



Fraunhofer Institute for
Environmental, Safety and Energy
Technology UMSICHT

Enhanced Carbon-To-X-Output Technology

An advanced technology for hydrogen-rich syngas production using staged gasification

Wolfgang Gebhard | Fraunhofer UMSICHT
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EXO – Enhanced Carbon-To-X-Output

Agenda

- Enhanced Carbon-To-X-Output process
- EXO-pilot plant
- Experimental investigations and results
- Summary & Outlook



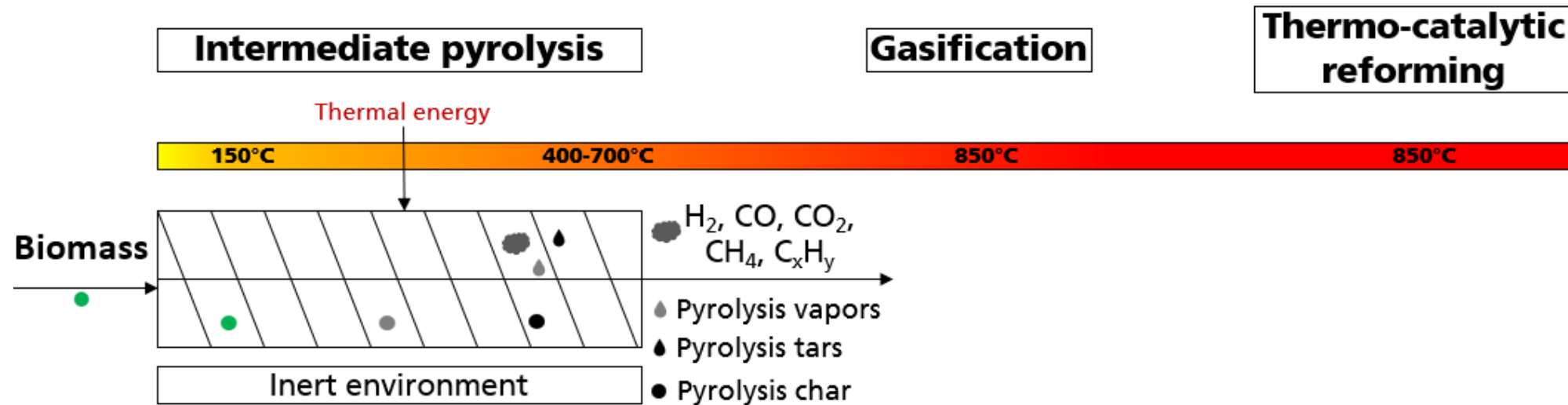
EXO – Enhanced Carbon-To-X-Output

Enhanced Carbon-To-X-Output Process



EXO – Enhanced Carbon-To-X-Output

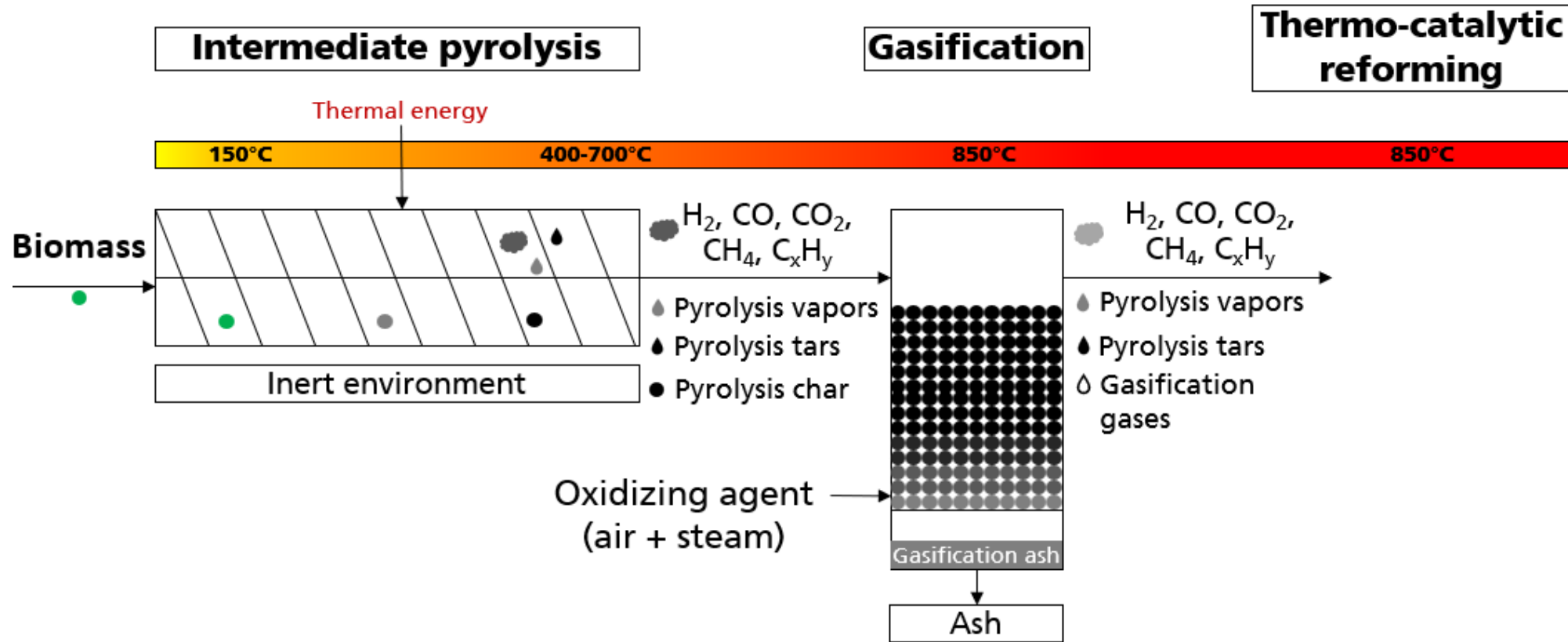
Enhanced Carbon-To-X-Output Process



H_2 – Hydrogen, CO – Carbon monoxide, CO_2 – Carbon dioxide, CH_4 – Methane, C_xH_y – Hydrocarbons

EXO – Enhanced Carbon-To-X-Output

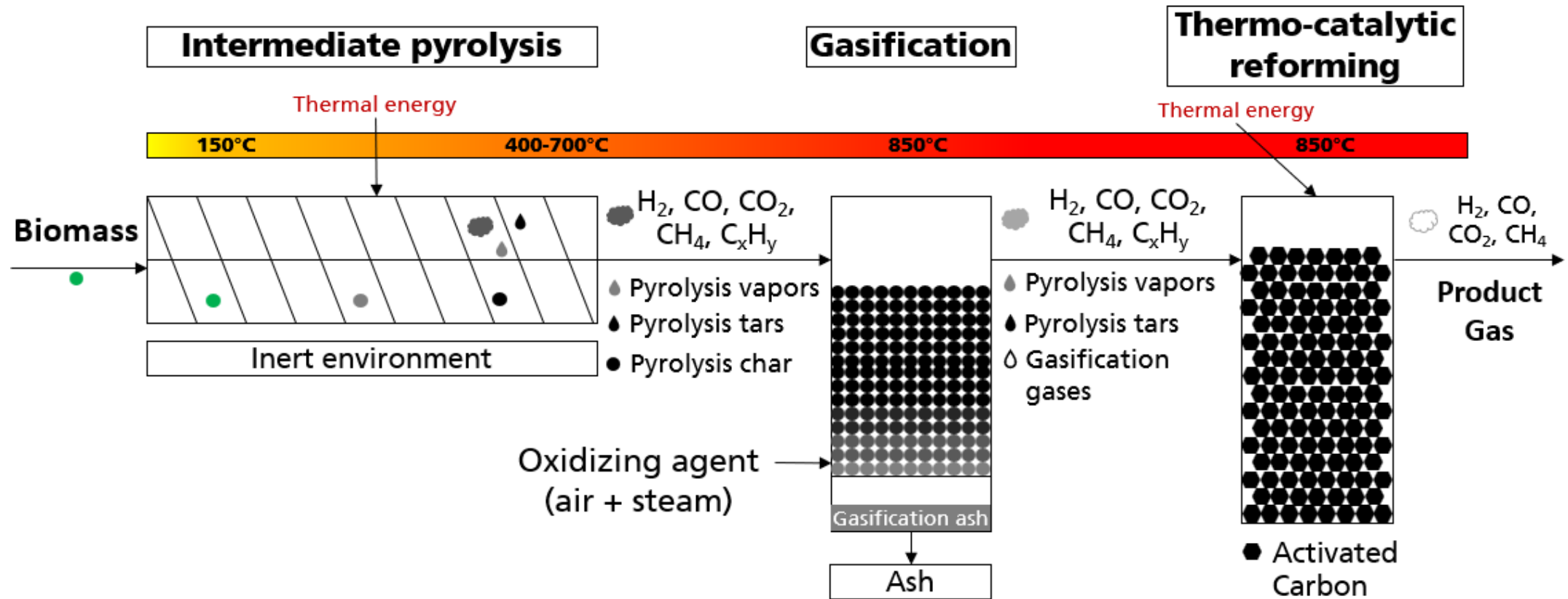
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Enhanced Carbon-To-X-Output Process



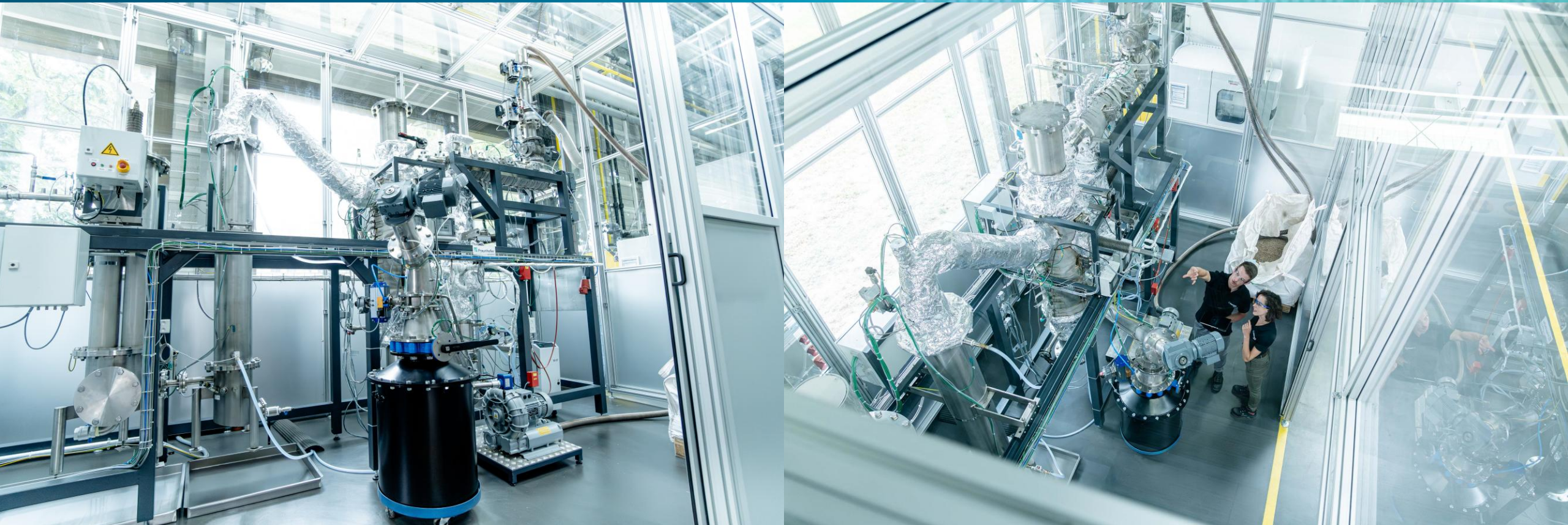
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EXO pilot plant at Fraunhofer UMSICHT Sulzbach-Rosenberg

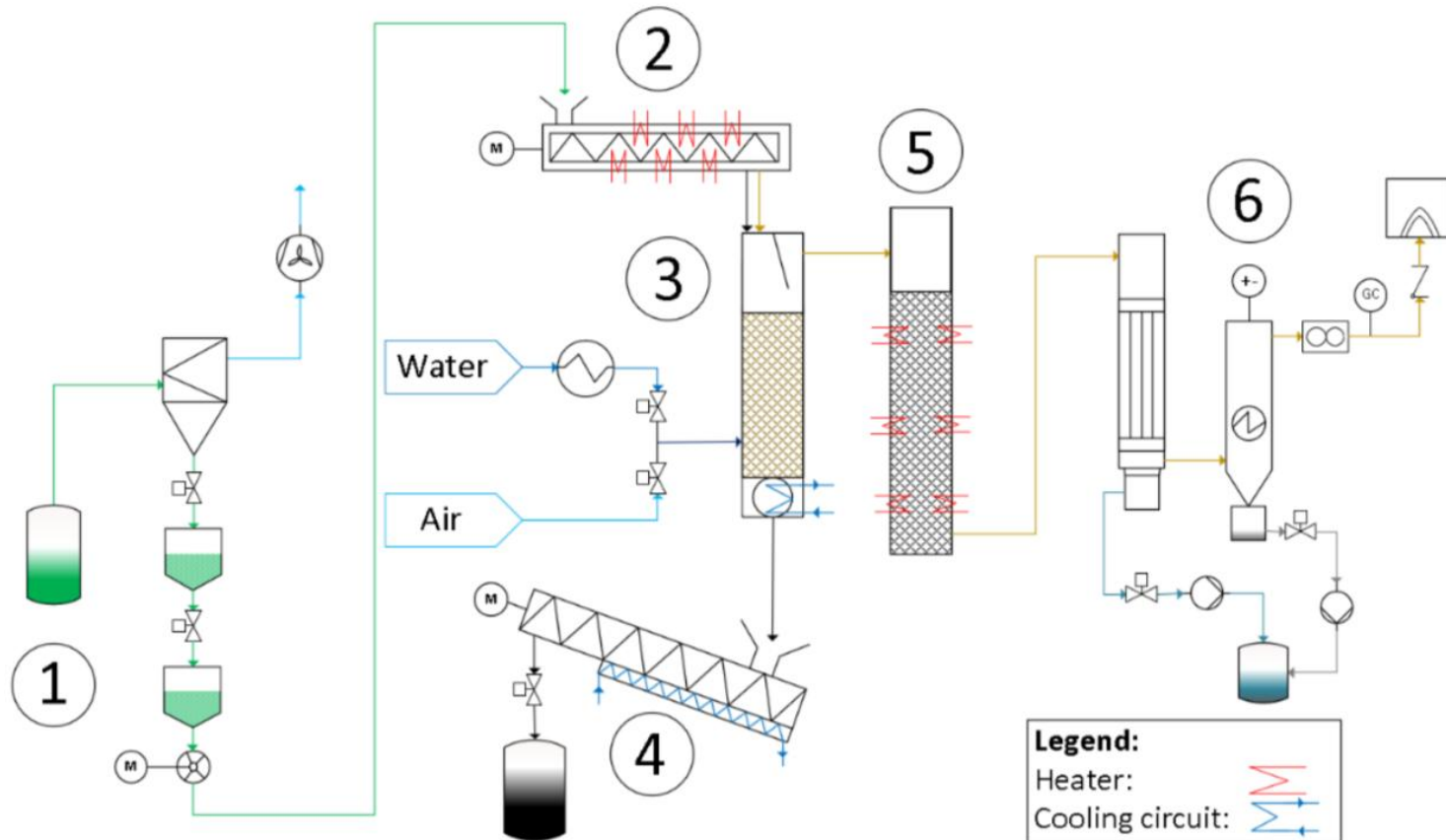


- Throughput of approx. 10 kg/h
- Conversion of ash-rich residue and waste biomass



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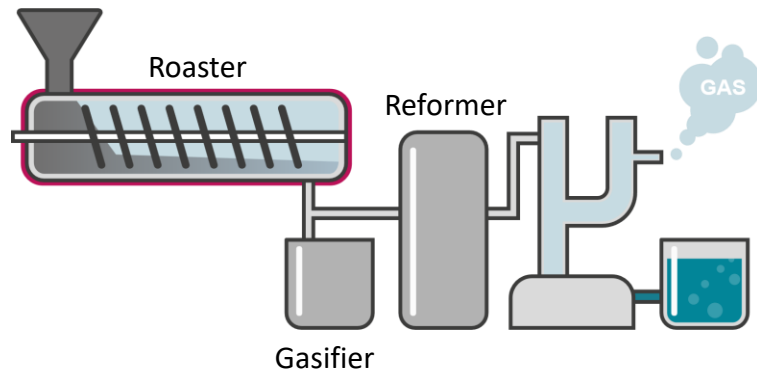
Process flow diagram of the pilot plant



1. Pneumatic feed system with a double-chamber sluice system
2. Pyrolysis screw reactor (Roaster)
3. Fixed bed counter-current gasifier
4. Ash discharge unit
5. Thermo-catalytic reforming reactor (Reformer)
6. Gas conditioning system, including cooling-unit and ESP

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Experimental investigations

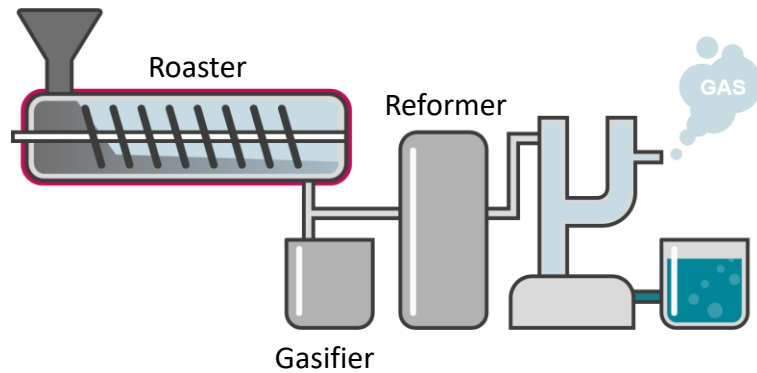


Operating conditions

Parameter	Unit	
Duration	h	4
Roaster temperature	°C	450
Gasifier temperature	°C	850
Reformer temperature	°C	900
Equivalence ratio (ER)		0.1
Feedstock throughput	kg _{wb} /h	12.68
Air supply	Nm ³ /h	5.06
Steam supply	m ³ /h	4.03
Nitrogen supply	Nm ³ /h	0.26

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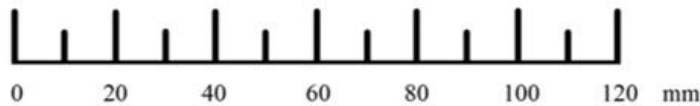
Feed characterization

Parameter	Unit	Sieve overflow from biowaste
Total water content	wt.% (wb)	3.8
C	wt.% (db)	44.5
H	wt.% (db)	5.4
N	wt.% (db)	1,63
S	wt.% (db)	0.169
O*	wt.% (db)	30.2
Ash content (550°C)	wt.% (db)	18.2
Higher Heating Value (HHV)	MJ/kg _{db}	18.2
Lower Heating Value (LHV)	MJ/kg _{db}	17.1

* Determined by difference

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Experimental results – gasifier ash characterization



- Mixture of primarily fine material with a small fraction of coarse structures
- Typical grey colour

Gasifier ash characterization

Parameter	Unit	
Total water content	wt.% (wb)	0.5
C	wt.% (db)	15.2
H	wt.% (db)	0.6
N	wt.% (db)	0.17
S	wt.% (db)	0.18
O*	wt.% (db)	6.7
Ash content (815°C)	wt.% (db)	77.2
Higher Heating Value (HHV)	MJ/kg _{db}	5.77
Lower Heating Value (LHV)	MJ/kg _{db}	5.64

* Determined by Difference

- Characteristic of the EXO-gasifier ash:
 - low carbon-content
 - high ash content
- Carbon-conversion in the gasifier unit of approx. 90%

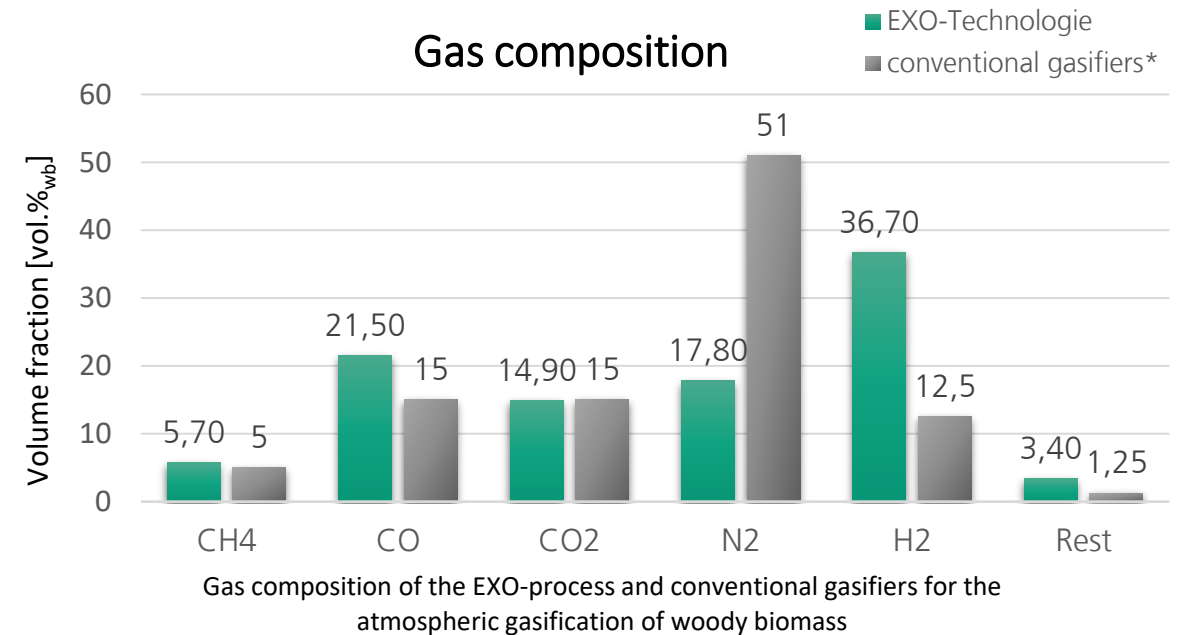
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Experimental Results – product gas characterization

Product gas characterization

Parameter	Unit	EXO	Conventional gasifiers*
Methane (CH ₄)	vol.% _{wb}	5.7	3 – 7
Carbon monoxide (CO)	vol.% _{wb}	21.5	9 – 21
Carbon dioxide (CO ₂)	vol.% _{wb}	14.9	11 – 19
Nitrogen (N ₂)	vol.% _{wb}	17.8	42 – 60
Hydrogen (H ₂)	vol.% _{wb}	36.7	6 – 19
Hydrogen sulfide (H ₂ S)	vol.% _{wb}	0.055	
Rest (C _x H _y)	vol.% _{wb}	3.345	0.5 – 2
Gas production	Nm ³ /h	15.27	
Gas yield	Nm ³ /kg _{Feed,wb}	1.2	1.7 – 2.2
Hydrogen production	g _{H2} /h	522.81	
Hydrogen yield	g _{H2} /kg _{Feed,wb}	41.23	
Lower Heating Value (LHV)	MJ/m ³ _{wb}	10.18	3 – 6.5

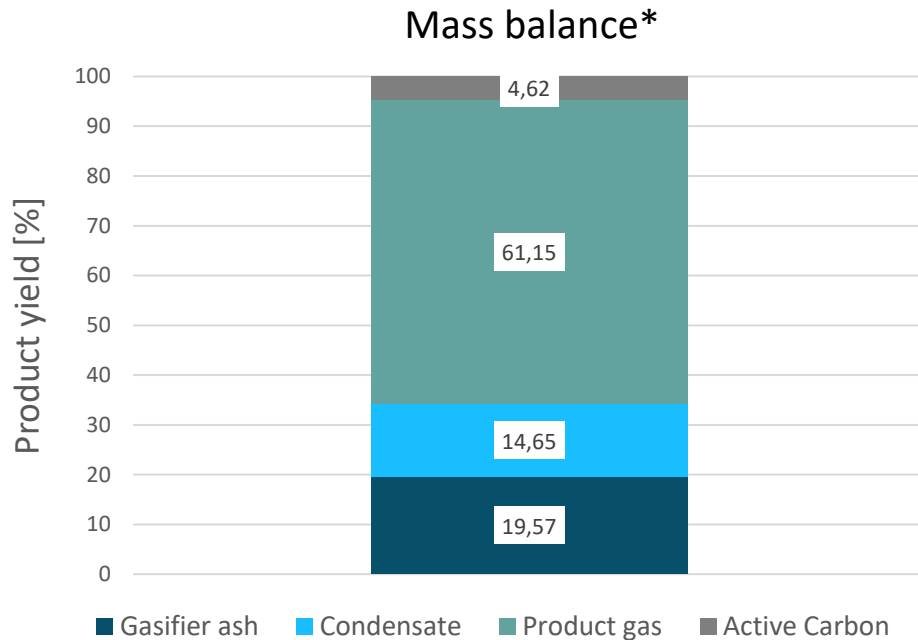
*KALTSCHMITT, Martin ; HOFBAUER, Hermann ; LENZ, Volker: *Energie aus Biomasse*. Wiesbaden: Springer Fachmedien Wiesbaden, 2024



- Characteristic of the EXO product gas:
 - High Hydrogen amount
 - H₂:CO ratio (1.71) → suitable for downstream syntheses
 - High calorific value (for a producer gas)
- Unnecessary downstream Shift-reactors
- High cold gas efficiency of approx. 79.3%

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Experimental Results – mass balance

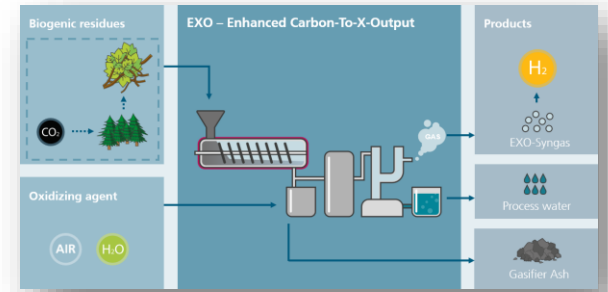


- High amount of gasifier ash, due to the high ash content in the feedstock
- Condensate without tars and oil, low organic fraction
- High amount of product gas
- Weight increase of the active carbon in the Reformer (adsorption and coking reactions of long-chain hydrocarbons)

* Balanced on the total plant input (consists of feedstock, air, steam, nitrogen)

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Summary and Outlook



1

Key findings:

- Successful demonstration of the conversion of ash-rich feedstocks
- Efficient and robust gasification technology
- Demonstration of alternative utilization pathways for sieve overflow from biowaste

2

Summary:

- Product gas hydrogen amount of 36.7 vol.%
- Hydrogen yield of $41.23 \text{ g}_{\text{H}_2}/\text{kg}_{\text{Feed,wb}}$
- Product gas yield of $1.2 \text{ Nm}^3/\text{kg}_{\text{Feed,wb}}$
- Cold gas efficiency of 79.3%

3

Outlook:

- Experimental campaigns with a focus on systematic parameter studies
- Further optimization of overall process efficiency
- Further optimization of the carbon conversion rate
- Continued development towards industrial applicability and scale-up

Thank you for your attention.

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