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Impact of **steam injection** and **air enrichment** on **two-stage downdraft** wood gasification

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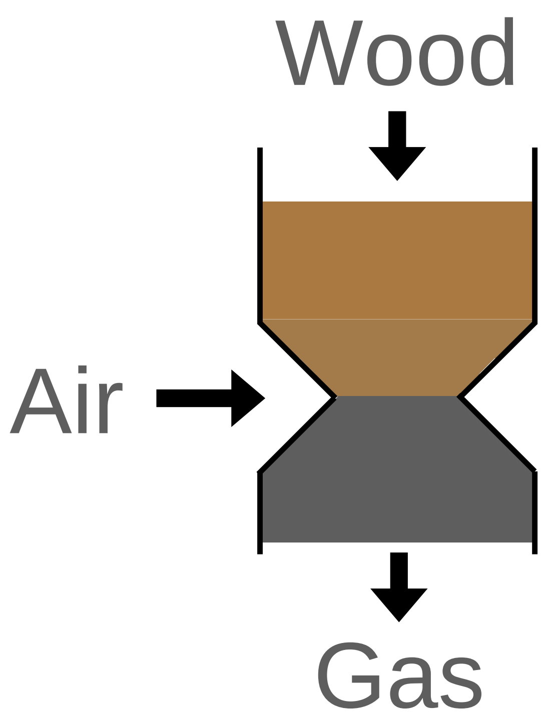
Vienna, Austria

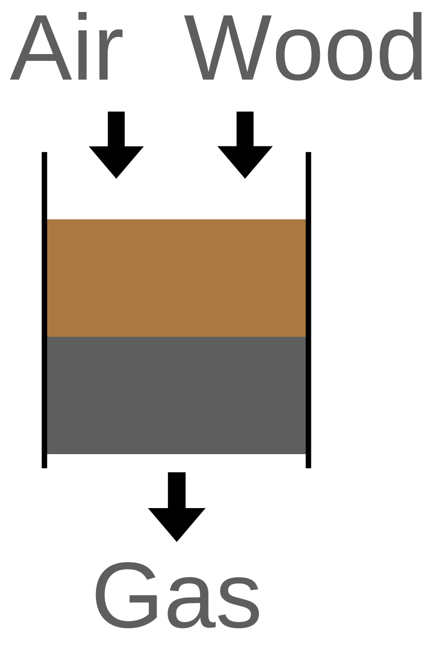
Two-stage downdraft gasification

Applied to CHP and small industrial processes

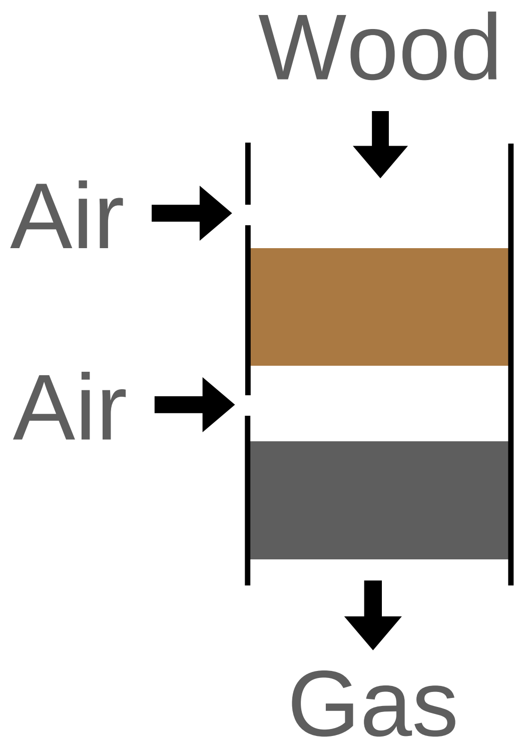
- **Woody biomass gasification**
  - **Fixed bed**
    - **Downdraft <2 MW**
      - Throated



      - Open-top

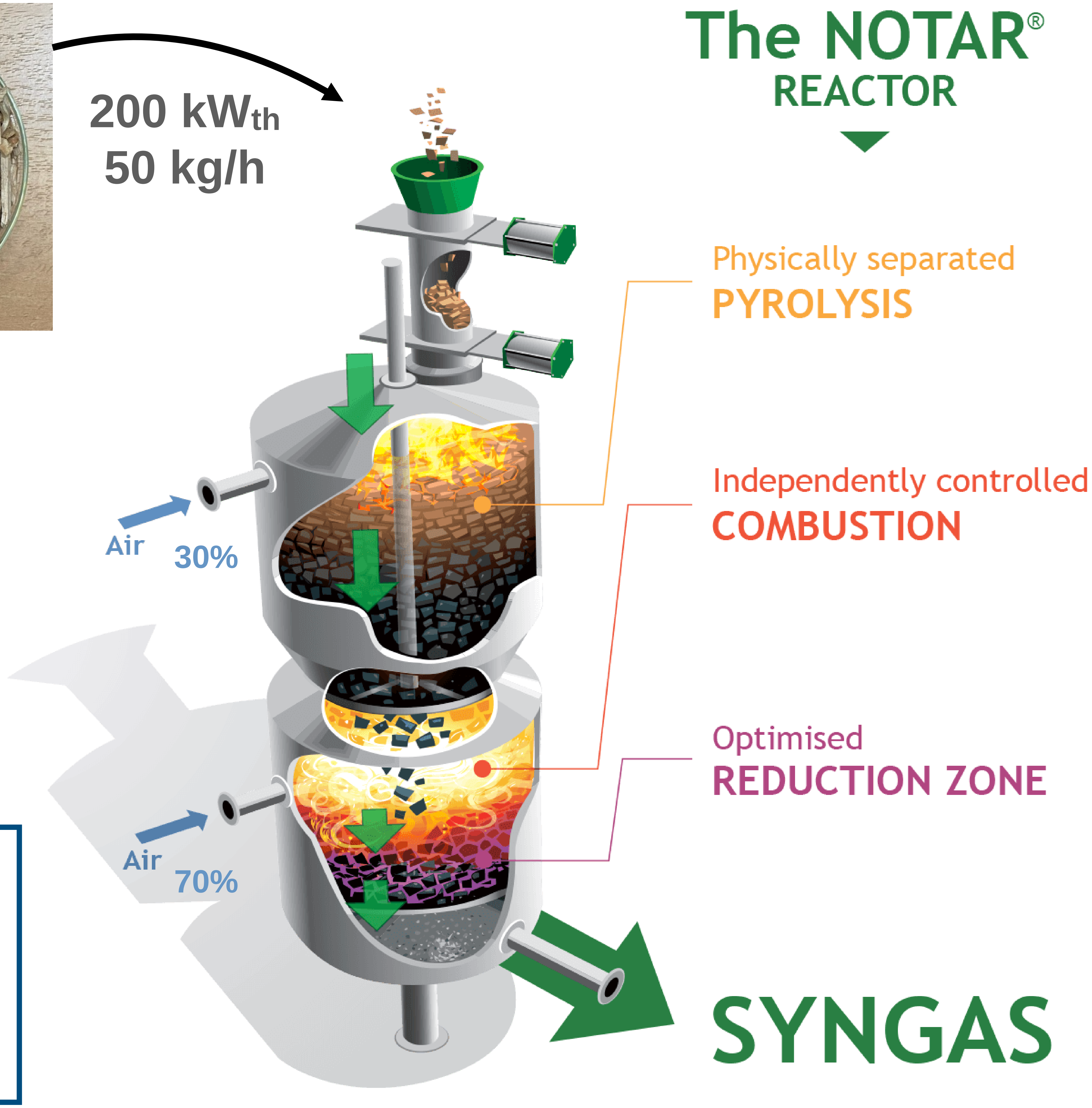


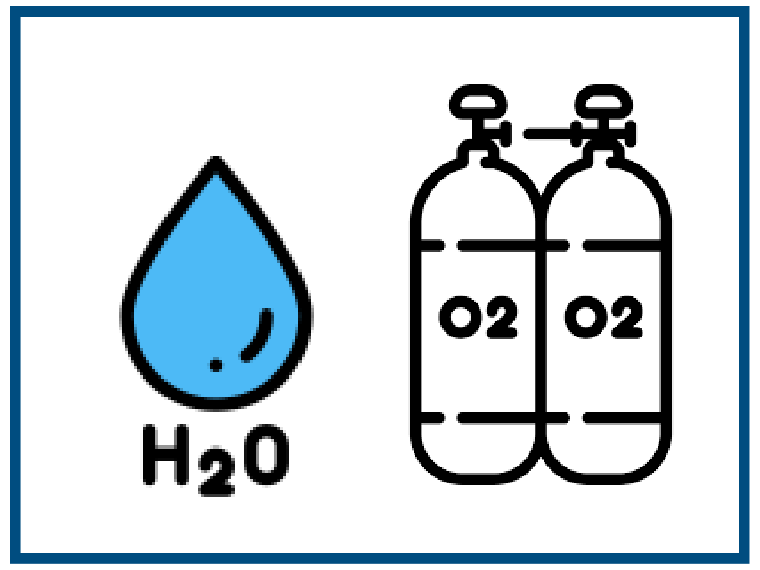
      - **Two-stage**

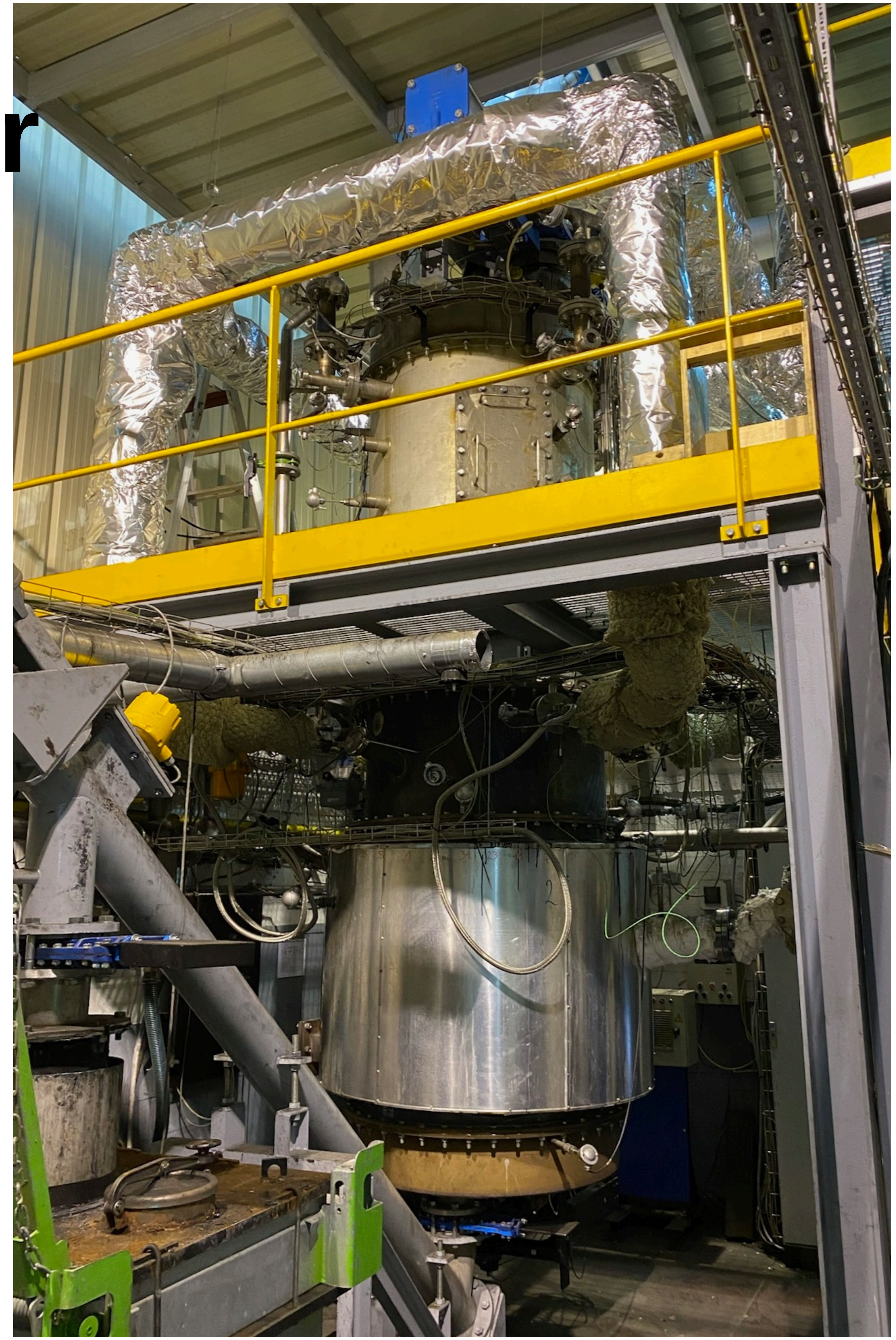


    - Updraft <10 MW
  - Fluidized bed <100 MW
  - Entrained flow <1000 MW

Two-stage downdraft gasifier

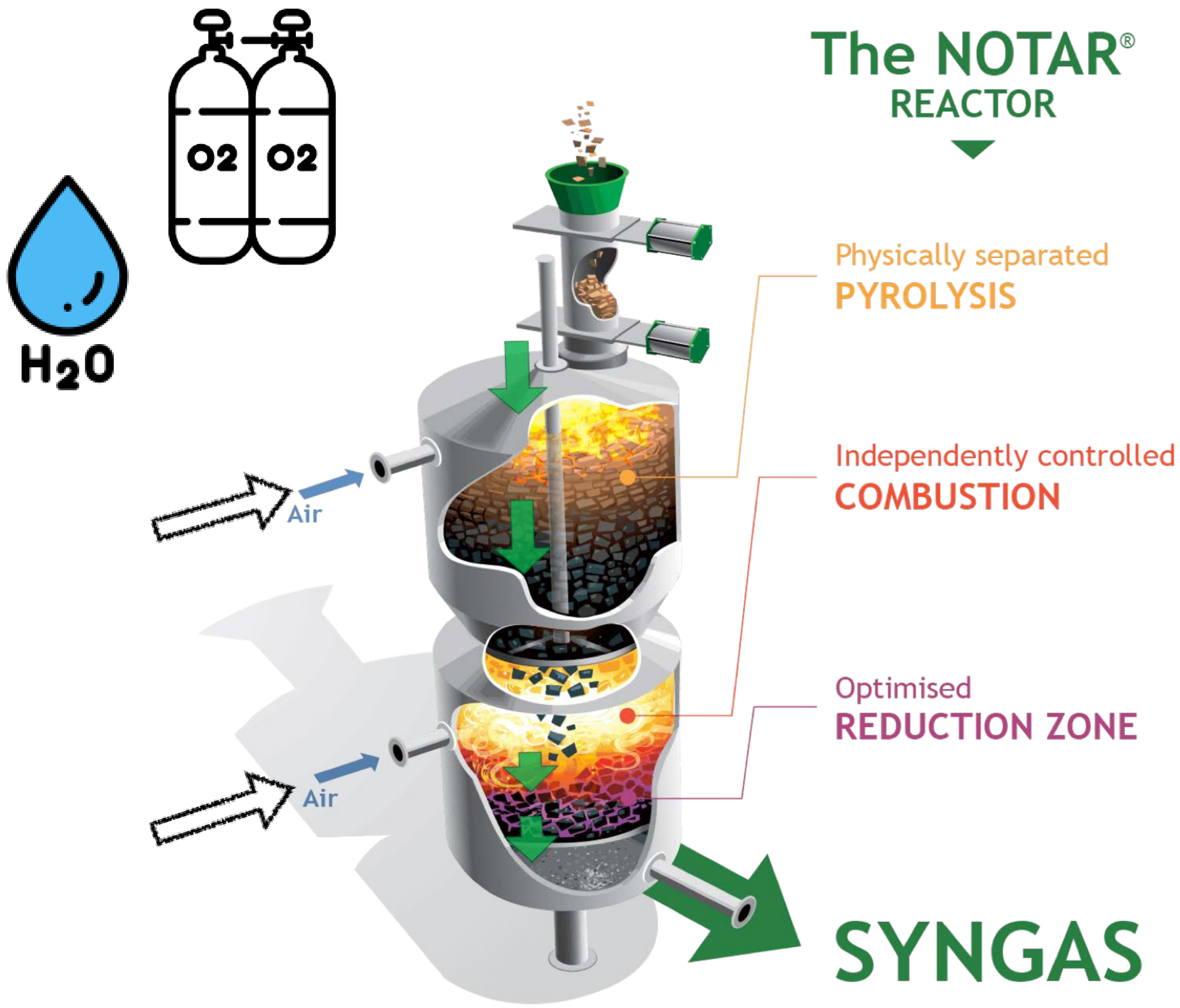






Research objectives

Enhance two-stage downdraft gasification with steam and O_2



- Improve syngas quality as a fuel (**LHV**)
- Support process **stability** under O_2 enrichment
- Enhance **tar** reforming

Agenda

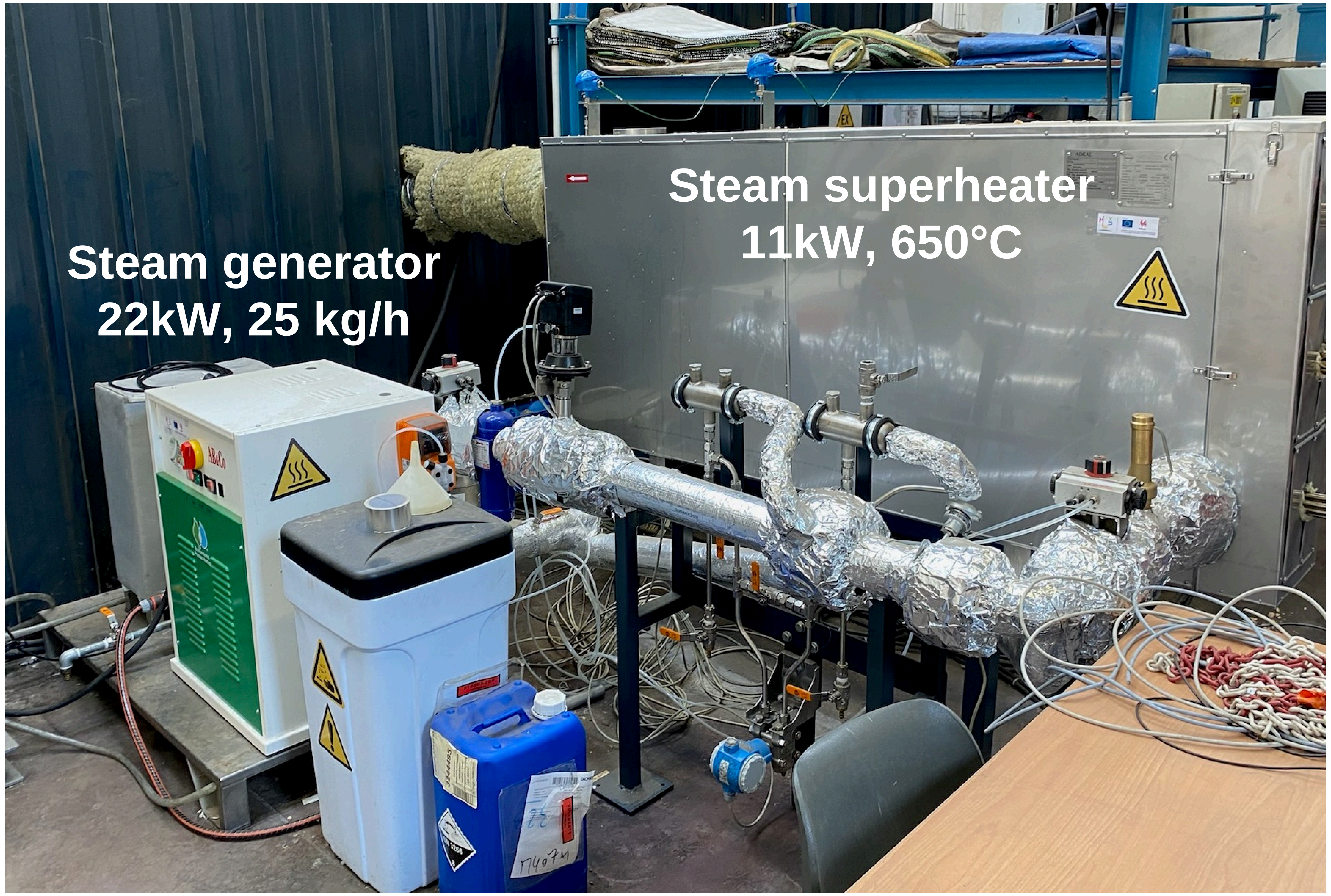
1. **Experimental set-up and conditions**
2. Air-steam gasification
3. Air-O_2 and O_2-steam gasification

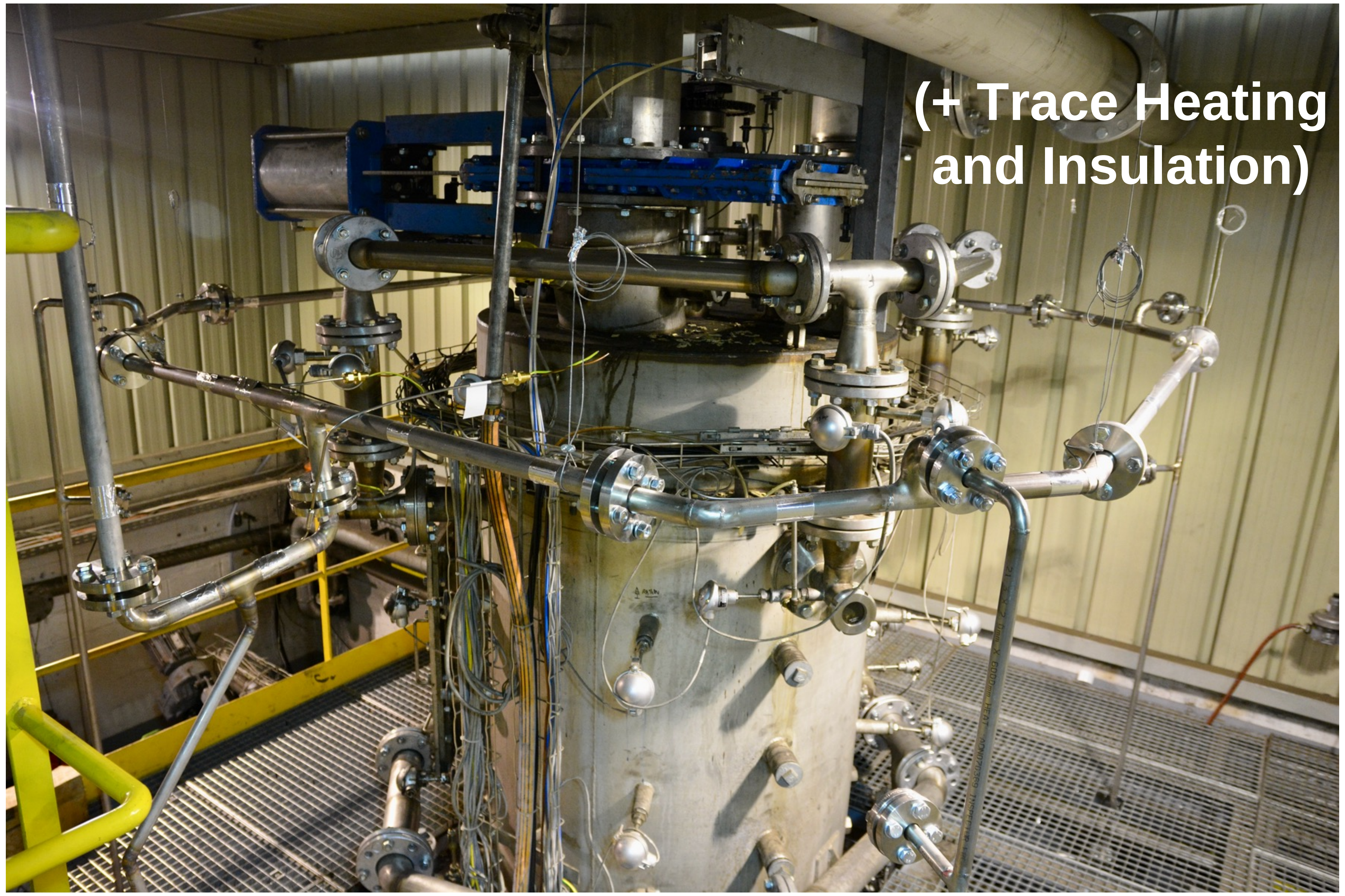

Test Gasifier Plant
Clean syngas to flare/engine
1. Gasifier
2. Ash extraction
3. Cyclone
4. Condenser with water scrubbing for tar removal
5. Granular filters

Wood chips hopper

Oven-dry wood chips
Moisture content = 8.7%
LHV = 16.5 MJ/kg
$CH_{1.32}O_{0.65}$

Steam injection

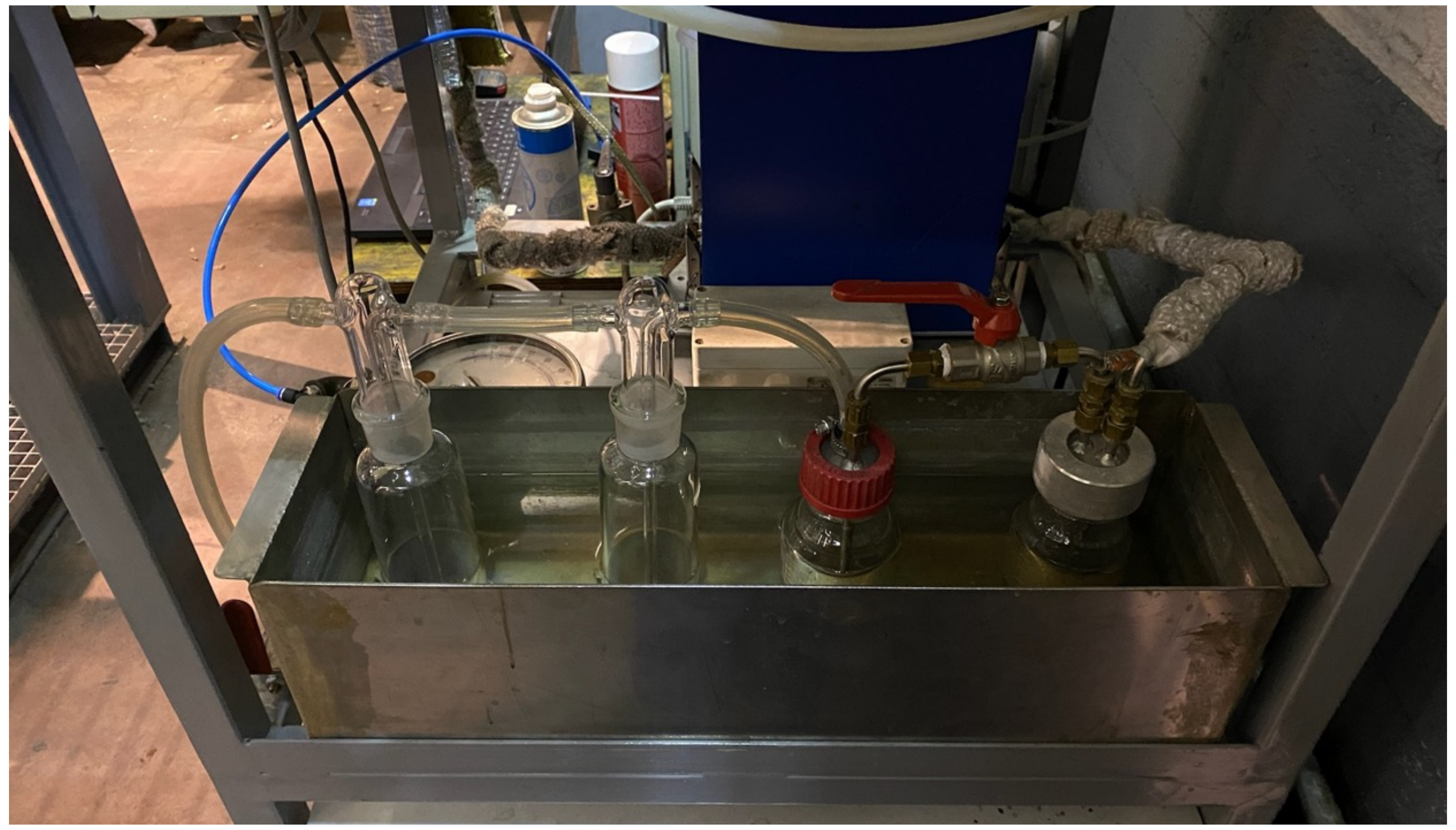




Injection with the secondary air in the oxidation zone

Oxygen generator

Tar protocol



Syngas composition analysis

Direct analyser with NDIR and TCD + on-line GC-MS/FID/TCD

CO
CO_2
CH_4

H_2

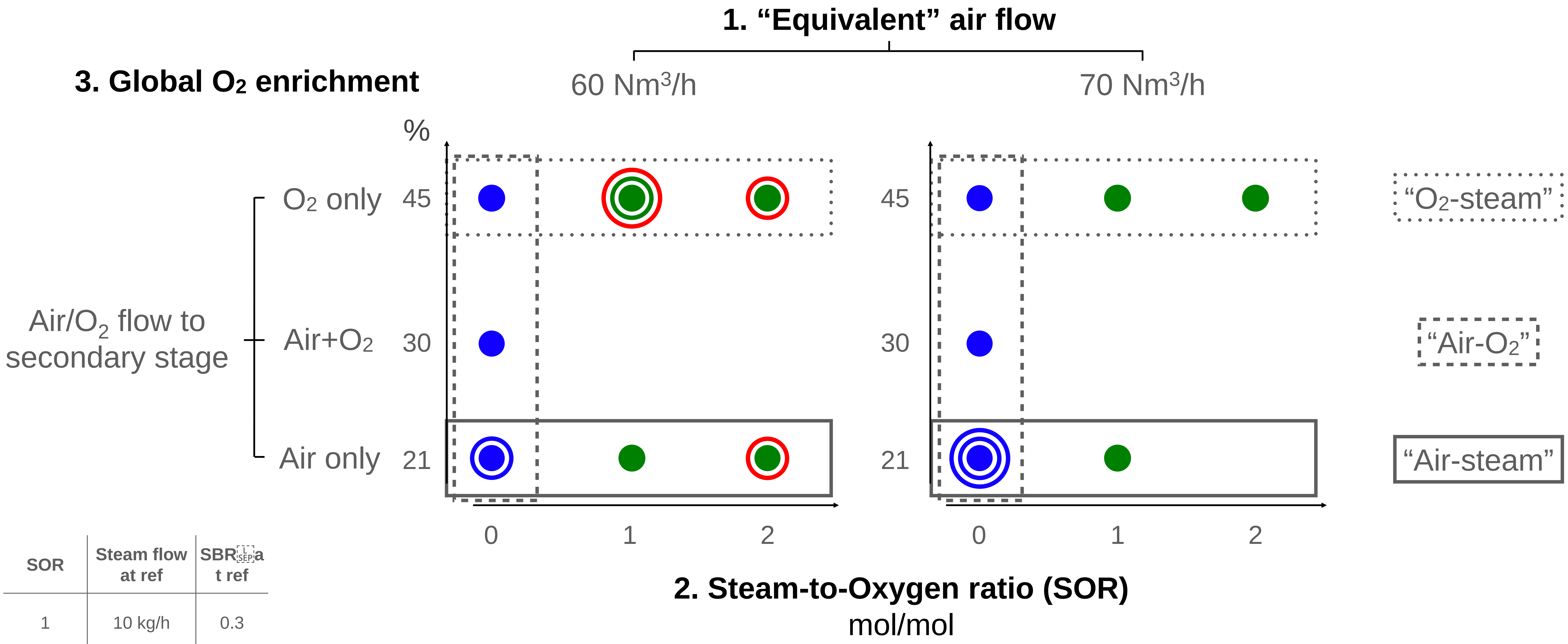
C_6H_6
C_2H_4
C_2H_6
CH_3OH
CH_3COCH_3
C_3H_6
H_2S
COS
…

N_2
CO
CO_2
CH_4

Experimental conditions

4. Steam temperature

- LT 100-150°C
- HT 250-450°C



SOR	Steam flow at ref	SBR at ref
1	10 kg/h	0.3
2	20 kg/h	0.6

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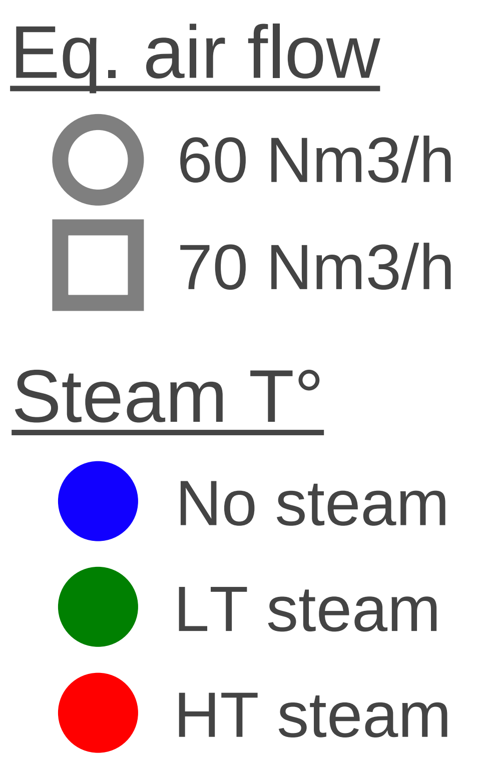
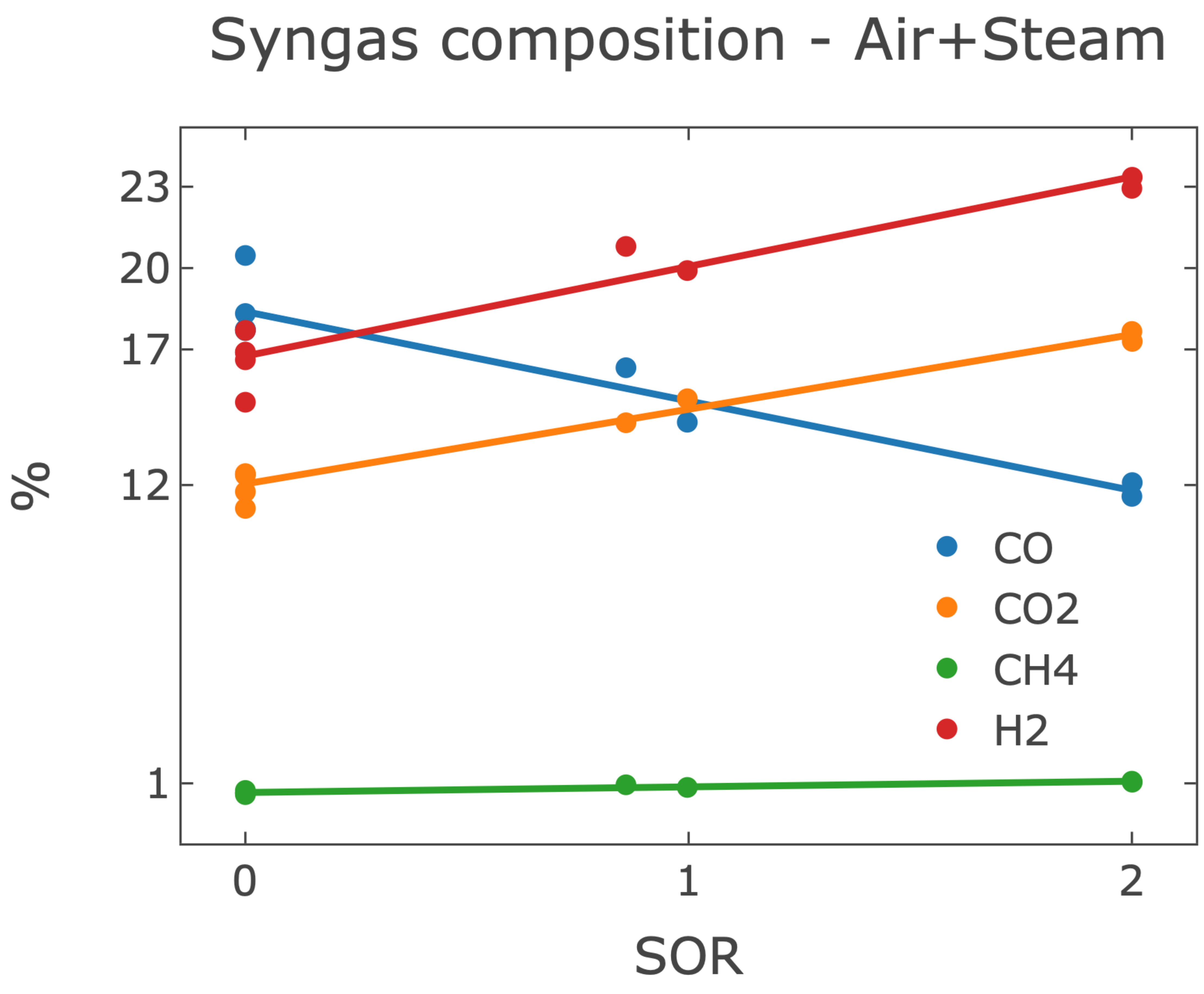
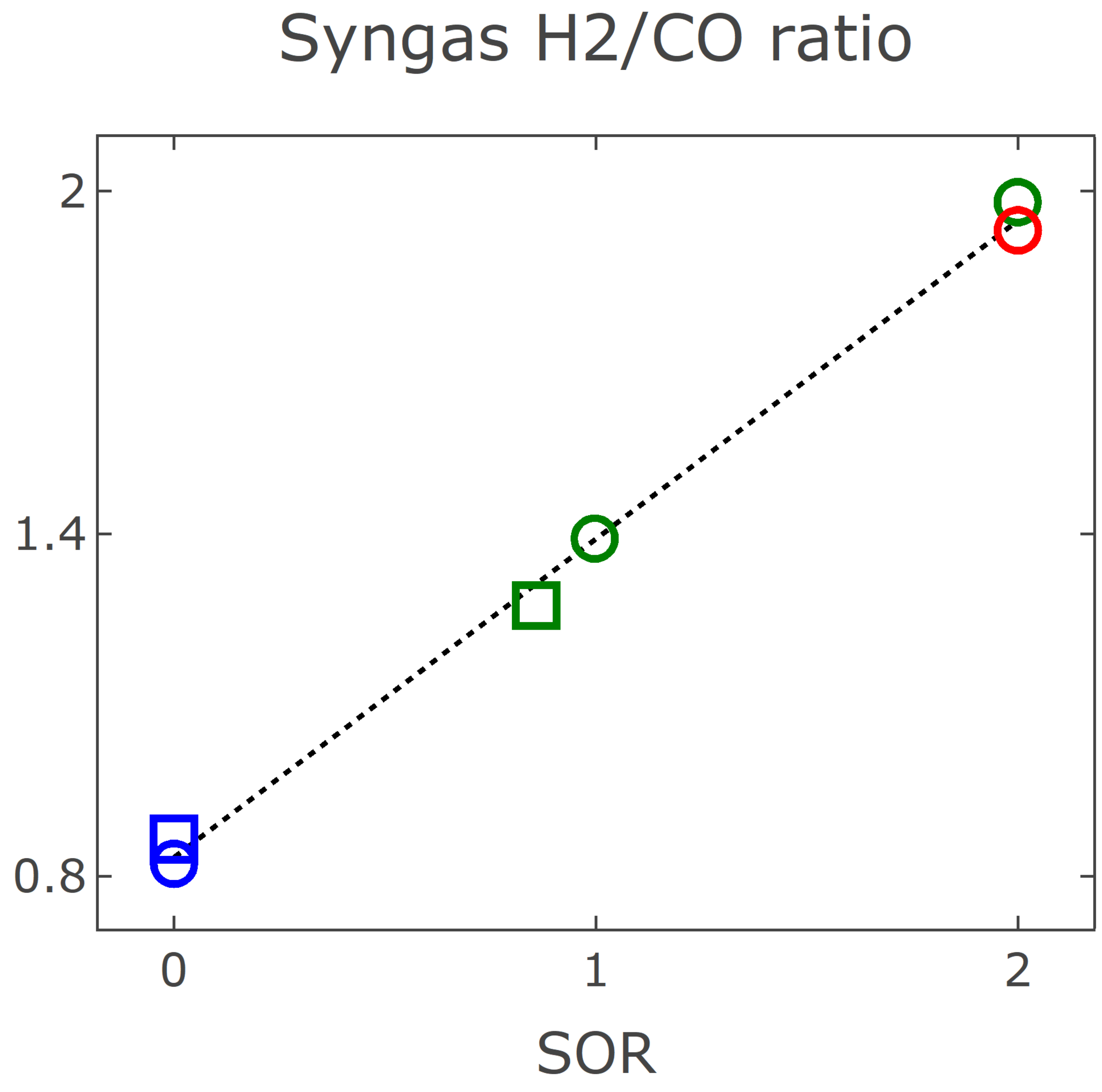
Syngas composition

Steam shifts composition from CO to H_2

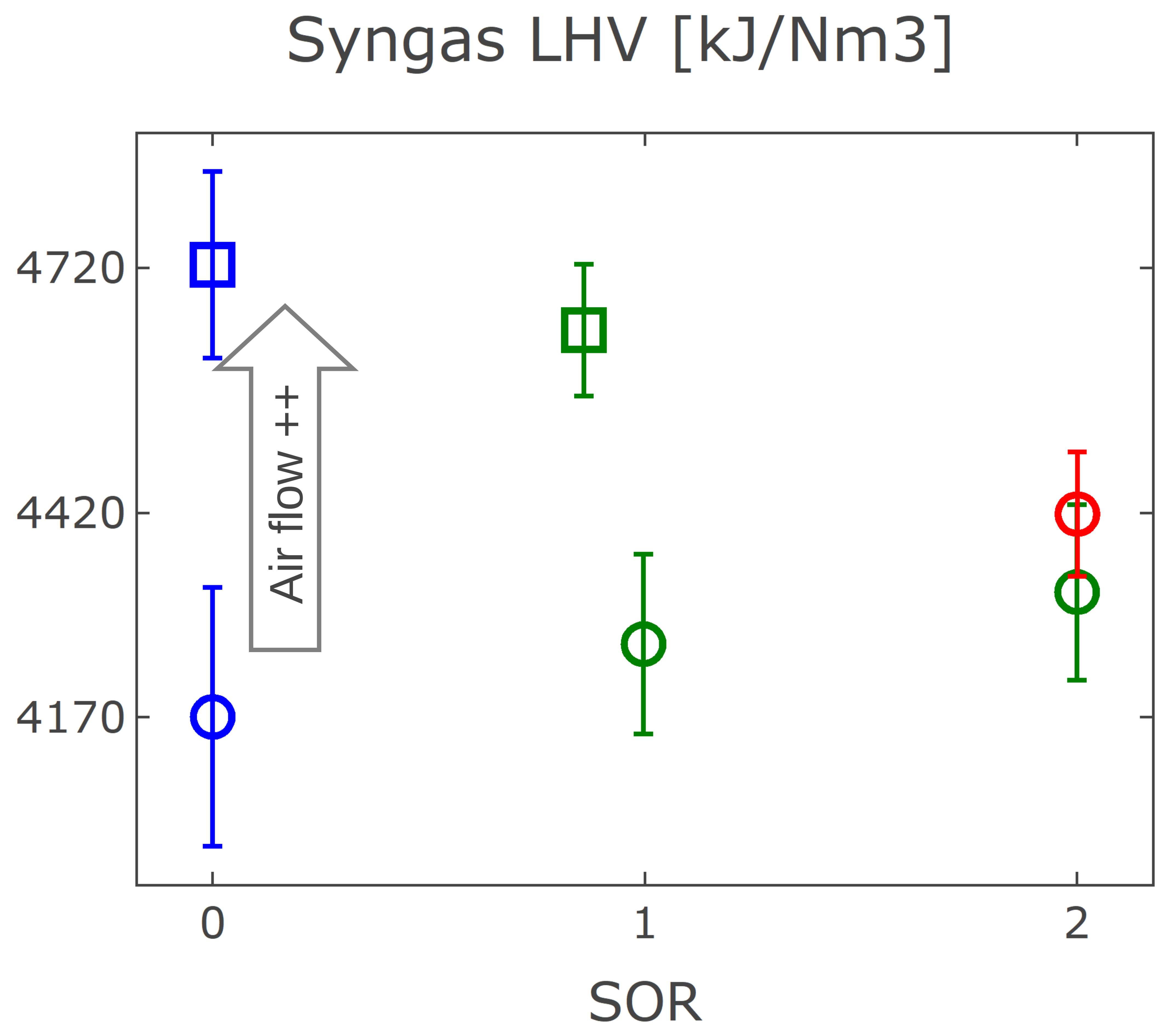


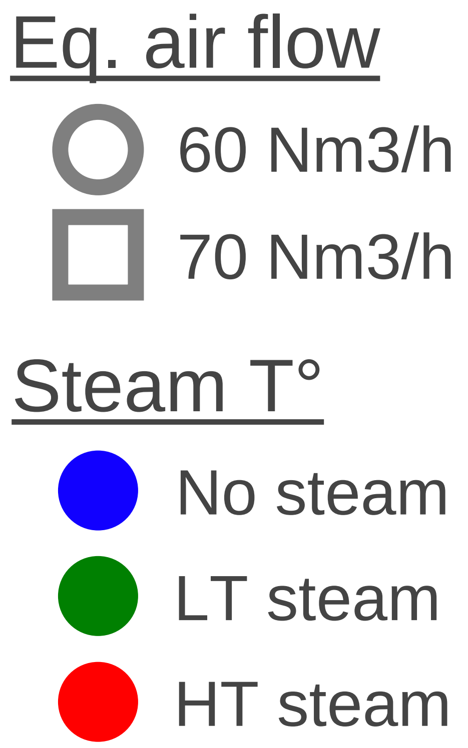




Syngas LHV

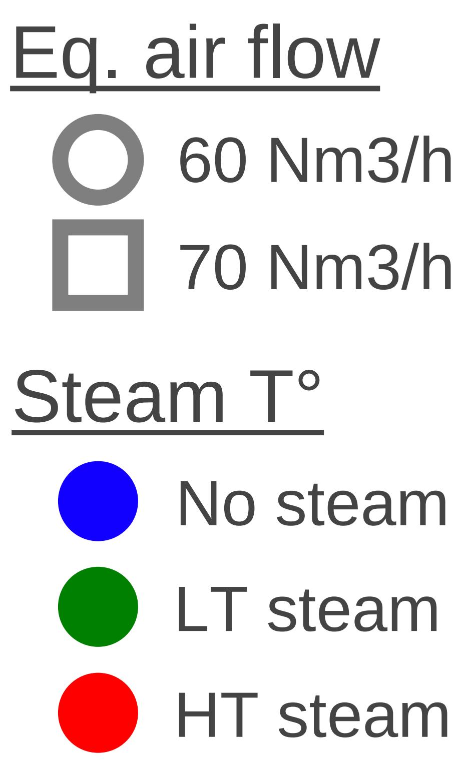
Impact of steam is limited, compared to increased air flow

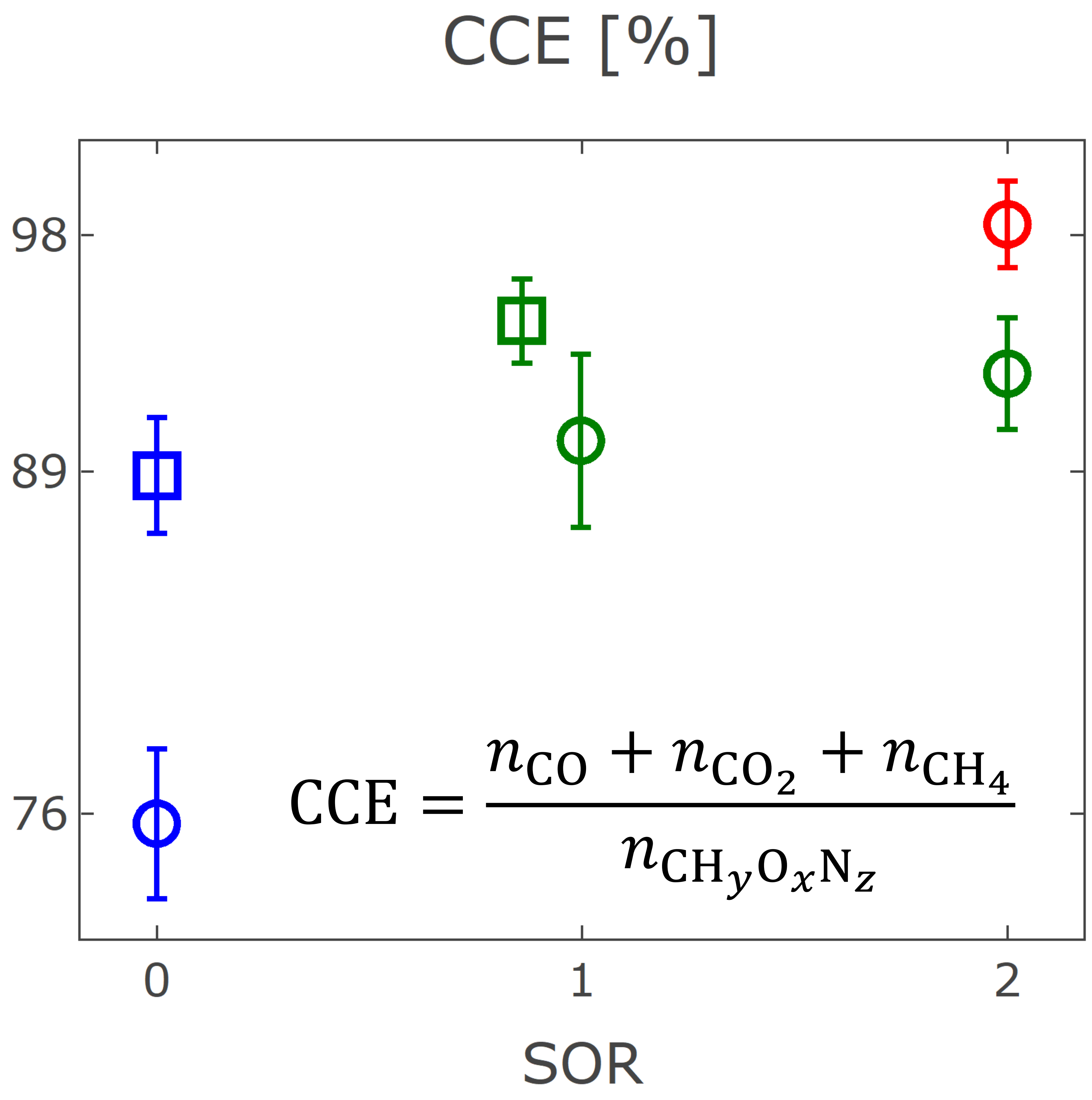


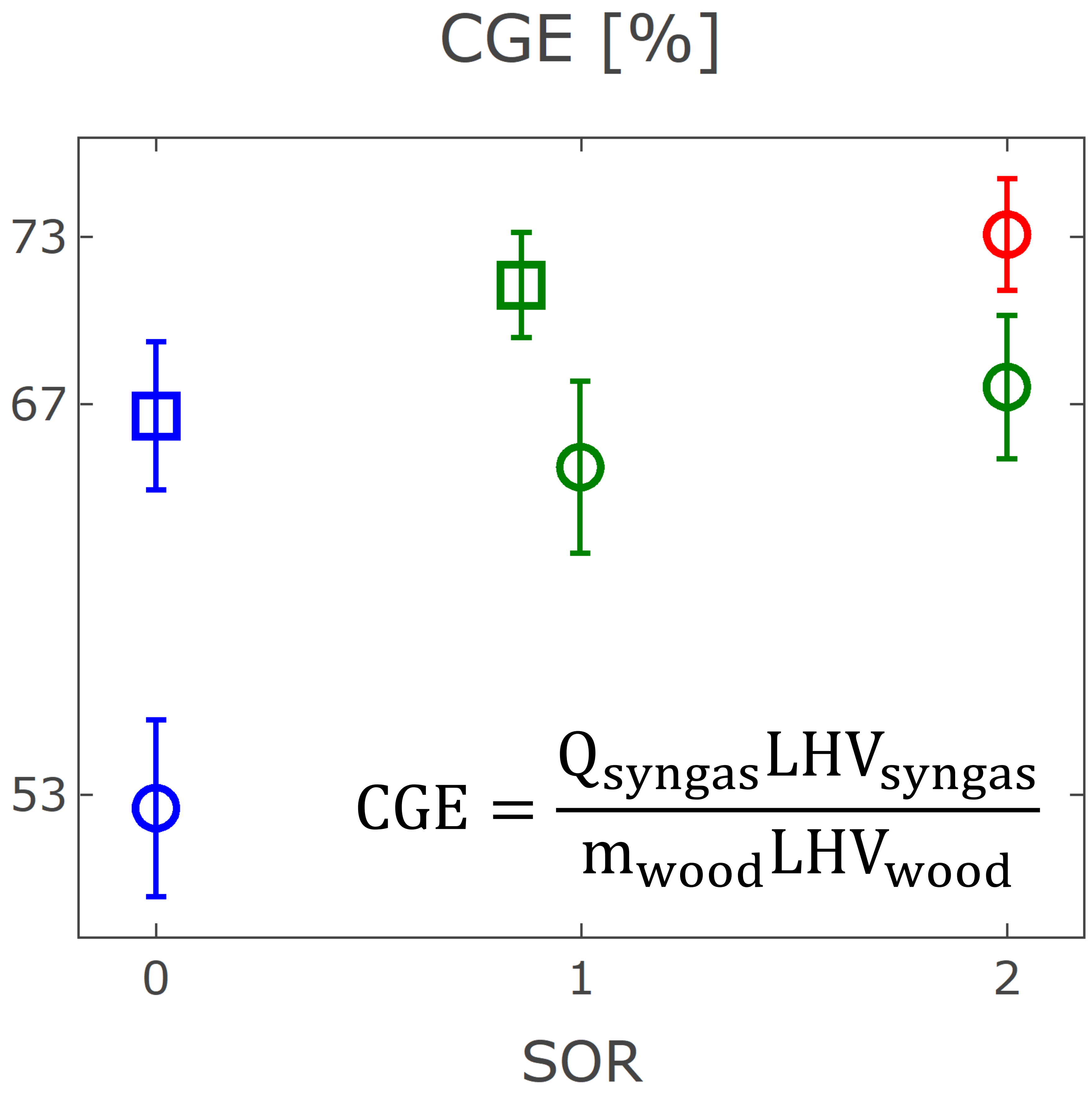


Gasification efficiency

Steam enhances carbon conversion and cold gas efficiency

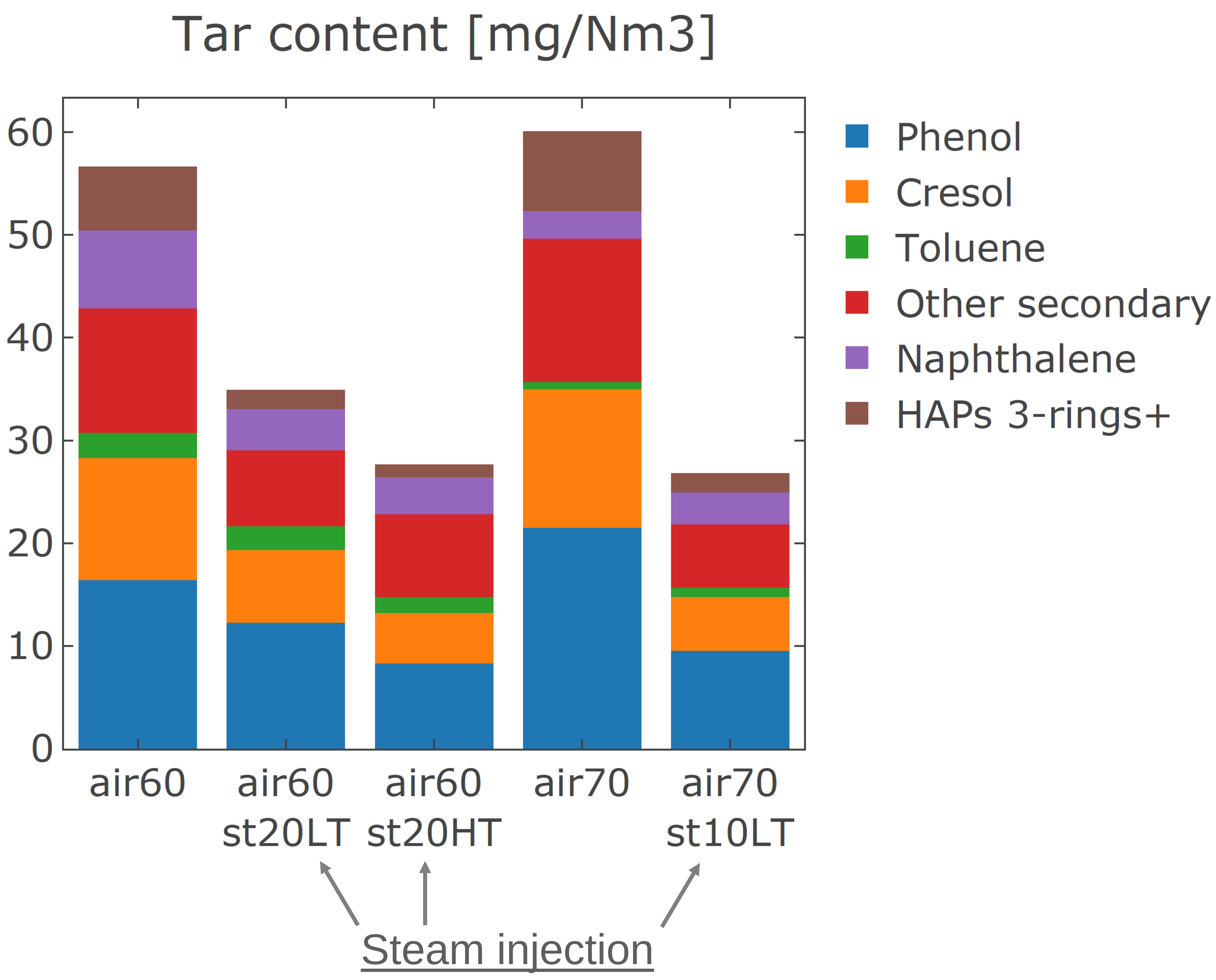


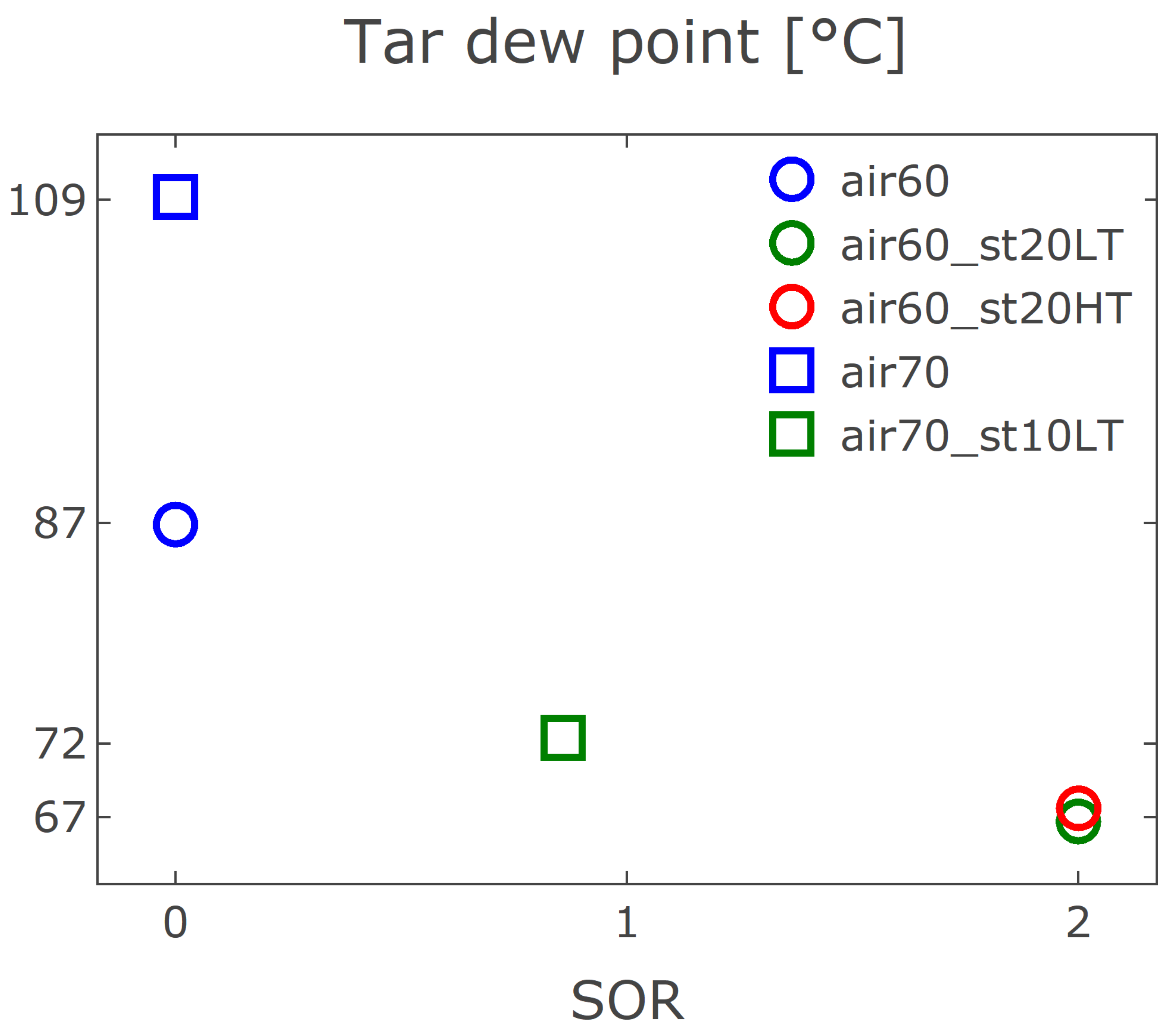




Tar composition and dew point

Improved conversion of secondary and tertiary tar into benzene





Agenda

1. Experimental set-up and conditions

2. Air-steam gasification

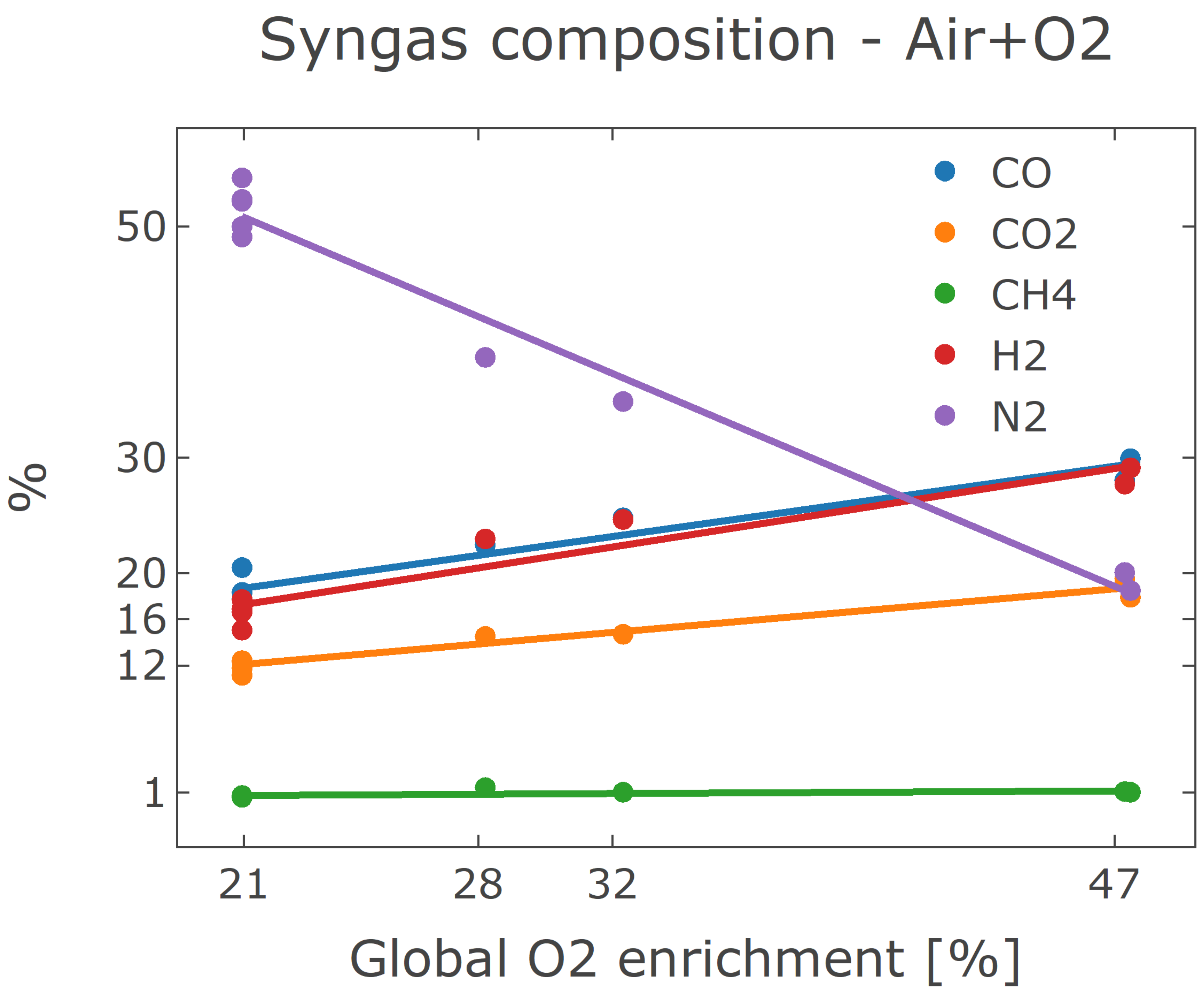
3. **Air-O_2 and O_2-steam gasification**

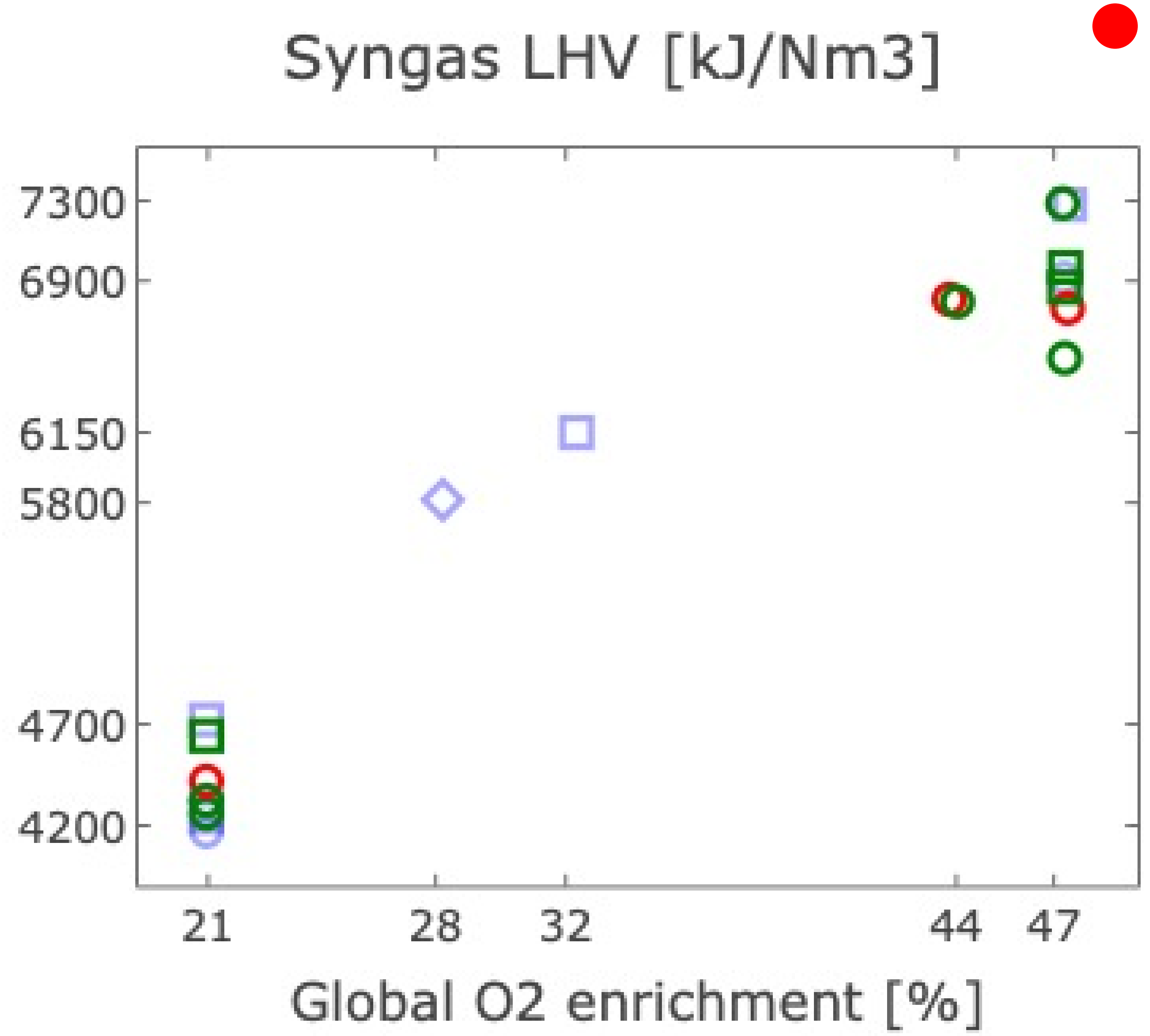
Air-O_2: Syngas composition

Removal of N_2 boosts the syngas LHV

Eq. air flow
60 Nm3/h
65 Nm3/h
70 Nm3/h

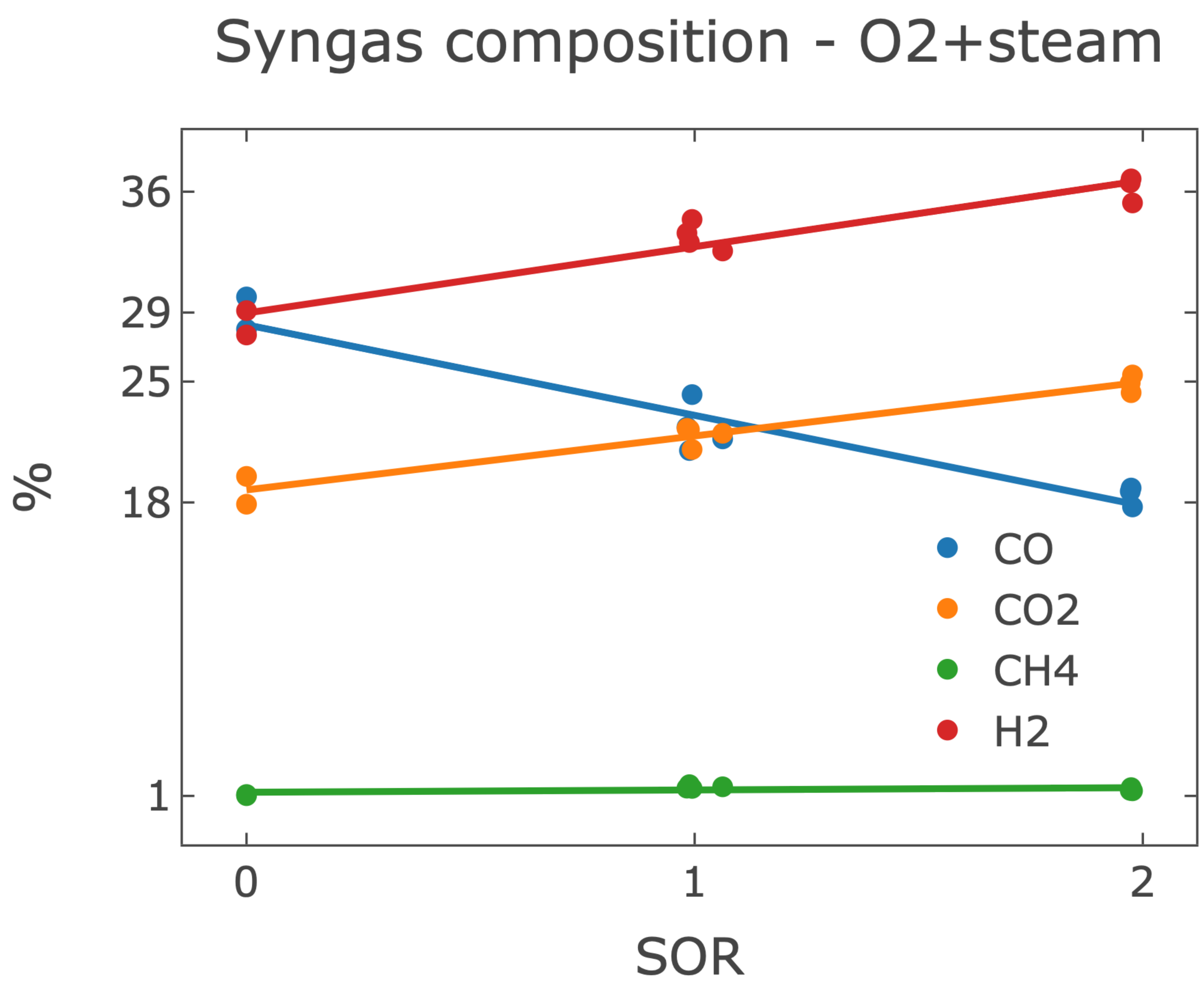
Steam T°
No steam
LT steam
HT steam

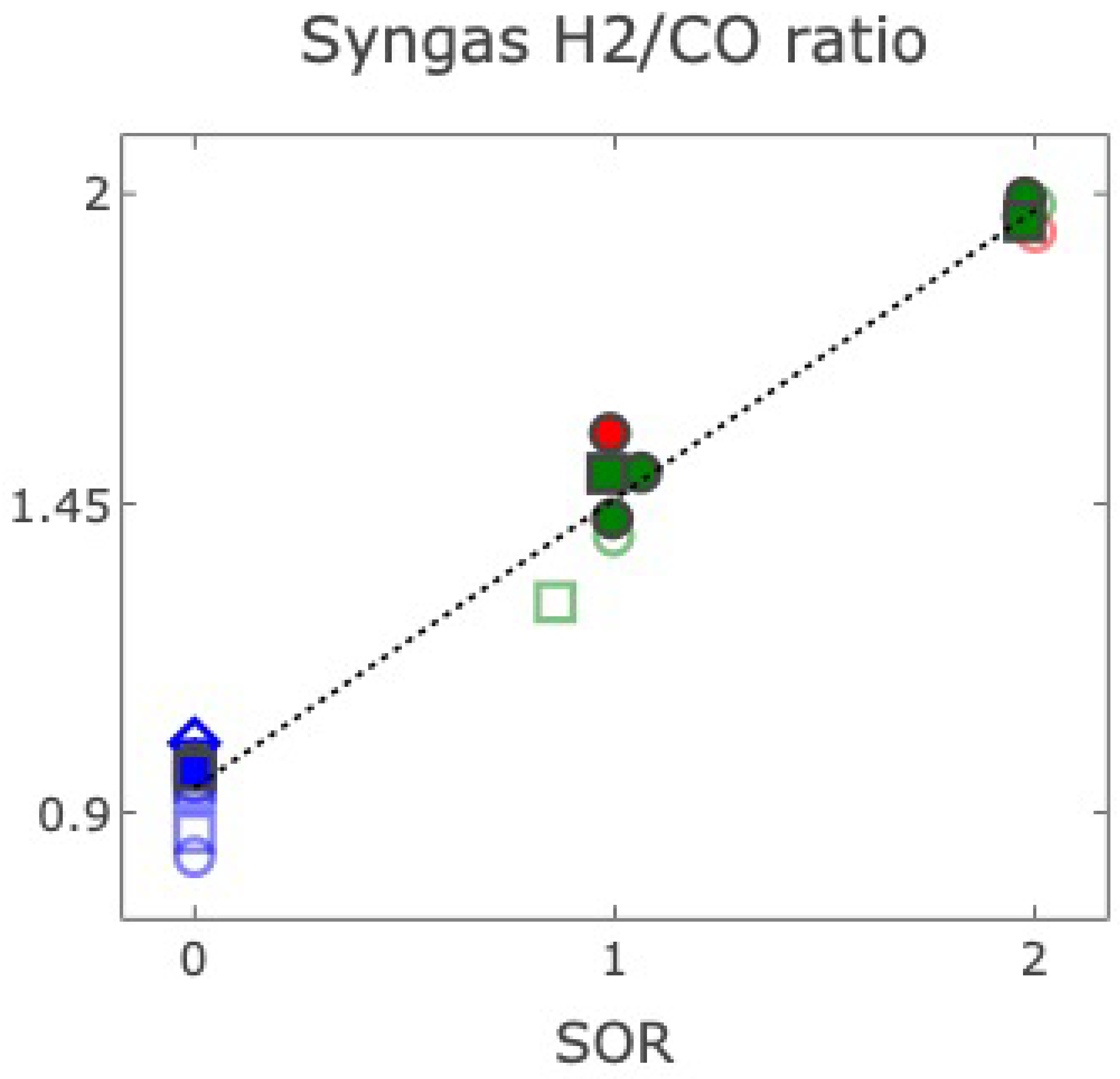




O_2-steam: Syngas composition

Steam (still) shifts composition from CO to H_2





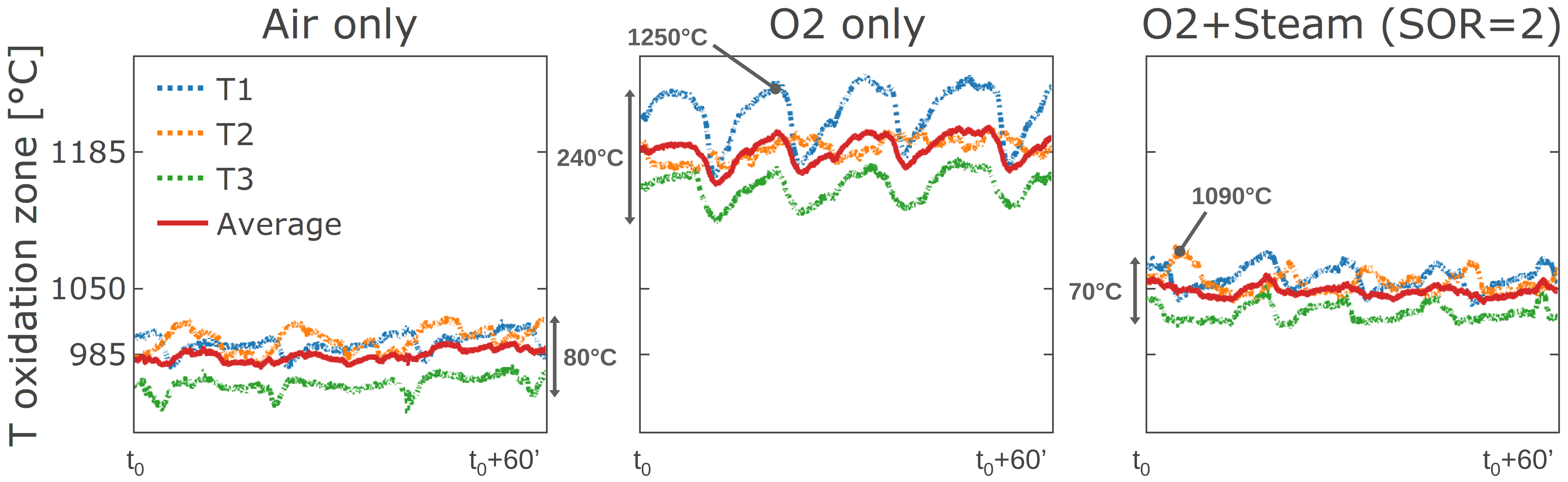
Eq. air flow
60 Nm3/h
65 Nm3/h
70 Nm3/h

Steam T°
No steam
LT steam
HT steam

Air/O_2
Air
Air+O_2
O_2

O_2-steam: Oxidation zone temperature

Steam damps temperature fluctuations from O_2 enrichment



O_2-steam: Oxidation zone temperature

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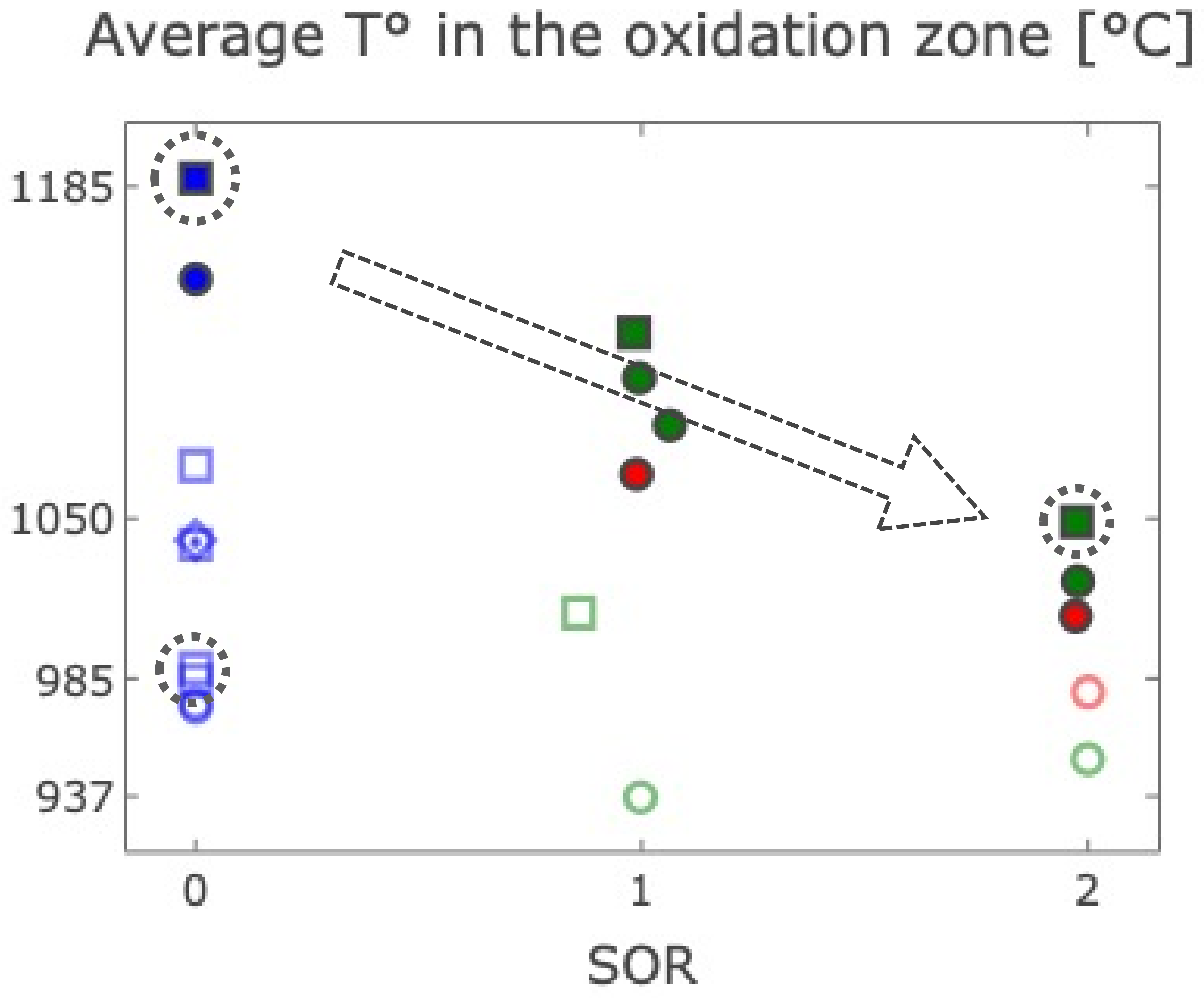
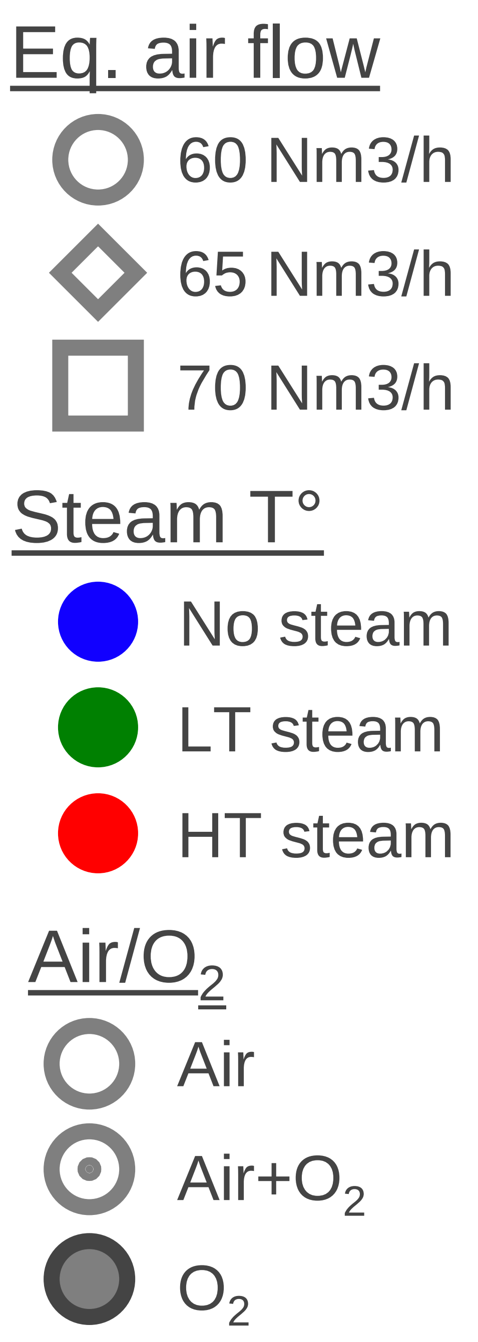
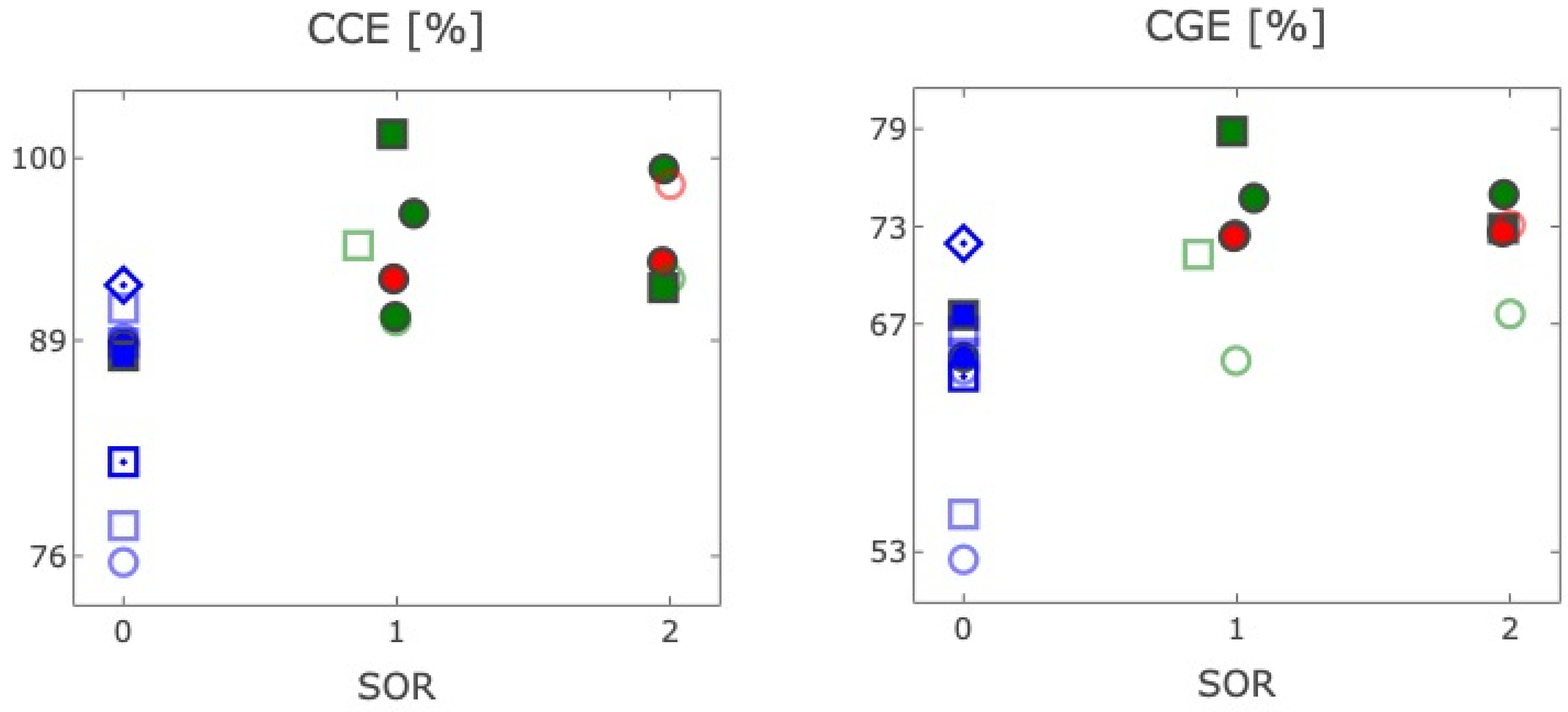
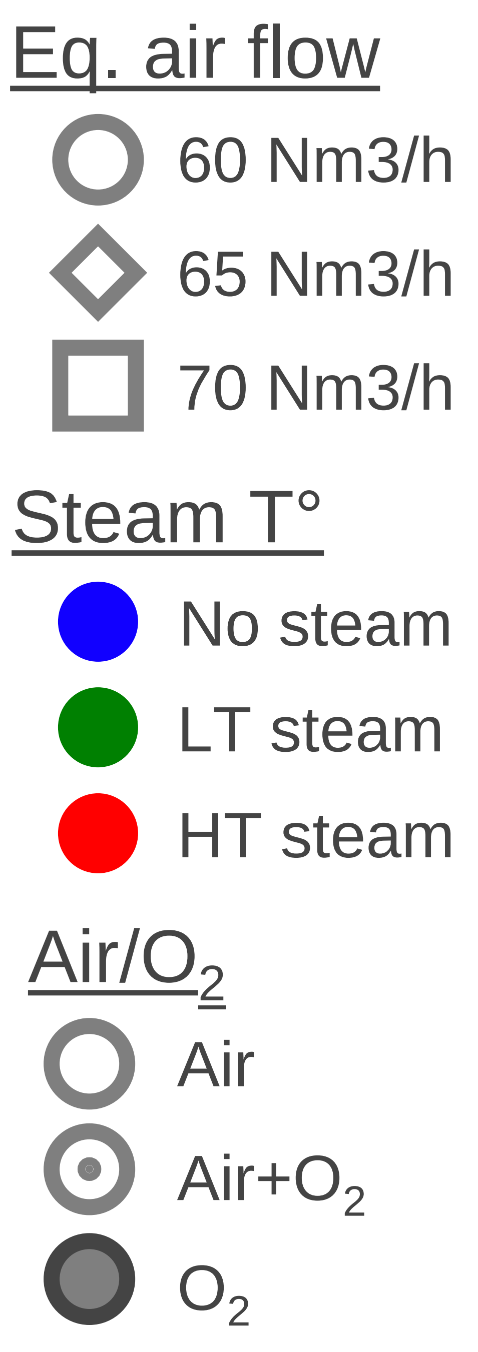




O_2-steam: Gasification efficiency

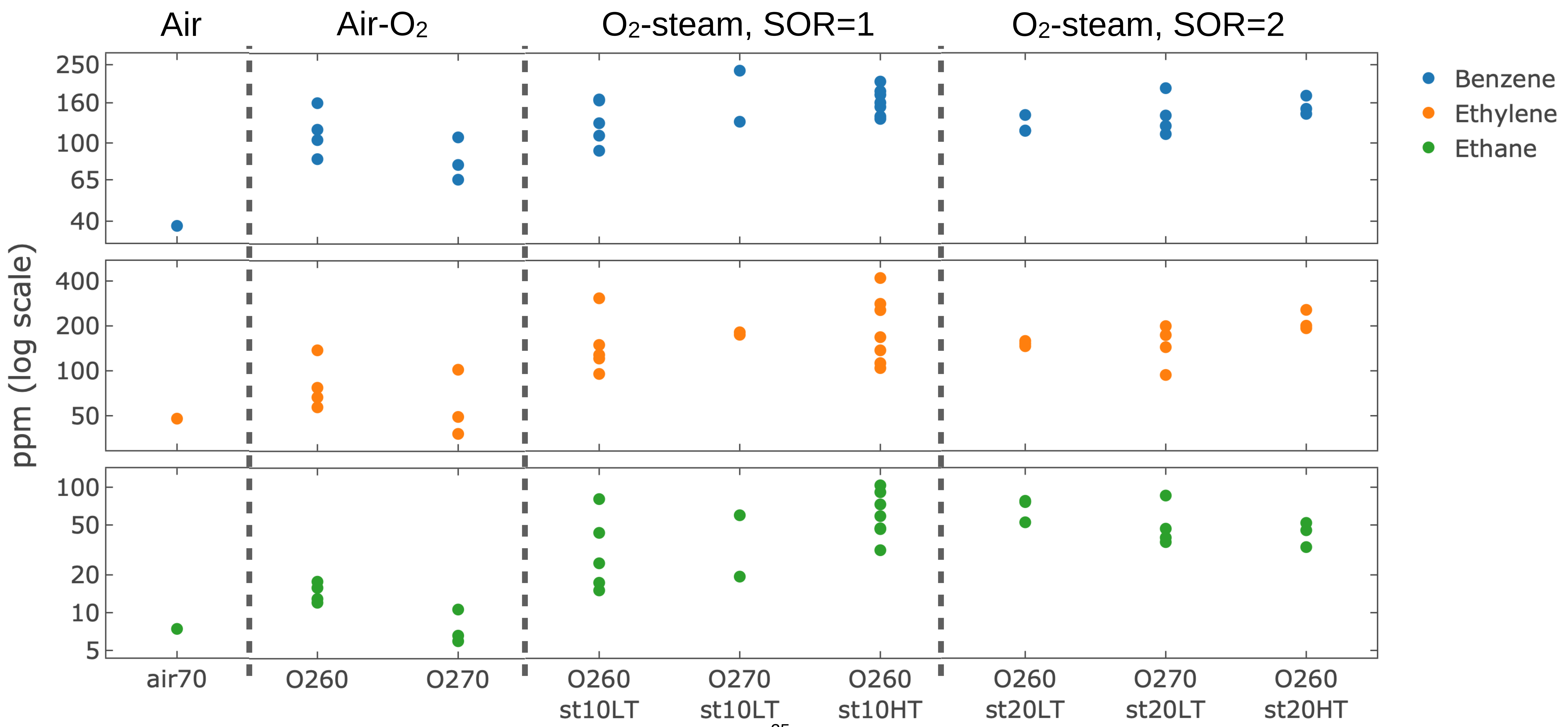
Steam (still) enhances carbon conversion efficiency





Light hydrocarbons

Steam and O_2 increase the presence of C_2 and benzene



Conclusions

- Steam "shifts" syngas composition from CO to H_2, boosting the **H_2/CO ratio**

- Oxygen use at the secondary stage yields a +60% increase of the syngas **LHV**

- Steam efficiently acts as a "**thermal damper**" in combination with O_2, at the cost of a small reduction of the syngas LHV

- Steam favors a complete **carbon conversion**, for a higher gasification efficiency. **CGE** is maximized by the combined use of steam and oxygen

- Steam supports the reforming of **secondary** and **tertiary tar** into benzene

Perspectives

Remaining work on the experimental data:

- Analysis of **tar samples** by GCMS
- Refined post-processing:

  ➞impact of **secondary factors** (*eq. air flow, steam temperature, air ratio*)

  ➞impact of **uncontrolled factors** (*gasifier pre-heating, pyrolysis zone stability*)

Future experiments:

- Injection of steam and oxygen in the **pyrolysis zone**

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