



EUBCE 2025
33rd European Biomass
Conference & Exhibition



Valencia,
Spain



9 - 12
June



Fraunhofer
UMSICHT

Fraunhofer Institute for
Environmental, Safety and Energy
Technology UMSICHT

Enhanced Carbon-To-X-Output Technology

– An Advanced Technology Combining Pyrolysis and Gasification of Biogenic Residues for the Production of Hydrogen-rich Syngas

Wolfgang Gebhard | Fraunhofer UMSICHT
10.06.2025

EXO – Enhanced Carbon-To-X-Output

Agenda



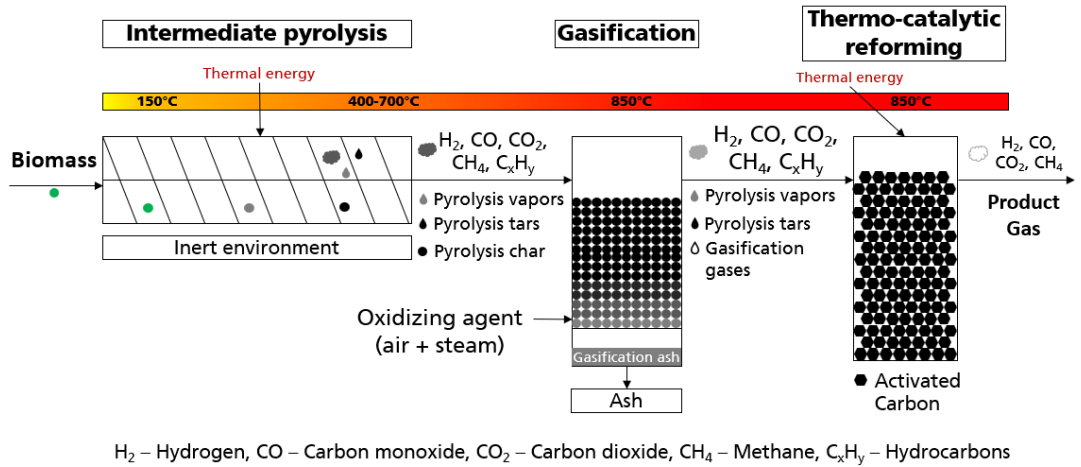
Fraunhofer

- 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



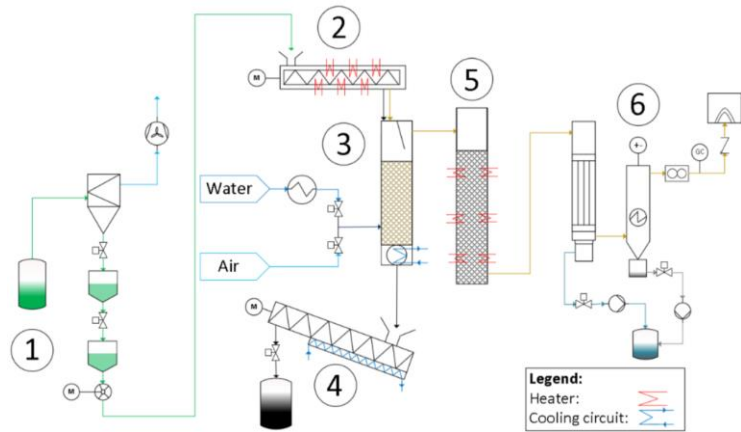
EXO – Enhanced Carbon-To-X-Output

EXO pilot plant at Fraunhofer UMSICHT Sulzbach-Rosenberg



EXO – Enhanced Carbon-To-X-Output

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. Catalytic reforming reactor (Reformer)
6. Gas conditioning system, including cooling-unit and ESP

EXO – Enhanced Carbon-To-X-Output

Experimental investigations

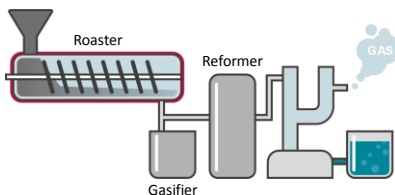
Operating conditions

Parameter	Unit	
Duration	h	4
Roaster temperature	°C	450
Gasifier temperature	°C	850
Reformer temperature	°C	850
Equivalence ratio (ER)		0.13
Feedstock throughput	kg/h	11.25
Air supply	m ³ /h	3.76
Steam supply	m ³ /h	4.89
Nitrogen supply	m ³ /h	0.3

Feed Characterization

Parameter	Unit	Sewage sludge
Total water content	wt. %	8.3
C	wt. % (db)	25.2
H	wt. % (db)	3.7
N	wt. % (db)	3.6
S	wt. % (db)	0.804
O*	wt. % (db)	14.8
Ash content (550°C)	wt. % (db)	51.9
Higher Heating Value (HHV)	MJ/kg	11.0
Lower Heating Value (LHV)	MJ/kg	10.20

* Determined by difference



EXO – Enhanced Carbon-To-X-Output

Experimental Results – Gasifier Ash Characterization



- Mixture of fine and pellet-like structures
- Reddish-brown colour (iron oxide)

Gasifier Ash Characterization

Parameter	Unit	
Total water content	wt. %	0.4
C	wt. % (db)	4.5
H	wt. % (db)	0.2
N	wt. % (db)	0.24
S	wt. % (db)	0.16
O*	wt. % (db)	0
Ash content (815°C)	wt. % (db)	94.9
Higher Heating Value (HHV)	MJ/kg	1.75
Lower Heating Value (LHV)	MJ/kg	1.70

* Determined by Difference

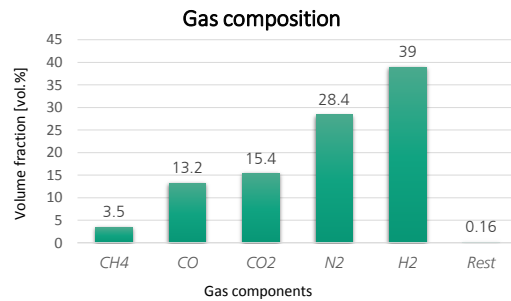
- Characteristic of the EXO Gasifier ash:
 - low carbon-content
 - high ash content
 - Low heating value
- Efficient Carbon-conversion in the gasifier unit of approx. 82.14%

EXO – Enhanced Carbon-To-X-Output

Experimental Results – Product Gas Characterization

Product Gas Characterization

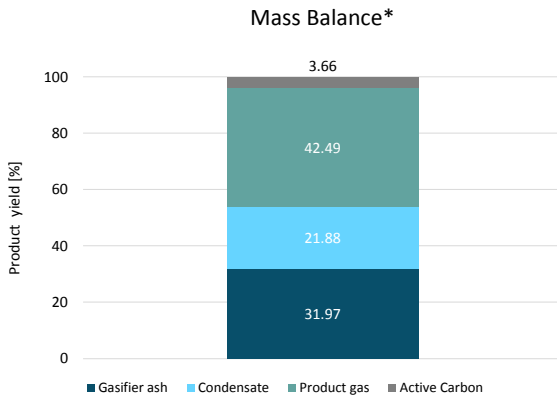
Parameter	Unit	
Methane (CH ₄)	vol. %	3.5
Carbon monoxide (CO)	vol. %	13.2
Carbon dioxide (CO ₂)	vol. %	15.4
Nitrogen (N ₂)	vol. %	28.4
Hydrogen (H ₂)	vol. %	39.0
Hydrogen sulfide (H ₂ S)	vol. %	0.34
Rest (C _x H _y)	vol. %	0.16
Gas production	m ³ /h	11.27
Gas yield	m ³ /kg _{Feed}	1.00
Hydrogen production	g _{H₂} /h	401.3
Hydrogen yield	g _{H₂} /kg _{Feed}	35.7
Lower Heating Value (LHV)	MJ/m ³	7.27



- Characteristic of the EXO product gas:
 - High Hydrogen amount
 - High H₂:CO ratio (3:1) → fits perfect for subsequent syntheses
 - High calorific value (for a producer gas)
- No following Shift-reactors are needed
- High cold gas efficiency of approx. 79.3%

EXO – Enhanced Carbon-To-X-Output

Experimental Results – Mass Balance



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

- 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)

EXO – Enhanced Carbon-To-X-Output

Summary and Outlook

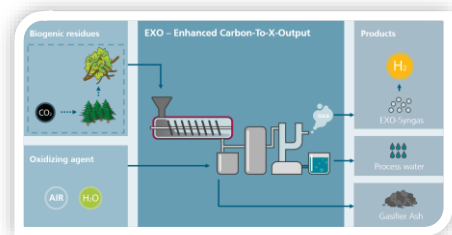
Summary

Experimental investigations show that

- ❖ The EXO technology provides an efficient possibility to convert ash-rich feedstocks into hydrogen-rich syngas
- ❖ The EXO product gas has a high hydrogen amount of 39 vol.%
- ❖ The EXO process offers a high hydrogen yield of 35.7 $\text{g}_{\text{H}_2}/\text{kg}_{\text{Feed}}$ and a product gas yield of 1.0 $\text{m}^3/\text{kg}_{\text{Feed}}$
- ❖ The EXO process has a high cold gas efficiency of 79.3%

Outlook

- ❖ Further experiments are conducted as part of parameter studies
- ❖ The EXO technology gets further optimized and to enhance the overall efficiency and applicability in industrial settings





Thank you



EUBCE 2025

33rd European Biomass Conference & Exhibition

9 - 12 June | Conference & Exhibition
13 June | Technical Tours
Valencia, Spain

eubce.com



Contact

Wolfgang Gebhard
Department Advanced Carbon Conversion Technologies
wolfgang.gebhard@umsicht.fraunhofer.de

Fraunhofer Institute for Environmental, Safety
and Energy Technology UMSICHT
Institute Branch Sulzbach-Rosenberg
An der Maxhütte 1
92237 Sulzbach-Rosenberg
www.umsicht-suro.fraunhofer.de



Fraunhofer Institute for
Environmental, Safety and Energy
Technology UMSICHT

This work was supported by the "Bayerisches Staatsministerium für
Wirtschaft, Landesentwicklung und Energie"