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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 (H2) by means of water electrolysis. Next the H2 is biologically reacted (2) with the carbon dioxide (CO2) coming from biogas to form pipeline grade methane (CH4) 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 CO2 feedstocks: 1) Anaerobic digester (Data set #1) and Biogas upgrade plant (Data set #2)

Steady state simulations (Data set #1) (Anaerobic digester) Steady state simulations (Data set #2) (Biogas upgrade plant)

Dynamic simulations (Data set #1) (Anaerobic digester) Dynamic simulations (Data set #2) (Biogas upgrade plant)

Future work
1) addition of H2S 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

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 (Gasg) flows considered as inputs
3) Qin is variable (Qin ≠ Qout)
4) Metabolic water production as a result of hydrogenotrophic methanogenesis

References