8TH INTERNATIONAL CONFERENCE
ON SUSTAINABLE SOLID WASTE MANAGEMENT
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Evaluation of the polymeric membranes' performance in terms of laboratory-scale CO_2 removal/separation from biogas

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Introduction (1/3)

- Increasing organic waste disposal → emergent need for their use, aiming to energy recovery and nutrients' recycling
- Anaerobic Digestion (AD) → Crude biogas production, consisting of:
  - Methane (50-75%), Carbon Dioxide (50-25%)
  - Minor impurities (Hydrogen Sulfide H_2S, NH_3, Moisture, Siloxanes)
- Necessity of pre-treatment for the elimination of minor impurities
- Biogas Upgrade using polymeric membranes
- Purpose: 95% CH_4 Purity

Introduction (2/3)

- Asymmetric Hollow fiber (HF) membranes
  - Hollow fibers: bundled in compact volume
  - Shell: hollow fibers' housing
- Separation principle:
  - Permeability difference of gases
  - Pressure difference between shell and fibers
- Retentate Stream: Product gas, rich in Methane
- Permeate Stream: Recycling stream, rich in Carbon Dioxide

Introduction (3/3)

Polysulfone HF 2-stage membrane

Polymeric membranes' main benefits when applied for biogas upgrade

(+) Wide commercial use

(+) High Perm-selectivity

(+) Low production cost

(+) Easy to scale up

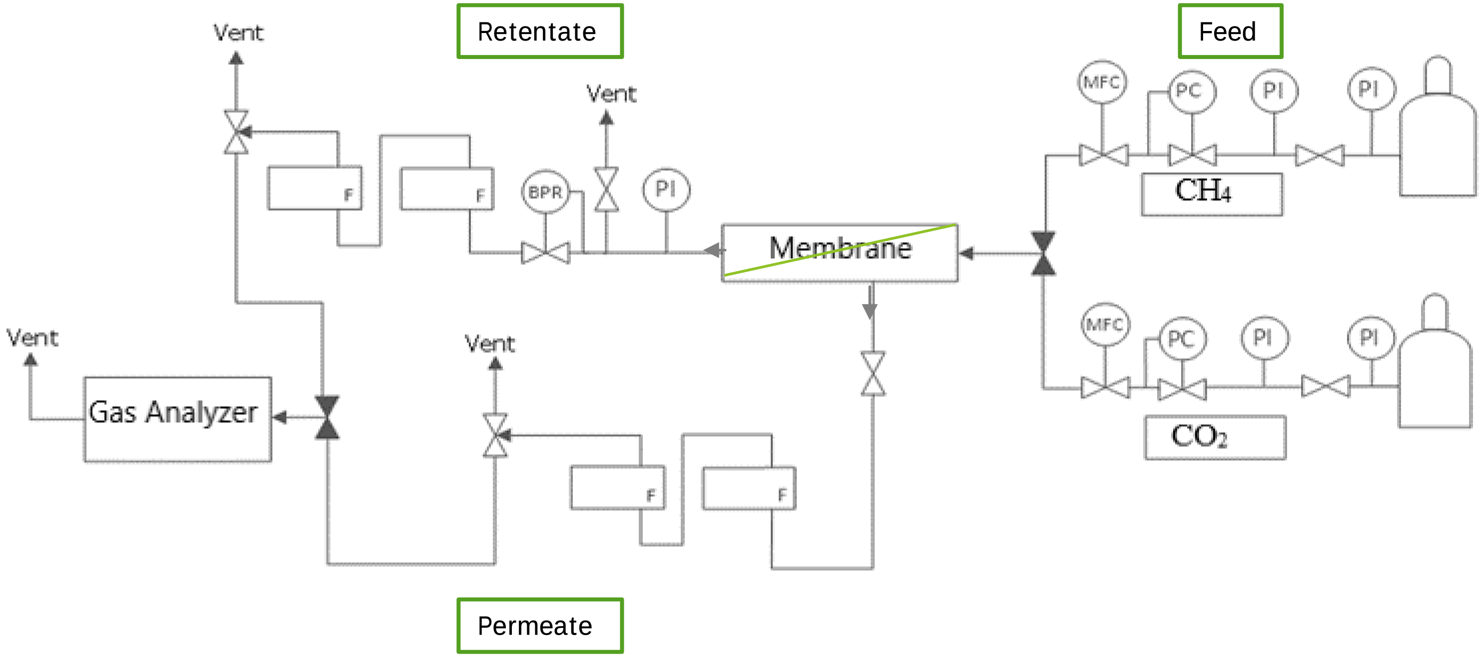
(-) Plasticization, physical aging problems

Purpose

- Investigation of a biogas upgrade system using polymeric membranes
- Evaluation of various polymeric membranes
- Design of a membrane setup for the upgrade of biogas on a laboratory scale
- Simultaneous recycling of captured CO_2

Experimental Setup (1/4)

- **Flowchart of the experimental set-up**



PI: Pressure Indicator

PC: Pressure Controller

MFC: Mass Flow Controller

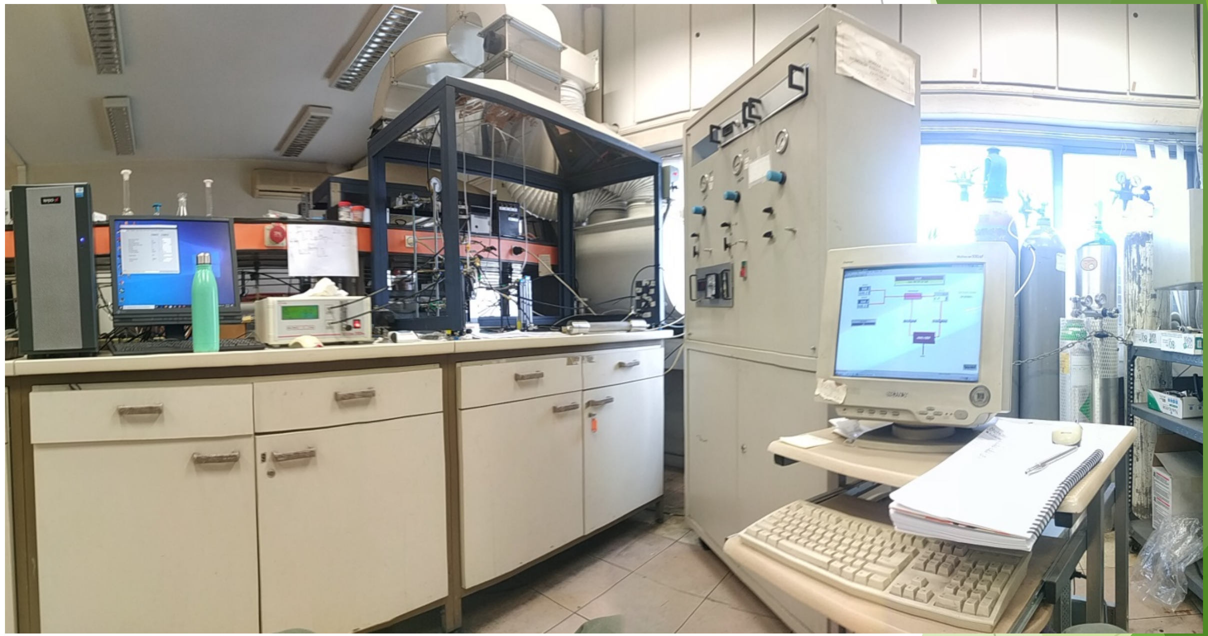
F: Flowmeter

BPR: Back Pressure Regulator

Experimental Setup (2/4)

Experimental conditions for gas separation tests.

Experimental condition	Mixed gas separation (CH_4/CO_2)
Feed gas composition, (%vol)	55/45, 60/40, 65/45, 70/30
Feed pressure, (bar)	0.7 – 1.5
Permeate pressure, (bar)	0
Feed temperature, (ºC)	20



Experimental Part (3/4)

Properties of used membrane	Type: MCH-1512A
Hollow fiber material	Polysulfone
Hollow fiber OD, (mm)	55
Length, L (m)	0.365
Effective area (m^2)	1.4

- Countercurrent flow

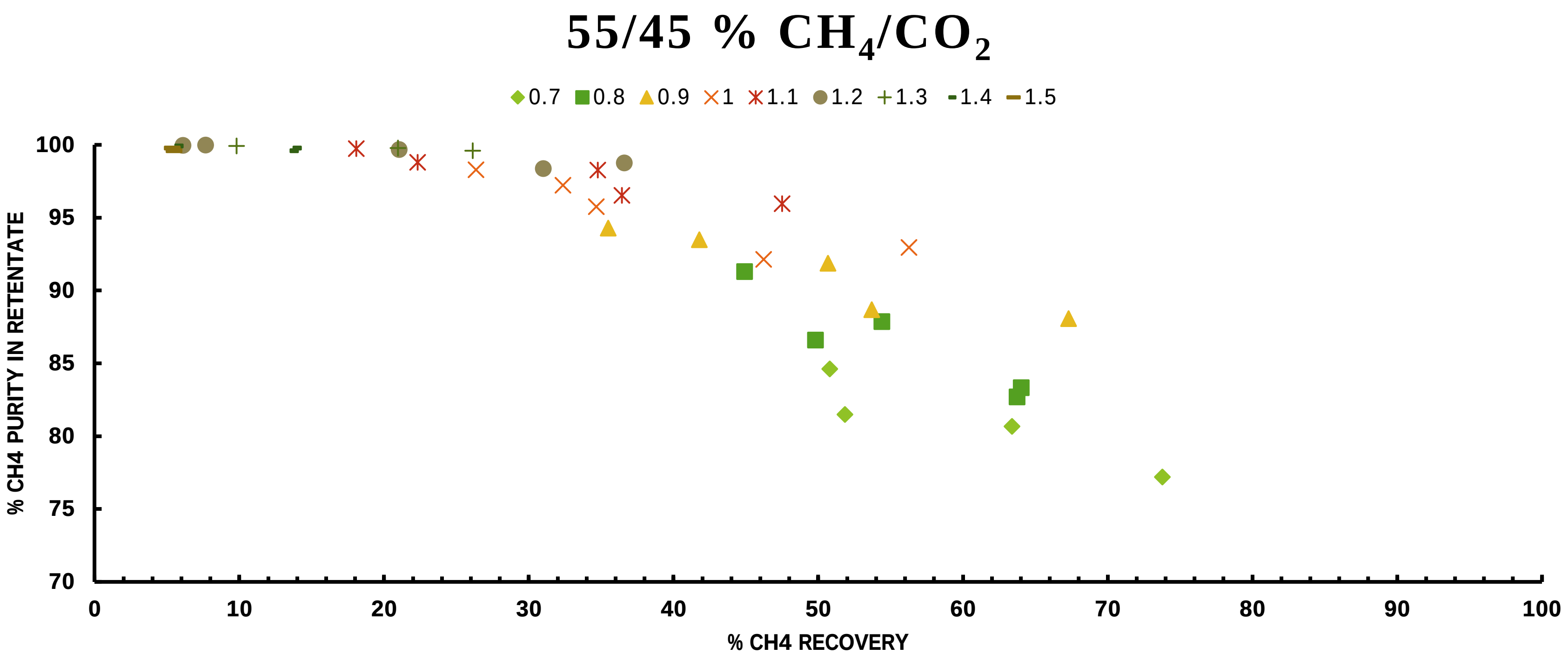
Experimental Part (4/4)

Gas separation experiments

- Binary gas mixture of CH_4 and CO_2
- 2-stage membrane module
- Back Pressure Regulator
- Mass flow controllers/Flow meters for each stream
- Gas Analyzer (Rapidox 3100EAM)

Results (1/8)

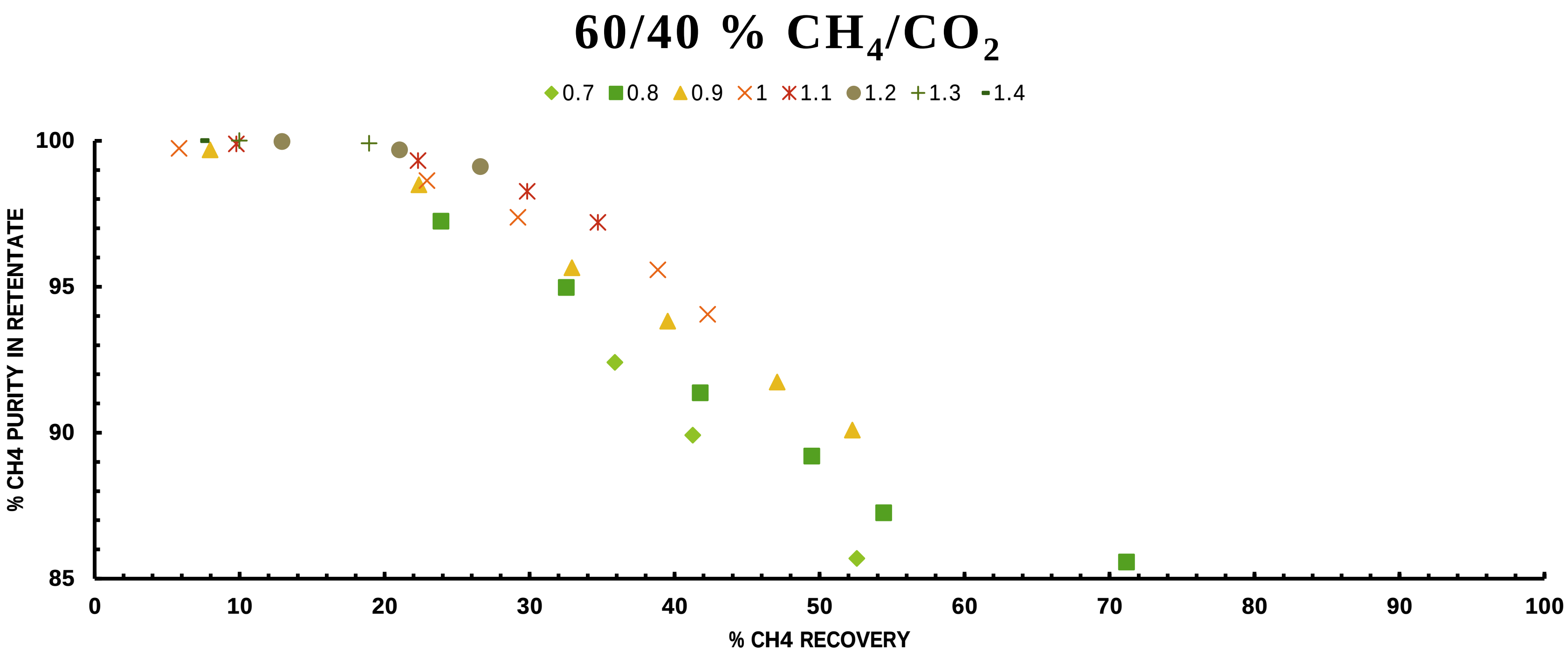
Figure 1: Gas separation performance for various feed pressure values (0.7 – 1.5 bar) (gas composition: 55% CH_4/45% CO_2)



Increase of CH_4 purity when CH_4 recovery diminishes.
Purity > 95% around 40% recovery.

Results (2/8)

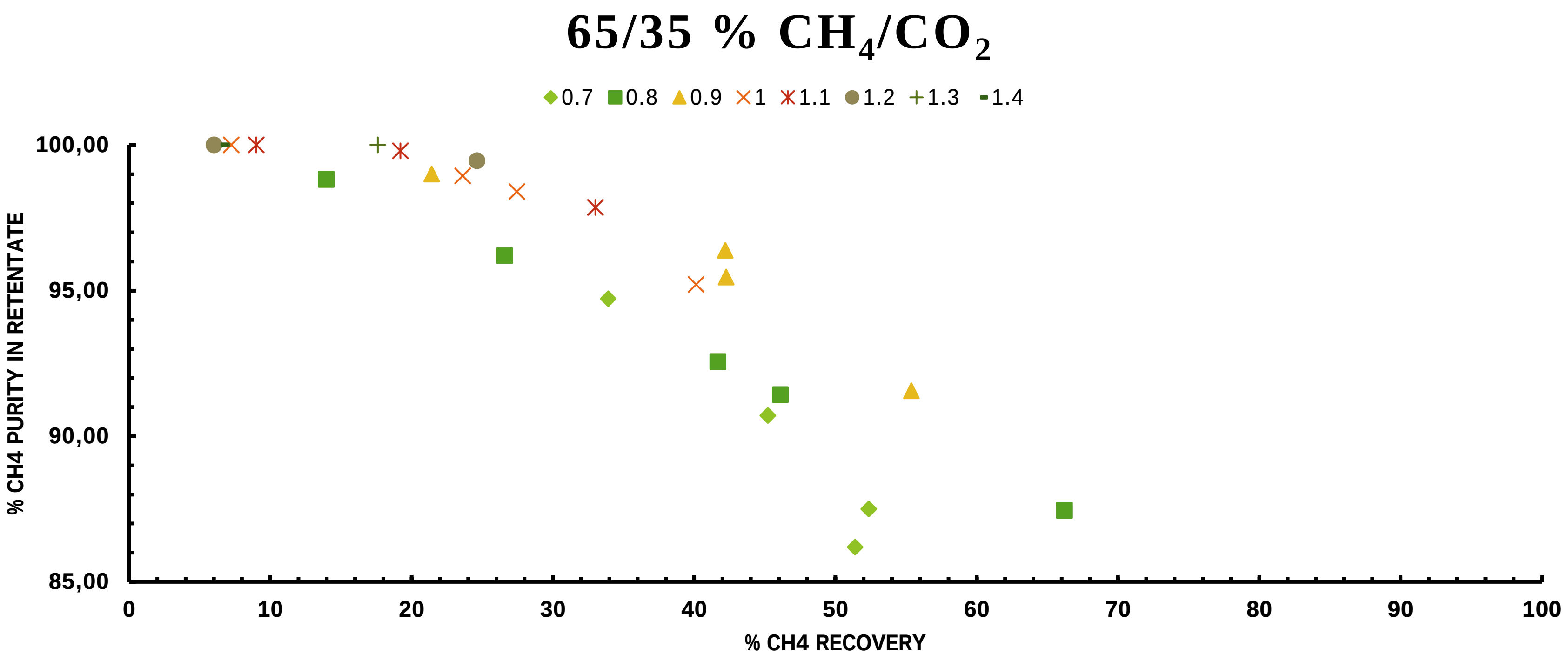
Figure 2: Gas separation performance for various back pressure values (0.7 – 1.5 bar) (gas composition: 60% CH_4/40% CO_2)



Increase of CH_4 purity when CH_4 recovery reduces.
Purity > 95% around 40% recovery.

Results (3/8)

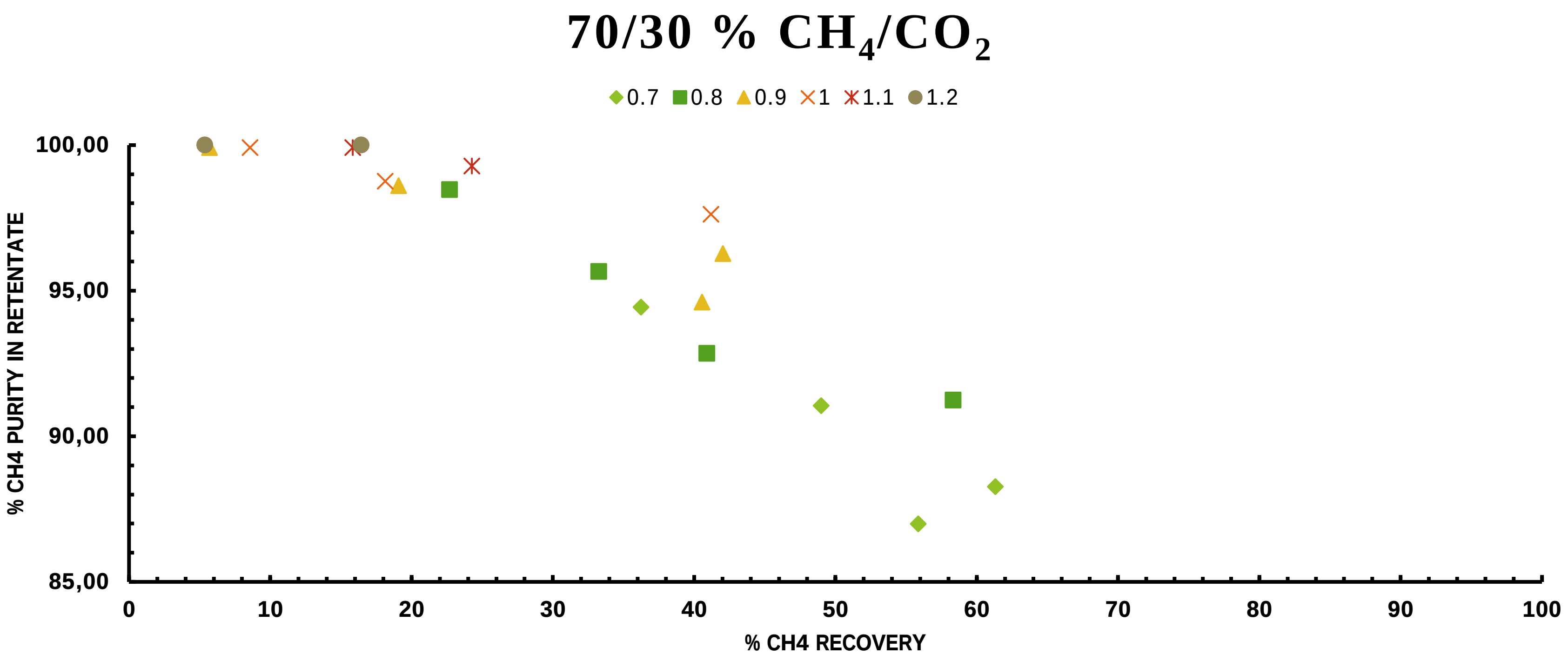
Figure 3: Gas separation performance for various back pressure values (0.7 – 1.5 bar) (gas composition: 65% CH_4/35% CO_2)



Increase of CH_4 purity when CH_4 recovery reduces.
Purity > 95% around 40% recovery.

Results (4/8)

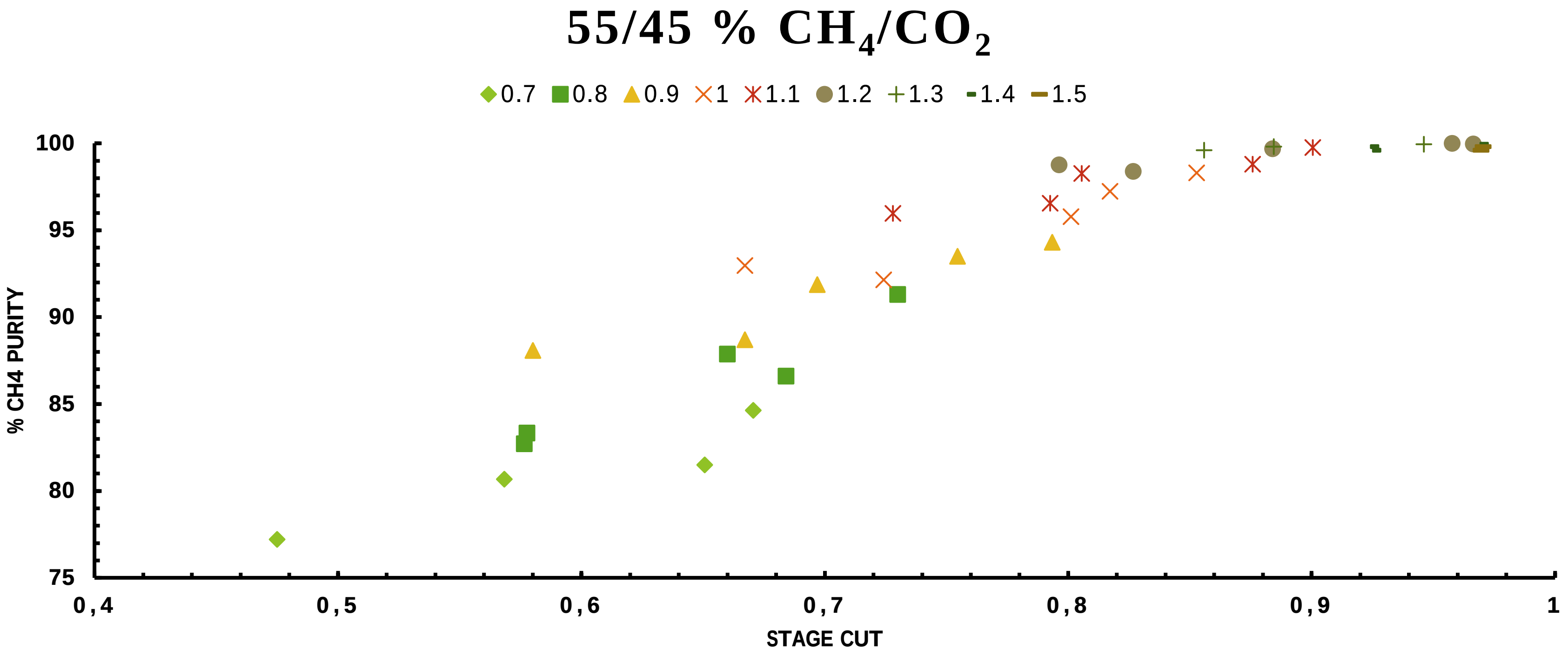
Figure 4: Gas separation for various back pressure values (0.7 – 1.5 bar)
(gas composition: 70% CH_4/30% CO_2)



Increase of CH_4 purity when CH_4 recovery reduces.
Purity > 95% around 40% recovery.

Results (5/8)

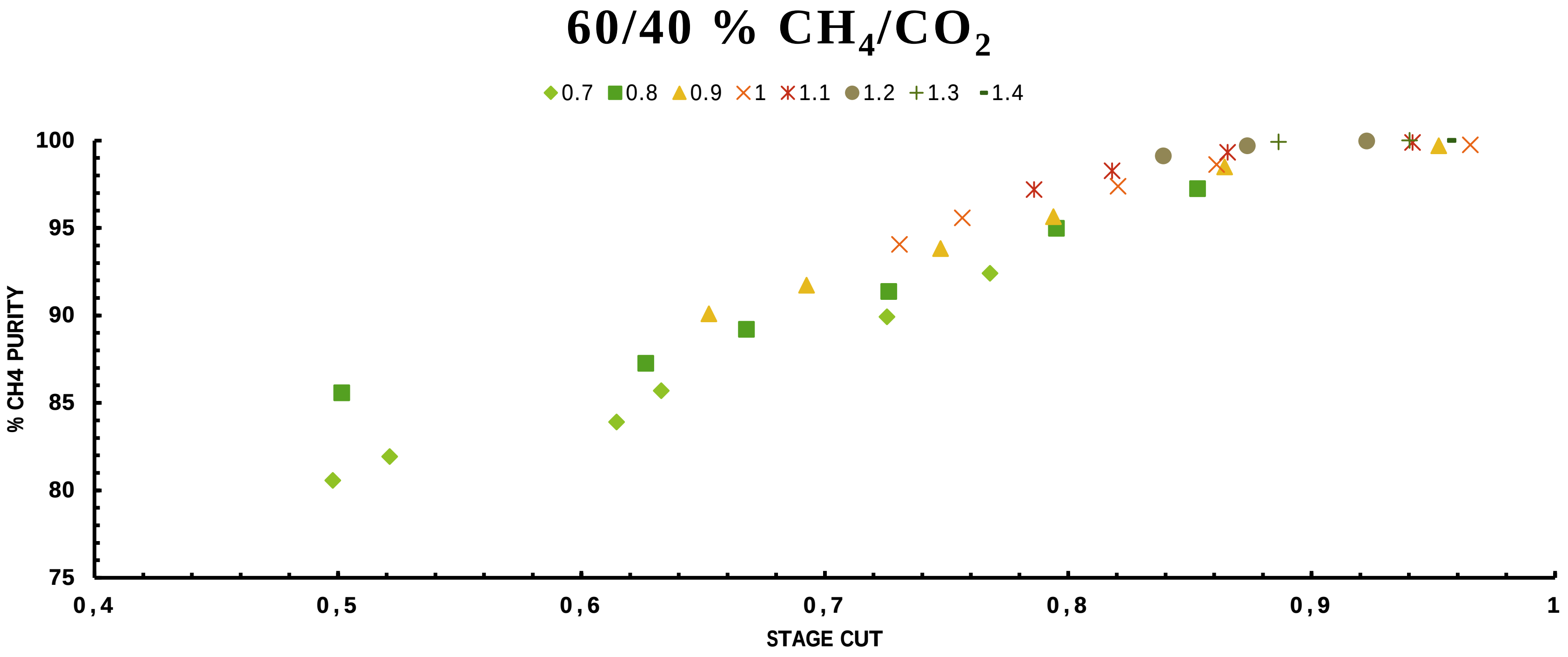
Figure 5: Effect of stage cut on CH_4 purity for various feed pressure values (0.7 – 1.5 bar) (gas composition: 55% CH_4/45% CO_2)



Increase of stage cut values leads to higher CH_4 purity.
Purity > 95% when stage cut > 0.74 for feed pressure = 1.1 bar

Results (6/8)

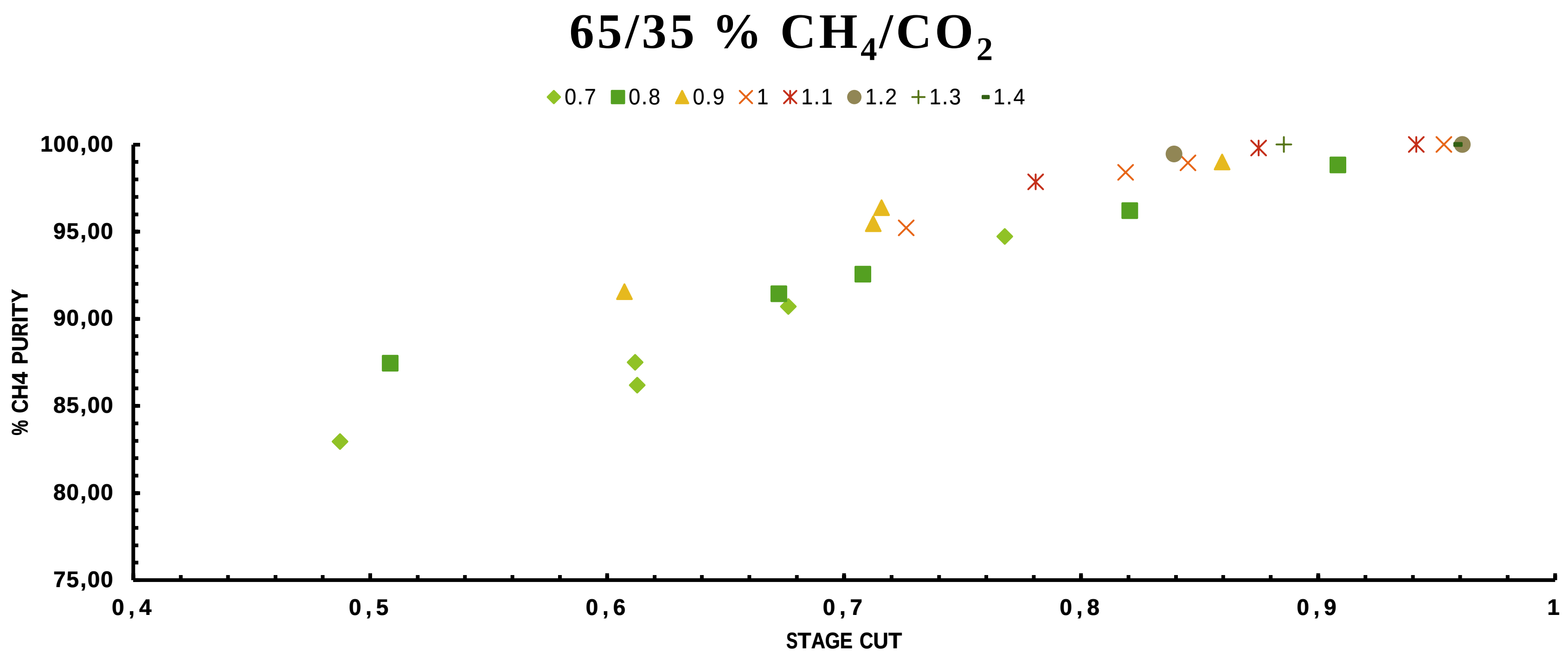
Figure 6: Effect of stage cut on CH_4 purity for various feed pressure values (0.7 – 1.5 bar) (gas composition: 60% CH_4/40% CO_2)



Increase of stage cut values leads to higher CH_4 purity.
Purity > 95% when stage cut > 0.75 for feed pressure = 1 bar

Results (7/8)

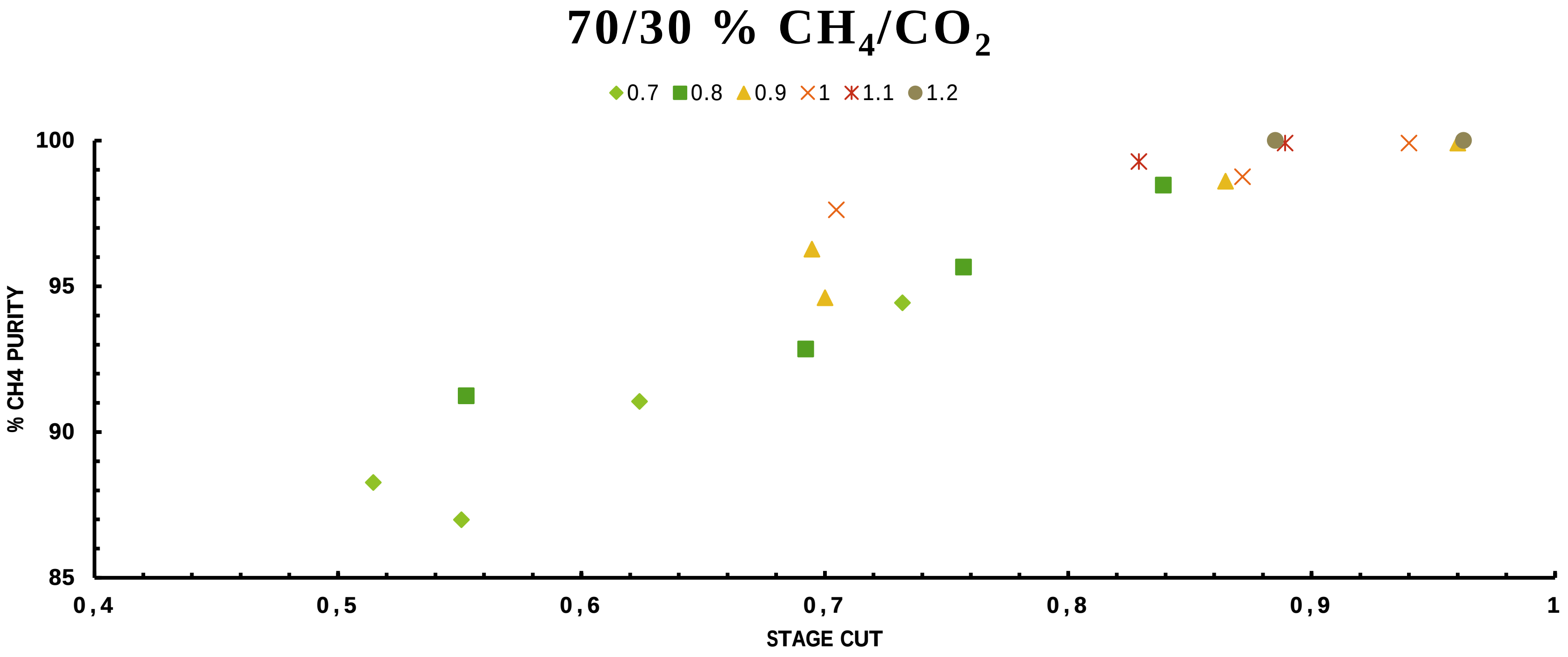
Figure 7: Effect of stage cut on CH_4 purity for various feed pressure values (0.7 – 1.5 bar) (gas composition: 65% CH_4/35% CO_2)



Increase of stage cut values leads to higher CH_4 purity.
Purity > 95% when stage cut > 0.7 for feed pressure = 0.9 bar

Results (8/8)

Figure 8: Effect of stage cut on CH_4 purity for various feed pressure values (0.7 – 1.5 bar) (gas composition: 70% CH_4/30% CO_2)



Increase of stage cut values leads to higher CH_4 purity.
Purity > 95% when stage cut > 0.7 for feed pressure = 0.9 bar

Conclusions (1/2)

- High purity biomethane separation is achieved

 (>95% CH_4) for feed pressures higher than 1 bar

- CH_4 recovery: decreases with increasing stage cut, while CH_4 purity increases

Optimum conditions :

40% CH_4 recovery $\rightarrow$ > 95% CH_4 purity

..recovery ratio can be improved with the add of extra modules or recycle streams

Conclusions (2/2)

- Stage cut: higher stage cut values → higher CH_4 purities

Optimum conditions

Stage cut between 0.7-0.9 → >95% CH_4 purity

(-) Lower stage cut leads in low CH_4 purity or limited biogas capture.

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Thank you for your attention

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