ECN System for MEthanation (ESME)

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Vienna, 4 June 2015

www.ecn.nl

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1. Introduction

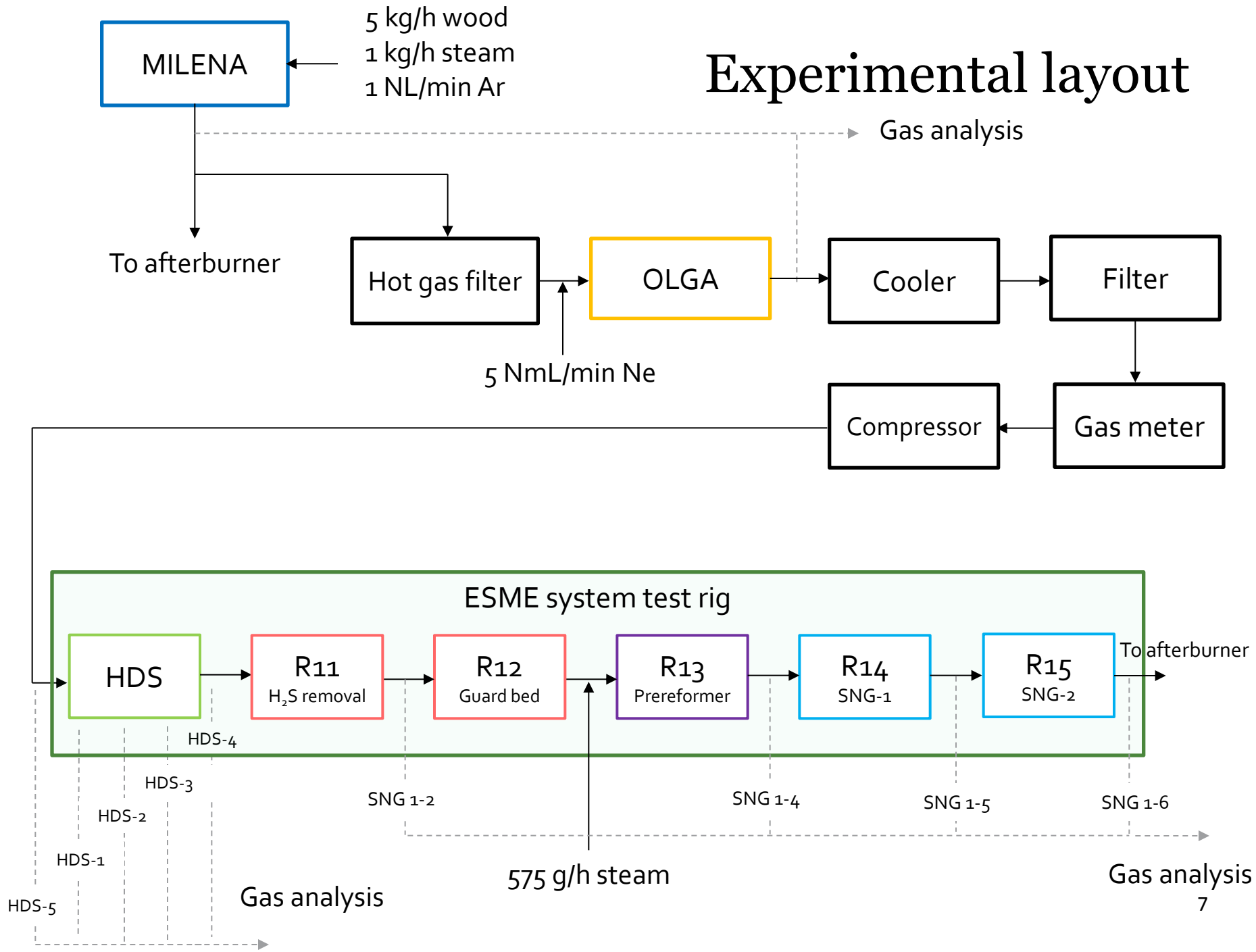
- ECN: development of technology for efficient production of SNG from biomass gasification → MILENA and OLGA.
- Patented technology for methanation of gas from biomass gasification: **E**CN **S**ystem for **ME**thanation (ESME).
- ESME designed especially for gas from BFB, CFB and allothermal gasifiers (e.g. ECN MILENA, TUV FICFB).

1. Introduction

- ESME concept: smart sequence of the different units:
  - More efficient conversion of producer gas from BG to SNG because HC (e.g. benzene) are not removed but converted → available for conversion to CH_4.
  - Prereformer: simultaneous HC reforming and methanation.
  - Reduced compression cost.
- Main parts of the system extensively tested downstream atmospheric gasification.

Contents

Experimental layout



Experimental layout

Experimental layout

MILENA

5 kg/h wood
1 kg/h steam
1 NL/min Ar

Gas analysis

OLGA

Cooler

Filter

/min Ne

Compressor

Gas meter

ystem test rig

R13
Prereformer

R14
SNG-1

R15
SNG-2

To afterburner

SNG 1-4

SNG 1-5

SNG 1-6

HDS-1

HDS-5

Gas analysis

575 g/h steam

Gas analysis

Experimental layout

Experimental layout

Experimental layout

MILENA

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R13
Prereformer

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SNG-1

R15
SNG-2

To afterburner

SNG 1-4

SNG 1-5

SNG 1-6

575 g/h steam

Gas analysis

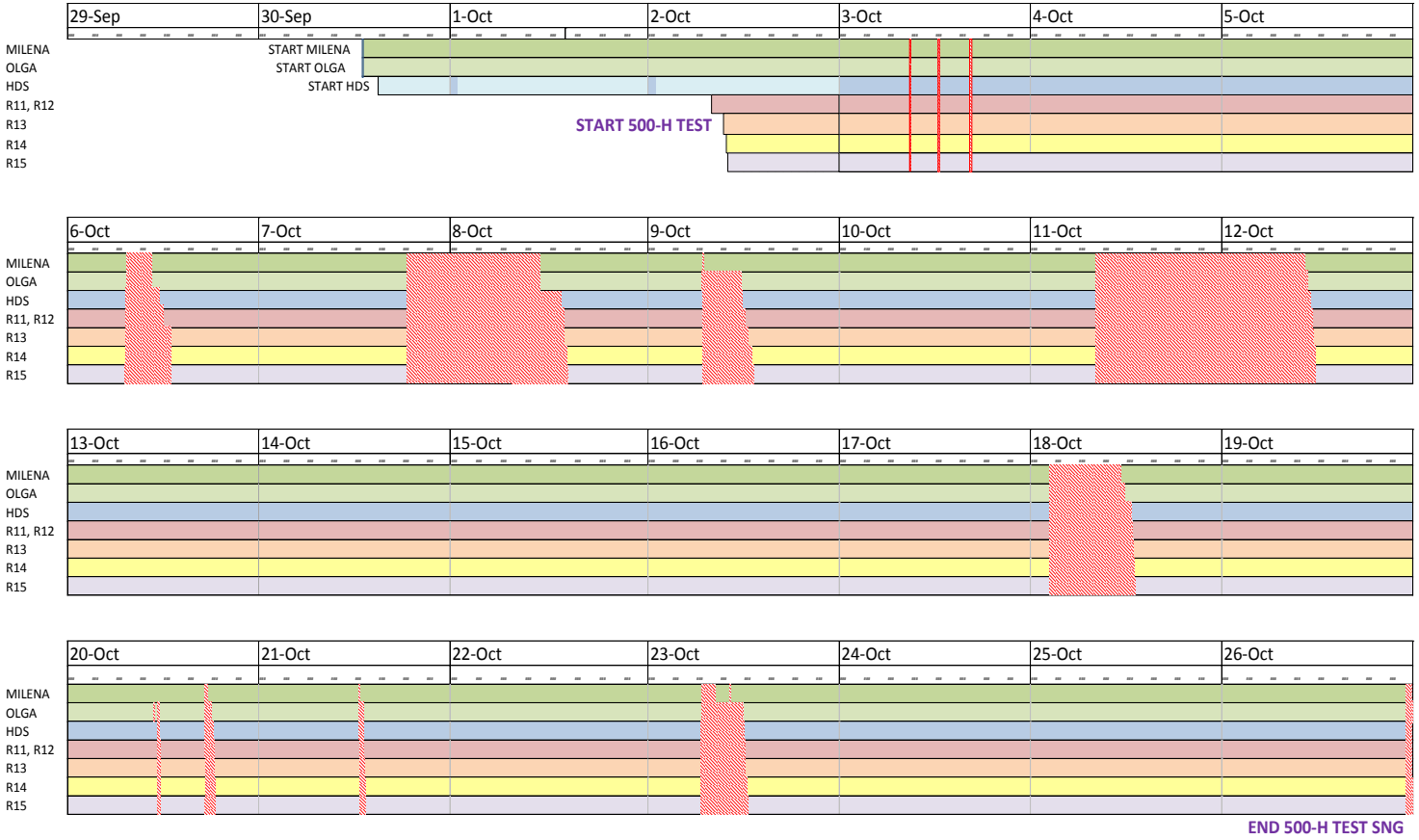
Gas analysis

HDS-5

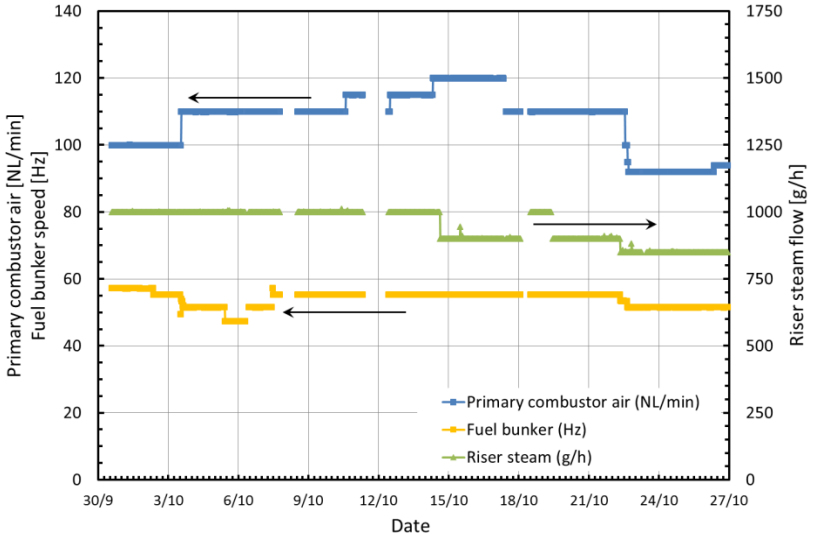
Overview 500-hour bio-SNG test

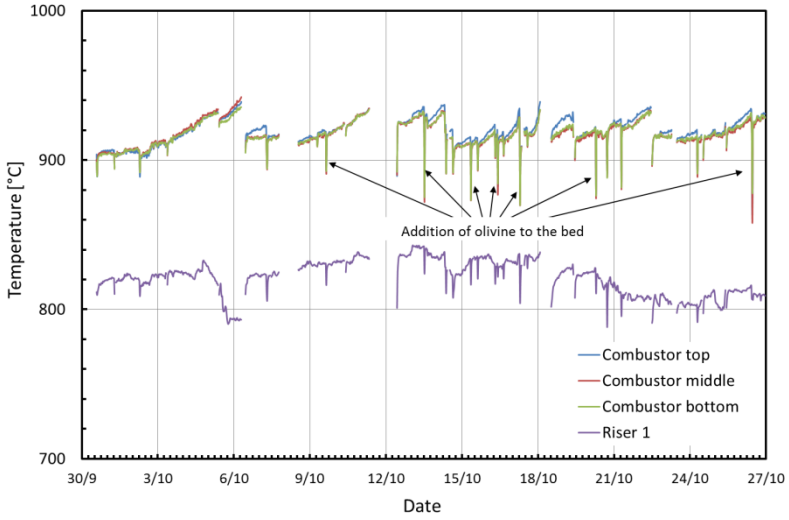
Number of operating hours			
MILENA	OLGA	HDS	SNG-2
580	570	560	**515**

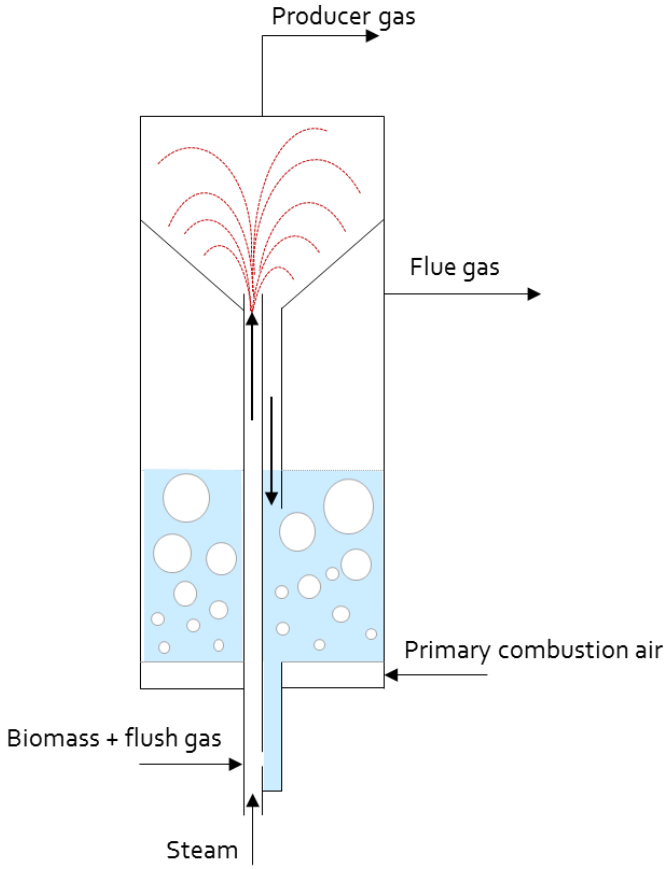
Availability
- MILENA: ~90%.
- MILENA + OLGA + ESME ~ 85%.



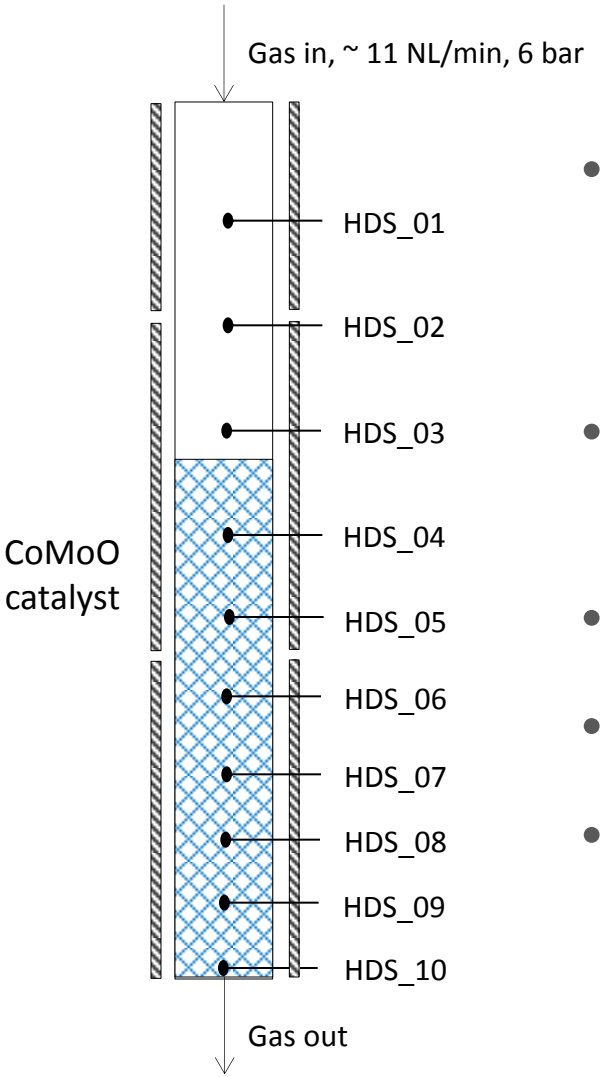
MILENA operation







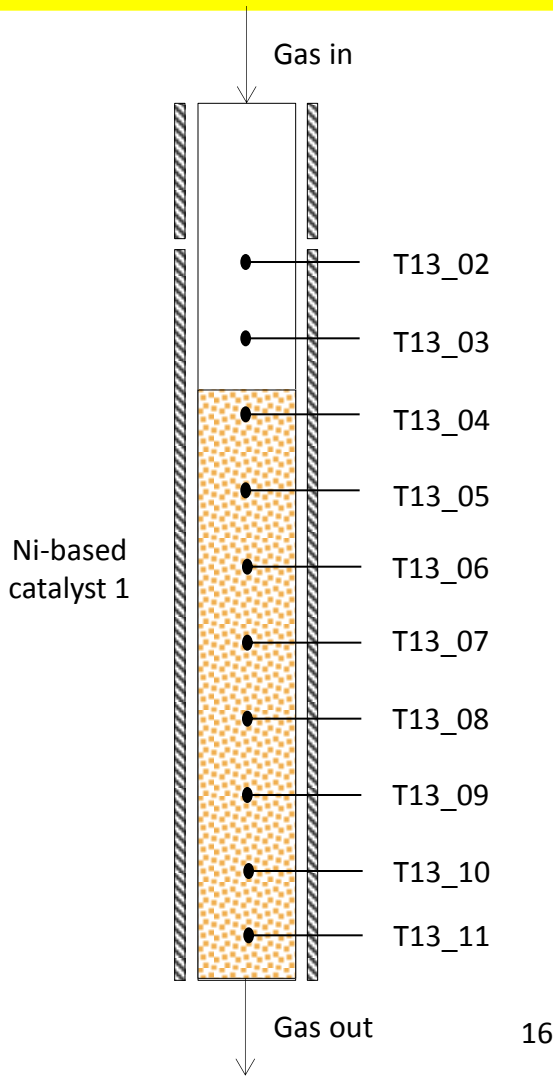
HDS unit



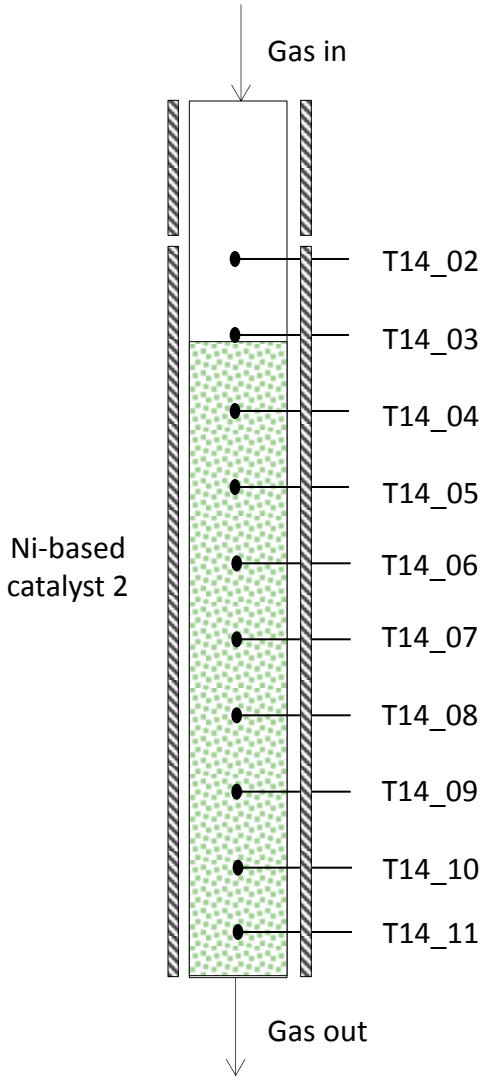
- Converts organic S (e.g. thiophene) to H_2S and COS; hydrogenates C_2H_4 and C_2H_2 into C_2H_6.
- Fixed-bed reactor with commercial CoMoO catalyst.
- Inlet gas T set at 280°C.
- GHSV = 200-250 h^{-1}.
- H_2S and COS removed downstream by ZnO.

Prereformer unit, R13

- Converts aromatic HC and produces CH_4 → autothermal operation.
- Fixed-bed filled with a commercial Ni-based catalyst (19 mm diameter x 12 mm pellets).
- Operation at ~6 bar; inlet gas T set at 340°C.
- 575 g/h steam added to the gas upstream the reactor.
- GHSV ~ 2000 h^{-1}.



Methanation units, R14 & R15



- Fixed-bed filled with a commercial Ni-based catalyst (4 mm diameter x 5 mm), different from prereformer catalyst.
- R14: inlet gas T set at 230°C.
- R15: inlet gas T set at 240°C.
- GHSV ~ 2000 h^{-1}.

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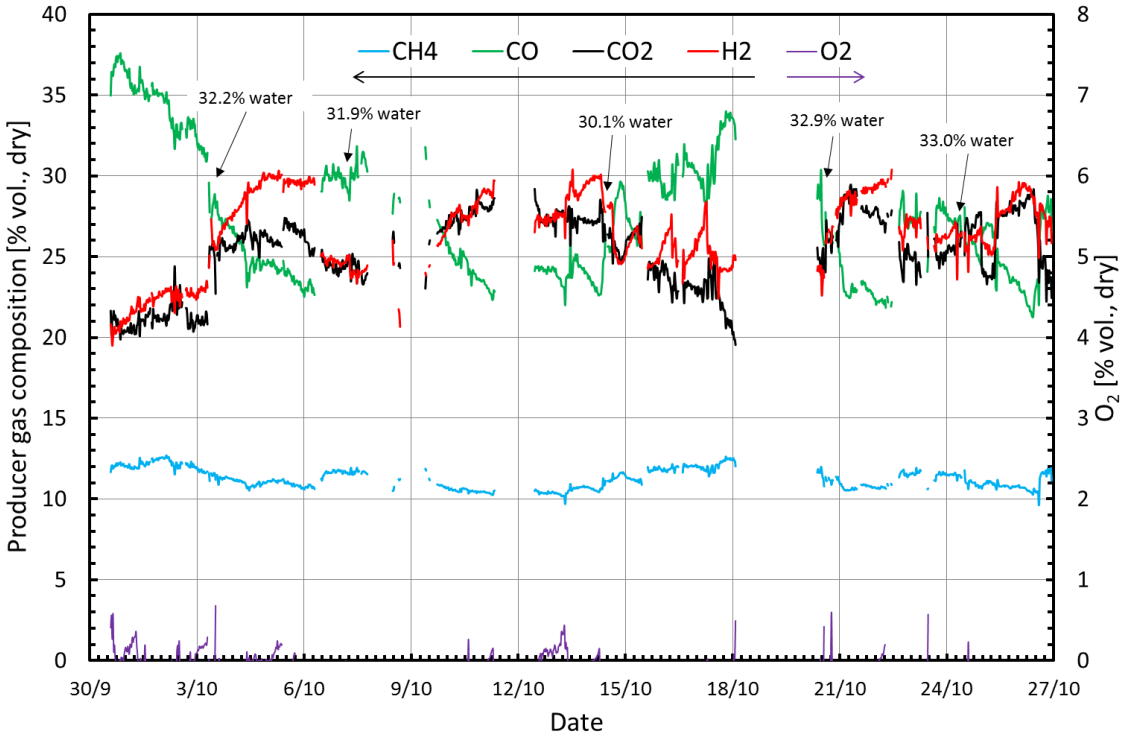
MILENA/OLGA performance

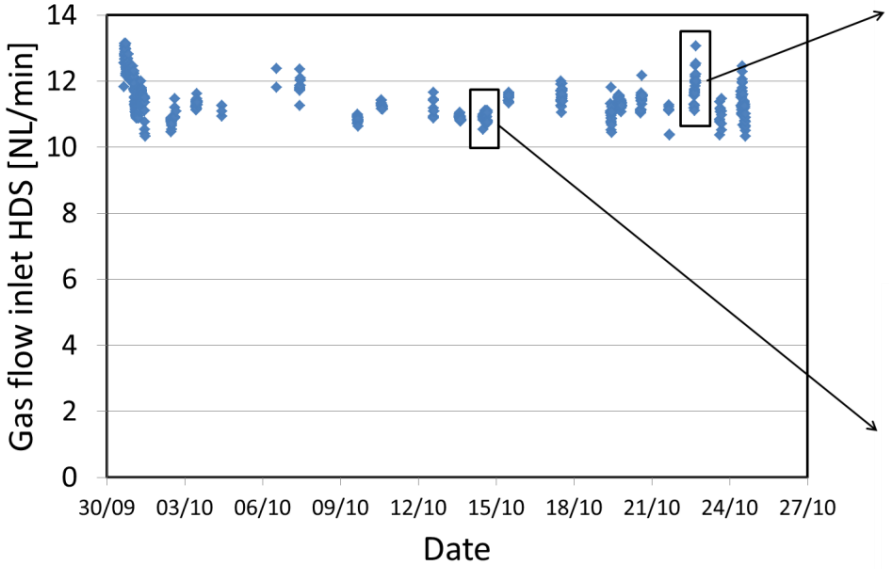
Producer gas composition:

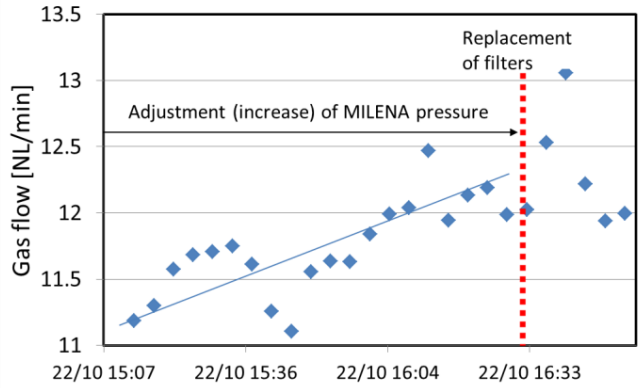


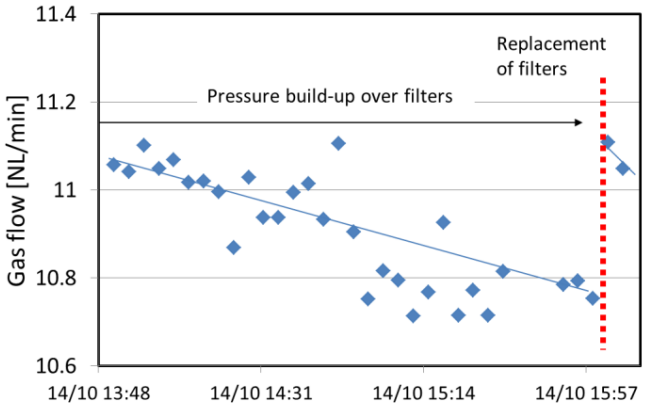
- Trends in time: higher H_2 and CO_2, lower CO → olivine activation over time.
- After shutdown/maintenance (i.e. refilling with fresh bed material): back to initial values.
- OLGA reduces tar content from ~ 30 g/Nm³ dry to ~ 1 g/Nm³ dry (remaining mainly 1-ring compounds).

ESME performance

Inlet flow rate:



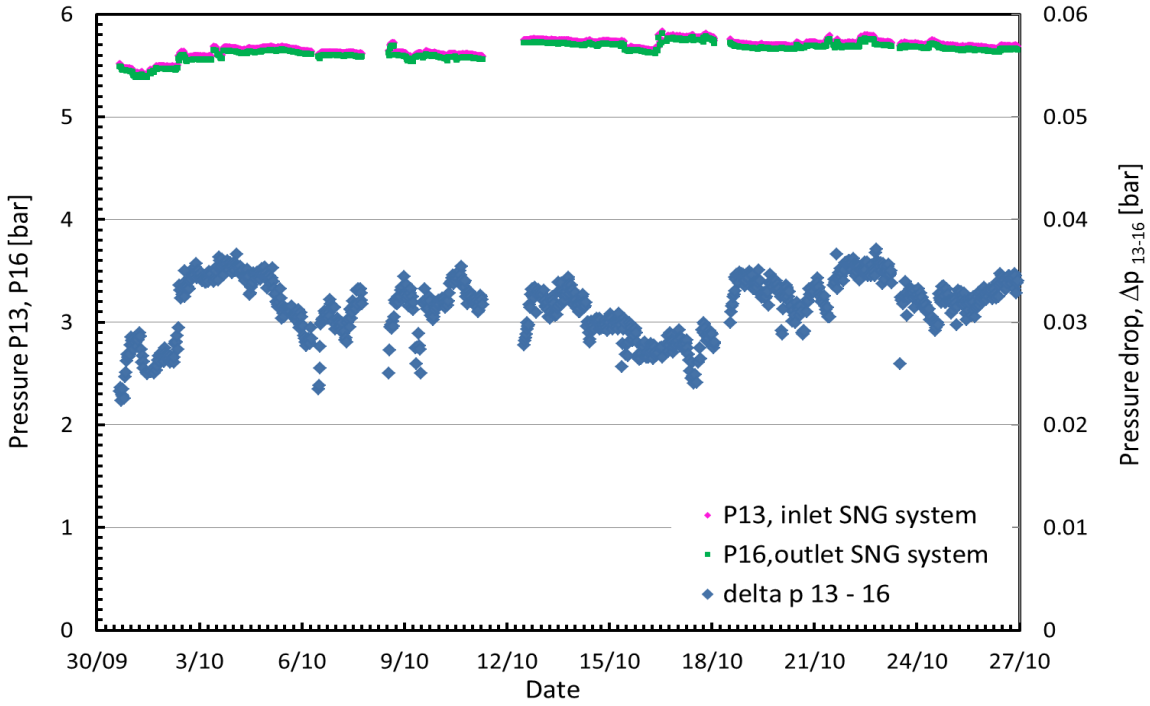




- Target inlet flow: 11 – 12 NL/min.
- Slight variations in flow over time (e.g. adjustment of MILENA pressure, changing flow resistance over filters, adjustment of compressor frequency).

ESME performance

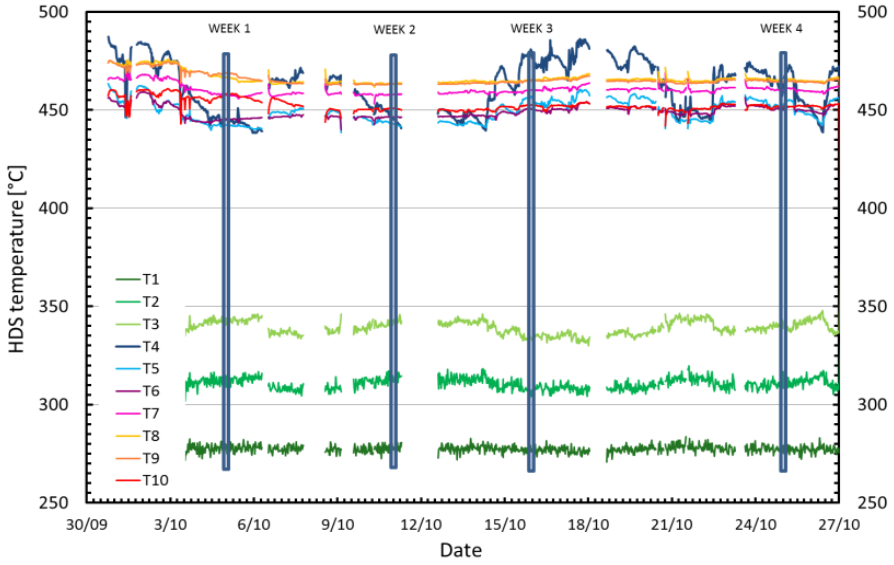
Pressure drop:

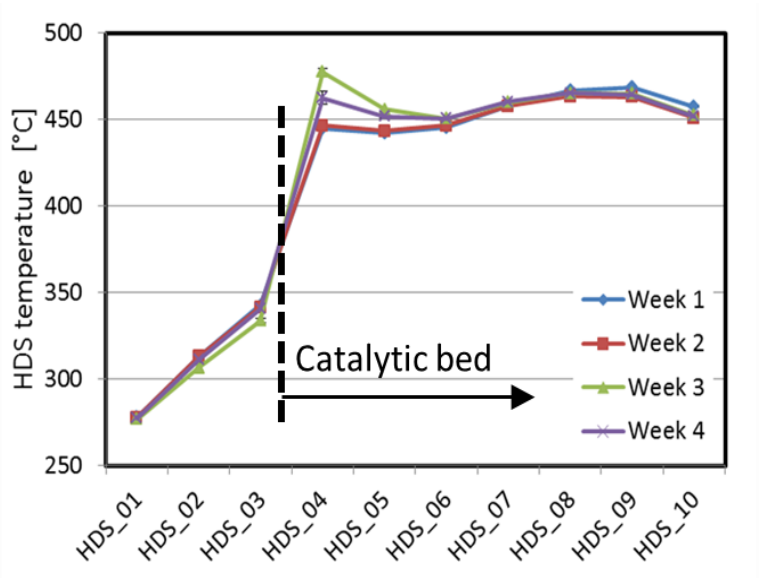


- Pressure drop over ESME (inlet R13 -- outlet R15) ~ 30 mbar throughout the test.
- Similarly to flow, small variations over time.
- Stability of operation of the whole methanation system.

ESME performance

HDS temperature profile:

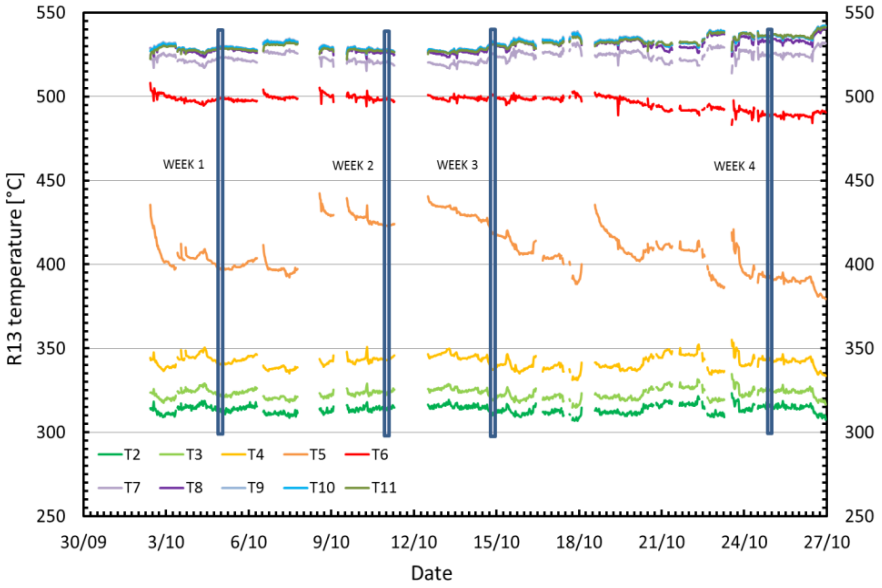


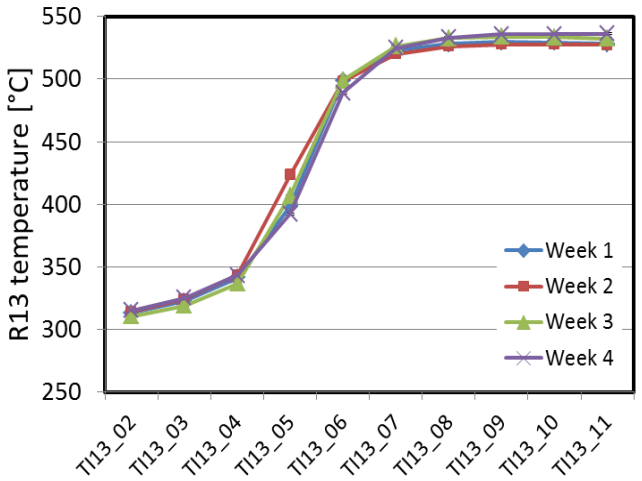


- Stable operation of HDS reactor.
- Irregular behavior of T_4: changes in composition/flow/pressure of inlet gas.
- The HDS catalyst is able to convert organic S compounds down to detection limits.

ESME performance

Prereformer temperature profile:

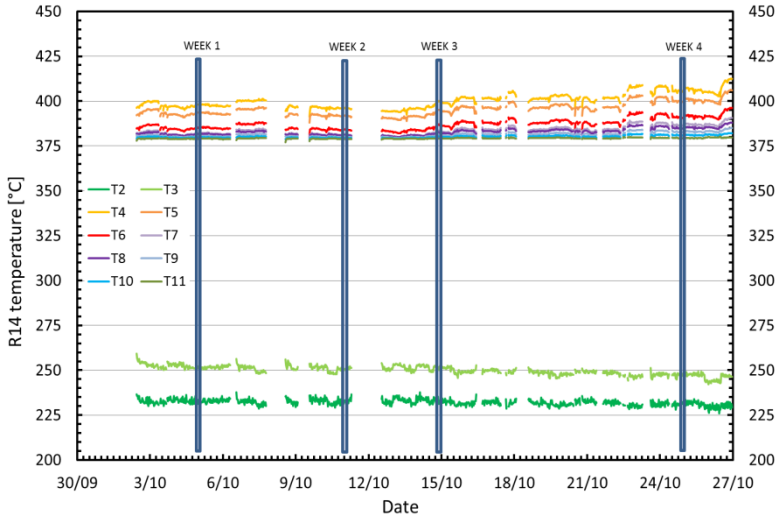


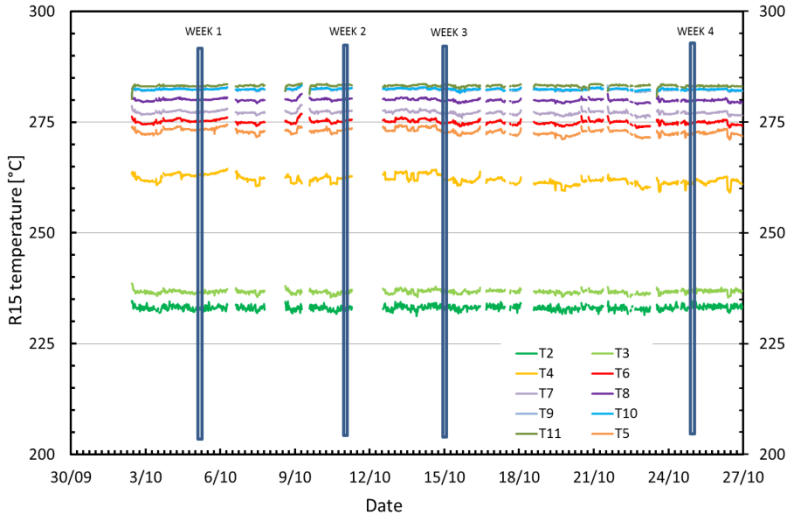


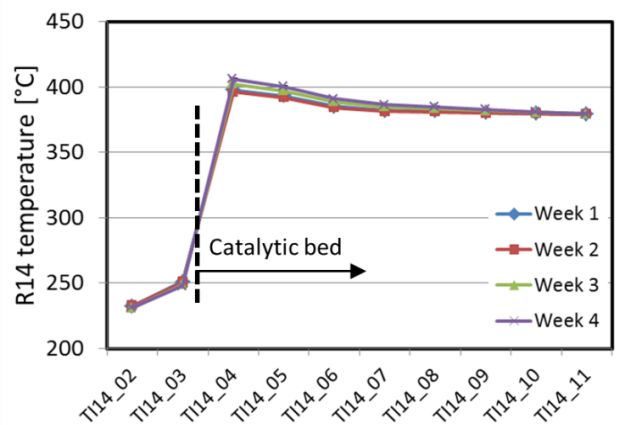
- T5 decreases over time: catalyst deactivation or variations in pressure or flow over the system.
- Re-start after shutdown resets T5 to initial values.
- After 500 h operation, catalyst degradation not clear from T profile.
- Negligible changes in gas composition over 500 hours.

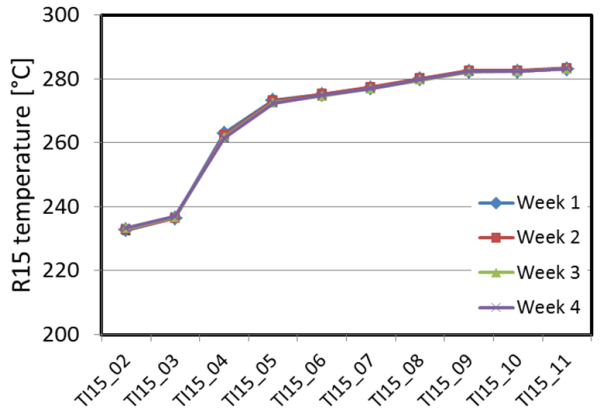
ESME performance

Methanation-1 & 2 temperature profile:

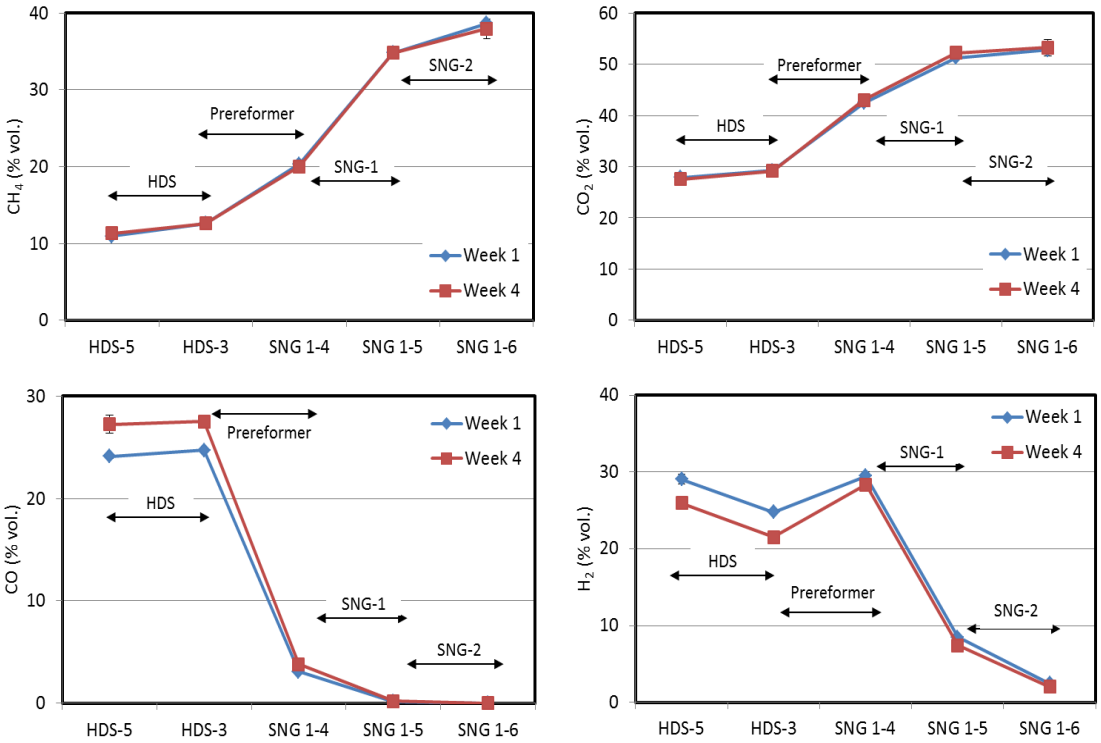








Evolution of gas composition

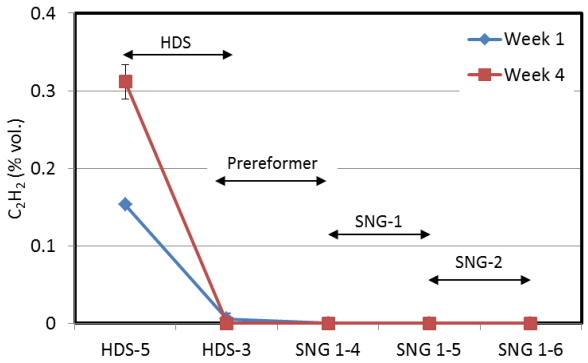


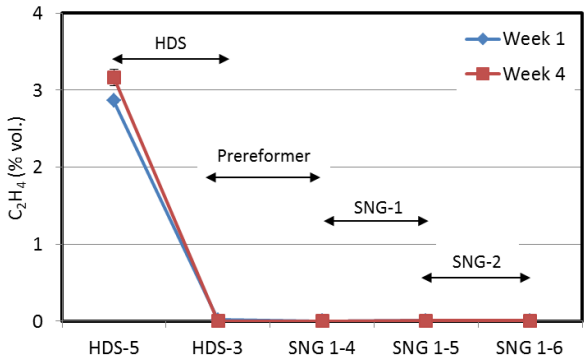
- CH_4: from 11% vol. to ~40% vol.
- CO: from 25-28% vol. to ~100 ppmv.
- H_2: from 26-29% vol. to ~2% vol.
- Thermodynamic equilibrium is reached.
- No apparent change in catalysts activity.

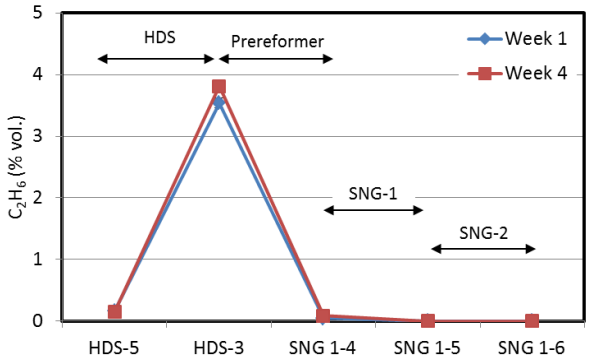
Evolution of gas composition

C_2H_2, C_2H_4, C_2H_6:

- C_2H_4 and C_2H_2 are completely hydrogenated to C_2H_6 in the HDS unit.
- Afterwards, C_2H_6 is converted in the prereformer.
- Catalytic activity of HDS, prereformer and methanation units remains apparently constant after several hundred hours operation.

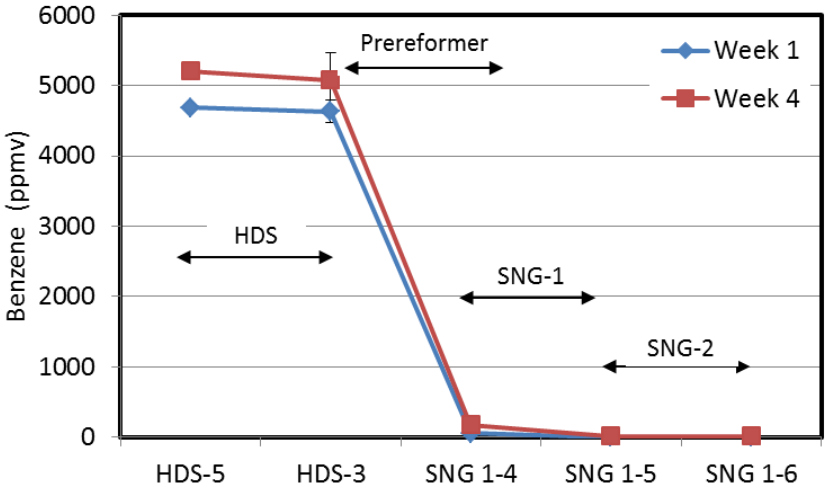


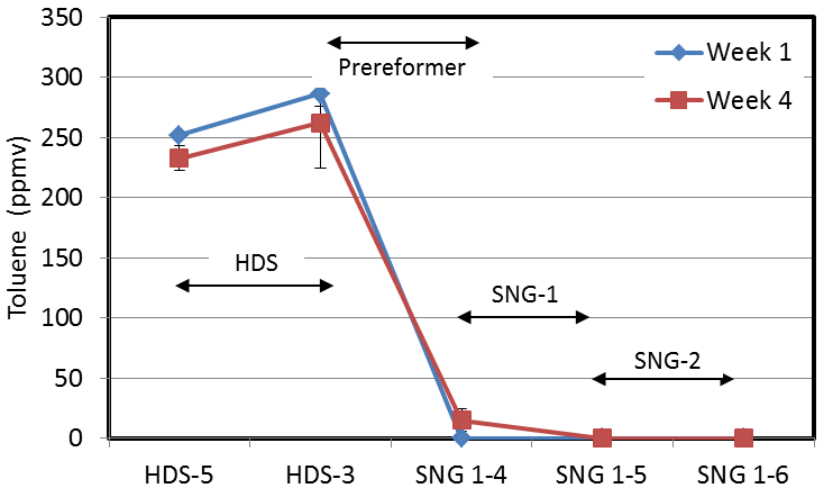




Evolution of gas composition

Benzene, toluene:





- Benzene: from 5000 ppmv dry (inlet HDS) to approximately 0 ppmv dry after R13.
- Similar trends for toluene.

Contents

4. Conclusions

- **E**CN **S**ystem for **ME**thanation (ESME): novel technology for SNG from biomass gasification.
- Successful 500-h test downstream MILENA and OLGA in October 2014:
  - MILENA availability ~ 90%; availability of (MILENA + OLGA + ESME) ~ 85%.
  - "Raw bio-SNG": 52% vol. CO_2, 39% vol. CH_4, 2% vol. H_2, (N_2, Ar, Ne), traces of CO and C_2H_6.
  - CH_4 production also in prereformer → positive effect on the heat balance of R13.
  - Catalyst degradation not observed or near detection limits.
  - Catalytic activity of HDS, prereformer and methanation units remains apparently constant after several hundred hours operation.
- **Important step for scale-up of bioSNG production → 300 m³/h SNG pilot-scale facility planned in the Netherlands.**

Lastly…

Thanks for your attention

This work is part of the project *Advanced Gas Technology development phase 2* (AGATE2), which has received support from the Energy Delta Gas Research (EDGaR) programme. EDGaR acknowledges the contribution of funding agencies: The Northern Netherlands Provinces (SNN) Investing in your future, the European Fund for Regional Development, the Ministry of Economic Affairs, and the Province of Groningen. Part of the work has been performed within the BRISK Project, which is funded by the European Commission Seventh Framework Programme (Capacities). The work has been co-funded by the Program Subsidy from the Ministry of Economic Affairs.

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