Economic analysis of innovative bio-methane technologies in SEMPRE-BIO

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Photo: Biogas research plant at DBFZ

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Agenda

- Introduction SEMPRE-BIO
- Methodology
- Case Study 1: Prefinal results and electricity investigation (PEMEL and Biomethanation – Spain)
- Case Study 2: Prefinal results (Pyrolysis and Biomethanation – France)
- Case Study 3: Prefinal results (Cryogenic Separation – Belgium)
- Summary and Outlook

SEMPRE-BIO: Innovative Biomethane Production

Three innovation ecosystems tested in pilot scale: Project end September 2026

Goals:

1. Increase cost effectivesness of conversion in biomethane production
2. Diversify conversion technologies
3. Contribute to market uptake of biomethane technologies
4. Contribute to demonstration of pilot plants of innovative technologies

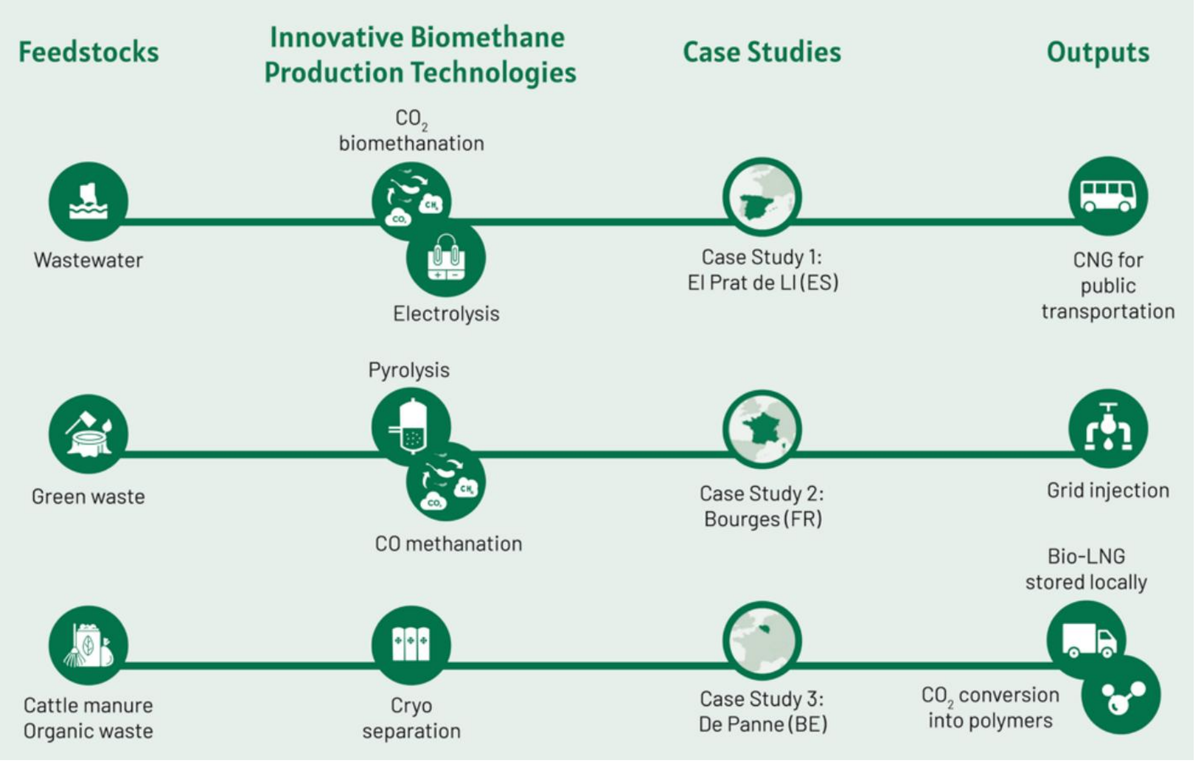


Illustration: Sempre-bio.com

Methodology Costing Analysis

- Used method: Levelized cost of energy (LCOE):

$$\mathrm{LCOE} = \frac{present\ value\ of\ total\ lifetime\ cost\ [€]}{present\ value\ of\ total\ lifetime\ energy\ units\ [m^3]}$$

- Energy unit defined as m³ biomethane under standard conditions (273.15K, 1,013.25 bar) with >95% methane purity
- Evaluation of scale up plants:
  - Based on process modelling by project partner SINTEF
  - Additional information from technology providers in project team
  - Scale up sizes based on output in biomethane: 125 m³/h – 2000 m³/h
- System boundaries: Focus on evaluation of core innovative process

Case Study 1: System Boundaries, Overview for Costing

- Base case: 250 bar pressurisation
- (Additional case for market uptake: grid injection 16 bar)
- System boundaries: PEMEL + biomethanation + pressurisation
- WWTP excluded
- Biogas procurement: cost of opportunity
- Selling point: Filling station at plant location: 250 Bars
- 2 types of biomethane – revenue 0.9 €/m³
- Biomethane from sewage sludge
- E-methane: green electrolysis + biogenic CO2

→ Electrolysis operation subject to RED III

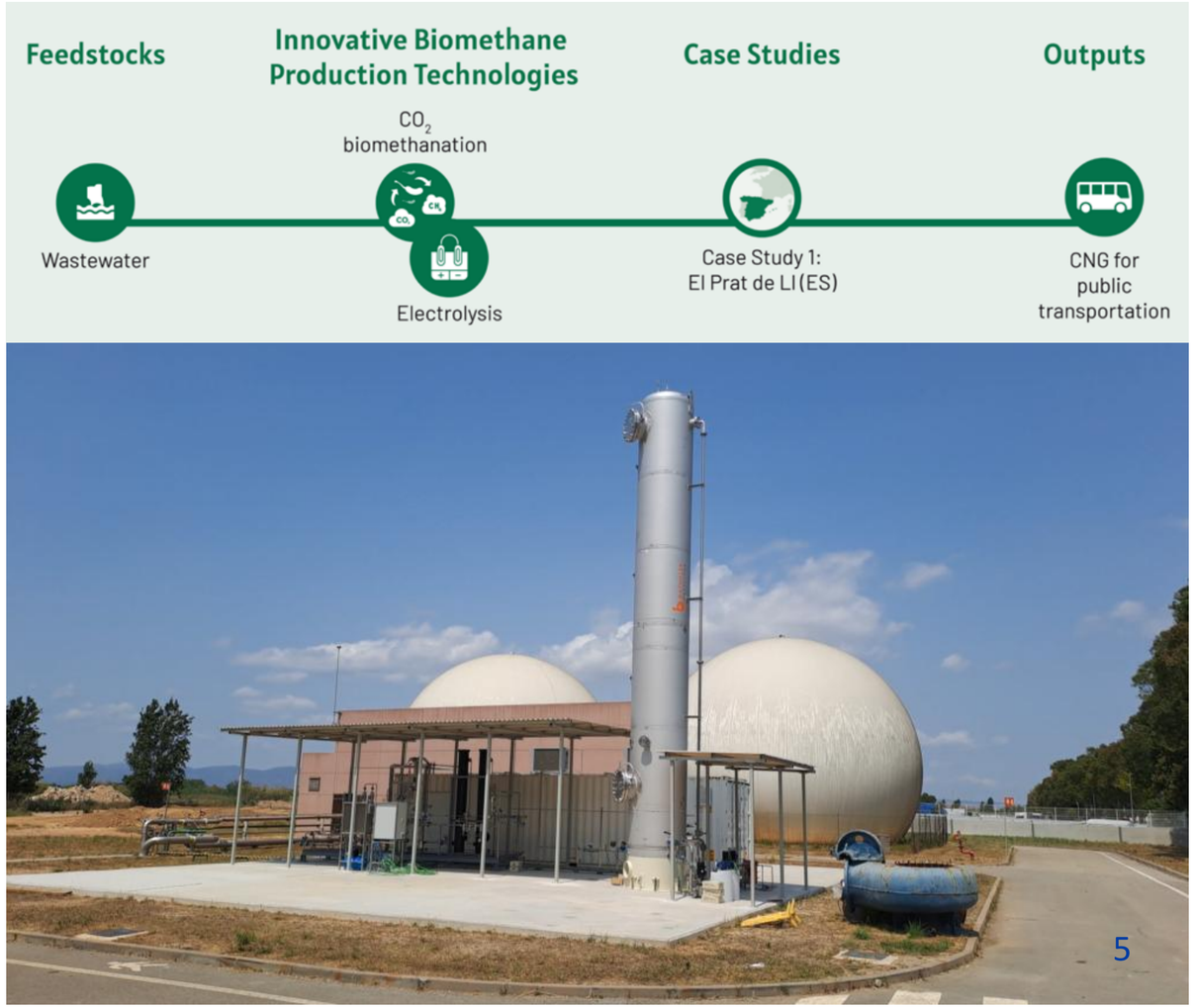


Illustration: SEMPRE-BIO.com; Image: SEMPRE-BIO.com (CS 1)

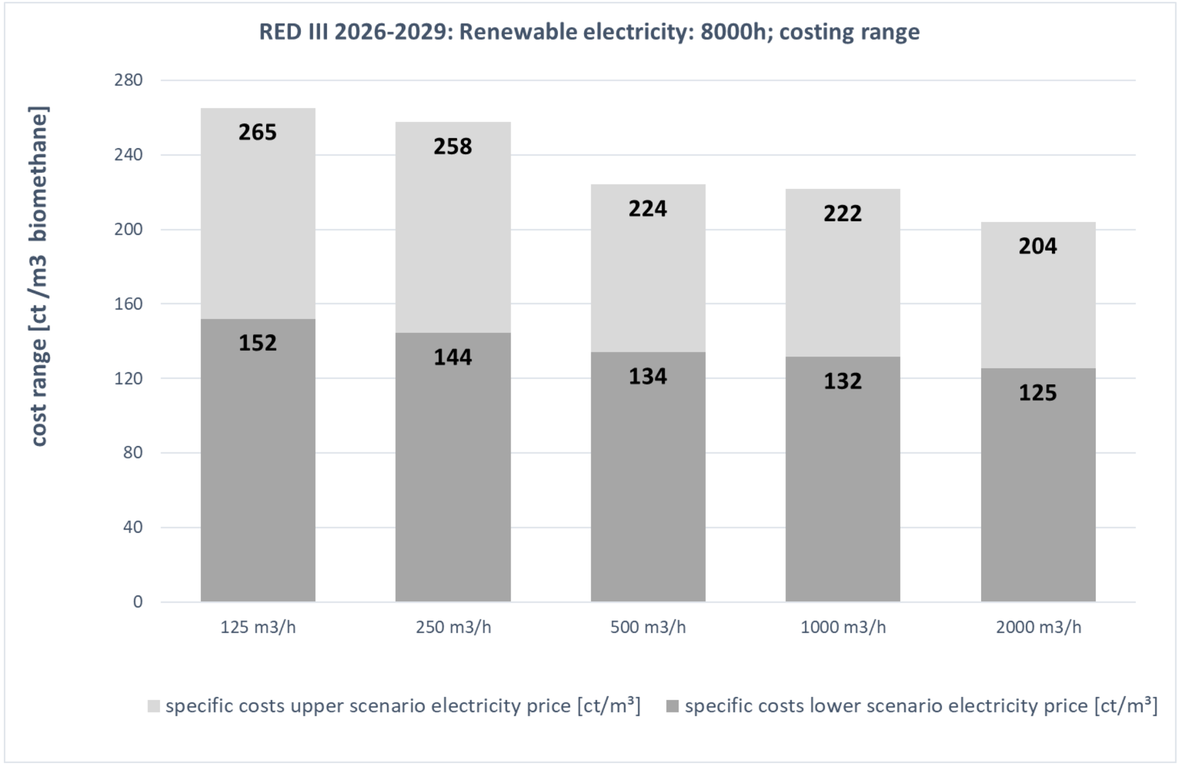
Case Study 1 - PEMEL & Biomethanation: RED III until 2030 Biomethane cost range

- Base case: CNG (250 bar), 8000 h
- E-methane compliant to RED III until 2030: monthly correlation of green electricity generation
- High OPEX-share: electricity price for electrolysis
- Cost range through electricity price variation:
  - 2.65€/m³ to 1.25€/m³
  - 2.04€/m³ to 1.25€/m³ on largest plant

→ Change in regulation in 2030

→ Market uptake: Electricity crucial in terms of regulation and costs

→ Additional analysis of electricity generation and price



Case Study 1 – RED III Hourly Correlation: Green Electricity Framework

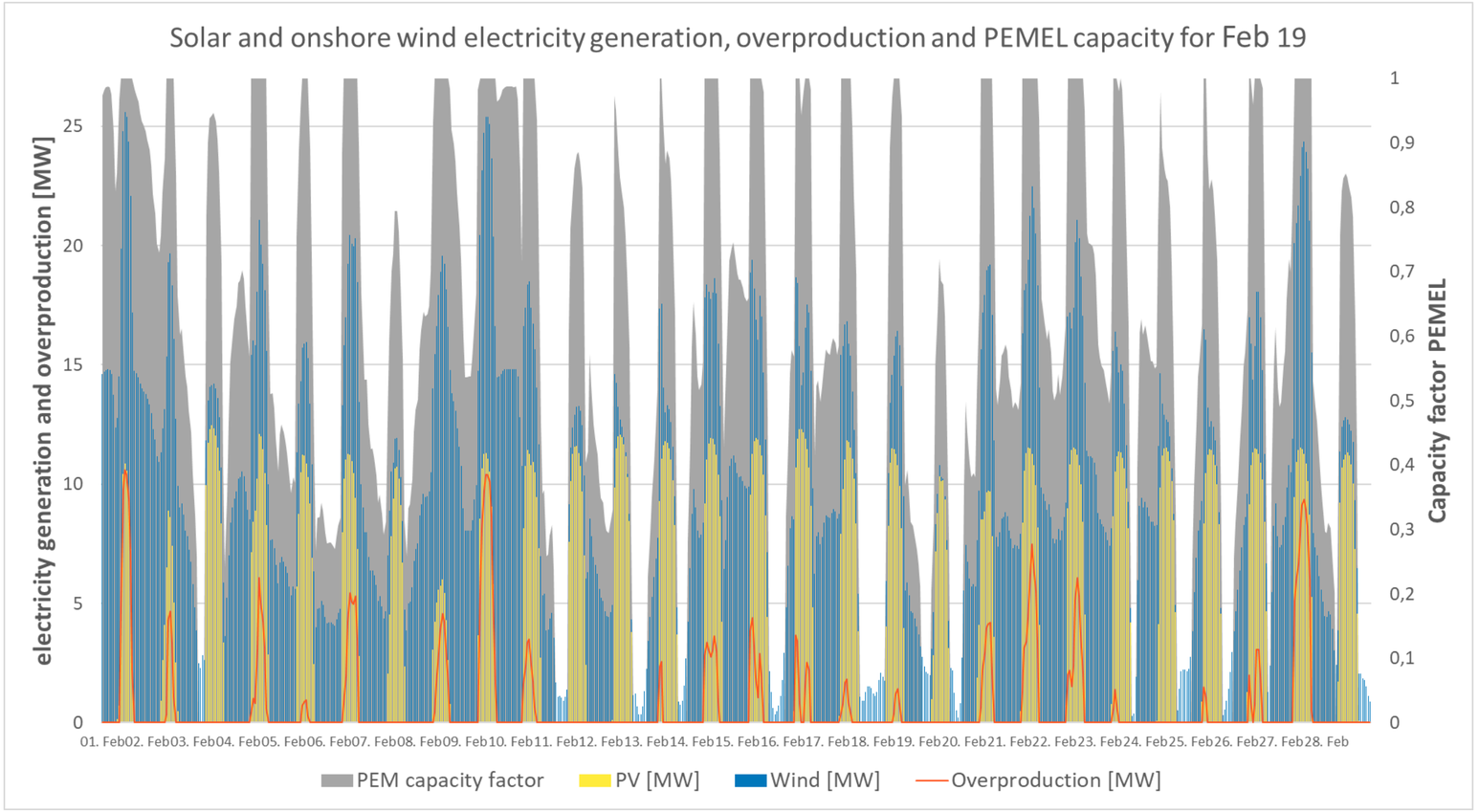
Methodology green electricity

- Weather data (2019) translated into electricity [1-3]
- Min. Capacity 20% for PEMEL
- Overproduction electricity of 5.6% without cost compensation
- LCOE [4-6] + grid levies [7]

Example: Onshore wind and Solar:

- 15 MW Wind
- 15 MW Solar
- 15 MW PEMEL

→ Resulting Capacity factor PEMEL for February 2019: 60%



1 Pfenninger & Staffell 2019: Simulations on PV and Wind energy. https://www.renewables.ninja/about; 2 Pfenninger & Staffell 2016: Long-term patterns of European PV output using 30 years of validated hourly reanalysis and satellite data. Energy 114, pp. 1251-1265. doi: 10.1016/j.energy.2016.08.060; 3 Staffell & Pfenninger 2016: Using Bias-Corrected Reanalysis to Simulate Current and Future Wind Power Output. Energy 114, pp. 1224-1239. doi: 10.1016/j.energy.2016.08.068; 4 Carvalho et al. 2025: Comparative Viability of Photovoltaic Investments Across European Countries Using Payback Periods and the Levelized Cost of Energy. Energies 2025, 18 (17), 4676; https://doi.org/10.3390/en18174676; 5 Thomas et al. 2025: Levelized cost of energy for various floating offshore wind farm designs in the areas covered by the Spanish maritime spatial planning. Applied Energy, 381, 125165.; 6 IRENA (2025), Renewable power generation costs in 2024, International Renewable Energy Agency, Abu Dhabi.; 7 Eurostat 2025: Electricity costs Europe: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_price_statistics#Electricity_prices_for_non-household_consumers; Diagram: own work based on [1-3]

Case Study 1 - PEMEL & biomethanation; RED III from 2030: Solar and Onshore Wind Electricity: balance cost – revenue

Solar and onshore wind, filling station (250 bar), reduced load hours: Capacity Factor: 64.5% or 5650 Load hours, electricity price 5.6 - 6.4 ct/kWh

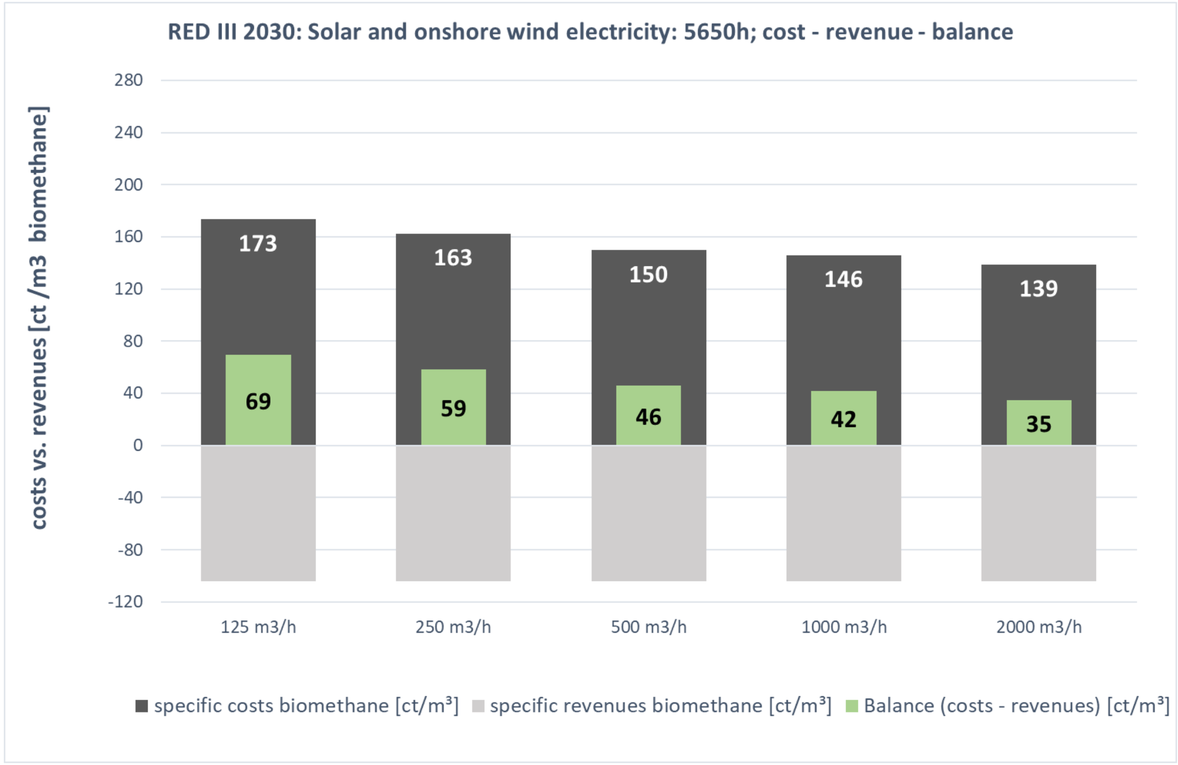
➔ **LCOE in range of 1.73 €/m³ to 1.39 €/m³**

→ Operation according to energy generation

→ Onshore wind significantly cheaper

→ Overproduction of 5.6%

➔ **Onshore wind and solar most economical**



Case Study 2: System Boundaries, Overview for Costing

- Base case: Pyrolysis, biomethanation, biogas upgrading, grid injection
- (Additional cases for market uptake: H_2 addition)
- System boundaries: Biomass supply + Pyrolysis + biomethanation + pressurisation
- 3 types of revenues
- Biomethane: 0.9 €/m³
- Biochar: 200 €/t
- Carbon Credits of Biochar : CDR: 140 €/t CO_2

Illustration: SEMPRE-BIO.com; Image: SEMPRE-BIO.com (CS 2)

Case Study 2: Pyrolysis & Biomethanation: Costs

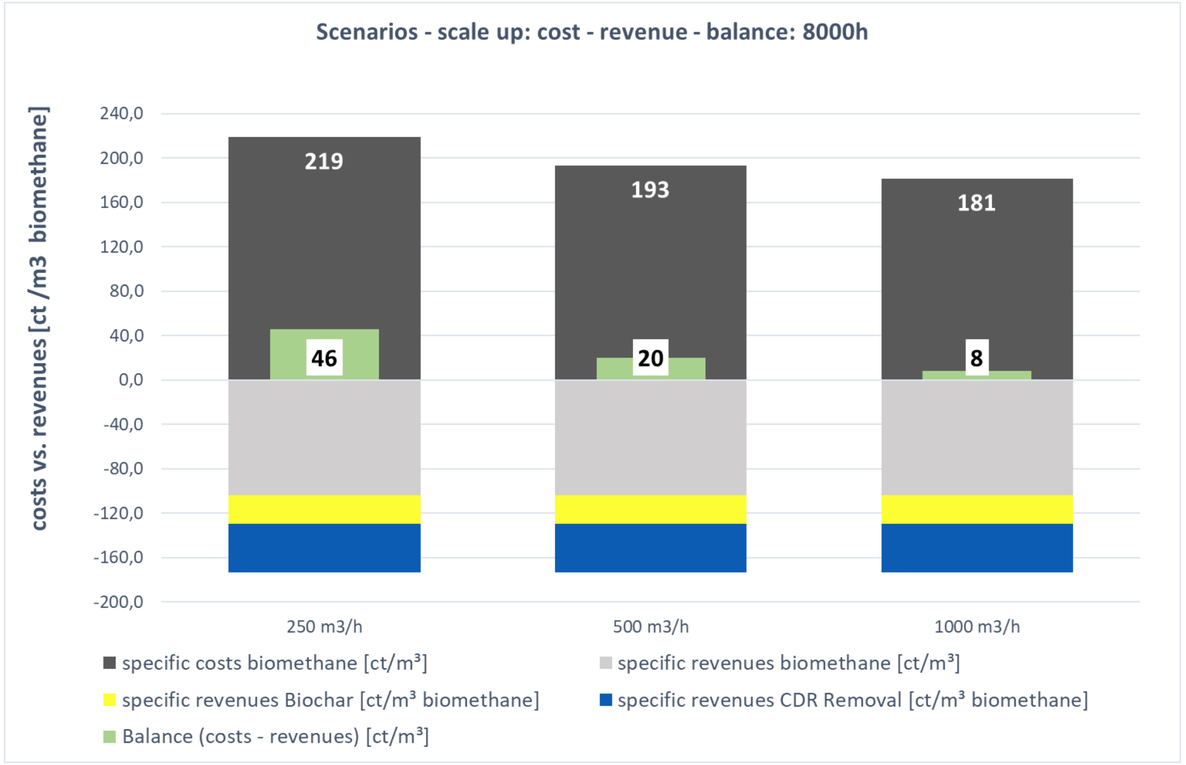
Base case: Pyrolysis, Biomethanation, biogas upgrading, grid injection

➔ **LCOE in range 2.19€/m³ to 1.82 €/m³**

➔ Revenue diversification

➔ Market uptake: Continuous market development for CDR and Biochar necessary

Other scenarios in the project: hydrogen addition through electrolysis and purchase



Case Study 3: System Boundaries, Overview for Costing

- Base case: cryogenic separation
- (Additional cases: direct CO_2 valorisation: proteins and biochemicals/biopolymers)
- System boundaries:
- Biogasplant excluded
- Biogas procurement: cost of opportunity CHP
- Digestate procurement: cost-neutral due to nutrient surplus region
- Selling point: at plant location
- 2 types of revenues
- Bio-LNG: 0.9 €/m³
- Liquid CO_2: 80 €/t

Illustration: SEMPRE-BIO.com; Image: SEMPRE-BIO.com (CS 3)

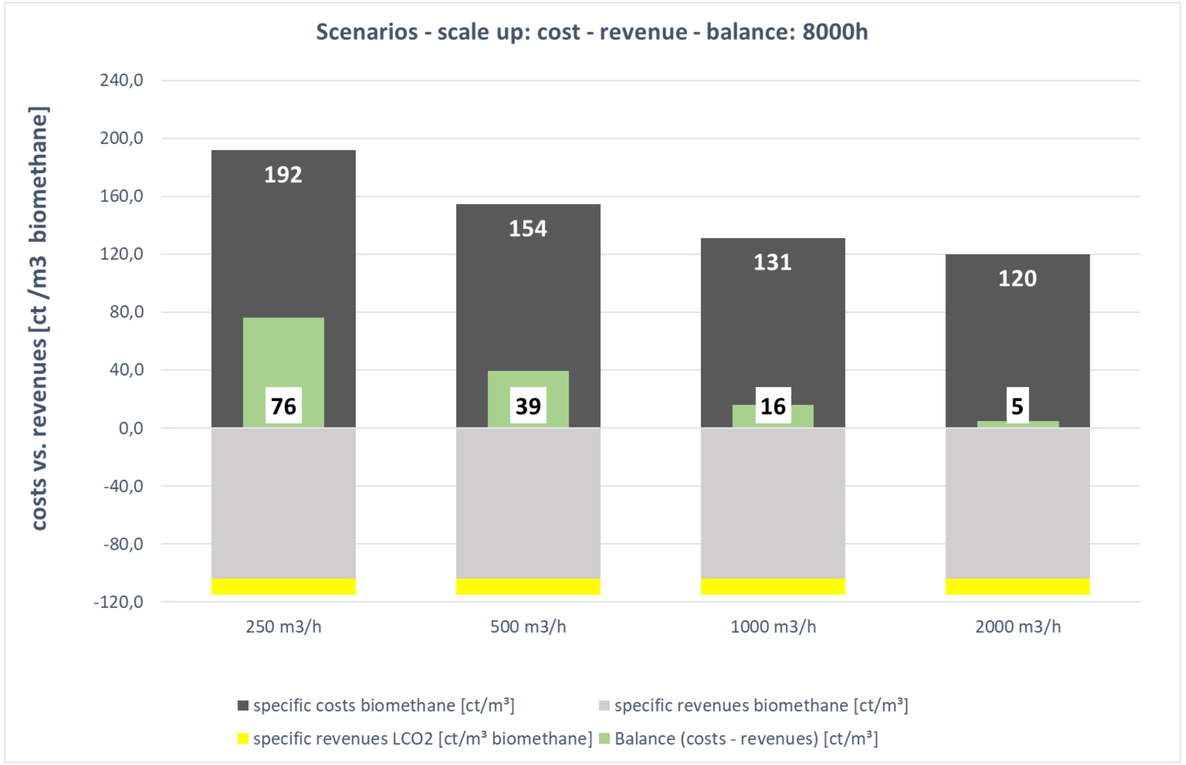
Case Study 3: Cryogenic Separation: Costs

Base Case: cryogenic separation

➔ **LCOE in range 1.92 €/m³ to 1.20 €/m³**

→ Market uptake: Distribution network essential due to expensive transportability of liquified goods

Other scenarios in the project: CO2 – valorisation through protein and biochemical/biopolymer production



Summary and Outlook

Summary:

Three innovative technologies for biomethane production evaluated (different feedstocks, technologies products and markets)

→Current evaluation of scale ups show small gap to profitability
→Individual market uptake requirements per technology (location, distribution)
→Future revenue development crucial for investigated technologies

Next steps:

- Sensitivity analysis
- Market uptake analysis: implementation markets and regions
- Cost Reduction potentials

Thank you

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