



University  
of Bremen



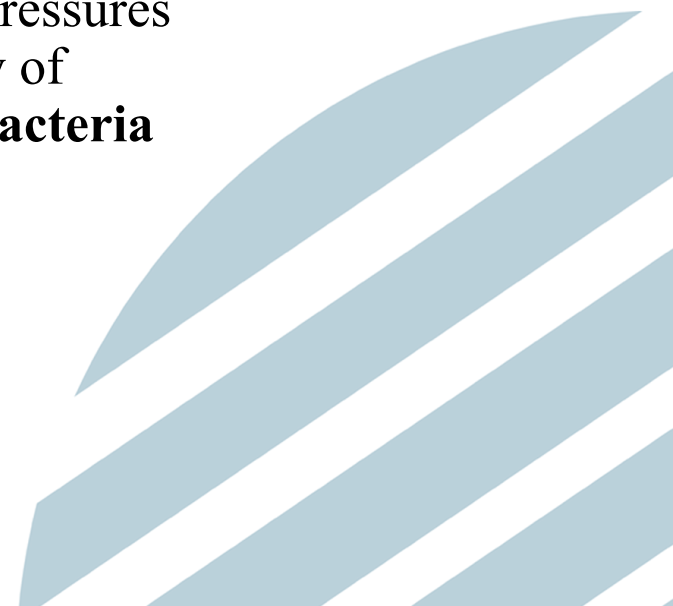
CENTER OF  
APPLIED SPACE TECHNOLOGY  
AND MICROGRAVITY

# Influence of **atmospheric pressure**, and of the partial pressures of **CO<sub>2</sub>** and **N<sub>2</sub>**, on the productivity and mass-efficiency of biological ISRU systems based on diazotrophic **cyanobacteria**

Cyprien Verseux, Tiago P. Ramalho, Emma Bohuon, Nils Kunst, Viktoria Lang  
& Christiane Heinicke

ZARM, University of Bremen

MELiSSA Conference  
October 7<sup>th</sup>, 2025



# Exploring Mars, sustainably

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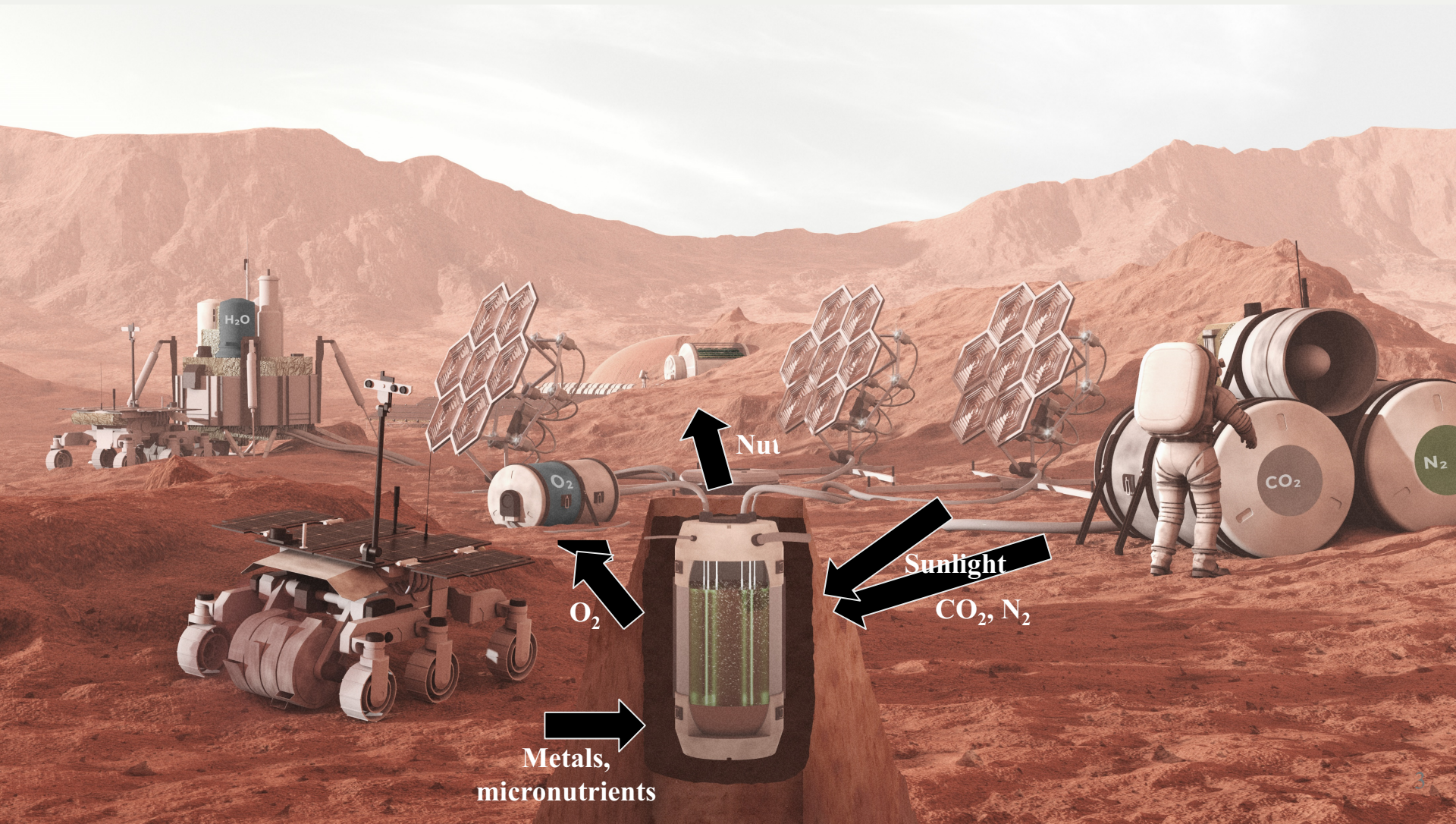
**Moon: 2027**

**Mars: 2039 (tentative)**

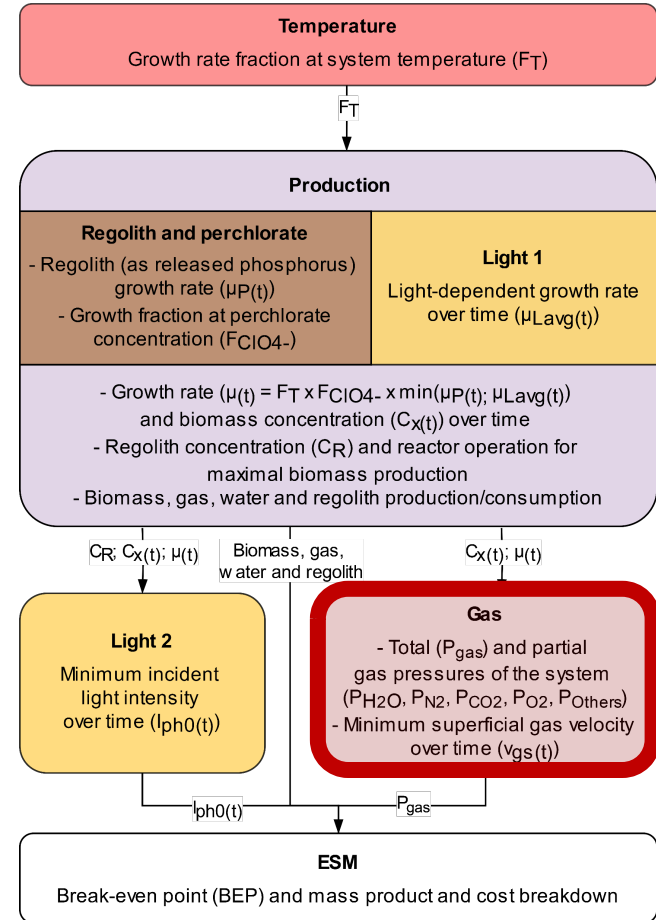
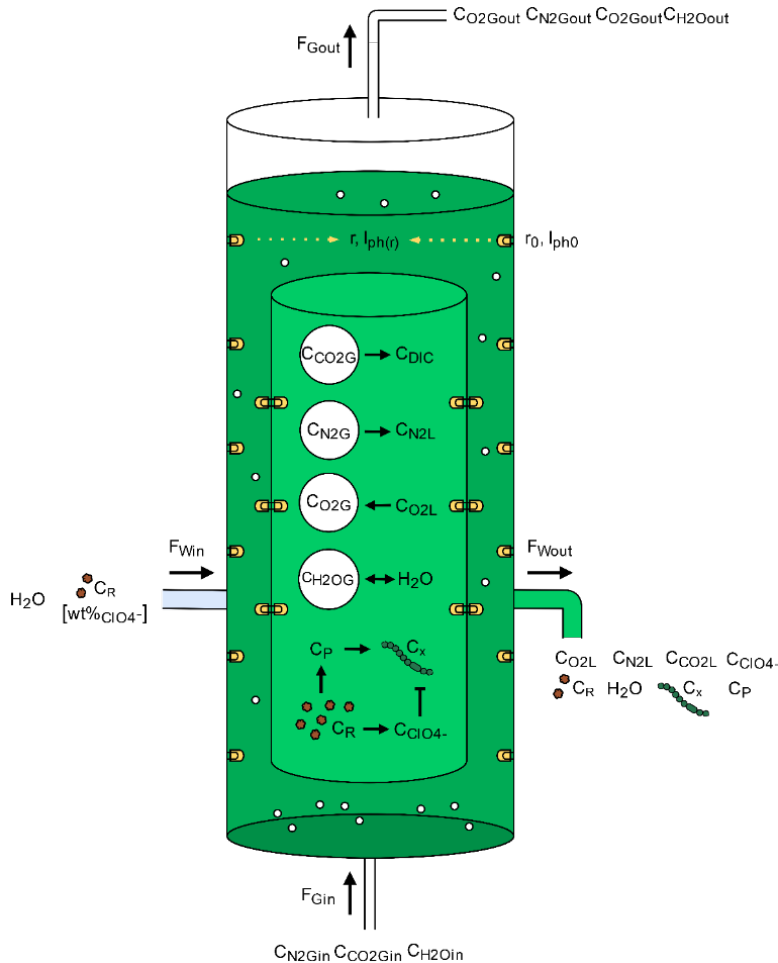
**For sustainability: resources should be produced on site.**

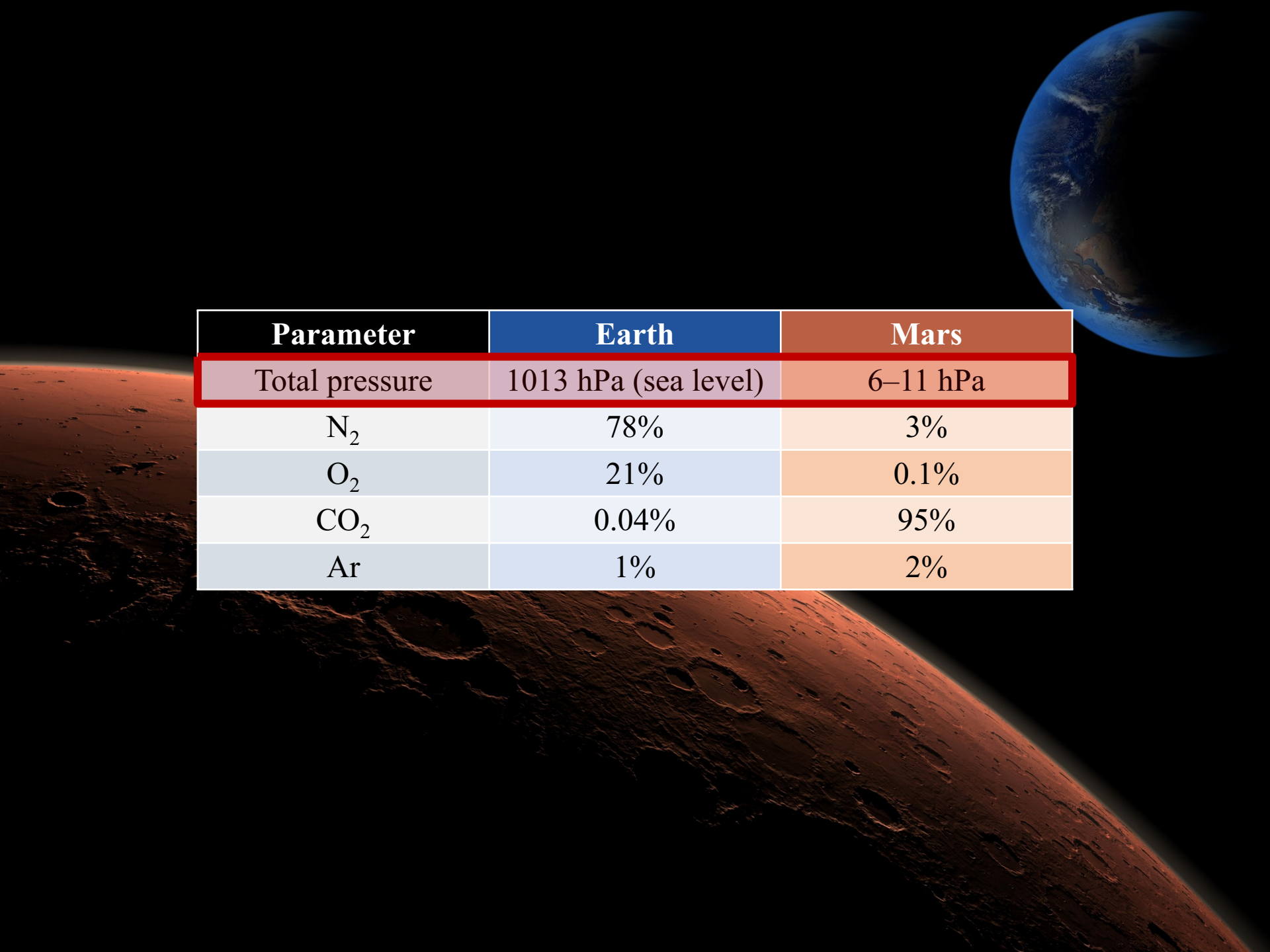


# Cyanobacteria provide a solution, but...



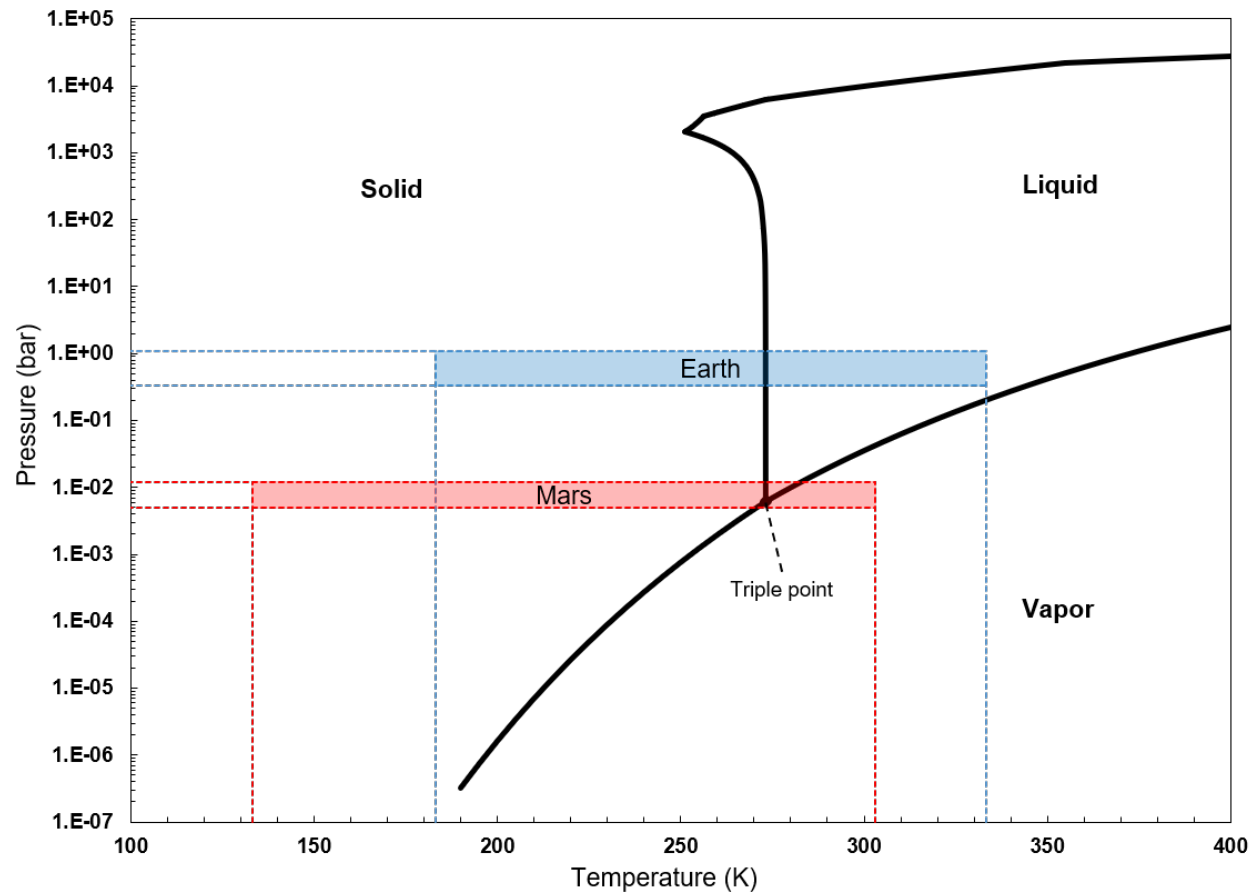
# Resource-efficiency must be determined

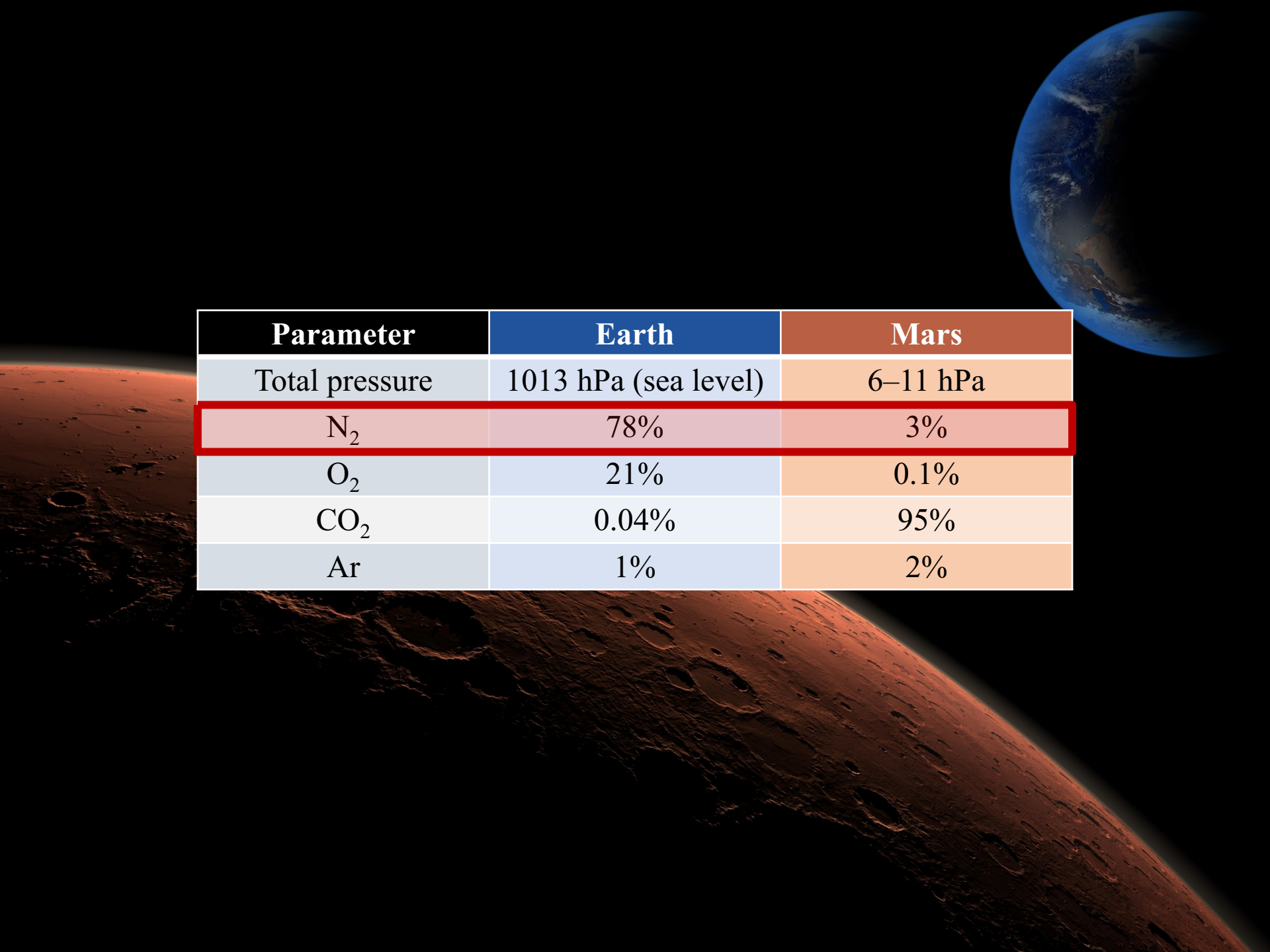




Parameter	Earth	Mars
Total pressure	1013 hPa (sea level)	6–11 hPa
N <sub>2</sub>	78%	3%
O <sub>2</sub>	21%	0.1%
CO <sub>2</sub>	0.04%	95%
Ar	1%	2%

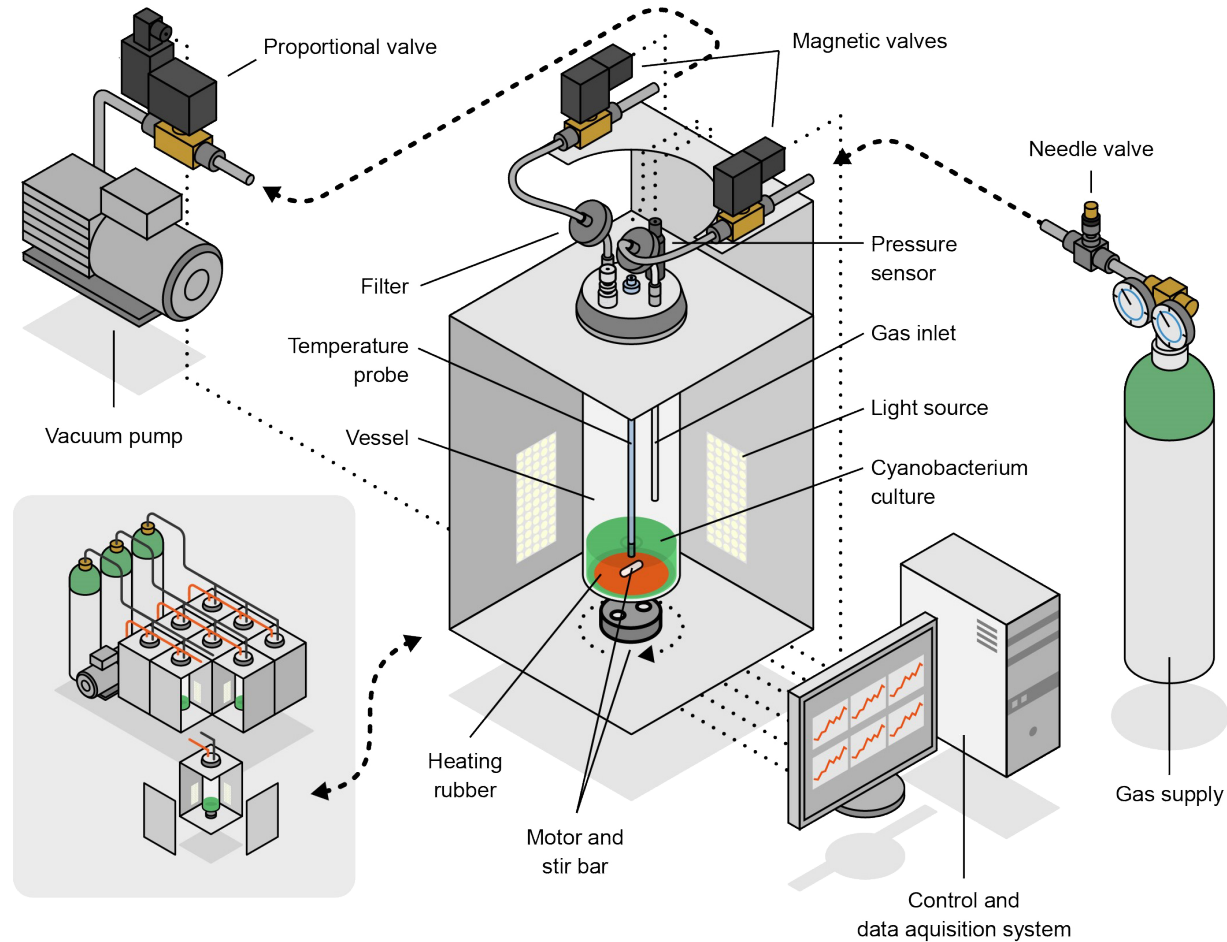
# How low can the pressure be?





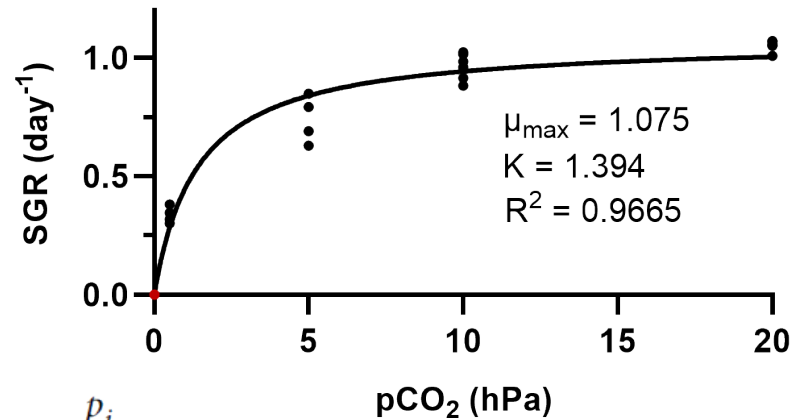
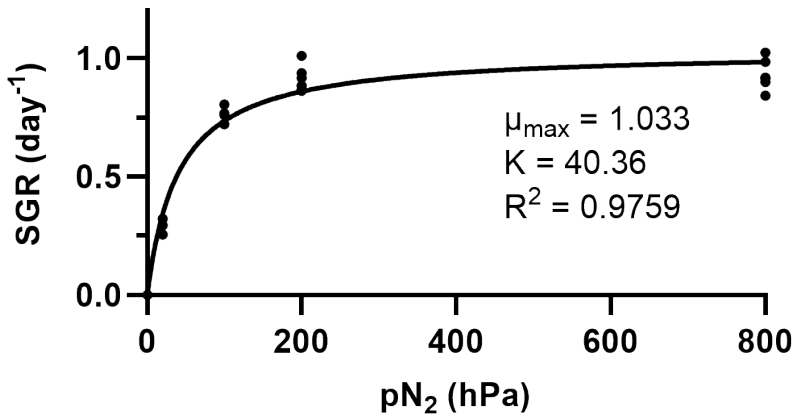
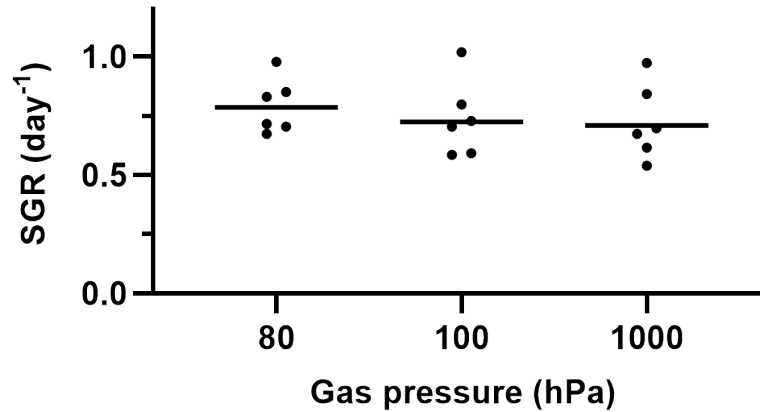
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# Atmos: A low-pressure photobioreactor



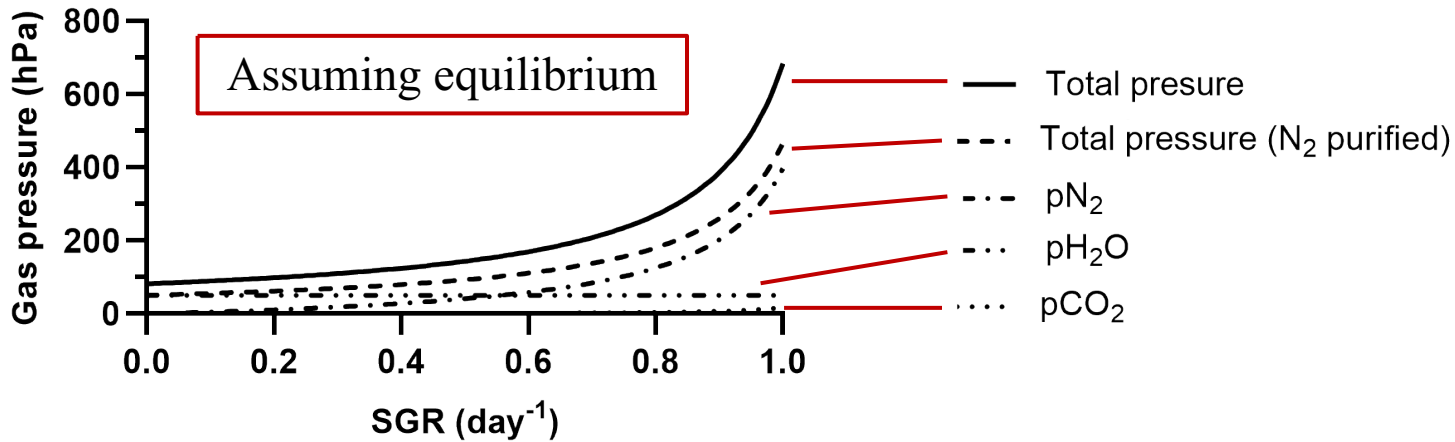


# Growth as a function of atmospheric parameters



$$\mu_i = \mu_{\max(i)} \cdot \frac{p_i}{p_i + K_i}$$

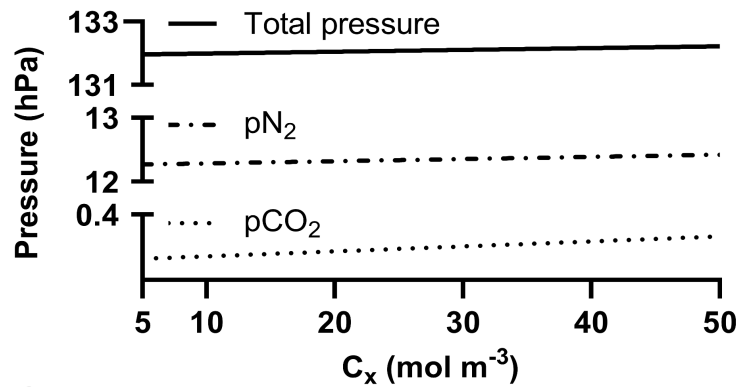
# Growth as a function of atmospheric parameters



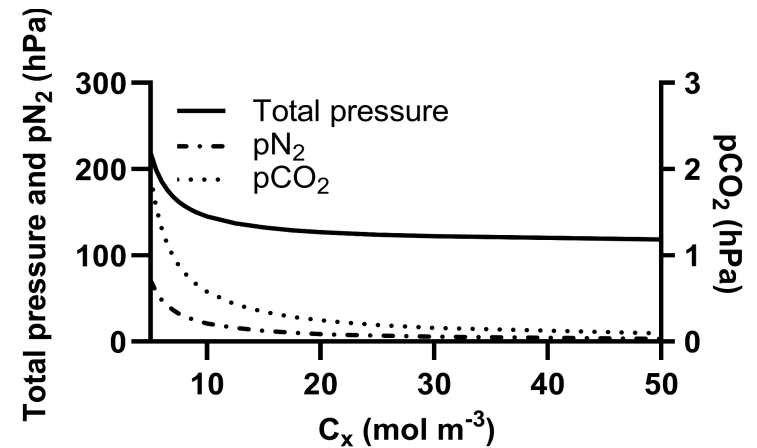
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# Pressure in the cultivation system

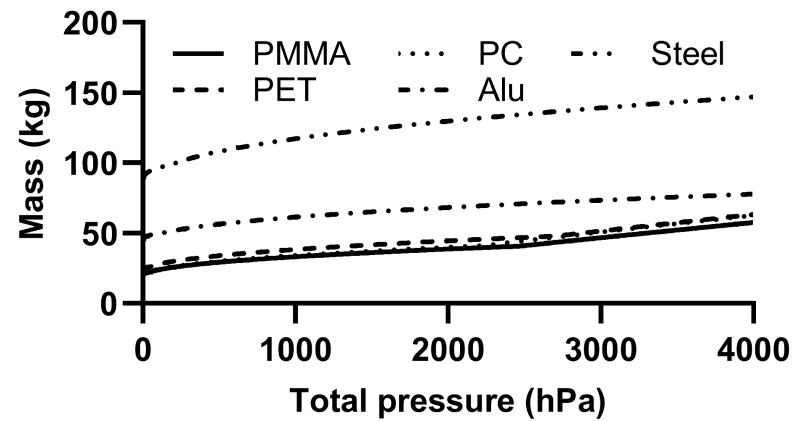
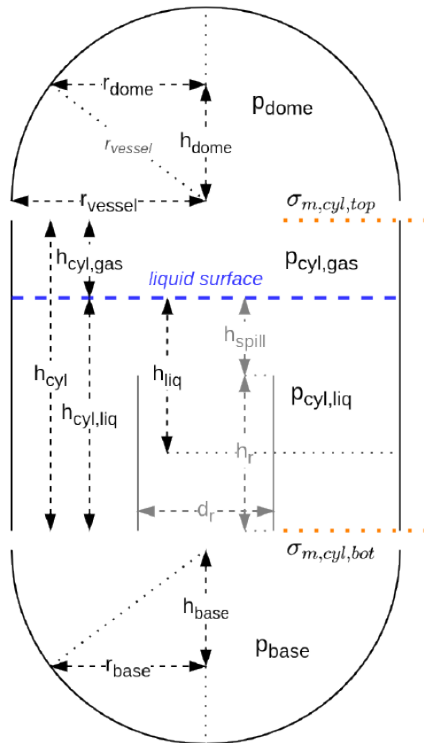
Fixed SGR ( $0.2 \text{ day}^{-1}$ )



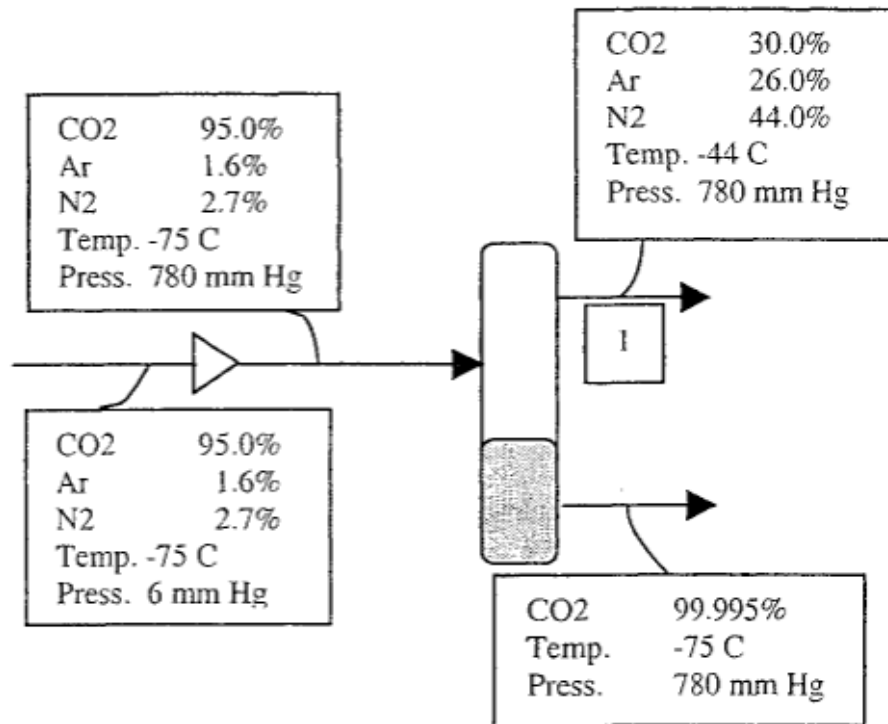
Fixed productivity ( $100 \text{ g m}^{-3} \text{ day}^{-1}$ )



# Pressure in the cultivation system

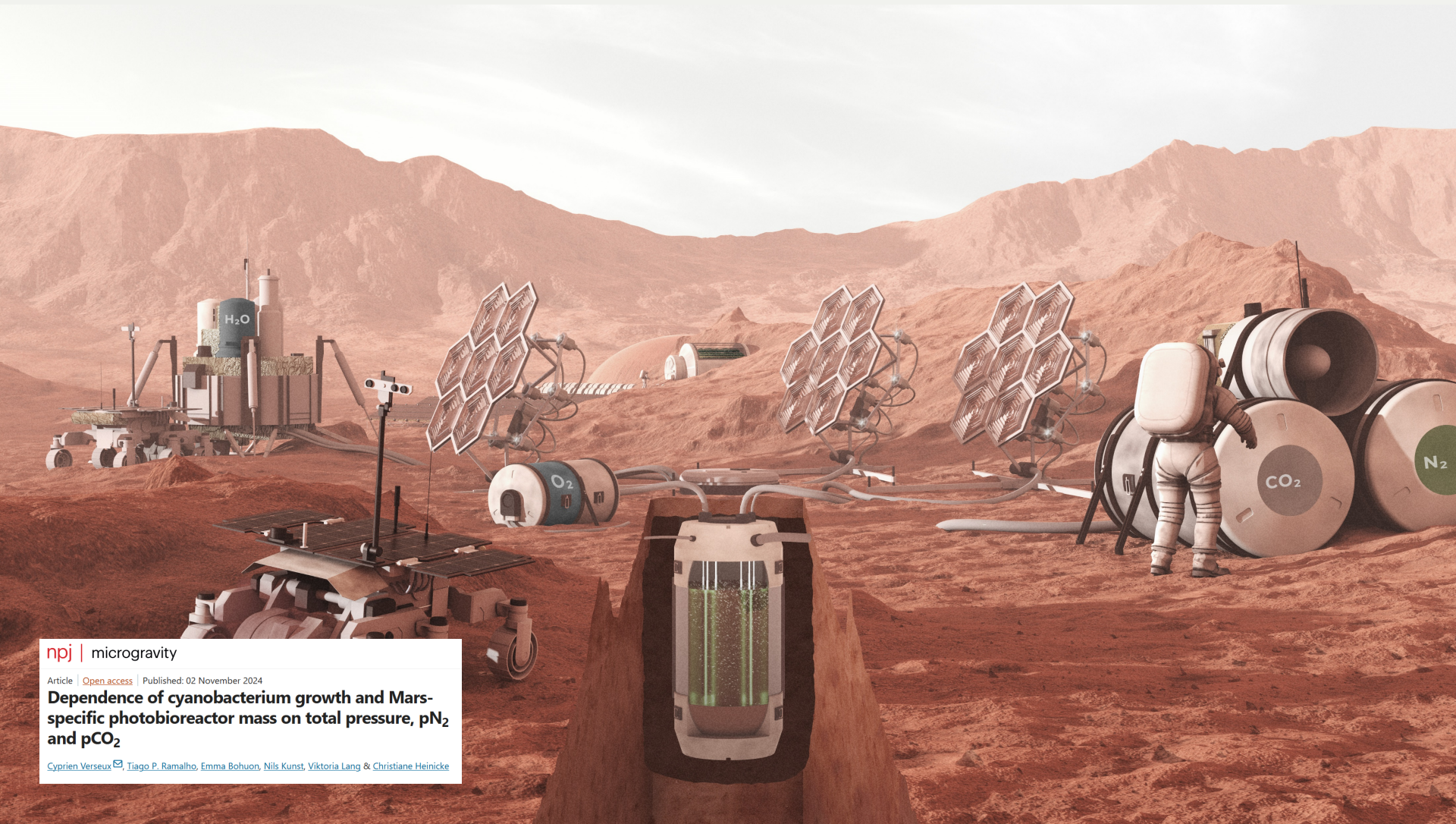


# N<sub>2</sub>-rich air as waste product?



AIAA 2002-0467  
Membrane Separation Processes at Low  
Temperatures  
Clyde Parrish  
NASA Kennedy  
Kennedy Space Center, FL

# Conclusion



npj | microgravity

Article | [Open access](#) | Published: 02 November 2024

**Dependence of cyanobacterium growth and Mars-specific photobioreactor mass on total pressure,  $pN_2$  and  $pCO_2$**

Cyprien Verseux , Tiago P. Ramalho, Emma Bohuon, Nils Kunst, Viktoria Lang & Christiane Heinicke

# Conclusion

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Universität  
Bremen



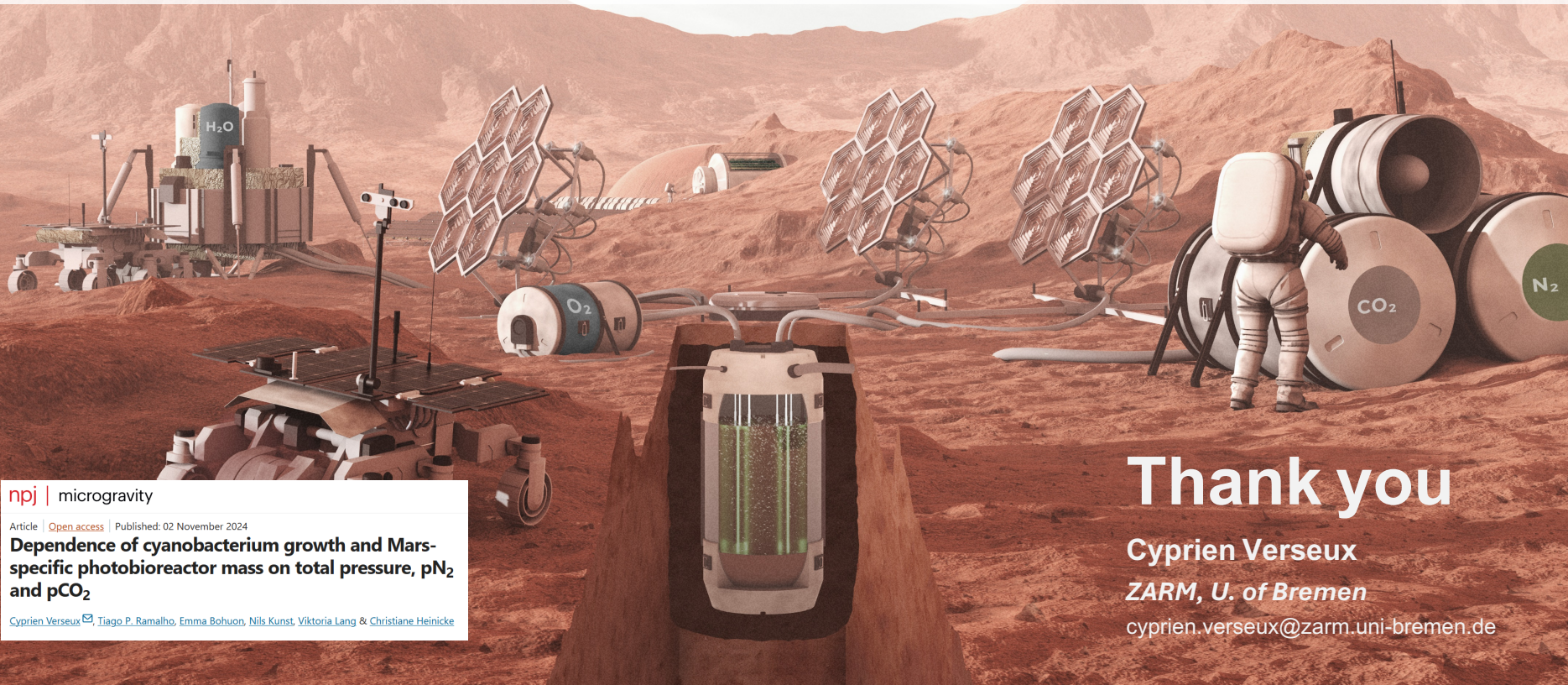
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the European Union



erc  
European Research Council  
Established by the European Commission



npj | microgravity

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**Dependence of cyanobacterium growth and Mars-specific photobioreactor mass on total pressure,  $pN_2$  and  $pCO_2$**

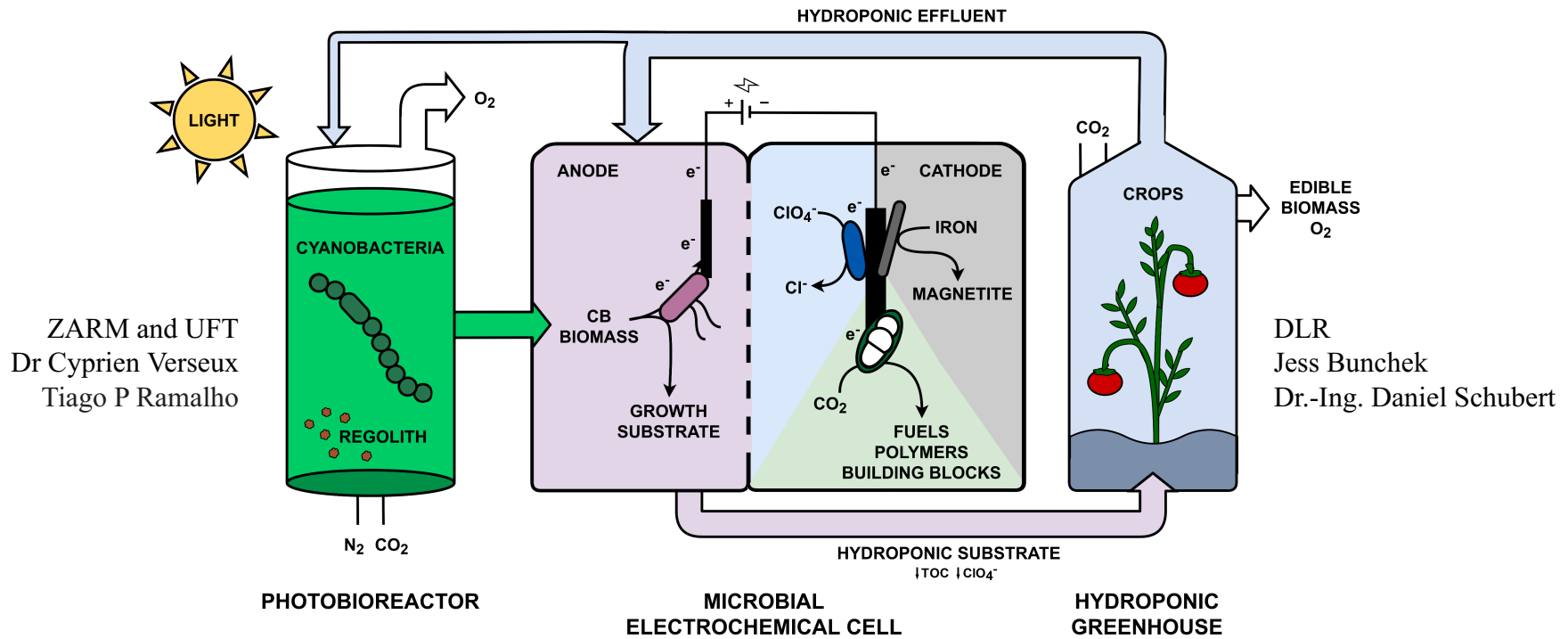
Cyprien Verseux [Tiago P. Ramalho](#), [Emma Bohuon](#), [Nils Kunst](#), [Viktorija Lang](#) & [Christiane Heinicke](#)

# Thank you

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ZARM, U. of Bremen

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# Downstream processes: Bioproduction on Mars



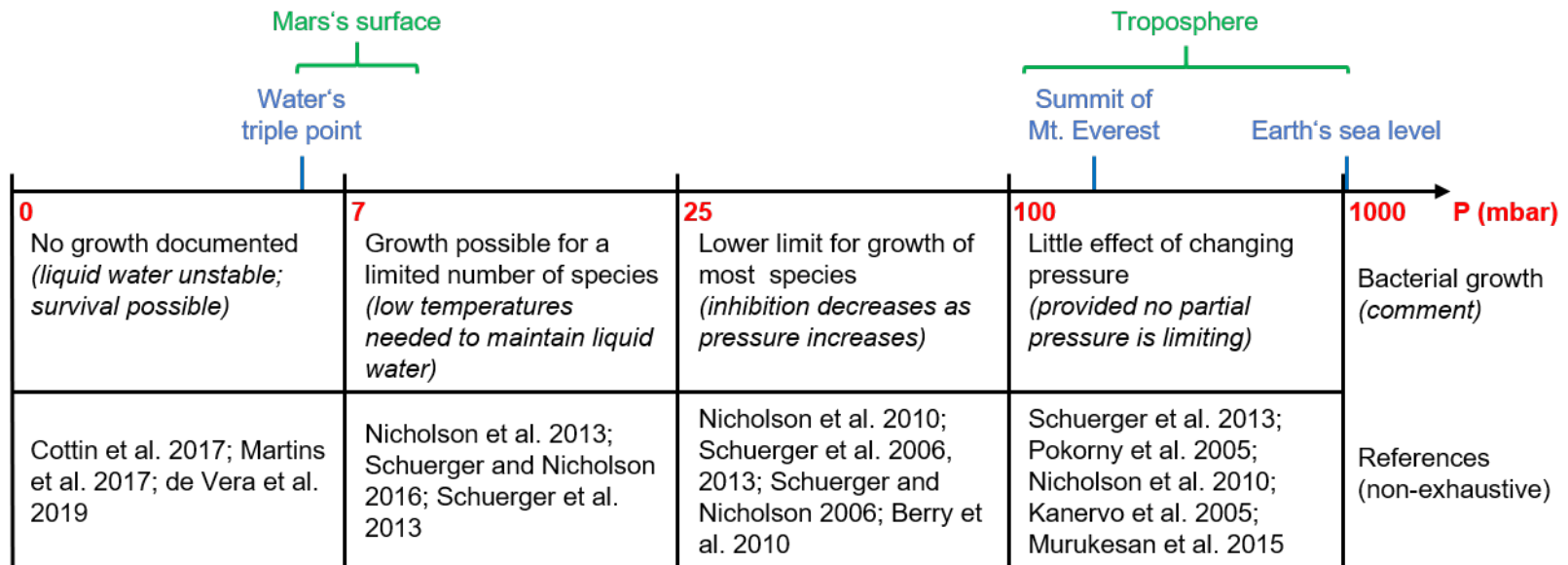
ZARM and UFT  
Dr Cyprien Verseux  
Tiago P Ramalho

DLR  
Jess Bunchek  
Dr.-Ing. Daniel Schubert

UFT  
Dr. Guillaume Pillot  
Prof. Dr.-Ing. habil. Sven Kerzenmacher

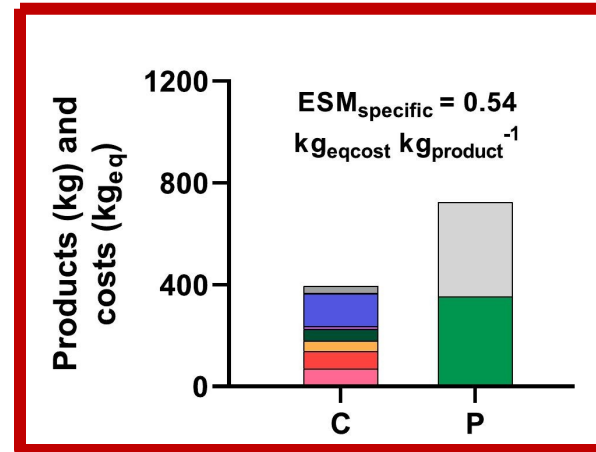
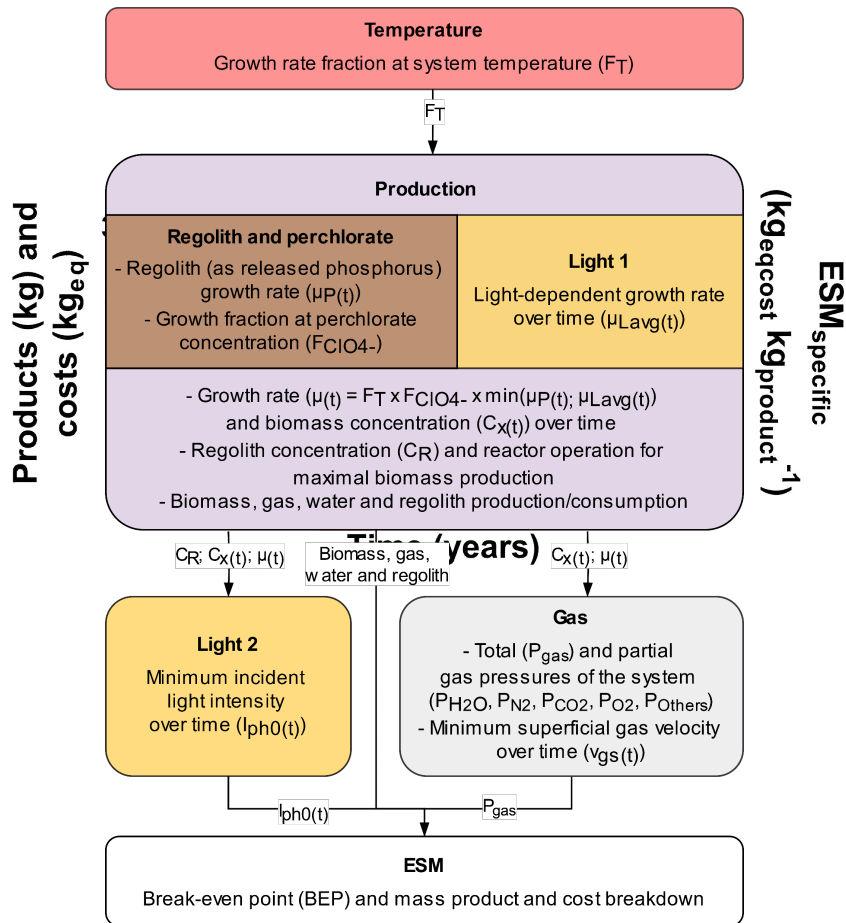


# How low can the pressure be?



Verseux. *Frontiers in Astronomy and Space Sciences* 7 (2020): 30.

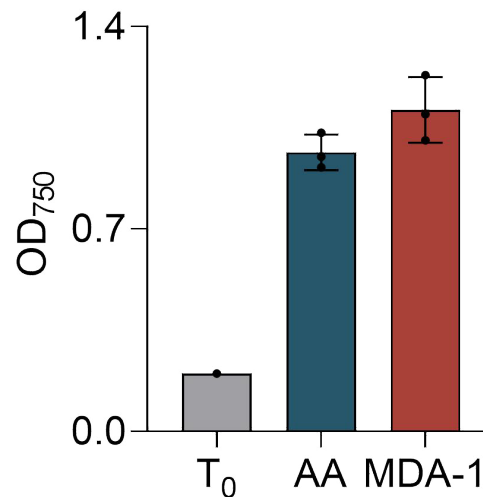
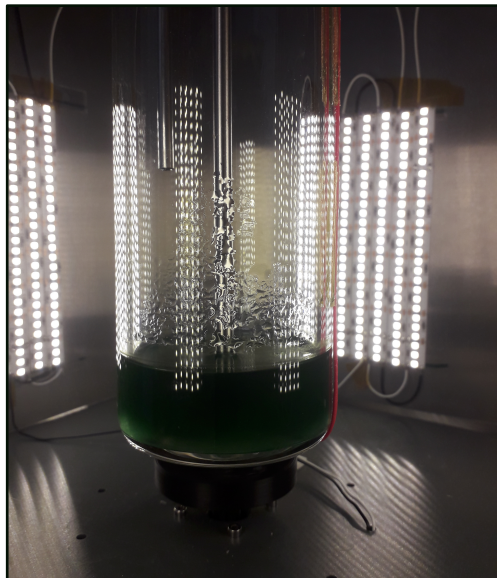
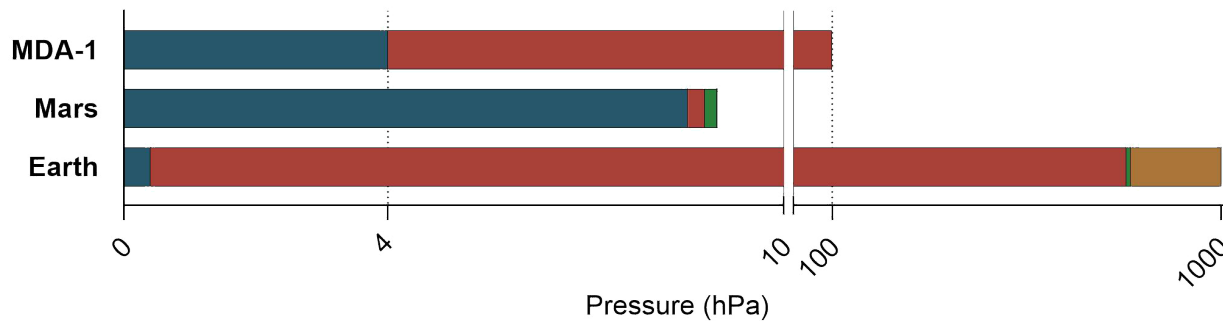
# Efficiency of cyanobacterium cultivation



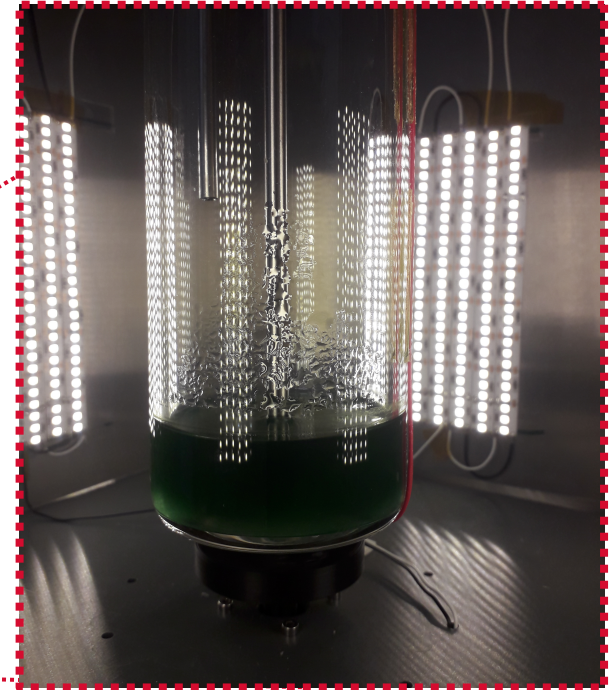
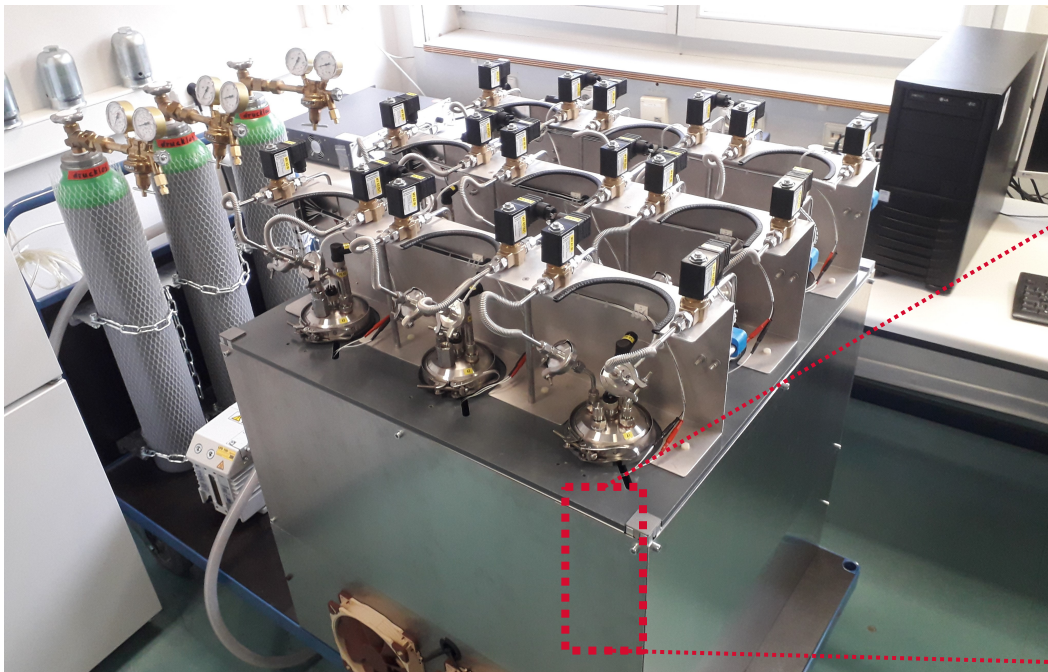
- Products (P)**
- Biomass
  - Oxygen
- Costs (C)**
- Mass
  - Power
  - Crew time
  - Volume
  - Water
  - CO<sub>2</sub>
  - Thermal control

# Vigorous growth under a low pressure of N<sub>2</sub> and CO<sub>2</sub>

Atmosphere	Pressure (hPa)	CO <sub>2</sub>	N <sub>2</sub>	Ar	O <sub>2</sub>
<b>MDA-1</b>	100	4%	96%	0%	0%
<b>Mars</b>	6–11	95%	2.8%	2.1%	0.1%
<b>Earth</b>	1013 (sea level)	0.04%	78%	1%	21%



# Atmos: A low-pressure photobioreactor



# Today and tomorrow

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Funded by  
the European Union



European Research Council  
Established by the European Commission

## MarCyano

Understanding responses of cyanobacteria to Mars cultivation conditions



EXCELLENCE  
STRATEGY

of the German federal & state governments

Martian Mindset

## Biomass on the rock

Harnessing rock-microbe interactions in support of process chains on Mars

# Growth as a function of atmospheric parameters

$$\mu_i = \mu_{max(i)} \cdot \frac{p_i}{p_i + K_i}$$

