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Mechanistic modelling of a full-scale bio-catalytic methanation reactor

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Motivation

Electricity production by wind and solar power is growing rapidly in recent years, but their fluctuating character accordingly increases periods where electricity production exceeds demand. Rather than e.g. temporarily reducing production from wind turbines, the renewable electricity may be valorized by powering biogas upgrading.

Bio-catalytic reactor

The reactor is part of a technology that converts, first, (1) electricity into hydrogen (H_2) by means of water electrolysis. Next the H_2 is biologically reacted (2) with the carbon dioxide (CO_2) coming from biogas to form pipeline grade methane (CH_4) for direct injection into the existing natural gas grid

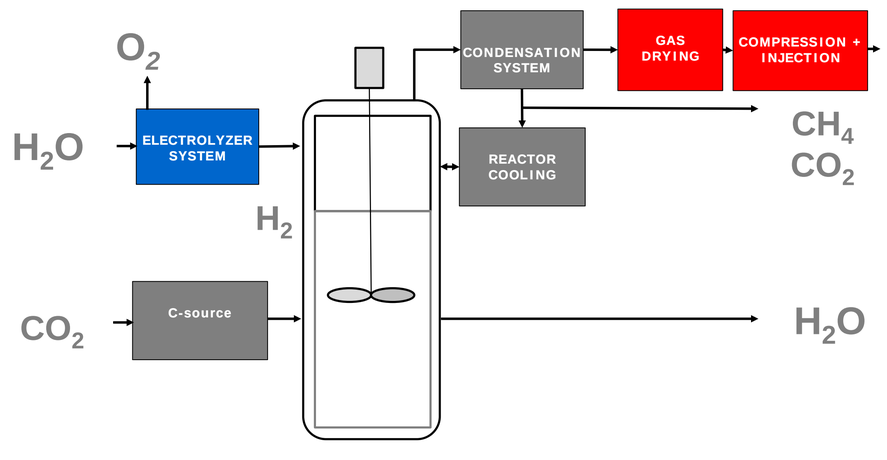
Case study

The full-scale system is currently running at Avedøre wastewater treatment plant (WWTP) in Hvidovre (Denmark) using biogas as CO_2 feedstocks: 1) Anaerobic digester (Data set #1) and Biogas upgrade plant (Data set #2)

Mathematical model

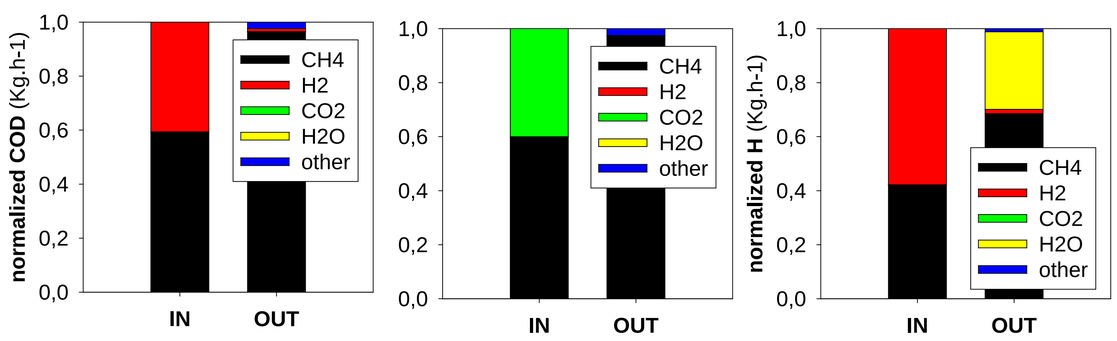
The main biochemical processes are based on the Anaerobic Digestion Model No 1 (ADM1) (**Batstone *et al*., 2002**) with the following modification:

1) An advanced weak acid base chemistry model (**Flores-Alsina *et al*., 2015**)
2) Gas (Gas_{in}) flows considered as inputs
3) V_{Liq} is variable ($Q_{in} \neq Q_{out}$)
4) Metabolic water production as a result of hydrogenotrophic metanogensis

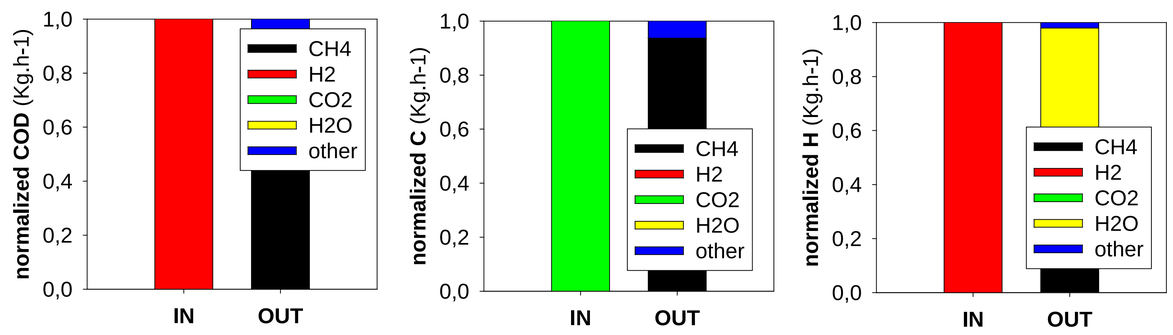


$$CO_2 + 4H_2 \Rightarrow CH_4 + 2H2O$$

Steady state simulations (Data set #1) (Anaerobic digester)



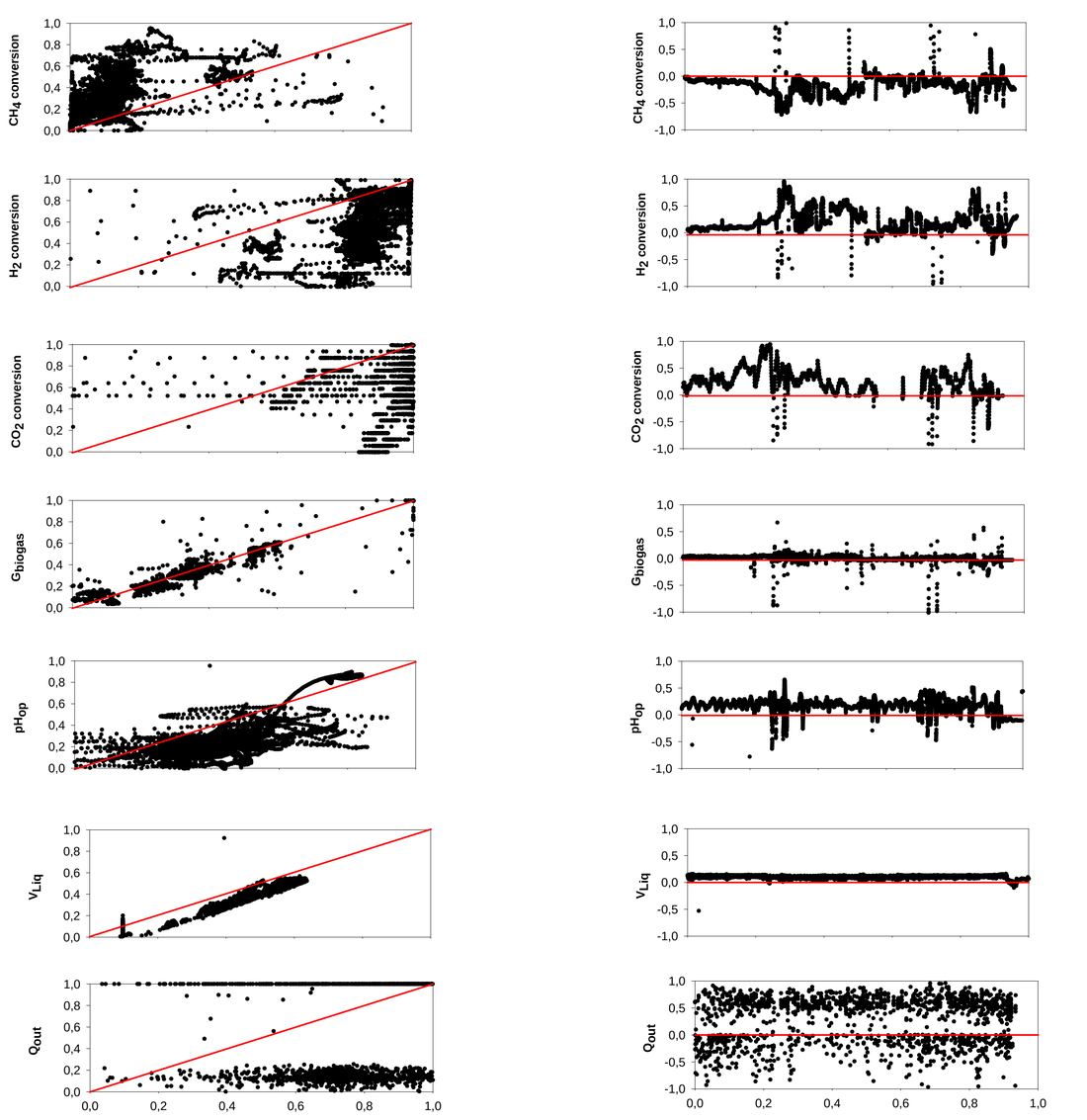
Steady state simulations (Data set #2) (Biogas upgrade plant)



Dynamic simulations (Data set #1) (Anaerobic digester)

Predicted values versus full-scale measurements (max-min, normalized values)

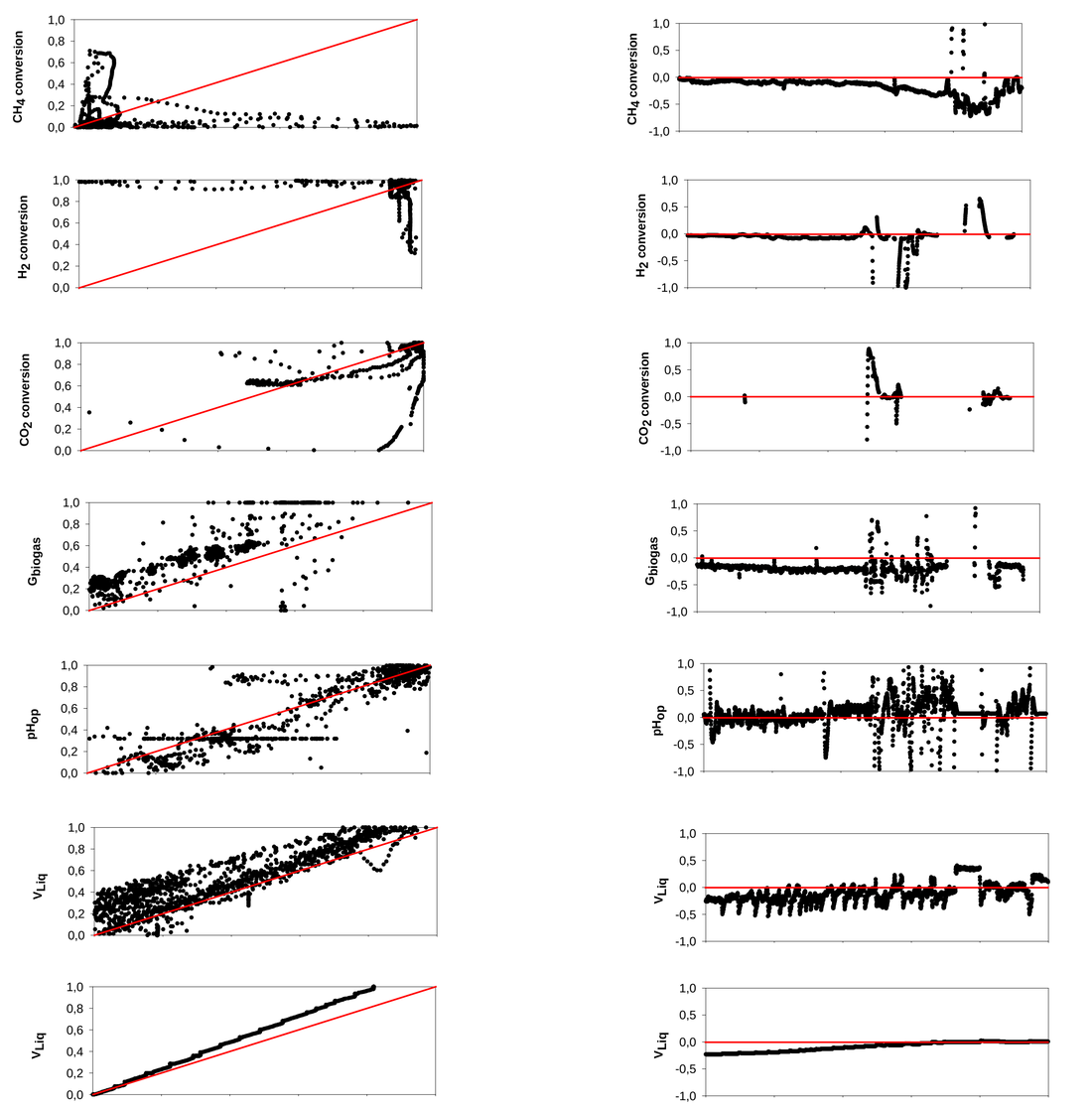
Residuals, Predicted values - full-scale measurements (max- min, normalized values)



Dynamic simulations (Data set #2) (Biogas upgrade plant)

Predicted values versus full-scale measurements (max-min, normalized values)

Residuals, Predicted values - full-scale measurements (max- min, normalized values)



Future work

1) addition of H_2S data and how this affects growth / inhibition of archaea, 2) pressure gradients within the reactor, 3) improved mass transfer model to have a more realistic view of the gas dissolution/stripping phenomena, 4) evaluation of different loading conditions to test reactor capacity

References

Batstone D.J. et al., (2002). Anaerobic Digestion Model No. 1. IWA Scientific and Technical Report No. 13. London, UK; Flores-Alsina, X et al., (2015). Water Research. 85, 255-265.