

## THE CONCEPT

A process assessment of an advanced plant for **Dimethyl-ether (DME)** production plant from biomass or waste is carried out in this work, addressing the need of a Diesel substitute contributing at the decarbonization of the transport sector. *FLEDGED H2020 EU project* investigates a new route for DME synthesis from biomass [1], aiming at process intensification and cost reduction.

The concept is based on the coupling of (i) a **flexible Sorption-Enhanced Gasification of biomass (SEG)** and (ii) a **Sorption-Enhanced DME Synthesis reactor (SEDMES)**:

• The SEG process consists of an **indirect gasification process** where a CaO-based sorbent material is circulated between the gasifier and combustor reactors [2]. The CaO reacts with the  $CO_2$  formed inside



the gasifier, enhancing the reactions towards hydrogen production.

The SEDMED relies on the presence in a single reactor of (i) a catalyst for direct DME synthesis and (ii)
a water sorbent [3]. Cyclic operation of reactors allows high single pass carbon conversion, avoiding off-gas recirculation.

Block diagram of reforming reactor and electrolysis unit integration in the Sorption-Enhanced DME synthesis plant

The **flexibility** of this process relies on the possibility of adjusting the composition of the syngas at gasifier outlet acting on the flow rate of the solids fed to the gasifier and on its temperature. The tailored syngas allows simplifying the syngas conditioning section, removing water gas shift reactor and CO<sub>2</sub> separation unit, therefore reducing the expected fuel production costs. Moreover, the gasifier operation can be modified to accommodate an **intermittent hydrogen addition** before the synthesis step.

## METHODOLOGY

Mass and energy balances of a stand-alone DME production plant have been solved using Aspen Plus. **Gasification** temperature is adjusted to obtain the desired M-module, defined as  $M = (H_2-CO_2) / (CO+CO_2)$ , at synthesis reactor inlet, namely a value of 2.

Due to the low gasification temperature, the methane content is high (up to  $6.28\%_{dry}$ ). Hence, **an auto-thermal reformer** is included, aiming at converting hydrocarbons to useful reactants (H<sub>2</sub>, CO and CO<sub>2</sub>), exploiting the high water content of the syngas.

The **SEDMES section** is not simulated in detail, but a fixed yield of 90% from carbon to DME is assumed and the sorbent minimum performance evaluated.

Auxiliary electrical consumption includes mainly the inter-cooled compression up to 25 bar and oxygen production for the reformer from an **air separation unit** (case A, 0.27  $kWh_{el}/kg_{02}$ ). Alternatively, an **electrolysis** system (case B, 52.4  $kWh_{el}/kg_{H2}$ ) provides O<sub>2</sub> and H<sub>2</sub>, importing electricity from the grid. Electricity is internally produced by a heat recovery steam cycle ( $\eta_{el}$  around 20%) and a co-generative ICE, the latter exploiting the synthesis offgas ( $\eta_{el}$  around 40%,  $\eta_{th}$  around 40%).

Results for a ligneous biomass input of 100 MW<sub>LHV</sub> (as-received, moisture 45%)

Performance indexes	No reformer	A – Reformer only	$B - P2X (O_2 from$
		(O <sub>2</sub> from ASU)	electrolysis)(1)
SEG			
Gasifier temperature [°C]	720.2	718.2	725.7
M at gasifier outlet	2.0	2.12	1.74
Captured CO <sub>2</sub> [% inlet C]	20.83	21.93	17.73
Biomass input to gasifier [%]	94.8	94.9	94.6
CGE <sub>SEG</sub> [%]	67.56	67.60	67.46
CGE <sup>u</sup> <sub>SEG</sub> [%] <sup>(2)</sup>	50.93	50.93	50.92
Reformer			
Temperature [°C]	-	800	800
CH <sub>4</sub> conversion [%]	-	99.9	99.9
S/C	-	4.19	3.83
CGE <sub>REF</sub> [%]	_	95.91	96.16
O <sub>2</sub> injection [kg/s]	_	0.45	0.43
SEDMES			
DME production [kg/s]	1.49	1.91	2.09
CGE <sub>SEDMES</sub> [%]	93.42	92.28	92.24
CGE <sub>PURIFICATION</sub> [%]	66.29	85.26	85.65
Overall			
CGE <sub>global</sub> [%]	42.91	54.95	60.29
EE [%]	9.12	3.24	-6.10
CGE <sub>eq</sub> [%]	58.64	60.74	51.11 (68.11 <sup>(3)</sup> )
Auxiliaries consumption [MW]	5.70	6.91	16.63

**Performance indexes** for the analysis are the cold gas efficiency (CGE) and the electrical efficiency (EE). An equivalent CGE considers the avoided consumption in a conventional biomass plant for producing the exported electricity with  $\eta_{el,ref}$  of 34%.



<sup>(1)</sup> Electrolysis system sized on oxygen demand, resulting in a 10 MW<sub>el</sub> unit
<sup>(2)</sup> This index considers only the contribution of reactants useful for DME synthesis (H<sub>2</sub> and CO)
<sup>(3)</sup> Electrolysis consumption excluded, if electricity it is not produced from additional biomass.

## **RESULTS and CONCLUSIONS**

- ✓ Methane reforming strongly increase DME production (+28%), with a consequent reduction of electricity export (-35%), that is the main objective of the plant. The equivalent CGE also increases, evidencing a positive impact on primary energy consumption.
- ✓ The substitution of the ASU with an electrolysis system (Power-to-X option) allows to further increase the DME production (+10%), requiring low-price electricity from the grid or dedicated RES

Comparison of performance indexes with selected literature, considering different technologies for biomass gasification (Air = air-fed gasifier, Oxy = oxy-fed gasifier) and DME synthesis (OT = Once-through, Rec = Products recirculation). Details in [1].

plants (negative electrical efficiency).

✓ The additional DME production due to hydrogen injection, with respect to the electricity provided to the electrolysis system is about 0.50 MJ<sub>DME</sub>/MJ<sub>EL</sub>, almost independently from the hydrogen flow.

✓ Plant performance is aligned with available literature and economic impact from process intensification has to be evaluated.

## **BIBLIOGRAPHY**

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[3] J. Boon, J. van Kampen et al., Reversible deactivation of γ-alumina by steam in the gas-phase dehydration of methanol to dimethyl ether, Catalysis Communications, 119 (2019), 22-27, doi:10.1016/j.catcom.2018.10.008

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