BECOOL

Brazil-EU Cooperation for Development of Advanced Lignocellulosic Biofuels

The MILENA platform; Technical demonstration of FT biofuels production

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TNO innovation for life

Biofuels workshop
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TNO

- **OUR MISSION**

  TNO connects people and knowledge to create innovations that boost the competitive strength of industry and the well-being of society in a sustainable way.

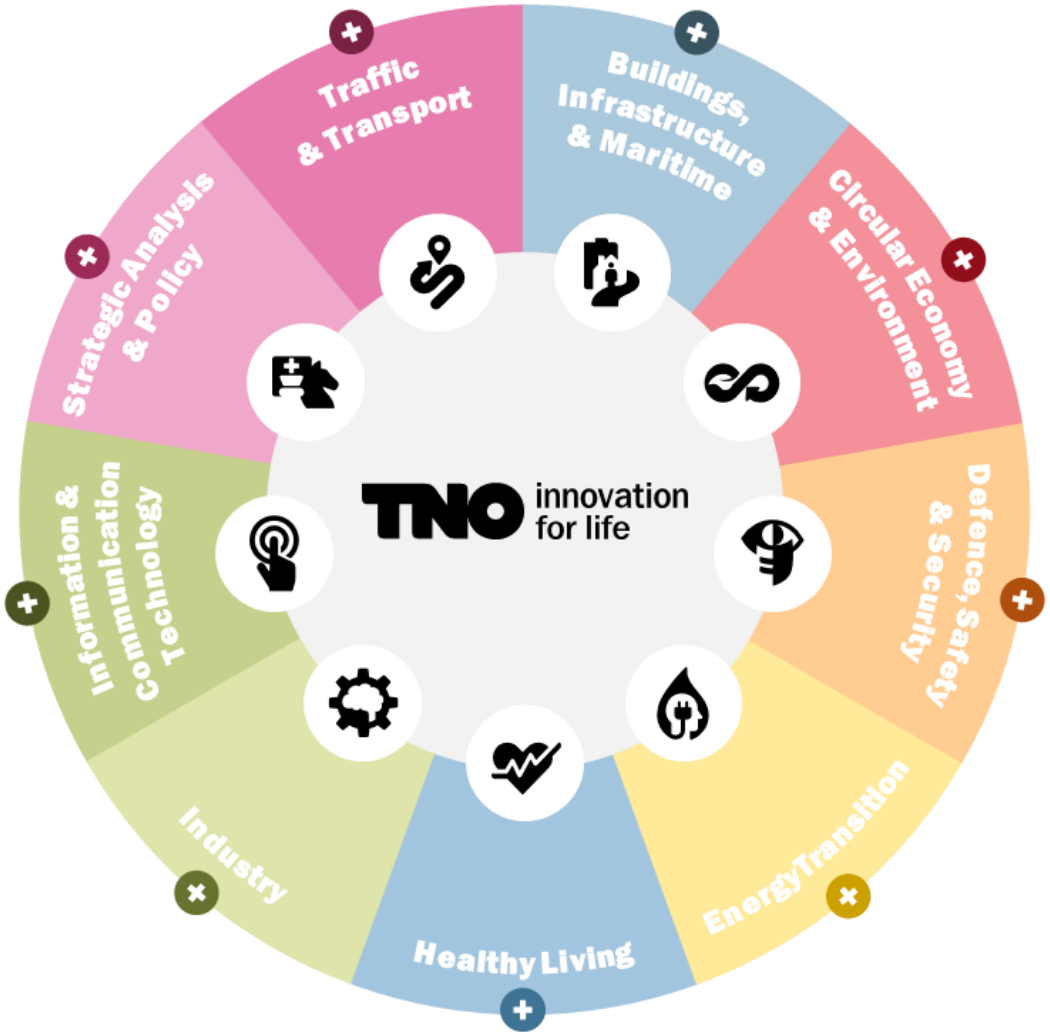
- **UNIT ENERGY TRANSITION**

  SOLAR ENERGY

  WIND ENERGY

  ENERGY EFFICIENCY

  BIOBASED AND CIRCULAR TECHNOLOGIES (BCT)

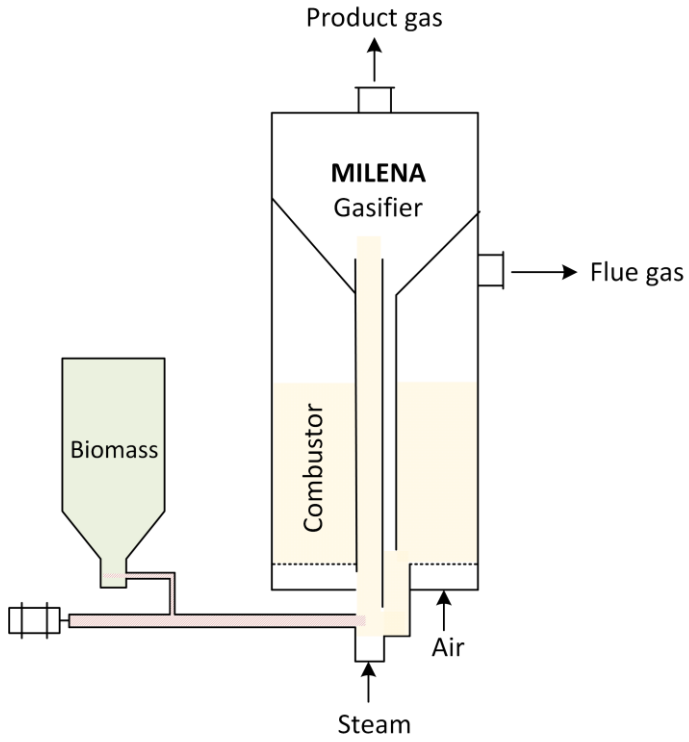


BCT: Gasification

- Gasification: conversion of biomass/residues to a product gas rich in syngas
  - PG can be converted into heat, power, fuels or chemicals

TNO's core technology: MILENA

- ✓ Fluidized/circulating bed
- ✓ Indirect gasification
- ✓ High calorific product gas
- ✓ No pure O_2/ASU required
- ✓ High feedstock flexibility
- ✓ Chemicals co-production



Why biomass gasification?

- Biomass: biofuels 70-80% reduction of GHG emissions.
  - Light energy into chemical energy, direct!
  - Also includes CO_2 capture!!
  - Not dependent on renewable electricity
    - Power to X; H_2 and CO_2 availability of ren. electricity (i.e. not yet green)

- Key technology to produce renewable biofuels from its syngas
  - Drop in quality fuels can be produced, e.g. SAF
  - SAF blending mandates announced in EU, 2% in 2025, 5% in 2030 and 63% in 2050
    - In 2020 <0.05% SAF in EU

References: EU REDII (2018/2001), EU ReFuel package (2021), SkyNRG market outlook on SAF (2021)

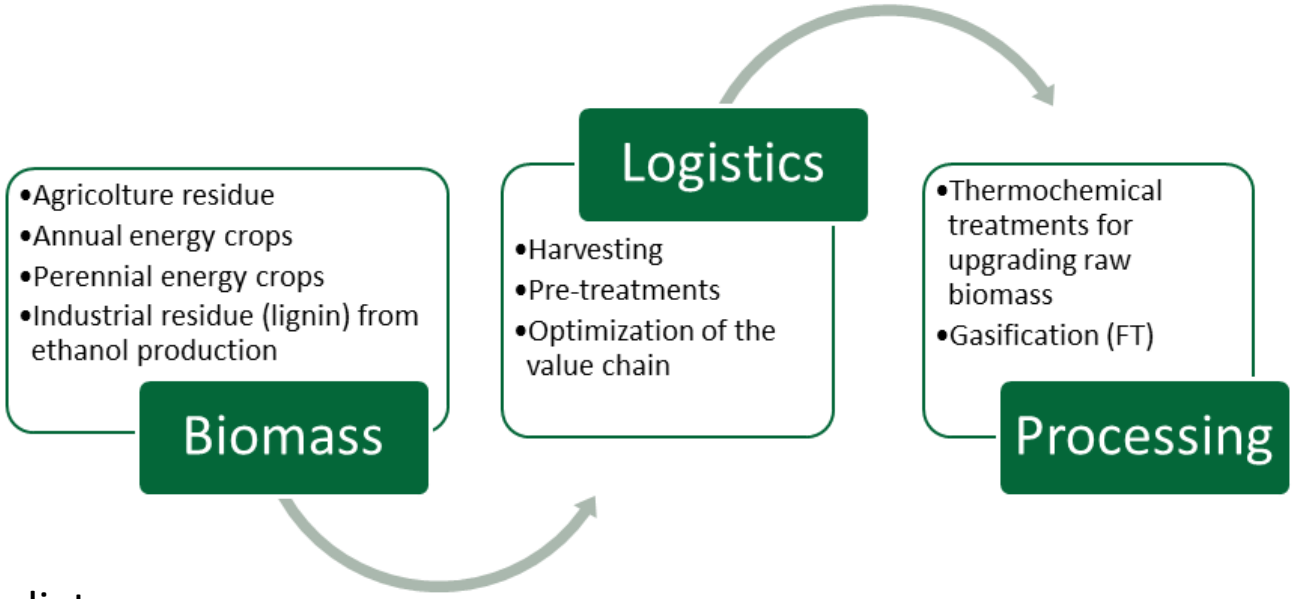
The BECOOL project

BECOOL is a research and innovation project to promote the cooperation between EU and Brazil in the development of advanced biofuels (especially kerosene), from sustainable agricultural value chains, based on lignocellulosic biomass.

Horizon 2020

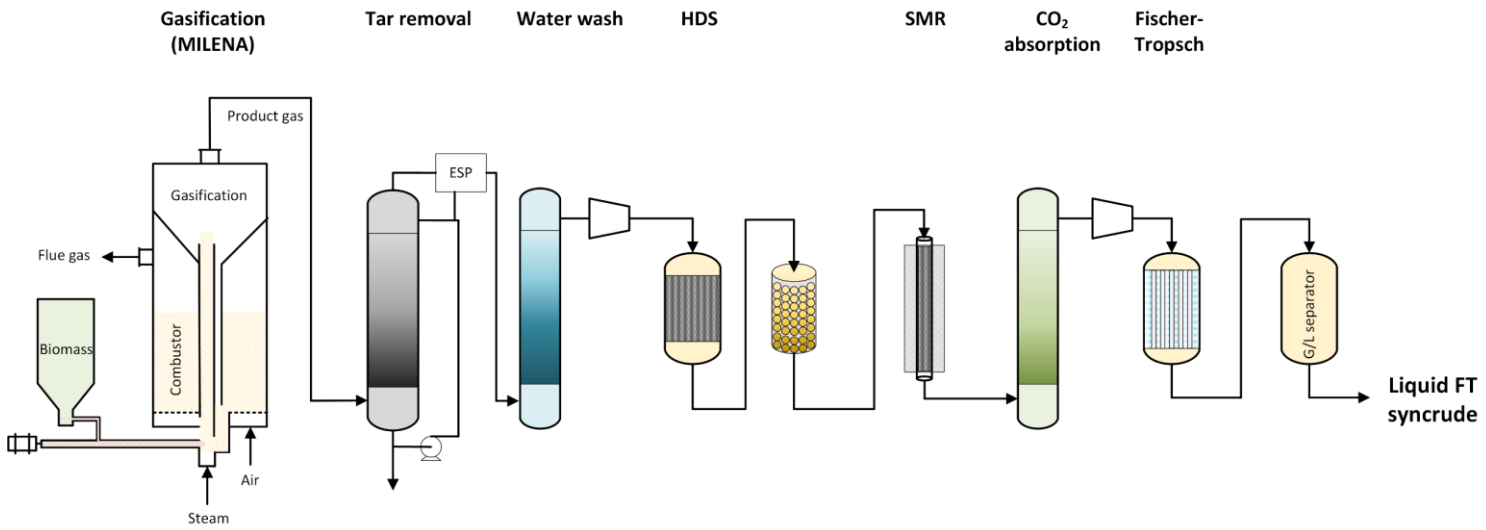
Objectives

- Developing and validating integrated technology packages
- Strengthen EU-Brazil cooperation



Gasification of bagasse, biomass and intermediate energy carriers to advanced biofuels, via FTS (WP3)

The MILENA gasification route



Mass/energy balance

- Overall energy efficiency ~45%, carbon conv.~ 34%
- Wood; 18 MJ/kg, Liquid Product; 43 MJ/kg

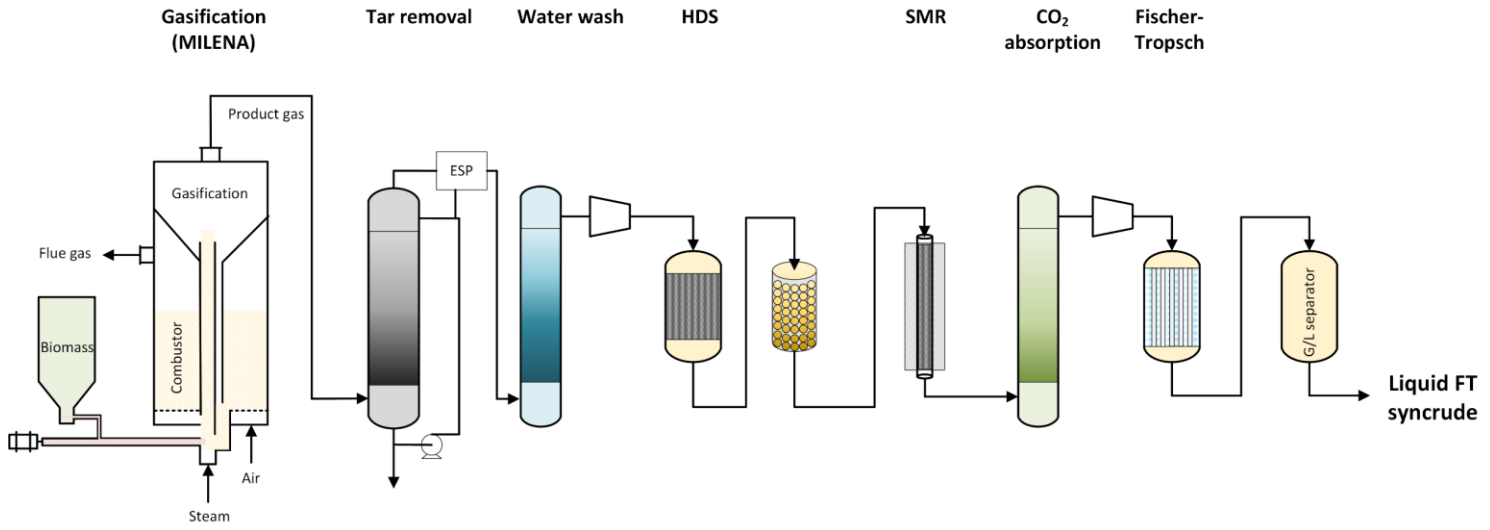
Economics

- Production costs; IEA (2019)*: 21-40 €/GJ (0.77-1.47 €/L)
- Shown approach on high end of that range (part of project scope)

Technical feasibility → Demonstrate in experiment

** IEA report (2019) Advanced Biofuels – Potential for Cost Reduction*

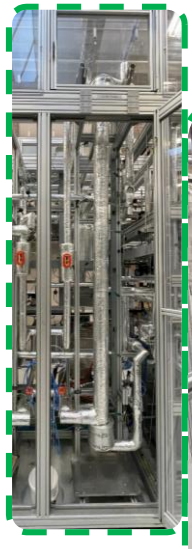
The MILENA gasification route



Objectives:

- Wood + bagasse gasification
- Complete tar removal to DP<10°C
- S/N removal up to <1ppmv
- SMR outlet $H_2/CO = 2$
- SMR >95+% CH_4 conversion
- CO_2 removal to <0.5 vol%
- FT liquid production (40-50% conv.)

Lab setup – commissioned in 2021

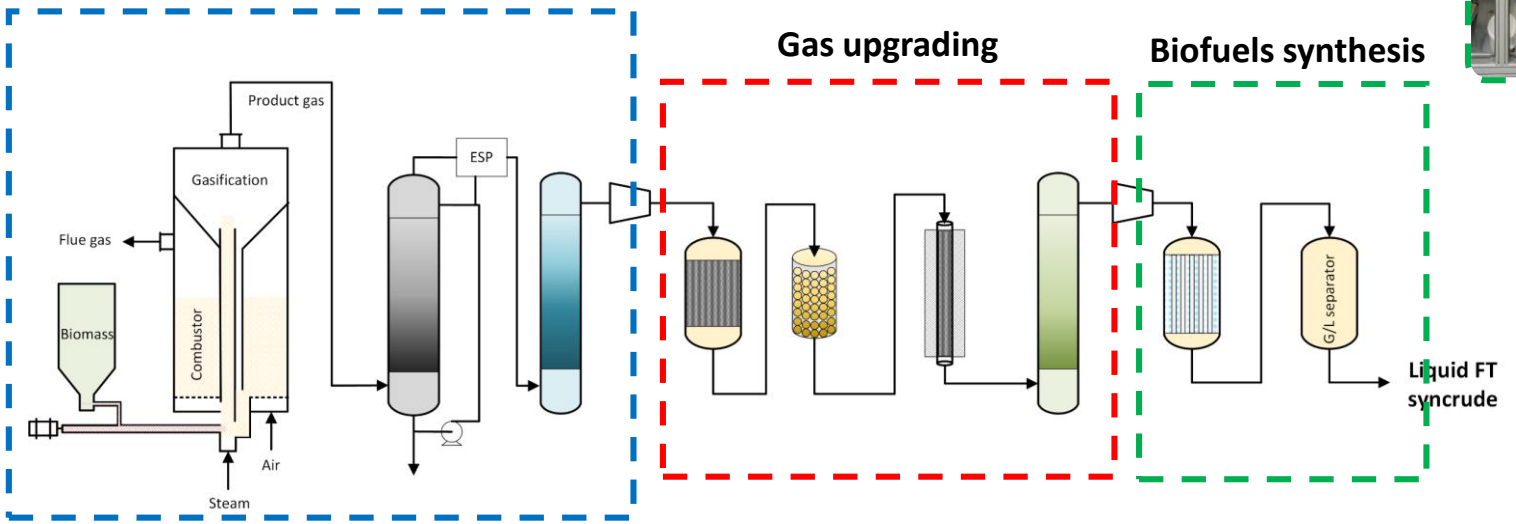


Biomass input:
5 kg/h

Gasification + gas cleaning

Gas upgrading

Biofuels synthesis



The experiment…

- Main feedstock: wood (beech) chips
- Additional feedstock: bagasse pellets

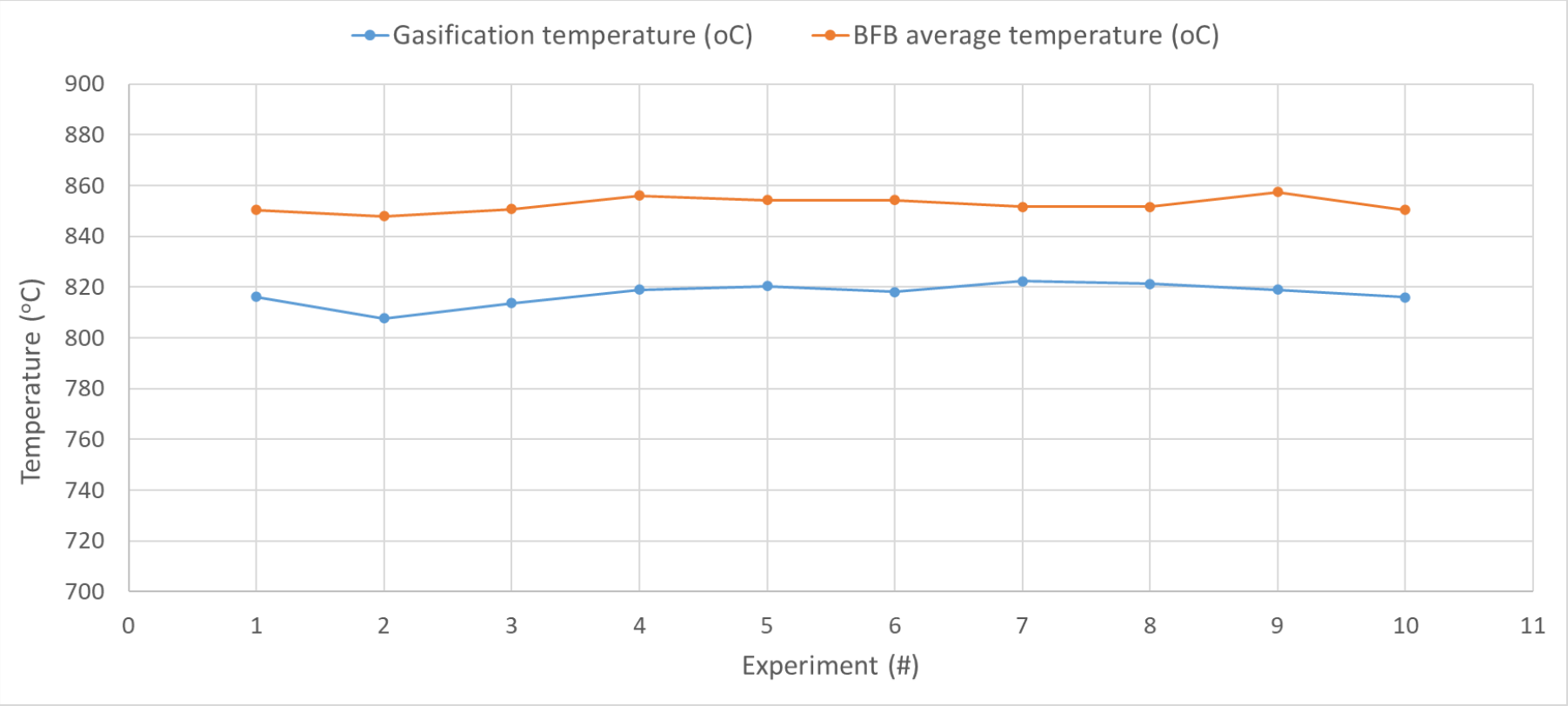
- One day experiments

	Gasification	Upgrading	Synthesis
Day 1			
Day 2			
Day 3			
Day 4			
Day 5			
Day 6			
Day 7			
Day 8			
Day 9, BAG			
Day 10			

The team:

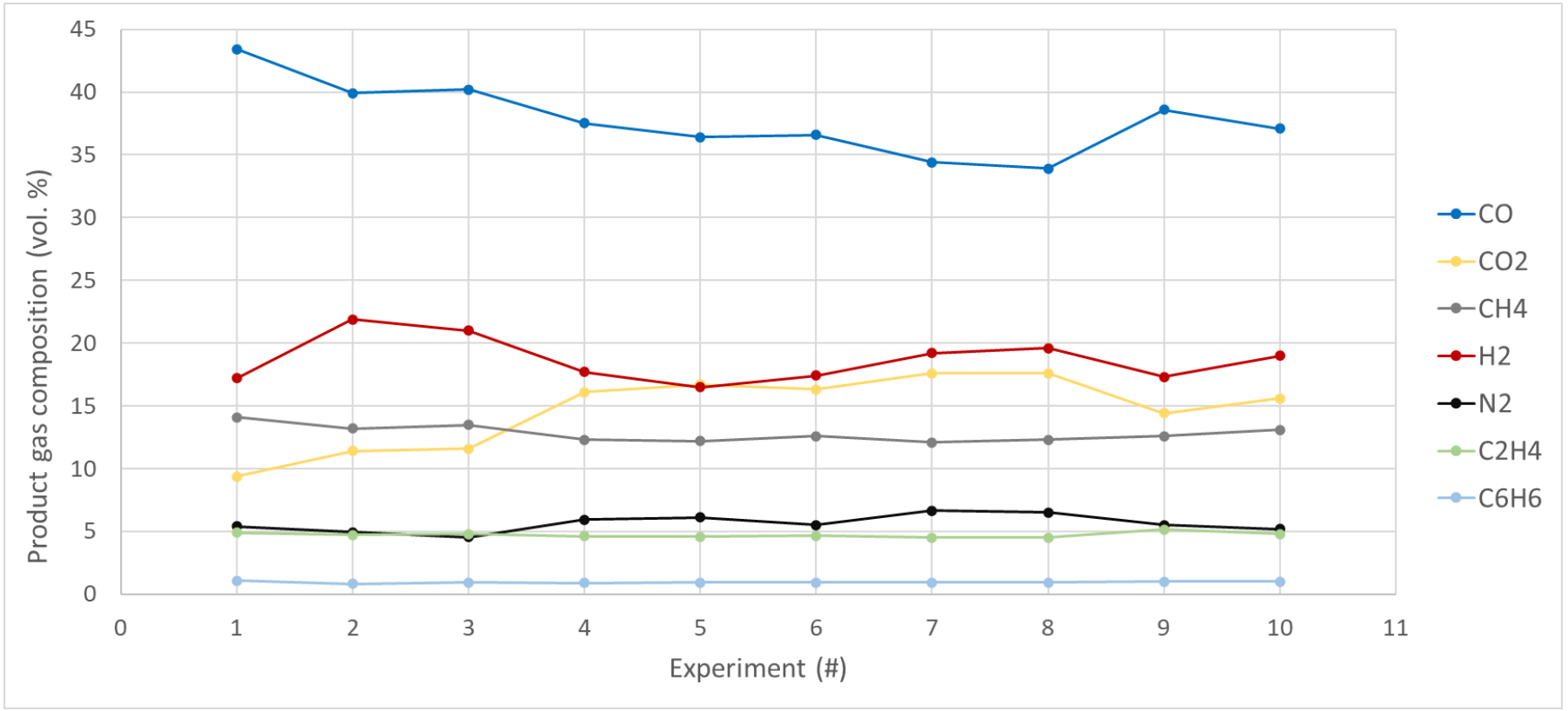
- 5 technicians/operators
- 3 analysts
- 2 scientists

Gasification overview



- As desired: very stable gasification conditions

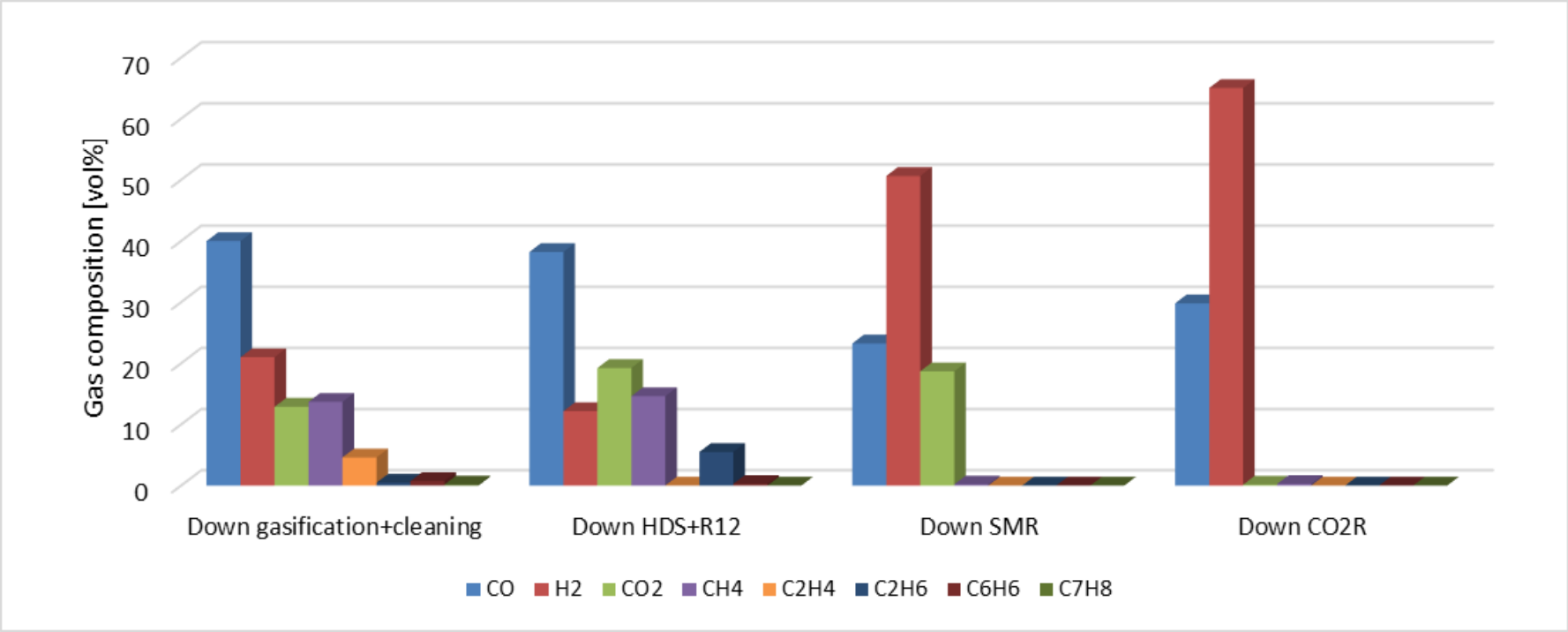
Gasification overview



- Gas compositions relatively stable over the different days

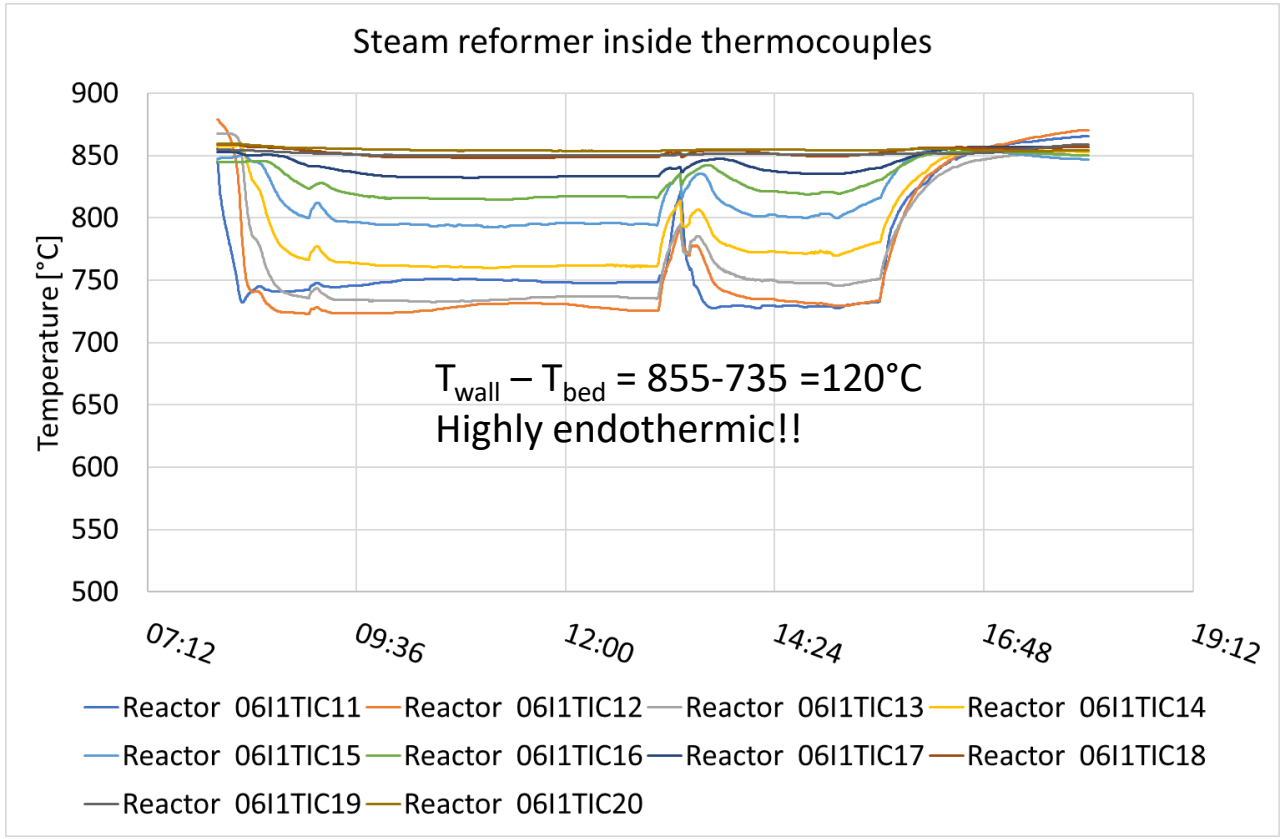
Gas upgrading results

Flow: 3050 NL/h H_2/CO: 0.5 d: 0.96 g/NL	Flow: 591 NL/h H_2/CO: 0.3 d: 1.08 g/NL	Flow: 1238 NL/h H_2/CO: 2.2 d: 0.76 g/NL	Flow: 1005 NL/h H_2/CO: 2.2 d: 0.50 g/NL

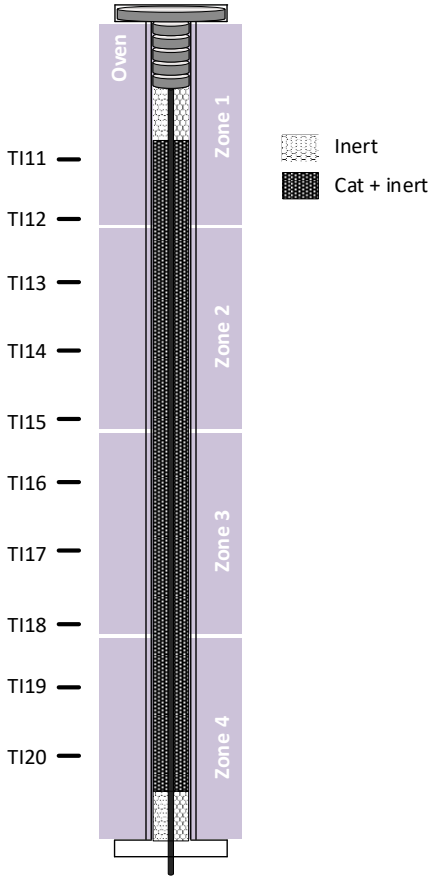


- ✓ Complete sulphur removal
- ✓ Steam reforming to achieve desired H_2/CO ratio
- ✓ Complete CO_2 capture from the product gas

SMR results (day 6)



Inlet flow: 600 NL/h, Steam: 710 g/h, P = 5 barg



Tset = 875°C all

- About half the reactor length needed to reach equilibrium
- Thermodynamic equilibrium (theoretical) reached in gas outlet

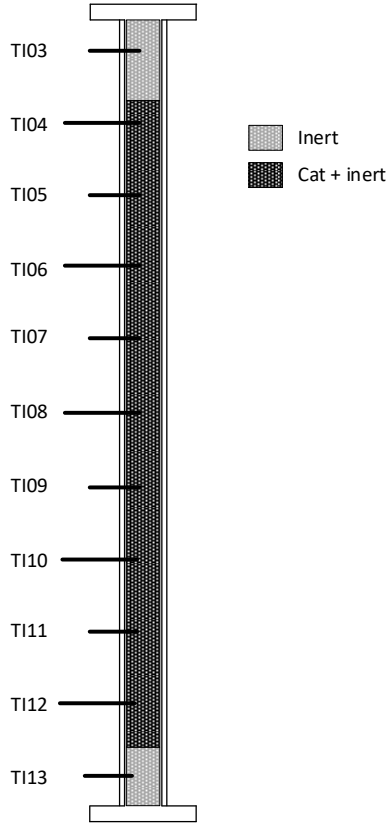
Biofuels synthesis: The FT pilot unit

$$n\,CO + (2n+1)\,H_2 \rightarrow C_nH_{2n+2} + n\,H_2O \quad (\Delta H_r = -165\ kJ/mol_{CO})$$

- P/T design 100 barg, 350°C
- Tube size: 2500 mm (L) x 26 mm (ID)
- Heat control: Thermal oil
- Inlet flow, max: 1640 g/h (gas panel/bio-Syngas)

FT catalyst pellets (cobalt)

SiC pellets

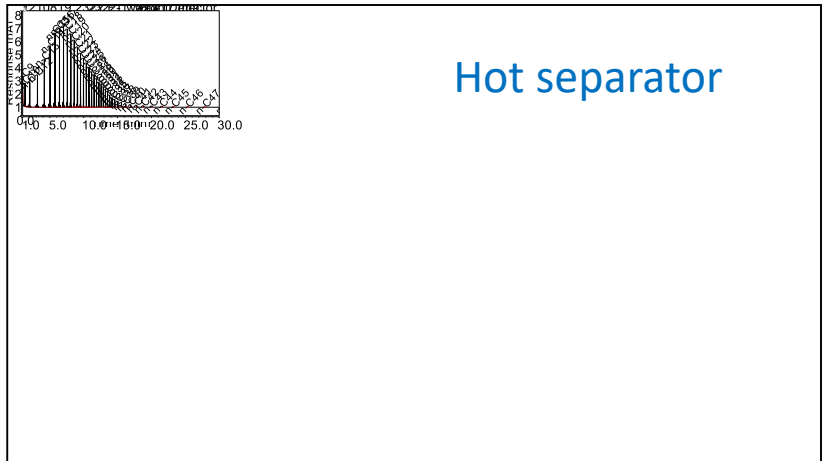


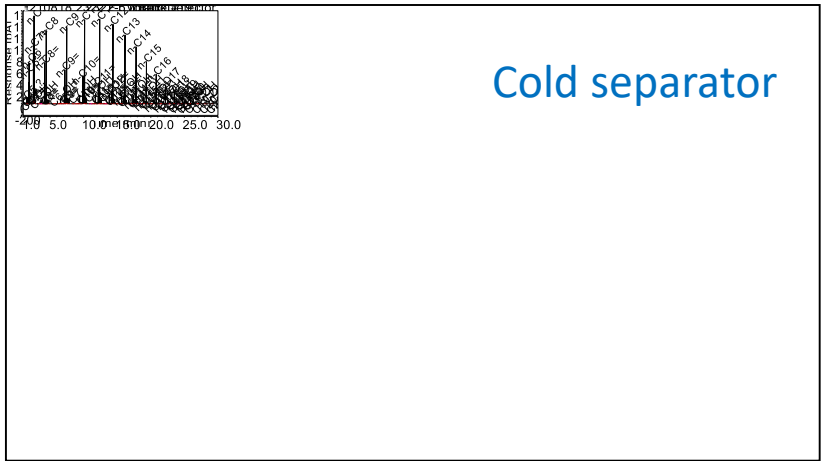
Biofuels synthesis results

Under steady state conditions

- Flow: 600 g/h bio-syngas
- CO Conversion: 34.2 %
- Selectivity C_{5+}: 80.3 (α = 0.85)
- Selectivity CH_4: 10.9

- More than 3.5 L liquid/wax hydrocarbon product.





Conclusions and outlook

Successful technical demonstration of FT biofuel production

Technical successes

- ✓ Gasification BW and BAG
- ✓ Gas cleaning, tar, S, N to <ppm level
- ✓ Steam reforming to H_2/CO of 2.0
- ✓ CH_4 conversion at >98%
- ✓ CO_2 removal to <0.5 vol%
- ✓ FT liquid/wax >3.5 L

Future

- Duration experiments
- Monitor catalyst deactivation
- FTS – improve heat management to obtain 50+% CO conversion
- Detailed economics

Thanks to the team

- Special thanks to Herman, Dennis, Edwin, Marco D, Marco G, Arnold and Tom
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Partners

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btg biomass technology group

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crea Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

KAΠE CRES

DBFZ

etaflorence renewable energies

TNO innovation for life

IIASA International Institute for Applied Systems Analysis

RE·CORD

VTT

WAGENINGEN UNIVERSITY & RESEARCH

Thank you for your attention!

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