# Das Rheticusprojekt

EnergieDialog
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# Technical photosynthesis involving $CO_2$ electrolysis and fermentation

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Biocatalysis Electrocatalysis
Photocatalysis

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https://www.nature.com/articles/s41929-017-0005-1

In addition Nature has published a video „learning from leaves" based on the article:

https://www.youtube.com/watch?v=VK-dULEK-rc



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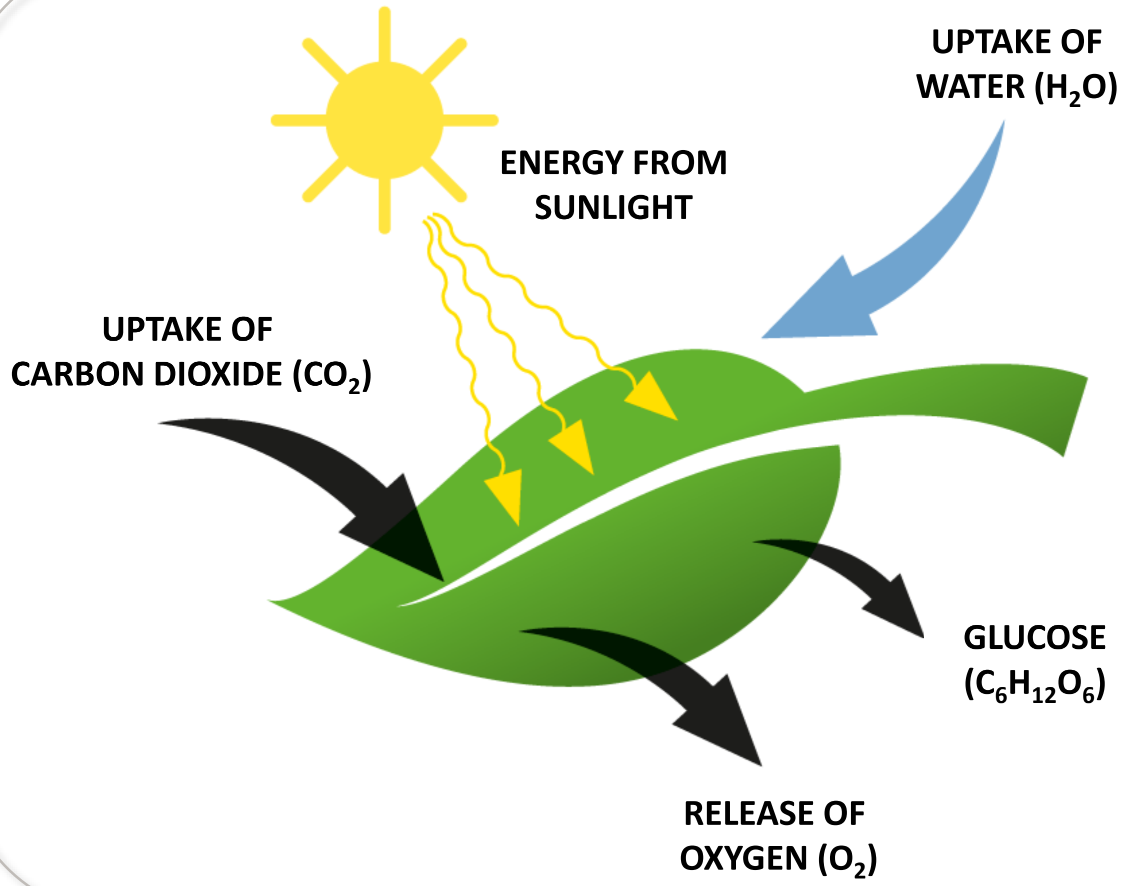
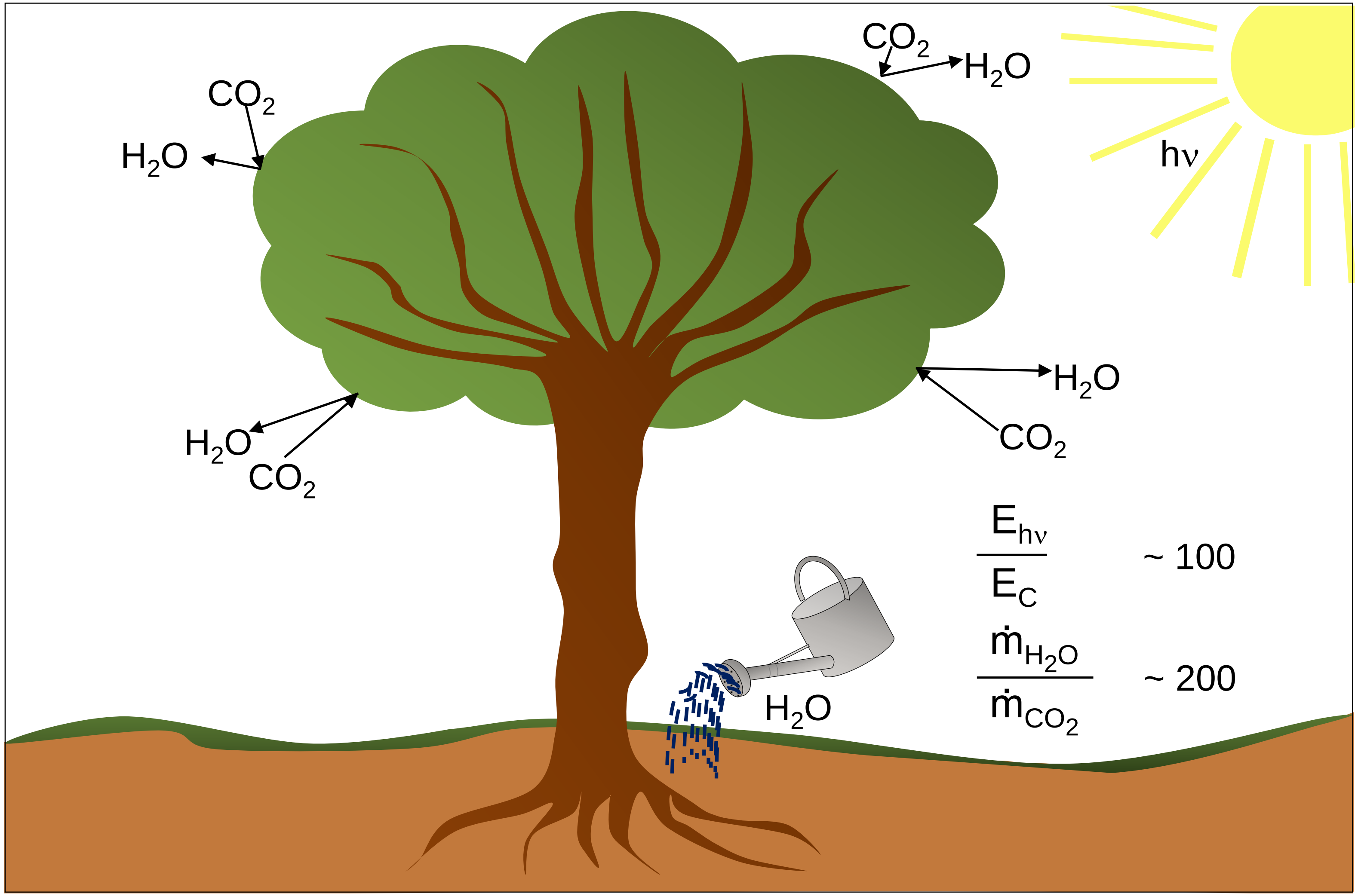
# Photosynthesis – converts sunlight, water and $CO_2$ into organic compounds

Light/light energy is absorbed – „harvested“ (e.g. by Chlorophyll) and converted in chemical energy

Usage of the chemical energy together with $CO_2$ and water to build up energy rich, organic compounds (e.g. sugar, fatty acids etc.)



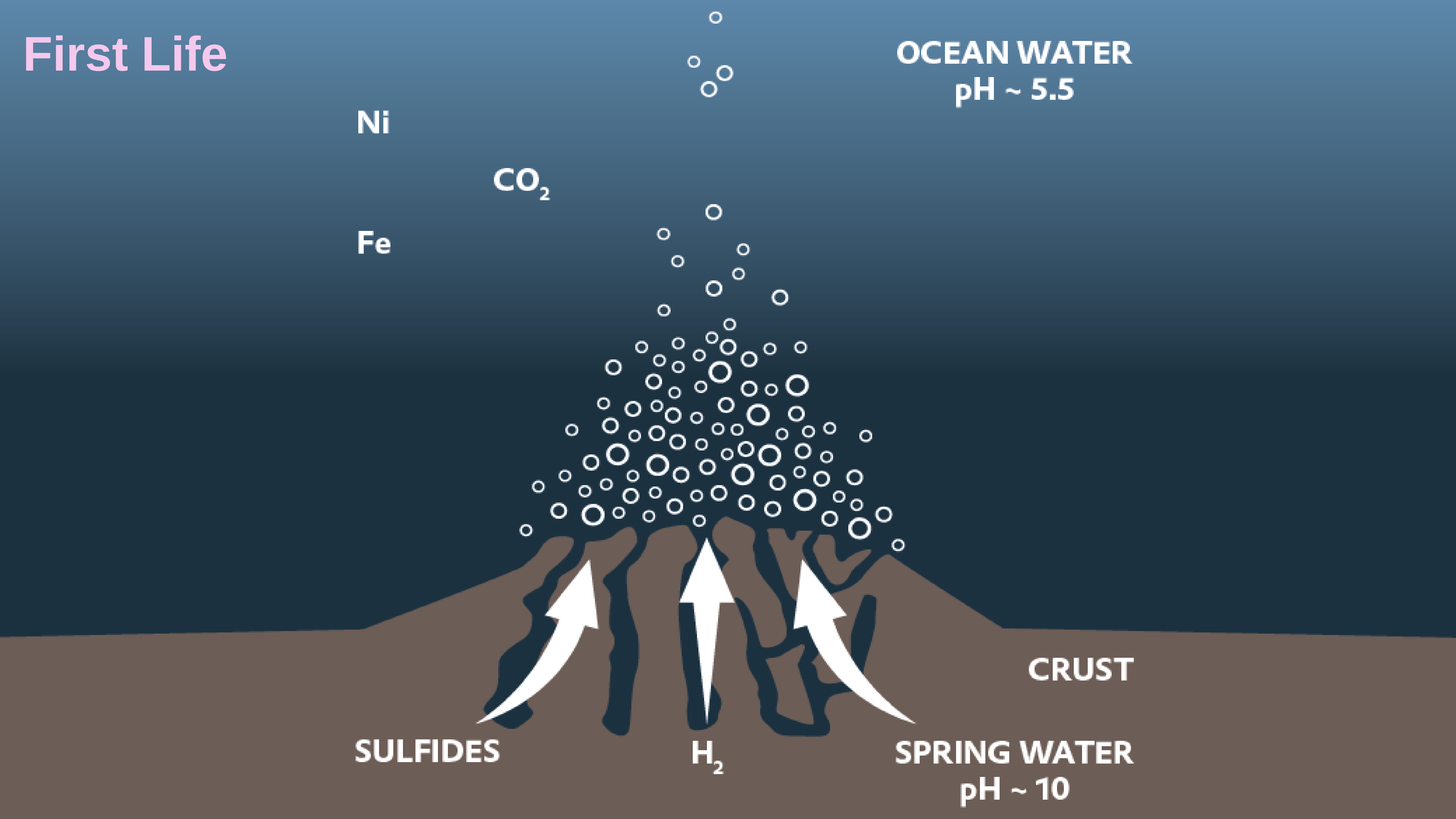
# Photosynthesis – efficiencies and utilizations



# Photosynthesis indicators

| Artificial | Carbon Efficiency % | Energy Efficiency % | Water Utilization $kg_{H_2O}$ / $kg_{CO_2}$ |
|---|---|---|---|
| Natural | 99.999 | 1 | 200 |
| Sugar Cane | > 95 | < 1 | > 200 |
| Artificial | > 95 | >> 1 | << 100 |

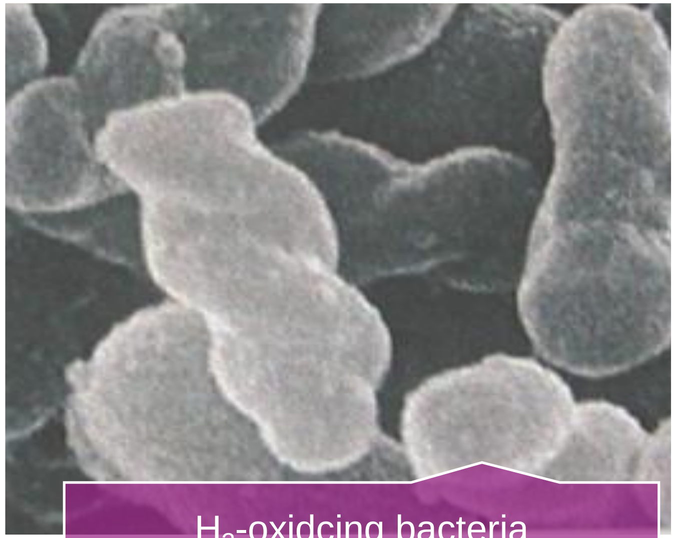
# First Life



OCEAN WATER
pH ~ 5.5
Ni
$CO_2$
Fe
CRUST
SULFIDES
$H_2$
SPRING WATER
pH ~ 10

# Nature provides gas consuming bacteria species

Methanotrophic bacteria
organisms that are able to use methane as sole carbon and energy source



$H_2$-oxidcing bacteria
Assimilate $CO_2/H_2/O_2$ via Calvin-Cycle to carbonhydrates


acetogenic bacteria
convert $CO/CO_2/H_2$ to acetate

Source:
www.mpg.de/7427999/zoom.jpg
https://upload.wikimedia.org/wikipedia/commons/b/b2/Methylococcus_capsulatus.png
http://blogs.scientificamerican.com/media/inline/blog/Image/Clostridium-ljungdahlii.jpg



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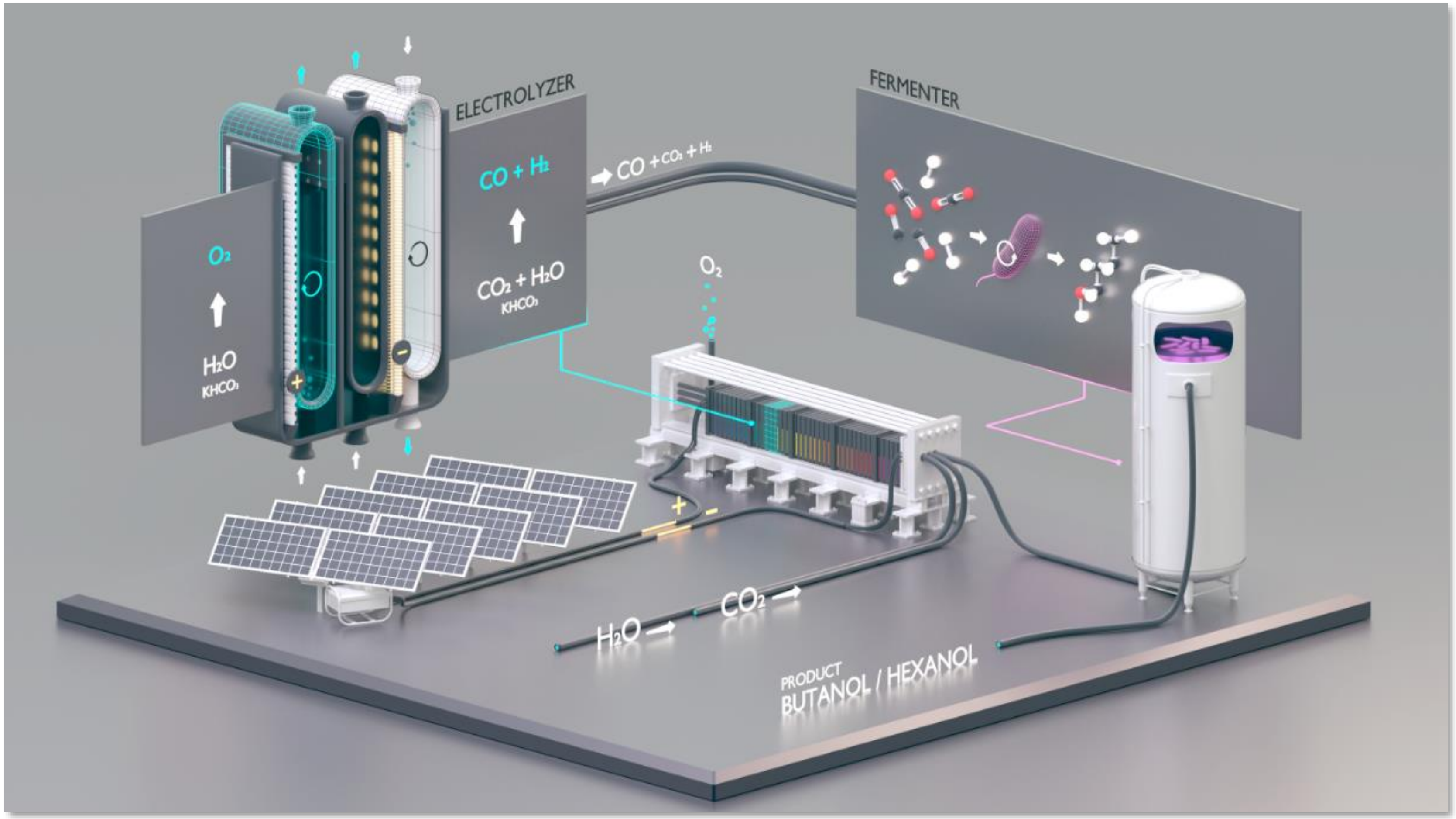
# RHETICUS – an overview




## Objectives

- Joint research project to convert carbon dioxide ($CO_2$) into specialty chemicals (like butanol and hexanol) using electricity from renewable sources and bacteria
- Pilot plant scheduled to start up 2020 at the Evonik facility in Marl, Germany
- Production plant with a capacity of up to 20,000 tons a year as possible target capacity

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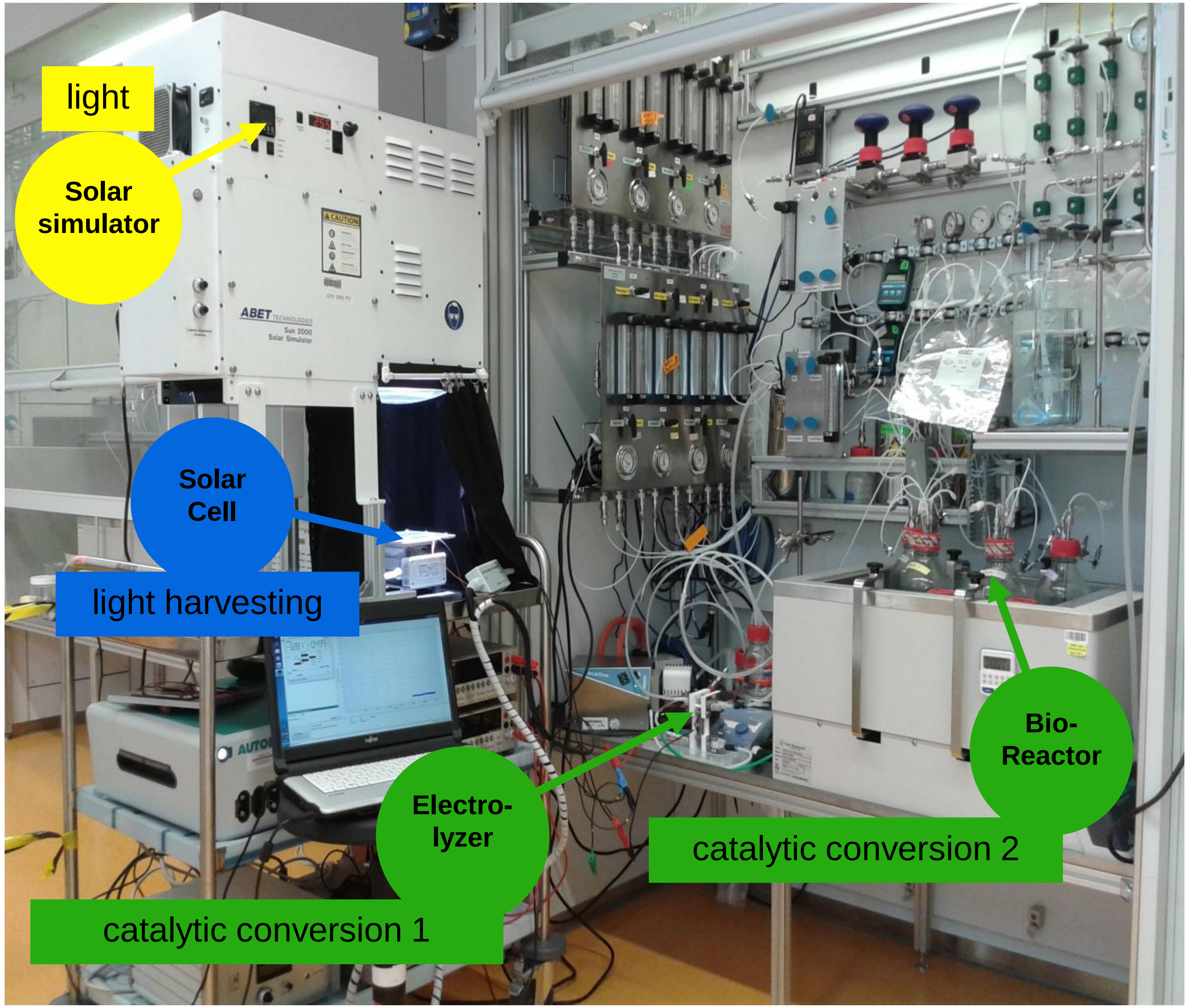
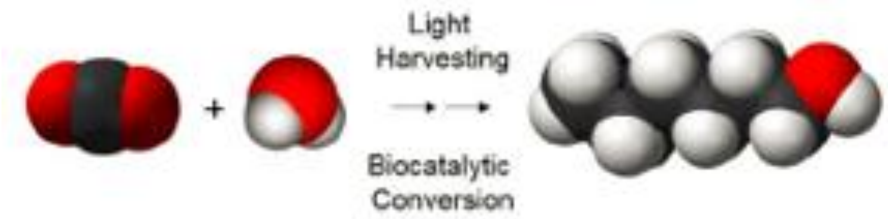
# Experimental set up



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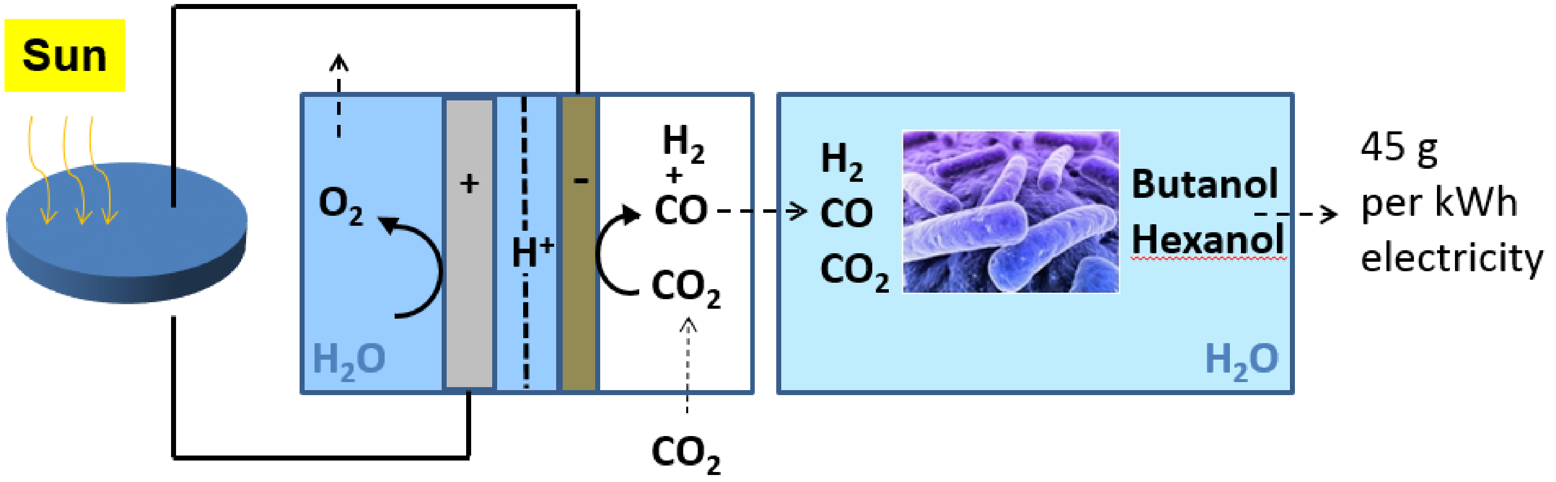
# Experimental results

| Artificial | Carbon Efficiency % | Energy Efficiency % | Water Utilization $kg_{H_2O}$ / $kg_{CO_2}$ |
|---|---|---|---|
| **Natural** | 99.999 | 1 | 200 |
| **Sugar Cane** | > 95 | < 1 | > 200 |
| **Artificial** | > 95 | > 5 | < 50 |

# Example: Butanol and Hexanol




| | | |
|---|---|---|
| **PV cells** | **$CO_2$- and $H_2O$ electrolyzer** | **Fermenters**<br>*Clostridium autoethanogenum* +<br>*Clostridium kluyveri* |
| EE up to 20% | EE-CO up to 47%<br>EE-$H_2$ up to 70%<br>FE-CO + FE-$H_2$ near 100% | EE near 80%<br>FE near 100% |

Prize of 1 kWh PV electricity
= 2.5 cent

Prize per 45 g alcohols
= 5.4 cent



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# Main Cost Drivers

$$\text{Price} = f\left(\begin{matrix}\text{electricity}\\ \text{price}\end{matrix},\ \begin{matrix}CO_2\\ \text{price}\end{matrix}\right)$$



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# Product price $\left[\frac{€}{to}\right]$ of natural photosynthesis

| Country | Europe | US | Brazil |
|---|---|---|---|
| Price | 800 | 450 | 450 |



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# Summary

Artificial photosynthesis (Rheticus) approaches present needs for $CO_2$ based synthesis of chemicals and is one concept to combat climate change by a negative emission.

Adaption of political framework is necessary to ensure competitiveness of German and European industry.

We need in line of the European Green Deal….

- an Adaption of European State Aid Direction and Guidelines to enable cross sectoral industrial cooperation
- cross country cooperation not only for electrolysis technologies to produce hydrogen. In future we also need them for technologies to produce specialty chemicals
- incentives to invest in low carbon technologies for example via carbon contracts of Difference
- ideas how we can integrate a payment for negative emissions in the Emissions Trade Systen

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First of all we need lower cost for electricity supply !!!

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