Process design of WWTP anaerobic digestion biogas upgrade to Compressed Natural Gas (CNG) for applications in public transportation

EUBCE 2024
26th June 2024
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EUBCE
32nd European Biomass Conference & Exhibition

HORIZON EUROPE

Introduction

- **Biogas production** is an effective solution to protect the environment by **recycling organic waste streams into renewable energy**, while simultaneously **reducing GHG emissions**.

- Novel and cost-effective biomethane production solutions must be found to maximize the carbon utilization in the feedstock. The main **challenges** are:

1) **decrease** investment and operational **costs**
2) **optimize feedstock supply** and use
3) identify alternative and **cheaper feedstocks**
4) **improve** plant **efficiency** and operations
5) increase and **monetize co-benefits from** the commercialization of **side-products**.

This project has received funding from the European Union's Horizon Europe programme under grant agreement № 101084297

The SEMPRE-BIO project

- SEMPRE-BIO's aim is to **demonstrate** novel and **cost-effective biomethane production solutions** to support **circular economy** and **reduce dependence on fossil fuels**.

- 5 innovative biomethane production technologies will be **tested in 3 plants** through Europe.

- International consortium with **partners from different sectors**, including research, industry, academia, end-users and farmers.

SEMPRE-BIO

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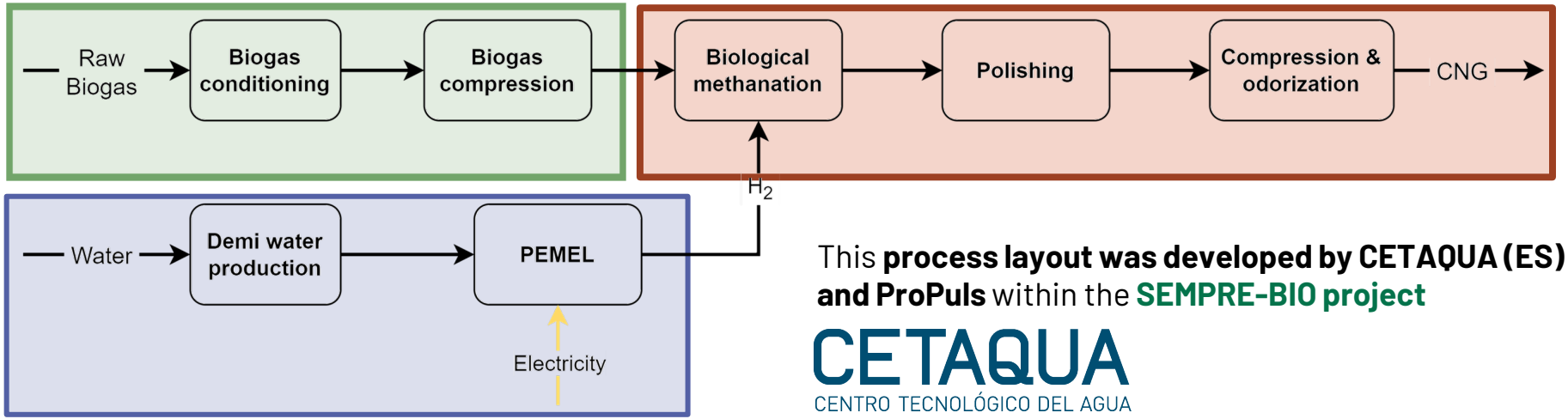
European Commission

Overview and process description

The target is design, modelling, and evaluate key performance indicators for an efficient **full-scale biogas-to-biomethane plant** using an innovative combination of **bio-methanation** and proton exchange membrane **water electrolysis**.



This **process layout was developed by CETAQUA (ES) and ProPuls** within the **SEMPRE-BIO project**

CETAQUA
CENTRO TECNOLÓGICO DEL AGUA

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Raw gas pretreatment and compression

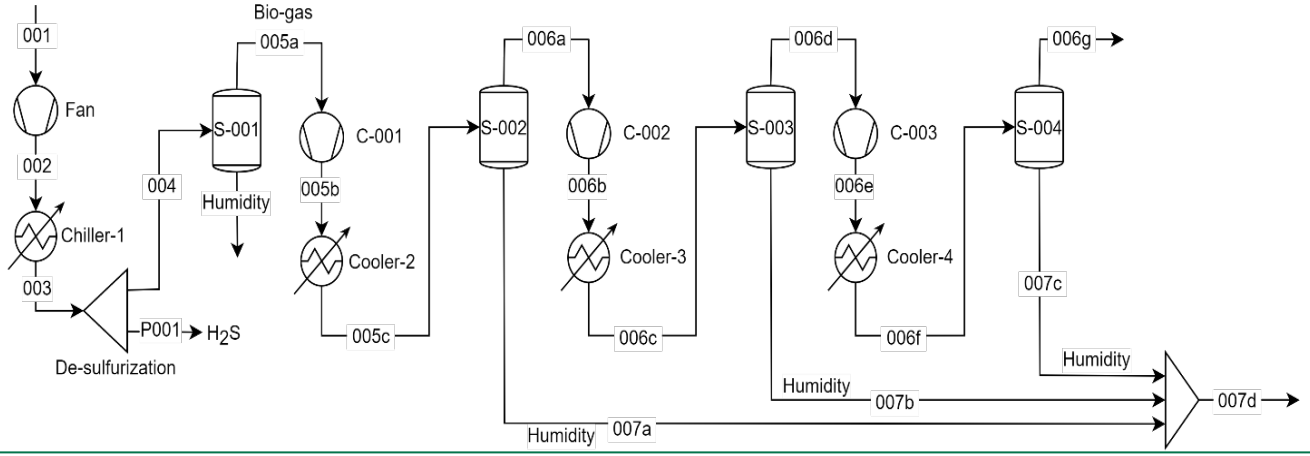
Feedstock: biogas from **Baix Llobregat Waste-Water Treatment Plant (WWTP)** (Barcelona, Spain)[2]

Size of feedstock: **370 Nm^3/h biogas**

Composition: CH_4/CO_2 molar ratio of 1.87, 1.5 mol% N_2, and traces of H_2S

ASSUMPTIONS:

- Chilling to 5°C
- 99.99% H_2S removal efficiency
- **Compression to 8 bar for methanation**



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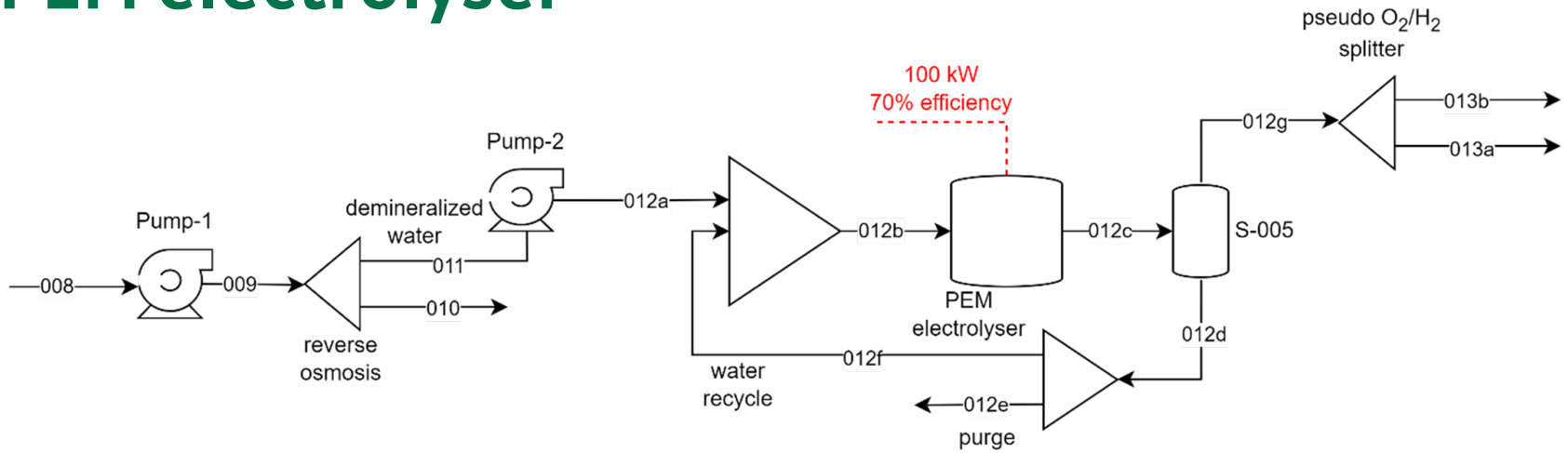
PEM electrolyser



ASSUMPTIONS:

- Simplified model retrieved from the literature[3]: only water splitting reaction is considered
- **1.6 MW overall capacity (three stacks of 550 kW)** and **70% efficiency**
- H_2O feed rate is regulated to achieve the **H_2 production required** by the methanation stoichiometry (**0.16 g H_2/ g biogas**)
- Conversion is tuned based on the assigned capacity and efficiency

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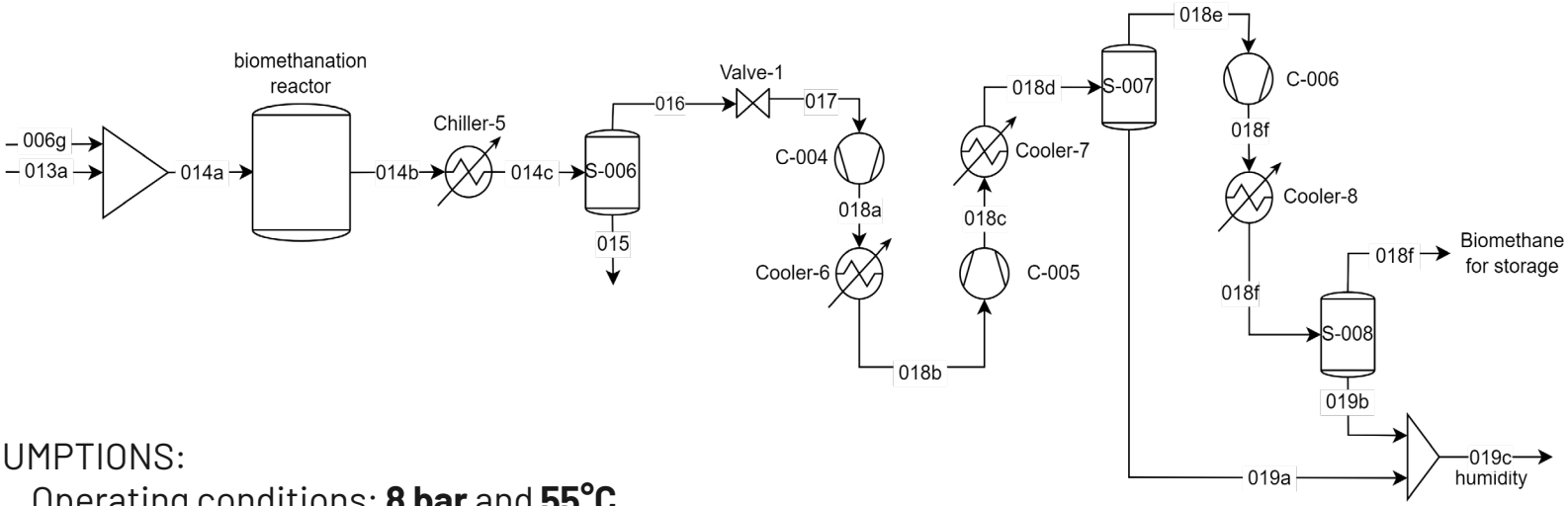
Bio-methanation



ASSUMPTIONS:

- Operating conditions: **8 bar** and **55°C**
- Reactor is modelled as a **fixed conversion reactor**, where enzymes catalyse the conversion of hydrogen and carbon dioxide into methane according to reaction:

$$CO_2 + 4\,H_2 \rightarrow CH_4 + 2\,H_2O$$

- Conversion of 98.5% for the limiting reactant (i.e., CO_2)
- **Biomethane is compressed to 250 bar for storage** as CNG

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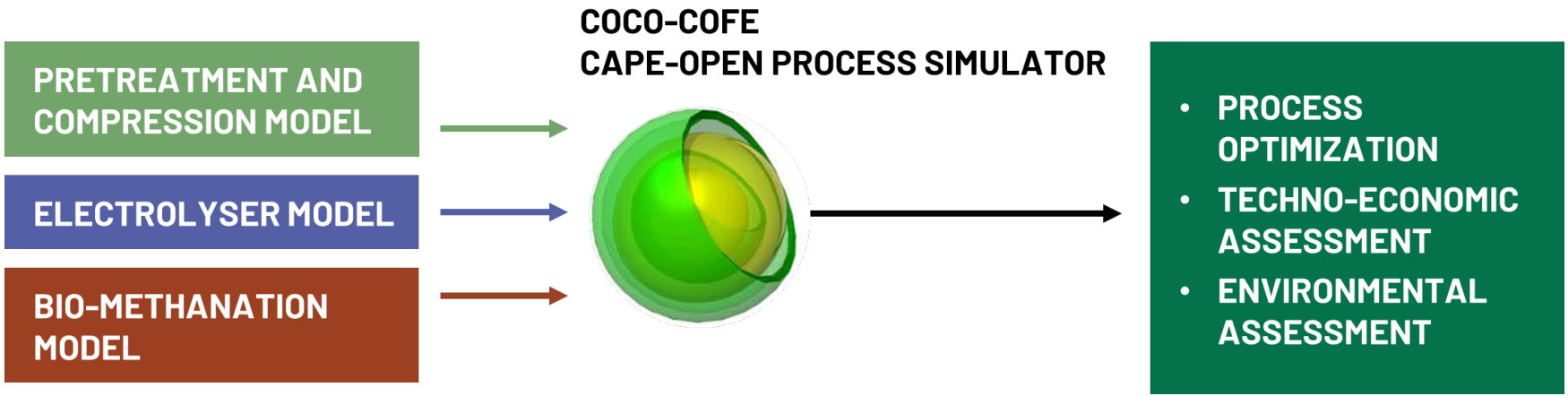
Flowsheet development



- The sub-models are integrated in **COCO-COFE simulation environment**
- The simulation provides the **mass and energy balance for the process**

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Results

The **key performance indicators** for **productivity** and **energy consumption** have been assessed.

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

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Highlights

- **Increased CH_4 productivity by 53%** with respect to the CH_4 content in raw biogas
- The **process yields high-purity biomethane** (>97 vol% CH_4) from a medium-concentrated feedstock (65 vol% CH_4)
- **O_2 production can be valorised** (e.g., oxyfuel combustion for steam generation)
- The **major electricity consumption** is associated with the **PEMEL** unit (24.2 MJ/kg CH_4), which does not depend on the considered storage pressure.

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Conclusions and future steps

- An **innovative technology** for producing **biomethane from industrial wastewater** has been assessed
- A **model** has been **developed and implemented** in process simulator to get the mass and energy balance
- **Key performance indicators** show that the proposed **technology is promising**
- The obtained **results** will be used as a **starting point to perform an economic and environmental assessment** (in progress), which are necessary to test the feasibility of the process.

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Acknowledgements

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SEMPRE-BIO

Funded by the European Union

This was a joint work:

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