Task 33 Workshop “Hydrogen production via gasification and inclusion of hydrogen in gasification processes”
19-04-2023, Edmonton

Decentral Production of PEMFC Suitable Hydrogen from Air Gasification of Wood

FCTRAC

Fuel cell tractor
fuelled with biogenic hydrogen

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Outline

Introduction – Project FCTRAC

BioH_2Modul

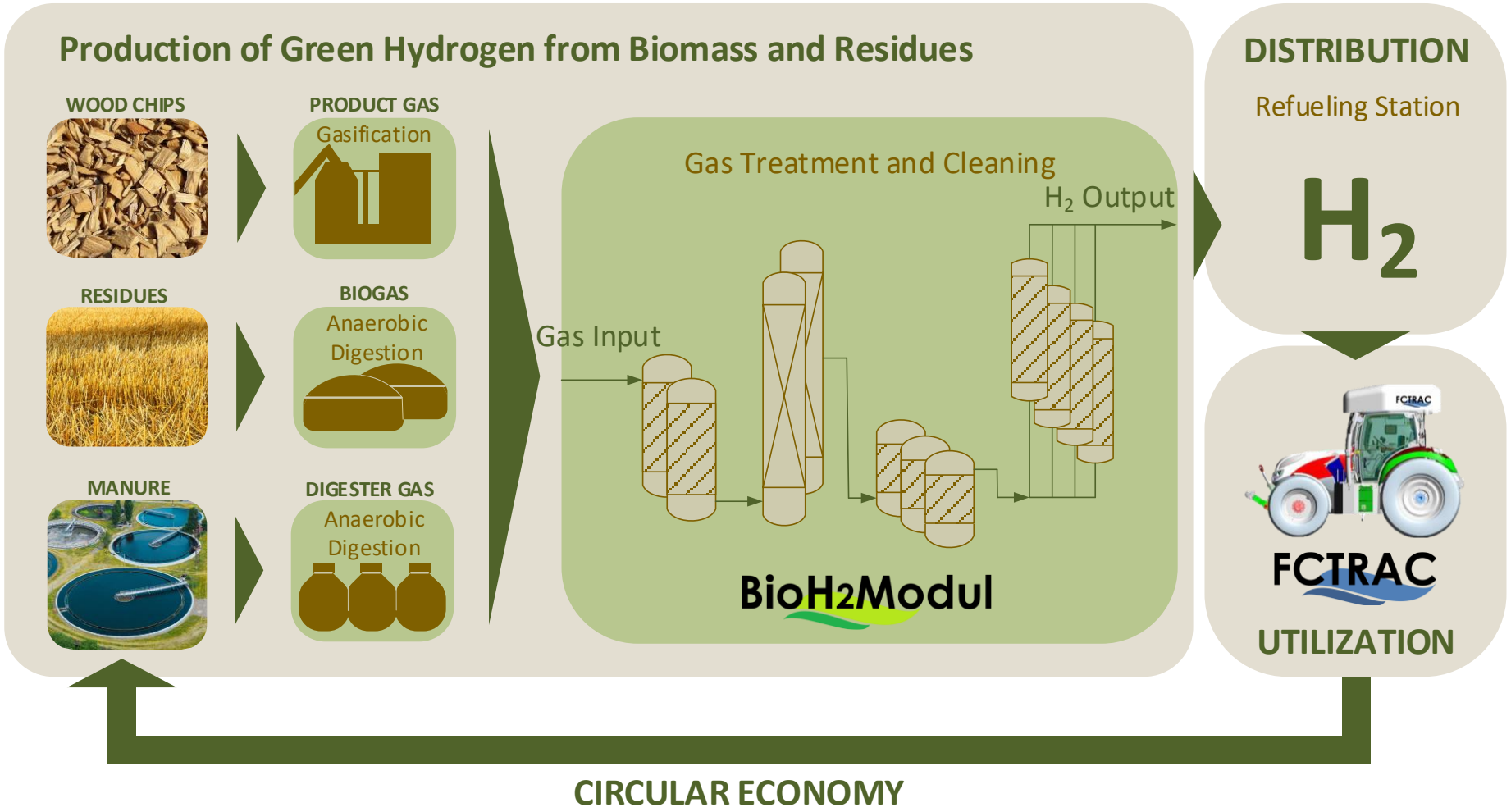
- Process Chains for H_2 Production from Biomass-derived Gases
- Motivation - H_2 Production in Existing CHP Plants
- Design Case of BioH_2Modul and Plant Capacity
- Current Status on Site in Carinthia
- Next Steps and Outlook

Mini-BioH_2Modul

- Lab-scale Investigations at ICEBE Technical Laboratory
- Experiments with a Lab-scale Pressure Swing Adsorption Plant for H_2 Production from Synthetic Gas Mixtures

Project FCTRAC

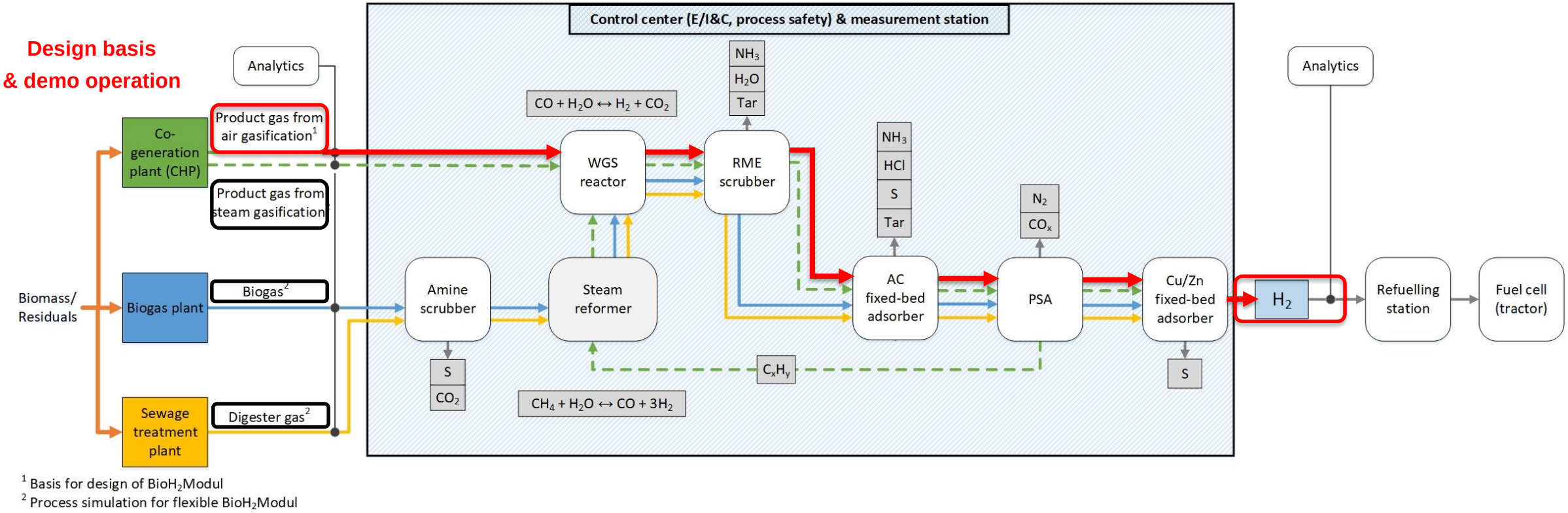
Concept of Sustainable and Input-flexible H_2 Production for Fuel Cell Tractor Application



Process Chains for H_2 Production from Biomass-derived Gases

Concept of Flexible BioH_2Modul

Design basis & demo operation



[1] Basis for design of BioH_2Modul
[2] Process simulation for flexible BioH_2Modul

Techno-economic assessment

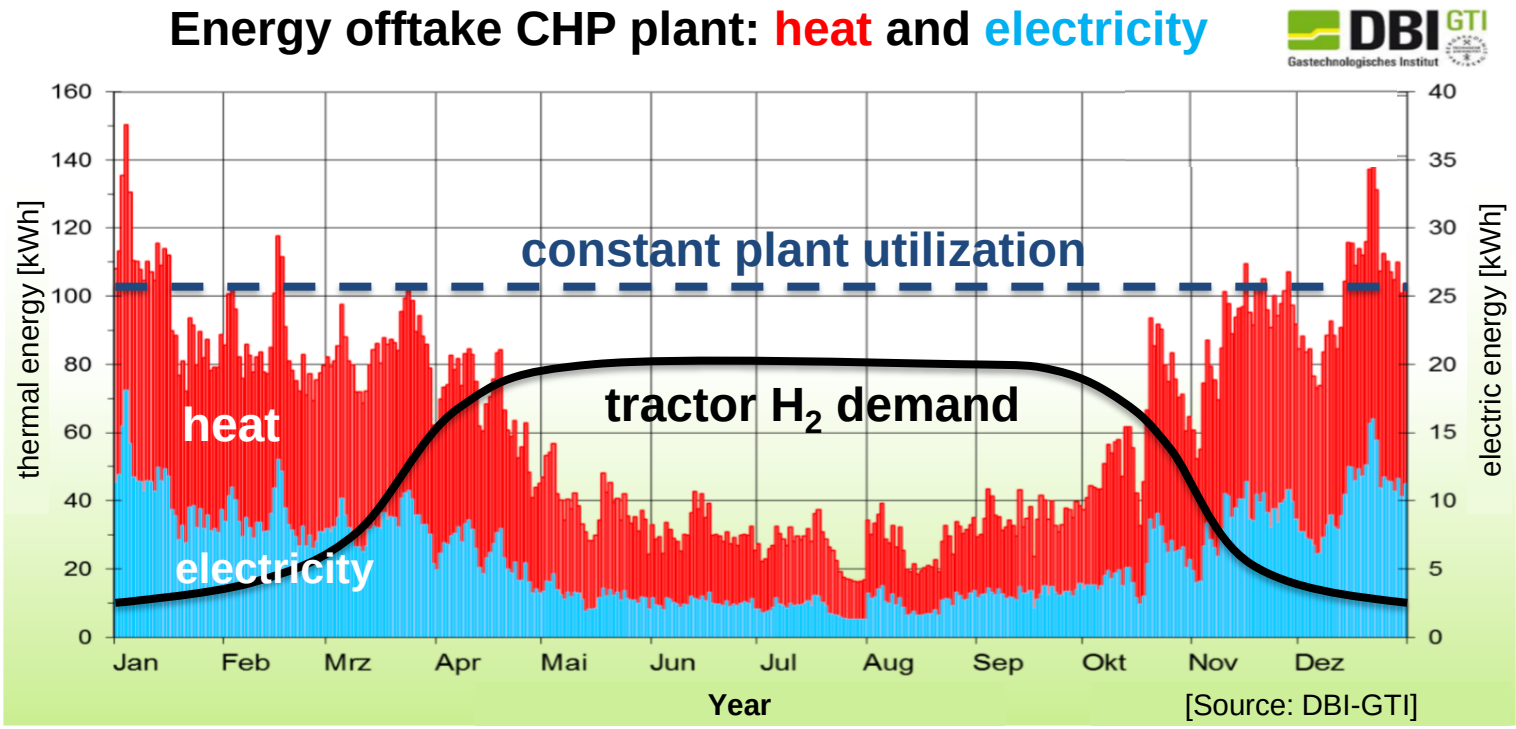
BioH2Modul

Motivation
H_2 Production in Existing CHP Plants

Seasonal energy demand: CHP plant heat and electricity output

→ High potential for **H_2 production** by existing plants in **low energy season**

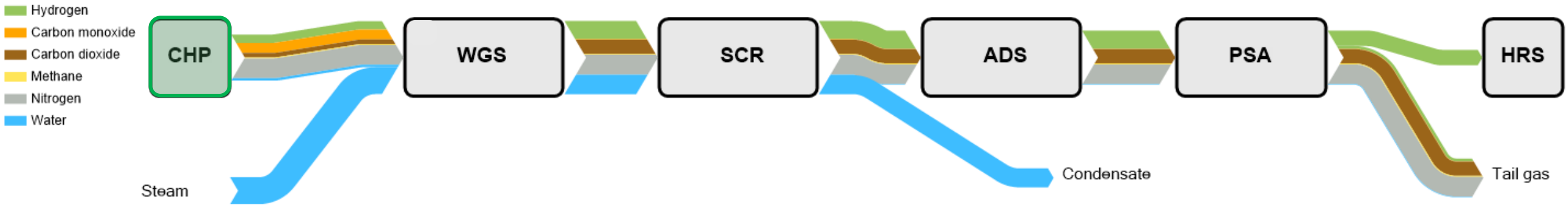
→ Increase of overall efficiency of existing plants - constant plant utilization



https://www.dbi-gruppe.de/files/PDFs/Flyer_Broschuere/81_Gasanwendung_FY_Monitoring_2014.pdf -

Design Case of BioH$_2$Modul and Plant Capacity
Detailed Process Chain

Combined heat and power plant

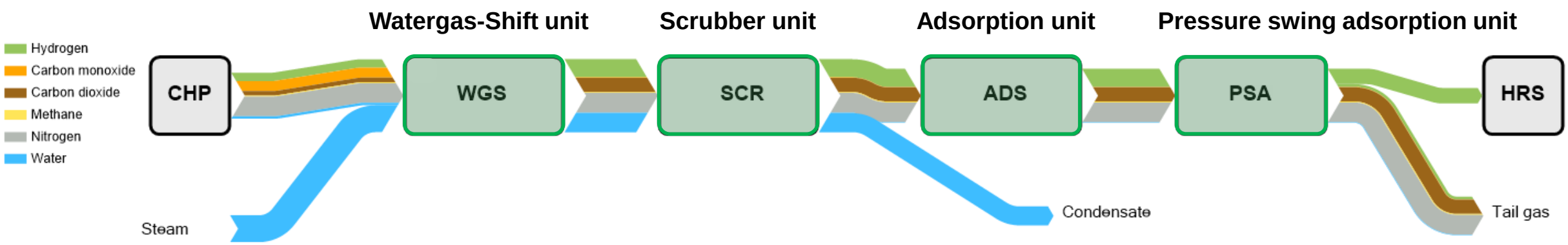


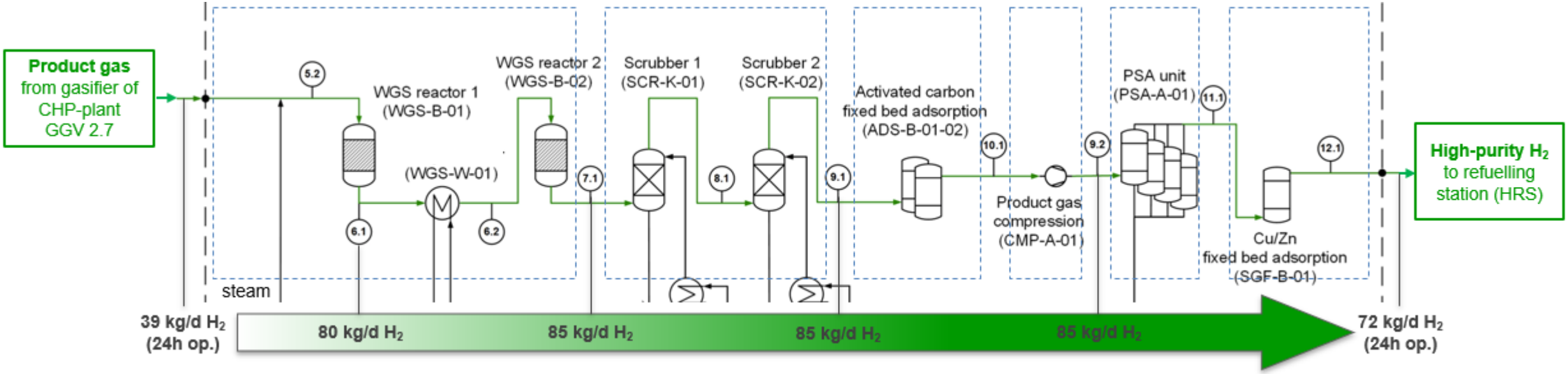
Gas composition	Unit	Fixed-bed gasifier product gas[1]
H_2	vol.-%$_{db}$	**17.2**
CO	vol.-%$_{db}$	**21.2**
CO_2	vol.-%$_{db}$	**12.6**
CH_4	vol.-%$_{db}$	**2.5**
N_2	vol.-%$_{db}$	**46.0**
C_xH_y	vol.-%$_{db}$	**0.4**
H_2O	vol.-%	n.a.

[1] M. Simone, F. Barontini, C. Nicolella und L. Tognotti: Gasification of pelletized biomass in a pilot scale downdraft gasifier. Bioresource Technology (116), 403-412 (2012)

Design Case of BioH$_2$Modul and Plant Capacity

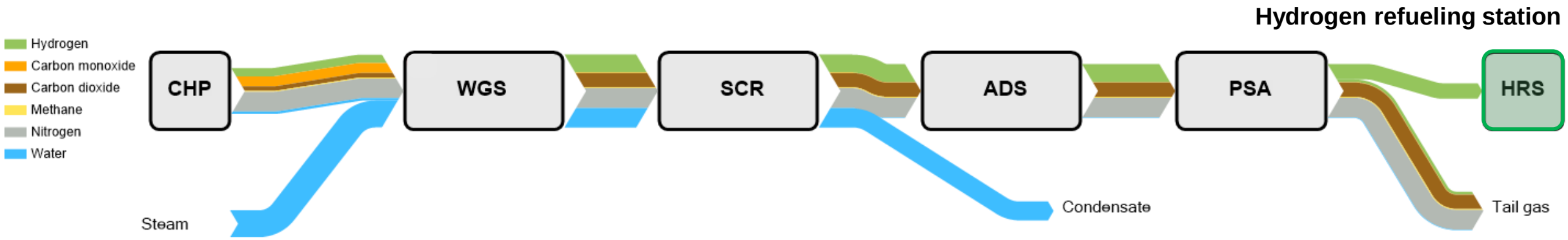
Detailed Process Chain





Design Case of BioH$_2$Modul and Plant Capacity

Detailed Process Chain



Hydrogen qualitiy according to ISO 14687

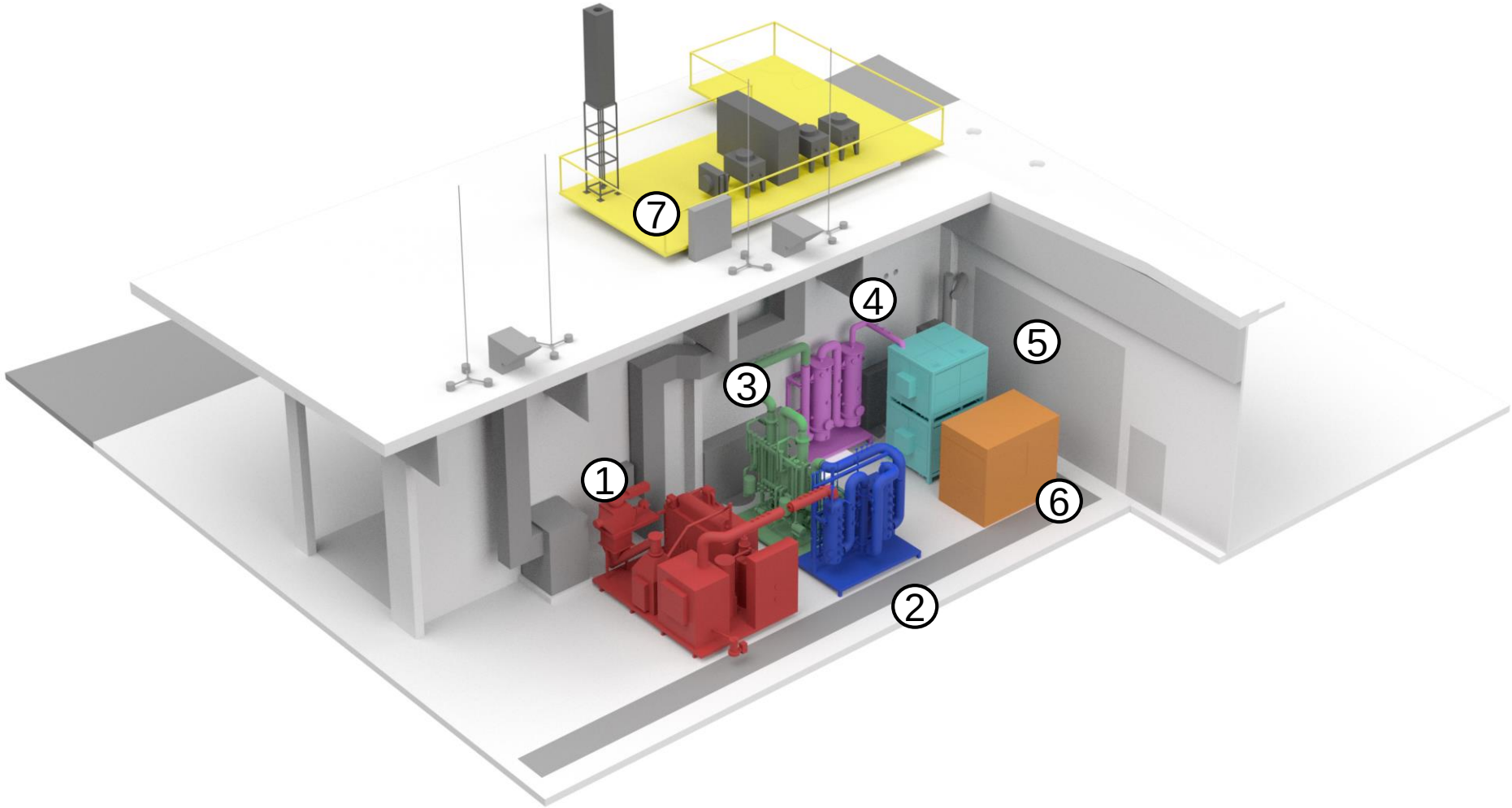
Table 2 — Fuel quality specification for PEM fuel cell road vehicle application

Constituents[a] (assay)	Type I, Type II grade D
Hydrogen fuel index (minimum mole fraction)[b]	99,97 %
Total non-hydrogen gases (maximum)	300 µmol/mol
Maximum concentration of individual contaminants	
Water (H_2O)	5 µmol/mol
Total hydrocarbons except methane[c] (C1 equivalent)	2 µmol/mol
Methane (CH_4)	100 µmol/mol
Oxygen (O_2)	5 µmol/mol
Helium (He)	300 µmol/mol
[a] For the constituents that are additive, such as total hydrocarbons and total sulphur compounds, the sum of the	

Constituents[a] (assay)	Type I, Type II grade D
Nitrogen (N_2)	300 µmol/mol
Argon (Ar)	300 µmol/mol
Carbon dioxide (CO_2)	2 µmol/mol
Carbon monoxide (CO)[d]	0,2 µmol/mol
Total sulphur compounds[e] (S1 equivalent)	0,004 µmol/mol
Formaldehyde (HCHO)[d]	0,2 µmol/mol
Formic acid (HCOOH)[d]	0,2 µmol/mol
Ammonia (NH_3)	0,1 µmol/mol
Halogenated compounds[f] (Halogen ion equivalent)	0,05 µmol/mol
Maximum particulate concentration[g]	1 mg/kg
[a] For the constituents that are additive, such as total hydrocarbons and total sulphur compounds, the sum of the	

Current Status on Site in Carinthia

3D Model of BioH_2Modul



(1) CHP plant

(2) Watergas-Shift unit

(3) Scrubber unit

(4) Adsorption unit

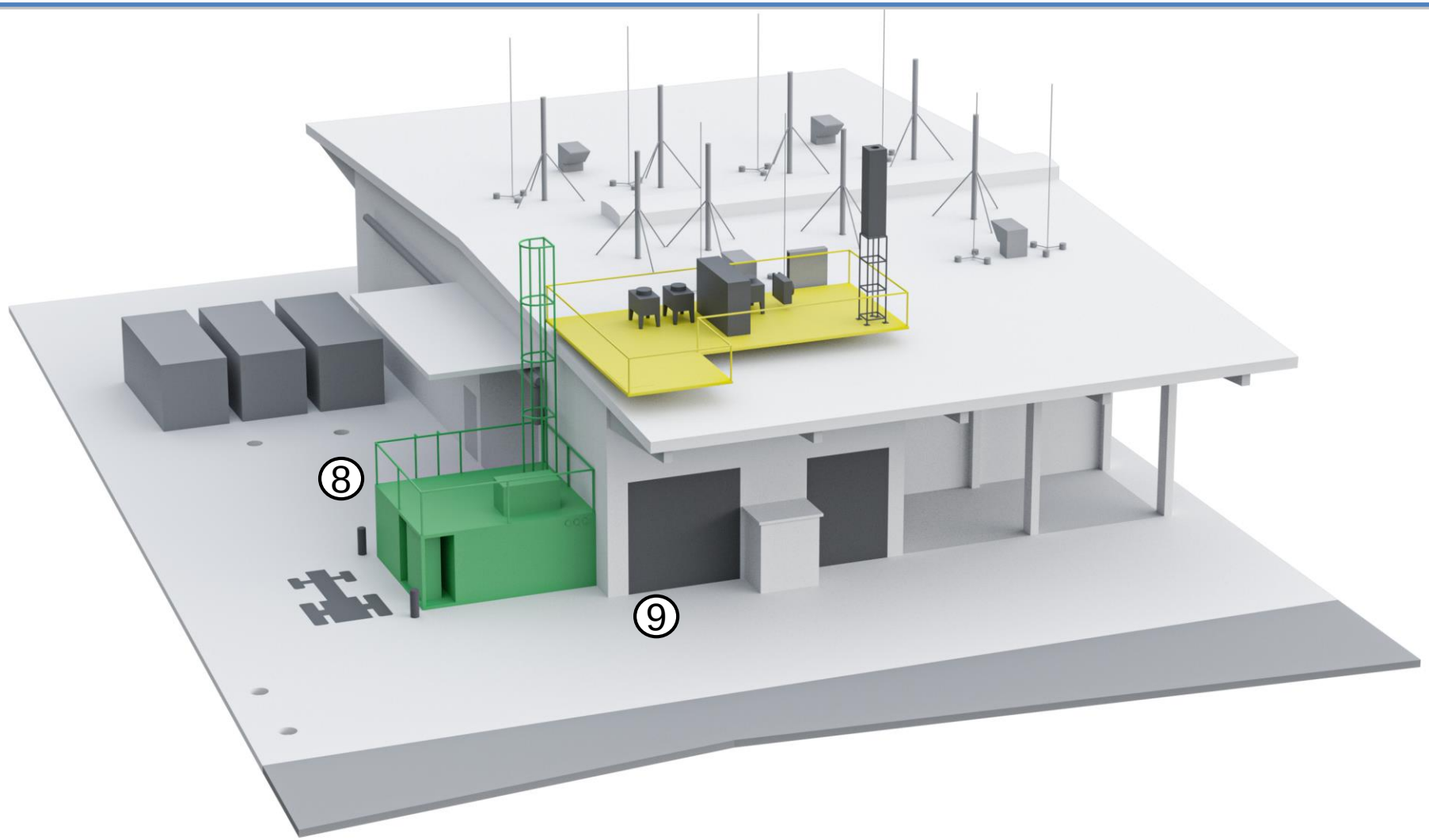
(5) Compressor unit

(6) Control station

(7) Auxiliary units

Current Status on Site in Carinthia

3D Model of BioH$_2$Modul

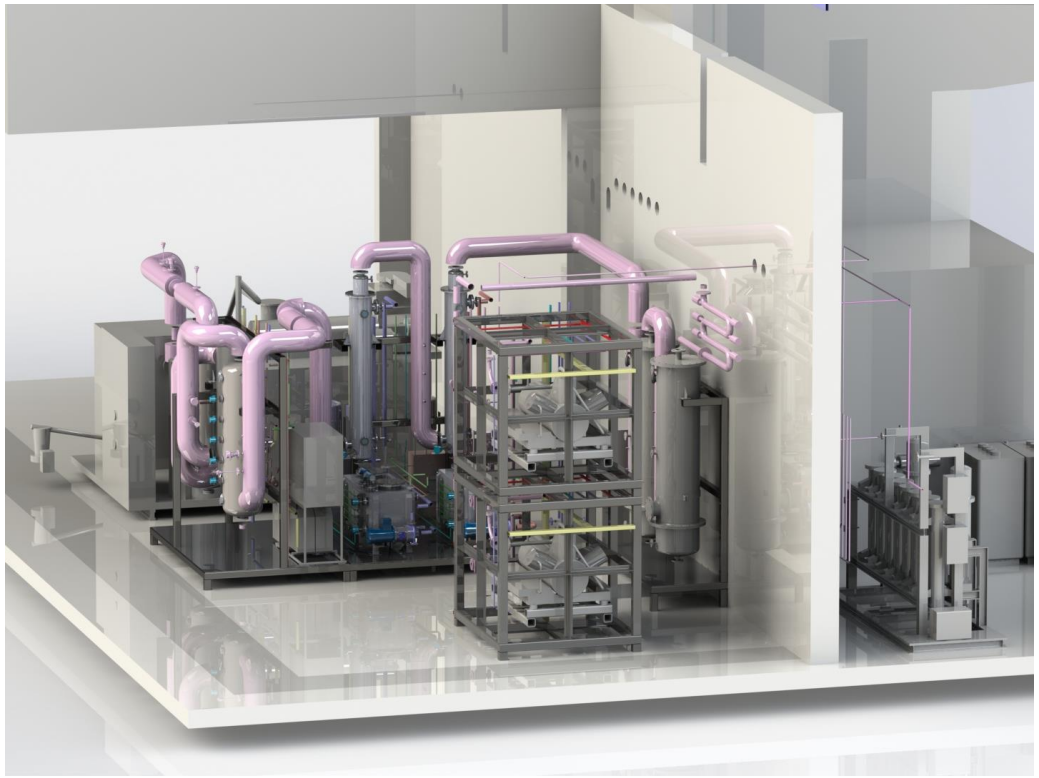


(8) Hydrogen refueling station

(9) Pressure swing adsorption unit

Next steps
Demonstration Operation of $BioH_2Modul$

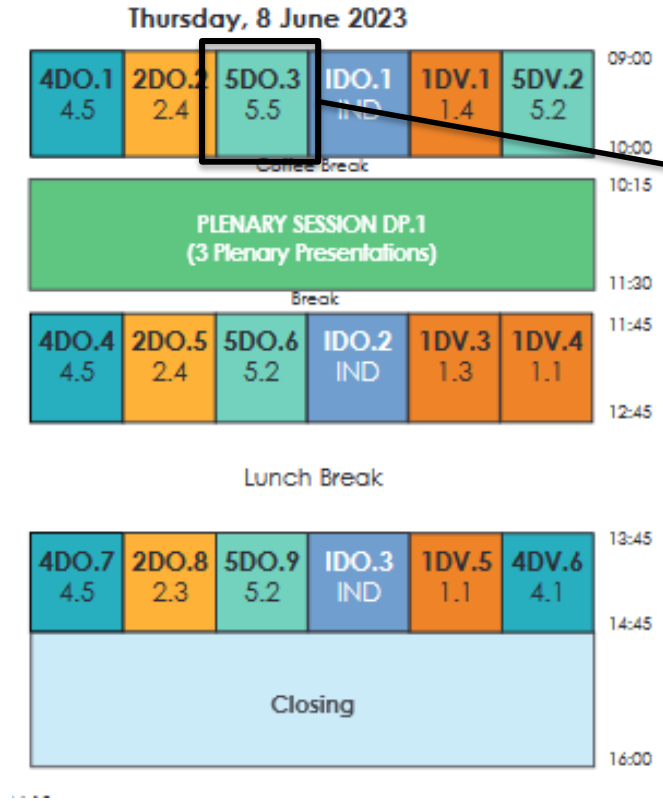
- Detail engineering and safety workshops completed
- Ongoing plant approval procedure
- Commissioning of $BioH_2Modul$ planned in September 2023
- Demonstration operation á 2 weeks
    1. Campaign: Steady-state operation
    2. Campaign: Parameter variations
    3. Campaign: Optimization
- Clarification of open issues in gas cleaning



Outlook
Techno-economic Analysis of BioH$_2$Modul

Presentation @ EUBCE 2023 in Bologna

“Techno-economic and Environmental Assessment of 1 MW Hydrogen Production from Woody Biomass Gasification”



VERONICA GUBIN

Vienna University of Technology,
AUSTRIA

Session reference: 5DO.3.4

▶ Techno-economic and Environmental Assessment of 1 MW Hydrogen Production from Woody Biomass Gasification

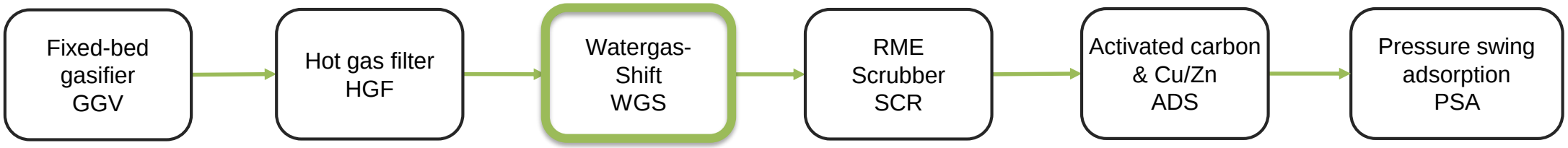
Mini-BioH$_2$Modul

Lab-scale Investigations at ICEBE Technical Laboratory

Fixed-bed gasifier GGV → Hot gas filter HGF → Watergas-Shift WGS → RME Scrubber SCR → Activated carbon & Cu/Zn ADS → Pressure swing adsorption PSA

Mini-BioH$_2$Modul

Lab-scale Investigations at ICEBE Technical Laboratory



Mini-BioH$_2$Modul

Lab-scale Investigations at ICEBE Technical Laboratory

Fixed-bed gasifier GGV → Hot gas filter HGF → Watergas-Shift WGS → RME Scrubber SCR → Activated carbon & Cu/Zn ADS → Pressure swing adsorption PSA

Procedure:

1. Adsorbent screening with manual operation of the PSA
   - Determination of the loading capacity X_i as a function of:
     - Adsorption pressure
     - Feed gas composition

   → „Breakthrough curves“

$$X_i(p_i) = \frac{Adsorbate\ mass}{Adsorbent\ mass}$$

2. Selection of adsorbents & determination of adsorbent quantities
   - E.g. activated carbon (AC) for CO_2- & zeolite (ZMS) for N_2-removal

3. Automated operation of the PSA

   →Determination of KPIs at selected operating parameters (Adsorption time, pressure levels, etc.)

Mini BioH$_2$Modul

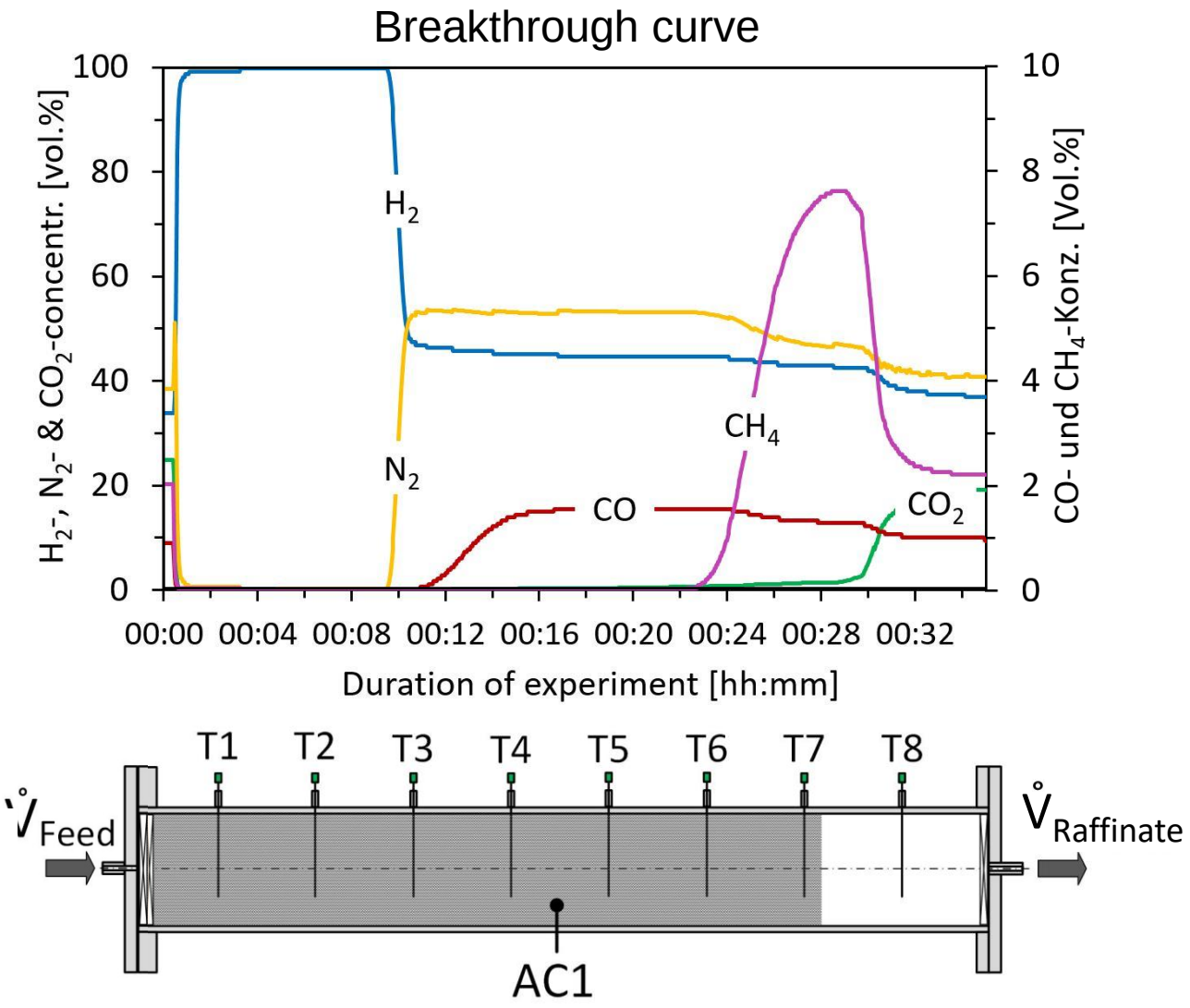
Experiments with a Lab-scale PSA Plant for H_2 Production from Synthetic Gas Mixtures

- Breakthrough curve
  - Adsorptive mass transfer zones (MTZs) migrate through adsorbent filling with different velocities

  → different breakthrough times $t_{BT,i}$

- Determination of the loading capacity X_i (of adsortive i):
  - Feed volumetric flow rate
  - Concentration of adsorptive i in the feed
  - Breakhrough time $t_{DB,i}$
  - Adsorbent mass $m_{Ads,k}$

- Temperature profile:
  - Estimation of the MTZ position in adsorbent filling



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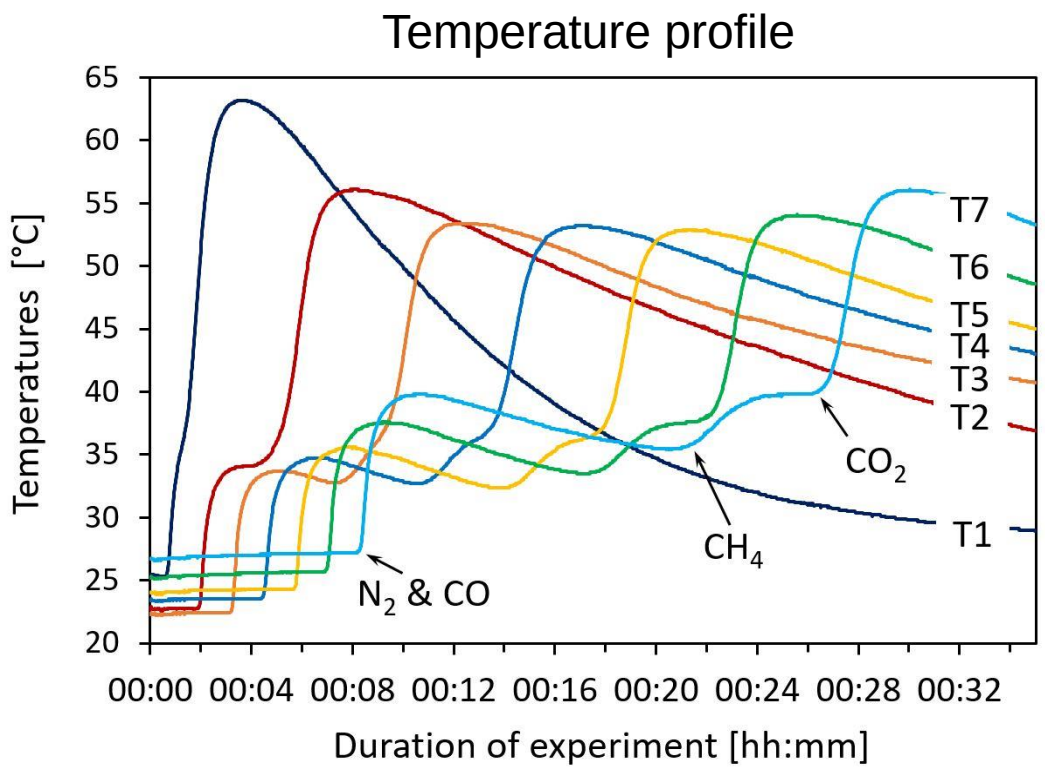


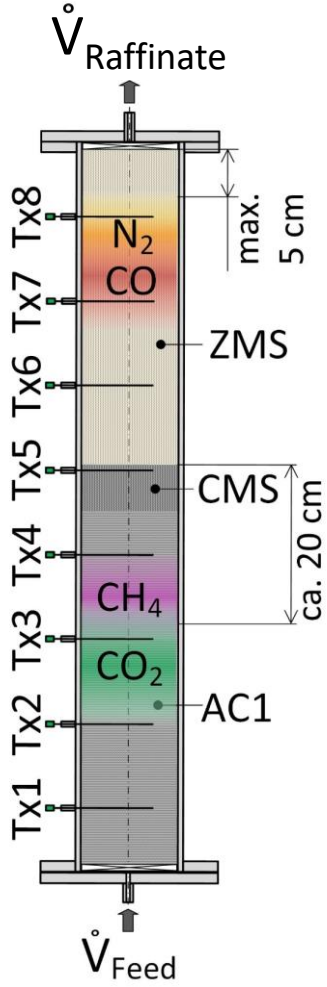
Mini BioH$_2$Modul

Experiments with a Lab-scale PSA Plant for H_2 Production from Synthetic Gas Mixtures

- By optimization of the experimental parameters:

Experimental parameters				
Parameters of adsorption				
Adsorption pressure (Reference)	p_{Ads} =	6,50	[bara]	
Pressure equalization at	p_{Equil} =	4,75	[bara]	
Adsorption time	t_{Ads} =	480	[s]	
Feed gas parameters				
Volumetric flowrate	$\dot{V}_{Feed}$ =	12,5	[slm]	

Process efficiency			
Key performance indicators: H_2-…			
Purity	φ_{H2} =	> 99,9	[Vol.%]
Recovery	Y_{H2} =	79,0	[%]
Productivity	P_{H2} =	1,33	[Nl/(kg·min)]

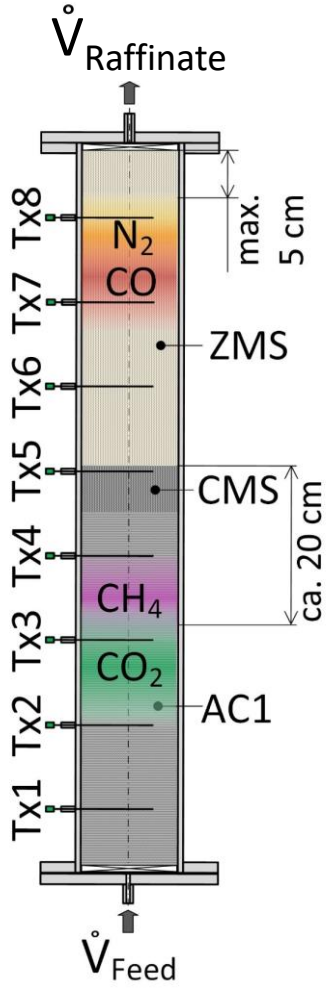


- By optimization of the experimental parameters:

Feed gas components	Raffinate composition	
	Reference (ISO 14687) [vol.%] bzw. *[vol.ppm]*	Obtained [vol.%] bzw. *[vol.ppm]*
H_2	> 99,97	> 99,9
N_2	*< 300*	*N.n.* [1)]
CO	*< 0,2*	*< 0,5* [1)]
CO_2	*< 2*	*< 5* [2)]
CH_4	*< 100*	*N.n.* [1)]

[1)] N_2-, CO- & CH_4-concentrations below detection limits of gas analysis. However, significantly lower concentrations than detection limit can be assumed
[2)] Continuing trend downwards

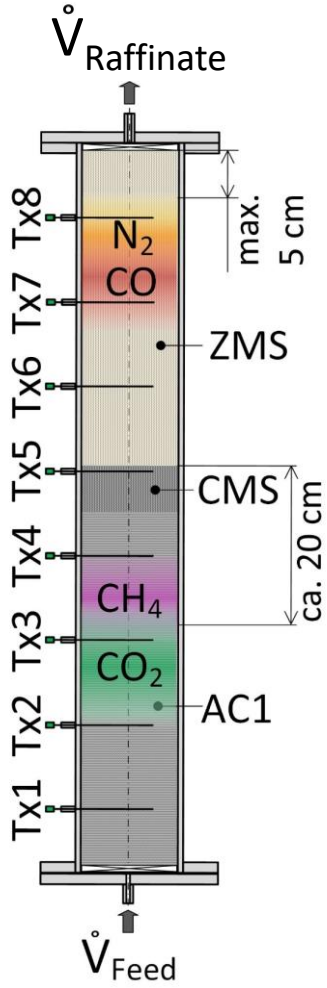
ISO 14687, „Hydrogen Fuel Quality – Product Specifications“, 2019



Achieved so far:

Process efficiency	Key performance indicators: H_2-…			
	Purity	φ_{H2} =	> 99,9	[Vol.%]
	Recovery	Y_{H2} =	79,0	[%]
	Productivity	P_{H2} =	1,33	[Nl/(kg·min)]

– For further improvement of the KPIs:
  - Adjustement of adsorbent filling → Recovery > 80% possible
  - Adsorbent screening of additional adsorbens
  - Mandatory: Improvement of gas analyis → Compliance with limits according to standard verifiable



Thank you for your attention!

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