SEMPRE-BIO

EUBCE
34th European Biomass Conference & Exhibition

SEMPRE-BIO Project: Comparison of Three Innovative Scaled-Up and Optimised Technologies For Biomethane Production and Its Purification

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SINTEF Industry – Process Technology

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Outlines

1 **Introduction**

Role of biogas in the EU decarbonization strategy

2 **Processes overview**

Block flow diagrams

3 **Results**

Main KPIs and other comments

4 **Conclusions**

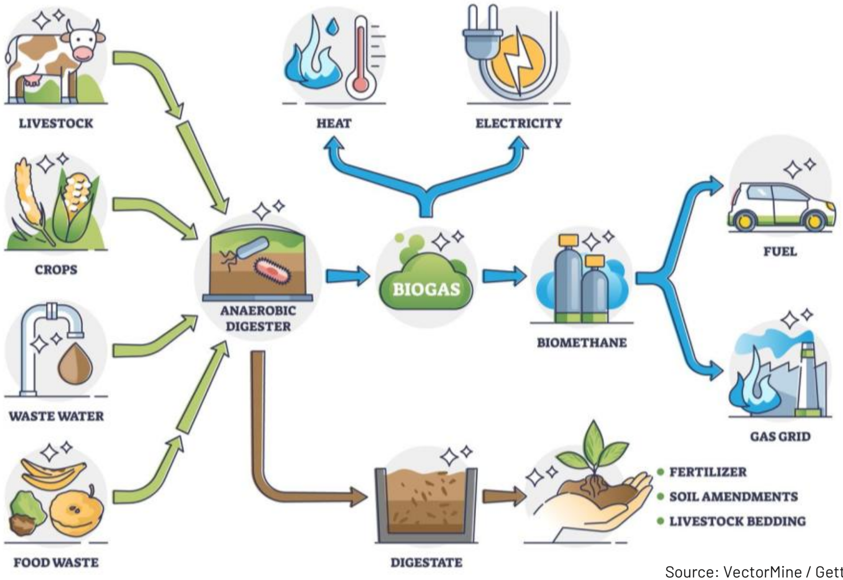
Achievements & future works

1.Introduction

Biogas production

- Mainly produced via **anaerobic digestion**
- **CH_4** content variable from **45 to 75 vol%**
- The remaining is **wet CO_2** with **traces of NH_3 and H_2S**
- **Upgrading** is necessary for applications of bio-CH_4 as **fuel** or **transport** (either gas o liquid)

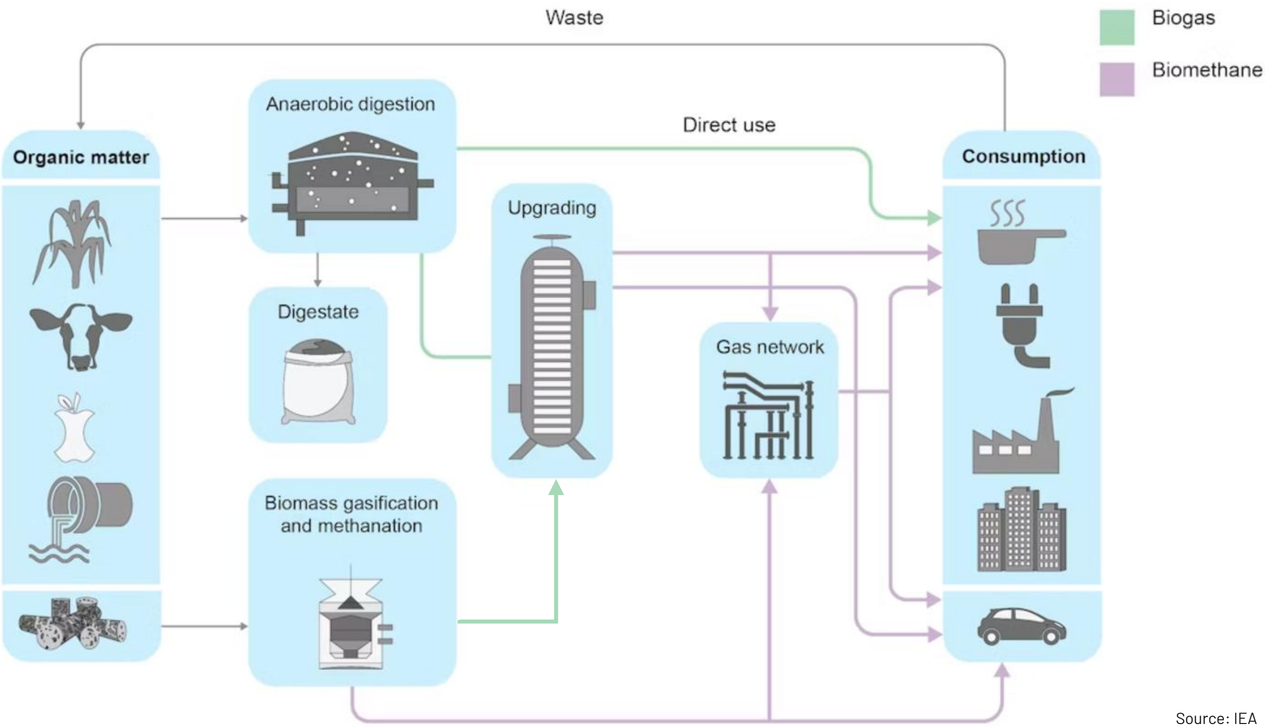
European Biogas Association - https://www.europeanbiogas.eu/
IEA - https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth/an-introduction-to-biogas-and-biomethane



Source: VectorMine / Getty Images

Biogas production

- Upgrading is crucial to meet **specs for transport in the NG grid**
- Upgrading is also relevant for **liquefaction** and delivery (supply chain)



Source: IEA

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SEMPRE-BIO project

- SEMPRE-BIO aims at **demonstrating novel and cost-effective bio-CH_4 production solutions** to support the circular economy and **reduce dependence on fossil fuels**
- Biomethane production tested in **3 demo plants** across Europe accounting for **different feedstocks**

SEMPRE-BIO

SEcuring doMestic PRoduction of cost-Effective BIOmethane

Total funding
€ 9 926 450

HORIZON-IA

Case studies

Aigües de Barcelona, Barcelona, Spain

Terrawatt, Marmagne, France

Bio-CH_4 synthesis/production

De zwanebloem, De Panne, Belgium

Biogas upgrade and bio-CH_4 Liquefaction

Source: SEMPRE-BIO webpage

2.Processes

CSI

Aigües de Barcelona, Barcelona, Spain

Direct biomethanation of biogas

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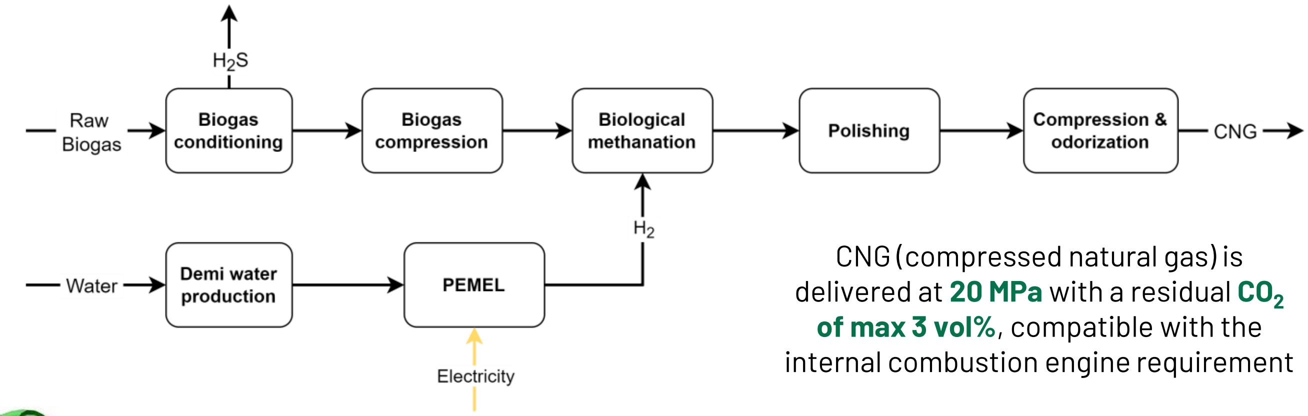
BFD CSI

- **Direct biomethanation of biogas** to bio-CH_4
- Application for transport engines burning bio-CH_4
- Simulation in **COFE V3.10**, license-free simulation software by AmsterChem



CNG (compressed natural gas) is delivered at **20 MPa** with a residual **CO_2 of max 3 vol%**, compatible with the internal combustion engine requirement

Technology provider: CETAQUA WATER TECHNOLOGY CENTRE

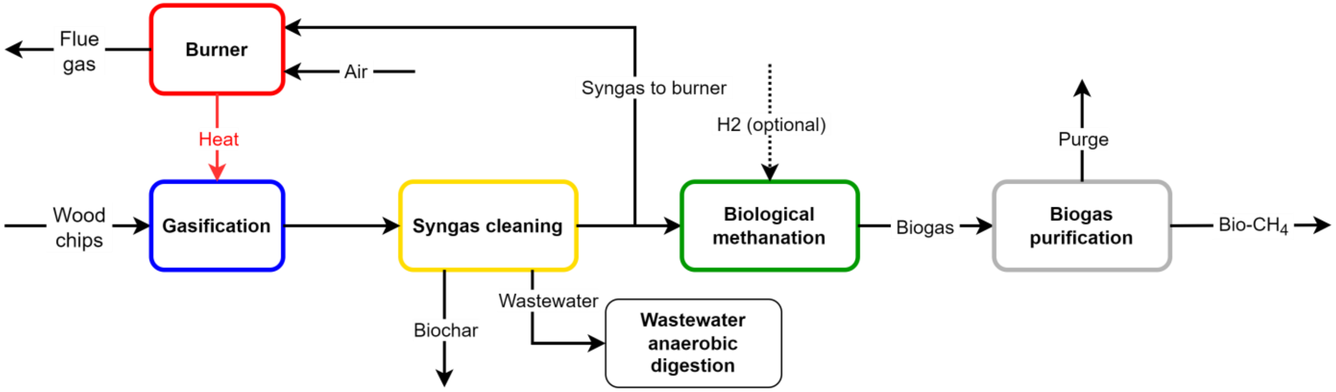
CS2

Terrawatt, Marmagne, France

Bio-syngas biomethanation

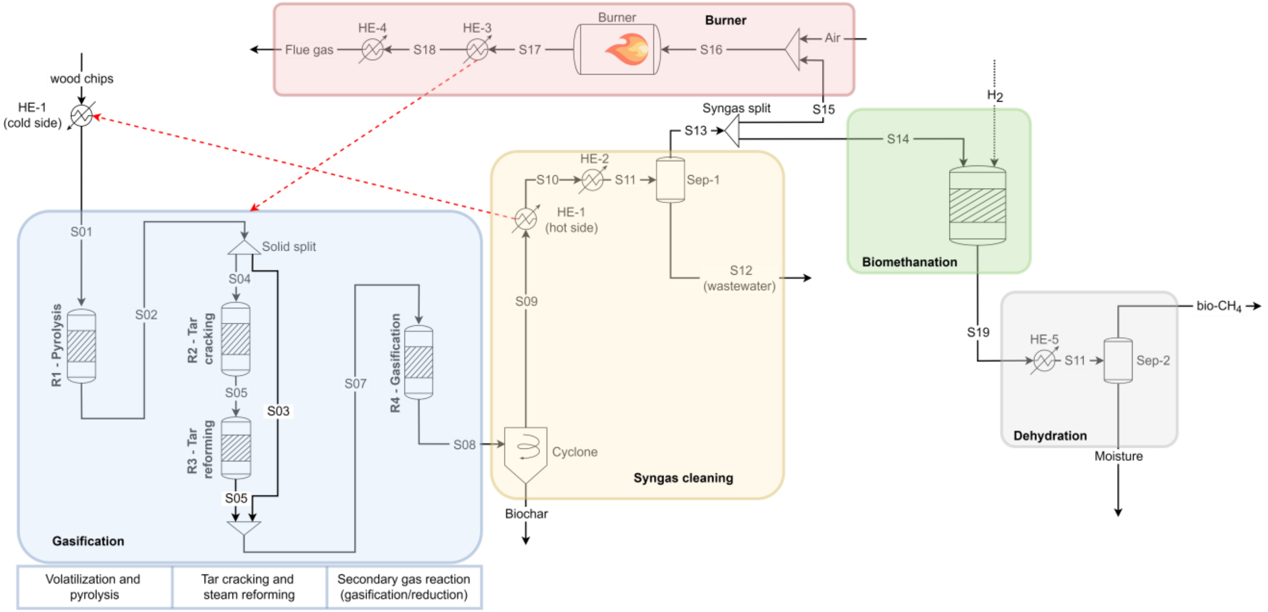
BFD CS2

- **Biomass gasification** followed by **biomethanation** of syngas
- Simulation in **COFE V3.10**, license-free simulation software by AmsterChem



Technology provider: terrawatt

PFD



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Modelling of pyrolysis

241

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A Novel Semi-Rigorous Model for Biomass Pyrolysis and Gasification

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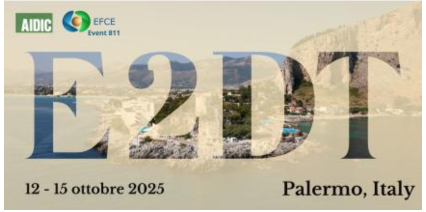

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CS3

De zwanebloem,
De Panne, Belgium

Biogas upgrade and
bio-CH_4 Liquefaction

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CS3

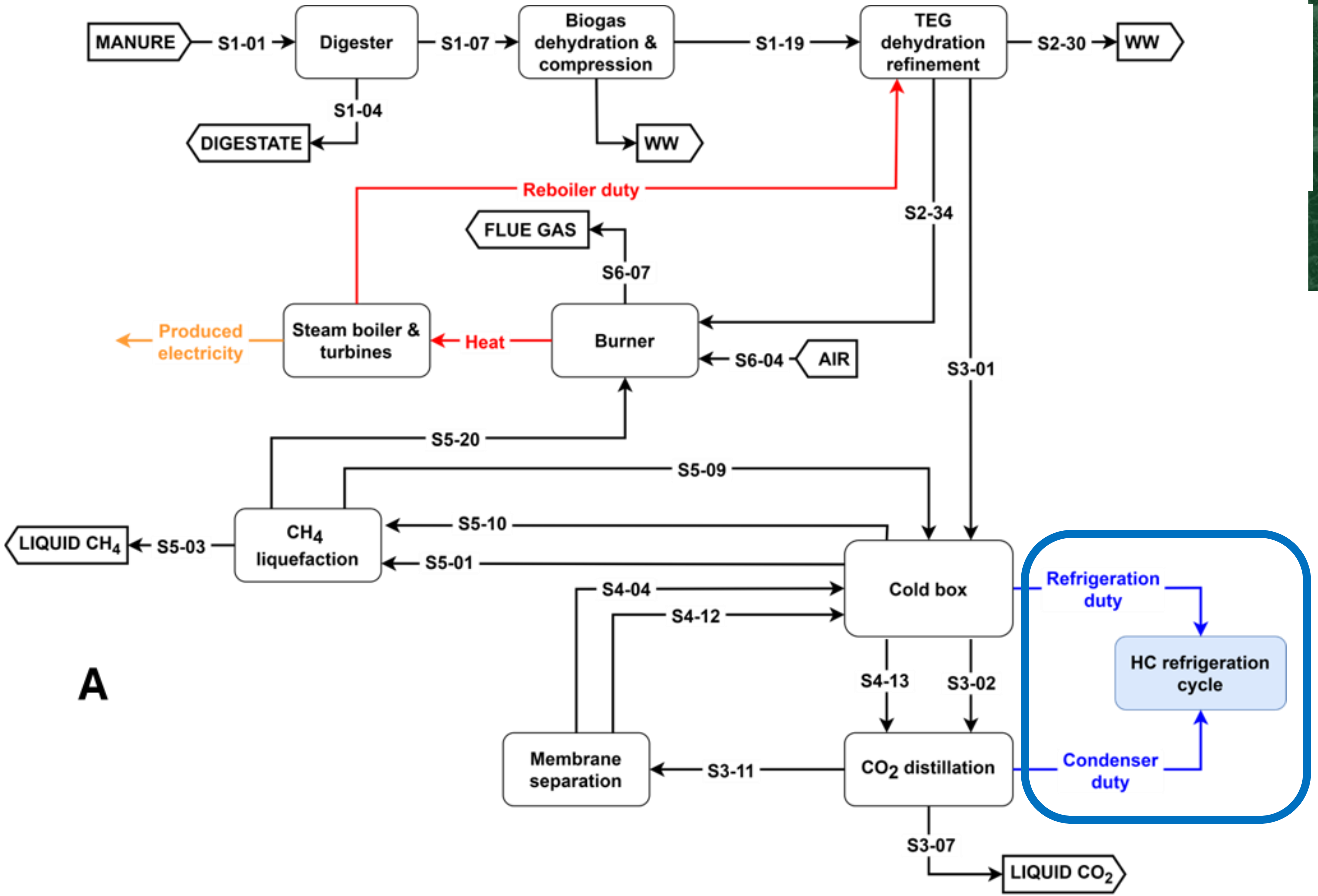
- **Upgrading** and **liquefaction** of bio-CH_4

- Application for transport of bio-CH_4 delivery in the absence of surrounding infrastructure (e.g., farms and remote biogas sites)

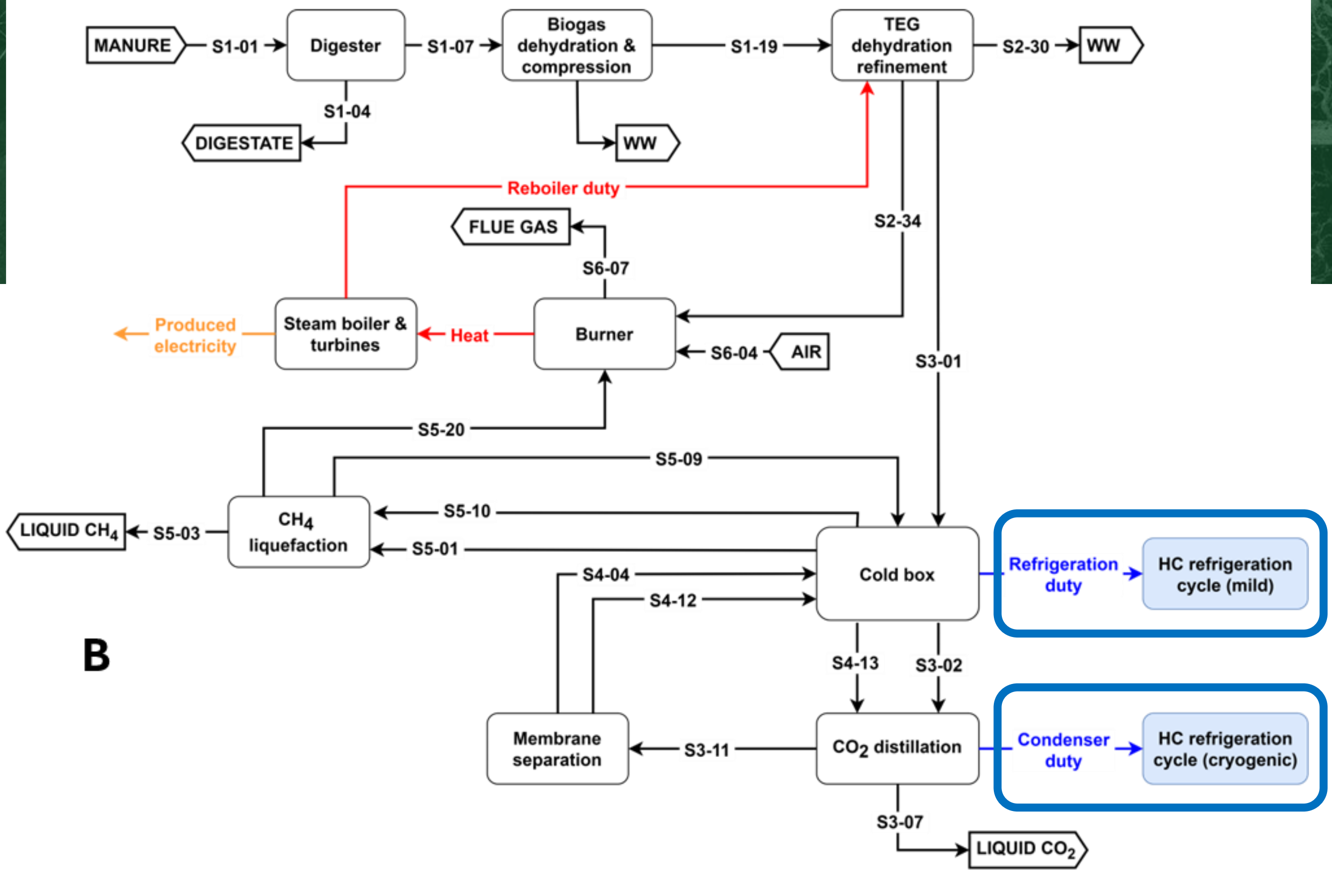
- Simulation in **COFE V3.10**, license-free simulation software by AmsterChem

Technology provider: Cryo Inox

CS3A

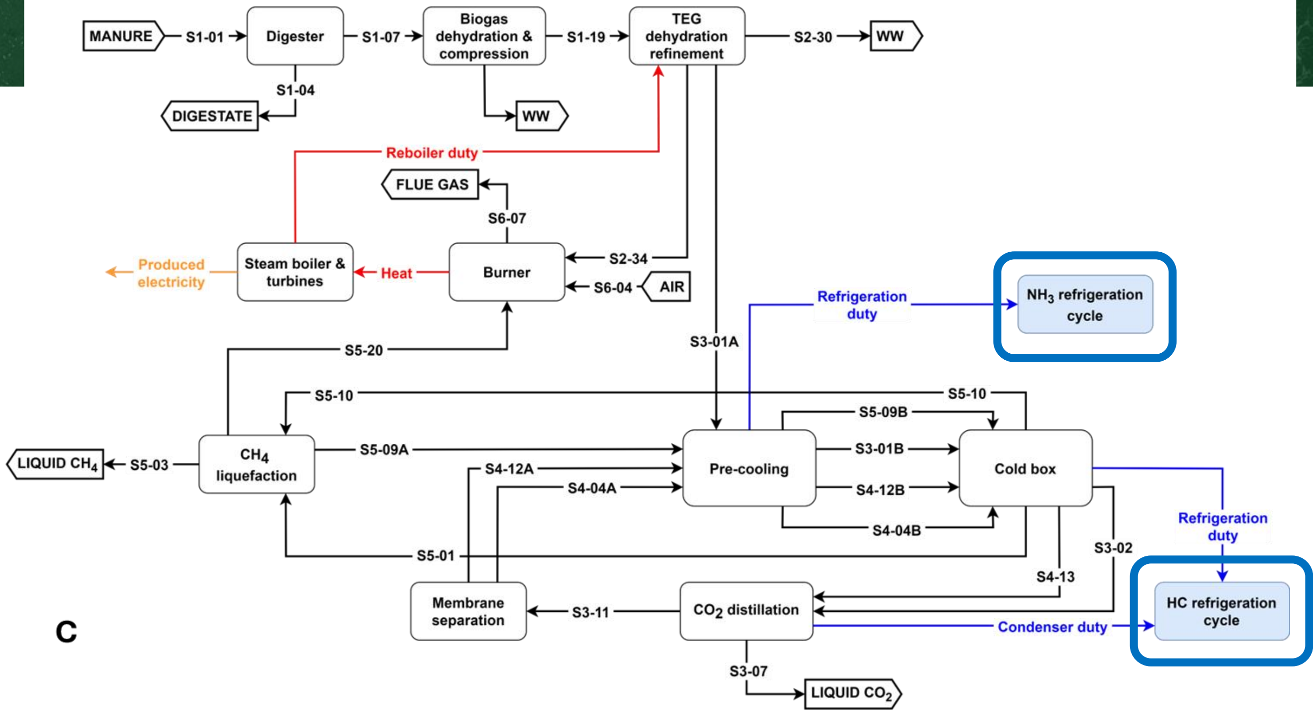

MANURE
S1-01
Digester
S1-07
Biogas dehydration & compression
S1-19
TEG dehydration refinement
S2-30
WW
S1-04
DIGESTATE
WW
Reboiler duty
S2-34
FLUE GAS
S6-07
Produced electricity
Steam boiler & turbines
Heat
Burner
S6-04
AIR
S3-01
S5-20
S5-09
LIQUID CH_4
S5-03
CH_4 liquefaction
S5-10
S5-01
Cold box
Refrigeration duty
HC refrigeration cycle
S4-04
S4-12
A
S4-13
S3-02
Membrane separation
S3-11
CO_2 distillation
Condenser duty
S3-07
LIQUID CO_2

CS3B



MANURE
S1-01
Digester
S1-07
Biogas dehydration & compression
S1-19
TEG dehydration refinement
S2-30
WW
S1-04
DIGESTATE
WW
Reboiler duty
FLUE GAS
S6-07
S2-34
Produced electricity
Steam boiler & turbines
Heat
Burner
S6-04
AIR
S3-01
S5-20
S5-09
LIQUID CH4
S5-03
CH4 liquefaction
S5-10
S5-01
S4-04
S4-12
Cold box
Refrigeration duty
HC refrigeration cycle (mild)
B
S4-13
S3-02
Membrane separation
S3-11
CO2 distillation
Condenser duty
HC refrigeration cycle (cryogenic)
S3-07
LIQUID CO2

CS3C


MANURE
S1-01
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Pre-cooling
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S4-12B
S4-04B
Refrigeration duty
S5-01
S3-02
S4-13
Membrane separation
S3-11
CO_2 distillation
Condenser duty
HC refrigeration cycle
S3-07
LIQUID CO_2

C

Refrigeration cycle optimisation

Systems & Control Transactions

Original Research Article
Peer Reviewed Conference Proceeding
ESCAPE 36 - European Symposium on Computer Aided Process Engineering
Sheffield, UK. 21-24 June 2026

PSE PRESS

Energy recovery from process purges: steam turbine integration and operation optimisation in biogas upgrading within SEMPRE-BIO project

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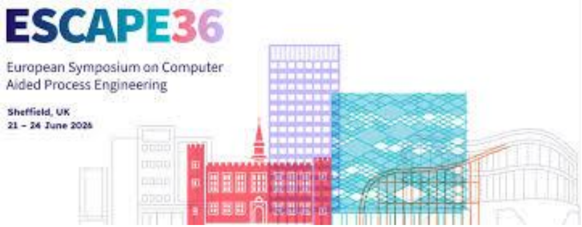

Open access paper coming soon!

3.Results

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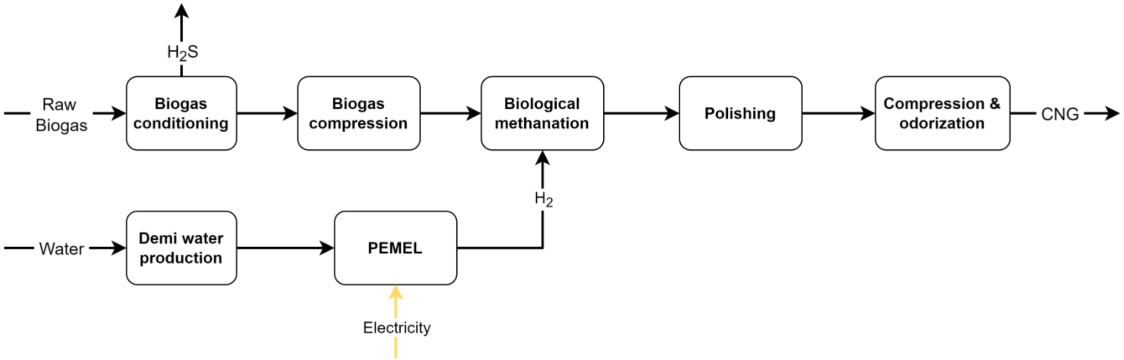
CS1

- The most relevant property of the compressed bio-CH4 is its dew point (Tdew) at 250 bar(a).
- CS1 can deliver compressed bio-CH4 with a purity of 98.45 vol% - corresponding to -60.5°C, in line with the European standard EN 16723-2:2017 for compressed natural gas for the use of Bio-CNG



CS2 – gasification KPI

KPI	Value	Note
Gas yield	1.23 $Nm^3_{dry\ syngas}/kg_{dry\ solid}$	In line with review work [1,2]
Syngas composition	H_2 > 45 vol% Other data are sensitive	On a dry basis without tars and in line with experimental data [1,2,3]
Tar yield	17.7 $g/kg_{dry\ solid}$	Comparable to other work [2]

[1] Marcantonio et al., 2020, Computation, 80 (4), 86
[2] Cerone et al., 2024, International Journal of Hydrogen Energy, 95, 1215-1221
[3] Gao et al., 2023, ACS Omega, 8, 31620-31631

CS2 – gasification KPI

KPI	Value	Note
Specify energy demand	1.02 kWh_{th}/kg_{dry} (3.66 MJ_{th}/kg_{dry})	In line with review articles using different wood feedstocks [4]
HHW	12.35 $MJ/Nm^3_{dry\ syngas}$	In line with literature values [1-4]
LHW	10.60 $MJ/Nm^3_{dry\ syngas}$	

[1] Marcantonio et al., 2020, Computation, 80 (4), 86
[2] Cerone et al., 2024, International Journal of Hydrogen Energy, 95, 1215-1221
[3] Gao et al., 2023, ACS Omega, 8, 31620-31631
[4] Daugaard D.E., Brown, R.C. 2003, Energy & Fuels, 17, 934-939

CS2 – biomethane production

	H_2 addition	Impurities (vol%)	CH4 yield ($Nm^3_{CH4}/kg_{dry\ solid}$)	Notes
CS2A (extra H_2)	54.9 $kg_{H2}/t_{dry\ solid}$	CO_2 0.03% Other sensitive	0.32 $Nm^3_{CH4}/kg_{dry\ solid}$	H_2 addition pushes CO_x conversion that generates H_2O that is condensed
CS2B (**no** extra H_2)	-	CO_2 30.06% Other sensitive	0.15 $Nm^3_{CH4}/kg_{dry\ solid}$	

CS3 – refrigeration

	Refrigeration layout	HC mixture	NH_3	Refrigerant use
CS3A	Single loop	**800 kg/h**	-	Reference
CS3B	Double loop	392.5 kg/h (mild) 326.7 kg/h (cryo) **755.2 kg/h (total)**	-	-5.6%
CS3C	Double loop with two refrigerants	**637 kg/h**	**34.0 kg/h**	-16.1%

CS3 – refrigeration

	Refrigeration layout	Compression HC mixture	Compression NH_3	Savings
CS3A	Single loop	**70.8 kW**	-	Benchmark
CS3B	Double loop	37.5 kW (mild) 22.6 kW (cryo) **66.1 kW (total)**	-	-6.2%
CS3C	Double loop with two refrigerants	**55.7 kW**	**5.9 kW**	-13.0%

CS3 – refrigeration

	Refrigeration layout	Total electricity demand (kW) [with turbine recovery (kW)]	Compression Refrigeration (kW)	Energy from steam turbine (kW)	Energy drop on the total electricity
CS3A	Single loop	**191.2** [173.0]	**70.8** (37.1%)	18.2 (9.52%)	Reference
CS3B	Double loop	**186.4** [168.2]	**66.1** (35.5%)	18.2 (9.77%)	-2.5%
CS3C	Double loop with two refrigerants	**181.9** [163.7]	**61.9** (34.1%)	18.2 (10.0%)	-5.2%

Comparison

	Scenario	Bio-CH_4 production	Bio-CH_4 purity (vol%)	Electricity demand [without electrolyser]
CS1		0.709 $Nm^3_{CH4}/Nm^3_{dry\ biogas}$	98.5 vol%	11.9 kWh_{el}/Nm^3_{CH4} [0.30 kWh_{el}/Nm^3_{CH4}]
CS2	A (H_2 added)	0.320 $Nm^3_{CH4}/kg_{dry\ solid}$ 0.260 $Nm^3_{CH4}/Nm^3_{dry\ biosyngas}$	95.2 vol%	9.1 kWh_{el}/Nm^3_{CH4} [Negligible]
	B (**no** H_2 added)	0.150 $Nm^3_{CH4}/kg_{dry\ solid}$ 0.122 $Nm^3_{CH4}/Nm^3_{dry\ biosyngas}$	45.0 vol%	Negligible
CS3		0.093 $Nm^3_{CH4}/kg_{dry\ solid}$ 0.591 $Nm^3_{CH4}/Nm^3_{dry\ biogas}$	99.99+ vol%	Opt A: 2.21 kWh_{el}/Nm^3_{CH4} Opt B: 2.15 kWh_{el}/Nm^3_{CH4} Opt C: 2.10 kWh_{el}/Nm^3_{CH4}

4.Conclusions

Conclusions

- **Three different technologies** have been modelled and simulated

- The process optimisation has been performed to reduce energy demand and **identify the best operational point** of the processes (constrained to biomethane purity) to **reduce energy demand** based on the end-user application

- Analysis showed that according to the process layout, feedstock, and train of the units of operation, the energy demand can change

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Thank you for your kind attention!

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