Prospects of Synthetic Renewable Methane production (methanation of CO_2 and H_2)

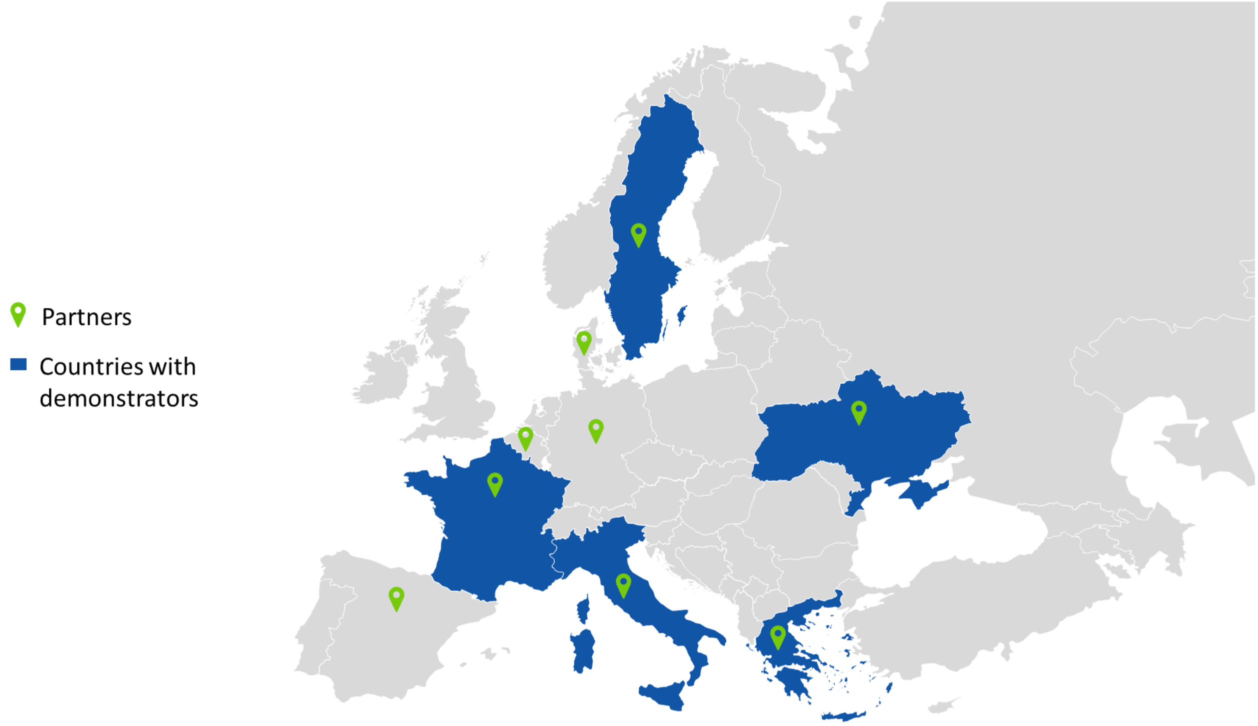
MHP "Ukraine", DBFZ & EE "Germany"

Co-funded by
the European Union

innovations in the BIOMETHAne uniVERSE

Project in a nutshell

- **BIOMETHAVERSE**: Demonstrating and Connecting Production Innovations in the **BIOMETHA**ne uni**VERSE (HORIZON EUROPE);**
- **54** months (October 2022- March 2027);
- **22** partners in **9** countries: ISINNOVA, ENEA, CAP, POLIMI, SIAD, CIC (**IT**), EBA (**BE**), FAU, DBFZ, EE (**DE**), UABIO, MHP (**UA**), BLAG, CERTH (**EL**), RISE, CORTUS, WARTSILA, SGA (**SE**), ENGIE (**FR**), AERIS, LEITAT (**ES**), DTU (**DK**);
- **9,871,773** € of EC funding (**70%** of EU funding);
- To **diversify** the technology basis for biomethane production in Europe, to **increase** its cost-effectiveness, and to **contribute** both to the uptake of biomethane technologies and to the priorities of the SET Plan Action 8.
- **Five innovative biomethane production pathways** in five European countries: France, Greece, Italy, Sweden, and Ukraine.



Co-funded by the European Union

Pillars of the project

- Demonstration of Innovative Biomethane Pathways
- Assessment and Optimisation of Innovative Biomethane Pathways
- Replicability, Planning Decisions, Market Penetration, and Policy Dimension
- Dissemination, Exploitation & Communication

Co-funded by the European Union

Demonstration of Innovative Biomethane Pathways

- **Design** and **implementation** of demonstration activities:
  - ✓ In-Situ and Ex-Situ Electromethanogenesis (**EMG**) in France
  - ✓ Ex-Situ Thermochemical/catalytic Methanation (**ETM**) in Greece
  - ✓ Ex-Situ Biological Methanation (**EBM**) in Italy
  - ✓ Ex-Situ Syngas Biological Methanation (**ESB**) in Sweden
  - ✓ In-Situ Biological Methanation (**IBM**) in Ukraine

- **Wrap-up** of demonstration activities

Co-funded by
the European Union

In-situ biological methanation (IBM)

Co-funded by
the European Union

Objectives

Demonstration of an innovative in-situ biological methanation pathway using a gas recirculation system, as well as the construction and implementation of a similar system and technology at a biogas plant in Ladyzhyn, Ukraine

- Increase the overall methane yield per given amount of feedstock, as well as the methane content (from ~55 % to ~85 %) of the produced biogas
- Provide a new design system in container-type DEMO installation for conducting research and testing on existing biogas installations in Ukraine and Europe

Co-funded by the European Union

Activities

A.1. Demonstration of an innovative IBM pathway in 50 L lab-scale reactors

A.2. Construction and installation of IBM demo reactor (10 m^3) at a biogas plant in Ukraine

A.3. Demonstration of IBM in the 10 m^3 demo reactor

A.4. Providing a concept for the implementation of IBM at biogas plants.

Co-funded by the European Union

A.1. Demonstration of IBM in 50 L lab-scale reactors

Task 1.1. Preparing the laboratory setup ✓

Task 1.2. Establishing a stable anaerobic digestion (AD) process ✓

Task 1.3. Establishing a stable IBM process ✓

Task 1.4. Determining process parameters ✓

Co-funded by the European Union

A.1. Demonstration of IBM in 50 L lab-scale reactors

➢ Laboratory setup

© Daniel N. Dzofou (DBFZ)

1: AD reactor
2: Mass flow controller
3: H_2 tank
4: Gas meter
5: Gas pump
6: Stirrer
7: Monitor
8: Water trap

© Ivan Traksler (MHP)

Co-funded by
the European Union

A.1. Demonstration of IBM in 50 L lab-scale reactors

➢ Operating parameters

Operating Parameters	Unit	MHP	DBFZ
Working volume of reactors	g	40,000	40,000
Temperature	°C	40 ± 1	42
Hydraulic Retention Time	days	100-120	50 - 70
Organic loading rate	(g_{VS}/L day^{-1})	1,8 ± 0.2	4 ± 0.2
daily feed (g FM)		**300-400**	**672 - 770**
Cow manure		✗	✓
Chicken manure		✓	✓
Corn sillage		✓	✓
Water		✓	✗
[illegible]		✗	✓

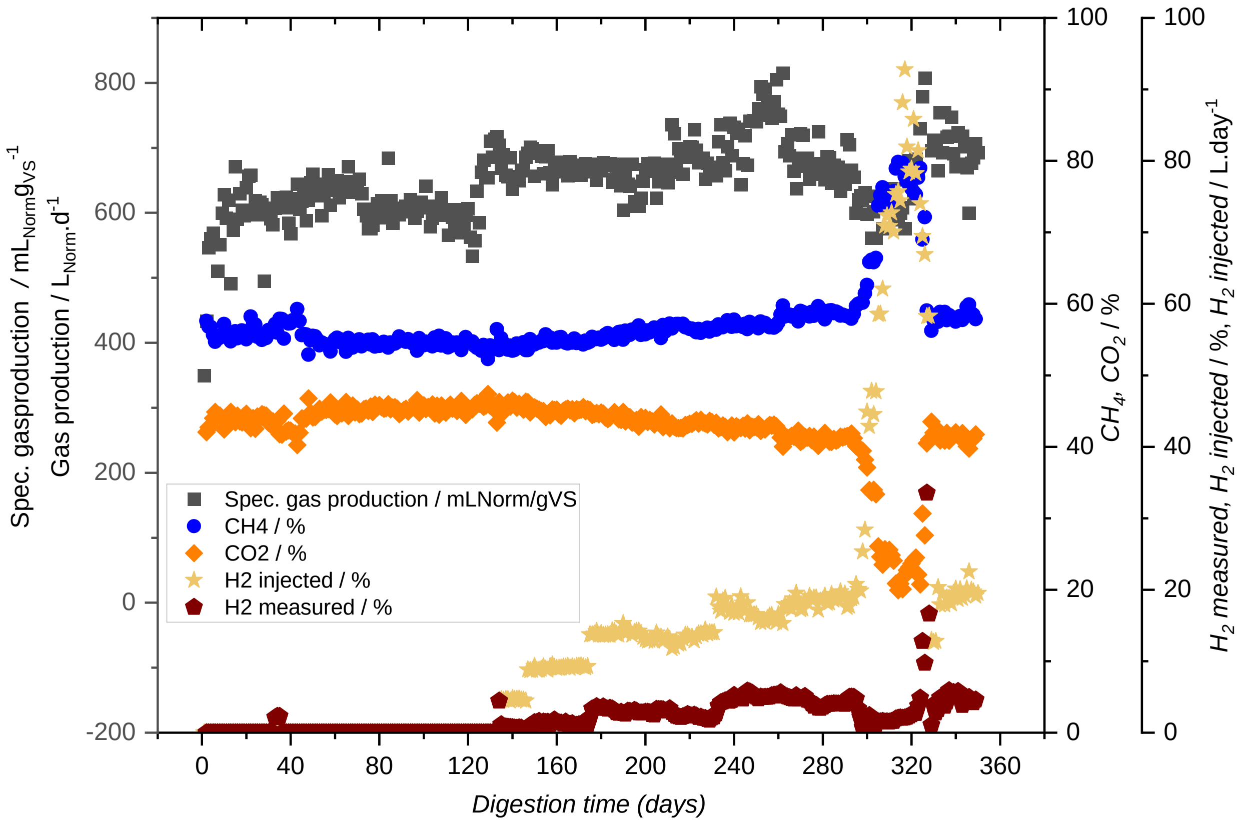
	Unit	Effluent		Cow manure		Chicken manure		Corn sillage	
		MHP	DBFZ	MHP	DBFZ	MHP	DBFZ	MHP	DBFZ
pH		8.00 ± 0.10	7.78 ± 0.13	-	7.23 ± 0.34	-	-	-	-
FOS/TAC	g_{FOS}/g_{CaCO3}	0.18 ± 0.10	0.19 ± 0.06	-	0.86 ± 0.35	-	2.33 ± 1.07	-	-
NH_4-N	$g.L^{-1}$	4.1 ± 0.40	3.40 ± 0.60	-	1.91 ± 0.21	7,50 ± 2,0	5.85 ± 5.16	-	-
TS	%	5.1 ± 0.4	8.63 ± 1.54	-	9.47 ± 0.95	74 ± 0.68	32.86 ± 1.48	37 ± 2	30.07 ± 3.76
VS	$\%_{TS}$	72.0 ± 8.15	73.93 ± 7.75	-	75.79 ± 1.35	85 ± 2.25	70.18 ± 5.20	95.19 ± 1.28	96.48 ± 0.74

Co-funded by the European Union

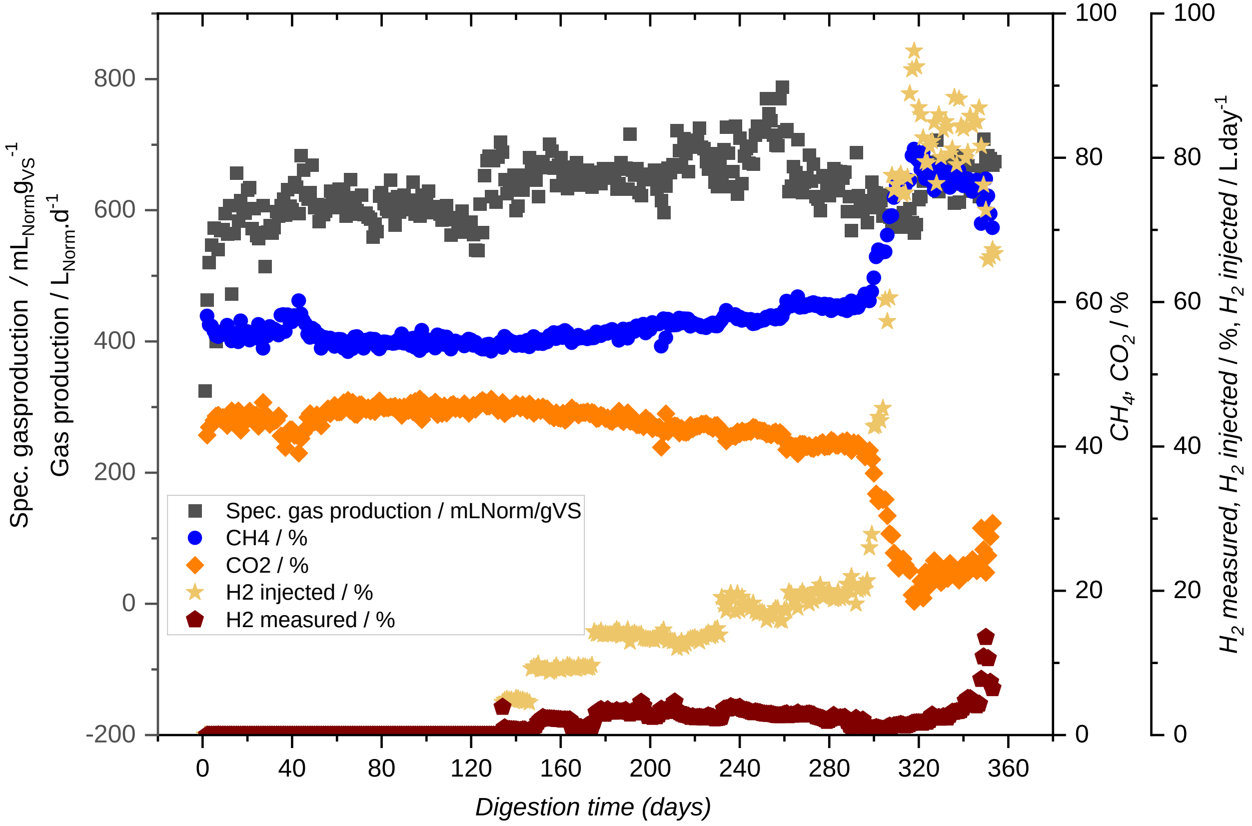
A.1. Demonstration of IBM in 50 L lab-scale reactors

Result to date: Specific biogas production, H_2 (injected & measured), CO_2 and CH_4 content in biogas

R1.19



R1.20



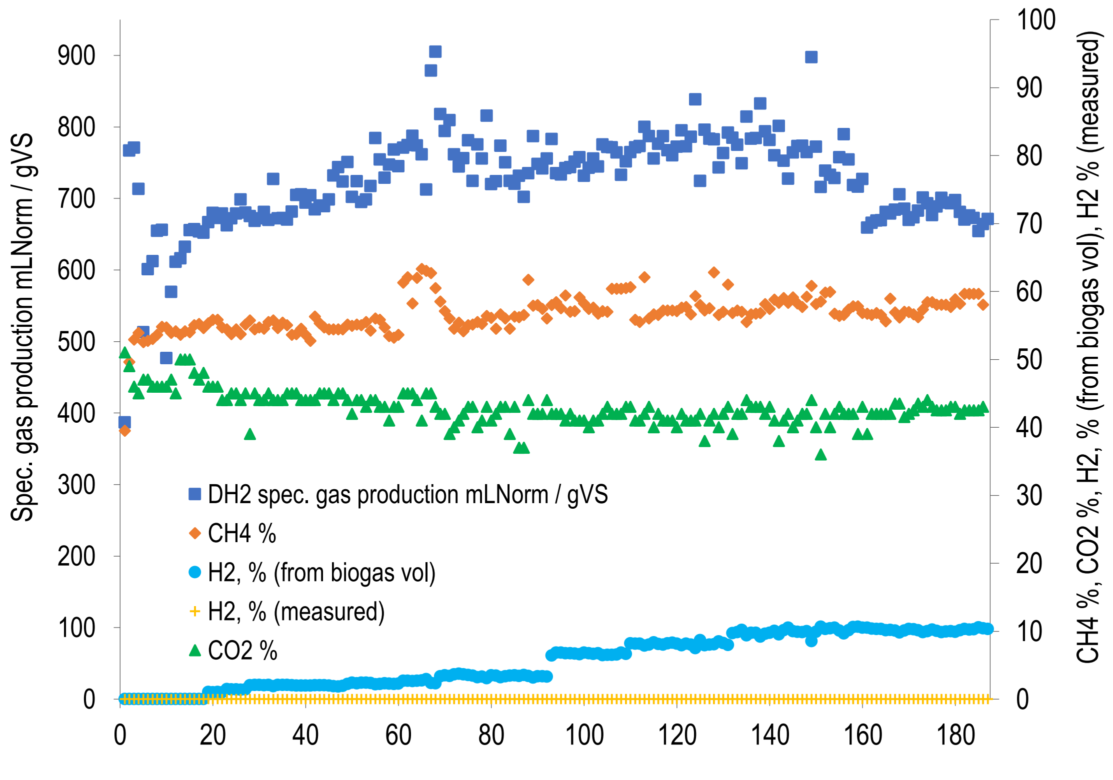
DBFZ reactors

Co-funded by the European Union

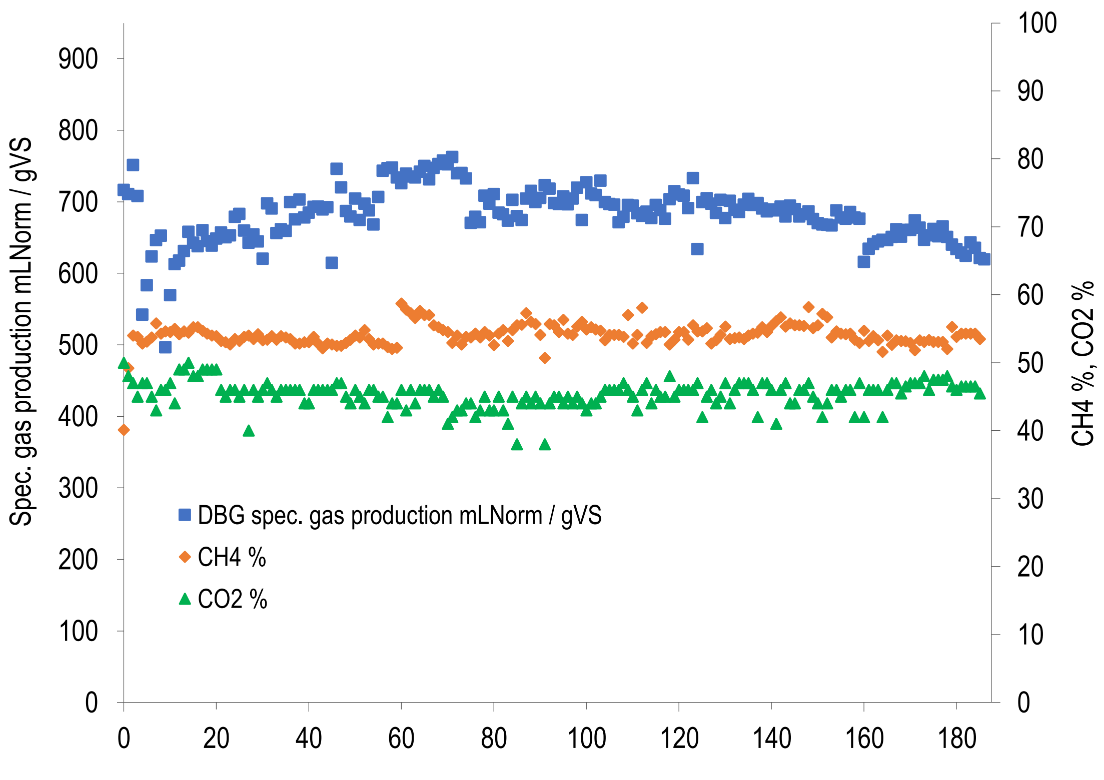
A.1. Demonstration of IBM in 50 L lab-scale reactors

Result to date: Specific biogas production, H_2, CO_2 and CH_4 content in biogas

With H2 injection



Without H2 injection



MHP reactors

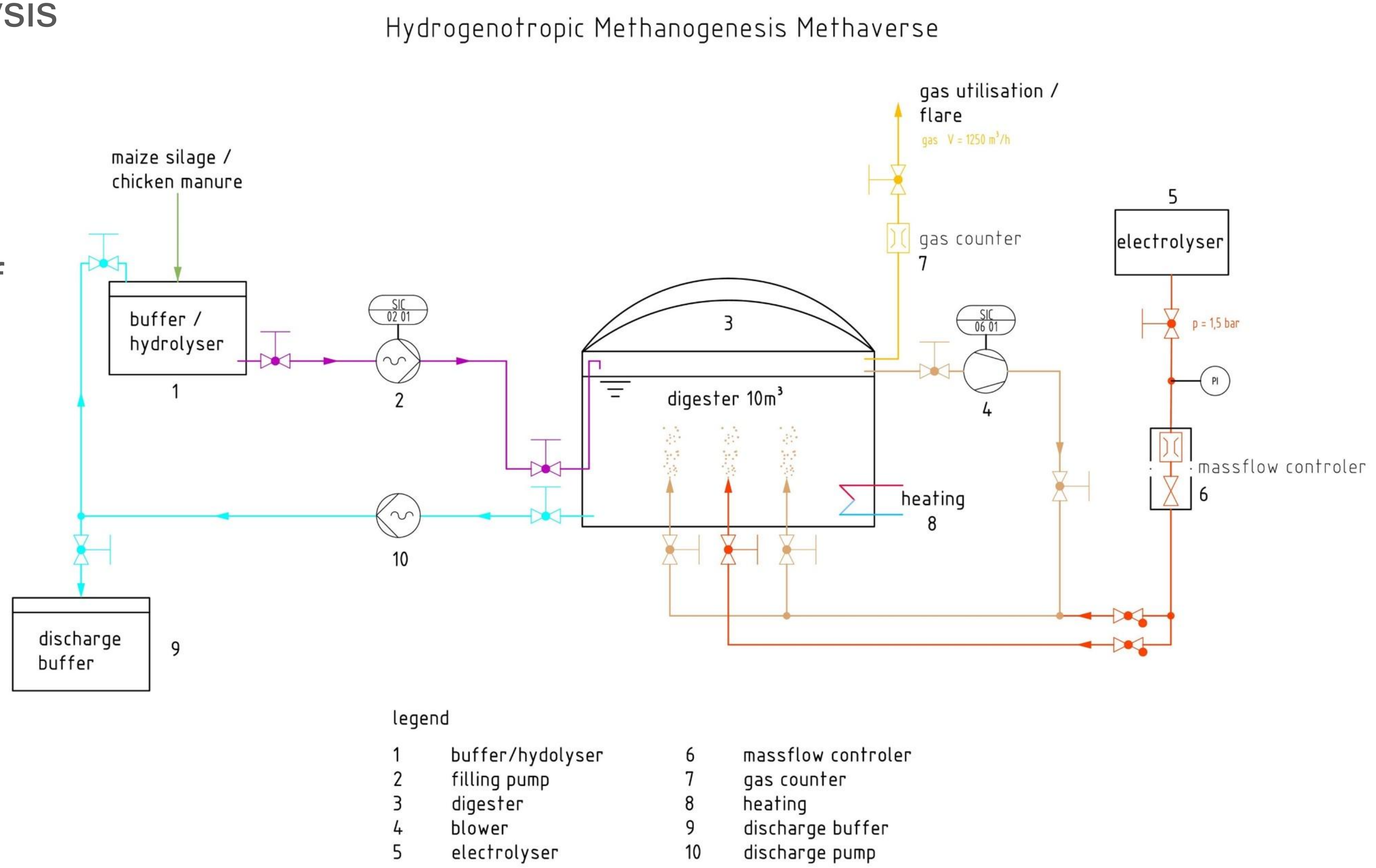
Co-funded by the European Union

A.2. Construction of an IBM demo reactor 10 m³

Pilot Plant concept

Ellmann Engineering
process solutions

Flow Chart Pilot Plant Ukraine



- Two-stage concept with separate hydrolysis
- Mesophilic main digester
- Fermenter circulation by gas injection
- Hydrogen dosing either simultaneously with gas circulation or independently
- Hydrogen dosing in a range of 2 - 40% of biogas production
- Automatic operation of the entire system
- Autonomous operation of the system without operating personnel possible for 1-2 days

Co-funded by the European Union

A.2. Construction of an IBM demo reactor 10 m^3

▪ Main Structure of the Plant

Ellmann Engineering
process solutions

- Standard sea container as a basis structure
- The system should be able to be transported using standard
- container trailers.
- The container is divided into the following separate sectors:
  - SCADA and control room
  - Electrolysis room
  - machine room
  - Digester
- Local provision limited to:
  - Electricity
  - Compressed air
  - communication
  - water
  - Waste water collection

Containerized In situ Demo Plant Ukraine

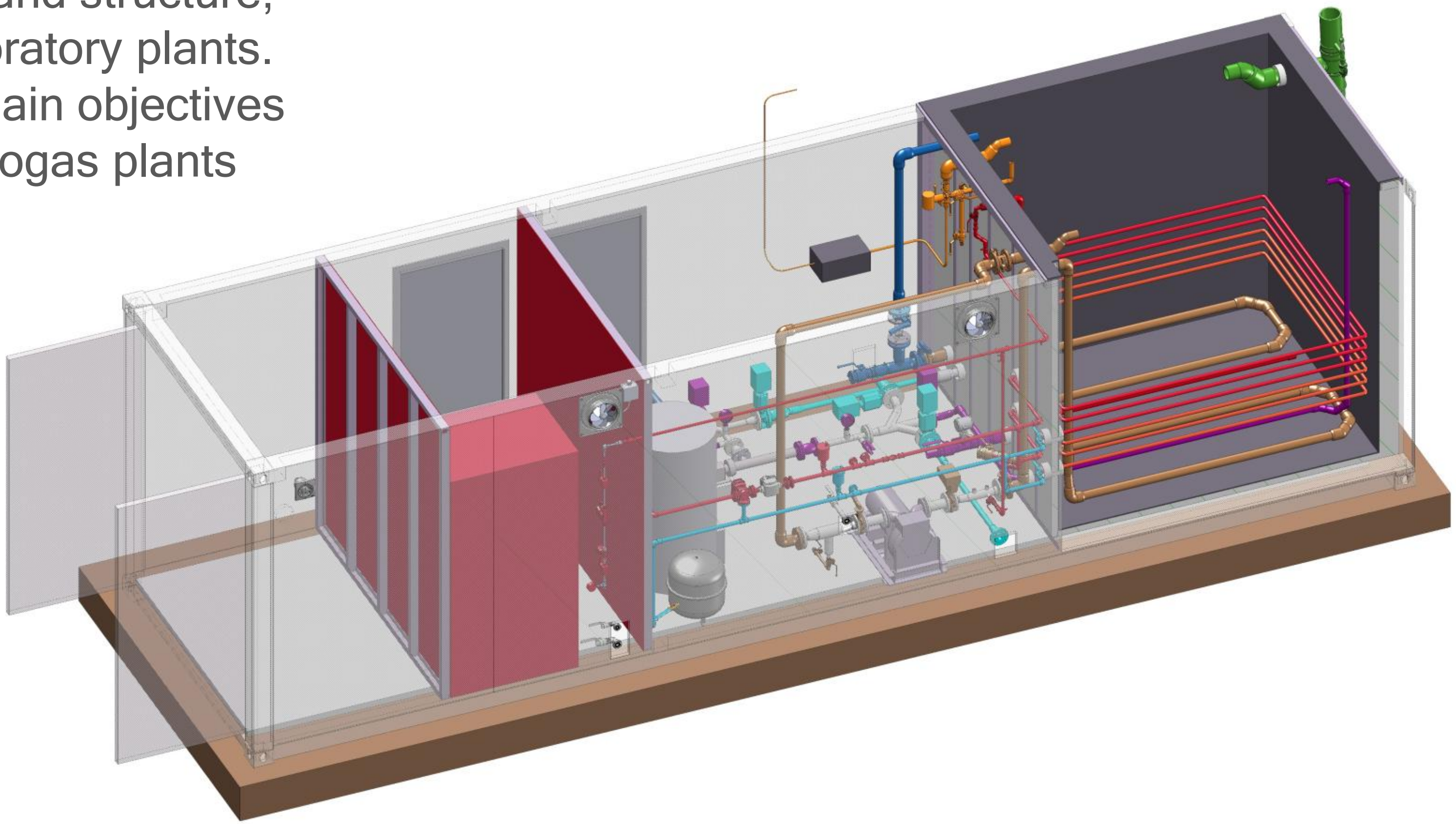
Co-funded by the European Union

A.2. Construction of an IBM demo reactor 10 m^3

▪ Technical Detailed Design

Ellmann Engineering
process solutions

Containerized In situ Demo Plant Ukraine



The pilot plant must have the essential characteristics of a conventional biogas plant in its equipment and structure, as well as mirroring the processes in the laboratory plants. This is all the more important as one of the main objectives of the research project is to retrofit existing biogas plants with IBM technology.
The following priorities therefore took centre stage in the design:

- Mesophilic process with temperatures between 37 - 45°C
- Gas circulation system in the fermenter, which corresponds to that of a large scale plant
- Integration of hydrogen distribution and injection into the gas circulation system.

Co-funded by the European Union

Demonstration of the electrolyser

Electrolyser purchased ✓
Commissioning works have been completed ✓
First green hydrogen produced ✓
Use of hydrogen for laboratory research ✓

1: Electrolyser
2: Hydrogen line
3: Hydrogen tank
4: Hydrogen sensor
5: Electricity control cabinet
6: Water purification system
7: Solar electricity storage system
8: GSM modem
9: Solar panels

Co-funded by
the European Union

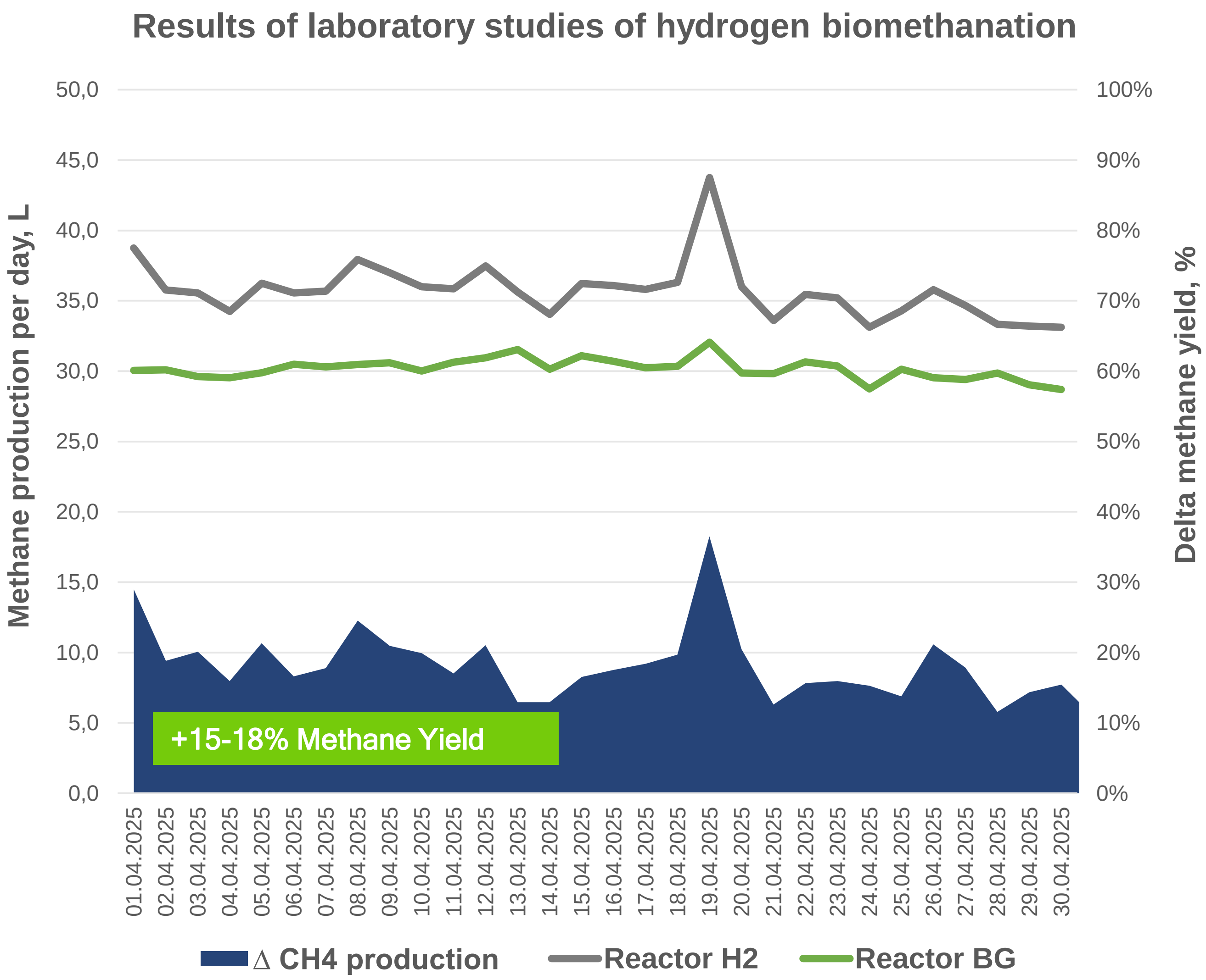
A.2. Construction and installation of an IBM demo reactor 10 m^3

- All equipment purchased ✓
- A 10 m^3 reactor was manufactured ✓
- The reactor heating system was tested ✓
- Connection of technical equipment ✓
- Electrical connection of technical equipment ✓
- Commissioning and start-up (end of 2024) ✓

1: Control system (SCADA)
2: Substrate feeding system
3: Heating system
4: Air compressor
5: Gas mixing system
6: Biogas pressure sensor
7: Gas meter
8: Hydrogen mass flow controller
9: Gaswarning system

Co-funded by the European Union

Results and Economic Prospects



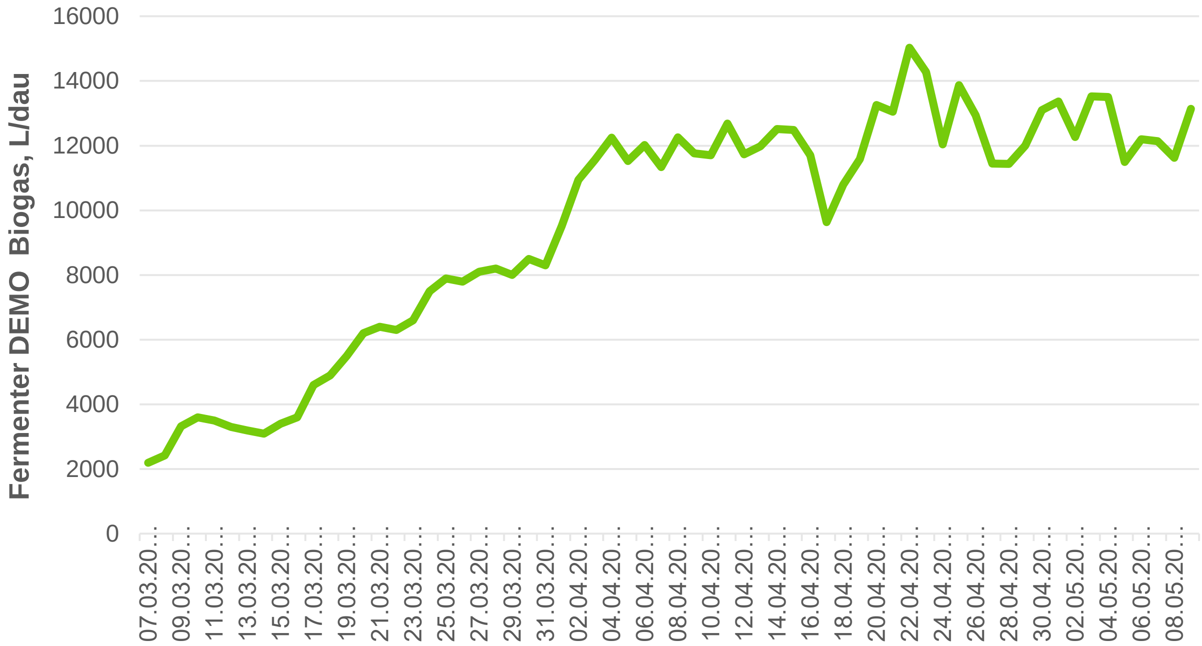
- Methane production increased by **15-18% daily** compared to the control reactor.
- 1 L of methane is obtained per **1-1,2 L** of hydrogen added
- Efficient electrolyzers (4.8-5.5 kWh/m³ H_2) and a biomethane price of ≥1,000€/1000* m³ make the technology profitable.

Parameters	Value
Volume of biomethane, m³	1000
Volume of hydrogen, m³	1200
Electricity consumption per 1 m³ of hydrogen, kWh	5.0
Electricity price, €/MWh	60
Total electricity cost for hydrogen production, €	360
Net Energy Margin (at a biomethane price of 1,000€ / 1000 m³), €	**640 €**

*agriportance GmbH. (2025, March 24). *Preisentwicklung von Biomethan | Hier verfolgen.* Agriportance GmbH. https://agriportance.com/de/preisentwicklung/biomethan-entwicklung-preise/

Co-funded by the European Union

Demonstration of IBM in 10 m³ Pilot Plant



Operating Parameters	Unit	Value
Volume of pilot plant	m^3	10
Temperature	°C	39
Hydraulic Retention Time	days	30 - 35
Organic loading rate	(g_{VS}/L day^{-1})	2.5 ± 0.2
pH		8.50 ± 0.10

Daily feed (kg FM)		300 - 320
Cow manure		280 - 300
Corn sillage		10 - 20
Output		
Biogas	L/day	12 000 ± 500
CH_4	%	59 ± 1

Co-funded by the European Union

IBM Demo Reactor. Key Technical Challenges

Demo-Scale Challenges:

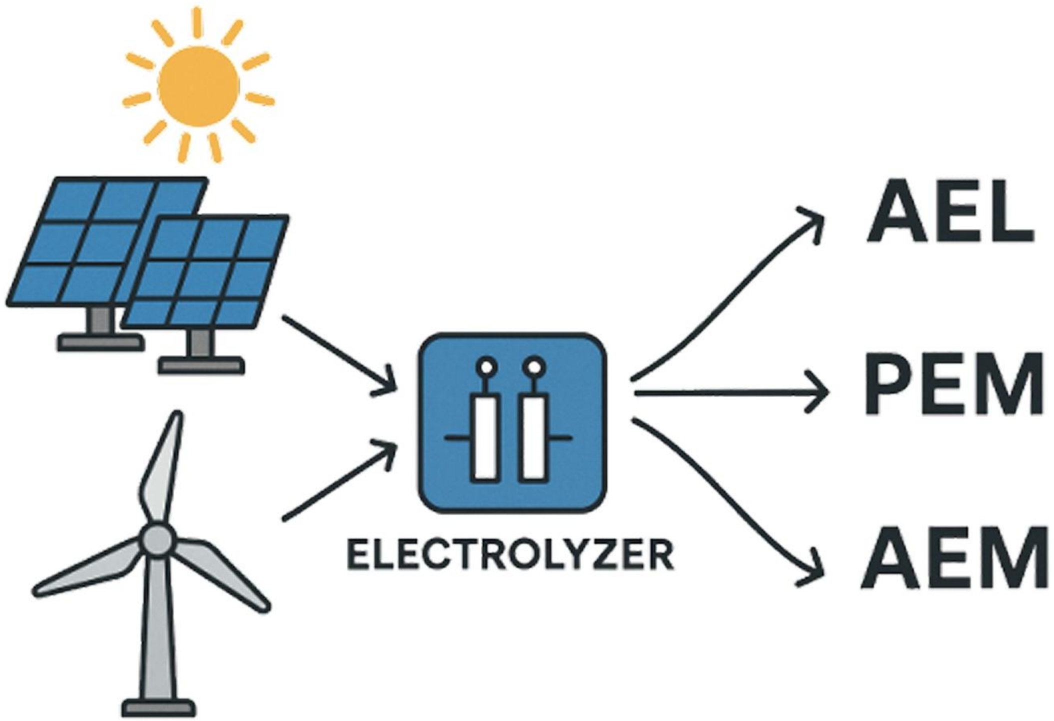
- High Energy Consumption for H2 Production. Solution: Deploying a containerized demo unit powered by solar panels and energy storage, ensuring continuous, cost-effective hydrogen generation.
- Organic Loading Rates (OLR). OLR affects hydrogen-to-methane transformation efficiency. We maintain an optimal OLR of ≥2.5 kg oTS/m³/day to ensure stable results.
- Ammonium Nitrogen Concentration. High ammonium nitrogen levels hinder hydrogen transformation. Using a feedstock mix with 2.5–3 g/L ensures process efficiency.

Industrial-Scale Challenges

- Scaling. Expanding the biogas plant to 1 MW requires further development of energy storage solutions, especially for renewable sources like solar, wind energy.
- High OLR. Industrial biogas plants operate at organic loading rates ≥3 kg oTS/m³/day, which presents a challenge since lab-scale experiments yield better results at lower loading rates. Optimizing the process for high OLRs remains a critical area of research.
- Mixing Systems: The shift from sparging (used in lab/demo setups) to mixer-based systems in industrial plants requires new methods for evenly distributing hydrogen in the fermenter to ensure efficient hydrogen-to-methane conversion.

Co-funded by
the European Union

Comparison of Electrolysis Technologies for Green Hydrogen Production



Technology	Hydrogen Production Efficiency	Investment Costs	Key Features
Alkaline Electrolyzer (AEL)	5-5.5 kWh/m³	\$7,000 - \$10,000	- Suitable for stable operations - Lower water consumption - Needs additional water treatment equipment
PEM Electrolyzer (PEM)	5.8-7 kWh/m³	€25,000+	- Ideal for flexible, high-purity hydrogen production - No lye management required - Quick and efficient
Anion Exchange Membrane (AEM)	4.8 kWh/m³	€15,000 - €20,000	- Cost-effective - Moderate water usage - Requires additional water treatment

Co-funded by the European Union

Policy expertise

Bioenergy Association of Ukraine UABIO

WP4 (Replicability, Planning Decisions, Market Penetration, and Policy Dimension)

D4.2 Biomethane Planning Decision Guide

Key messages:

- Export-oriented biomethane production
- 4 biomethane plants in Ukraine, total capacity - 41 million m3/year
- Focus on advanced materials for biomethane production (Annex IX to RED III)
- The need for synchronization of the Ukrainian biomethane register with the EU database
- No national support scheme for biomethane production in Ukraine. Only large investment projects – especially those exceeding €12 million – may be eligible for targeted state support
- At least 7 plants with a total capacity of 110 million m3/year are expected to be commissioned by the end of 2025

Co-funded by the European Union

Communication expertise

Bioenergy Association of Ukraine

- ✓ takes part in policy consulting activities for governmental authorities and professional discussions
- ✓ provides dissemination through channels – website, YouTube, Facebook, LinkedIn, etc.

WP5 (Dissemination, Exploitation & Communication)

Preparation of the Ukrainian version of the project newsletter:

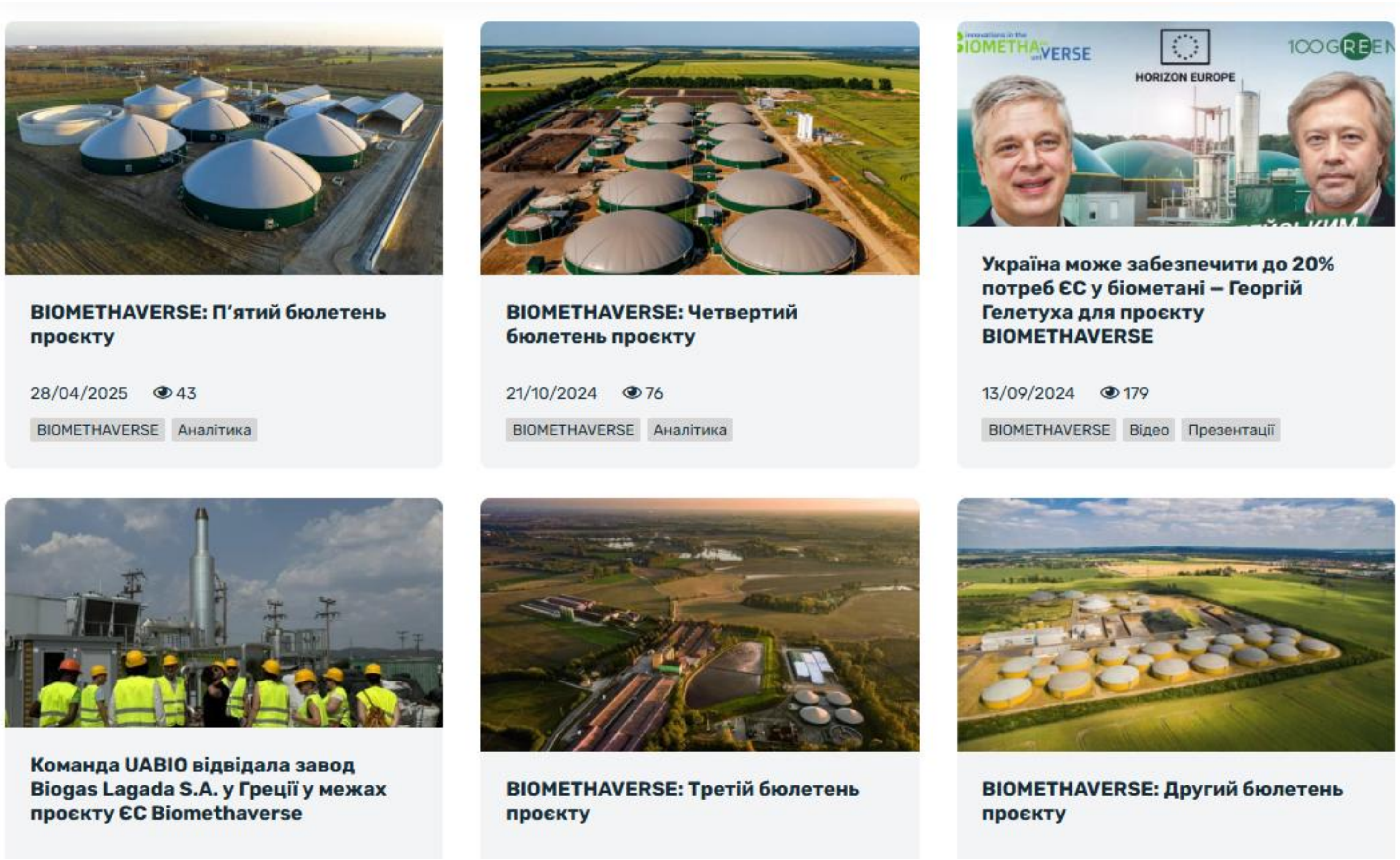
#1 - March 2023

#2 - August 2023

#3 - March 2024

#4 - September 2024

#5 - March 2025



Co-funded by the European Union

#Biomethaverse

Thank you!

Follow Biomethaverse:

www.biomethaverse.eu

@European_Biogas

@European_Biogas Association

Contact: DBFZ, MHP & EE
Email:
Daniel.Dzofou.Ngoumelah@dbfz.de
a.dombrovskiy@mhp.com.ua
reik@ellmann-gmbh.de

funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

Co-funded by the European Union