Institute for Energy Technology

Research for a better future

Renewable energy | Nuclear technology | Materials technology | Digitalization | Radiopharmacy and health | Oil and gas | Industry and environment | Safety and security

CONVERGE: CarbON Valorisation in Energy-efficient Green fuels

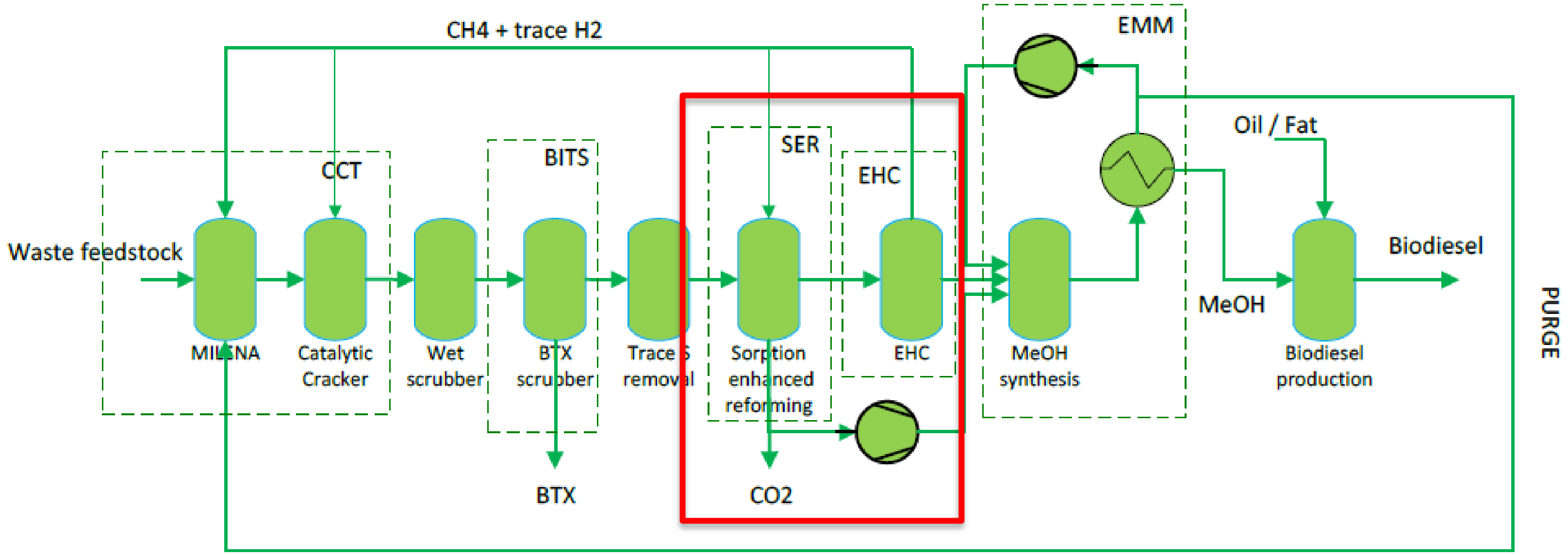
SER and SEWGS for CO_2 capture: preliminary experimental results

International Workshop on CO_2 capture and Utilization – February 17th 2021

CONVERGE WP3: Objectives

The main objective of WP3 is to validate the integration of the SER and EHC technologies at TRL5 in relevant operating conditions adapted to the CONVERGE concept with the following specific targets:

- Reduce the energy consumption for hydrogen production, CO_2 removal and compression to 1.2 MJ/kg CO_2
    - **Optimization of the CO_2 sorbent material used in the SER process**
    - **Development of new improved catalytic materials suited for the CONVERGE syngas**
- Extract and compress H_2 at >99.5% purity, 50 bar and at a primary energy consumption of 12 MJ/kg H_2
- Operate the SER and EHC for 500 hours on C1-C6 containing emulated syngas feed at 10 Nm^3/hr H_2 production



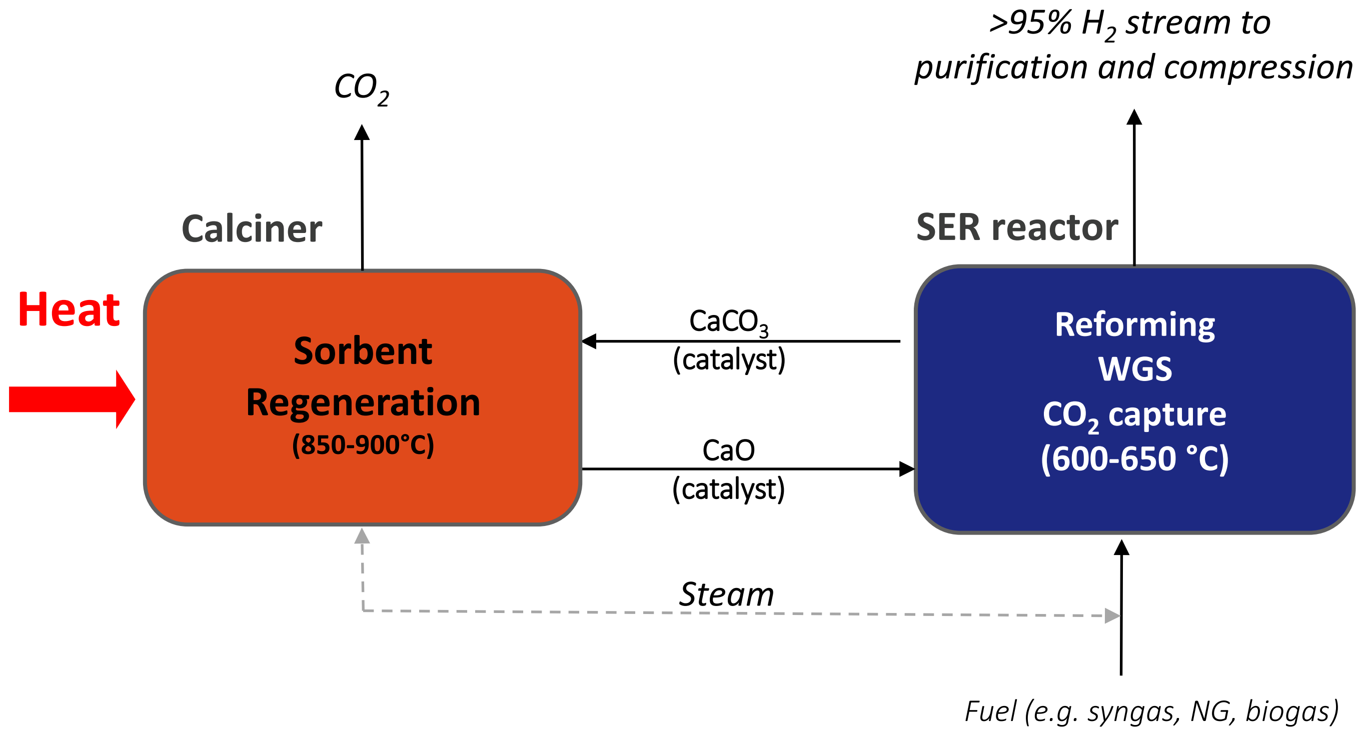
CONVERGE

CarbON Valorisation in Energy-efficient Green fuels

Sorption Enhanced reforming (SER)

SER integrates Reforming, Water-Gas Shift (WGS) and CO_2 separation through the addition of a high temperature CaO-based CO_2 solid sorbent

SER Concept scheme



Feed Gas after CCT

H2 - 41.9%

CO - 10.0%

CO2 - 32.4%

CH4 - 10.5%

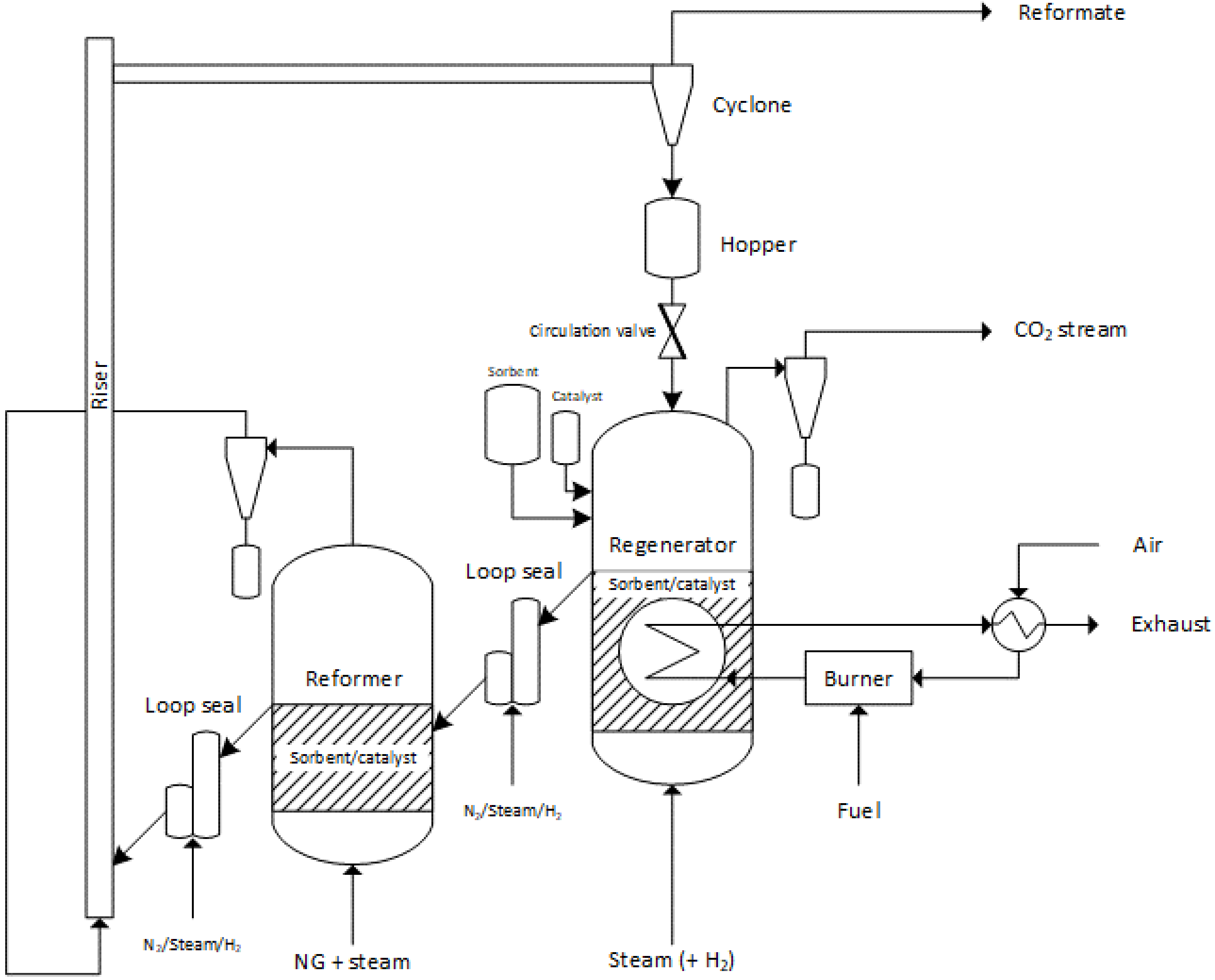
C2H4 - 4.4%

N2 - 0.9%

SER reactor technology developed at IFE

Dual Bubbling Fluidized Bed (DBFB) reactor system

- Dual bubbling fluidized bed reactor (DBFB)
  - 2 FB-reactors coupled with loop-seals and riser
  - Continuous mode
  - Bubbling regime
  - Circulation rate adjusted with slide valve

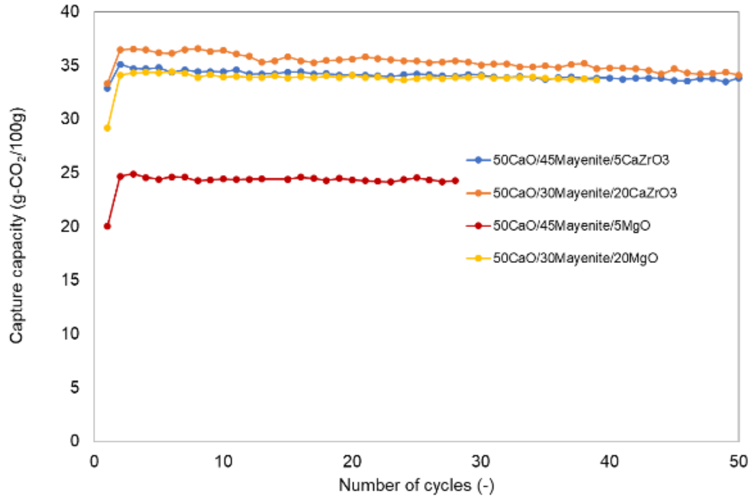


Materials Development and Optimization

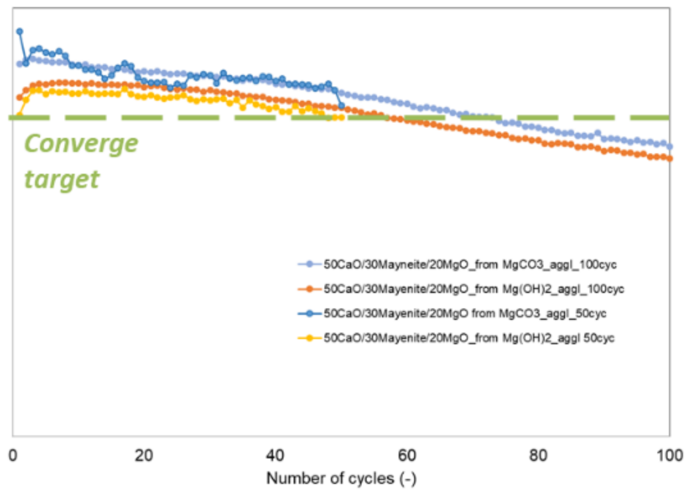
CO_2 sorbent material used in the SER process

- added a thermally stable dopant (ZrO_2, MgO and Fe_2O_3) in the CaO/Mayenite sorbent to increase its stability

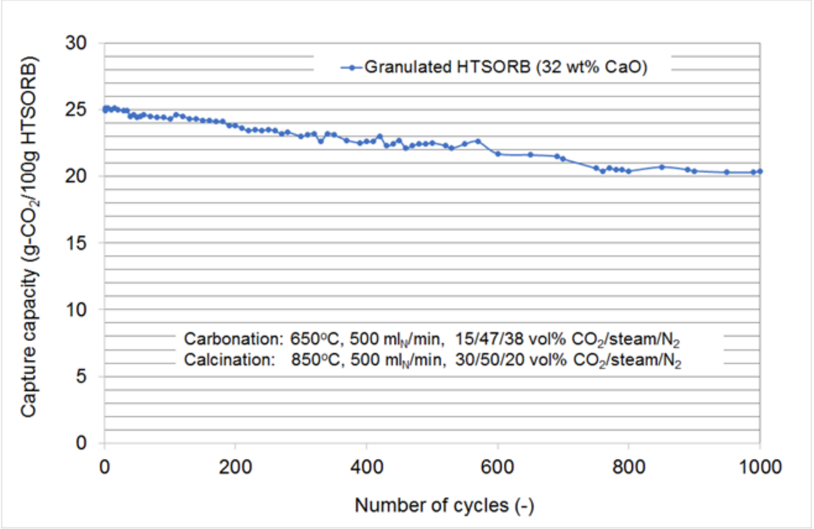
- HTSORB – Chosen for experiments



Sorbent powders: stable activity and capacity target achieved in some cases



100 cycles test: capacity decreases more severely. The addition of thermally stable agents does not allow reaching the target



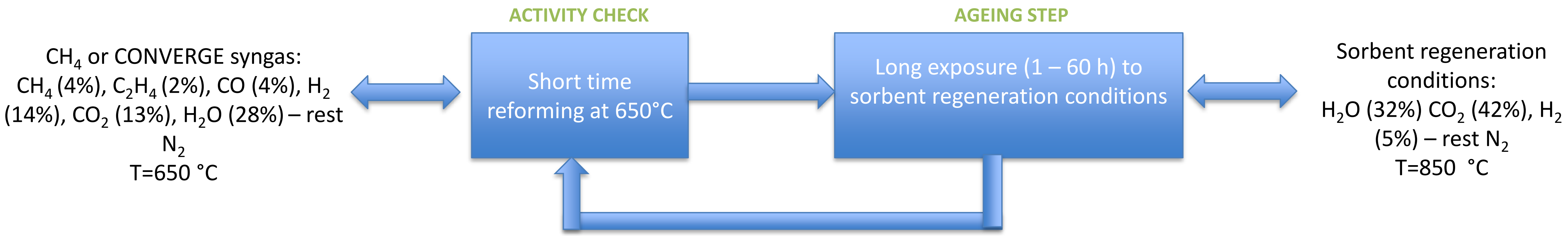
Long-term sorption capacity:
stabilized at < 20 g-CO_2/100g sorbent after 1000 carbonation-calcination cycles

Materials Development and Optimization

Development of catalyst tailored for SER process– Stability test

SER Catalyst testing and aging

- New catalytic set-up designed and constructed within CONVERGE project for “stability” and “kinetic” tests.



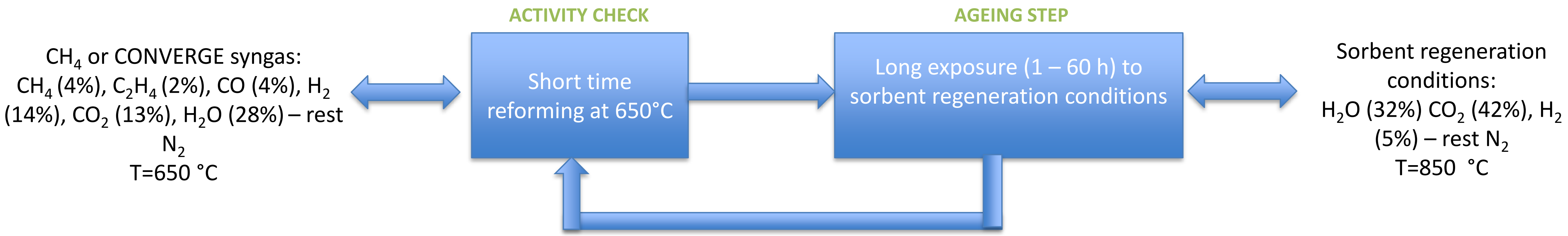
CarbON Valorisation in Energy-efficient Green fuels

Materials Development and Optimization

Development of catalyst tailored for SER process– Stability test

SER Catalyst testing and aging

- New catalytic set-up designed and constructed within CONVERGE project for “stability” and “kinetic” tests.



CONVERGE
CarbON Valorisation in Energy-efficient Green fuels

Materials Development and Optimization

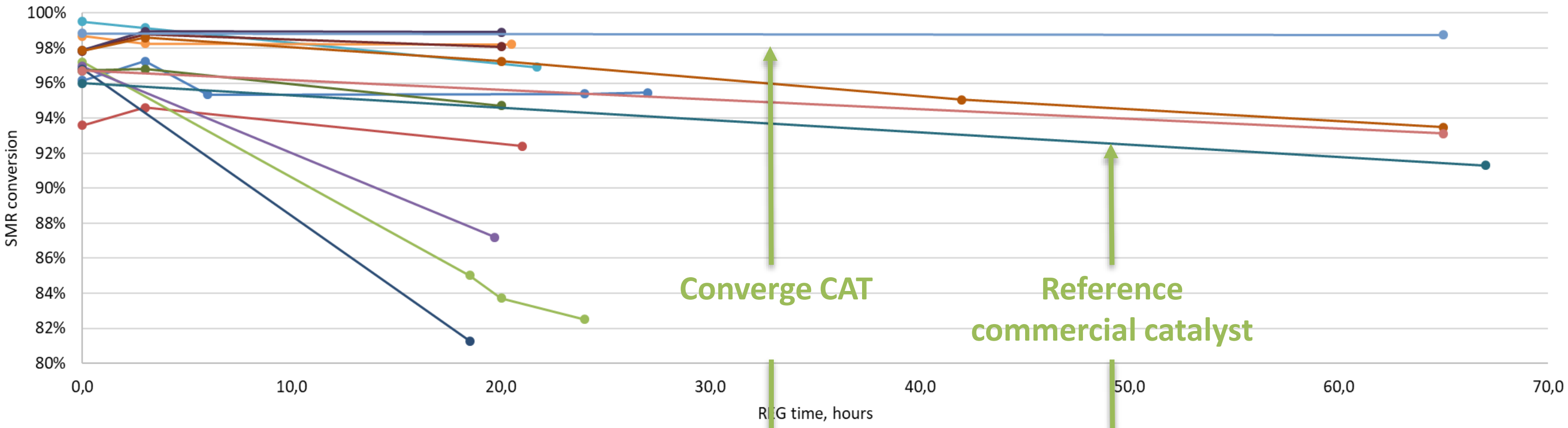
Development of catalyst tailored for SER process – Stability test

Stability tests:

Screening a matrix of 15-20 newly synthesized materials

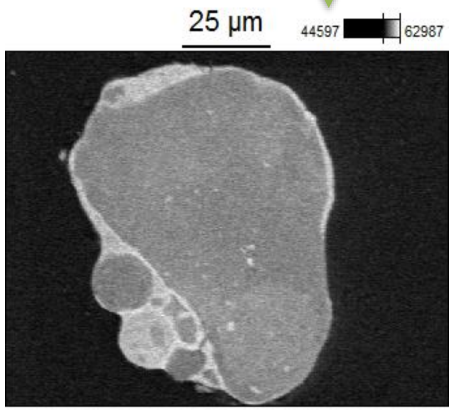
- 5 different supports
- 5-10-15-20 wt % Ni

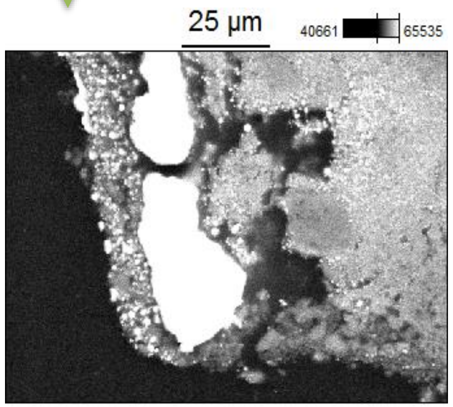
Satisfactory results, higher activity than commercial reference for some of the prepared catalysts



SEM characterization after 60h of test:

- Nickel sintering well evident in the commercial catalyst
- No evidence of nickel sintering but total nickel loading to be decreased to avoid nickel «envelop» effect

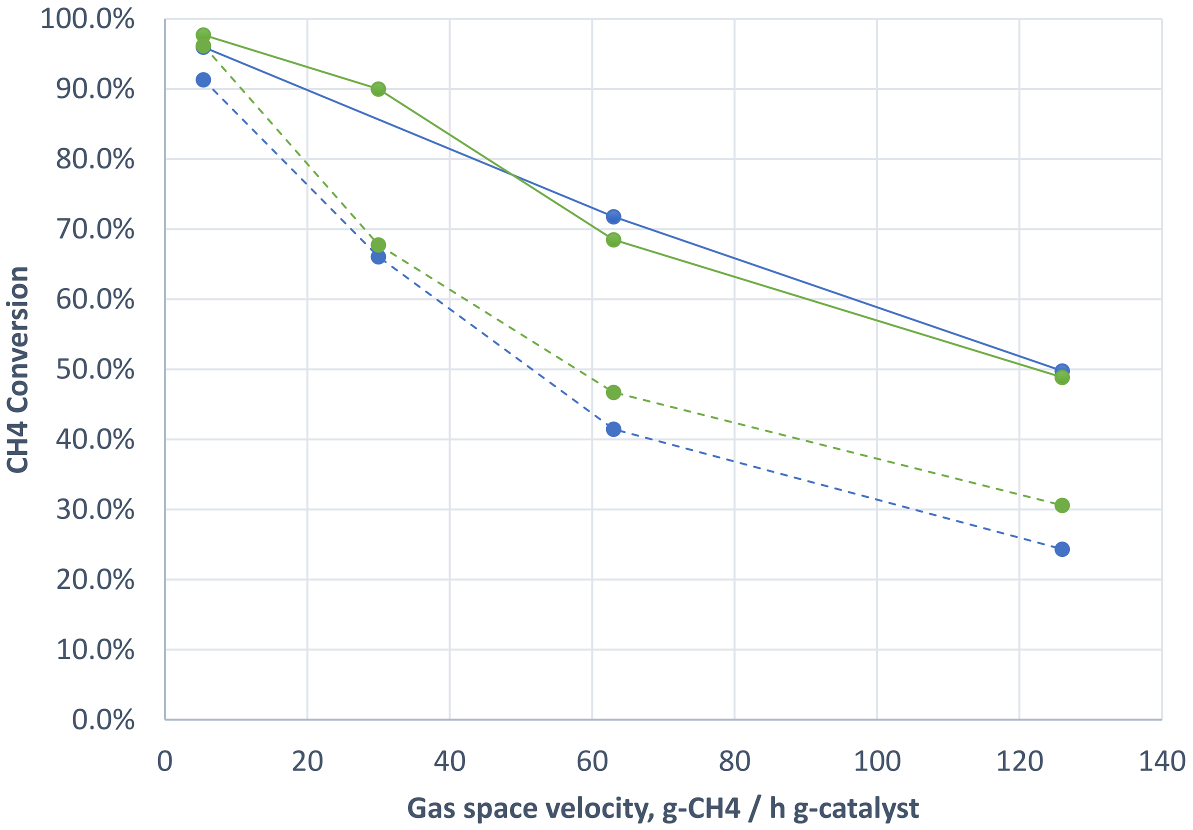




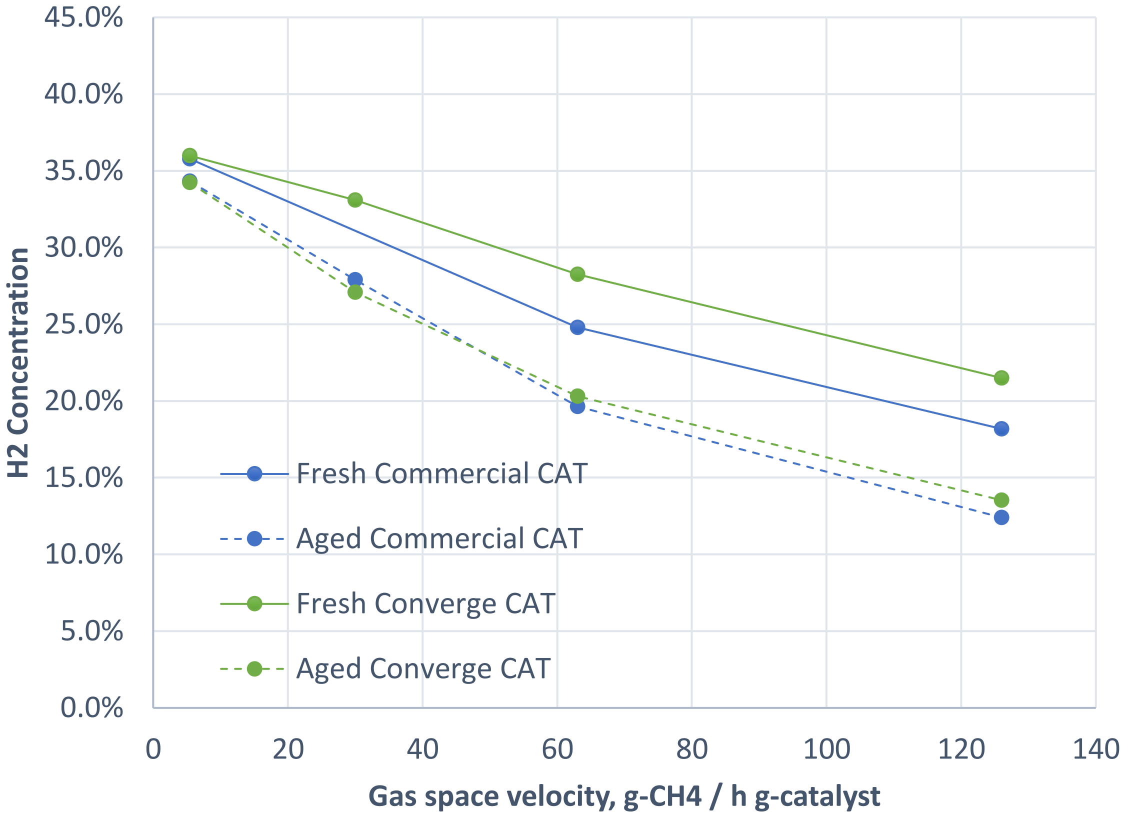
CONVERGE
CarbON Valorisation in Energy-efficient Green fuels

Materials Development and Optimization

Development of catalyst tailored for SER process– Stability test in SMR conditions (Aged 60h)



CH_4 conversion

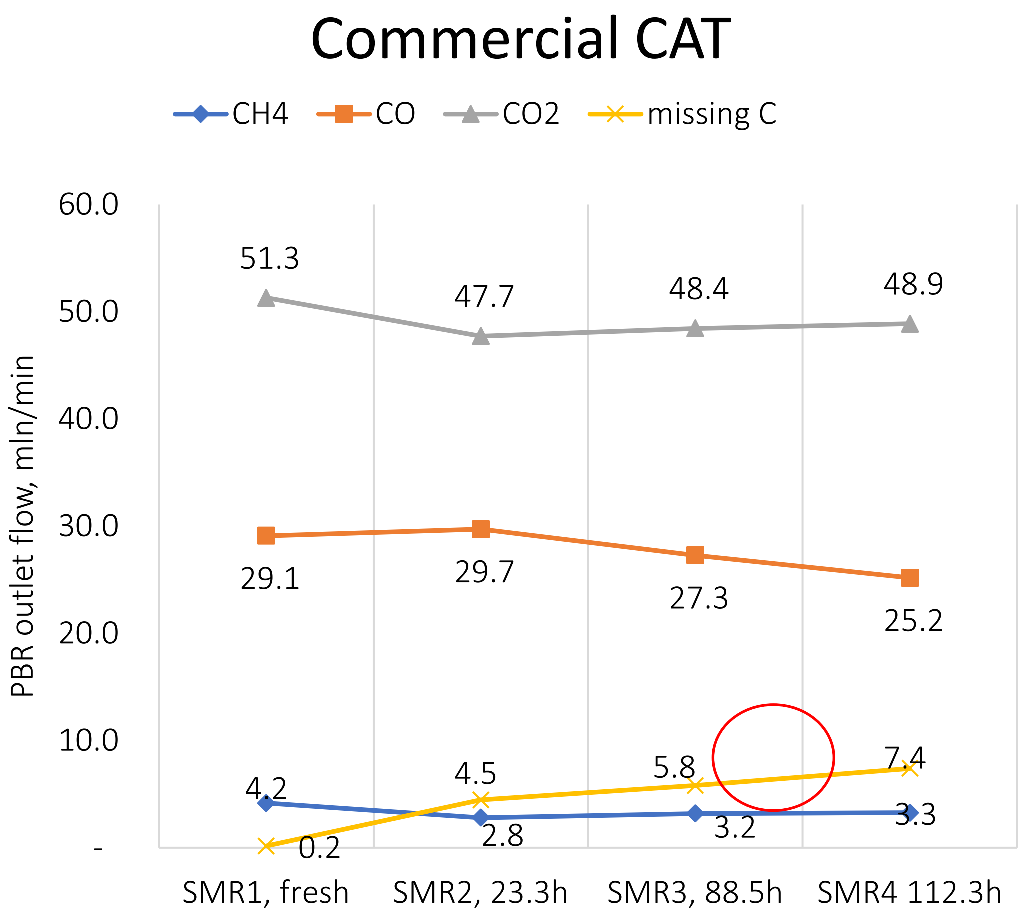


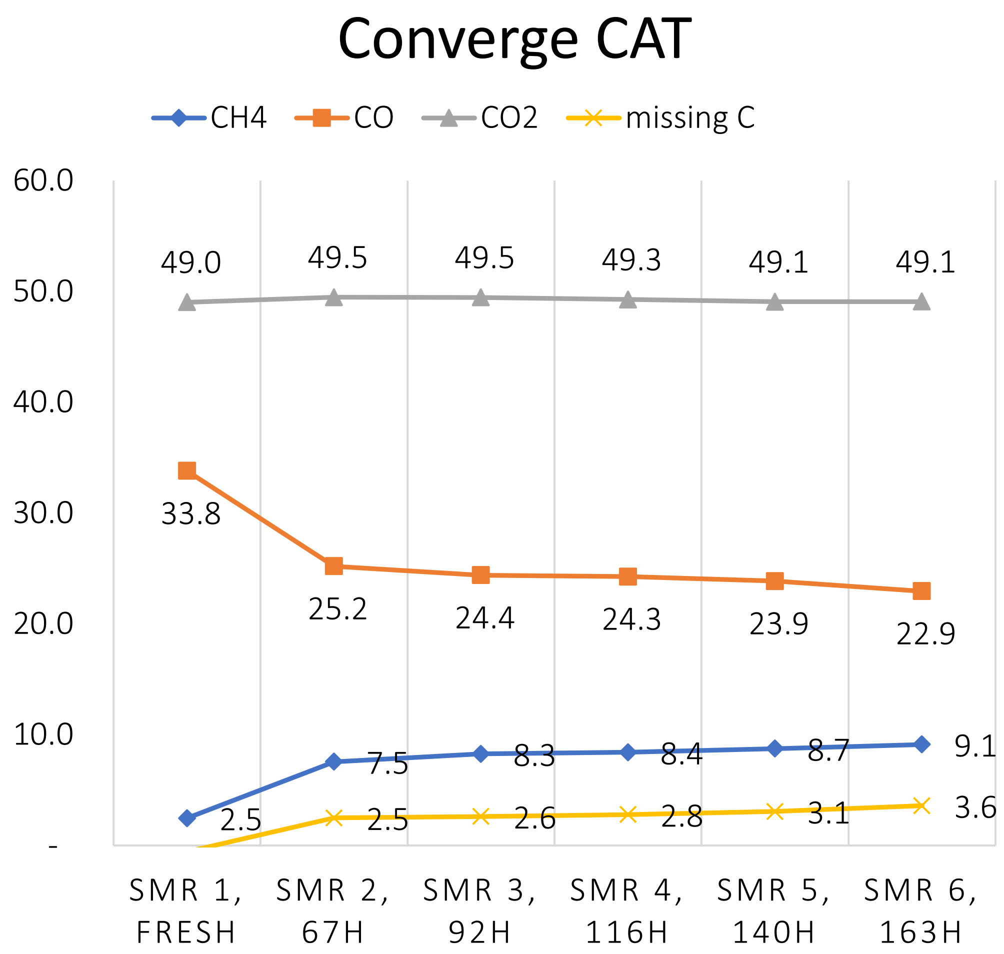
H_2 concentration

- Converge CAT presents better CH_4 conversion after aging. Difference more apparent in higher GSV.
- Converge CAT presents better H_2 selectivity fresh and after aging

Materials Development and Optimization

Development of catalyst tailored for SER process– Stability test





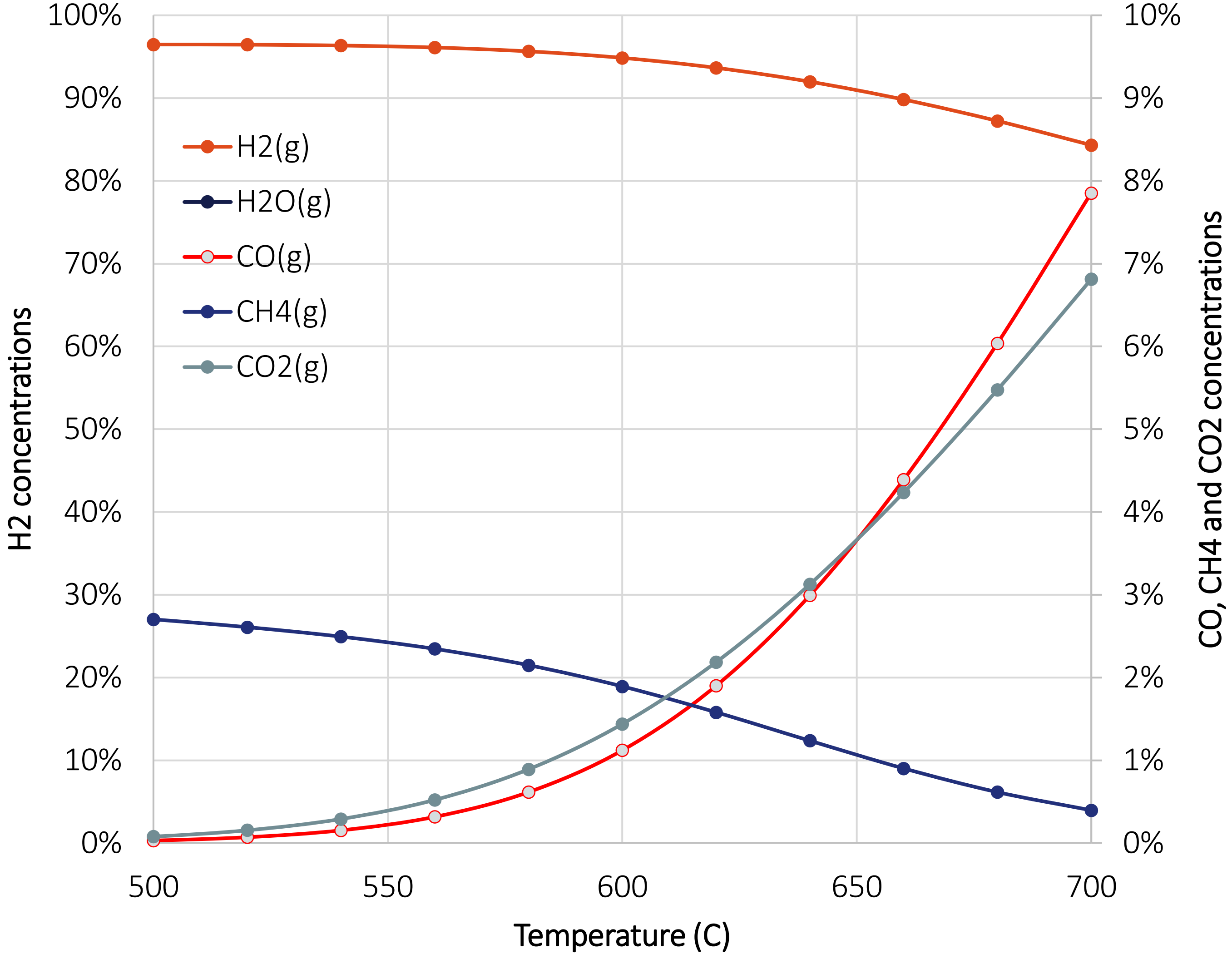
- Increase in carbon deposition. (TPO confirmed)
- Experiment stop after 120h aging – High pressure drop

- No carbon deposition
- Experiment stable during 160h aging

FBR Tests
SER/SEWGS – Equilibrium Trade-off

<u>Process Parameters</u>
Temperature: 650°C
Pressure: 0.5 barg
Fluidization velocity: 0.036 m/s

<u>Feedstock and Materials</u>
Gas Feed: (mol%): 41.9% H_2, 10.0% CO, 32.4% CO_2, 10.5% CH_4, 4.4% C_2H_4, 0.9% N_2
Steam R value: 2.0



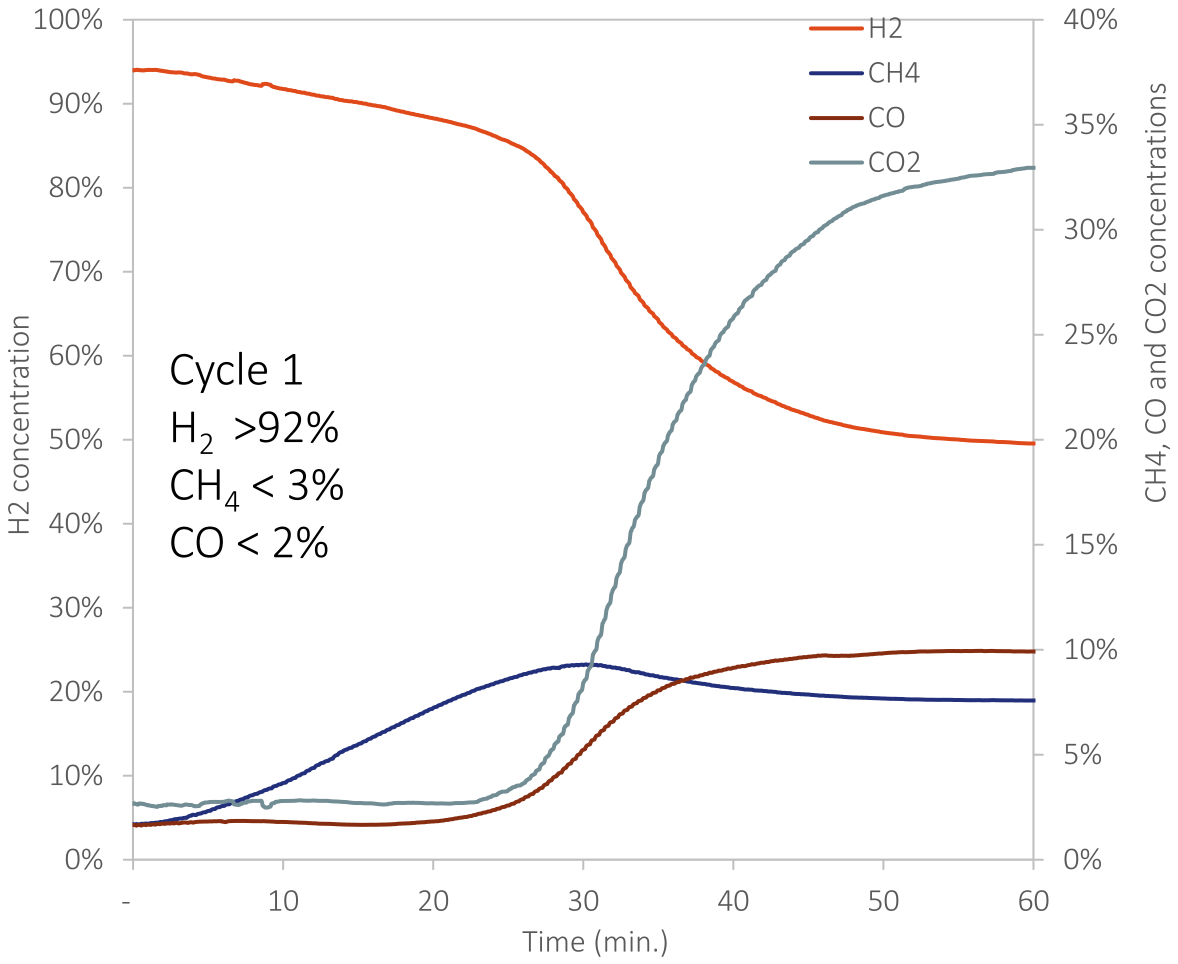
SER/SEWGS – With syngas - Converge Cat

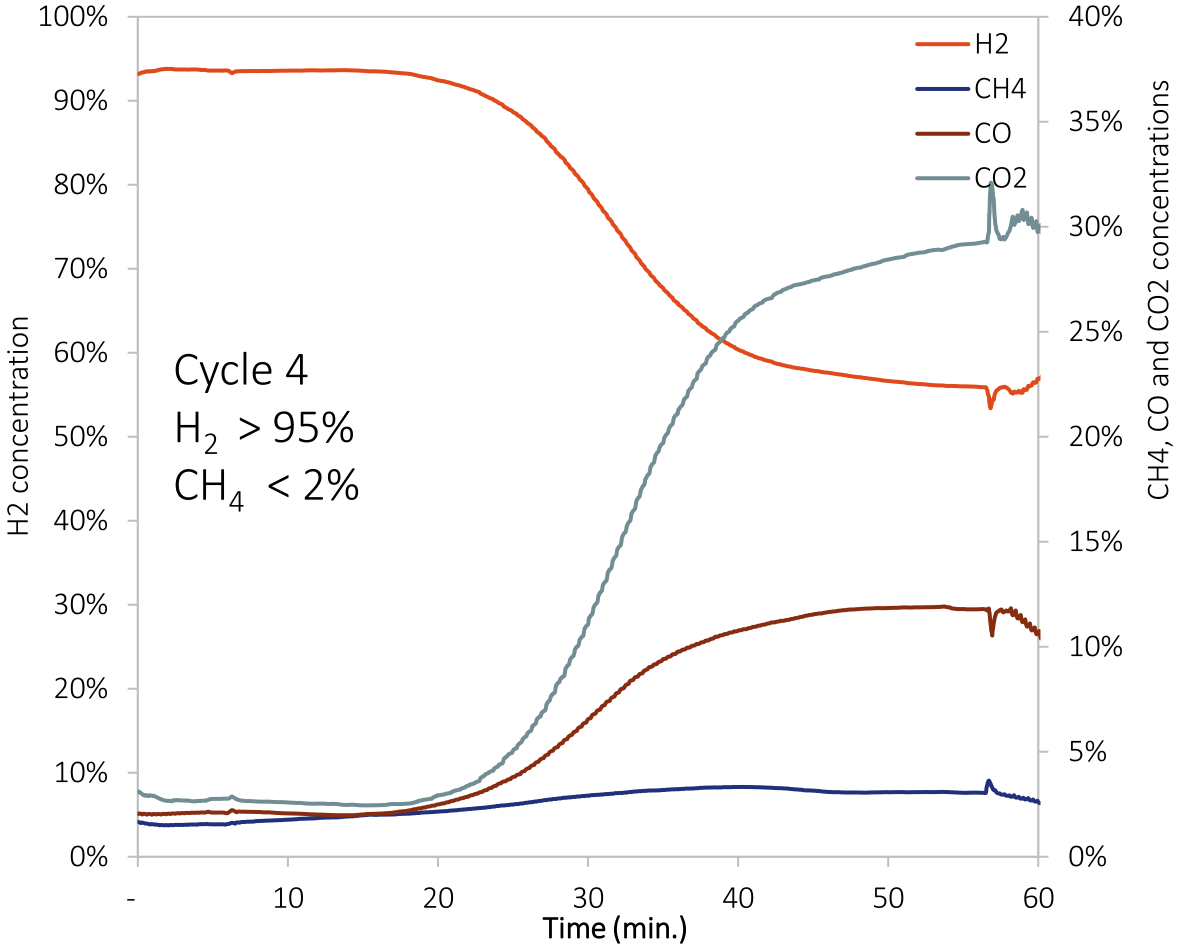
<u>Process Parameters</u>

<u>Temperature:</u> 650°C
<u>Pressure:</u> 0.36 barg
<u>Fluidization velocity:</u> 0.05 m/s

<u>Feedstock and Materials</u>

<u>Gas Feed:</u> (mol%): 41.9% H_2, 10.0% CO, 32.4% CO_2, 10.5% CH_4, 4.4% C_2H_4, 0.9% N_2
<u>Steam R value</u>: 2.0
<u>Materials:</u> 120.7 g CaO sorbent + 12.5 g Converge Cat

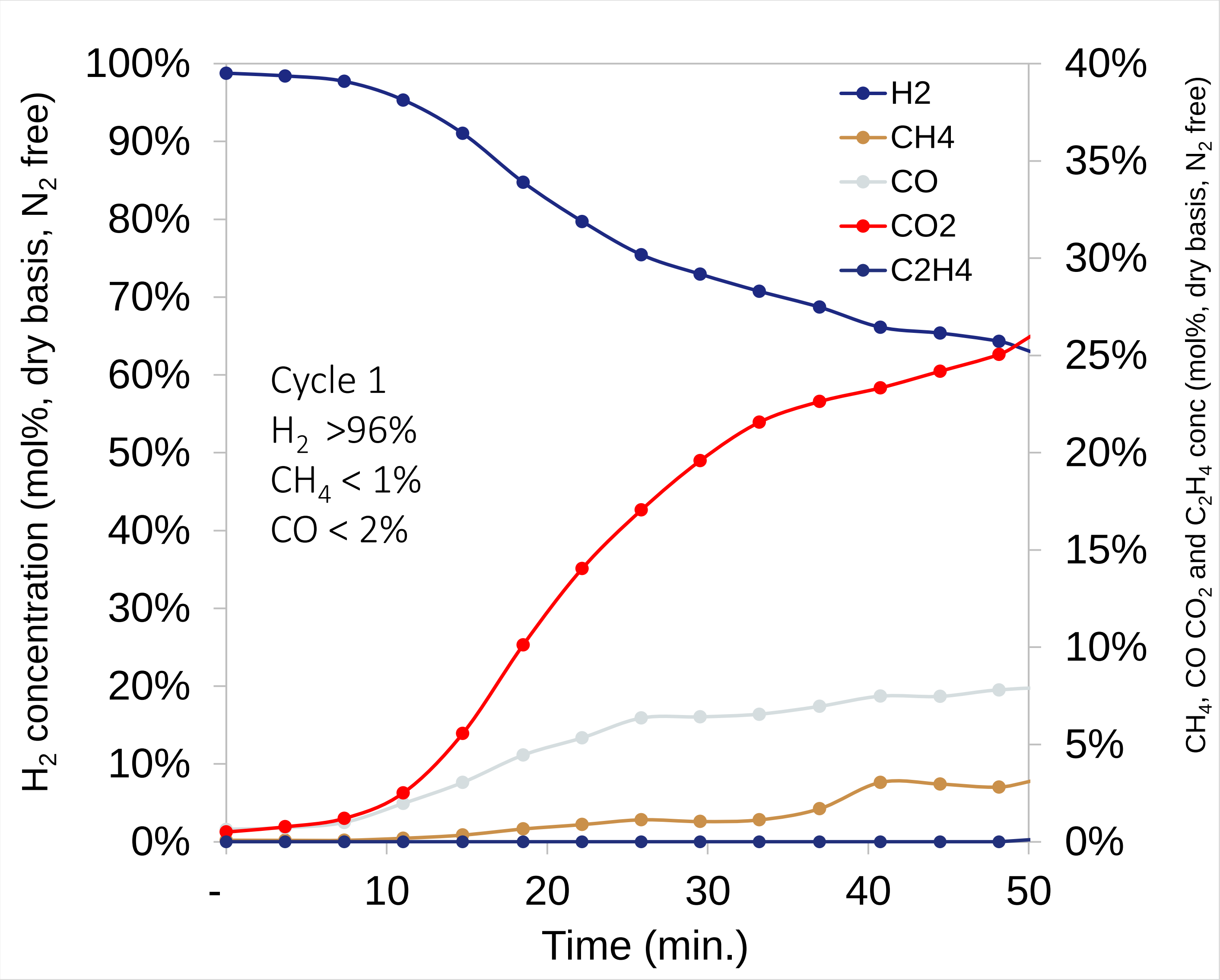




SER/SEWGS – With syngas and glycerol - Commercial Catalyst

Process Parameters
Temperature: 600°C
Pressure: 0.23 barg
Fluidization velocity: 0.053 m/s

Feedstock and Materials
Gas Feed: (mol%): 41.9% H2, 10.0% CO, 32.4% CO2, 10.5% CH4, 4.4% C2H4, 0.9% N2
Liquid Feed: glycerol 5% of gas feed
Steam R value: 2.0
Materials: 102 g CaO sorbent + 15.4 g Commercial Catalyst

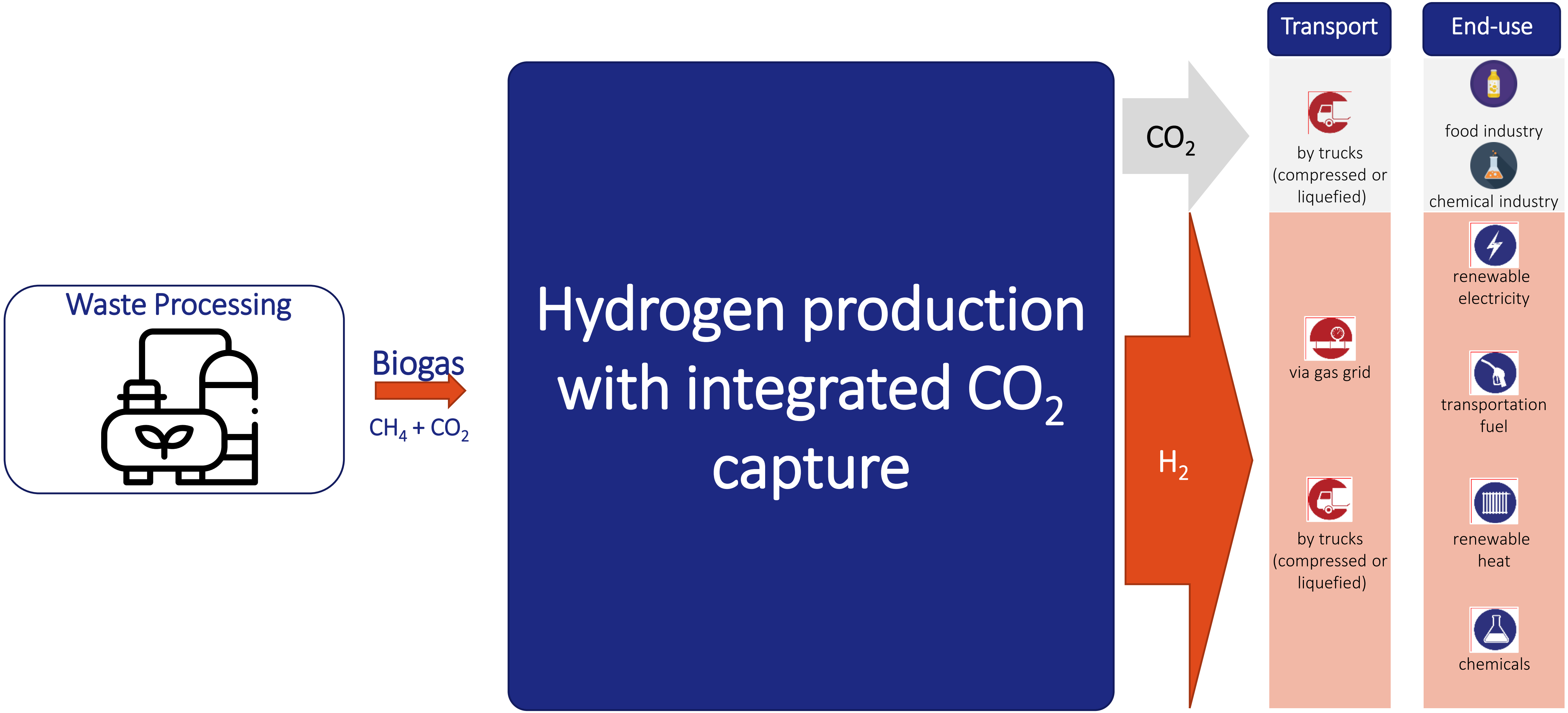


Next Steps
SER – EHC 500h demonstration at the IFE-HyNor Hydrogen Technology Center, Norway

Beyond CONVERGE

Bio4Fuels - Green Hydrogen from Biogas

Sorption Enhanced Reforming - SER

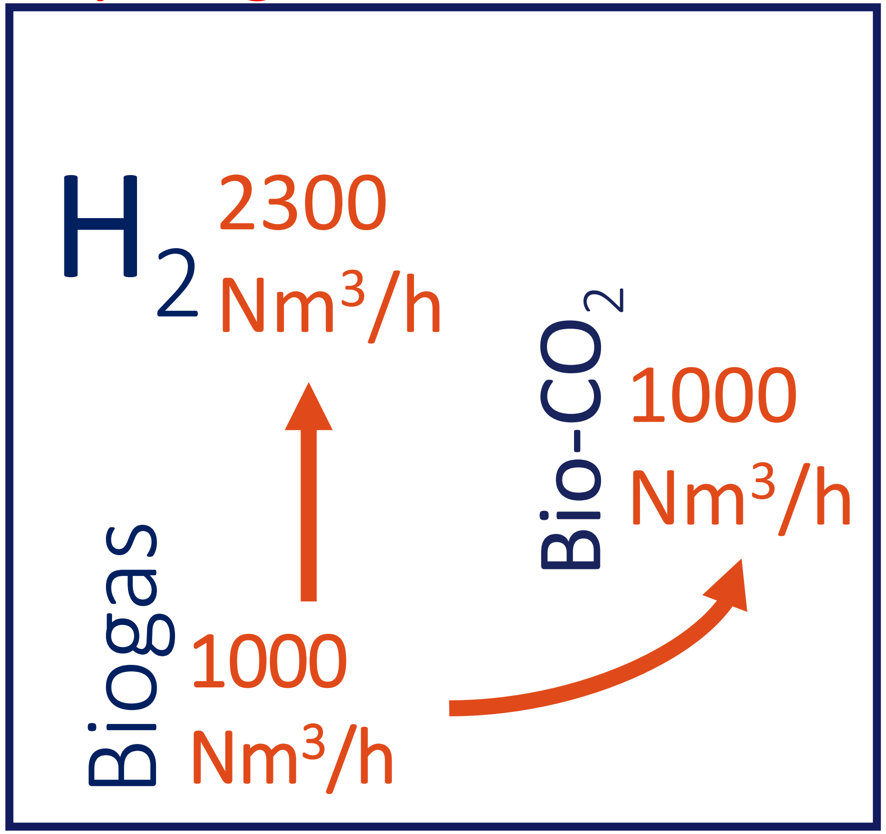


Biogas Upgrading - SER in Numbers

Conversion Efficiency

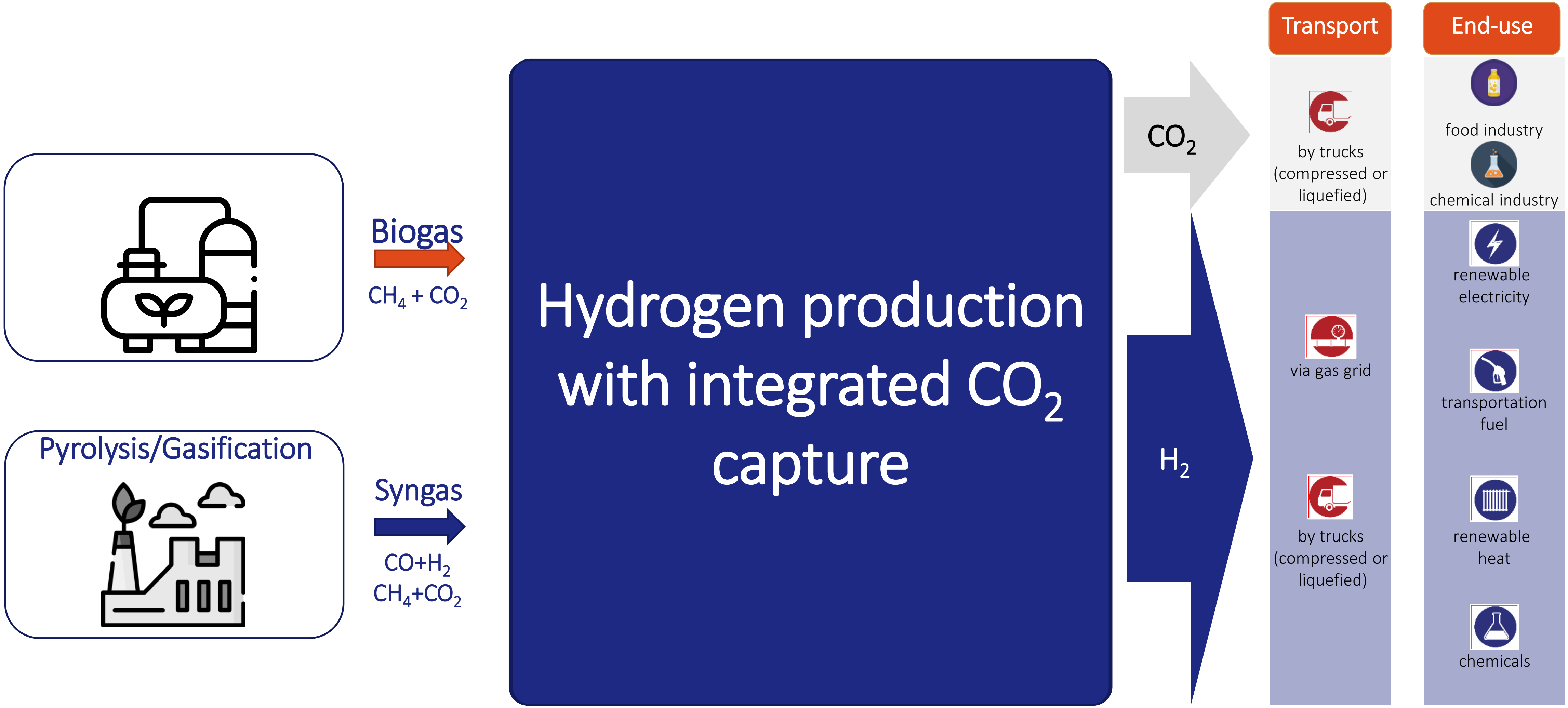
- H_2 yields (>98%) - for CH_4/CO_2 ratios varying between 1 and 2.33.
- CO_2 is over 98% pure.

Hydrogen Production



Green Hydrogen from Syngas and Biogas

Sorption Enhanced Water Gas Shift - SEWGS



Concluding Remarks

The Sorption-Enhanced Reforming/Shift technology (SER/SEWGS) allows to combine the reforming, shift and CO_2 separation in two reactor vessels only providing the following advantages:

- A simpler and intensified process with fewer reactors, leading to a potentially more compact system
- Fewer costly consumables (no shift catalysts, no CO_2 solvent + additives)
- Improved heat integration possibilities due to CO_2 removal at high temperature
- Separated H_2 (>95 vol%) and CO_2 (> 95 vol%) streams that can be recombined for different fuel/chemical synthesis (methanol, DME) or valorised separately for other markets.
- The excess CO_2 can be sequestrated (BECCS), used to substitute fossil CO_2 in industrial applications or as chemical, or combined with renewable H_2 to produce electro-fuels in power-to-X concepts for energy storage.
- The produced H_2 can also be used alone, as chemical or as fuel.
- Can reform liquid such as glycerol

- **These advantages result in CAPEX reduction of about 20-30% compared to conventional commercially available technologies.**

The CONVERGE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 818135

Website: www.converge-h2020.eu
Researchgate: **CONVERGE: CarbON Valorisation in Energy-efficient Green fuels**
Linkedin: **showcase/converge-horizon2020**

Antonio Oliveira
Researcher
antonio.oliveira@ife.no