SEMPRE-BIO

SEcuring doMestic PRoduction of cost-Effective BIOmethane

"Transforming diverse wastes into cost-effective biomethane"

23/01/2025

David Checa Sánchez

Organizado por:

CETAQUA
CENTRO TECNOLÓGICO DEL AGUA

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SEMPRE-BIO at glance

Goals

- Demonstrate novel and cost-effective biomethane production solutions and pathways.
- Increase the market up-take of biomethane related technologies.
- Support circular economy.
- Reduce dependence on fossil fuels.

Numbers

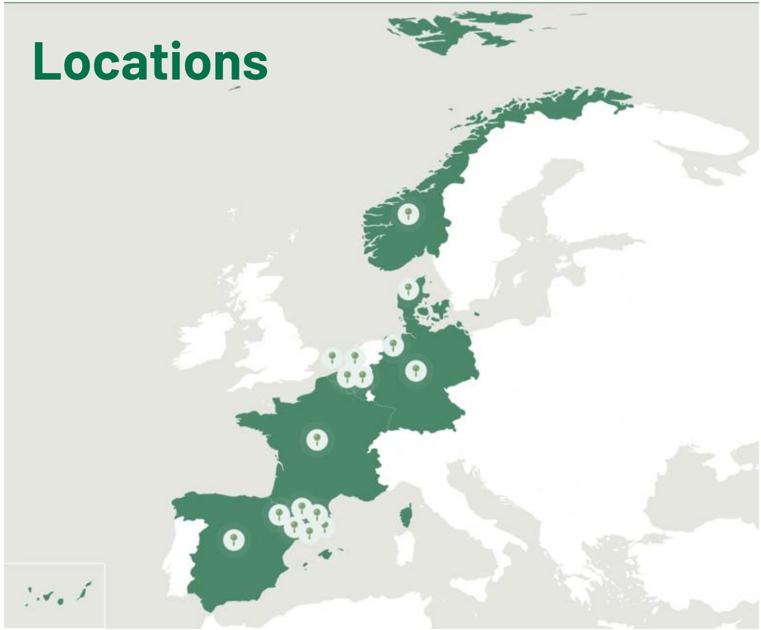
42
Months

17
Partners

7
Countries

9.9M
Funding

Locations



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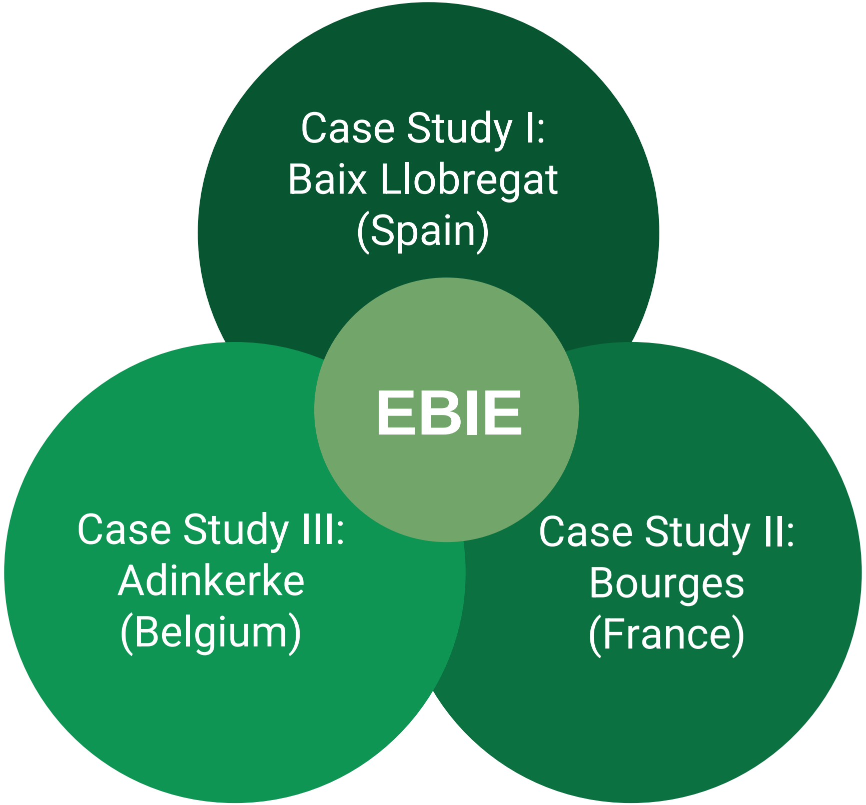

European Biomethane Innovation Ecosystem

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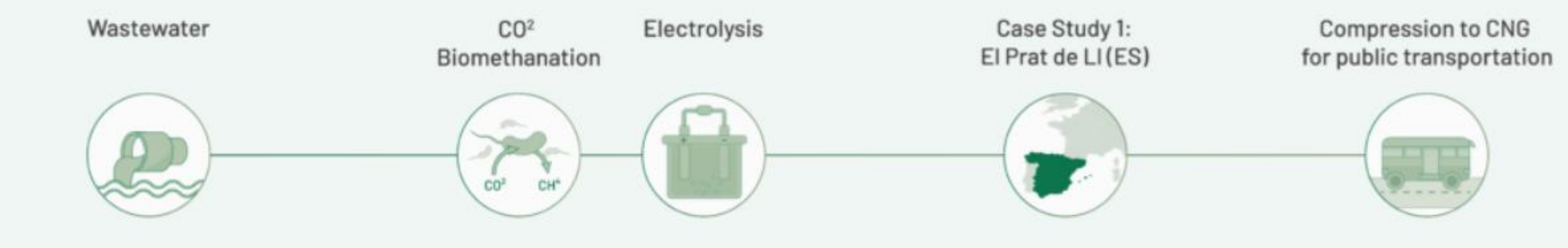
Caso de estudio 1: Baix Llobregat (Spain)

Feedstock	Technology	Site	Final use of biomethane



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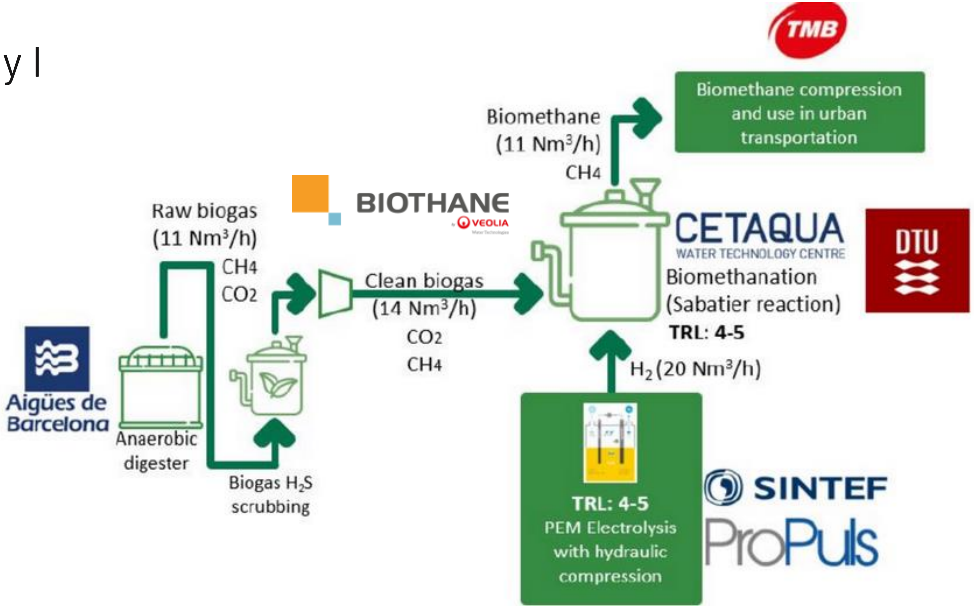
BIOTHANE by VEOLIA · Aigües de Barcelona · CETAQUA Centro Tecnológico del Agua · ProPuls · DTU · SINTEF · TMB

General schematic design

Case Study I



Partners:

Site: Aigües de Barcelona

Biomethanation: CETaqua/ DTU

H2: Propuls/ Sintef

End-user: TMB

Economic evaluation: DBFZ/SINTEF

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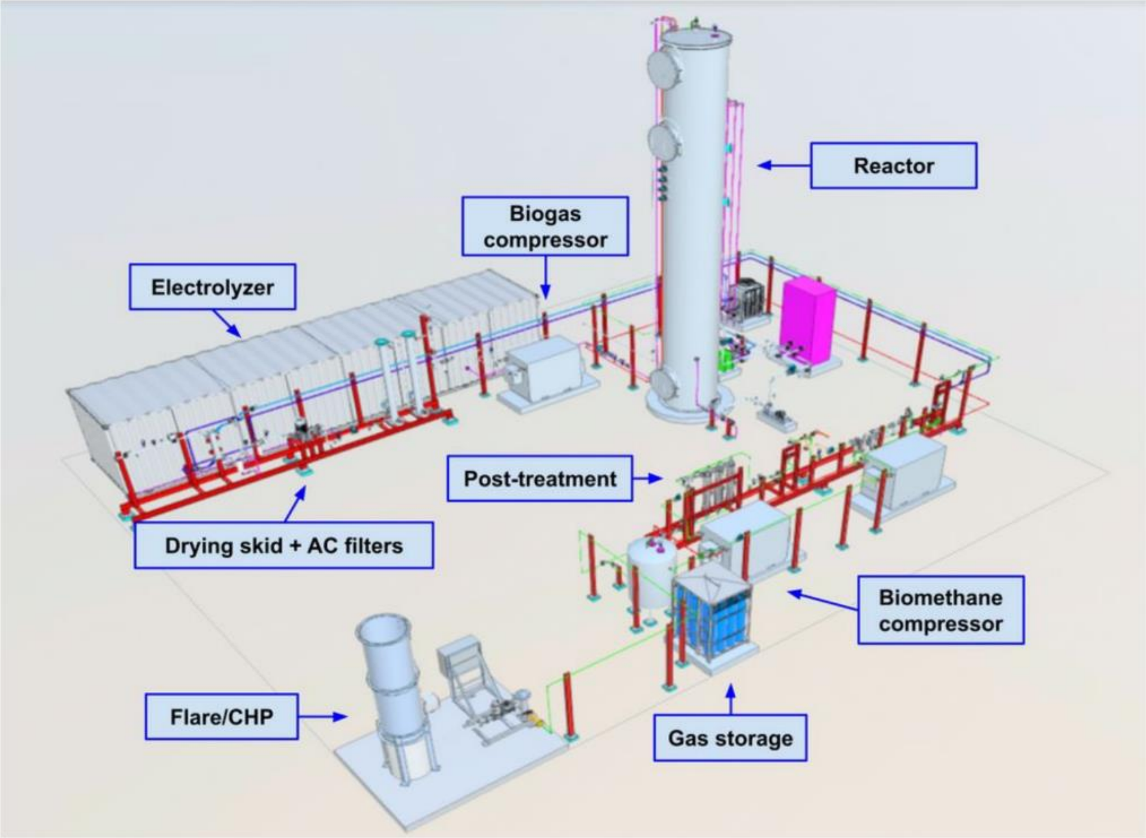
3D process diagram



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Pilot plant

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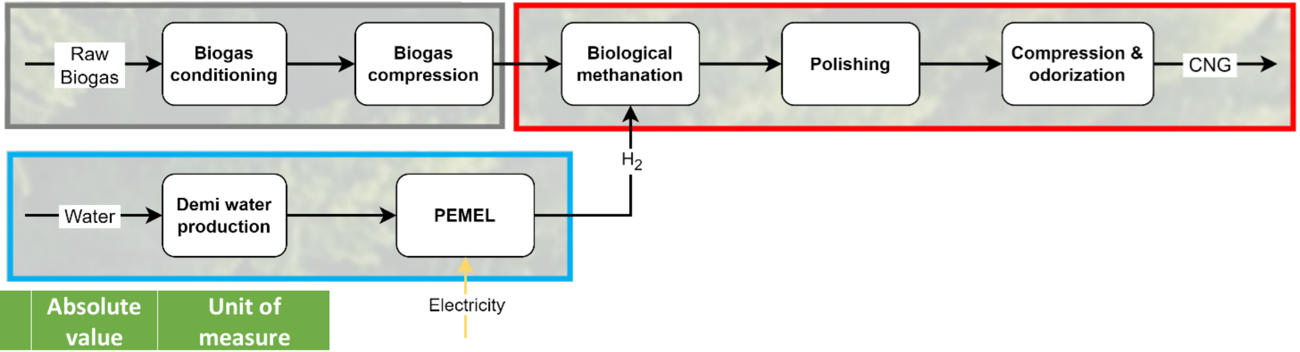
Process design results

- **COCO-COFE**: Cape-open process simulator



KPI	Specific value	Unit of measure	Absolute value	Unit of measure
H_2 production in PEMEL	0.077	kg/kg H_2O	39.2	kg/h
O_2 production in PEMEL	0.609	kg/kg H_2O	310.9	kg/h
Electricity demand for PEMEL	24.18	MJ/kg biomethane	1.6	MW
Biomethane production	0.588	kg/kg raw biogas	325	Nm^3/h
Biomethane purity	97.200	vol%		
Electricity demand for biogas compression	0.414	MJ/kg biomethane	28.81	kW
Electricity demand for biomethane compression	0.760	MJ/kg biomethane	50.40	kW
Overall electricity consumption	25.392	MJ/kg biomethane	1690.03	kW
Overall cooling duty	1.222	MJ/kg biomethane	81.05	kW
Refrigeration duty	0.596	MJ/kg biomethane	39.47	kW

- **Increased CH4 productivity by 53%** with respect to the CH4 content in raw biogas
- The process yields **high-purity biomethane** (>97 vol% CH4) from a medium-concentrated feedstock (65 vol% CH4)
- O2 production can be valorised (e.g., oxyfuel combustion for steam generation)
- The major electricity consumption is still associated with the PEMEL unit (24.2 MJ/kg CH4), which does not depend on the considered storage pressure.

Reference

17th International Conference on Greenhouse Gas Control Technologies, GHGT-17

20th -24th October 2024 Calgary, Canada

Modelling of bio-methanation, a promising route for GHG emission reduction

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Abstract

Biomethane production is an effective solution to protect air, water, and soil by recycling organic waste streams into renewable energy and soil improvement products, while simultaneously reducing the exploitation of fossil fuels (i.e., natural gas), thus reducing Greenhouse Gases (GHG) emissions. Novel and cost-effective biomethane production pathways are considered crucial to meet the European Green Deal and climate and energy targets for 2030 and the net zero greenhouse gas emissions by 2050, as well as to spread the market uptake of biomethane-related technologies. This contribution describes the design, model development, and evaluation of key performance indicators for two novel microorganisms-driven methanation routes: (1) biogas-to-biomethane plant using an innovative combination of bio-methanation and proton exchange membrane water electrolysis, and (2) methanation of a CO and CO_2-rich syngas generated via gasification from a woody green waste. Both case-studies are developed in cooperation with industrial entities and will establish novel European Biomethane Innovation Ecosystems as part of the SEMPRE-BIO project funded by the European Union Horizon program.

Keywords: biogas upgrading; biomethane; bio-methanation; gasification; electrolysis

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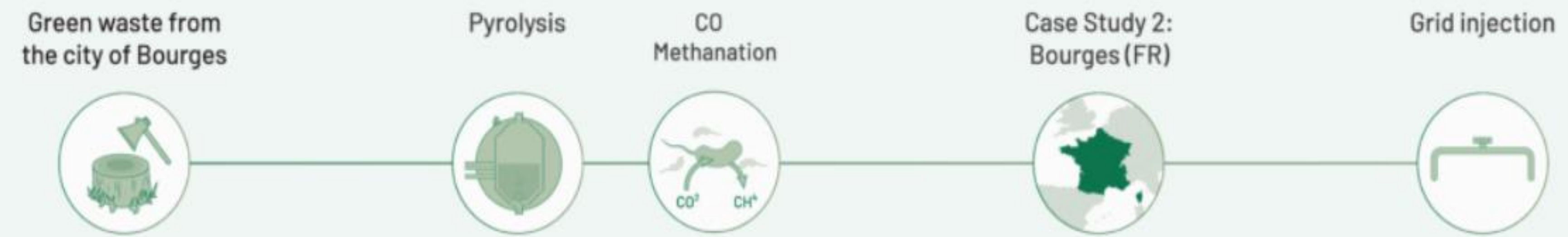
Caso de estudio 2: Bourges (France)

Feedstock	Technology	Site	Final use of biomethane



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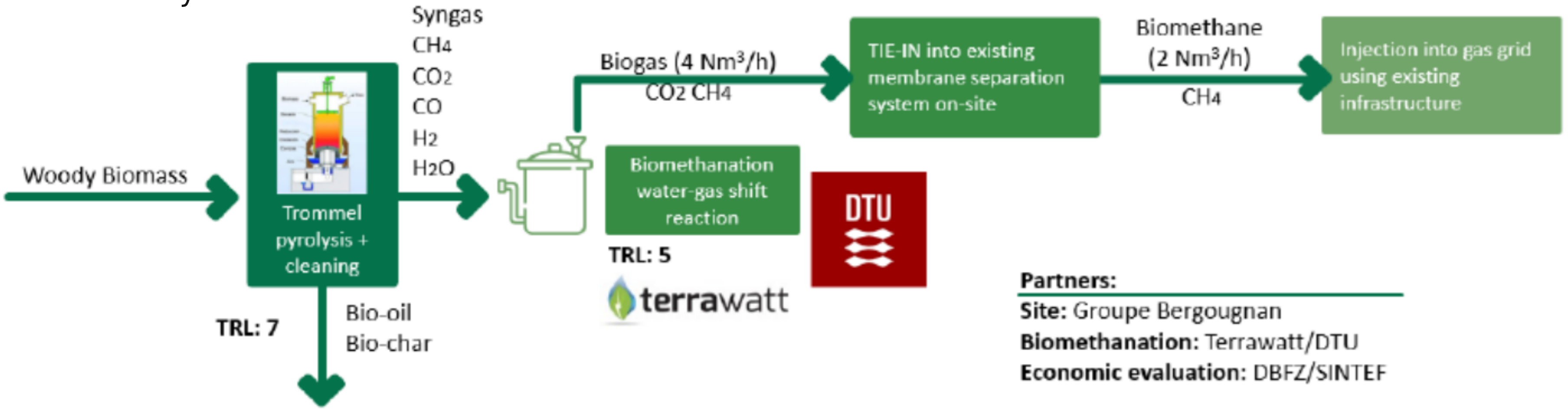
General schematic design

Case Study II



Partners:
Site: Groupe Bergougnan
Biomethanation: Terrawatt/DTU
Economic evaluation: DBFZ/SINTEF

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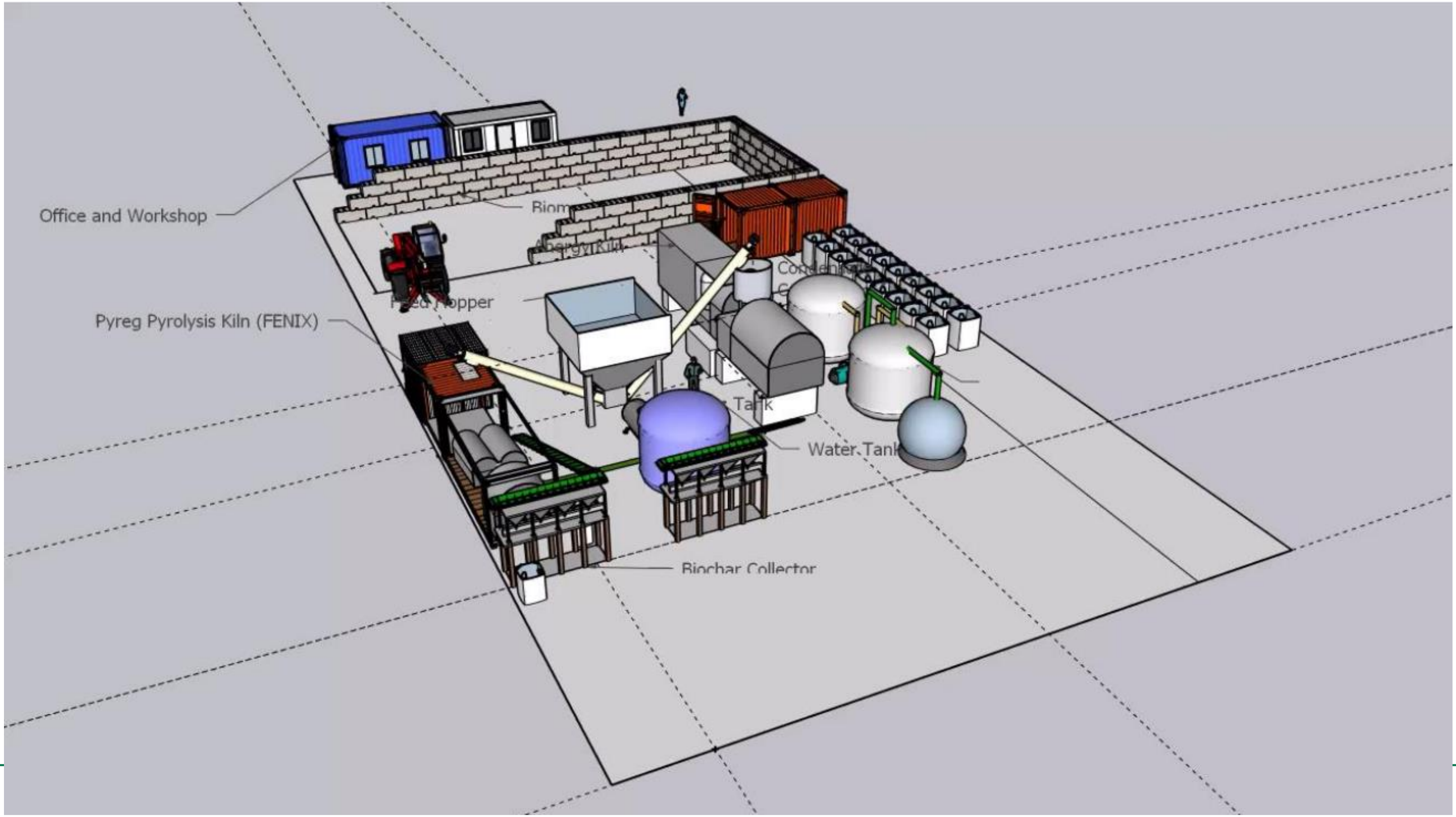
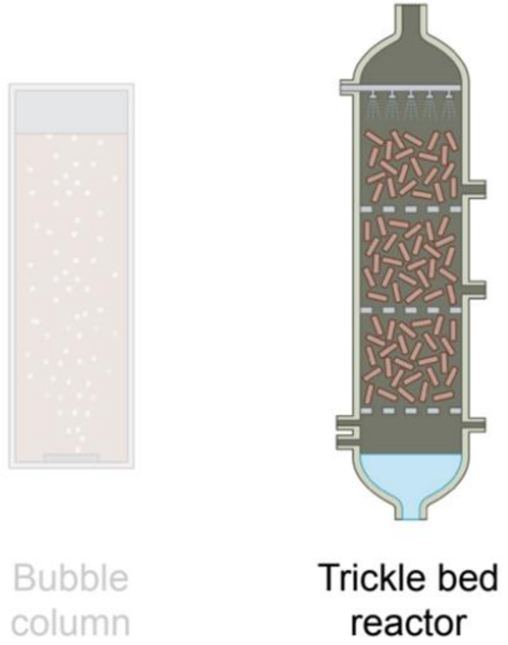
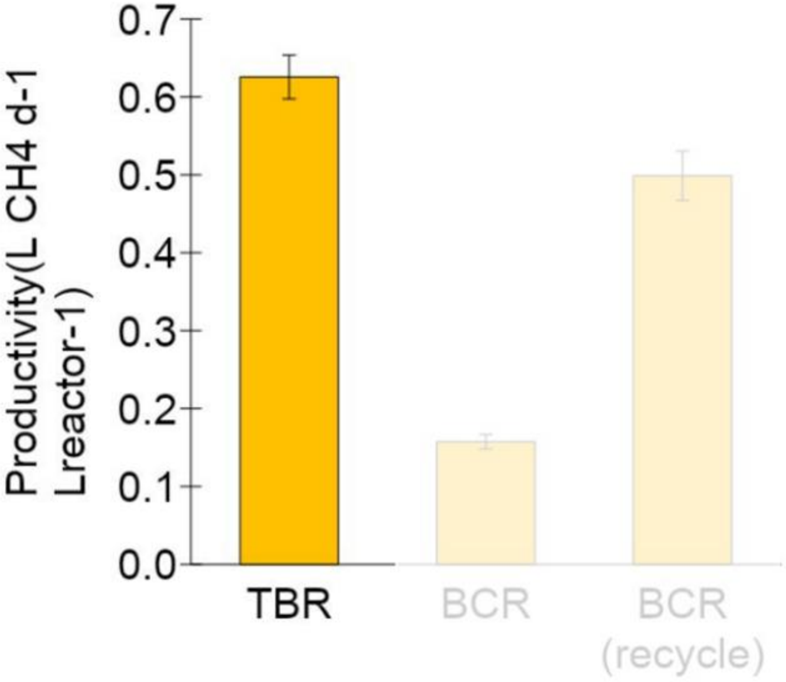
3D process diagram



Reactor type experiments

Biogas upgrading





Gas composition

Syngas biomethanation

Syngas e-donor/e-acceptor ratio:

Electron donors

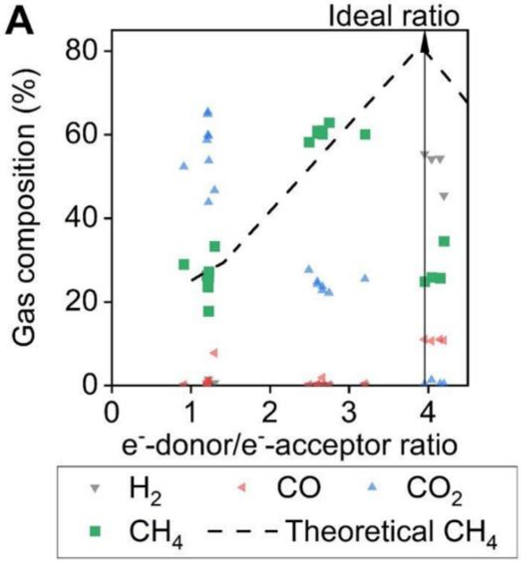
$$\frac{H_2 + CO}{CO + CO_2} = 4$$

Electron acceptor

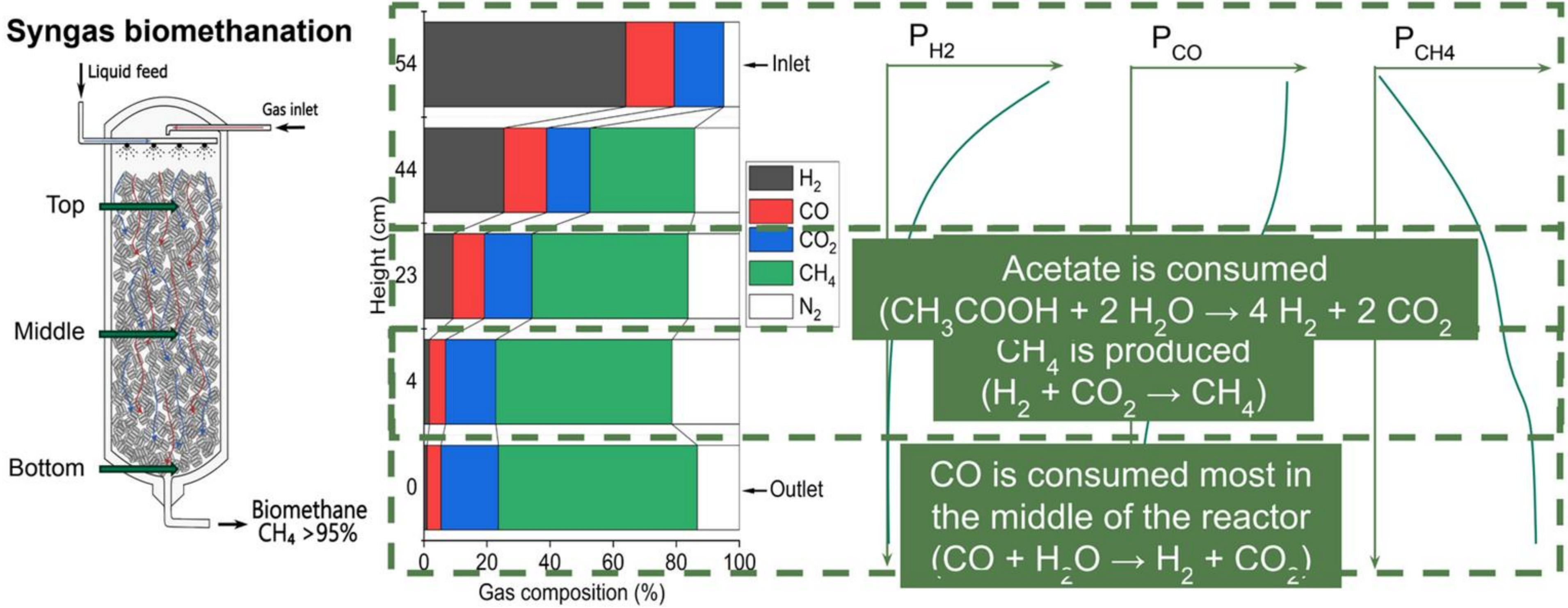
Ideal e-donor/e-acceptor ratio

- $CO2 + 4\ H2 \rightarrow CH4 + 2\ H2O$
- $CO + 3\ H2 \rightarrow CH4 + H2O$
- $4\ CO + 2\ H2O \rightarrow CH3COOH + 2\ CO2$

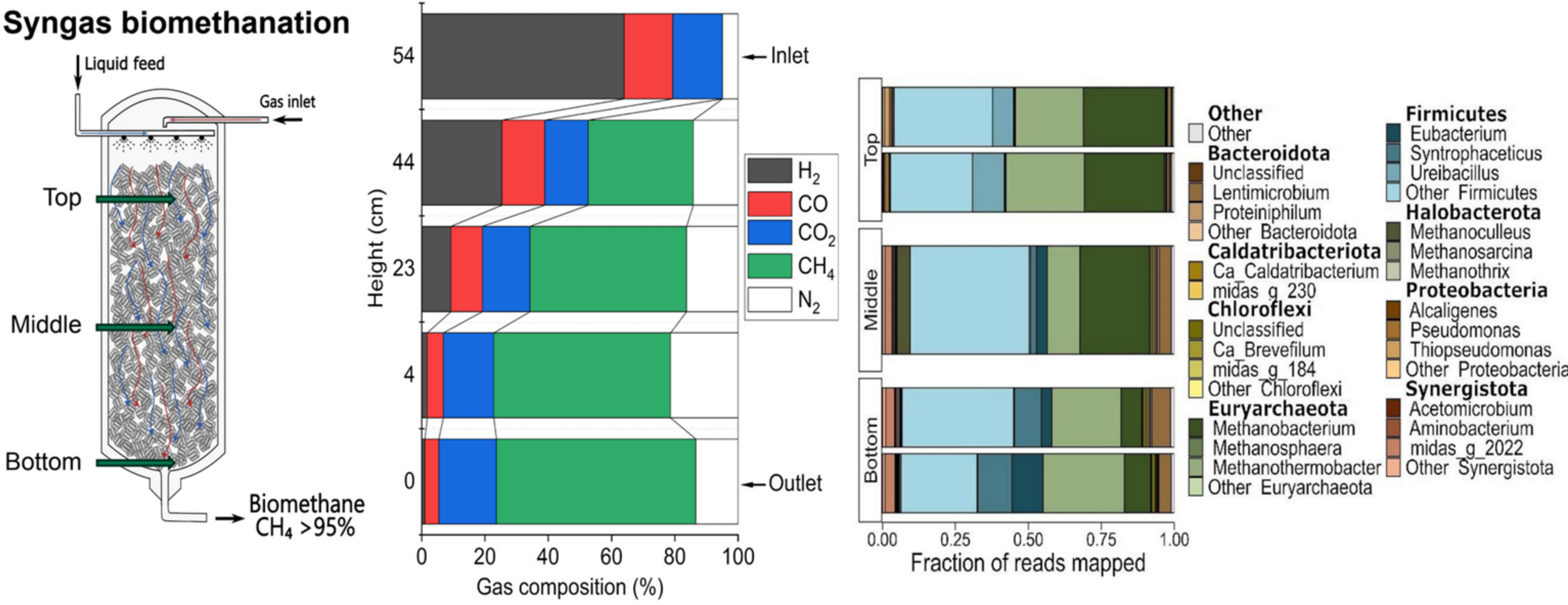
e-donor/e-acceptor ratio	Condition
2.7	Control
1.2	High CO
4.1	High H_2



Gas composition



Microbial community composition



Reference

Chemical Engineering Journal 500 (2024) 156629

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Contents lists available at ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

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Biofilm mass transfer and thermodynamic constraints shape biofilm in trickle bed reactor syngas biomethanation

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A R T I C L E I N F O

Keywords:
Syngas biomethanation
Trickle bed reactor
Mixed microbial consortia
Biofilm
Thermodynamics
Carbon capture

A B S T R A C T

Syngas (H_2, CO_2, CO) produced thermochemically from lignocellulosic biomass is an underexploited source for resource recovery and valorisation through its biological conversion for the production of a wide range of chemicals and fuels. Syngas biomethanation is one such promising bioconversion pathway, displaying interesting features such as high conversion efficiency and product selectivity, as methane is the sole product of the process. The biological conversion of syngas to high purity biomethane is still typically associated with a number of challenges related to the syngas composition, CO toxicity, and gas–liquid mass transfer limitations. In this work, the syngas biomethanation process carried out in trickle bed reactors was investigated at its boundary conditions to explore the limits of the process, focusing on syngas composition and mass-transfer conditions potentially limiting process performance. The process was found to be robust when exposed to CO excess, but highly sensitive to H_2 excess, which caused severe inhibition even under small amounts of excess H_2. This implies that biomethane purity comparable to natural gas can be achieved by addition of renewable H_2, but this requires precise control to avoid process failure. Modulating the liquid recirculation rate and gas residence time allowed for a maximum methane productivity of 9.8 ± 0.5 mmol CH_4 h^{-1} $L_{reactor}^{-1}$ with full conversion of H_2 and CO at a gas residence time of 1 h. Nevertheless, increasing the gas–liquid mass transfer with increasing liquid recirculation rate did not lead to increased methane productivity, which suggested additional rate-limiting bottlenecks in the process. Careful investigation of other factors potentially limiting the process led to the conclusion that diffusive transport of syngas components in the biofilm was the main bottleneck of the process. This diffusive limitation leads to a scenario of severe substrate scarcity in the biofilm phase that conditions the thermodynamic feasibility of the different biochemical reactions involved in syngas biomethanation. In turn, these thermodynamic constraints were found to drive the stratification of microbial groups and sequential consumption of syngas components along the height of the reactor.

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Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Carbon monoxide inhibition on acidogenic glucose fermentation and aceticlastic methanogenesis

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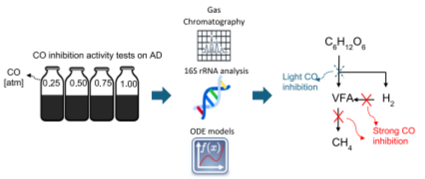
HIGHLIGHTS

- Investigation of CO inhibition at equilibrium concentrations with 0.25–1.00 atm.
- CO significantly inhibits aceticlastic methanogenesis and homoacetogenesis.
- Glucose degrading community shifts metabolism towards propionate production.
- Kinetic modeling of CO inhibitory effects on process performance.

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
CO fermentation
Microbial inhibition
Microbial community analysis
Kinetic modeling

ABSTRACT

Syngas and CO-rich off-gases are key chemical platforms to produce biofuels and bioproducts. From the perspective of optimizing and up-scaling CO co-digestion with organic waste streams, this study aims at assessing and quantifying the inhibitory effects of CO on acidogenic glucose fermentation and aceticlastic methanogenesis. Mesophilic cultures were fed in two sets of batch assays, respectively, with glucose and acetate while being exposed to dissolved CO in equilibrium with partial pressures in the range of 0.25–1.00 atm. Cumulative methane production and microbial monitoring revealed that aceticlastic methanogenic archaea were significantly inhibited (2–20 % of the methane production of CO non-exposed cultures). The acidogenic glucose degrading community was also inhibited by CO, although, thanks to its functional redundancy, shifted its metabolism towards propionate production. Future work should assess the sensitivity of hereby estimated CO inhibition parameters, e.g., on the simulation output of a continuous syngas co-digestion process with organic substrates.

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Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

From microbial heterogeneity to evolutionary insights: A strain-resolved metagenomic study of H_2S-induced changes in anaerobic biofilms

Gabriele Ghiotto [1,a], Nicola De Bernardini [1,a], Ginevra Giangeri [b], Panagiotis Tsapekos [b], Maria Gaspari [c], Panagiotis G. Kougias [c], Stefano Campanaro [a,*], Irini Angelidaki [b], Laura Treu [a]

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ARTICLE INFO

Keywords:
Carbon dioxide
Methanogenesis
Hydrogen sulfide
Metagenomics
Strain deconvolution
Single nucleotide variants

ABSTRACT

The hidden layers of genomic diversity in microbiota of biotechnological interest have been only partially explored and a deeper investigation that overcome species level resolution is needed. CO_2-fixating microbiota are prone to such evaluation as case study. A lab-scale trickle-bed reactor was employed to successfully achieve simultaneous biomethanation and desulfurization on artificial biogas and sulfur-rich biogas, and oxygen supplementation was also implemented. Under microaerophilic conditions, hydrogen sulfide removal efficiency of 81% and methane content of 95% were achieved. *Methanobacterium* sp. DTU45 emerged as predominant, and its metabolic function was tied to community-wide dynamics in sulfur catabolism. Genomic evolution was investigated in Gammaproteobacteria sp. DTU53, identified as the main contributor to microaerophilic desulfurization. Positive selection of variants in the hydrogen sulfide oxidation pathway was discovered and amino acid variants were localized on the sulfide entrance channel for sulfide:quinone oxidoreductase. Upon oxygen supplementation strain selection was the primary mechanism driving microbial adaptation, rather than a shift in species dominance. Selective pressure determined the emergence of new strains for example on Gammaproteobacteria sp. DTU53, providing in depth evidence of functional redundancy within the microbiome.

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Summary

Case study	CS1	CS2
Biomethane purity	97.2 vol%	96.1 vol%
Main impurity	N_2 (1.5 vol%)	CO (3 vol%)
Biomethane productivity	0.59 kg/kg raw biogas	0.46 kg/kg dry biomass (0.36 kg/kg syngas gasification)
Electricity demand	25.4 MJ/kg biomethane	1.26 MJ/kg biomethane
Cooling duty	1.22 MJ/kg biomethane	2.68 MJ/kg biomethane

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Expected results

01 Increase the profitability of conversion in the production of biomethane.

02 Diversify conversion technologies for biomethane.

03 Contribute to the acceptance of Biomethane technologies in the gas market.

04 Contribute to the priorities of SET Plan action 8.

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Expected impacts

- Biomethane as a substitute for imported LNG.
- Biomethane as a substitute for fuel in transportation.
- Reduction of CO_2 by 213 million tons/year by 2050.
- Diversify energy sources and new routes.
- Reduce the need for strategic reserves.
- Smaller extent of critical infrastructure to protect.

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Thank you!

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