HyPerFerment
More Efficient Biogas Plants via Hydrogen Production

N. Eggers; F. Giebner; D. Heinemann; M. Wagner; T. Birth,

	2030
Carbon Free	0,5 %
Based on Fossil Fuels	99,5 %

Data based on [1]

31st European Biomass Conference & Exhibiton, 5-8 June 2023

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	2030	2050	2050
Carbon Free	0,5 %	5 %	15 %
Based on Fossil Fuels	99,5 %	95 %	85 %

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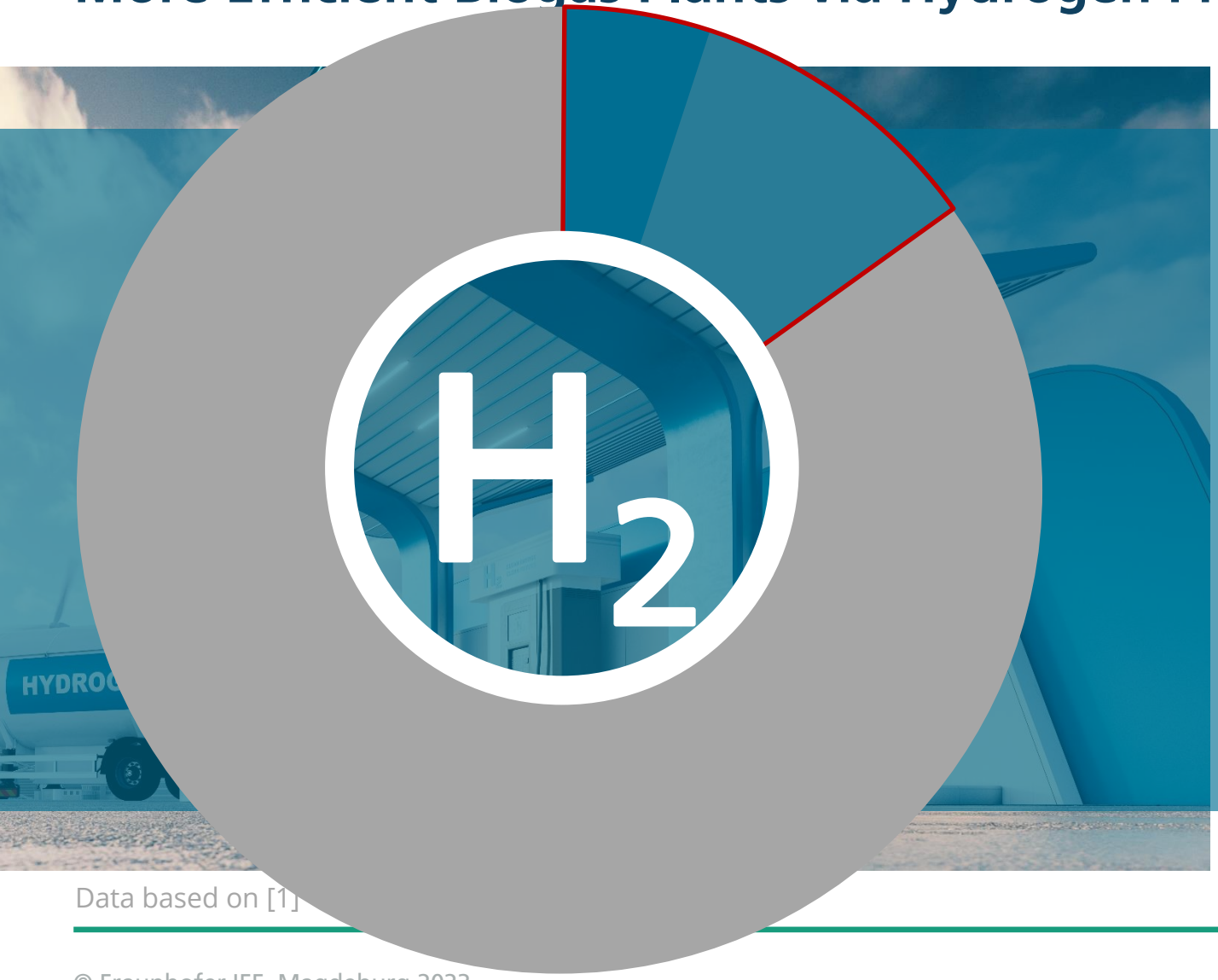

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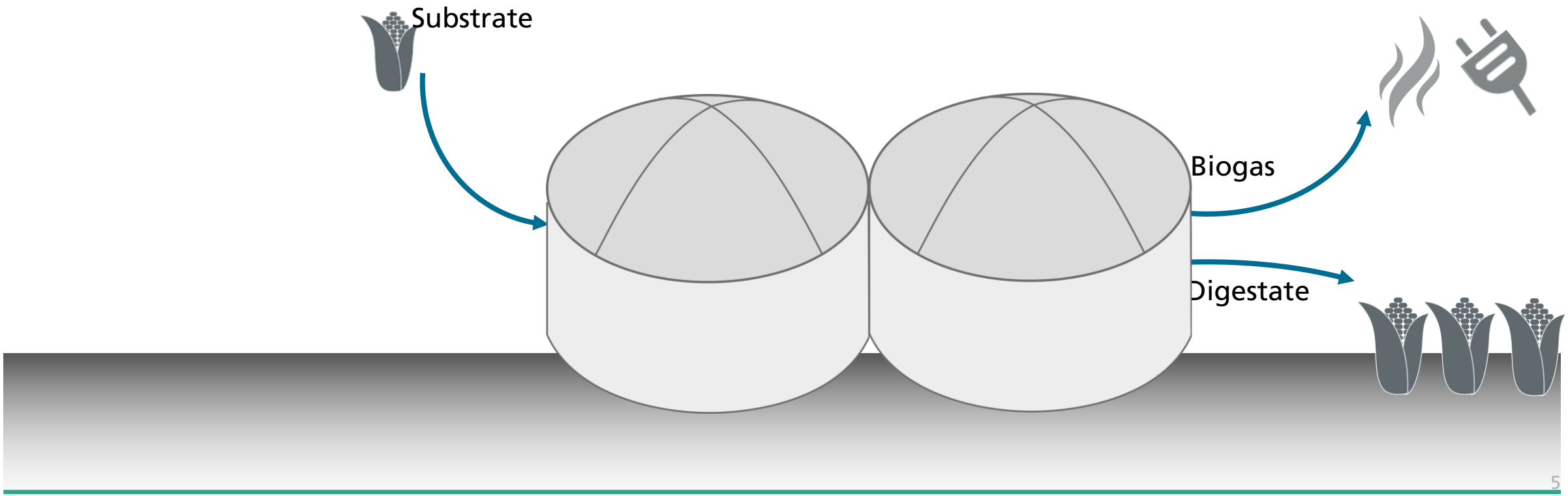
The Idea of HyPerFerment

Our Concept



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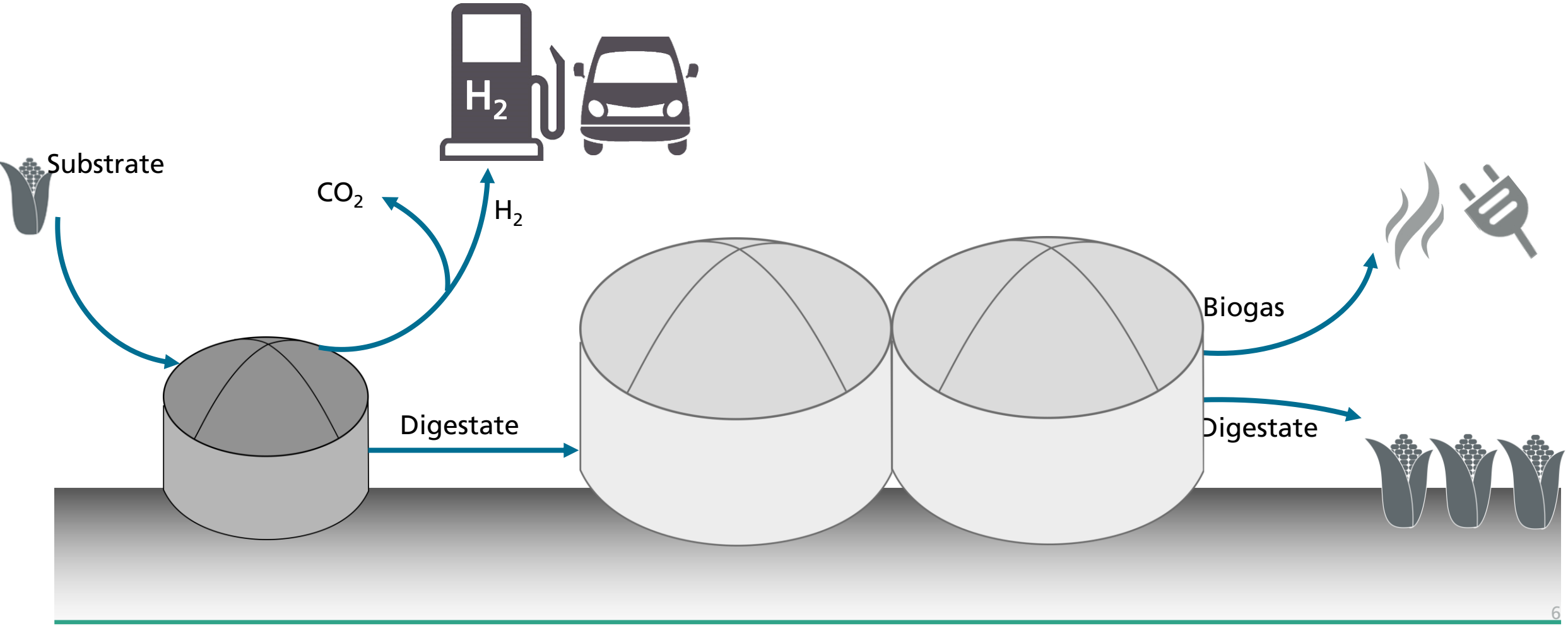

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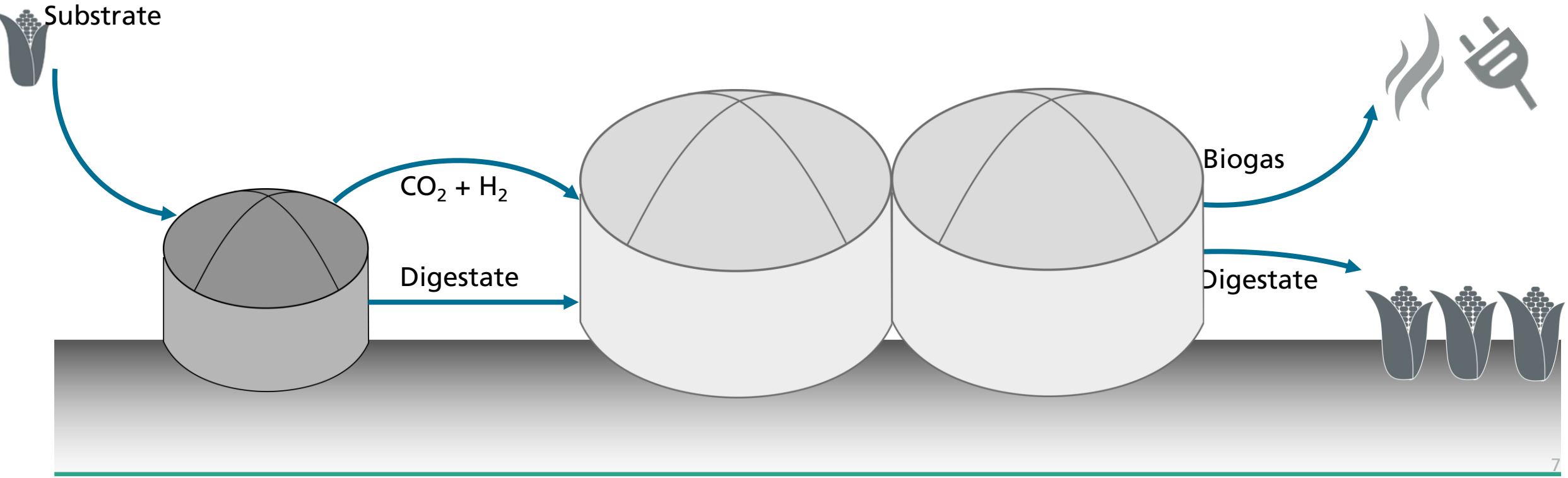

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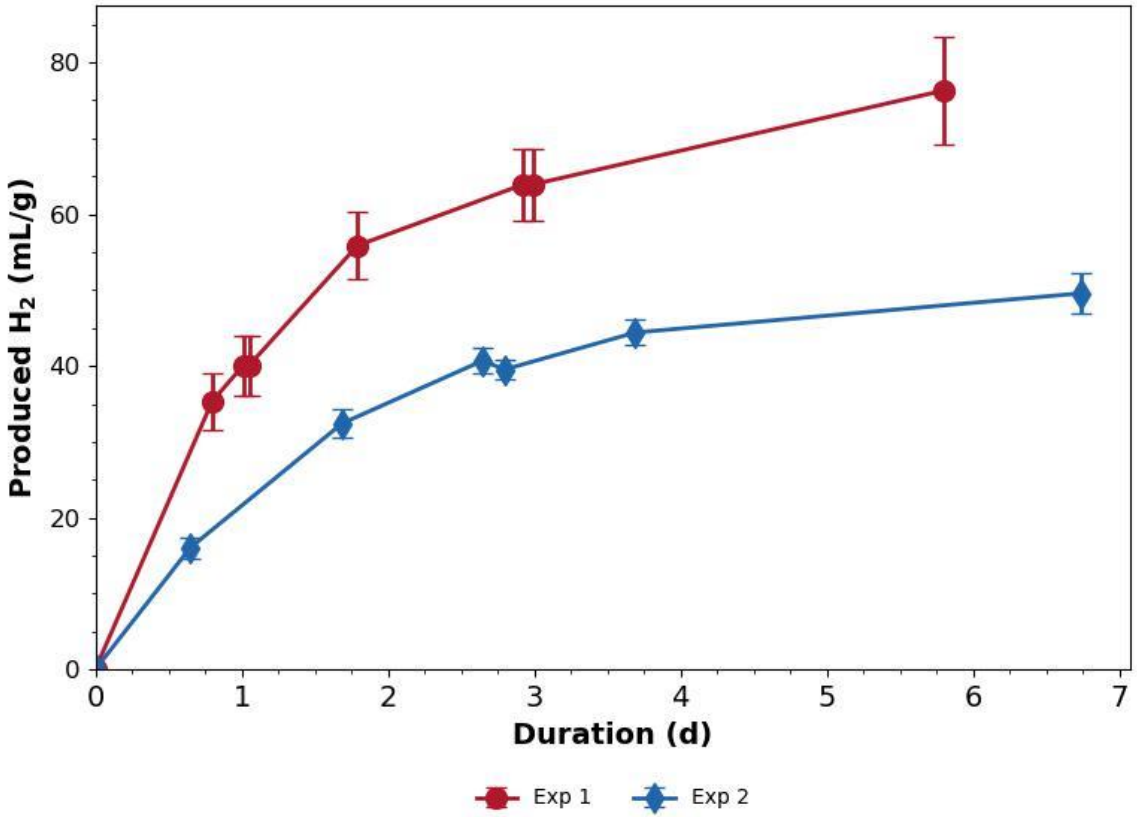
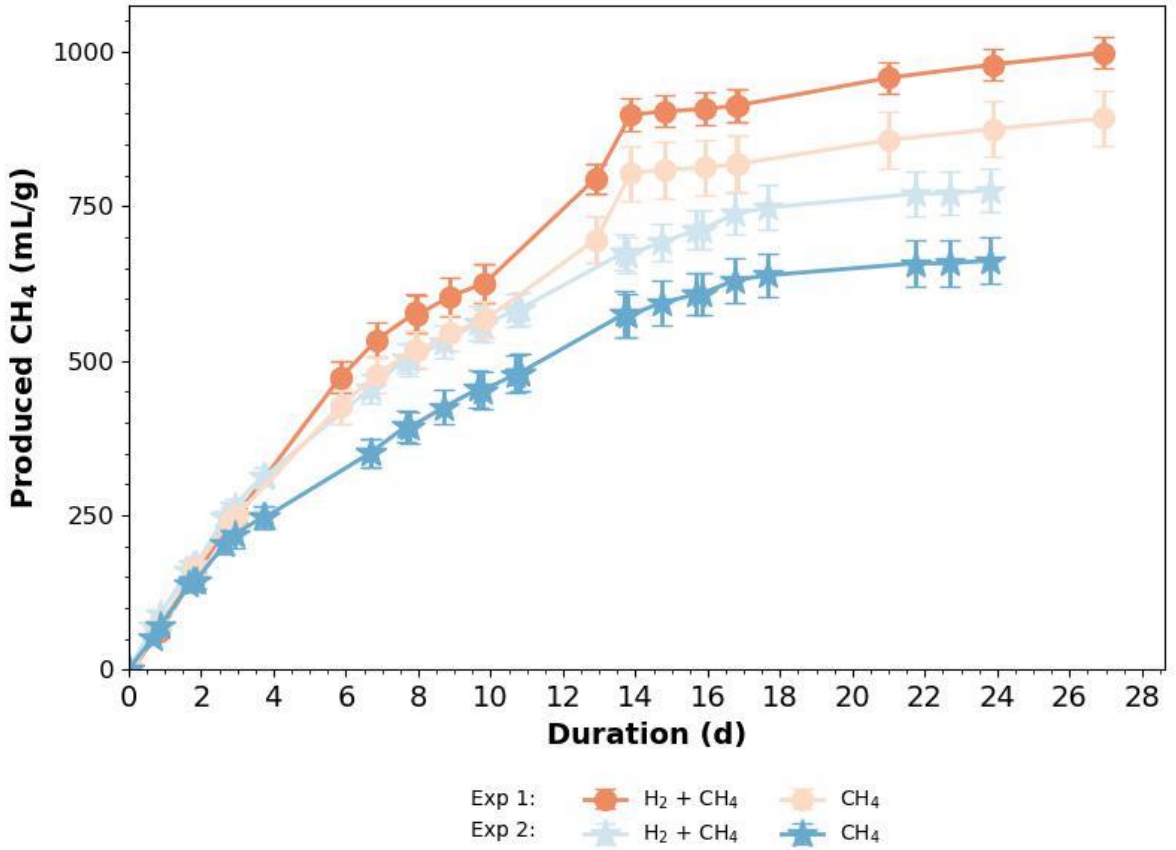
Experimental Data





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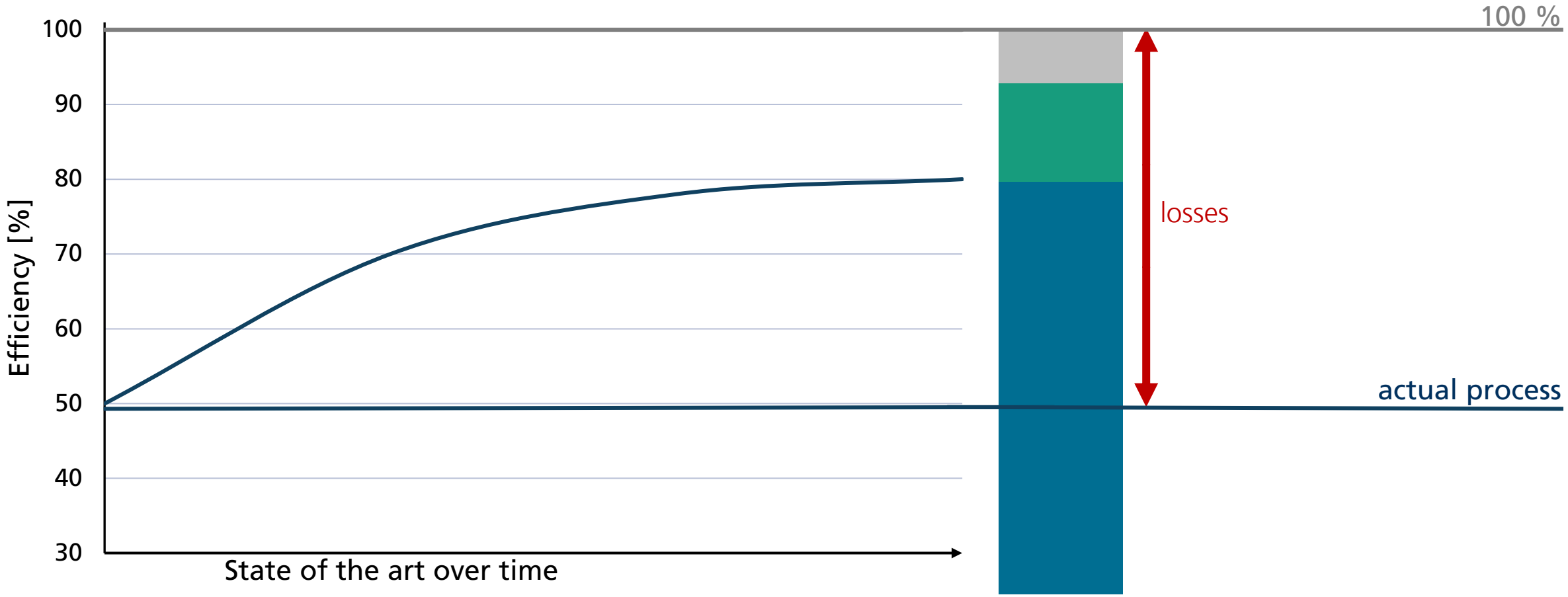
Efficiency Assessment
Methods and Challenges for Power2X



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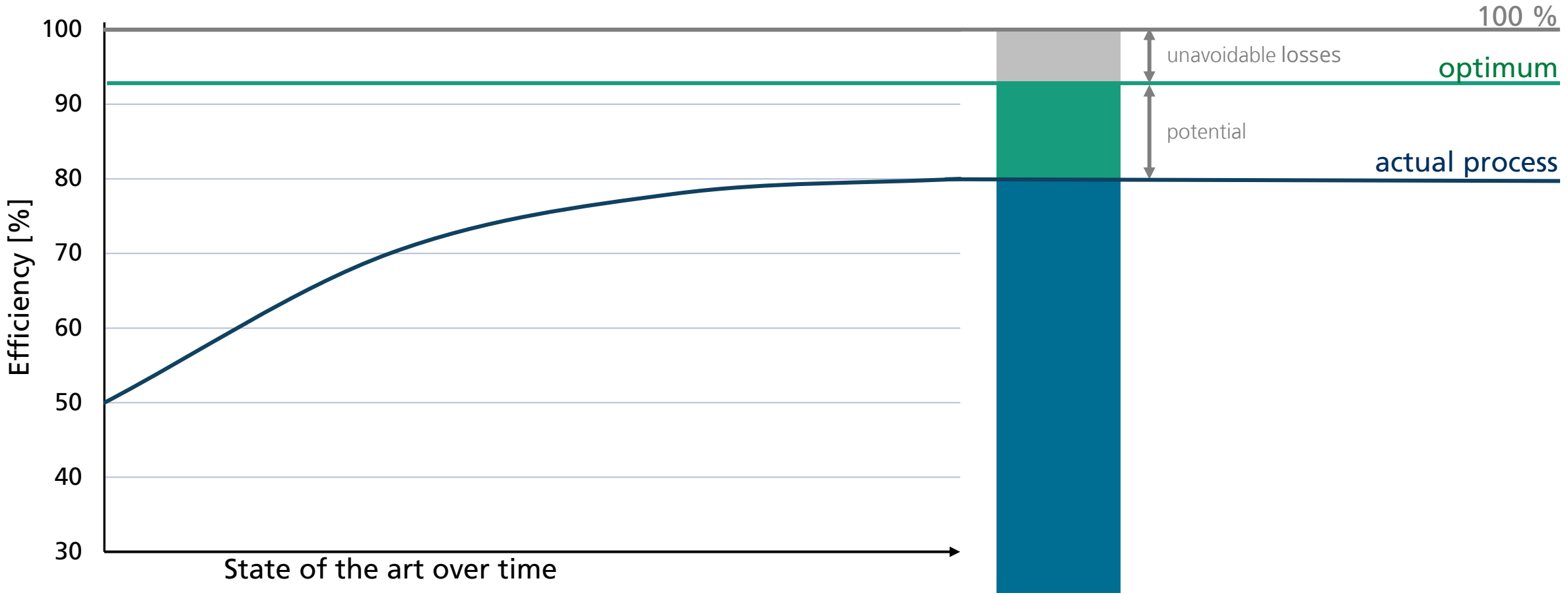

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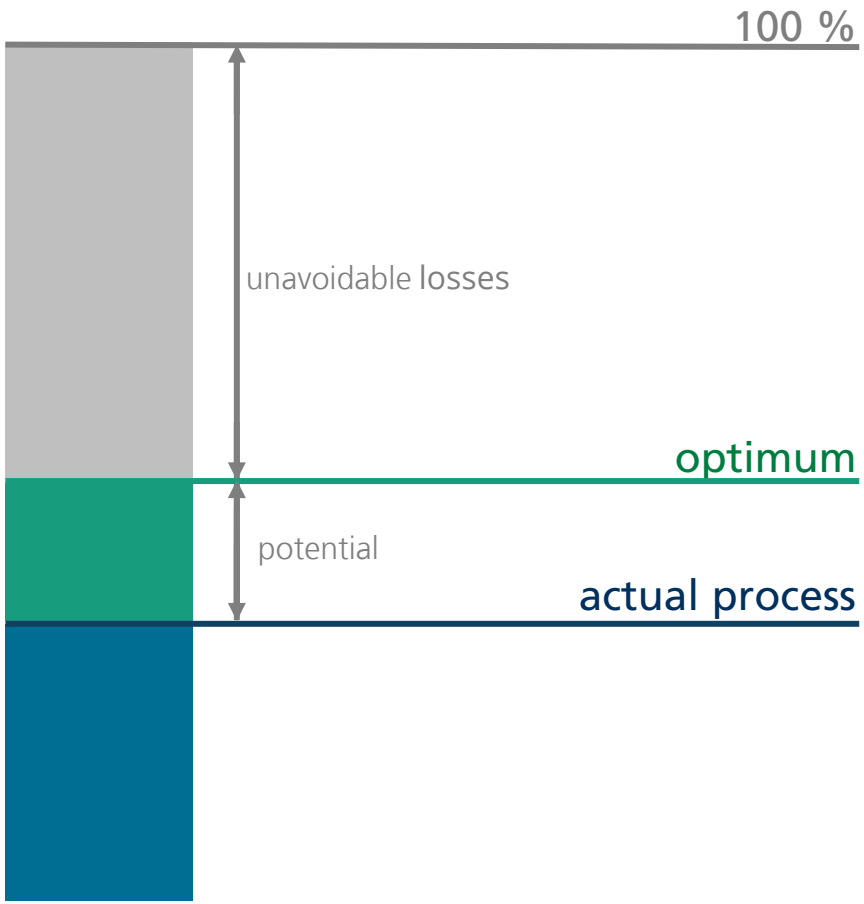
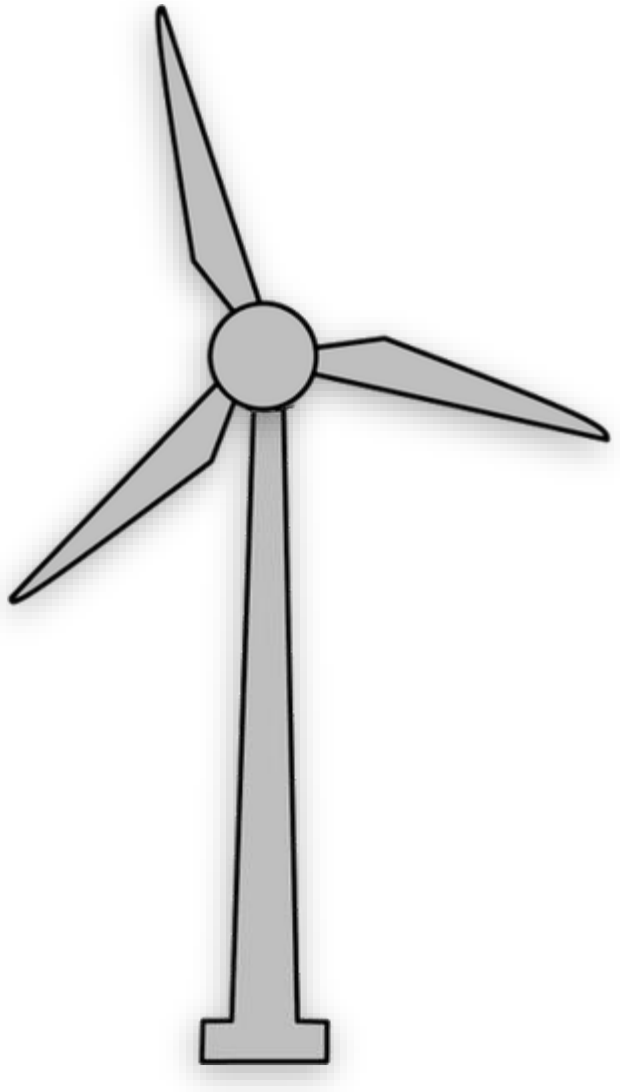
Efficiency Assessment
Betz Factor for Biological Processes?





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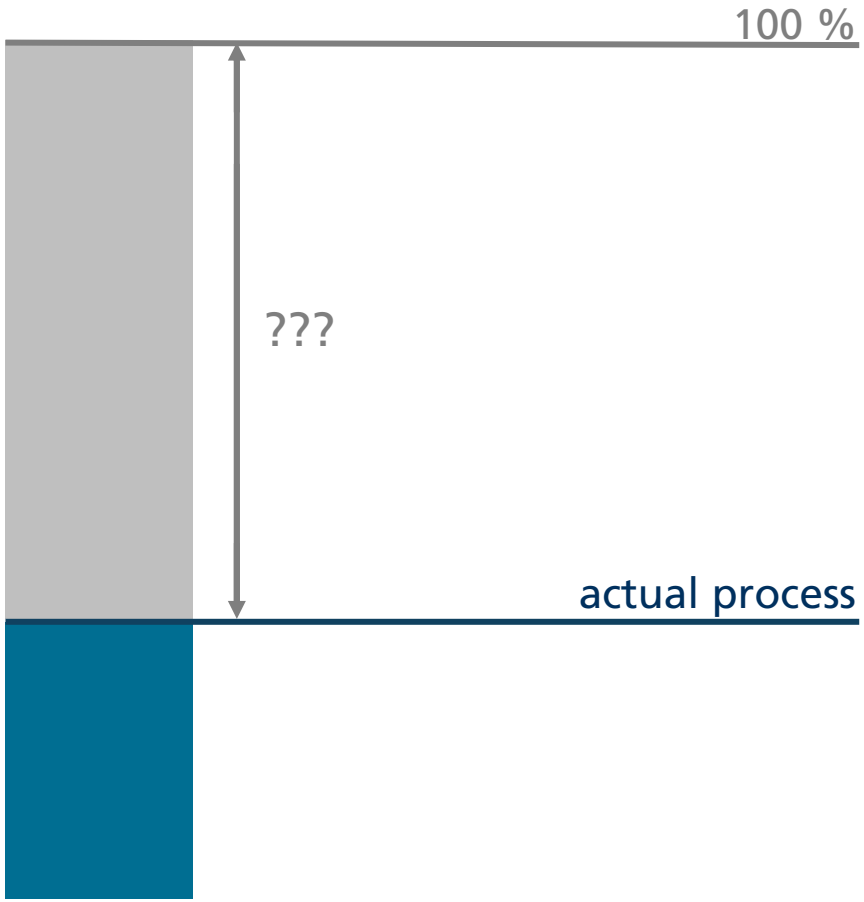

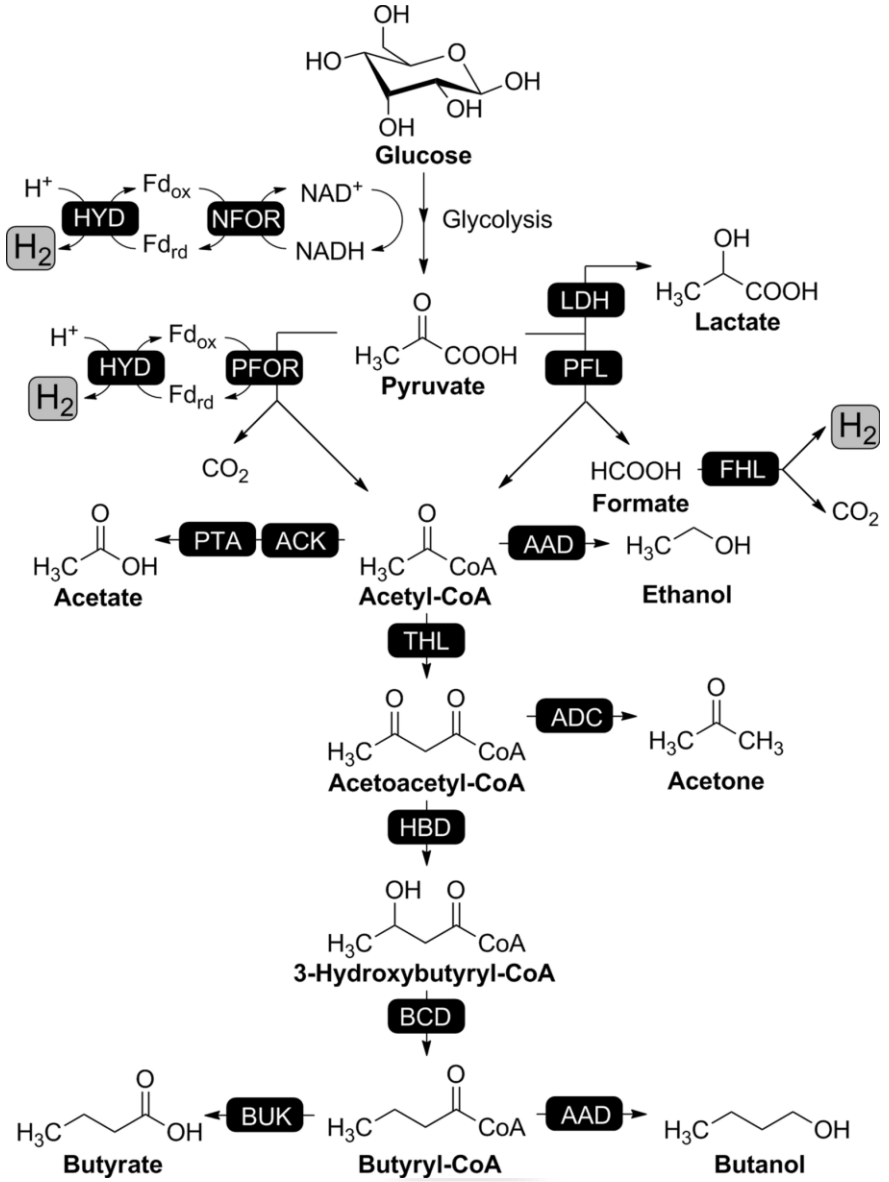

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Finding the Limits of Optimizability
Buswell & Boyle for Biogas Production

Limit of Optimizability. The maximum yield is obtained as a result of the metabolism of the microorganisms involved. [5]

Buswell and Boyle Stoichometrie. [3]

$$C_aH_bO_cN_dS_e + \left(a - \frac{b}{4} - \frac{c}{2} + \frac{3}{4}d + \frac{e}{2}\right)H_2O \rightarrow \left(\frac{a}{2} - \frac{b}{8} - \frac{c}{4} + \frac{3}{8}d + \frac{e}{4}\right)CO_2 + \left(\frac{a}{2} - \frac{b}{8} - \frac{c}{4} + \frac{3}{8}d + \frac{e}{4}\right)CH_4 + cNH_3 + dH_2$$

Model Validation. Based on experimental data, substances that were not decomposed were neglected in the determination of the maximum methane yield.

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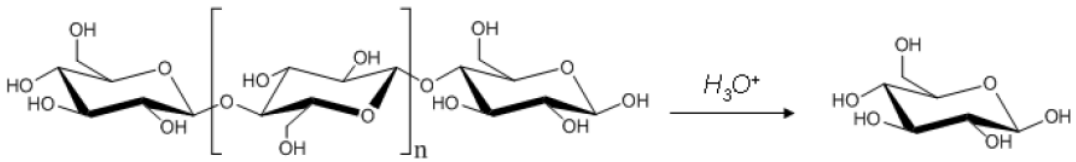
Finding the Limits of Optimizability
New Model for Dark Fermentation

Theoretical Hydrogen Yield. Consideration of three most important reaction steps. Adaptable depending on the substrate.

- Enzymatic saccharification[6]
- Fermentation of glucose [5]
- Fermentation of lipids (if applicable) [6]



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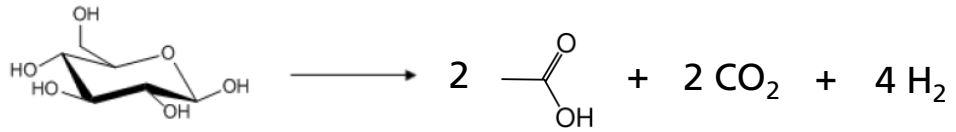

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$$C_nH_{2n}O_2 + 2H_2O \longrightarrow C_{n-2}H_{2n-4}O_2 + C_2H_4O_2 + 2H_2$$

Model Validation. Based on experimental data, substances that were not decomposed were neglected in the determination of the maximum methane yield.

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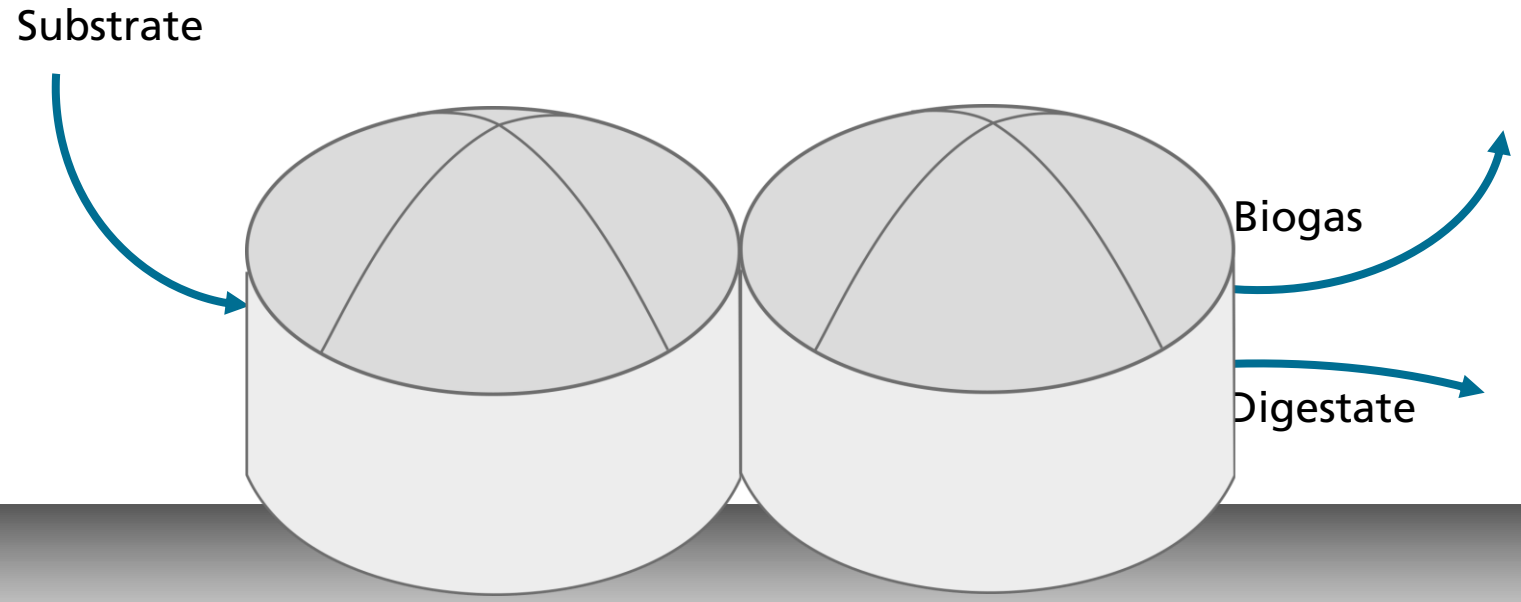
Finding the Limits of Optimizability

System Boundaries



$$C_aH_bO_cN_dS_e + \left(a - \frac{b}{4} - \frac{c}{2} + \frac{3}{4}d + \frac{e}{2}\right)H_2O$$
$$\rightarrow \left(\frac{a}{2} - \frac{b}{8} - \frac{c}{4} + \frac{3}{8}d + \frac{e}{4}\right)CO_2 + \left(\frac{a}{2} - \frac{b}{8} - \frac{c}{4} + \frac{3}{8}d + \frac{e}{4}\right)CH_4 + cNH_3 + dH_2$$

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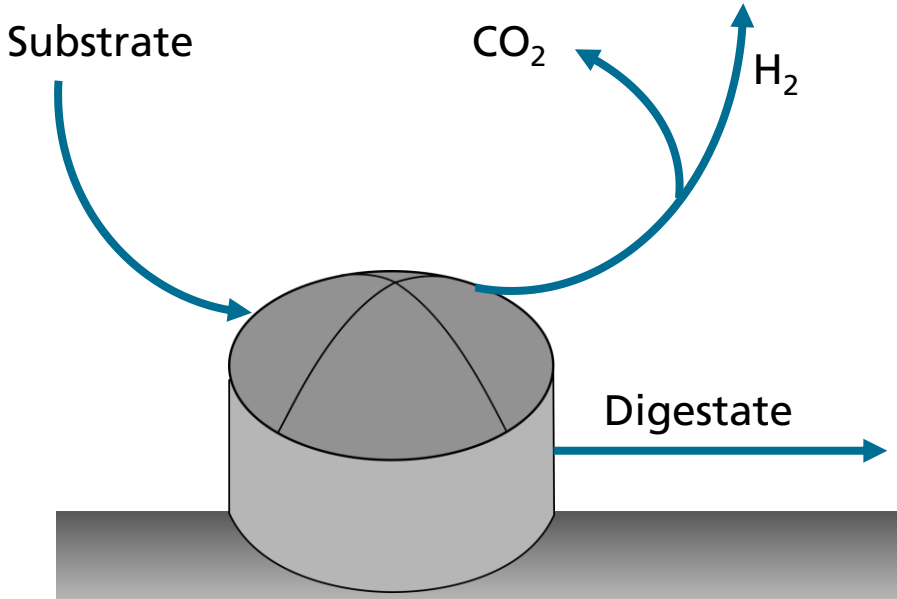

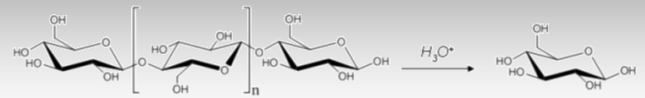

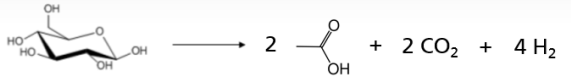

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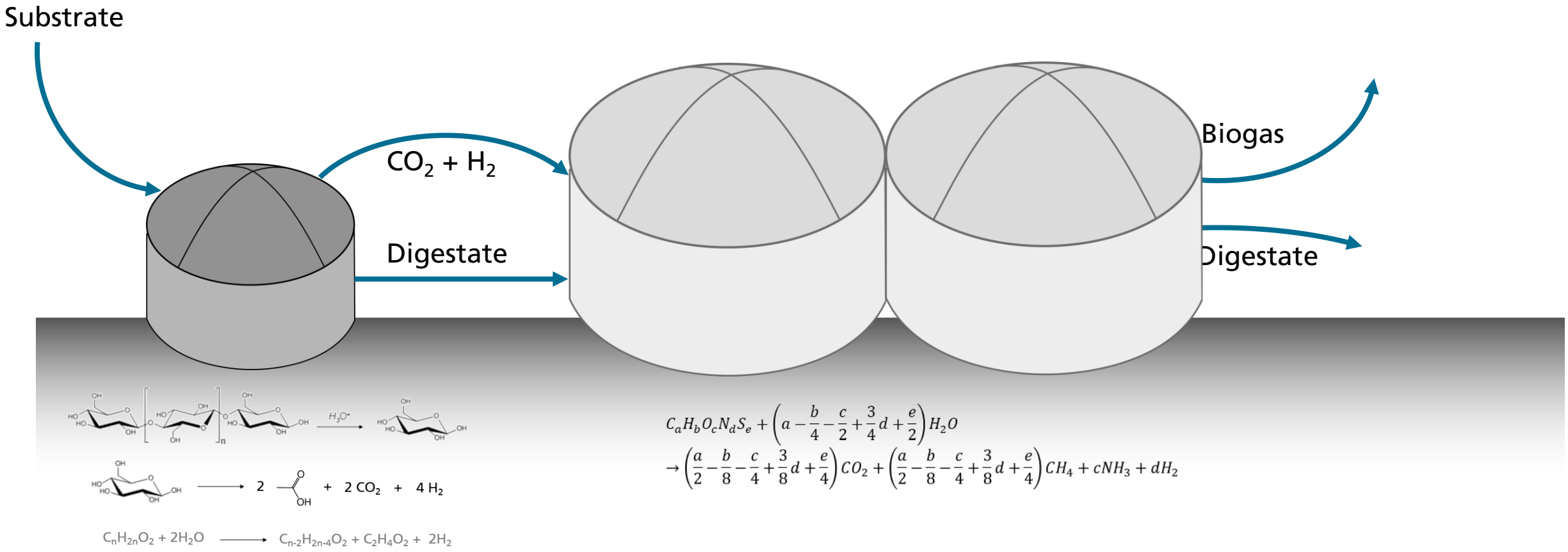

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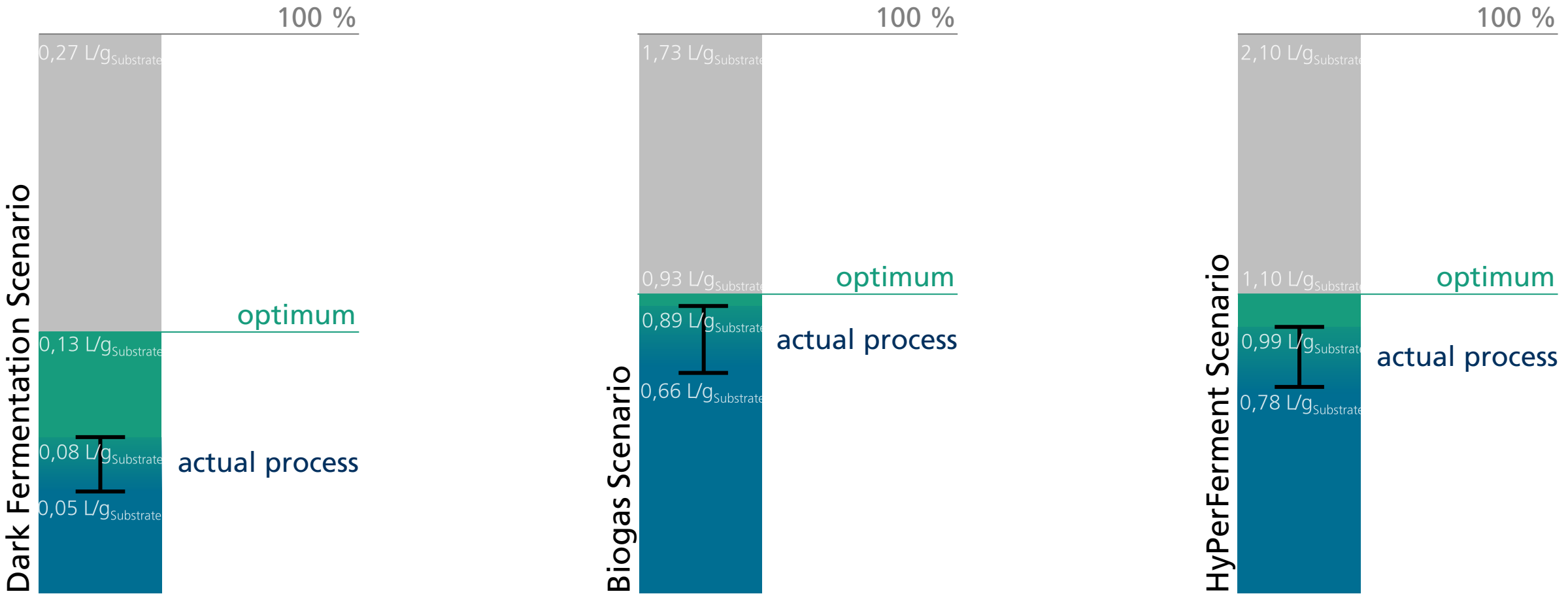
Finding the Limits of Optimizability
Preliminary Results for Corn Silage



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HyPerFerment
More Efficient Biogas Plants via Hydrogen Production

Literature

[1] DNV: “Hydrogen Forecast to 2050”, Høvik, Norway, 14 June 2022

[2] Y. Cao, H. Liu, W. Liu, J. Gao, M. Xian: “Debottlenecking the biological hydrogen production pathway of dark fermentation: insight into the impact of strain improvement”, Microbial Cell Factories 21 (2022)

[3] F. R. Hawkes, I. Hussy, G. Kyazze, R. M. Dinsdale, D. L. Hawkes: Continuous dark fermentative hydrogen production by mesophilic microflora: Principles and progress. International Journal of Hydrogen Energy 32 (2), S. 172-184 (2007)

[4] S. Ohl: Ermittlung der Biogas- und Methanausbeute ausgewählter Nawaro. Dissertationsschrift. Christian-Albrechts-Universität zu Kiel (2011)

[5] H. Kim, S. Moon, A. N. Abug, S. C. Choi, R. Zhang, Y. S. Oh: Effect of fermentation conditions on biohydrogen production from lipid-rich food material. International Journal of Hydrogen Energy 37, S. 15062 - 15069 (2012)

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How Efficient Can Hydrogen Be?
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