BIOLOGICAL METHANATION & MODELLING

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NEO CARBON ENERGY

NEO-CARBON ENERGY 9th RESEARCHERS' SEMINAR

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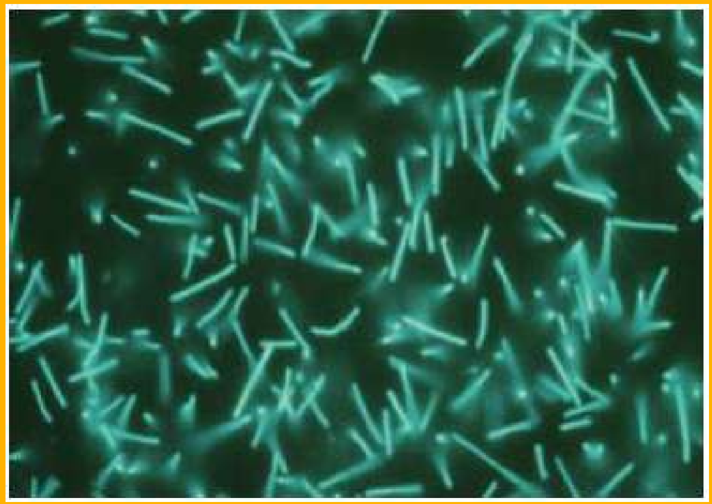
Contents

- Why biological methanation?
- Commercial status
- Modelling
- Results



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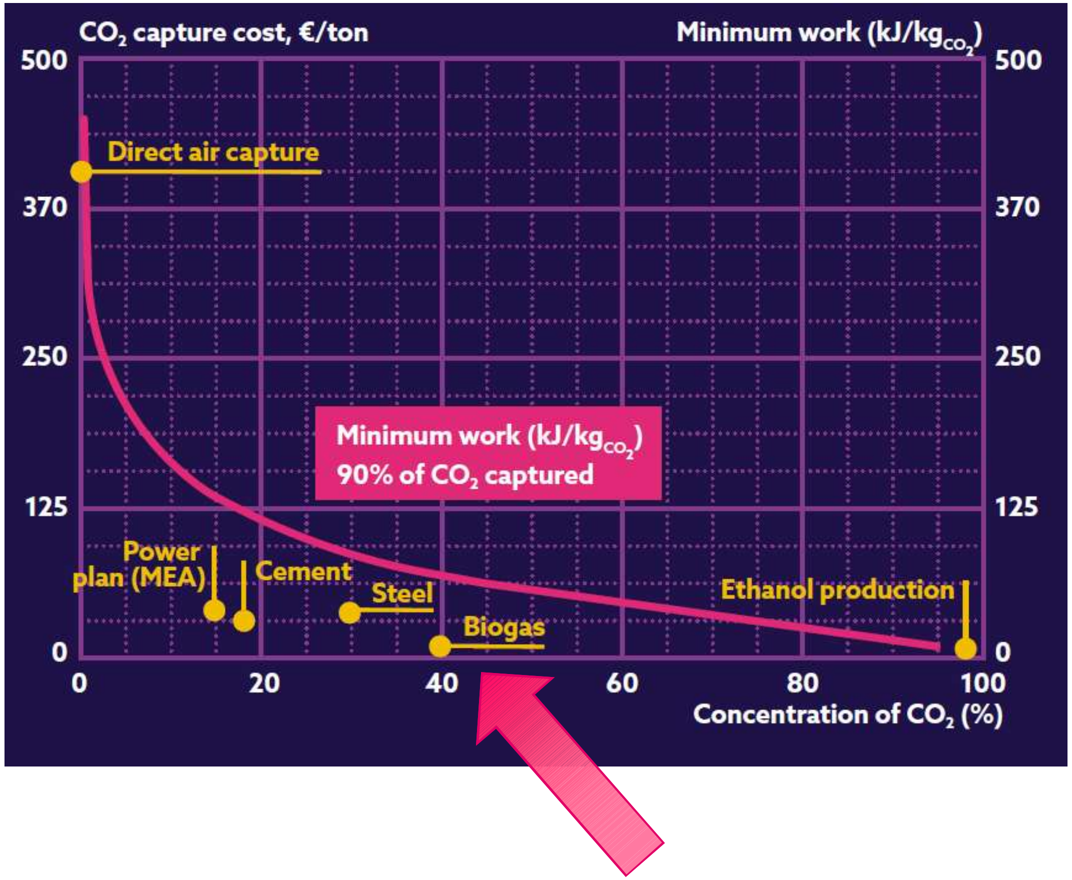
Why biological methanation?

- Biological methanation is a good solution if **biogas** is chosen as the CO_2 source.
- More simple option than the chemical methanation as it does not require CO_2 separation or cleaning



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Waste as a source

- PtG potential of CO_2 from Finnish wastewater is 19 MW_e.

Wastewater treatment plant	Prod. biogas 1000 m^3	CH_4 %	Prod. CH_4 1000 m^3	Additional CH_4 potential 1000 m^3	$P_{electrolyzer}$ MW_e
Espoo, Suomenoja	3926	63	2473	1256	2.53
Forssa	569	70	398	142	0.29
Helsinki, Viikinmäki	13322	62	8260	4396	8.85
Hämeenlinna, Paroinen	643	62	399	212	0.43
Joensuu, Kuhasalo	923	65	600	277	0.56
Jyväskylä, Nenäinniemi	2107	63	1327	674	1.36
Kuopio, Lehtoniemi	1166	68	793	315	0.63
Lahti, Kariniemi, Ali-Juhakkala	1925	60	1155	674	1.36
Maarianhamina, Lotsbroverket	413	40	165	227	0.46
Mikkeli, Kenkäveronniemi	418	67	280	117	0.24
Nurmijärvi, Klaukkala	61	70	43	15	0.03
Riihimäki	650	65	423	195	0.39
Salo	465	62	288	153	0.31
Tampere, Rahola	652	65	424	196	0.39
Tampere, Viikinlahti	2551	65	1658	765	1.54
Total	29791	-	18686	9616	19.36

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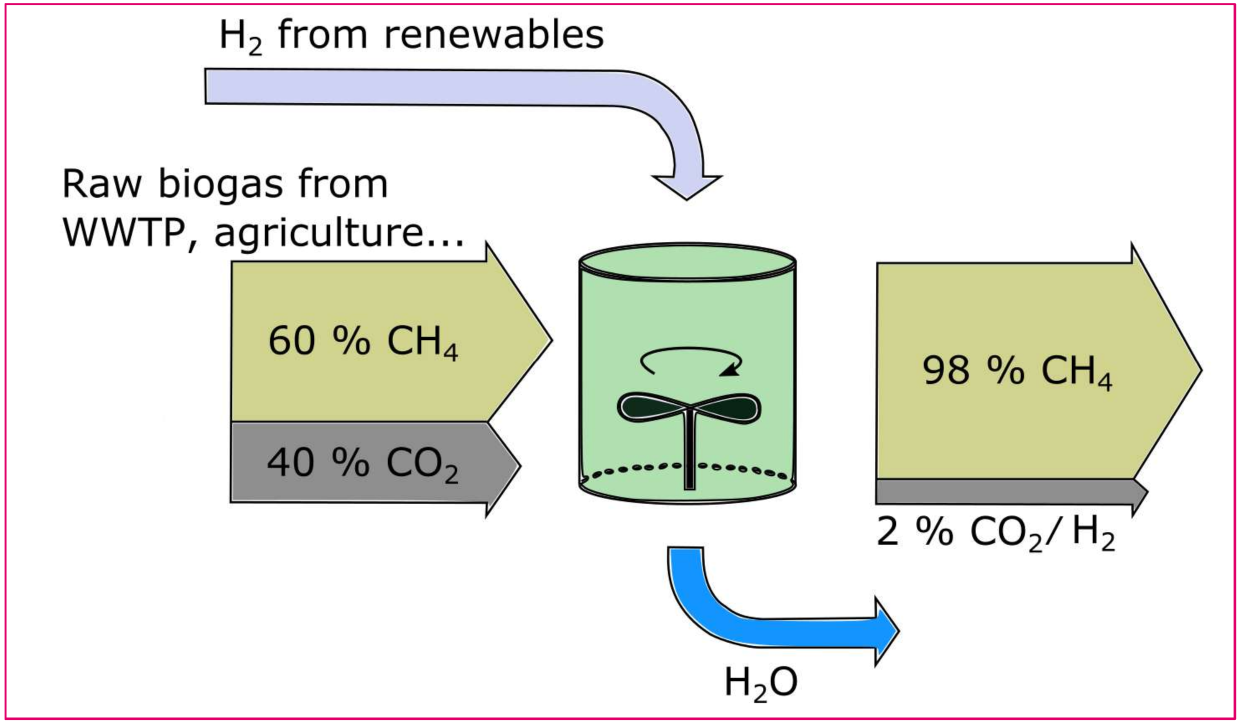
Antti Holopainen, Carbon sources for PtG applications in the Finnish energy system, M.Sc. Thesis, LUT, 2015

High carbon utilization

- CO_2 from biogas can be converted to usable CH_4 with high carbon efficiency.

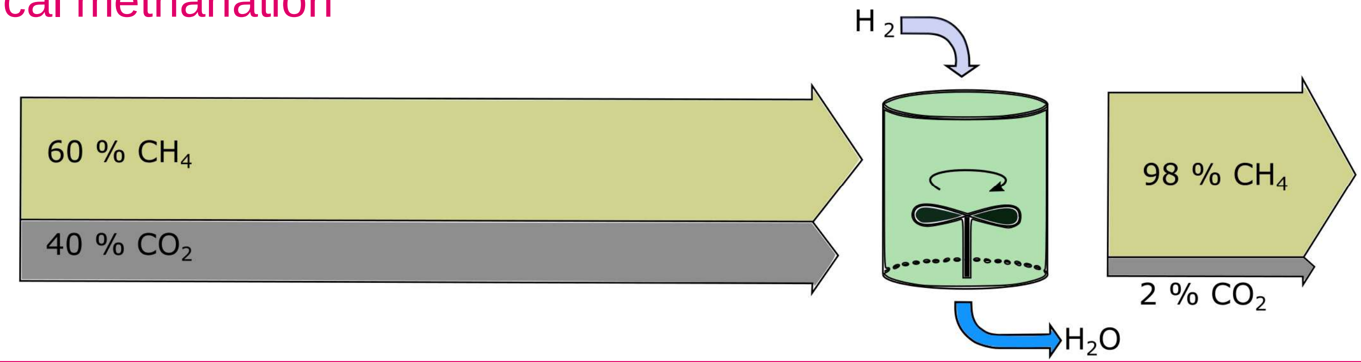
Biological methanation



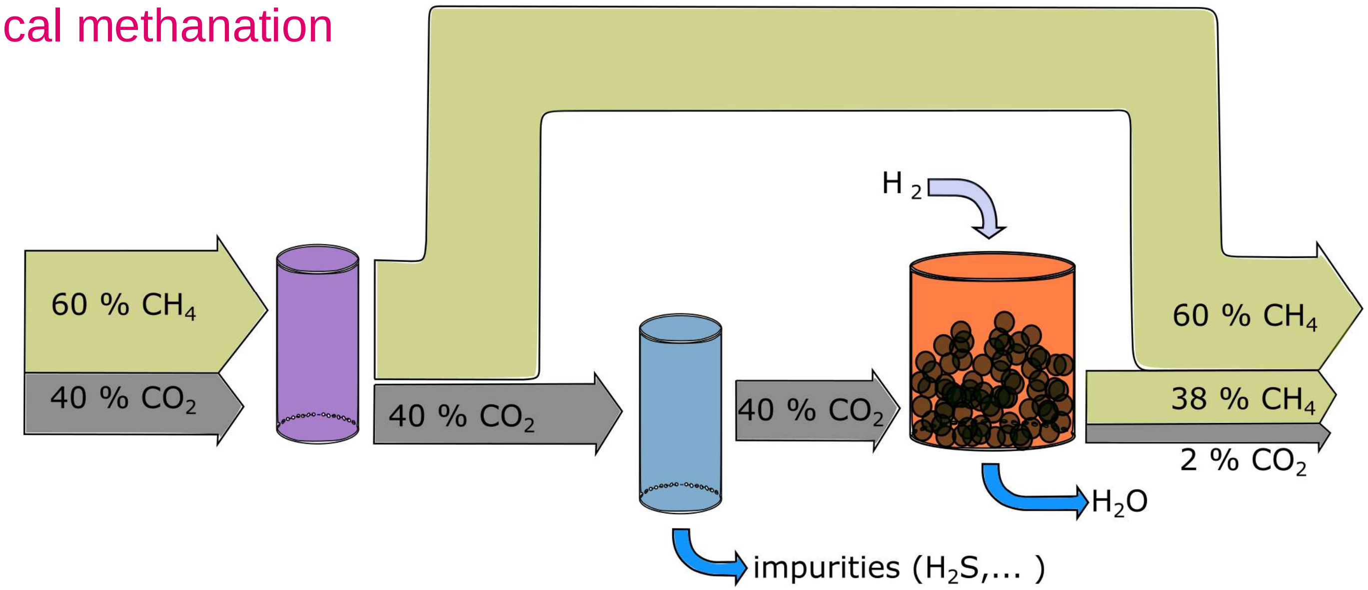
Simple process

- The separation and purification of CO_2 is not required, as in chemical process
  - The drawback is the increased reactor size due to inert CH_4 from biogas.
  - It is an optimization task between costs of separation and reactor size

Biological methanation



Chemical methanation



Commercial status

Electrochaea

Qvidja Kraft Ab

VIESSMANN

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Current technology

- Stirred tank reactor is the most dominant technology
- Electrochaea has the highest capacity: a reactor with 1 MW_e capacity
  - 10 MW_e system will be build for Power-to-Gas Hungary Ltd (PtG Hungary Ltd)
  - Part of EU-project STORE&GO and Powerstep
- Other companies
  - Viessmann (MikrobEnergy) in Germany
  - Qvidja Kraft in Finland

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Novel technology

- Several research groups are aiming for improved mass transfer (H_2 to archaea) with different technologies
- Target is to reduce energy consumption and increase the flexibility of the system
- Low methane production rate has been the biggest problem
- Also stirred tank reactors are studied

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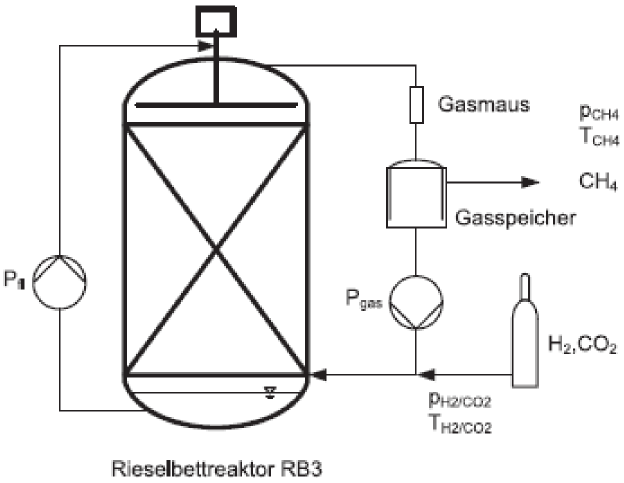
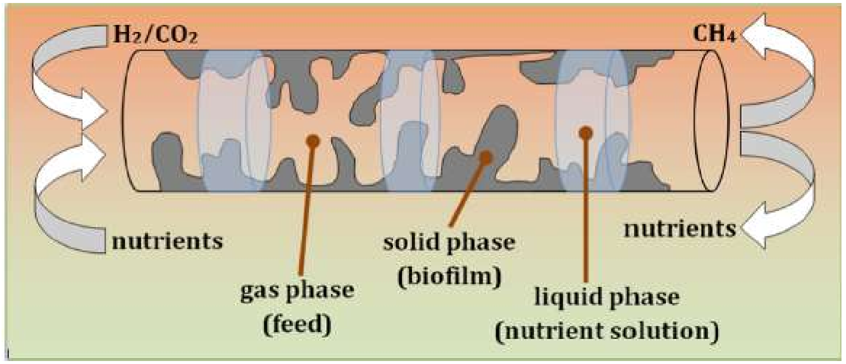
Novel technology

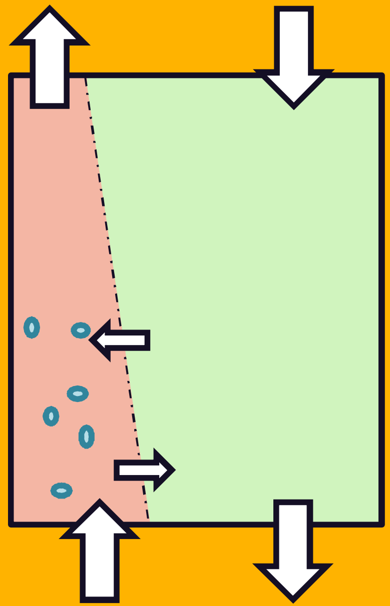
- **Trickle-bed reactor**
- Complex structures are holding biofilm
- Small amount of water is sprayed on top



- **Biofilm in tube**
- Archaea is kept wet with small liquid flow



Modelling



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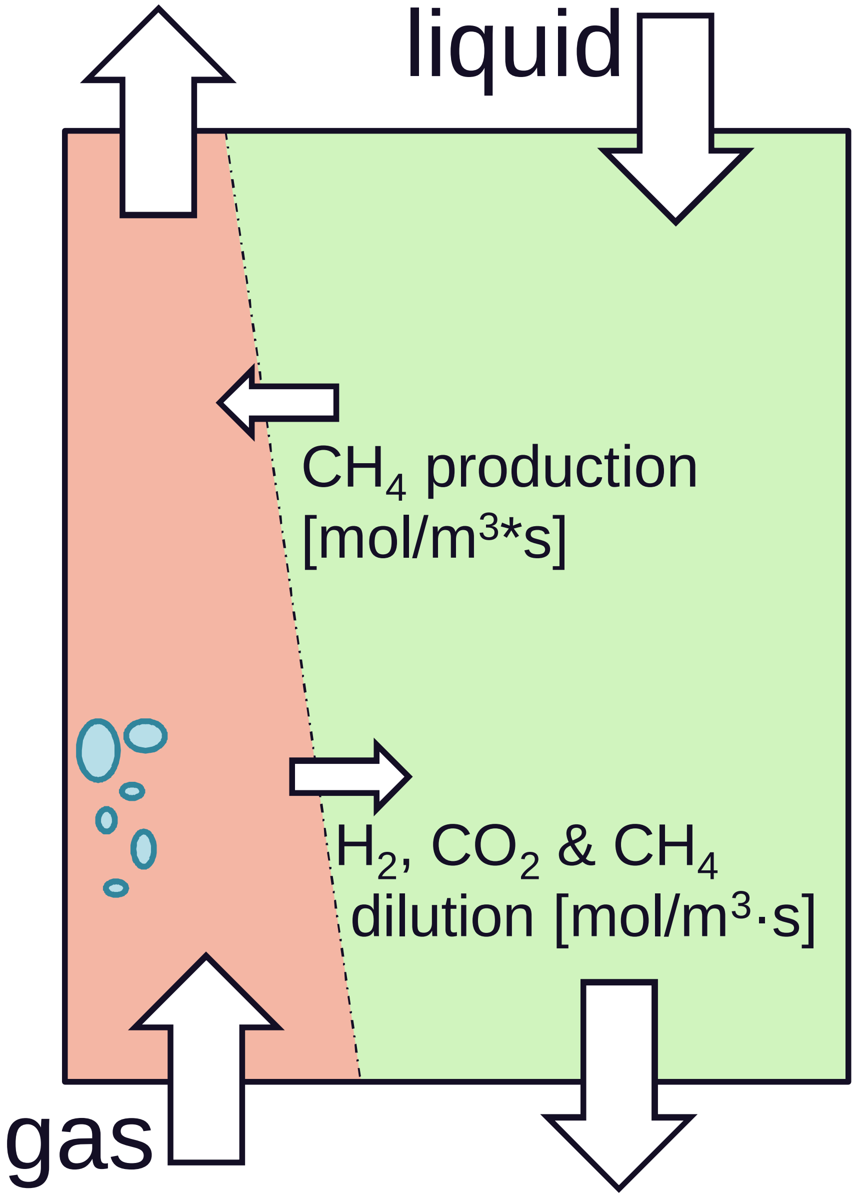
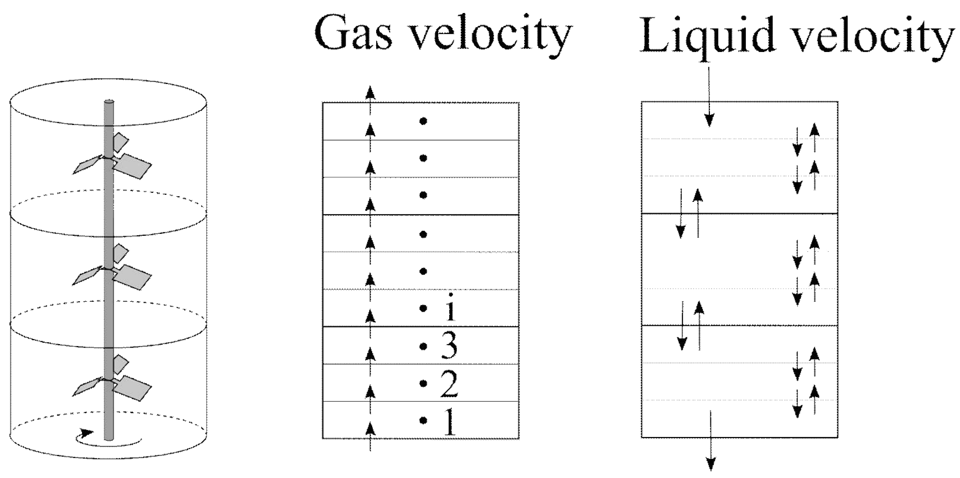
Main phenomena

- Dilution of input gases
  - CO_2 dilutes easily
  - H_2 is the problem, solution:
    - Heavy stirring (modeled)
    - High pressure (modeled)
    - Small bubbles from inlet (not modeled)
- Biological reactions
  - Biomass (archaea) grows slowly
  - Almost all absorbed H_2 is consumed immediately for CH_4 production

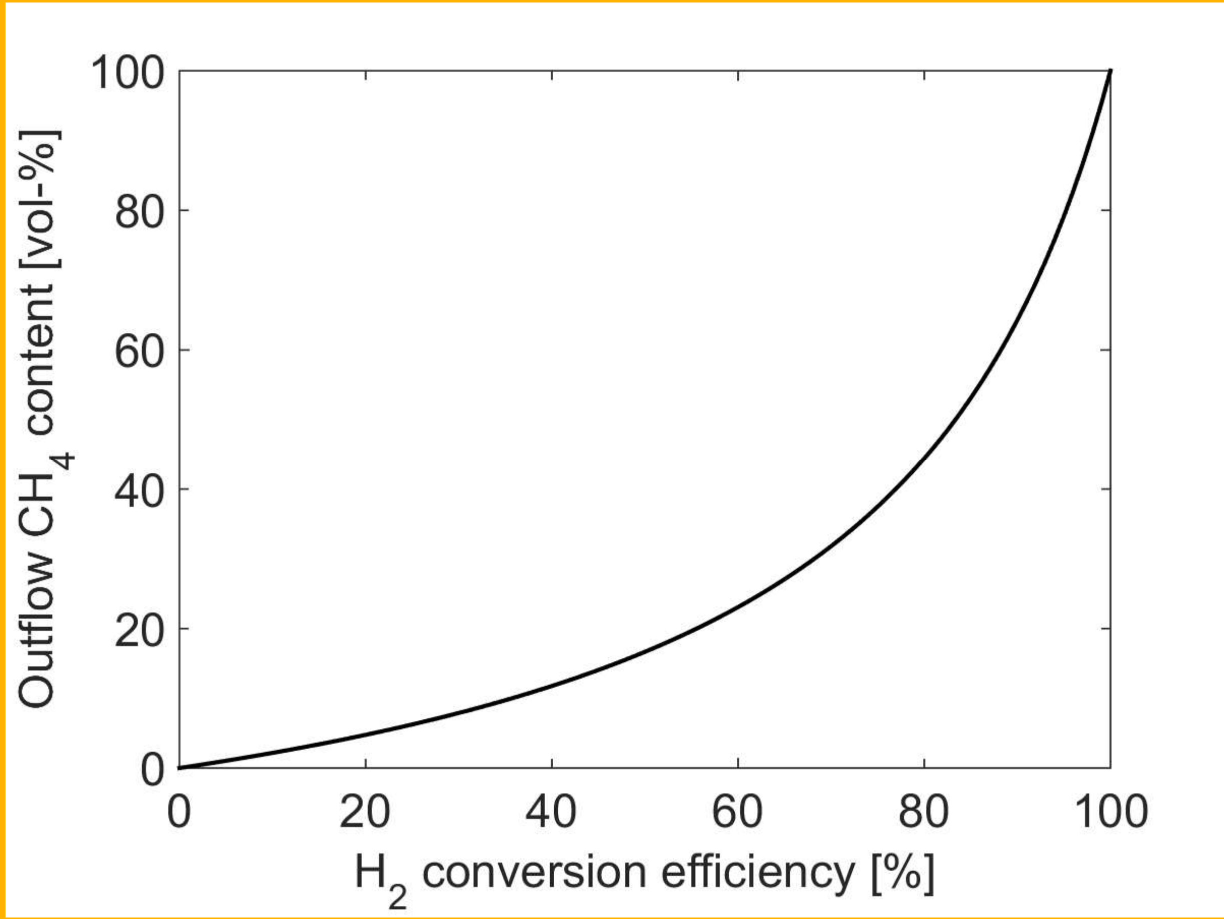


Model description

- One-dimensional
- Dynamical
- Implemented in Matlab
- Any input composition of H_2, CO_2 and CH_4
- Adjustable:
  - Dimensions (cylindrical)
  - Pressure
  - Number of impellers
  - Number of grid points



Results



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Dynamic one-dimensional model for biological methanation in a stirred tank reactor

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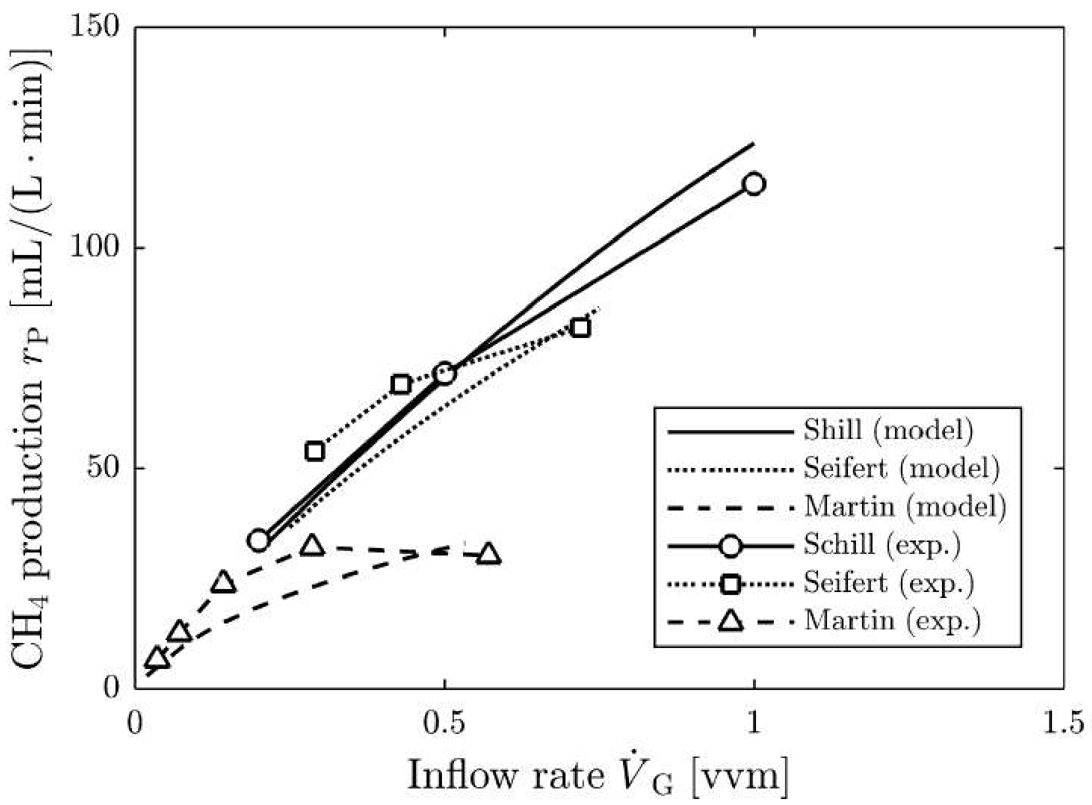
HIGHLIGHTS

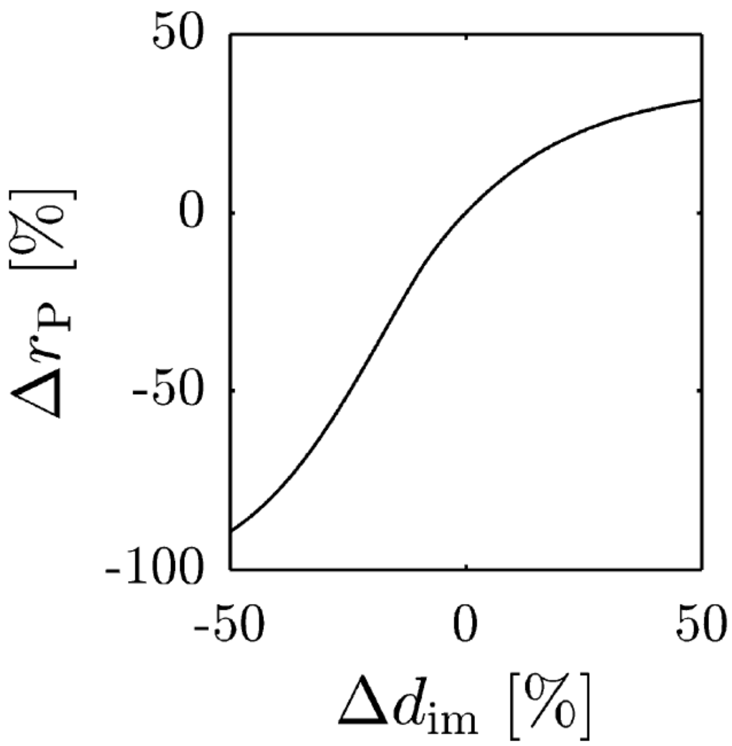
- Modelling of hydrodynamics, gas–liquid mass transfer and biological reactions in a continuously stirred tank reactor.
- General model framework can be utilized for different reactor designs and biocatalysts.
- High gas–liquid mass transfer rate is the most critical parameter for high output gas quality.
- Scale-up study predicts stirring power to be 0.7–1.1% of the electrolyser power in order to reach over 98% CH_4 gas output.
- Dynamic simulations show fast response to inflow transients.

Results: Validation

- Validation by measurements from literature
  - Effect of inflow rate, pressure, liquid flow rate and number of impellers
- Example below: effect of inflow rate and impeller diameter to CH_4 production



vvm = $m^3_{H2}/m^3_{reactor} \cdot min$



Results: Scale-up

- Electrolyser power: 1, 6 and 9 MW
- Number of impellers: 10 for all cases
- Pressure: 7.5 bar
- Biogas input: 50 % CH_4, 50 % CO_2

P_e [MW]	$D_{reactor}$ [m]	$H_{reactor}$ [m]	$D_{stirrer}$ [m]	$P_{stirring}$ [kW]	$Output_{CH4}$ [%]	$Output_{CH4}$ [Nm^3/h]	Heat [MW]
1.0	1.0	10	0.5	11	98.6	56	0.16
6.0	2.4	24	1.2	56	98.9	337	0.97
9.0	3.0	30	1.5	65	98.2	508	1.46

NEO-CARBON Energy project is one of the Tekes strategic research openings and the project is carried out in cooperation with Technical Research Centre of Finland VTT Ltd, Lappeenranta University of Technology LUT and University of Turku, Finland Futures Research Centre FFRC.