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Bioenergy & Biofuels LAB

Small-scale producer gas upgrading: hydrogen yield enhancement over a char bed reactor

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The biofuels gap

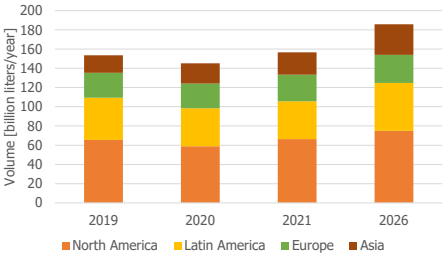


Fig. 1 *Biofuels demand by region [Renewables 2021, IEA]*

"Global demand for biofuels is set to grow by 41 billion litres, or 28 %, over 2021-2026" [Renewables 2021, IEA]

"Biofuels provide one of the most important options for decarbonising the transport sector" [Outlook 2022, IRENA]

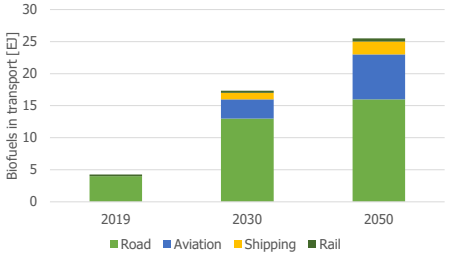
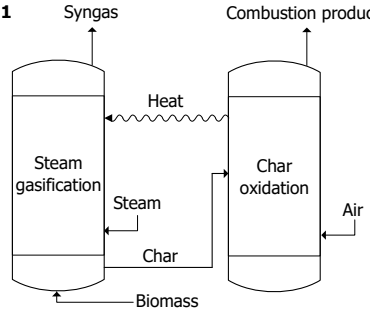


Fig. 2 *Use of biofuels in transport [Outlook 2022, IRENA]*

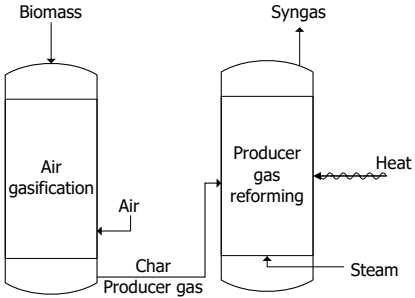
Gasification

		Air gasification	Oxygen gasification	Steam gasification
H_2	[vol.%$_{dry}$]	15	40	45
CO	[vol.%$_{dry}$]	20	40	25
CO_2	[vol.%$_{dry}$]	15	20	25
CH_4	[vol.%$_{dry}$]	2	-	5
N_2	[vol.%$_{dry}$]	48	-	-

OPTION 1



OPTION 2



Aims of the work

This work investigates the operation of a producer gas reforming unit under a range of temperatures and steam-to-syngas ratios and for each evaluate:

- Hydrogen concentration increase
- Hydrogen yield increase
- Compatibility of obtained syngas in the synthesis of different biofuel:
  - Fischer-Tropsch fuels

$$SM_{FT} = \frac{H_2}{CO} \tag{1}$$

  - Methanol

$$SM_{MeOH/DME} = \frac{H_2 - CO_2}{CO + CO_2} \tag{2}$$

  - Methane

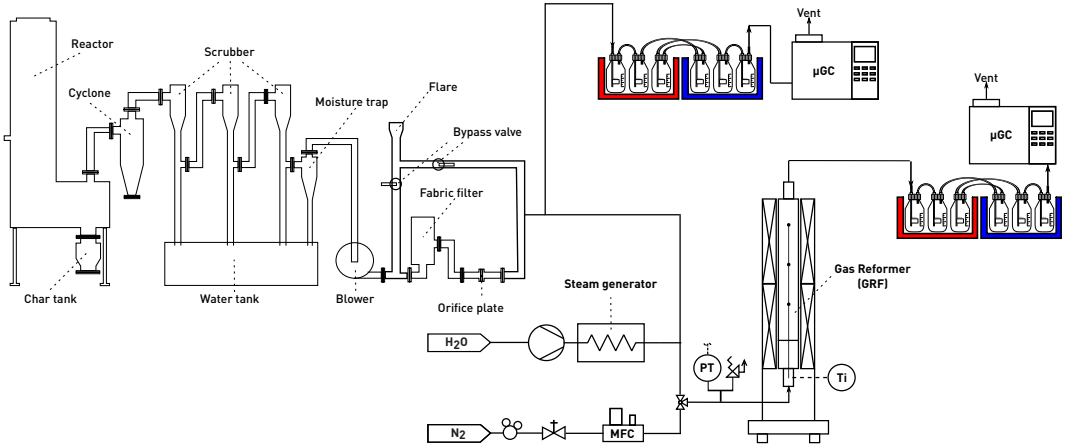
$$SM_{CH4} = \frac{H_2 + CO}{CO + CO_2} \tag{3}$$

Operating conditions

- Gasifier: Pilot-scale fixed-bed ($\sim$ 3 kg/h)
- Reformer: Fixed-bed allothermal reactor
- Temperature: 700 °C / 750 °C / 800 °C / 850 °C
- Steam flow (SF): from 0.0 g/h to 367.2 g/h

Label	SF-0	SF-3	SF-4	SF-6	SF-12	SF-14	SF-18	SF-23	SF-24
Flow [g/h]	0.0	47.7	61.9	92.0	184.8	214.5	274.6	352.3	367.2

Experimental layout



Experimental set-up

Experimental set-up

Fig. 1 *Open-top gasifier*

Fig. 2 *Gas reforming reactor*

1. Introduction

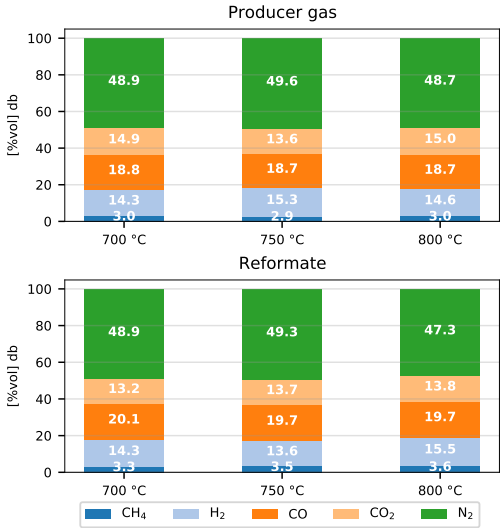
2. Methodology

3. Results

4. Conclusions

Gas concentrations

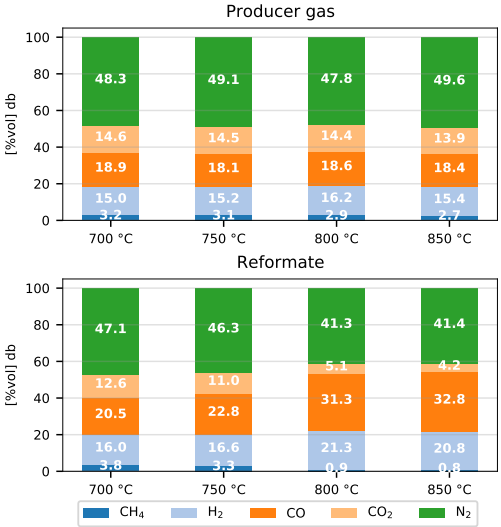
Temperature ✓ - Steam ✗ - Char ✗



- No considerable differences can be noticed

Gas concentrations

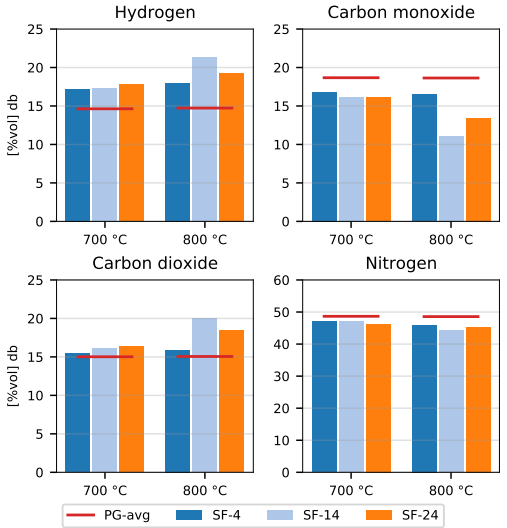
Temperature ✓ - Steam ✗ - Char ✓



- Increases in H_2 and CO concentrations in the higher temperature range (800 – 850 °C)
- $H_2 \longrightarrow$ from 15.4 % to 21.3 %
- $CO \longrightarrow$ from 18.4 % to 32.8 %

Gas concentrations

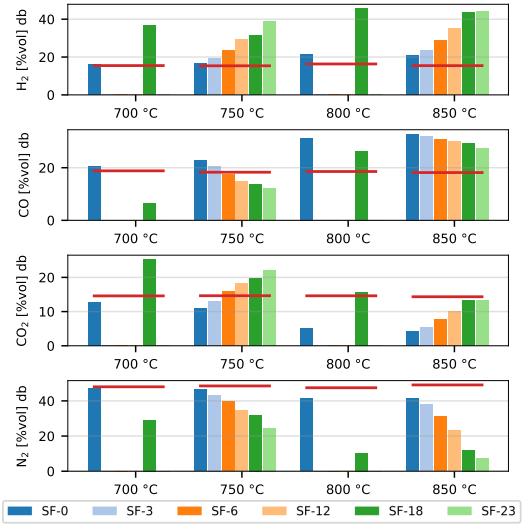
Temperature ✓ - Steam ✓ - Char ✗



- Increase in H_2 and CO_2 with a decrease in CO concentrations (WGS reaction)
- @ 800 °C and SF-14 same H_2 (21.3 %) to previous case, but lower CO (11.1 %)

Gas concentrations

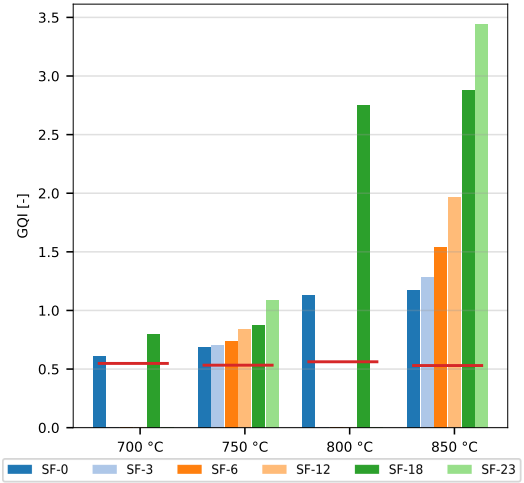
Temperature ✓ - Steam ✓ - Char ✓



- $H_2 \longrightarrow$ from 15.5 % to min 16.0 % (@ 700 °C, SF-0) or to max 45.6 % (@ 800 °C, SF-18)
- $CO \longrightarrow$ from 18.2 % to min 6.7 % (@ 700 °C, SF-18) or to max 32.8 % (@ 850 °C, SF-0)
- H_2 and CO follow an opposite trend $\longrightarrow$ prevailing of WGS reaction vs. char-steam gasification

Gas Quality Index (GQI)

Temperature ✓ - Steam ✓ - Char ✓

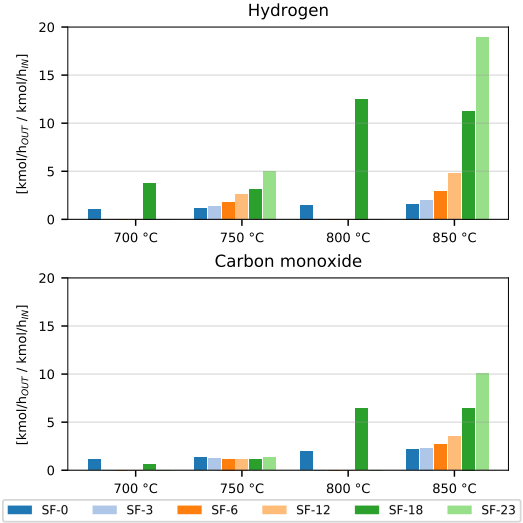


- GQI $\longrightarrow$ concentration of reducing equivalents

$$GQI[-] = \frac{mol_{H_2} + mol_{CO}}{mol_{N_2} + mol_{CO_2}}$$

- Producer gas average GQI $\longrightarrow$ 0.54
- GQI in reformate $\longrightarrow$ up to a maximum of 3.44 (+537 %) (@ 850 °C, SF-23)
- Growing gas quality at higher temperatures and steam flow rates

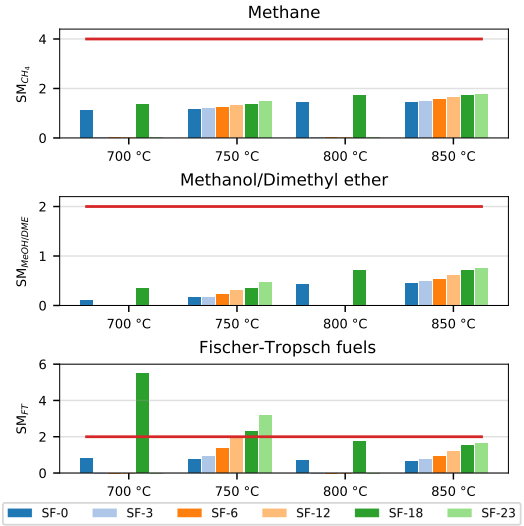
Temperature ✓ - Steam ✓ - Char ✓



- Very clear correlation with both temperature and steam flows for both H_2 and CO
- H_2 without steam $\longrightarrow$ +60 % H_2 @ 850 °C and SF-0
- H_2 with steam $\longrightarrow$ +1796 % H_2 @ 850 °C and SF-23

Stoichiometric ratios

Temperature ✓ - Steam ✓ - Char ✓



- Biomethane synthesis $\longrightarrow$ 44 % of the required ratio
- MeOH/DME synthesis $\longrightarrow$ 47 % of the required ratio
- FT fuels synthses $\longrightarrow$ three runs in the 700 – 750 °C range at the highest steam flow rates could surpass the required ratios

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Conclusions

- Increase in H_2 concentration is obtained at higher temperature, moving from 16.2 % to 21.3 %, without using steam, and to 45.6 %, with steam injection on the char-bed. CO concentration did not follow the same monotonic behavior
- Increase in H_2 flow rate across all cases, from a minimum of +9 % in the absence of steam at 700 °C to a maximum of +1796 % at 850 °C at the highest steam flow rate
- The syngas stoichiometric ratios are compatible for the Fischer-Tropsch synthesis, while for MeOH/DME and biomethane synthesis an additional amount of hydrogen is required

Acknowledgments

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"SMall-scale producer gas UPgrading for biofuels production"

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Thank you for your attention!

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