Synergies between biocatalytic methanation of power-to-gas hydrogen and carbon dioxide from alcoholic fermentation

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Introduction

Fluctuating energy peaks caused by renewable sources solar and wind require technologies to store energy and to balance fluctuation. A possible storage technology is power-to-gas (P2G), where electric energy is converted to hydrogen by electrolysis. Because of the lack of an adequate hydrogen infrastructure in Germany this P2G-hydrogen can be converted with carbon dioxide into methane. CO_2 can be obtained by breweries, winegrowers or champagne producers with CO_2 excess from alcoholic fermentation.

Tab. 1: Production of beer*, wine, sparkling wine/champagne* and bioethanol in Germany (2014) and resulting CO_2 emissions from fermentation (*data based on sales).

	Production (Germany)	CO_2 production
Beer	95 600 000 hl a^{-1}	312 000 t a^{-1}
Wine	9 202 000 hl a^{-1}	69 000 t a^{-1}
Sparkling wine / Champagne	3 174 000 hl a^{-1}	16 000 t a^{-1}
Bioethanol	726 000 t a^{-1}	693 000 t a^{-1}
$\sum$		1 090 000 t a^{-1}

Those 1 090 000 t a^{-1} CO_2 can be converted to about 400 000 t a^{-1} CH_4 which are about **5.6 TW h** of storable energy.

Methanation of carbon dioxide and hydrogen

Following reaction equation shows the conversion of CO_2 and hydrogen to methane.

$$CO_2 + 4\,H_2 \longrightarrow CH_4 + 2\,H_2O\ (l) \qquad \Delta H_R = -165\ \mathrm{kJ\,mol^{-1}}$$

Except for a chemical methanation (Sabatier process) there are microorganisms (archaea) which metabolize CO_2 to CH_4 under anaerobic conditions. The advantages of this biological over chemical process are moderate process parameters.

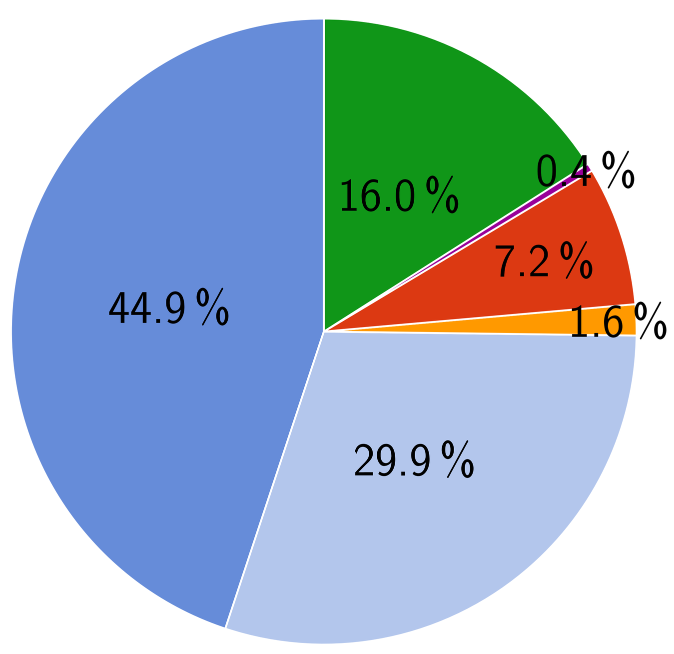
Tab. 2: Process parameters of chemical and biological methanation.

Process	Temperature ϑ	Pressure p	needed quality of CO_2 flow
chemical	400 °C	20 bar	high (catalysts)
biological	50 °C to 80 °C	< 10 bar	low

German energy demand

Netto electricity exports of Germany were 35.5 TW h in 2014. This energy can be used for P2G to balance fluctutating energy production. This energy can be converted via electrolysis into **8.8 bn m³ H_2** and afterwards via methanation into **2.2 bn m³ CH_4**.

electricity exports = 74.4 TW h
electricity imports = 38.9 TW h
netto electricity exports = 35.5 TW h



- Beer
- Wine
- Sparkling wine/ Champagne
- Bioethanol
- Biogas
- Other

Fig. 1: Different sources of CO_2 from alcoholic fermentation and their contribution to convert 2.2 bn m³ CO_2 to balance fluctuating electricity. Biogas information are based on the known sales in 2013.

Fig. 1 shows possible sources for methanation of **2.2 bn m³ CO_2**. As shown about 1/4 of demanded CO_2 can be provided by alcoholic fermentation. About 30 % can be obtained by biogas plants. Missing 44.9 % must be obtained by other sources. This figure shows that about one half of needed CO_2 is already available for methanation of 35.5 TW h electric energy excess.

Biorefinery cascade

Combination of three technologies, alcoholic fermentation, hydrothermal carbonization (HTC) and biocatalytic methanation, can lead to a CO_2 emission free biorefinery cascade. CO_2 from fermentation and HTC can be used to feed **archaea** and convert CO_2 into CH_4. Biomass will be completely converted into fuels and water.

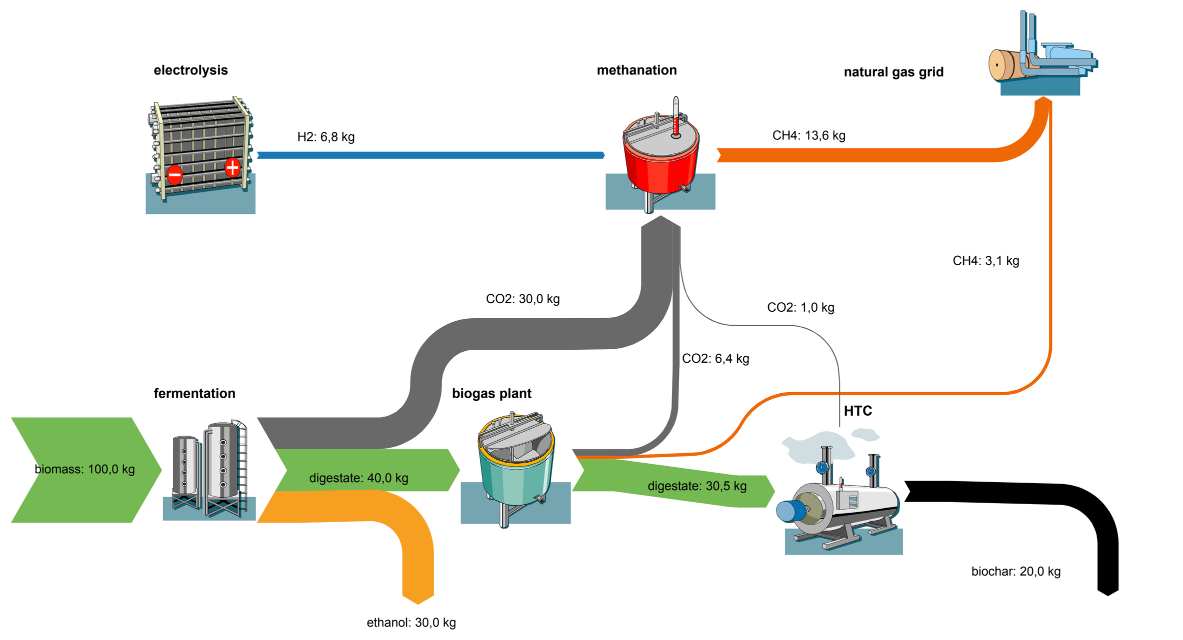


Fig. 2: Scheme of CO_2 emission free biorefinery process. Biomass and hydrogen from power-to-gas are converted to solid (20 % biochar), liquid (30 % bioethanol) and gaseous (16.7 %) fuels plus water (not shown).

Experimental Approach

Fig. 3: **Left:** Methanation in lab scale (0.5 l bottles on hot plate magnetic stirrer) with pressure indication. **Middle:** Pilot plant scale reactor with magnetic stirrer and baffles. **Right:** Relative pressure in in lab scale bottles with and without stirring during biological methanation at 65 °C with *Methanothermobacter marburgensis*.

- investigation of flexibility - start and stop behaviour
- increase conversion rate by investigation of stirring kinetics
- pilot scale plant with integrated bioethanol production
- feasability for mid-scale brewery in Germany

Advantages of CO_2 form alcoholic fermentation

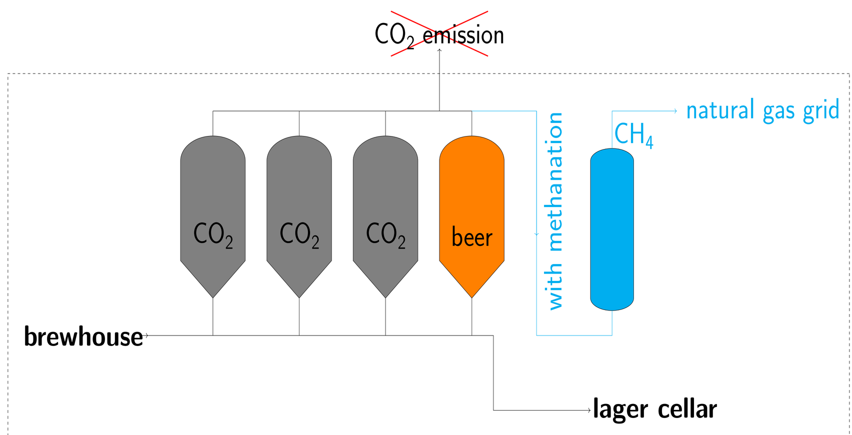


Fig. 4: Schematic fermentation cellar in a brewery with methanation reactor.

- decentral conversion of energy
- low costs of CO_2 (side stream)
- no purification needed (100 % CO_2)
- reduction of CO_2 emissions of breweries etc.
- negative CO_2 emissions (GHG emissions reduction potential)
- infrastructure (piping, vessels) already existent

References

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