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Storage of volatile renewable energy in the gas grid applying 3-phase methanation

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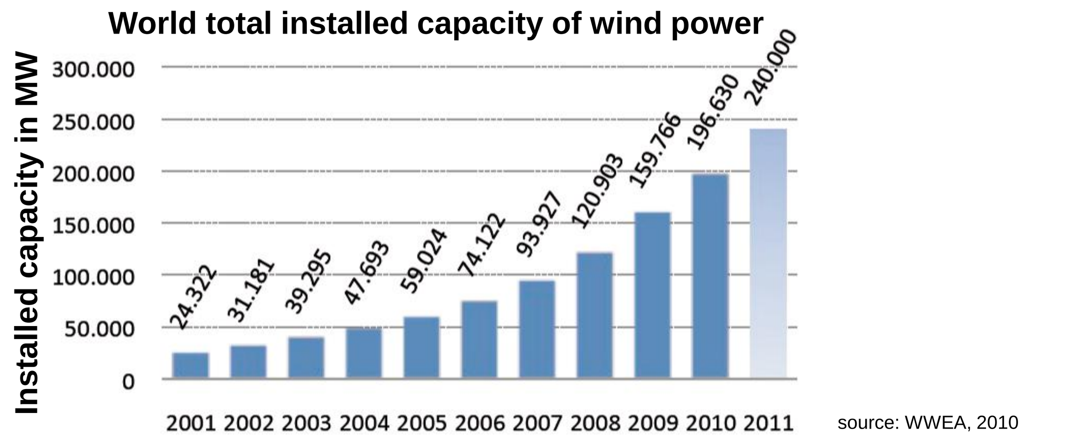
Objective

- Strong increase of wind power and photovoltaics



- Drawback: both are strongly fluctuative
- Power input and output of electricity grid have to be in balance permanently

⇨ Large storage capacity necessary

Electrolysis

- Use of surplus electricity for water electrolysis
- Operation at elevated pressure (20 - 30 bar)
- PEM electrolysis can handle volatile electricity

Power storage

Technologies with large capacity and storage duration of days or weeks:

- Pumped storage hydro power

⇨ High efficiency up to 85 %
⇨ Capacity very limited in most countries

- Compressed air energy storage (CAES)

⇨ Low energy density
⇨ Diabatic: poor efficiency of < 50 %
⇨ Adiabatic: not yet state-of-the-art

- **Power-to-Gas**

⇨ CH_4 as chemical energy carrier
⇨ Highest energy density
⇨ Efficiency up to 64 % (from power to CH_4)

Gas grid as energy storage

- Gas grid is well structured and developed in many countries

⇨ Energy distribution

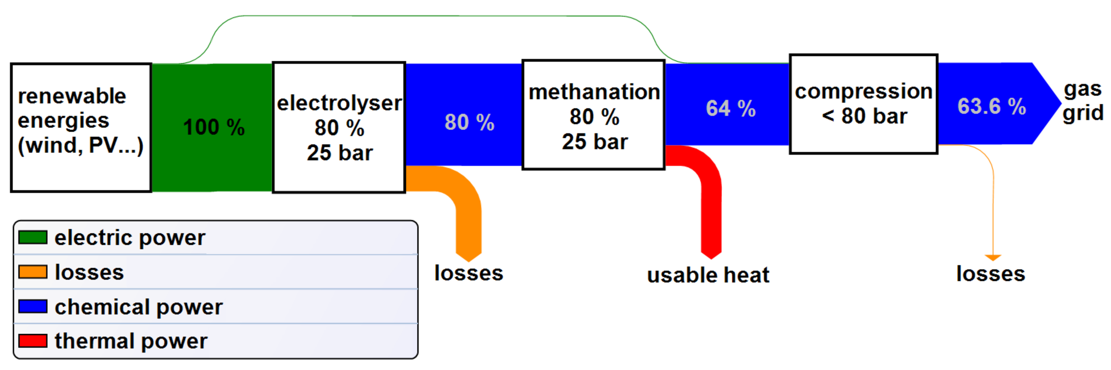
- Large storage capacity of > 3600 TWh

source: IGU, 2006

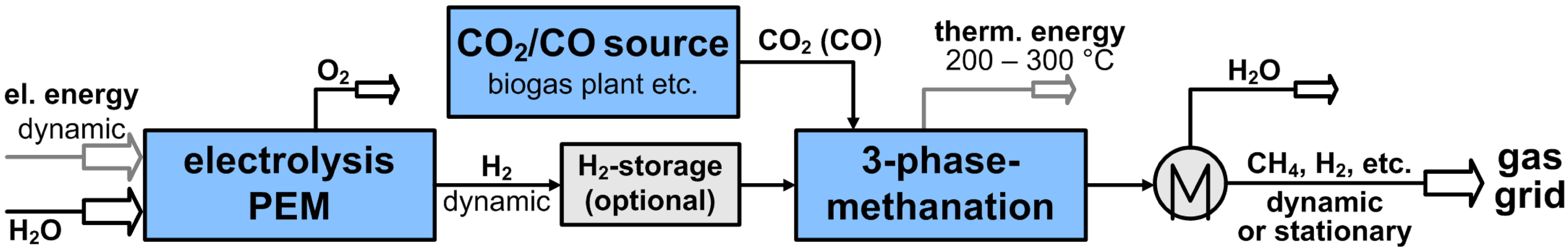
CO_2/CO sources

- Carbon sources in all scales available

small scale	middle scale	large scale
≈ 1 000 m³/h	≈ 5 000 m³/h	≈ 10 000 m³/h
- Biogas plants - CHP	- Biomass gasification	- Chemical industry



Process chain "Power-to-Gas"



3-phase methanation

Fundamentals of methanation

$3\,H_2 + CO \rightarrow CH_4 + H_2O_{(g)}$ $\quad \Delta_R H^0 = -206$ kJ/mol

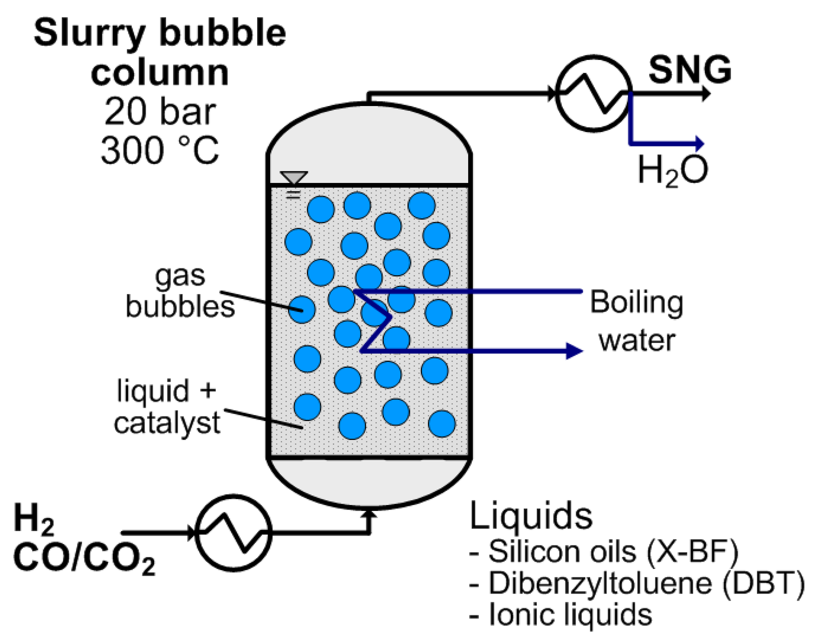
$4\,H_2 + CO_2 \rightarrow CH_4 + 2\,H_2O_{(g)}$ $\quad \Delta_R H^0 = -165$ kJ/mol

- Removal of reaction heat is the main issue
- State-of-the-art methanation reactors:

⇨ Fixed-bed and fluidized-bed reactor

- **Novel concept: 3-phase methanation**

⇨ Reactor is filled with an inert liquid
⇨ Catalyst (< 100 µm) is suspended in this liquid



Advantages of 3-phase methanation

- Only one reactor necessary
- High heat capacity of the liquid

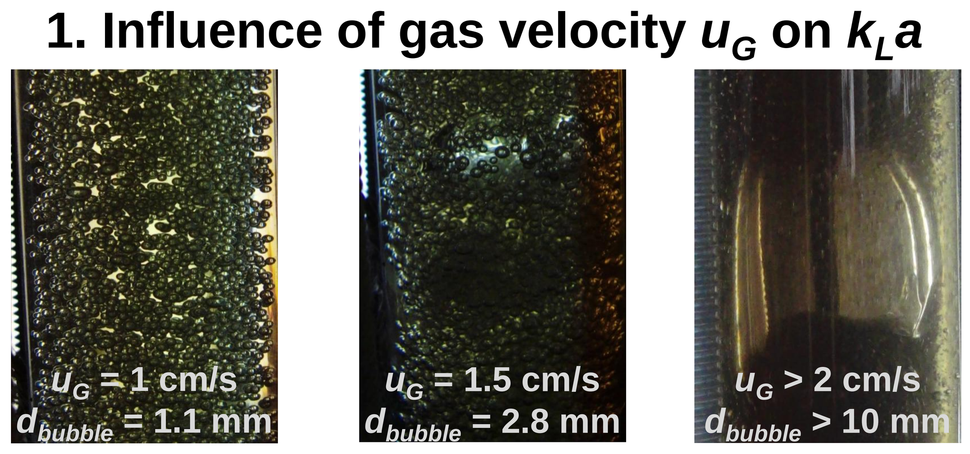
⇨ Simplified removal of waste heat
⇨ Isothermic operation possible
⇨ Buffers the effect of fluctuating feed streams

Aim of development

- Identification of operating parameters for optimized mass transfer in the liquid phase

Optimization of liquid-side mass transfer: $^V\Phi_i / V_R = k_L a \cdot (c^*_{iL} - c_{iL})$ ⇨ 1. Increase k_L 2. Increase a (= 6 · $\varepsilon_G / d_{bubble}$)

1. Influence of gas velocity u_G on $k_L a$



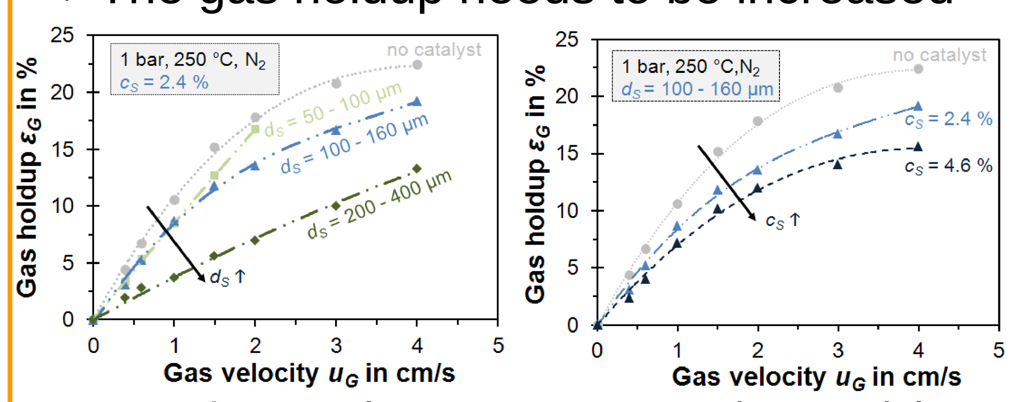
Homogeneous	Heterogeneous	Slug flow
a: ++	a: 0	a: --
k_L: 0	k_L: +	k_L: -
⇨ desired	⇨ desired	⇨ undesired

- Change of flow regime increases d_{bubble} strongly

2. Influence of catalyst on $k_L a$

- Gas holdup ε_G ↑ ⇨ a ↑

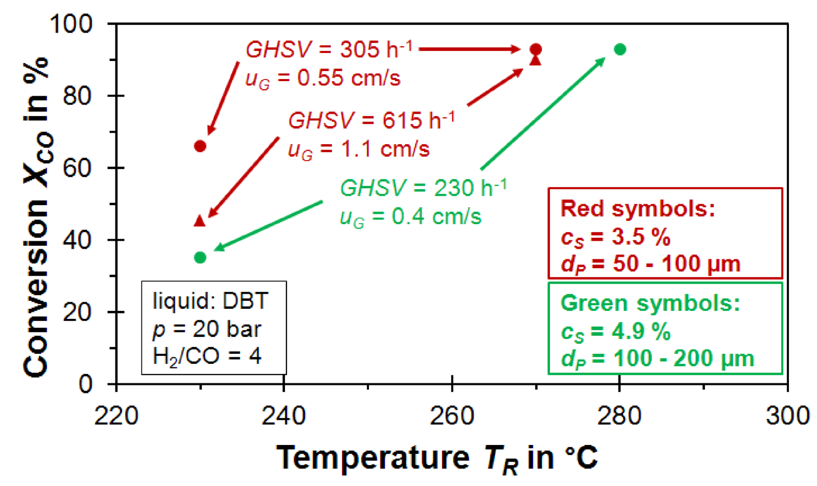
⇨ The gas holdup needs to be increased



- Increasing catalyst concentration decreases ε_G
- Increasing particle diameter decreases ε_G

3. Methanation in a slurry bubble column reactor

- Decrease of c_S and d_P increases conversion
- For u_G = 1.1 cm/s and T = 270 °C a high conversion and a high $GHSV$ can be achieved



$d_{Reactor} = 25\,mm$

$c_S = \frac{V_{Cat}}{V_{Cat} + V_{Liquid}(T)}$

$GHSV = \frac{^V\Phi_{total,NTP}}{V_{Reactor}}$

Conclusions

- Highest u_G before flow regime change should be used, slug flow is undesired
- Too little catalyst decreases the intrinsic reaction rate but too much decreases the mass transfer
- With the right operating conditions the 3-phase methanation achieves a high conversion at an also acceptable $GHSV$