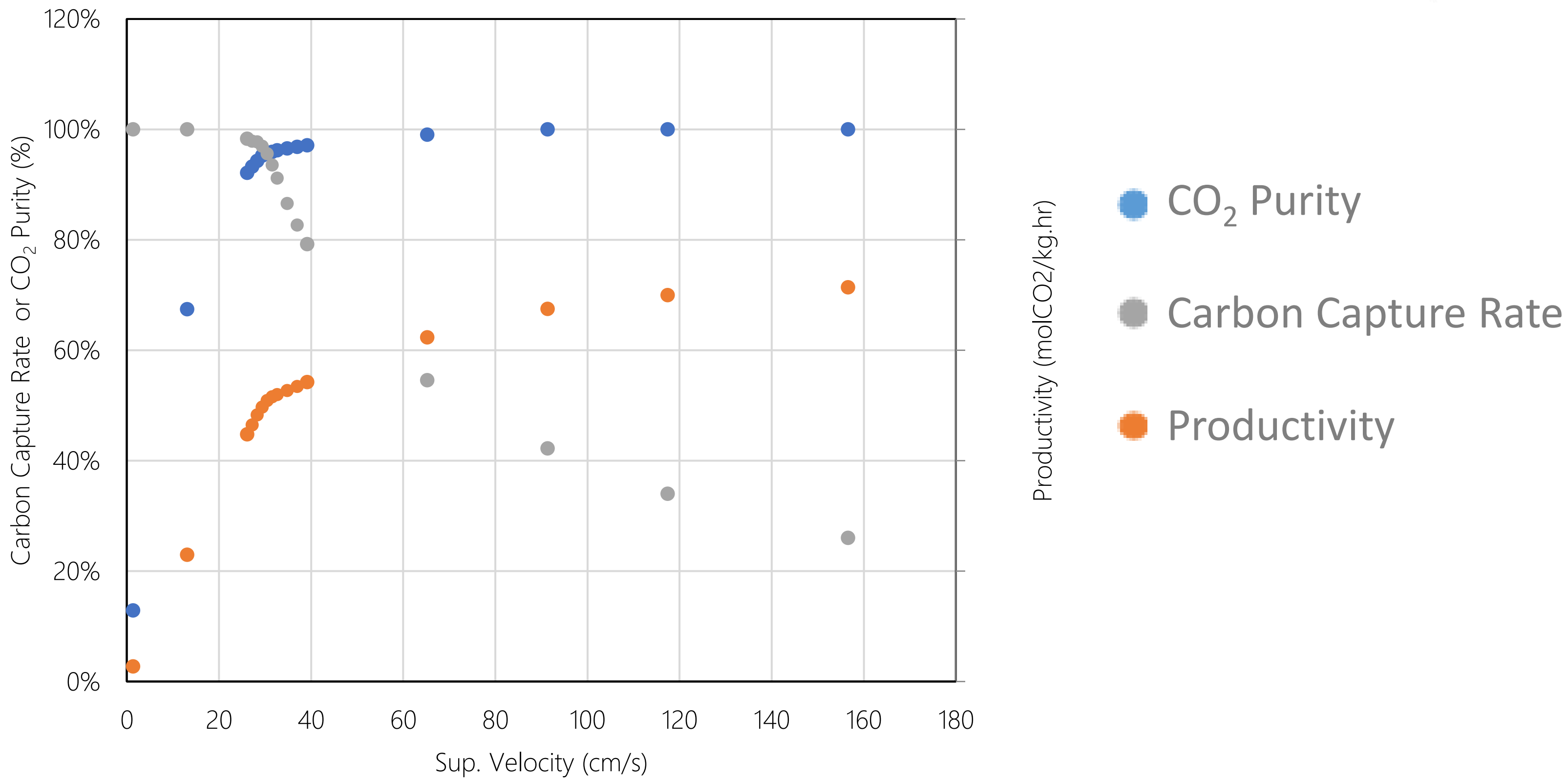
- Determine

Flow rates
Number of columns
Column height
Column diameter
Step durations

- CO_2 purity
- Carbon Capture Rated (CCR)
- Hydrogen recovery and purity

SEWGS: Cyclic simulations

- **Unit sizing**
  - Productivity
    - Feed flow, mol/kg
  - Purity and CCR

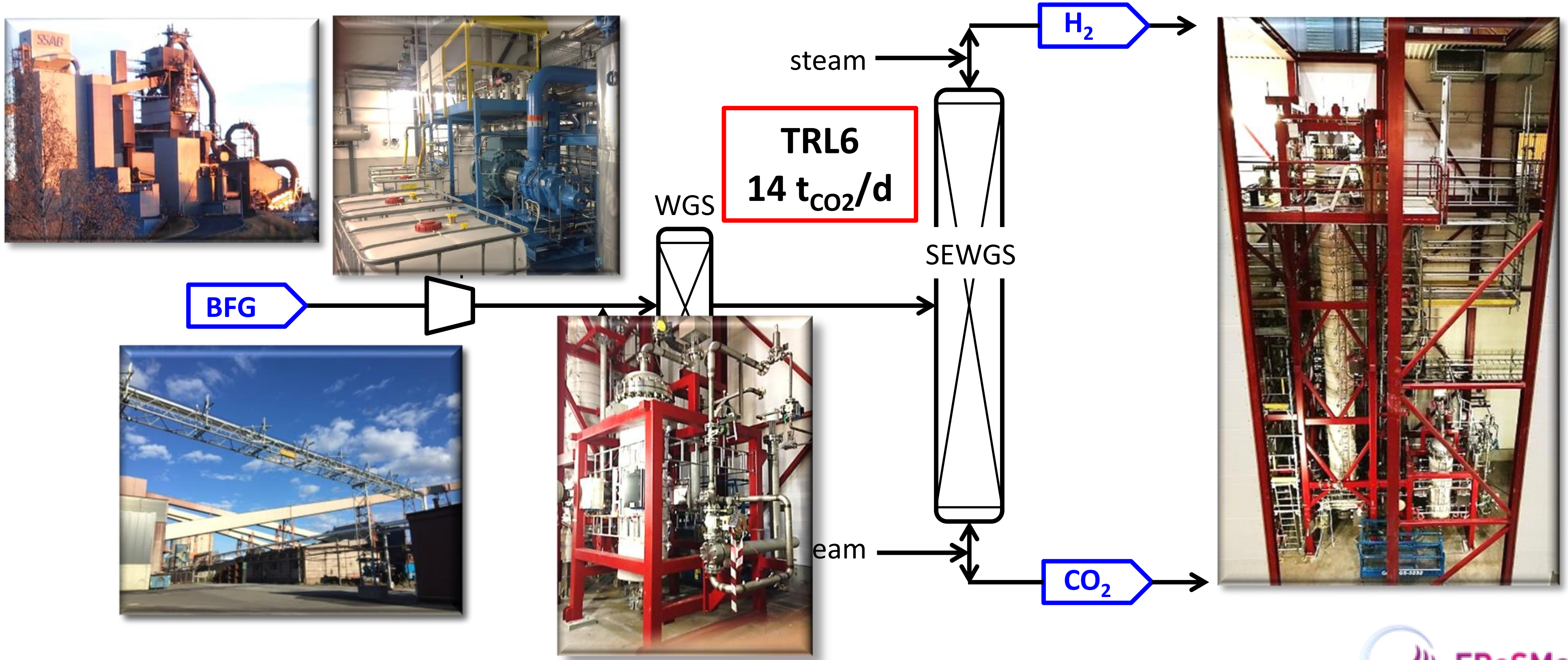


Cycle performance versus velocity; 24 bar

- The cyclic simulations were used for a full scale, 35 kNm^3/h BOFG SEWGS design
- The cyclic simulations were used for a prototype TRL7 scale design for SEWGS multi-column testing at Swerim (luleå, Sweden)

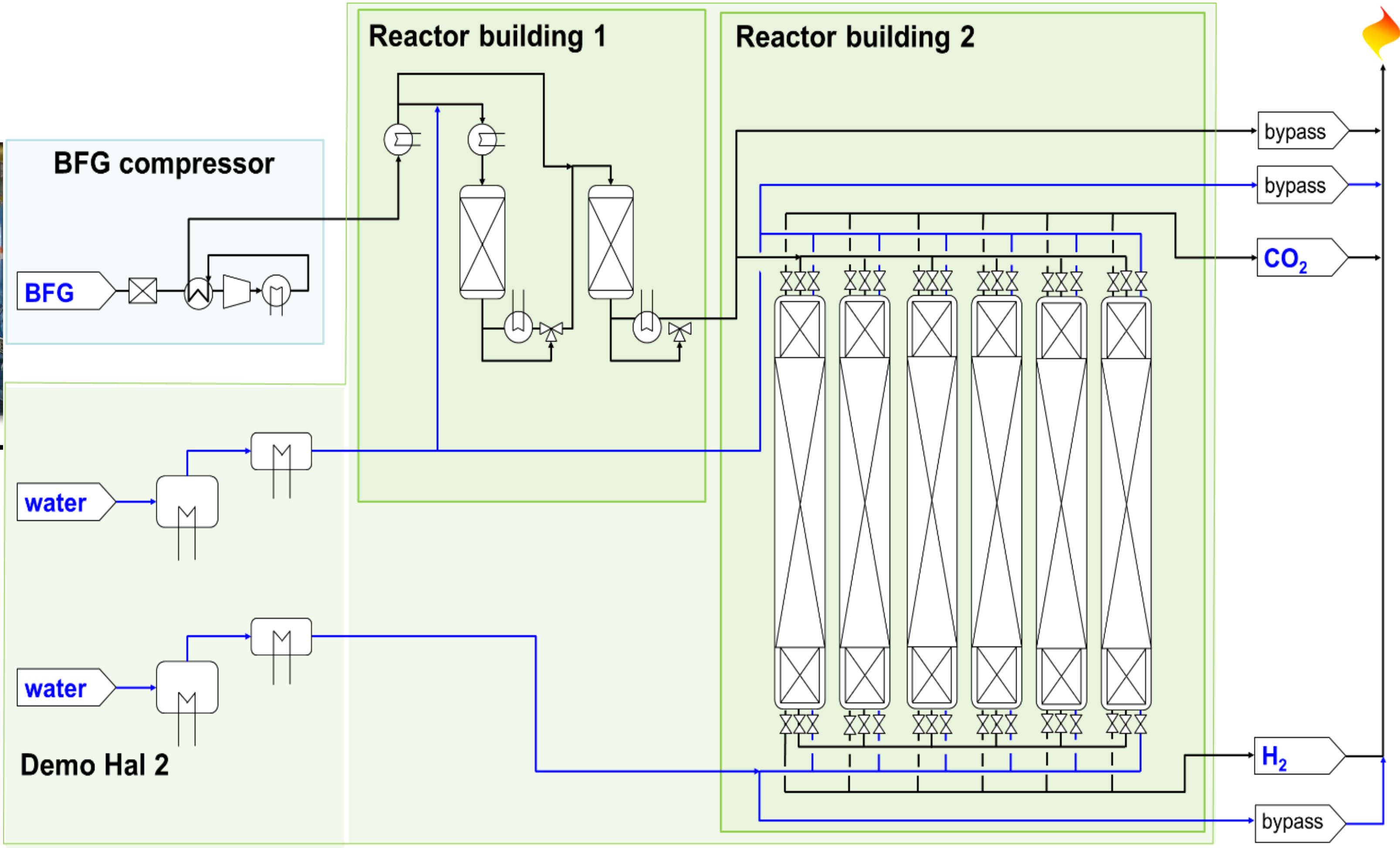
3) From STEPWISE PILOT to TRL7

STEPWISE: Cost effective CO_2 reduction in the Iron & Steel Industry



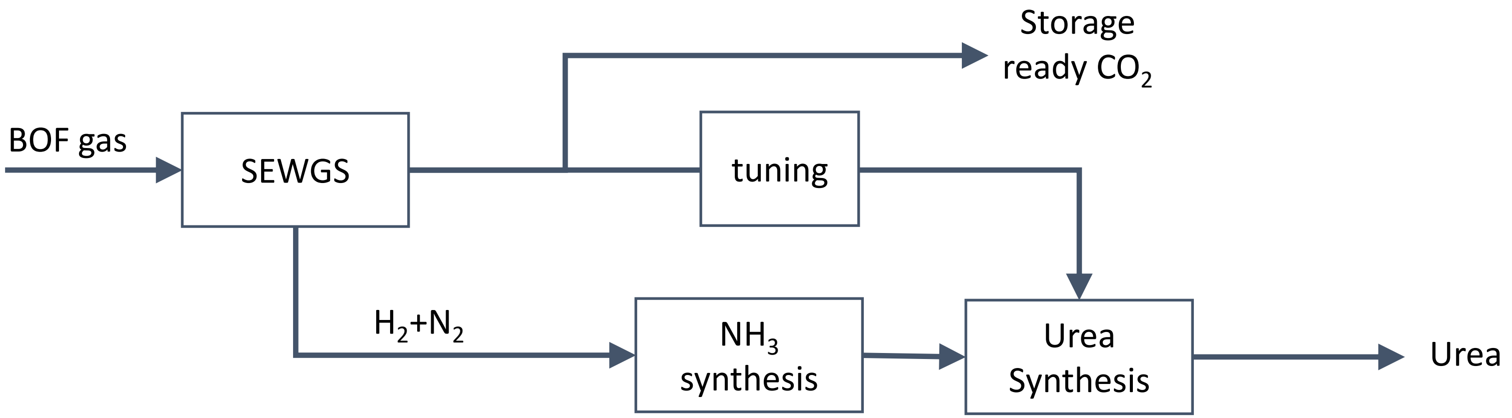
3) From STEPWISE PILOT to TRL7

Multi-column SEWGS in Luleå



A positive business case: Urea production from BOFG

- Residual gases in the steel industry contain N_2
- After SEWGS technology
  - N_2 goes with the H_2
  - Treated BOF gas has the right H_2/N_2 ratio for ammonia synthesis



➢INITIATE project (H2020, under review)

Summary: SEWGS and Elegancy

- The SEWGS Elegancy work contribute to the decarbonization and valorization of steel works gases, by extending the SEWGS functionality from blast furnace gas (BFG) to basic oxygen furnace gas (BOFG).

- SEWGS technology platform used with BOFG creates the CO2 utilization business cases with energy intensive CCS.
  Commodities can be produced while the remaining CO_2 is available at high purity for sequestration.

- Elegancy work prepares follow up multi column (CC(U)S) demonstration (TRL 7) on steel works gases, the crucial step towards commercial roll out.

Acknowledgement

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ELEGANCY

Accelerating CCS Technologies

The EU Framework Programme for Research and Innovation

HORIZON 2020