**Integration of power-to-gas concepts with biomass gasification in the Swedish electricity grid**

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**Highlights**

* A gasifier combined with an electrolyser implemented in an energy systems model
* The value of process flexibility is compared to hydrogen storage
* Results highlight the benefits of a flexible biomass gasification process

**1. Introduction**

The variability of wind and solar electricity generation will demand a flexible electricity system in the future. Simultaneously, increased demand for fuels and chemicals produced from biomass is expected in the future in response to climate change mitigation goals [1]. A power-to-gas concept, which produces H2 and O2 can contribute to balancing the electricity grid while increasing the output of biofuel production processes [2]. In the present study we suggest a concept where generated H2 is utilized to increase the output of methane from a biomass gasification plant by converting CO2 effluent from the gasification cold gas, using the Sabatier process. The purpose is to evaluate the value of having a direct, oxygen blown, gasification process that can use H2 to increase production when it is economical, in relation to a process with constant H2 demand.

**2. Methods**

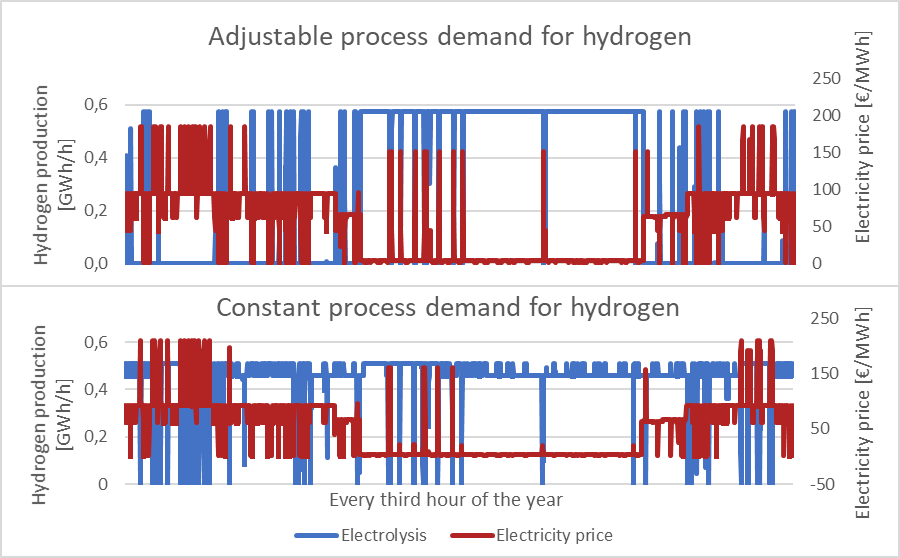
In a previous study, four process configurations were assessed for the upgrading of the produced gas to biomethane [3]. The considered configurations differ in terms of how CO2 separation and H2 separation are placed in relation to the Sabatier reactor in the flowsheet. Here, two gasification processes are considered, a flexible gasification process which can utilize H2 to increase production if it is beneficial from an economical perspective, and a non-flexible process that requires a constant feed of H2. Data generated from a sensitivity analysis over model parameters is used to create a linear surrogate model for CAPEX, OPEX and biomethane production as a function of CO2 recirculation and H2 addition (applying the partial least squares method). The equations are implemented in a cost-minimizing regional electricity system model [4]. Actual wind, solar and load data from Sweden is applied. The model optimizes the cost of the total electricity system and can produce biomethane with or without H2 addition; the biomass supply is limited to 100 TWh/year.

**3. Results and discussion**

Figure 1 shows the total H2 production and the electricity price over one year for the two types of gasifiers, the flexible one that can use H2 to enhance production of biomethane, and the one which requires a constant feed of H2 to generate biomethane of sufficient quality. For both cases, the model produced biomethane using all available biomass. In the flexible case, H2 is injected at 44% of the hours of the year, for the second case it is constantly required. The gasifier configuration with an adjustable hydrogen demand (Fig. 1 a)) uses electricity for hydrogen production at an average price of 4.5 €/MWh. The electrolysers in the adjustable gasification process are dimensioned to meet the maximal hydrogen demand from the process. To avoid electricity generation in gas turbines, the electrolysers are used with a storage to produce fuel for fuel cells if the biomethane price is above 70€/MWh. Implying, that it becomes cheaper to generate electricity at peak-load with fuel cells rather than using biomethane as fuel in gas turbines.

For the configuration with a constant demand for process hydrogen (Fig. 1 b)), the average electricity price for hydrogen production is 47 €/MWh. When high priced electricity is used for H2 production the value increases and there is an incentive to store hydrogen. Therefore, the optimized electrolyser is dimensioned with approximately 10% higher capacity than the maximum H2 input. Both the adjustable process and the process with constant demand increase the value of wind power contra the value of thermal generation techniques.

**a)**



**b)**

Figure 1. Hydrogen production and electricity price with a three-hour time resolution over 1 year. a) is a process configuration that can use H2 flexibly, b) is a process configuration that need constant feed of H2 to operate.

**4. Conclusions**

The adjustable gasification process uses low-priced electricity to increase methane production and the process with a constant H2 demand avoids H2 generation at the hours with highest electricity price by using storage. Both a static and flexible H2 demand increases the economic benefits of constructing variable electricity generation. Thus, there is economic incentive to combine electrolysers with biomass gasification from a process perspective while it constitutes a driving force to increase wind power capacity. Future work will include analysis of the possibilities to include CCS in the gasification process and sensitivity analysis on important economic parameters, e.g. biomass price.

**References**

[1] D. Connolly, B.V. Mathiesen, and I. Ridjan, Energy, 2014. 73: p. 110-125.

[2] V. Johansson, L. Göransson, Impacts of variation management on cost-optimal investments in wind power and solar photovoltaics. Renewable Energy Focus, Under review.

[3] J.M Ahlström, S. Harvey, and S. Papadokonstantakis, Computer Aided Chemical Engineering, 2018. 44: p. 109-114.

[4] L. Göransson, et al.,. Applied Energy, 2017. 197: p. 230-240.