LATEST RESULTS OF BIOLOGICAL METHANATION MODELLING

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NEO CARBON ENERGY

NEO-CARBON ENERGY 7th RESEARCHERS' SEMINAR

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Contents

- Concept of biological methanation
- Modelling of biomethanation in continuously stirred tank reactor
- Results

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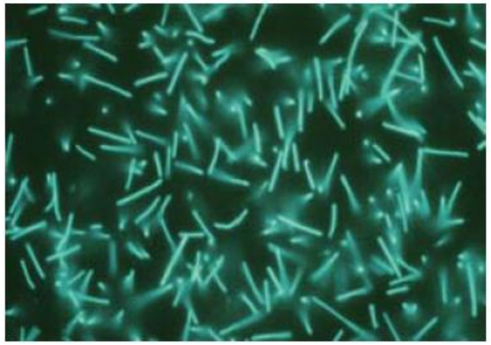
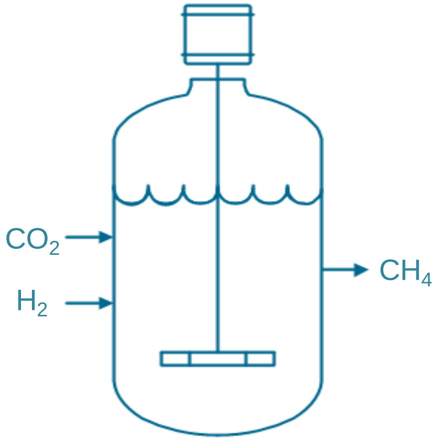
Biological methanation

- Methanation by micro-organisms, which obtain the energy for growth by anaerobically metabolizing H_2 and CO_2 and produce CH_4
- Methanation takes place within aqueous solution of micro-organisms (archaea).
- Reactor concepts: stirred tank, trickle bed, fixed bed, bubble column with porous plate inlet…
- Supplying gaseous hydrogen to micro-organisms is main challenge in the process
- Tolerant for impurities in input gases
- Dynamical operation is still a question, but it seems promising because of low operation temperature (< 70 C)





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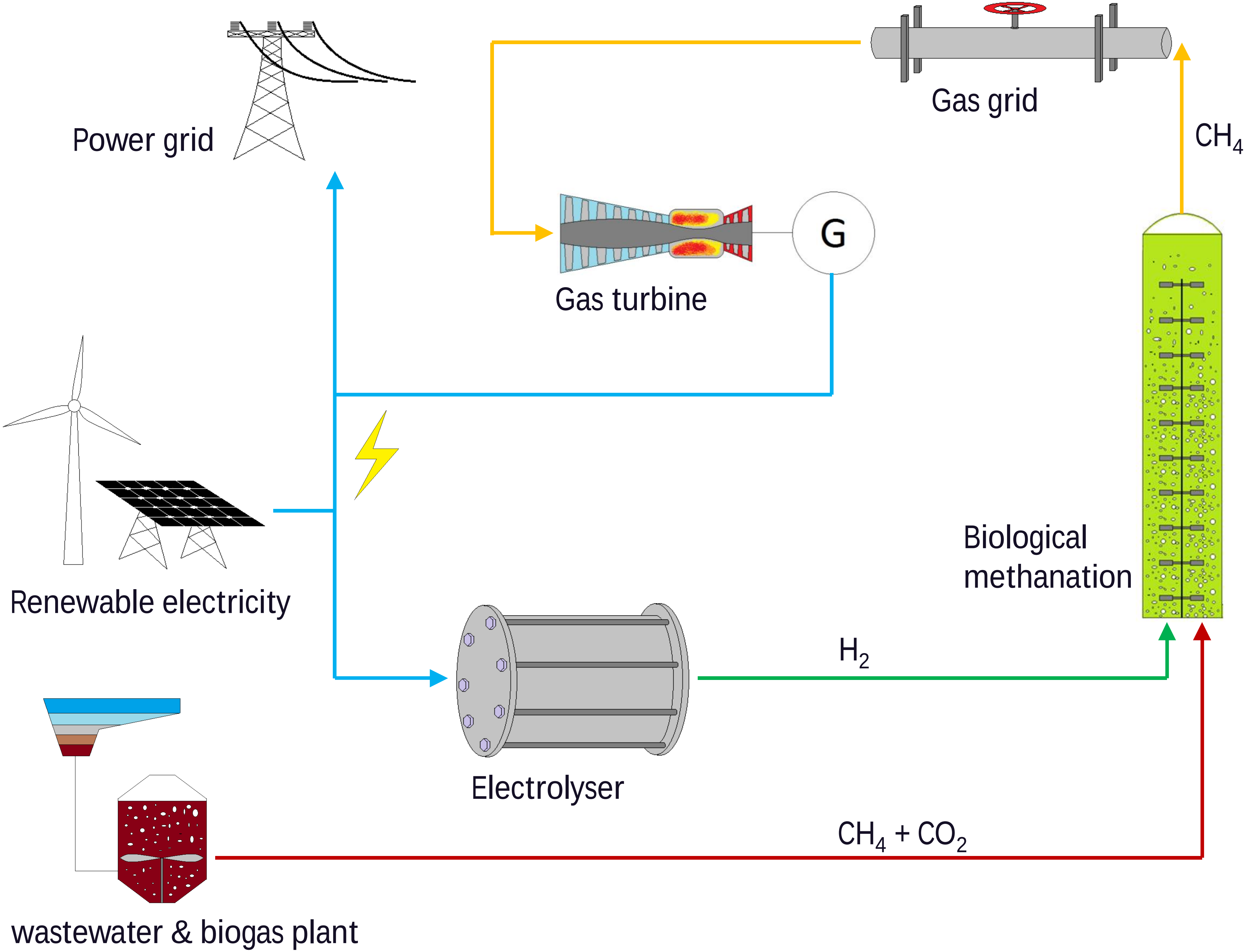
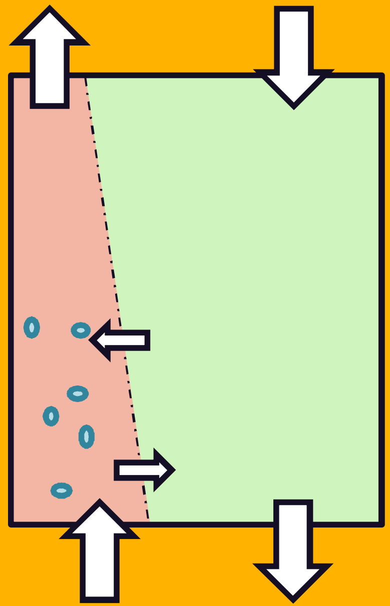


Power grid
Gas grid
CH_4
G
Gas turbine
Biological
methanation
Renewable electricity
H_2
Electrolyser
$CH_4 + CO_2$
wastewater & biogas plant

Modelling



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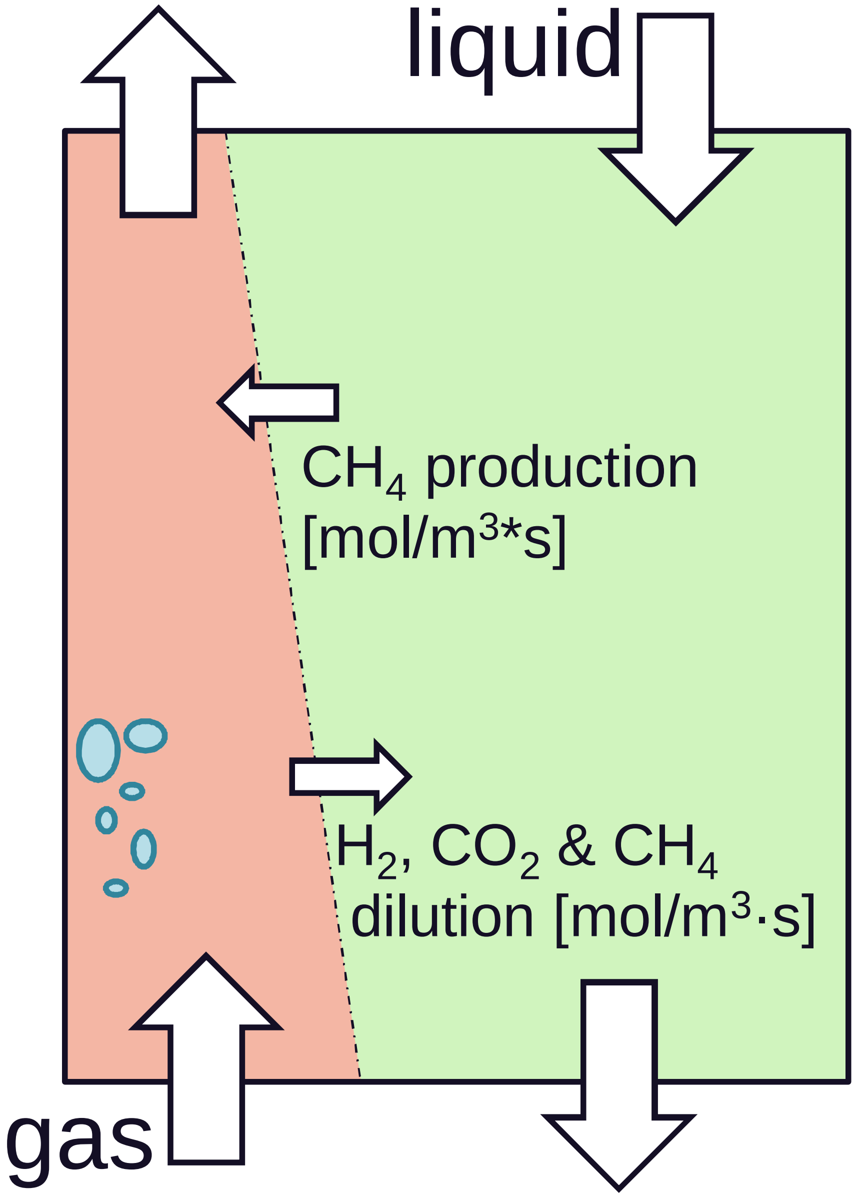
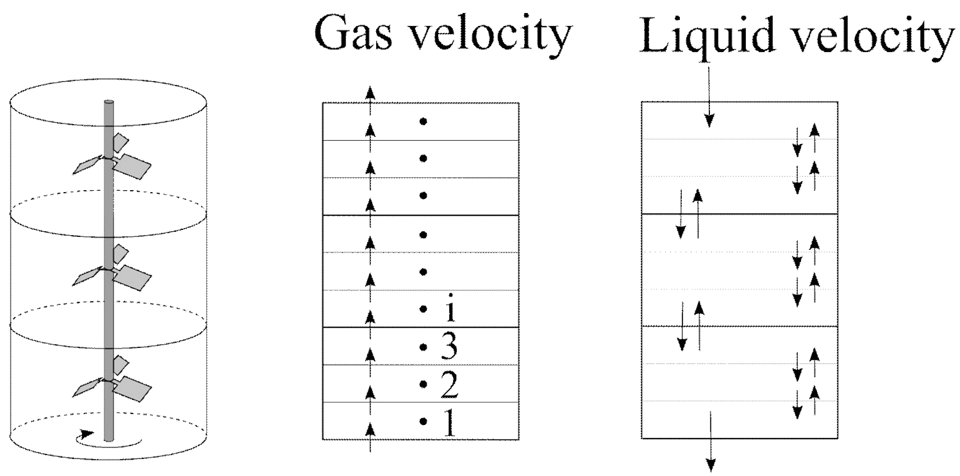
Main phenomena

- Gas-liquid mass transfer
  - CO_2 dilutes easily to liquid
  - H_2 is the problem, solution:
    - Stirring
    - Elevated pressure
    - Small bubbles from inlet
- Biological reactions
  - Biomass (archaea) grows
  - Biomass can consume large amounts of H_2
  - Almost all H_2 goes immediately for CH_4 production

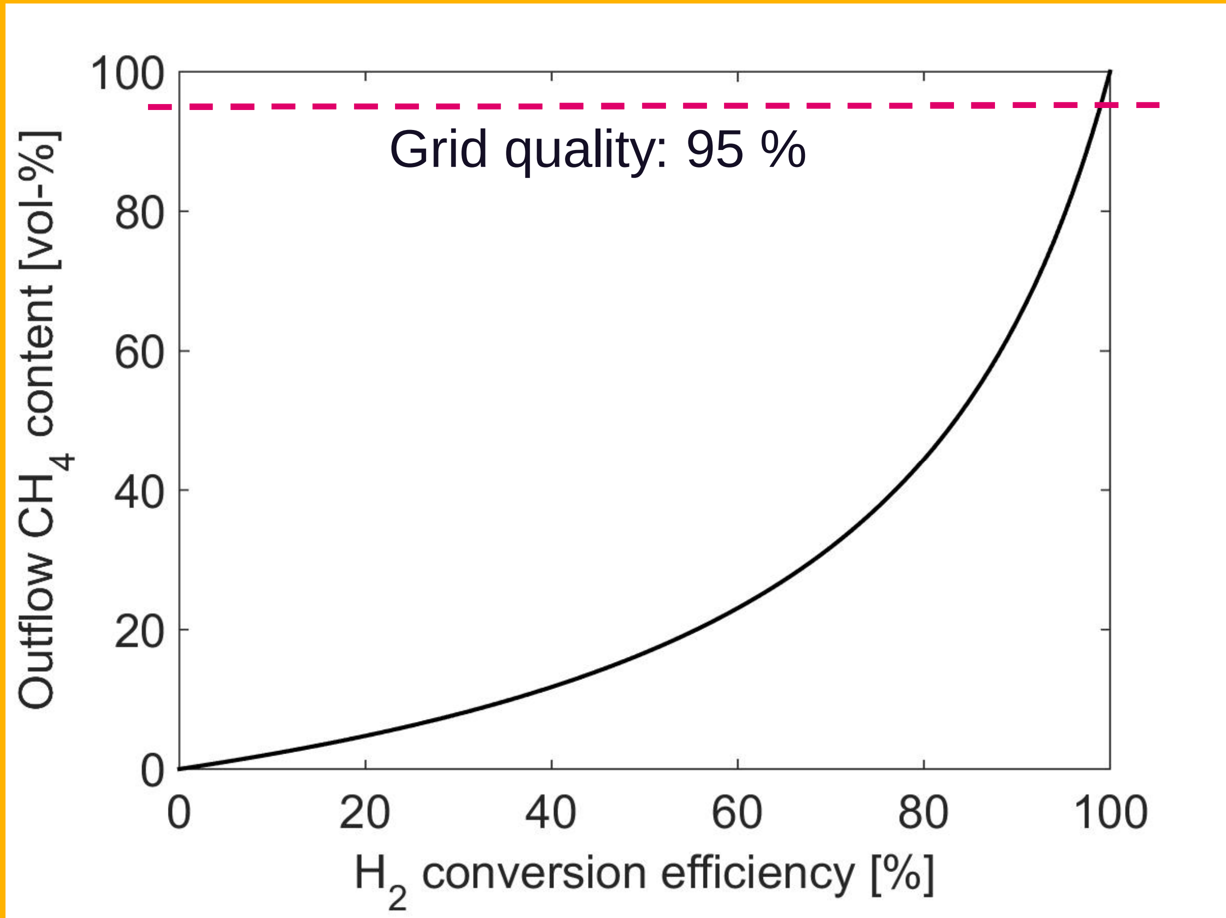


Model description

- 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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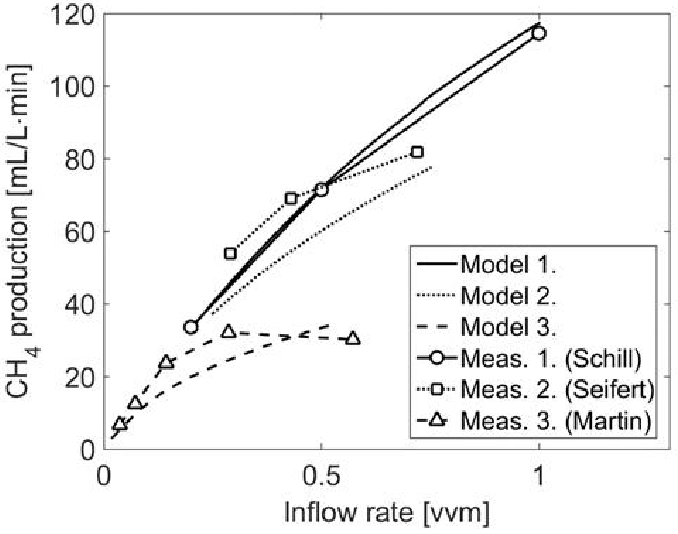
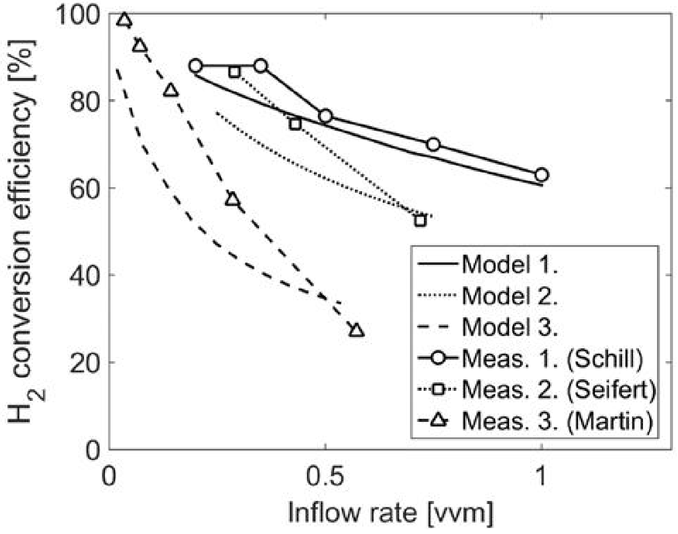
Results: Validation

- At first, model is validated by measurements from literature
- Studied parameters:
  - Inflow rate, pressure, liquid flow rate, number of impellers
- Example: CH4 production [mL/L·min] and H_2 conversion efficiency [%] as a function of inflow rate [vvm]

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





	V_{tot} [L]	V_{active} [L]	H:T [-]	D [m]	N [rpm]	n_t [-]	T [°C]
Schill et al.	2.0	1.45-1.55	2:1	0.065	1000	1	60
Seifert et al.	10.0	3.5-5.0	2:1	0.055	1500	1	65
Martin et al.	7.5	3.0-3.5	2:1	0.060	700	4	60

Shading: Estimated value

Results: Pilot scale

- Impeller diameter: from 0.36 to 0.44 m
- Electrolyser power: 1 MW
- Dimensions: height 10 m, width 0.8 m
- Stirring speed: 120 rpm, 10 impellers
- Pressure: 10 bar
- Biogas input: 50 % CH_4, 50 % CO_2

	$D_{impeller}$ [m]	$P_{stirring}$ [kW]	$Output_{CH4}$ [%]	H_2 conv. [%]	$Prod._{CH4}$ [Nm^3/h]
	0.36	1.7	85.4	93.1	35.1
	0.38	2.4	92.5	96.6	36.4
Base case	0.40	3.3	96.4	98.5	37.1
	0.42	4.5	98.2	99.4	37.5
	0.44	6.0	98.6	99.7	37.6

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Results: Pilot scale

- Pressure: 1, 5 and 10 bar

	p [bar]	$P_{stirring}$ [kW]	$Output_{CH4}$ [%]	H_2 conv. [%]	$Prod._{CH4}$ [Nm^3/h]
	1	1.8	52.5	69.3	26.1
	5	2.7	87.7	94.2	35.5
Base case	10	3.3	96.4	98.5	37.1

Results: Pilot scale

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Results: Scale-up

- Electrolyser power: 1, 5 and 10 MW
- Stirring speed:120 rpm
- Number of impellers: 10 for all cases
- Pressure: 10 bar
- Biogas input: 50 % CH_4, 50 % CO_2

P_e [MW]	$V_{reactor}$ [m³]	$D_{reactor}$ [m]	$H_{reactor}$ [m]	$D_{stirrer}$ [m]	$P_{stirring}$ [kW]	$Output_{CH4}$ [%]	$Prod._{CH4}$ [Nm³/h]
1	5	0.8	10	0.4	3	96	37
10	16	1	20	0.5	7	94	366
50	34	1.2	30	0.6	14	92	1805

Base case

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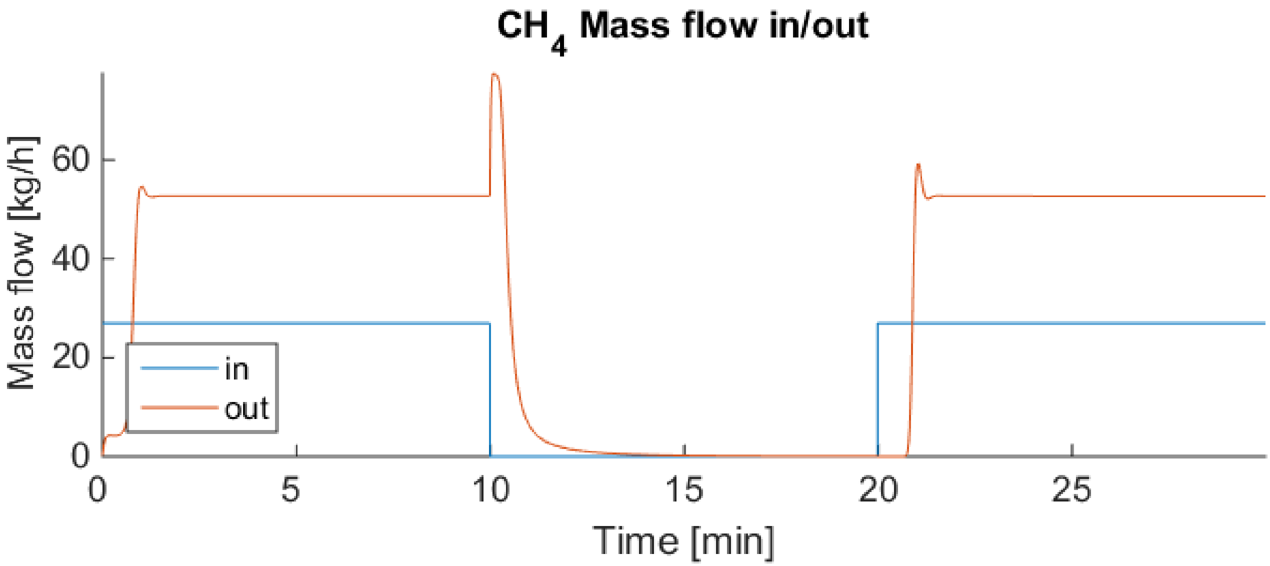
Base case

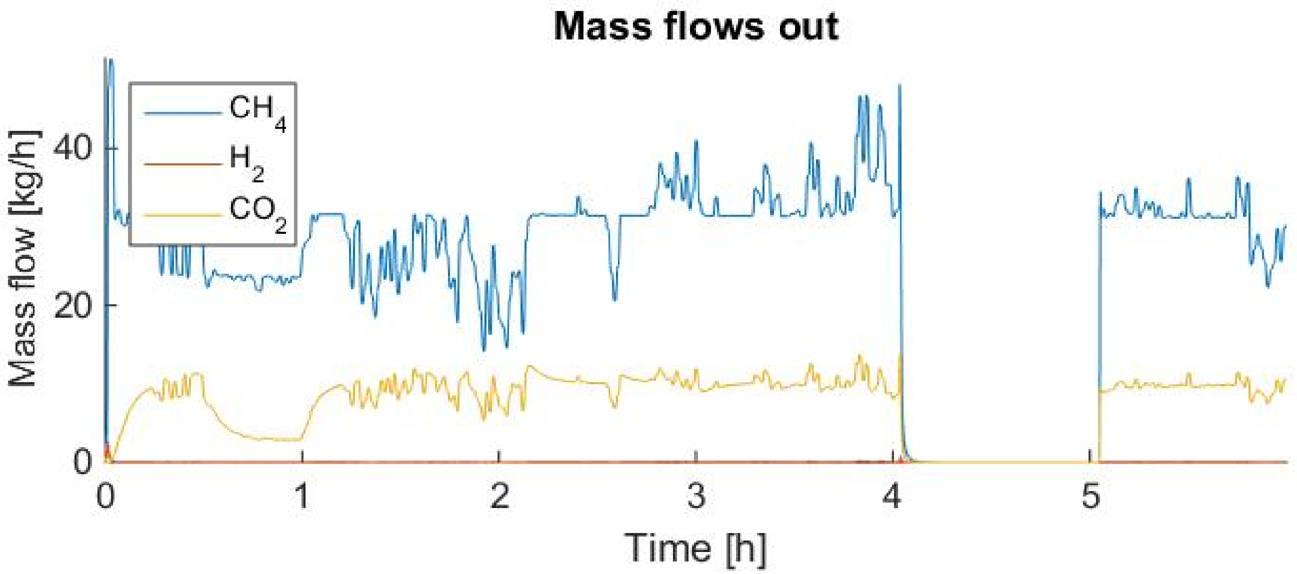
Results: Dynamic

- Step change in raw biogas input



Results: Dynamic

- Electrolyser operates for grid balancing services



Conclusions

- Model is validated against measurement data from literature
- Tuning of the model could be done with better details and measurements for specific reactor concept
- Model can be used for engineering purposes
  - Scale-up
  - Operational dynamics
  - Estimation for key performance numbers
- Future work: Apros-integration, analysis of dynamic operation, publishing results
- Model frame applied for further studies of gas-liquid mass transfer in different geometry in other project (Fermatra)

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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.