Tampere University

# Power-to-X: Potential of biomethane


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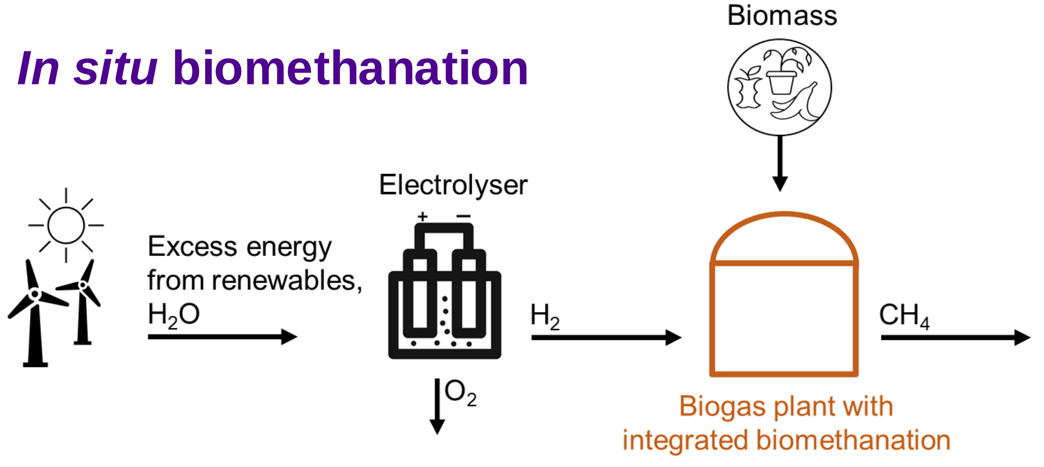
# Outline

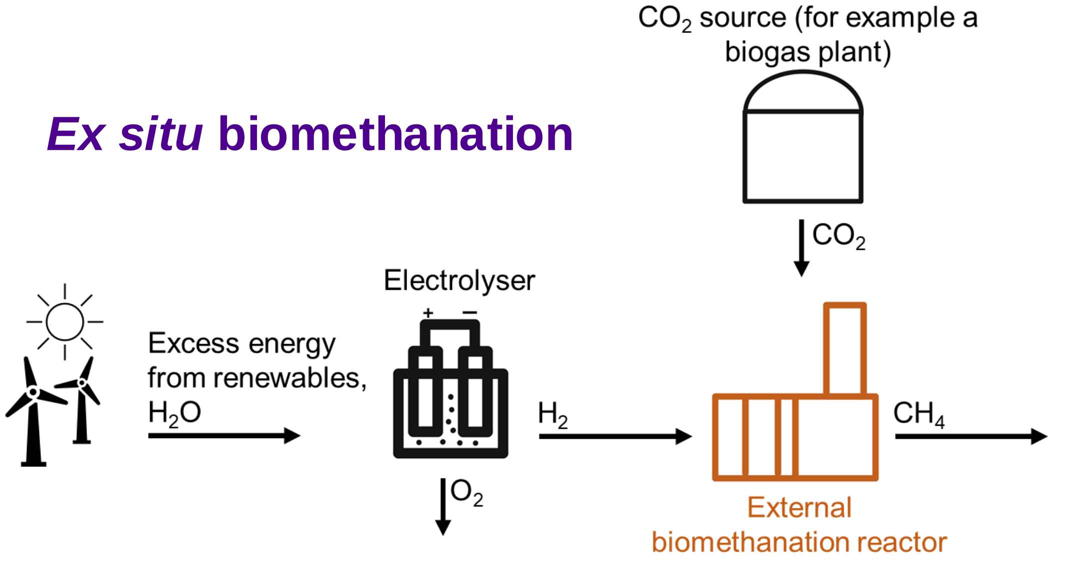
- Biological methanation
- Power-to-X: biological *vs*. chemical methanation
- Potential of biological methanation in Finland
- Important aspects to consider when planning biological methanation
- Conclusions

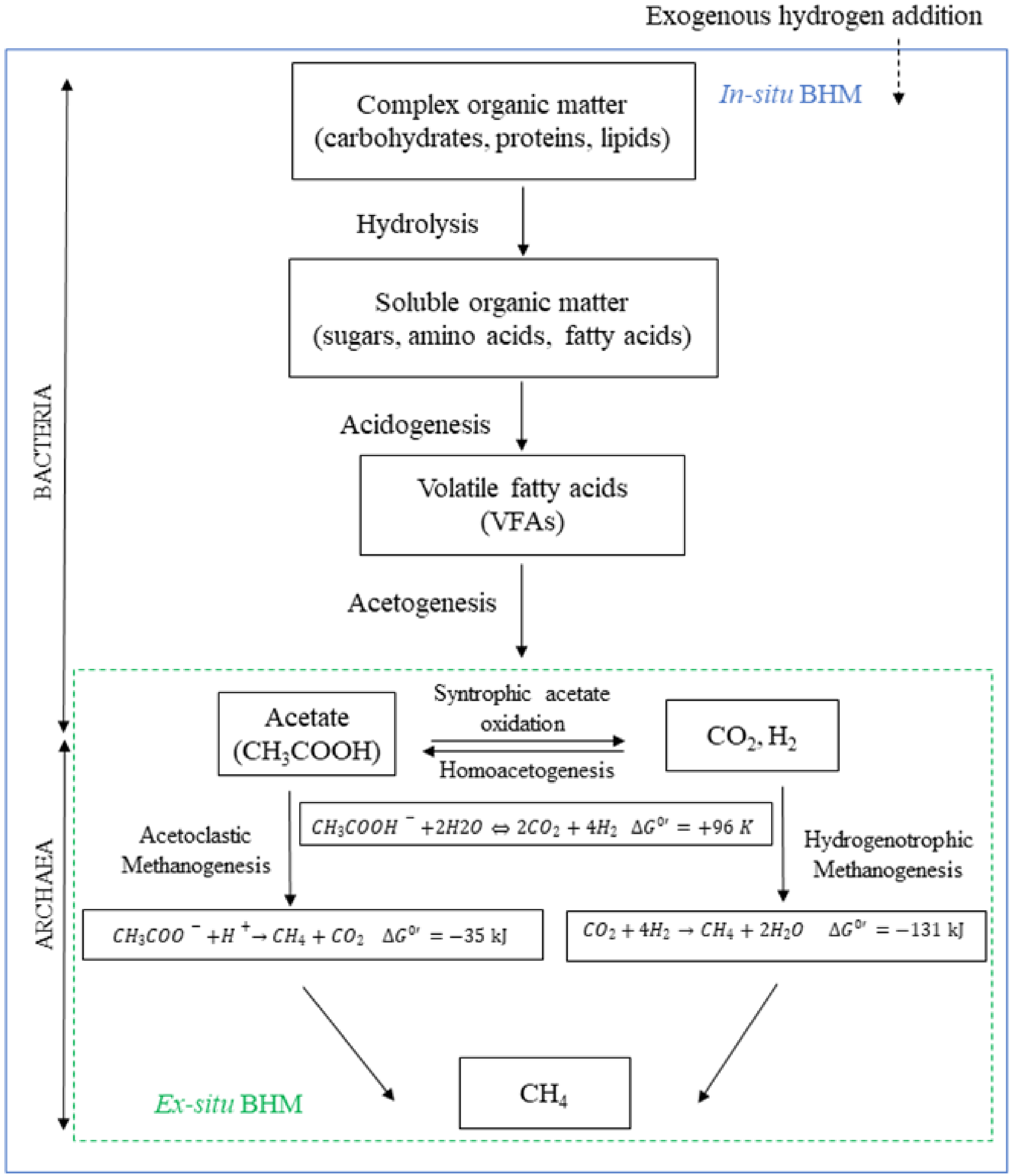
# Biological methanation

## *In situ* biomethanation




## *Ex situ* biomethanation




Figures: Maija Ijäs, Donya Kamravamanesh

# Power-to-X: biological *vs*. chemical methanation

Biological methanation

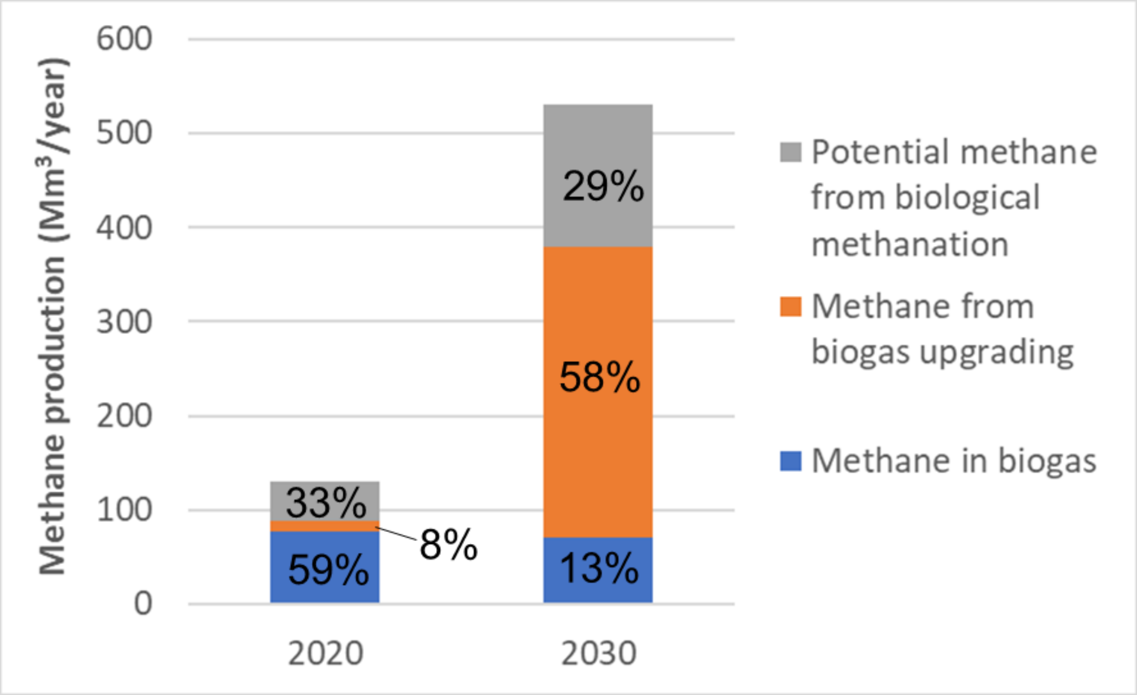
- Proceeds at ambient temperature (30-70°C) and low pressures (1-10 bars)
- Lower reaction rate
- Less sensitive towards impurities
- More challenging to keep microorganisms active under fluctuating gas streams
- First commercial applications

Catalytic methanation

- Proceeds at high temperatures (200-550°C) and pressures (1-100 bars)
- Higher reaction rate
- More sensitive towards impurities
- More resilient against feed gas flow changes
- Requires catalysts
- Has been under operation for a long time

# Potential of biological methanation in Finland – Biogas plants

| | 2020 | 2030 |
|---|---|---|
| Biogas plants (million m³/a) | | |
| $CH_4$ in biogas | 76.8 | 70.2 |
| $CH_4$ from biogas upgrading | 11.0 | 309.5 |
| **Total $CH_4$ production** | **87.8** | **379.7** |
| Biomethanation (million m³/a) | | |
| $CH_4$ from $CO_2$ in biogas | 37.1 | 30.8 |
| $CH_4$ from $CO_2$ in biogas upgrading | 4.9 | 120.8 |
| **Total biomethanation potential** | **42.0** | **151.6** |
| **Total $CH_4$ production** (million m³/a) | **129.8** | **531.3** |




Original data on methane production from biogas plants in 2020 and 2030 from Finnish Biocycle and Biogas Association

Maija Ijäs, MSc thesis, 2022, https://urn.fi/URN:NBN:fi:tuni-202210187668

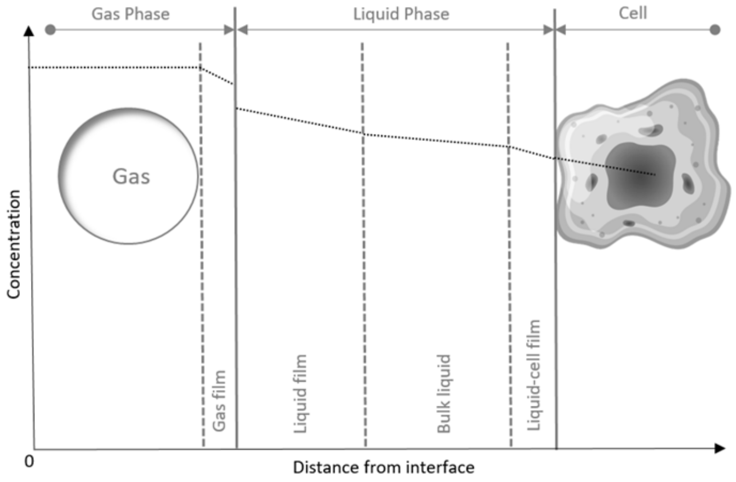
# Planning biological methanation – Hydrogen

$H_2$ production through electrolysis with renewable energy sources

- Electricity cost plays a crucial role in the feasibility of the process
- Life cycle assessment studies have shown that utilizing renewable electricity for $H_2$ evolution and taking into accoung the natural gas substituted benefits biological methanation scenarios
- $H_2$ storage and transportation for long distances is difficult and costly; potential to produce $H_2$ on site is gaining attention (electricity transport required)
- Another option: importing $CO_2$

Due to low $H_2$ solubility, the $H_2$ gas-liquid mass transfer is important

- Improving mixing e.g. via mechanical stirring or gas recirculation
- Using efficient gas diffusers
- Optimizing gas retention time
- Increasing temperature and/or pressure



# Planning biological methanation – Gas impurities and flow rate

Impurities may disrupt microbial performance

- $NO_2^-$ > $NO_3^-$ (130 ppm)
- $SO_x$ → $H_2S$ (80-355 ppm)
- Tar also may be inhibitory, partly due to PAHs and phenol
- CO may also serve as carbon source

Interruptions in flow rates

- Process recovery may take from hours to weeks depending e.g. on temperature and starvation time

| Gas stream origin | $O_2$ (%) | $N_2$ (%) | $CO_2$ (%) | $H_2O$ (%) | CO (ppm) | $NO_x$ (ppm) | $SO_x$ (ppm) |
|---|---|---|---|---|---|---|---|
| Coal combustion – flue gas[a] | 13 | 75.8 | 5.2 | 5.35 | 60 | 1500 | 600 |
| Refinery – flue gas[b] | 2 | 59 | 24 | 15 | N.A. | 25 | 5 |
| Pulp and paper mill limekiln – flue gas[c] | 1.2 | 47.4 | 20.4 | 30.9 | N.A. | 175 | 50 |
| Anaerobic digester – biogas[d] | 0-3 | 0-15 | 15-60 | 1-5 | <0.6 | N.A. | 0-10.000 ($H_2S$) |
| Landfill gas – biogas[e] | <1-17 | N.A. | 25-45 | 1-5 | N.A. | N.A. | 30-500 ($H_2S$) |
| Gasification of OFMSW – syngas[f] | N.A. | N.A. | 19.2 | N.A. | 25.79% | 0.053 | 0.5 |

# Conclusions

Biological methanation has the potential to improve methane production in biogas plants that are envisioned to increase in number in the near future

Biological methanation – important aspects to consider

- Process design, especially $H_2$ mass transfer
- Origin of $CO_2$ and $H_2$, which affect continuous *vs*. intermittent availability of the feed gases as well as the presence of impurities in the $CO_2$-rich stream
- Use of renewable electricity for $H_2$ production

Although biological methanation has several advantages over catalytic methanation, various aspects require further improvement

# Thank you!

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