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Enhancement of catalytic direct methanation for application in wastewater treatment plants

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Motivation

Wastewater treatment plants (WWTP) produce sewage gas as part of the sludge treatment. Nowadays, it is mostly burned in combined heat and power (CHP) units to compensate the high electricity costs for the water treatment, which accounts to 1-4% of the electricity consumption of many developed countries [1]. However, with an increasing share of renewables and therefore increasing volatility of electricity prices, this operational mode must be re-evaluated. In near future scenarios, the sale of energy in times of high demand and the storage of energy during periods of high supply could be an economically feasible alternative to the conventional power generation in CHP units.

In order to store surplus energy, the project KLÄFFIZIENT investigates the catalytic direct methanation of biogenic gases on WWTPs. In a reactor, the sewage gas mixes with hydrogen to form a methane-rich synthetic natural gas (SNG).

Oxygen, which is a byproduct to electrolysis, can be used synergistically to meet the demand for pure oxygen aeration on WWTPs – see Figure 1. KLÄFFIZIENT thereby focusses on two major challenges, which arise during commercialization and scale-up:

- The technological readiness of the methanation process with regards to sewage gases is subject to uncertainties and
- high electricity costs for hydrogen production challenge the economic performance of the concept.

KLÄFFIZIENT seeks to address both the technological as well as the economic dimension of the concept.

Approach

The issue of economic feasibility is tackled with hybrid system dynamics simulations, which are modelling and optimizing the plant schedule to minimize the overall production costs and to ensure oxygen supply for the WWTP as well as economically sound operational expenses for the methanation.

In preliminary static economic models, different plant-setups are compared, utilizing time-resolved day-ahead electricity price data, industry-scale electrolyzer properties and reaction data gathered from methanation experiments with biogenic gases. Also, a low price on carbon dioxide as well as the produced heat is assumed. Oxygen has a high revenue according to the real cost at one of the project partners' WWTP.

To avoid a loss of energy for the WWTP, the energy taken out by the sewage gas flow (i.e. the corresponding heating value of methane) is compensated with an equivalent recycle flow of SNG to the WWTP.

Capital expenditures for the methanation reactor are calculated for 25 years with respective interest rates. From own reactor setups, the scale-up costs are deducted with rapid estimation methods. The electrolyzer cost and efficiency is taken from literature in correspondence with a renowned supplier of electrolysis cells.

The main results from these economic models are minimized specific production costs from an optimization with variable electricity prices and plant scales. The electrolyzer scale has a lower bound to provide enough oxygen for the WWTP.

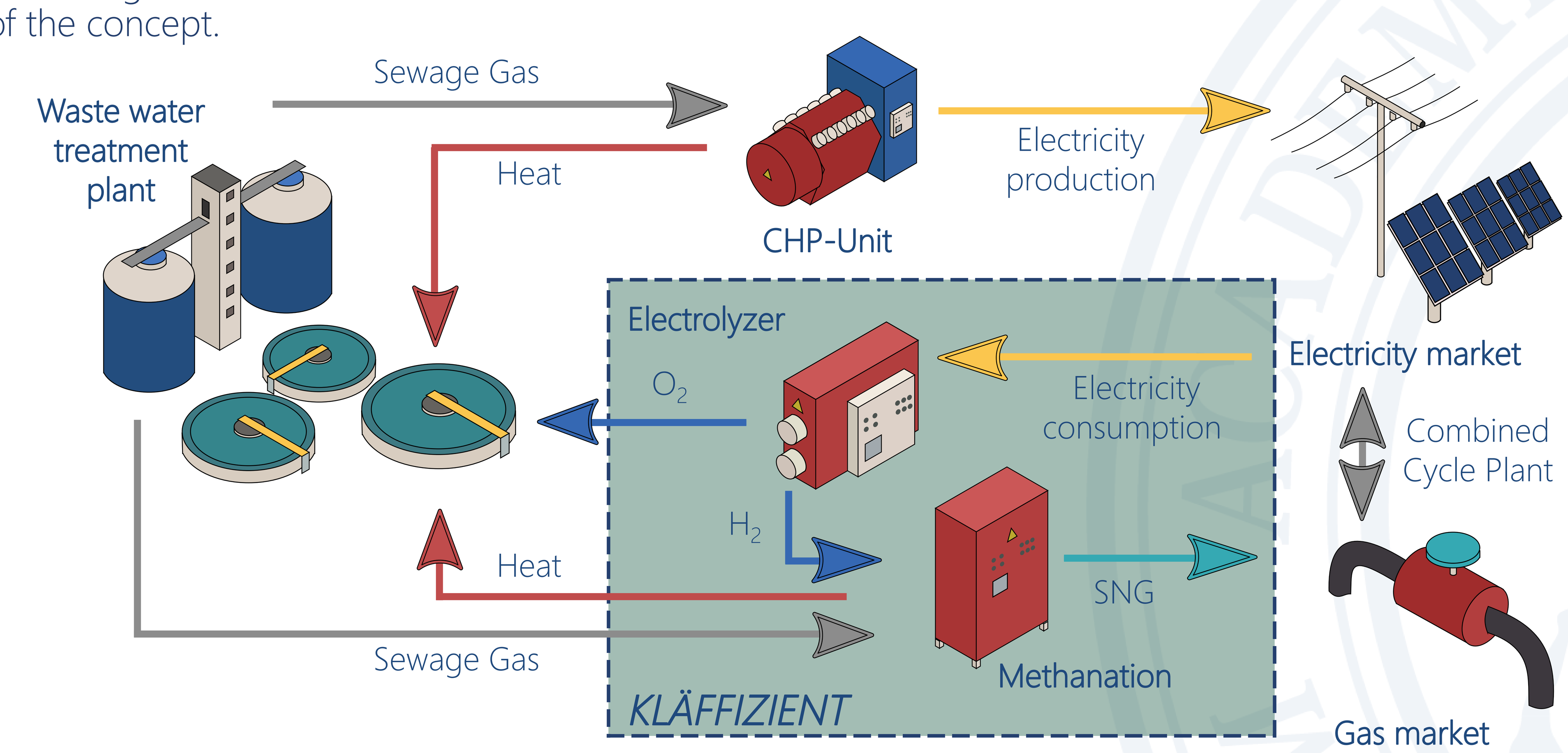

Figure 1: concept of KLÄFFIZIENT

Exemplary Results

Sensitivity analyses are conducted beforehand as depicted in Figure 2. They indicate a high dependency on the specific consumption costs, which stem mainly from electricity prices. However, these are decreasing with increasing power due to a higher price flexibility for the electrolyzer.

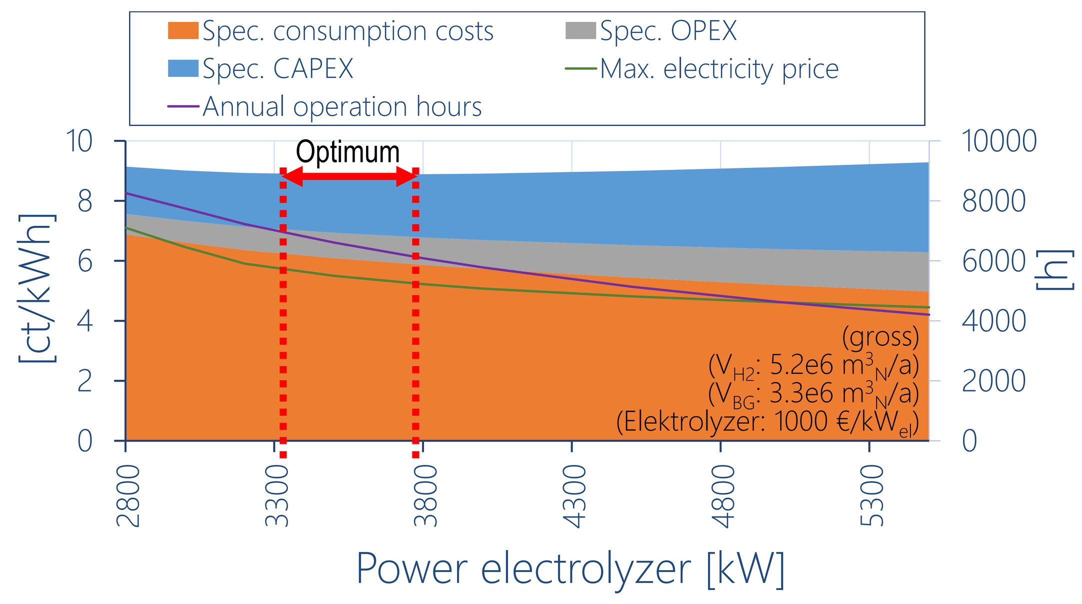

Figure 2: sensitivity analysis on electrolyzer power

Also, different scenarios are considered. Their cost compositions show a high dependency on the efficiency of the electrolyzer as well as its CAPEX – see Figure 3.

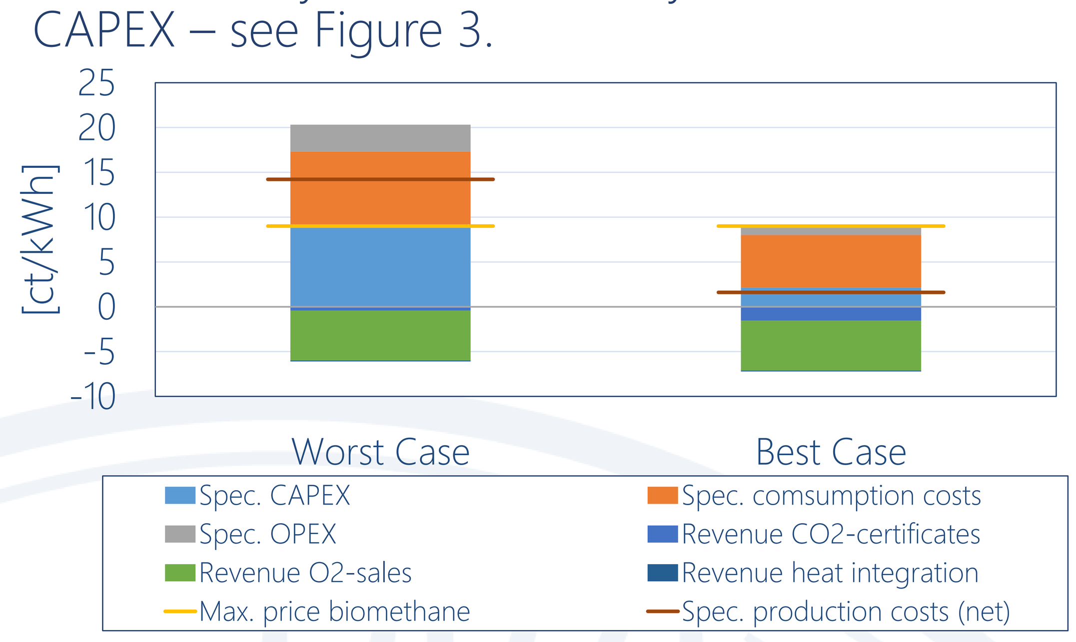

Figure 3: comparison of different scenarios

The major statements resulting from the preliminary calculations include:

- Under the current prices (worst case scenario), methanation of sewage gases is not yet economically viable
- The trend for decreasing manufacturing costs for electrolyzers (best case scenario) gives the technology great potential
- Heat revenues and CO_2-certificates play a minor role in economic efficiency
- In all cases, a marketing strategy for oxygen is crucial in order to offset high electricity prices.

Future work will focus on dynamic models, which will be incorporated in an on-site methanation reactor in order to demonstrate the technological as well as the economically optimized concept.

[1] Longo, S., et al. "Monitoring and diagnosis of energy consumption in wastewater treatment plants. A state of the art and proposals for improvement." *Applied energy* 179 (2016)

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