



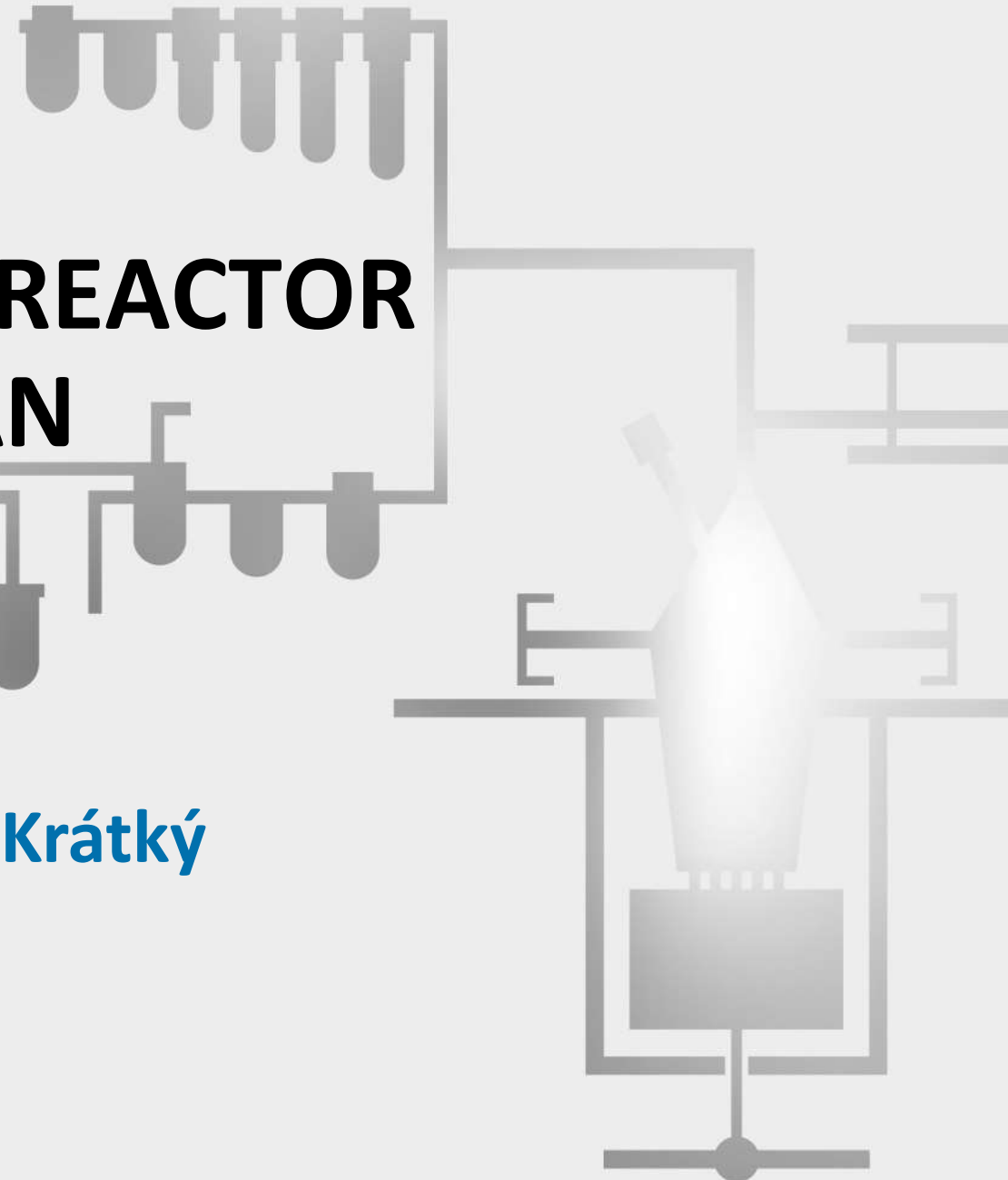
FACULTY
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DEPARTMENT OF PROCESS ENGINEERING

ADVANCES IN PHOTOBIOREACTOR DESIGN UNDER EUROPEAN CLIMATIC CONDITIONS

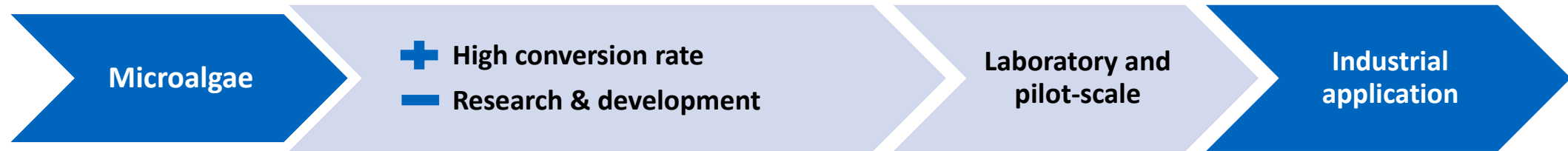
Vojtěch Bělohav, Radek Šulc, Lukáš Krátký

Czech Technical University in Prague
Faculty of Mechanical Engineering
Department of Process Engineering





Introduction | Microalgae cultivation and utilization



Biofuels



Food
industry



Pharmaceutical
industry



Chemical
industry



Biorefinery
concepts

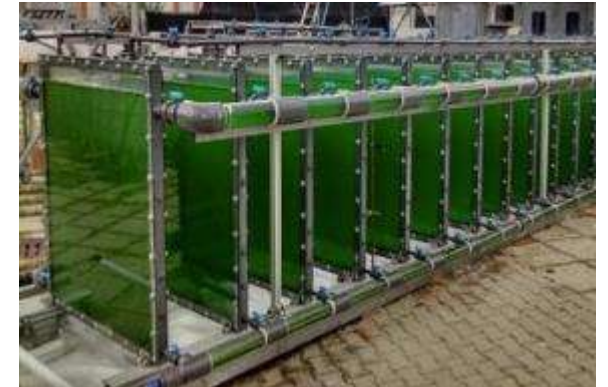


Introduction | Key cultivation factors

Temperature

Light

Mass
transfer



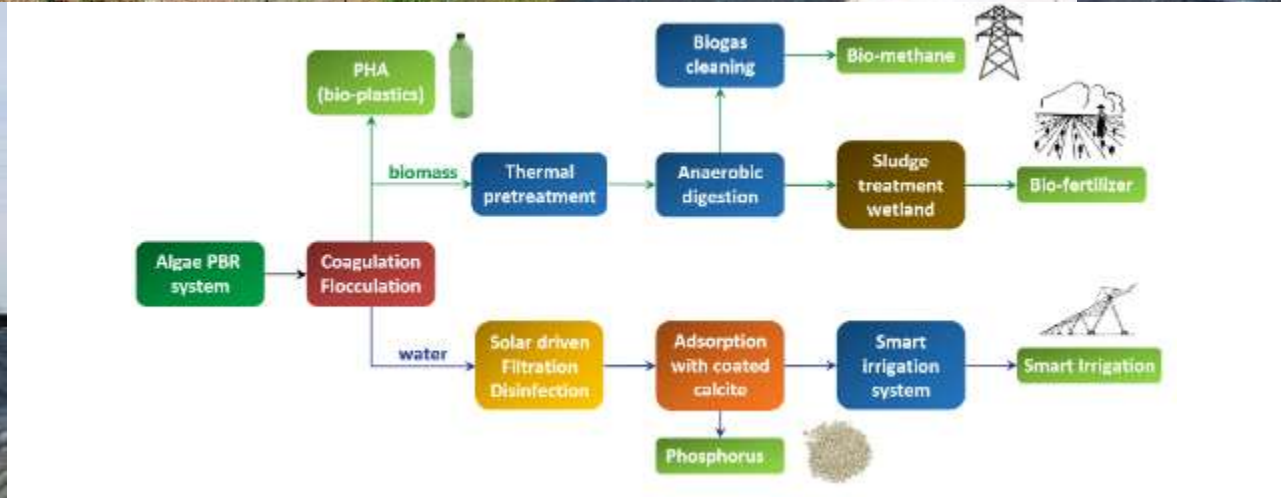


Hybrid tubular PBR | Barcelona, Spain





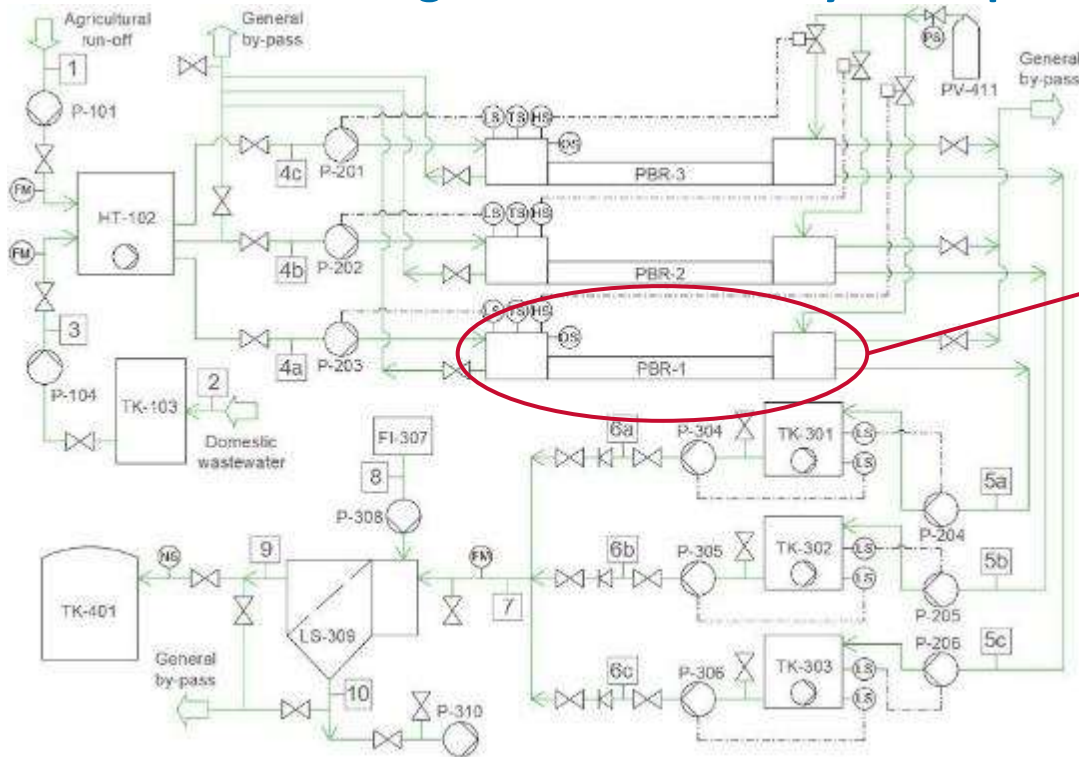
Hybrid tubular PBR | Barcelona, Spain



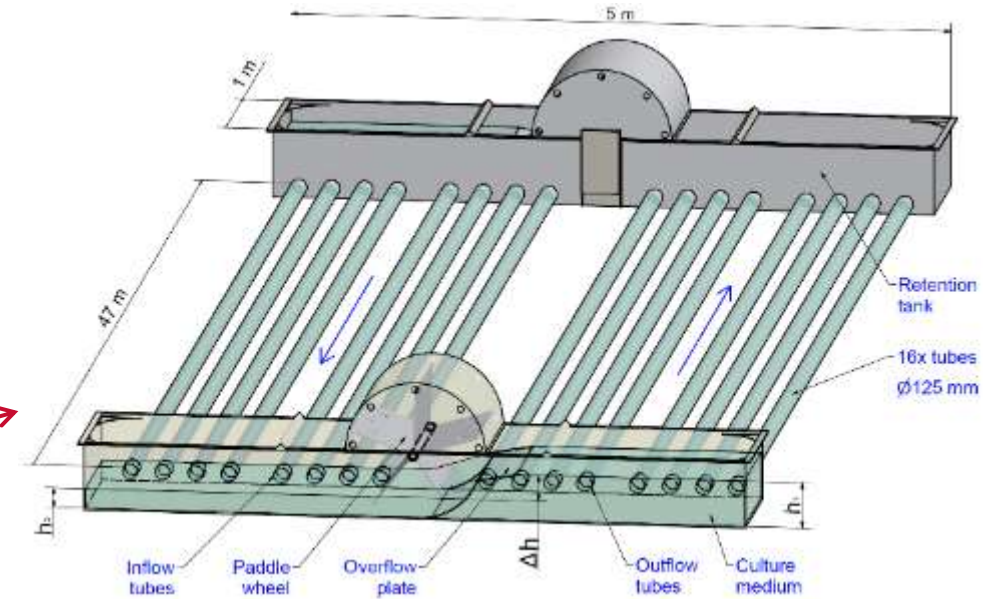


Hybrid tubular PBR | Barcelona, Spain

Process flow diagram of biorefinery concept



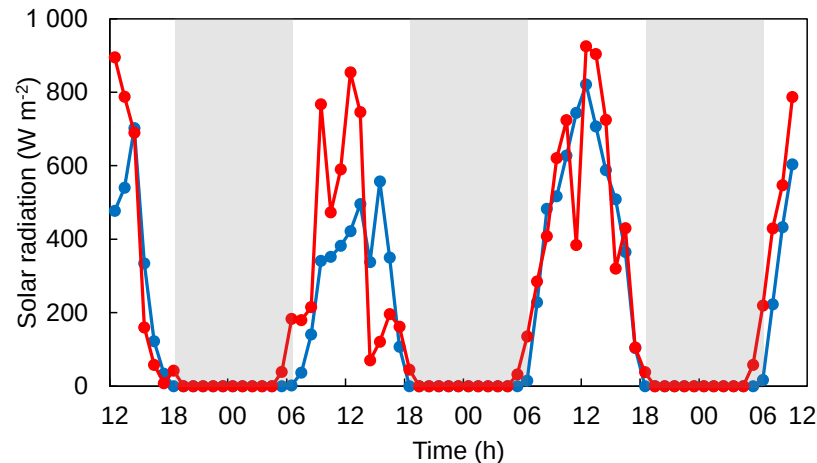
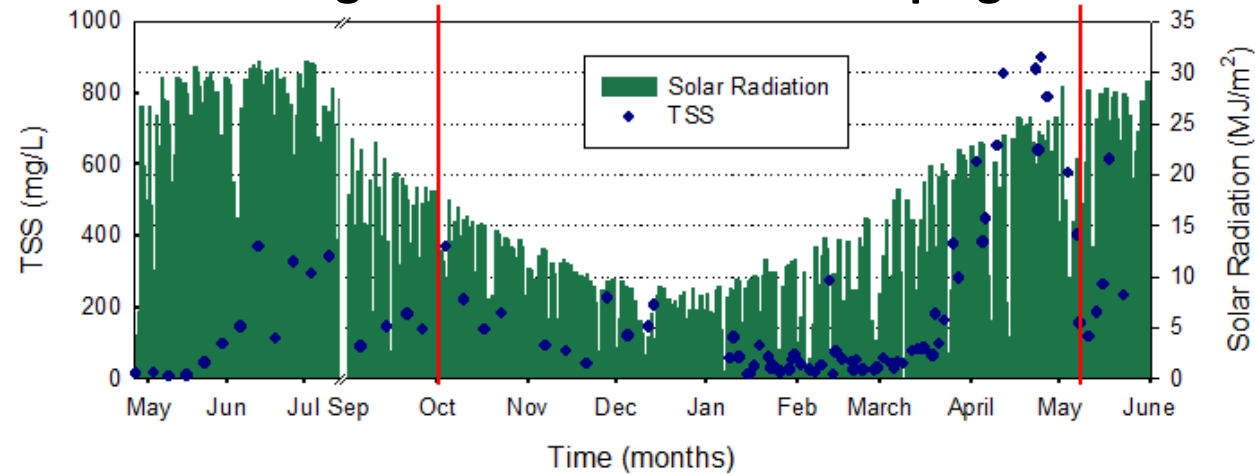
HHT PBR design



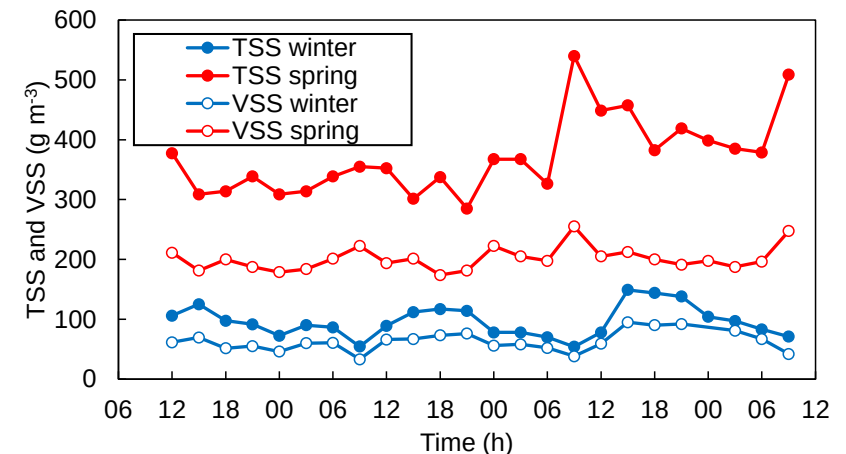
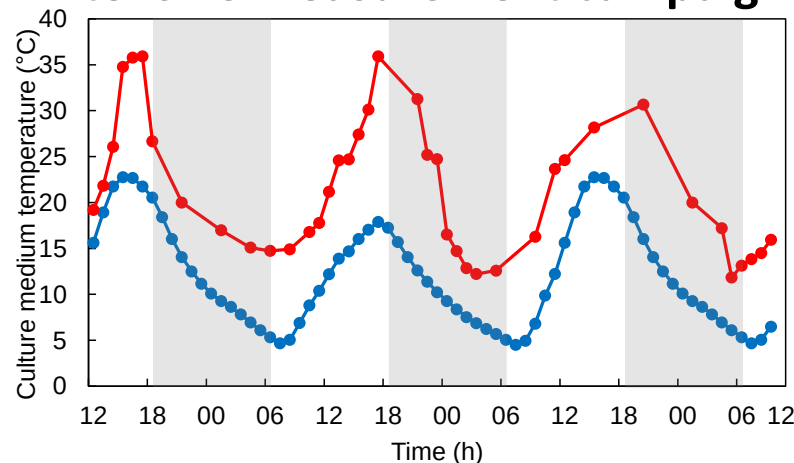


Hybrid tubular PBR | Barcelona, Spain

Long-term measurement campaign



Intensive measurement campaign





Biofilm formation | Barcelona, Spain





Tubular PBR | Prague, Czech Republic





Biofilm formation | Prague, Czech Republic



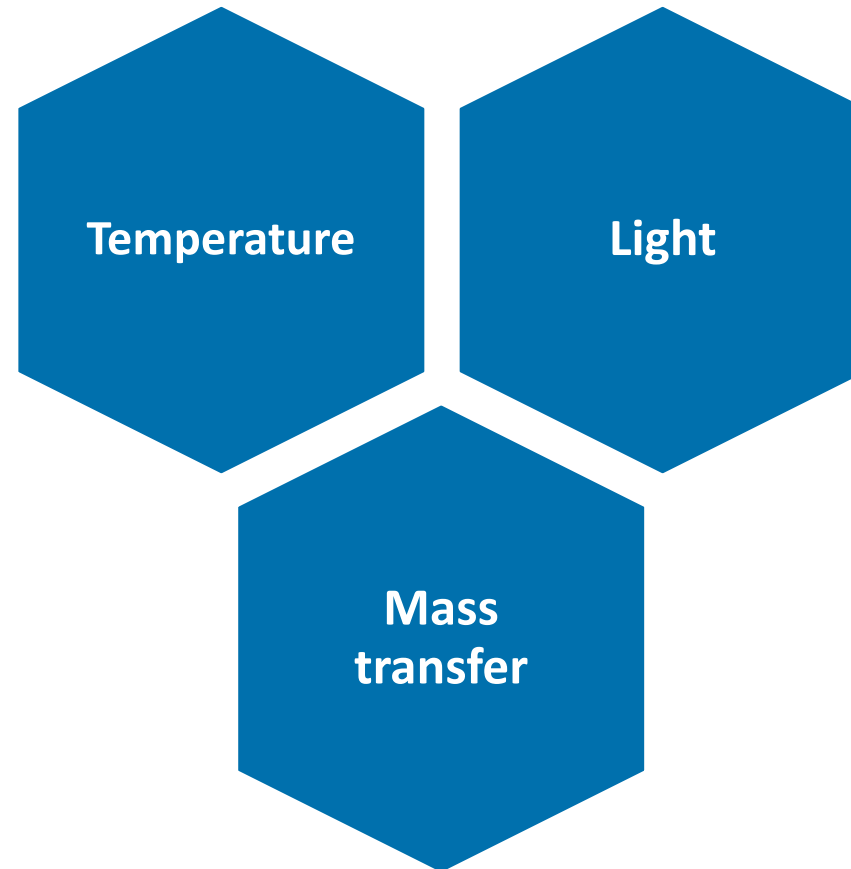


Biofilm formation | Prague, Czech Republic



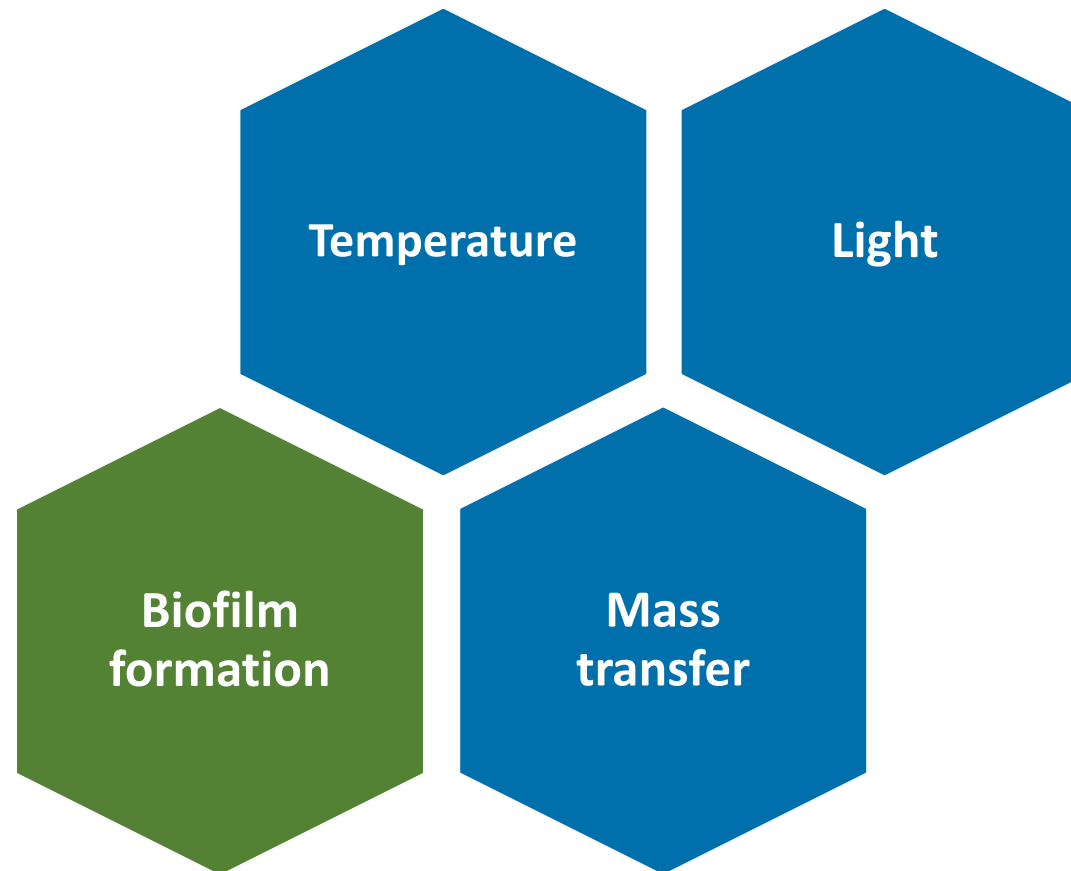


PBR | **Key cultivation factors**



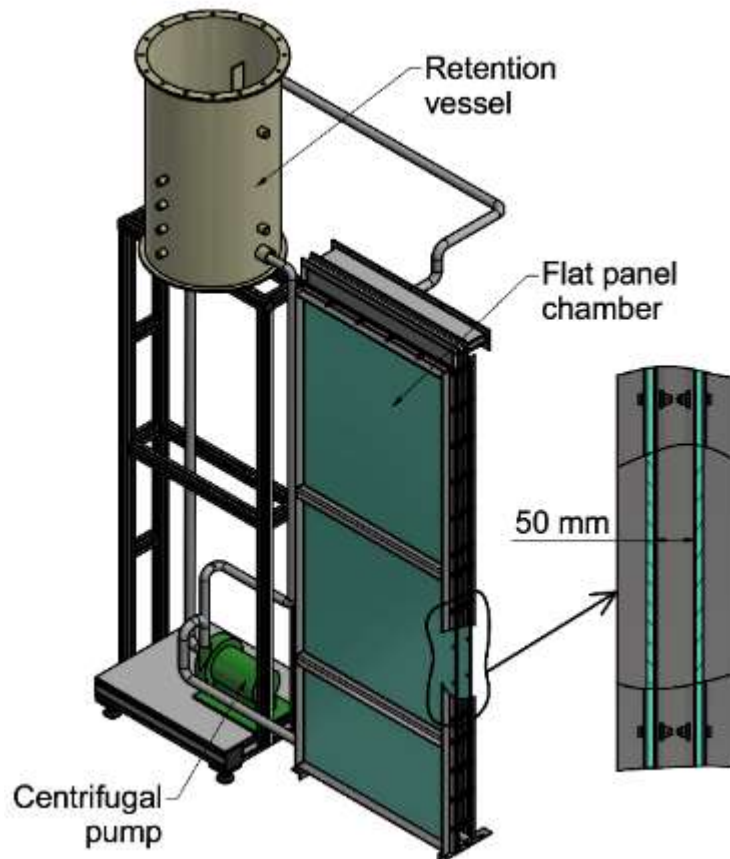


PBR | Key cultivation factors





Flat panel PBR | Prague, Czech Republic





Flat panel PBR | Prague, Czech Republic



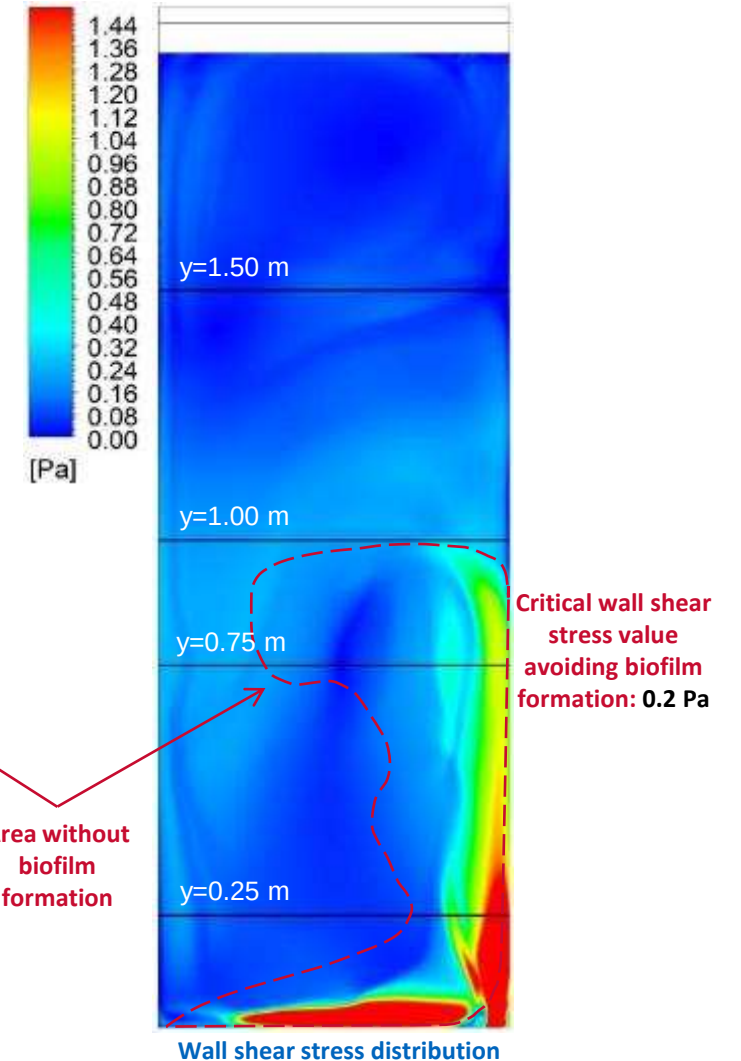
Biofilm fixed in FP PBR



Shear stress bellow the critical value
formed **70 %** of the total transparent
area of FP PBR

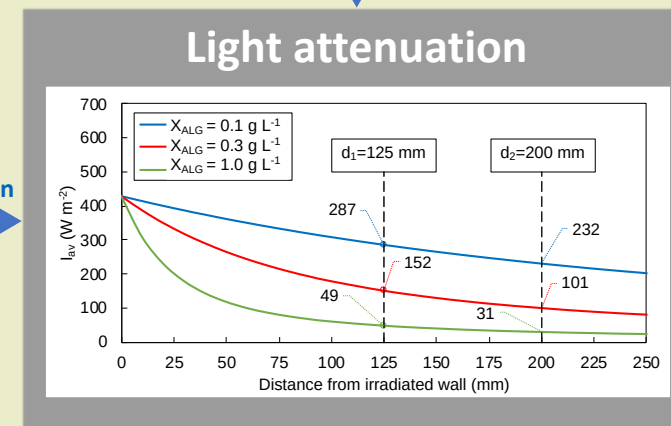
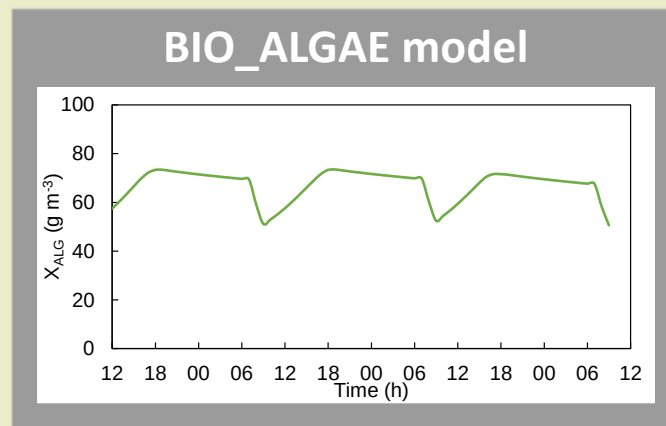
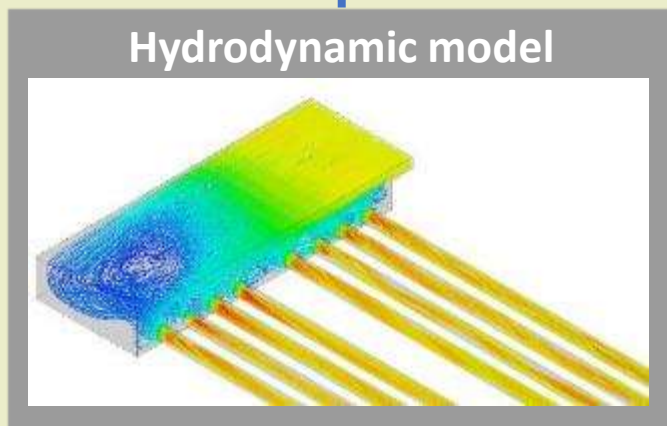
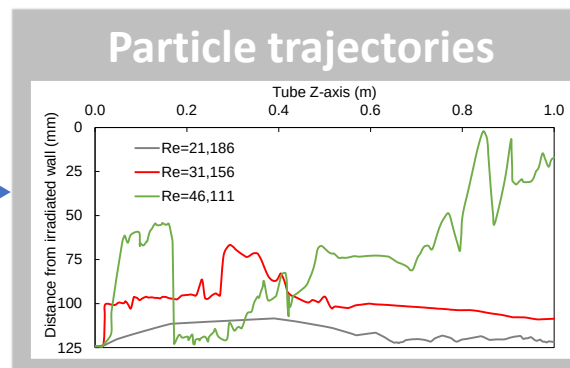


Fixed biofilm on transparent walls





Multi-physical
model



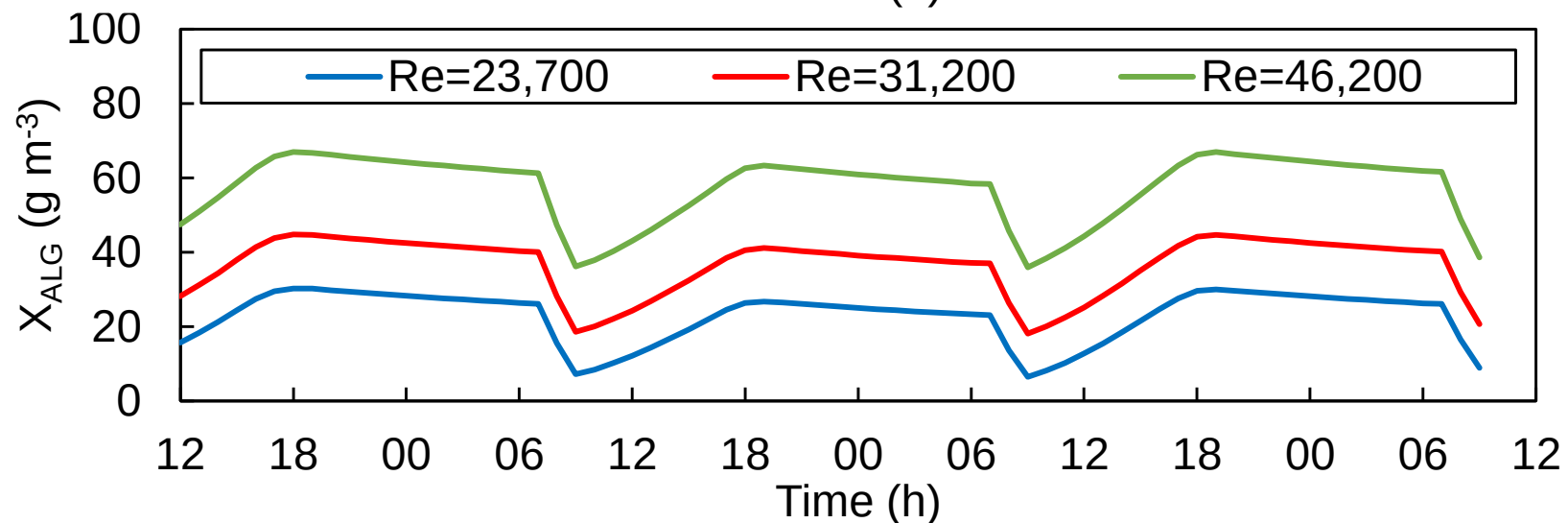
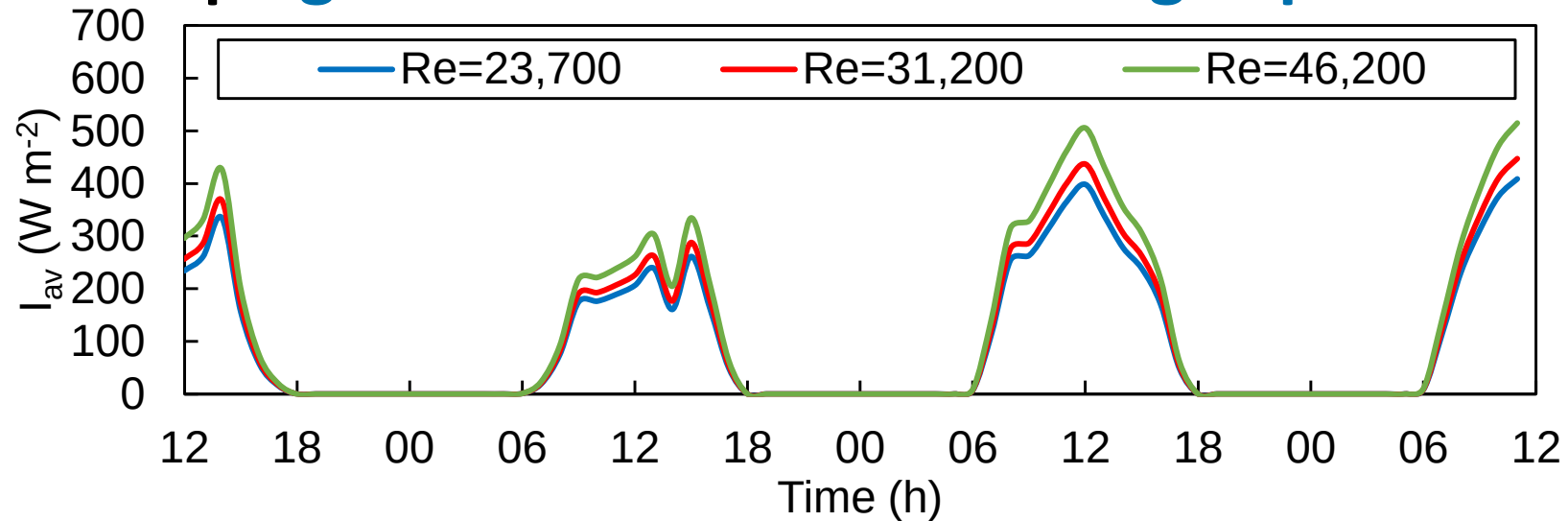
Light

Average intensity of
light radiation

$$I_{av} = \frac{I_0 \cdot [1 - e^{(-K_I \cdot X_C \cdot H)}]}{K_I \cdot X_C \cdot H}$$



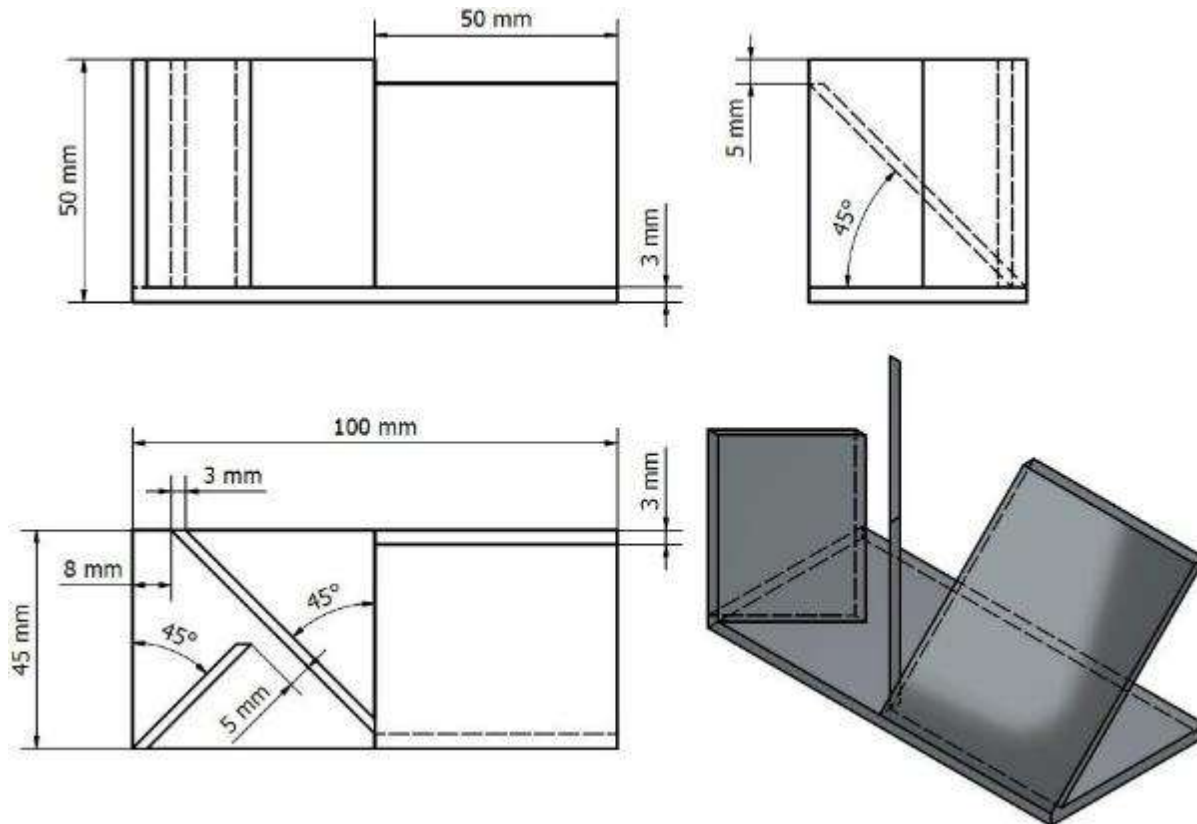
Hydrodynamics | Light conditions and Microalgae production





Flat panel PBR | Intensification of mixing

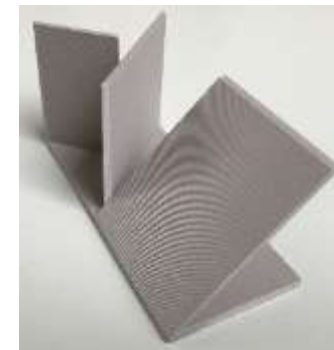
Dimensional scheme and 3D model



Static mixer in FP PBR chamber

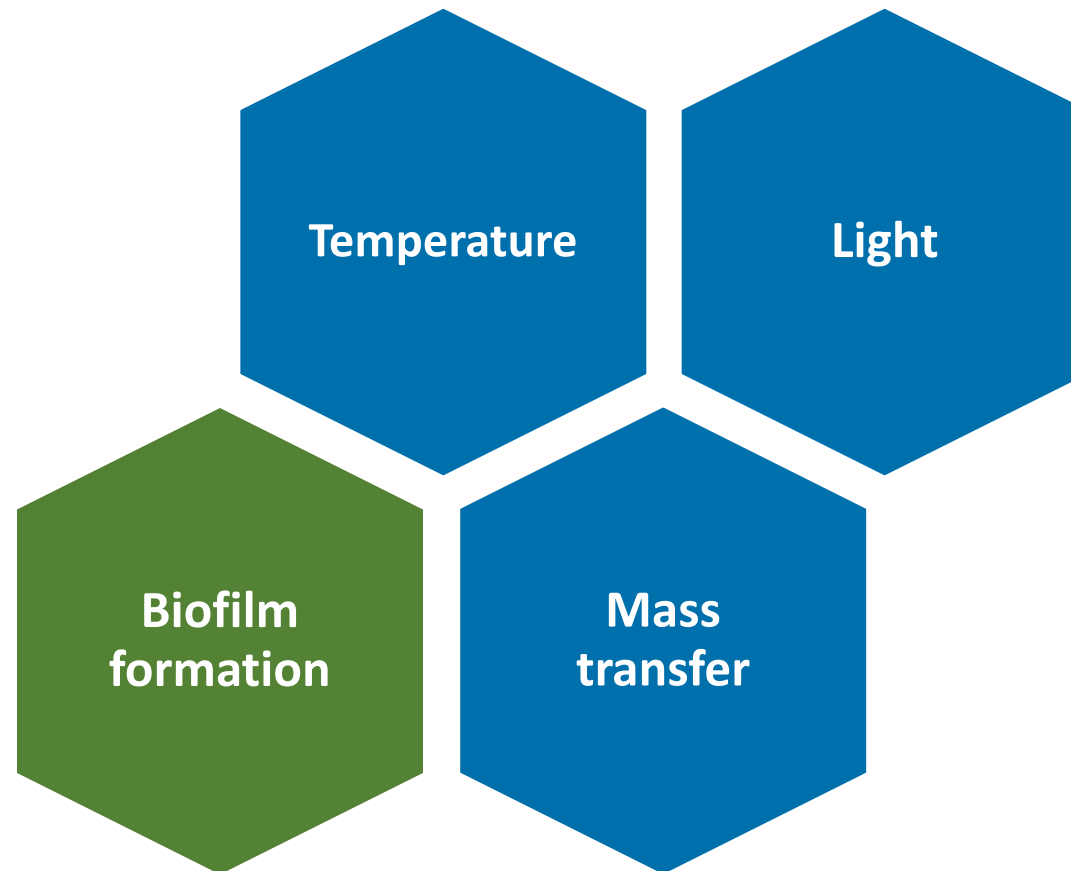


3D printed static mixer element



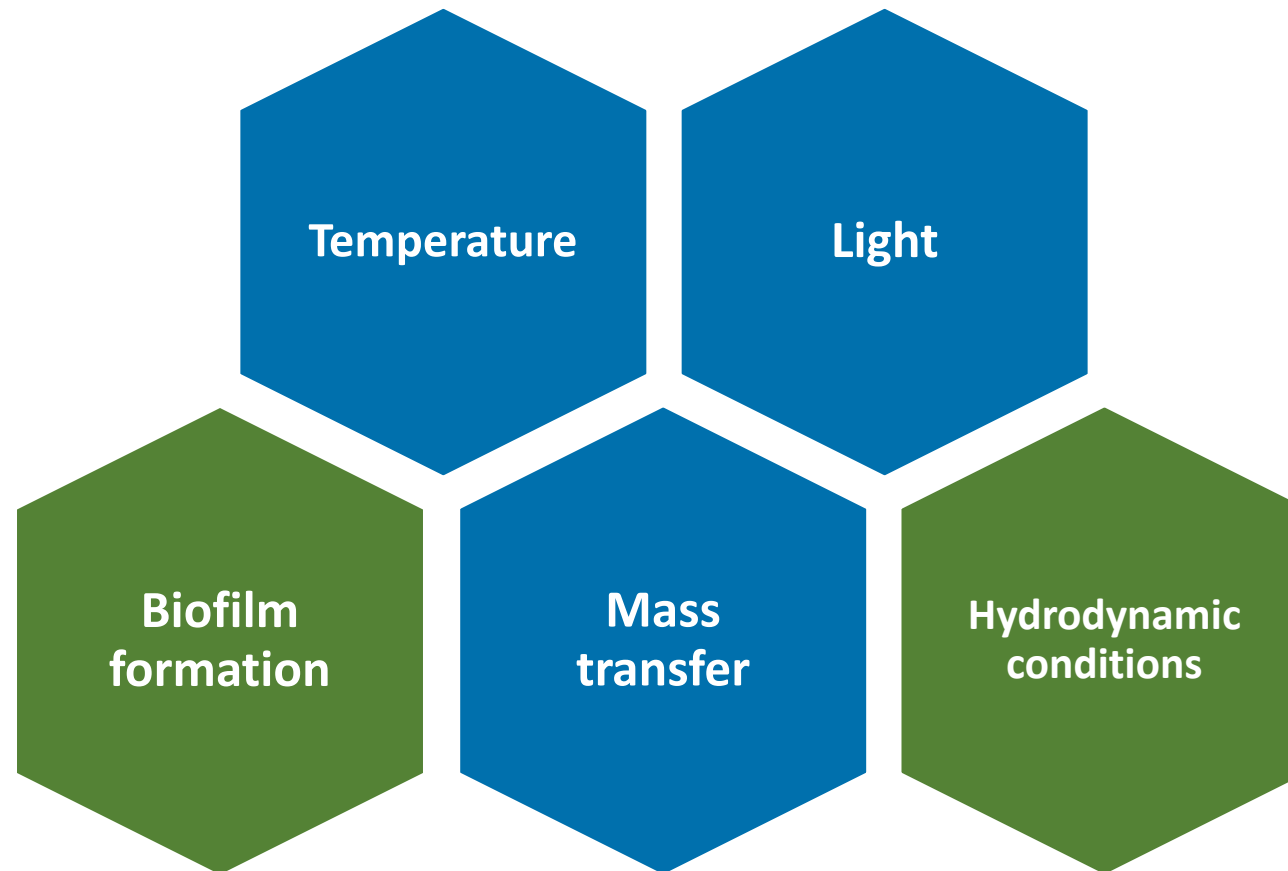


PBR | Key cultivation factors

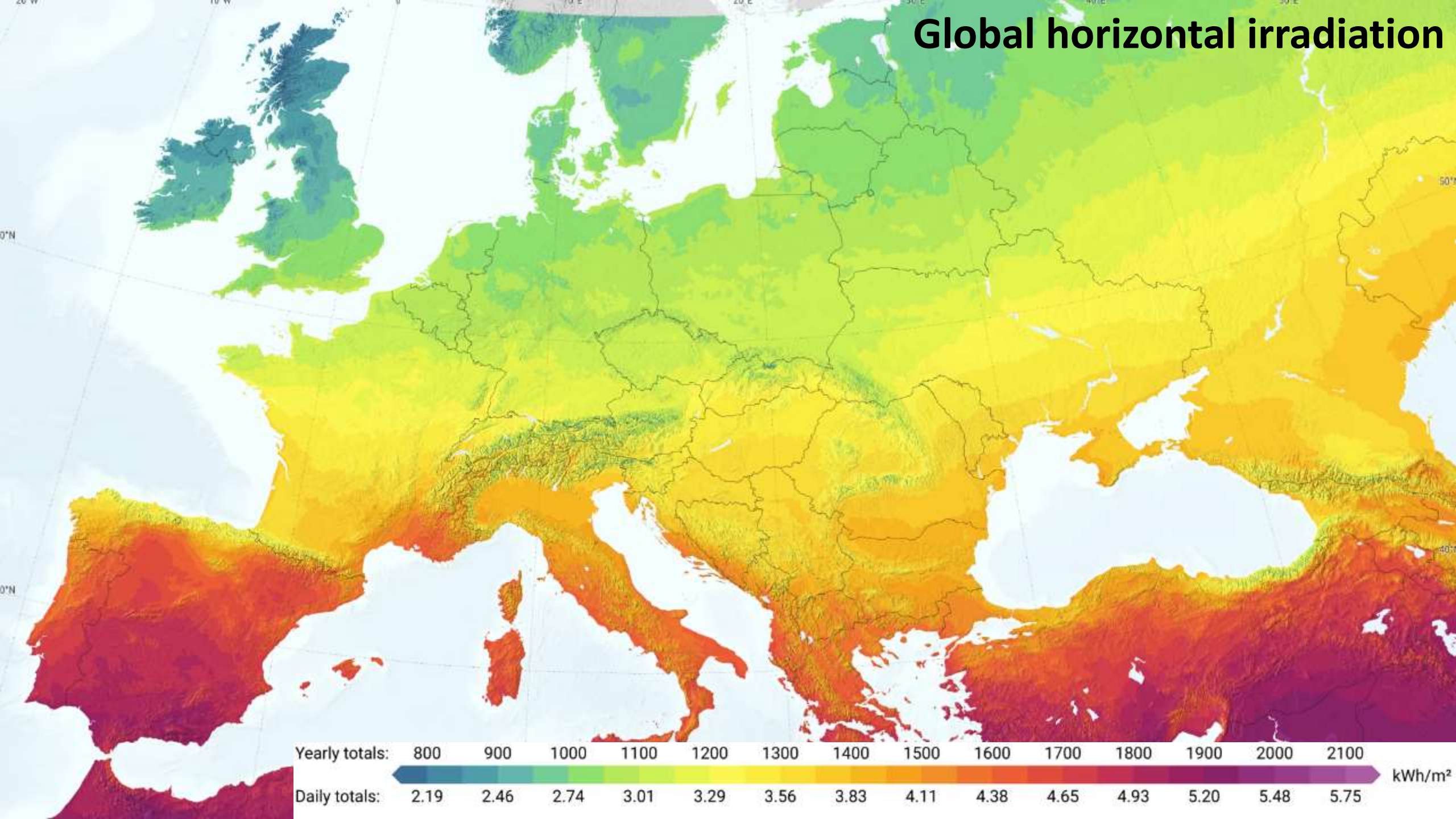




PBR | Key cultivation factors

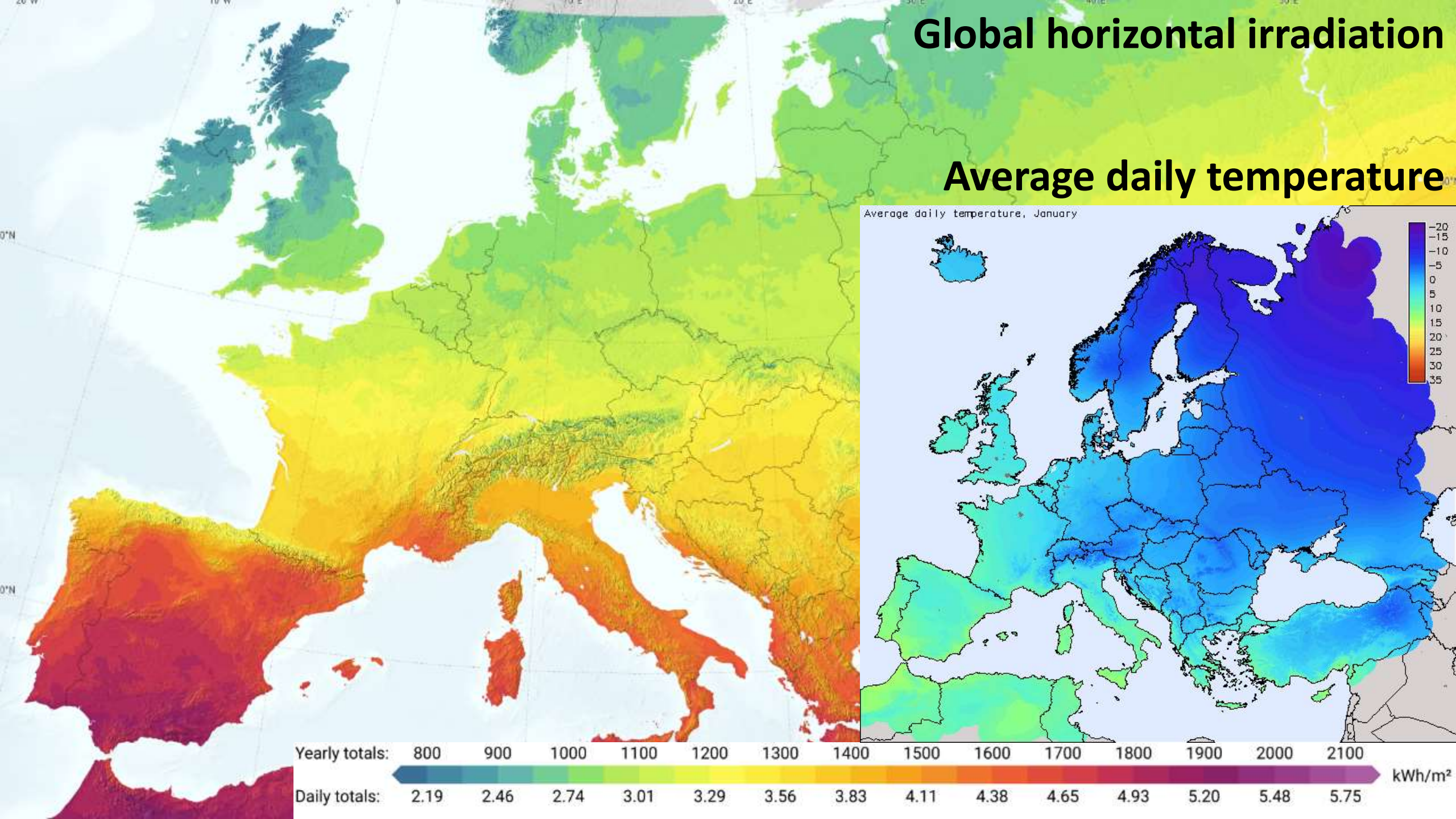


Global horizontal irradiation



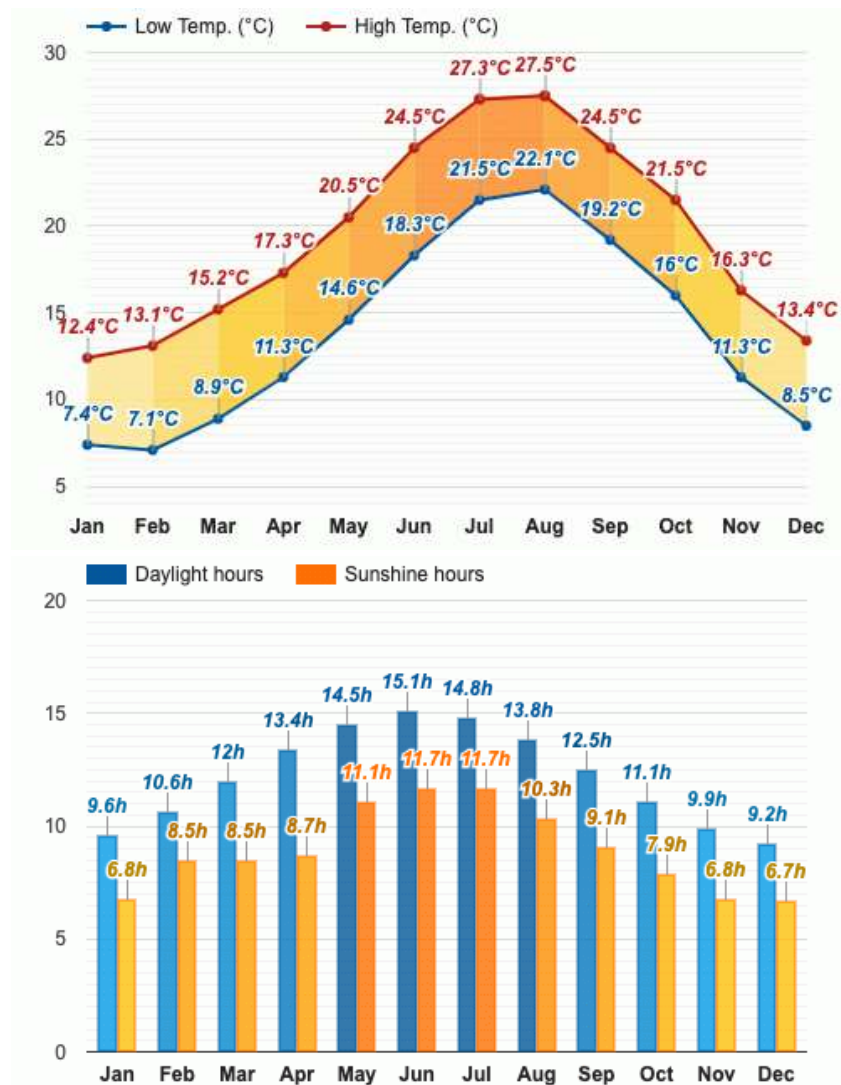
Global horizontal irradiation

Average daily temperature

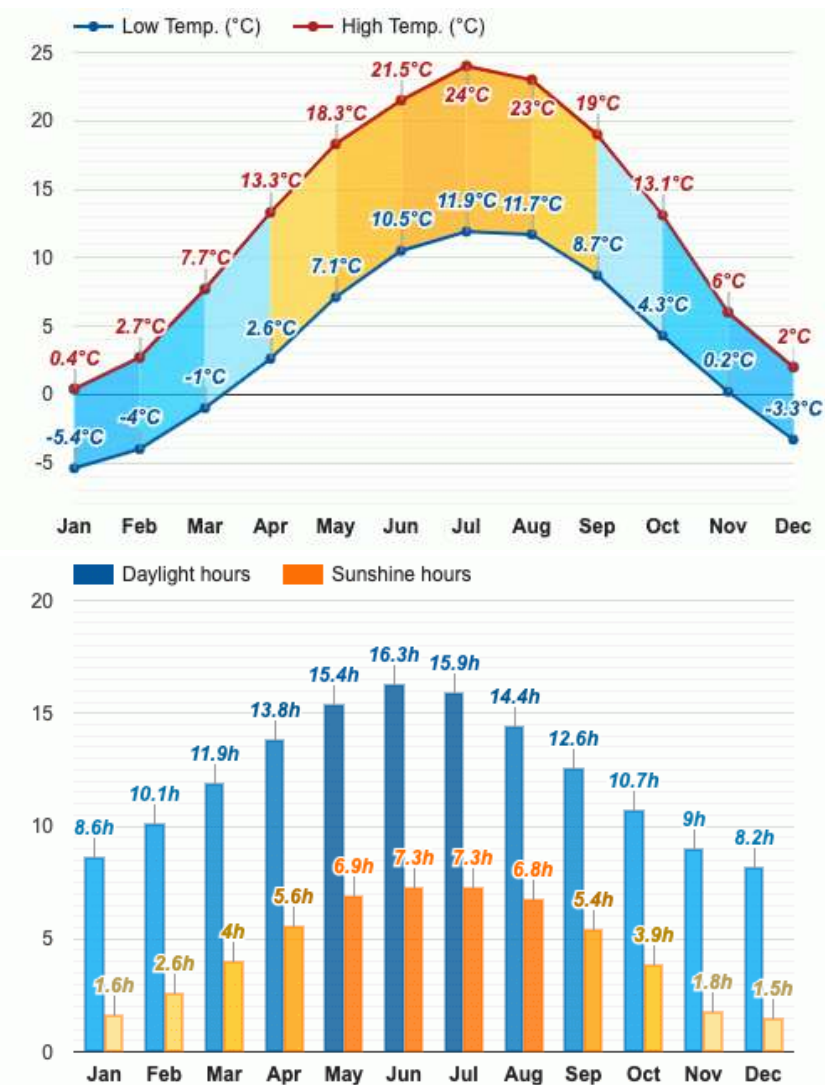




Barcelona | Spain

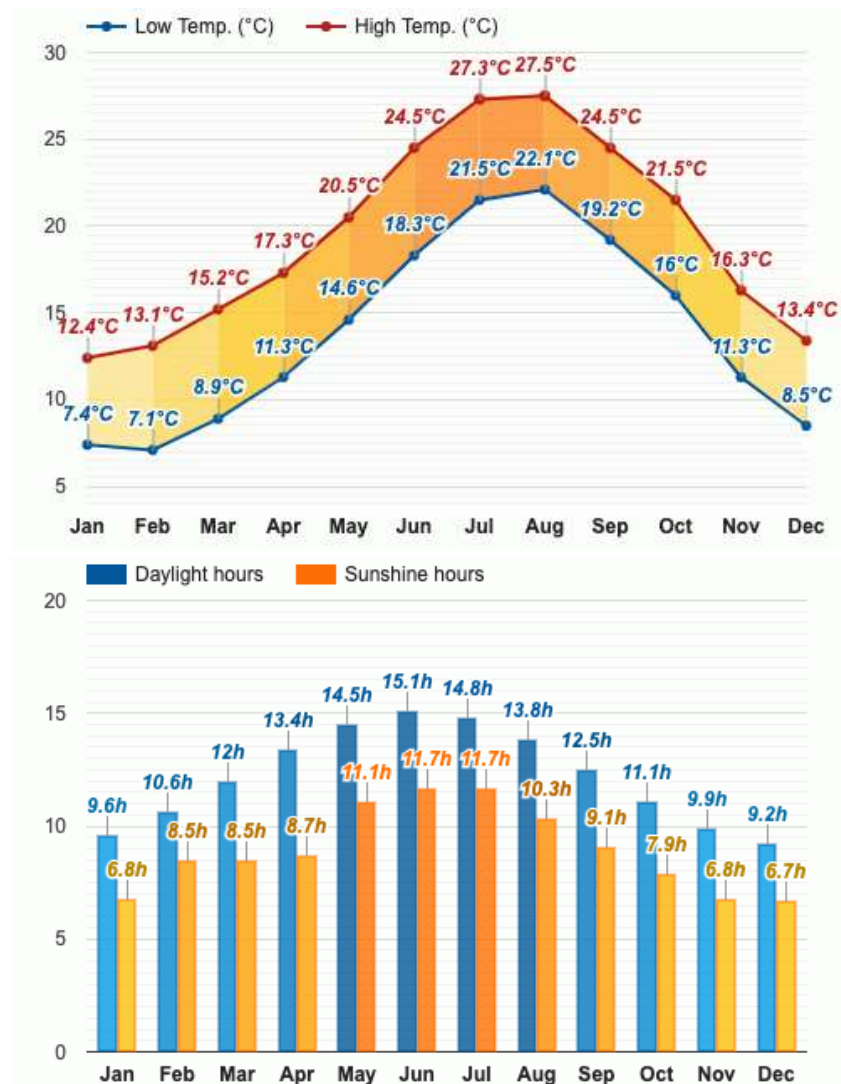


Prague | Czech Republic



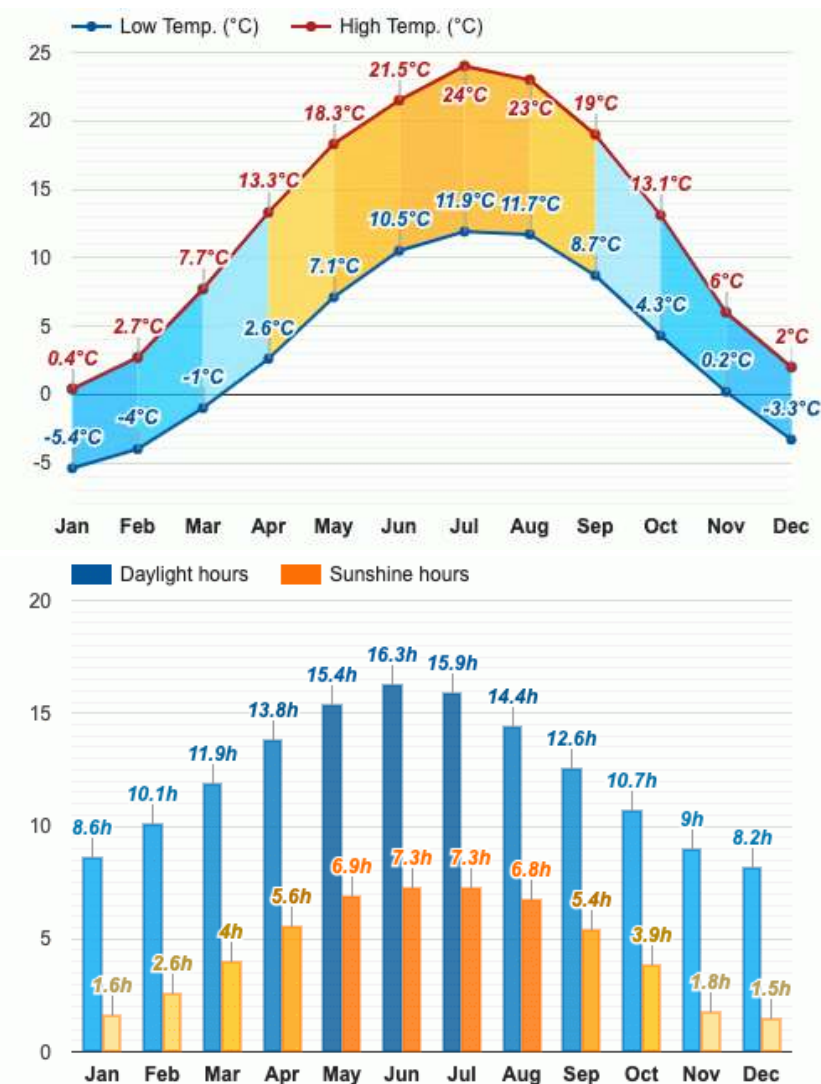


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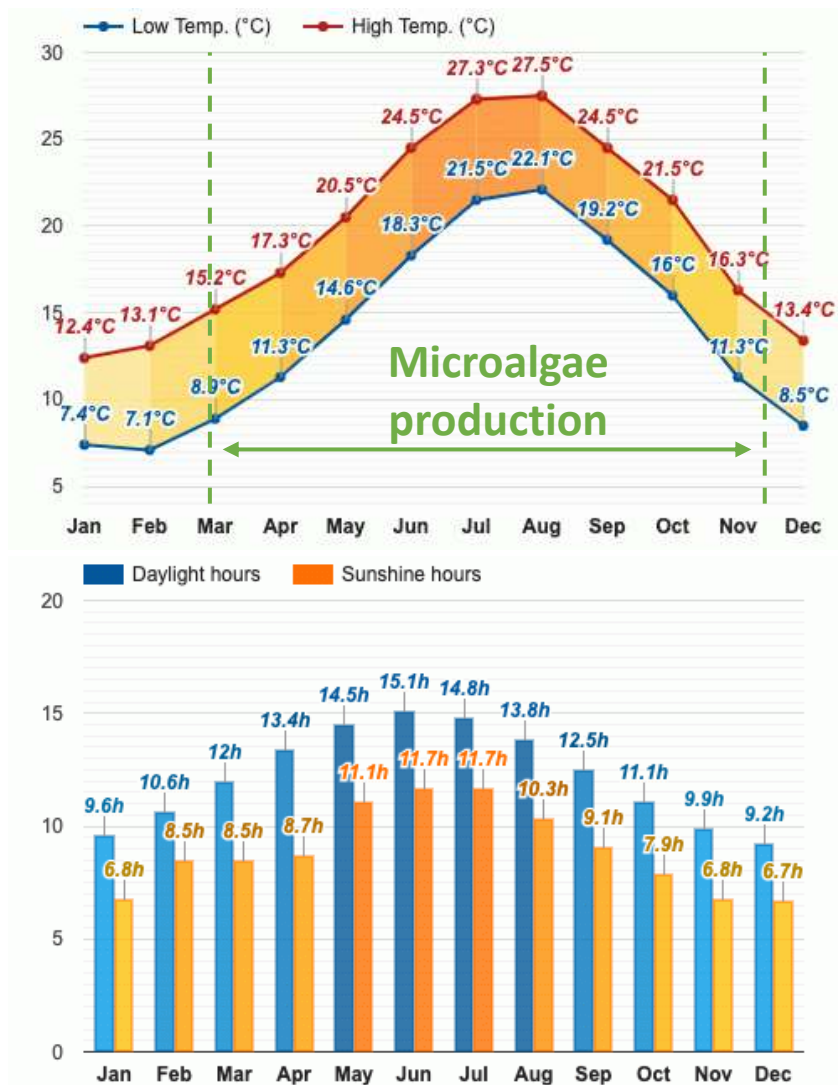
Chlorella vulgaris
15-28°C

Prague | Czech Republic



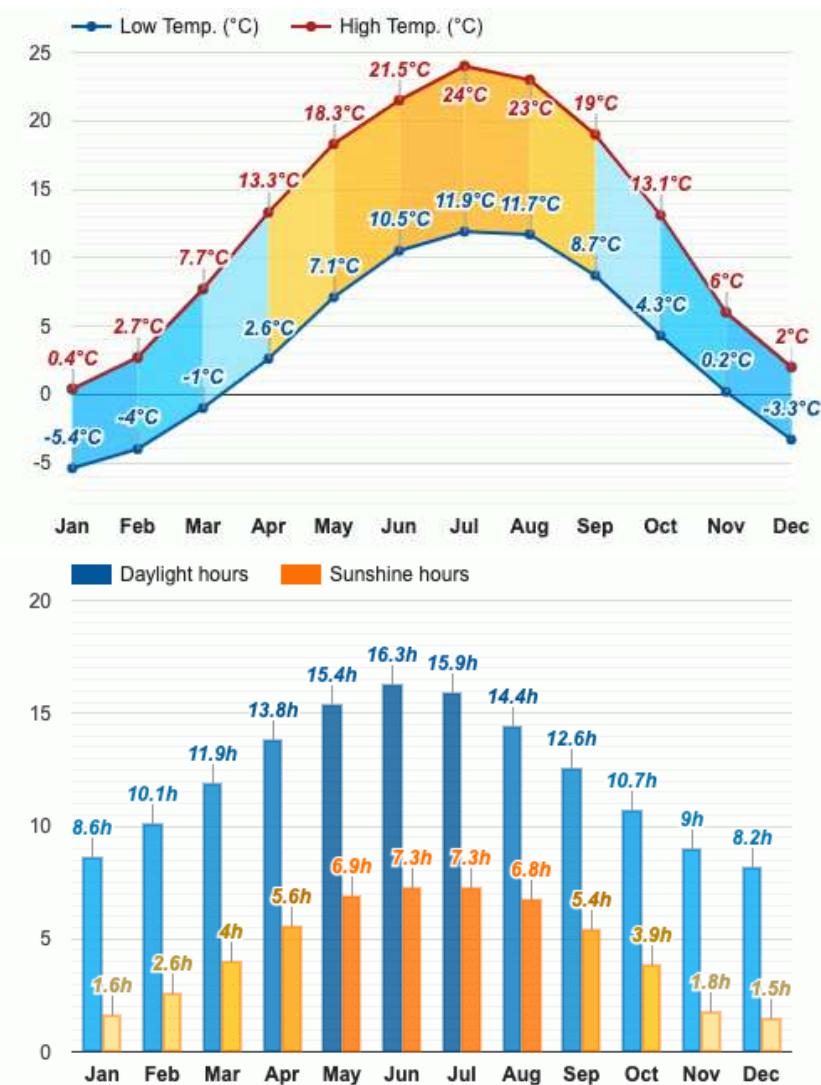


Barcelona | Spain



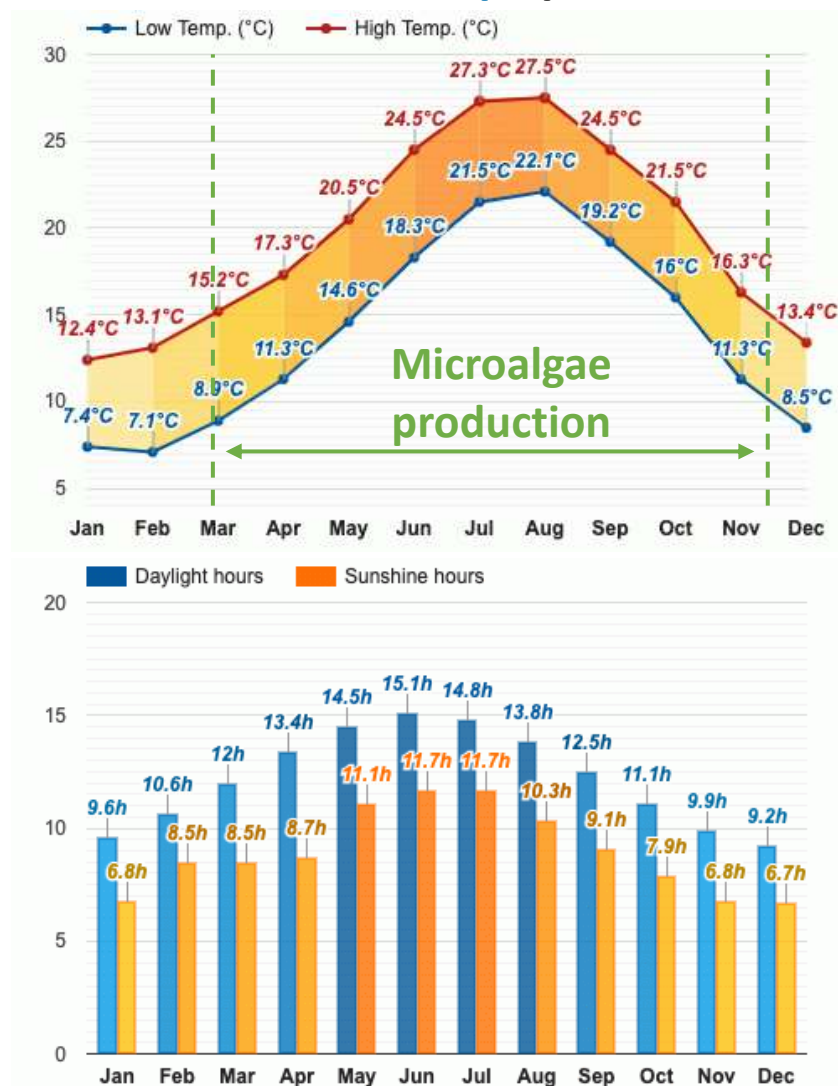
Chlorella vulgaris
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Prague | Czech Republic



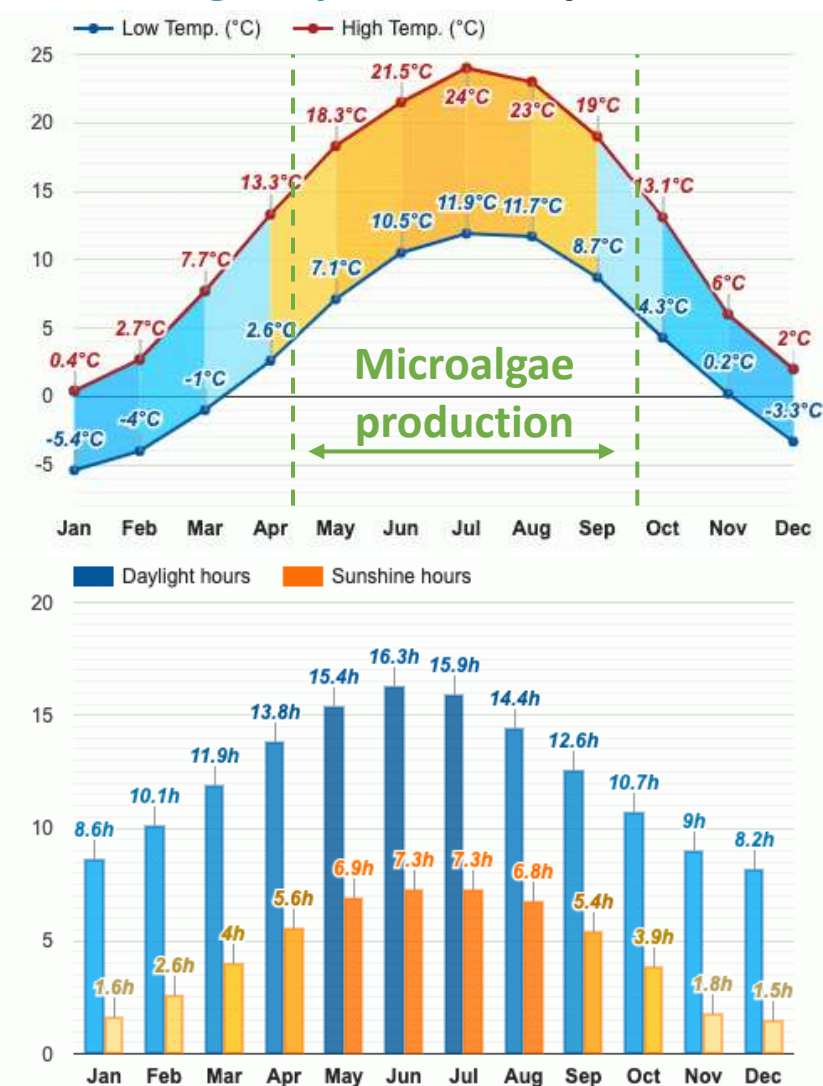


Barcelona | Spain



Chlorella vulgaris
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Snow microalgae | Svalbard, Norway





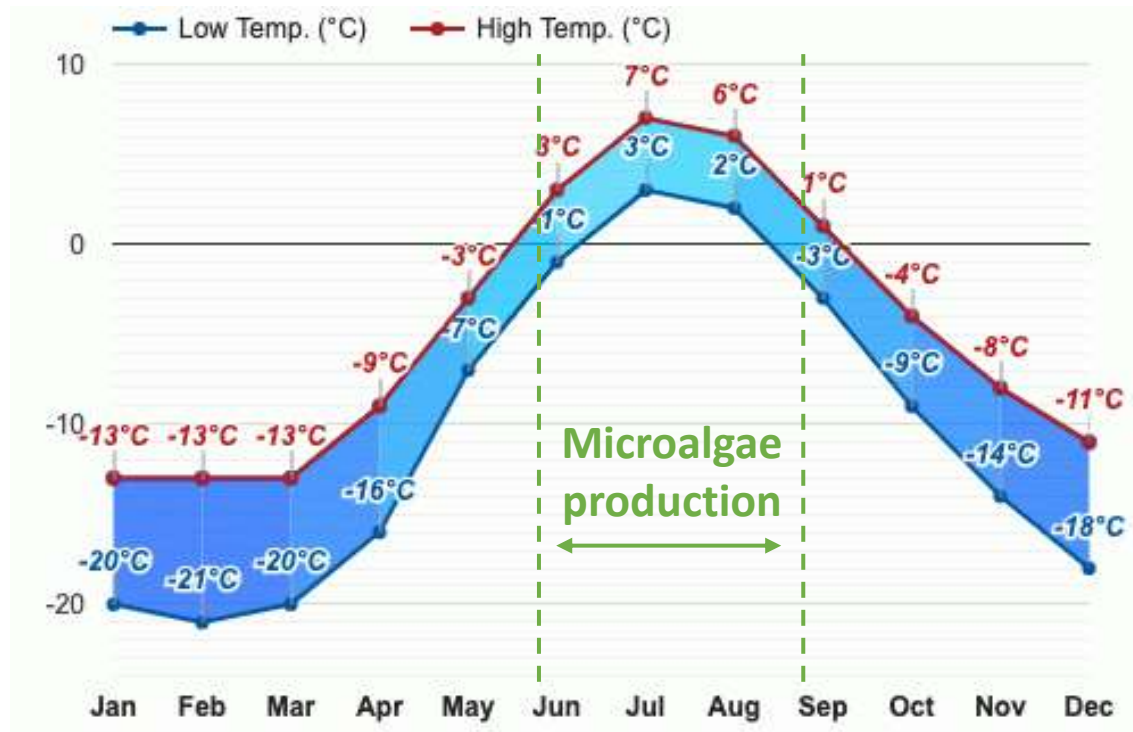
Snow microalgae | Svalbard, Norway





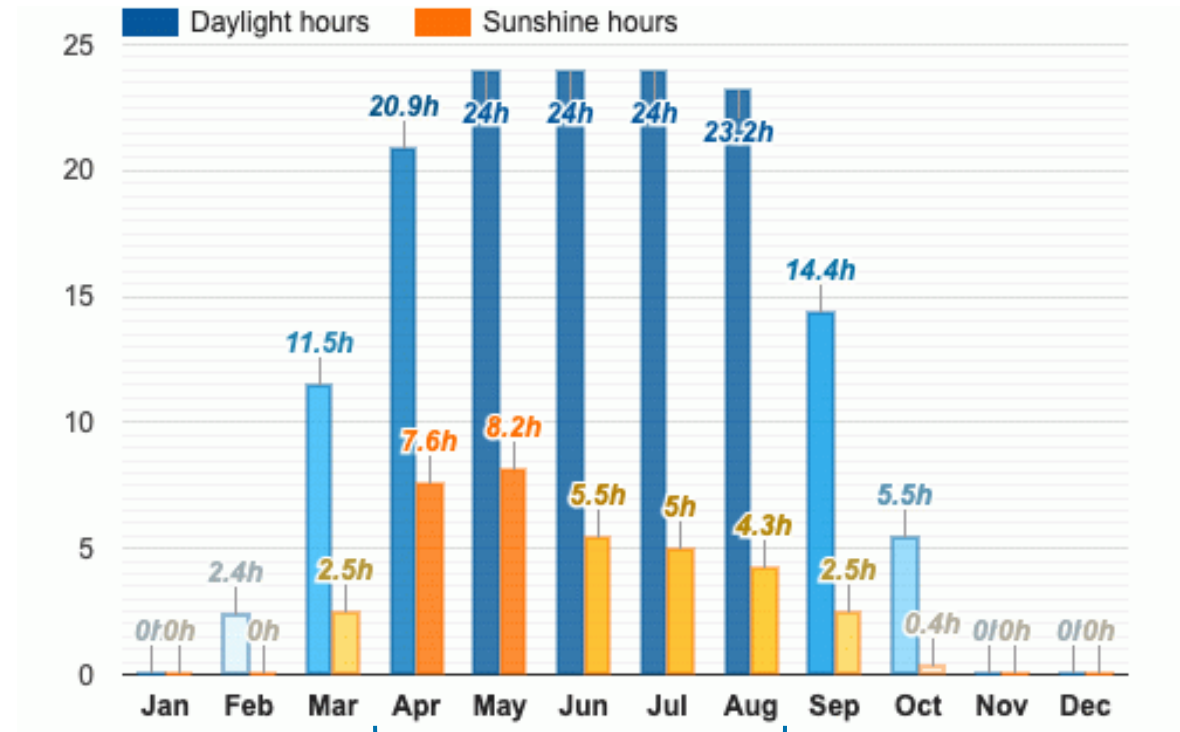
Snow microalgae | Svalbard, Norway

Average temperature



Chlamydomonas
> 2°C

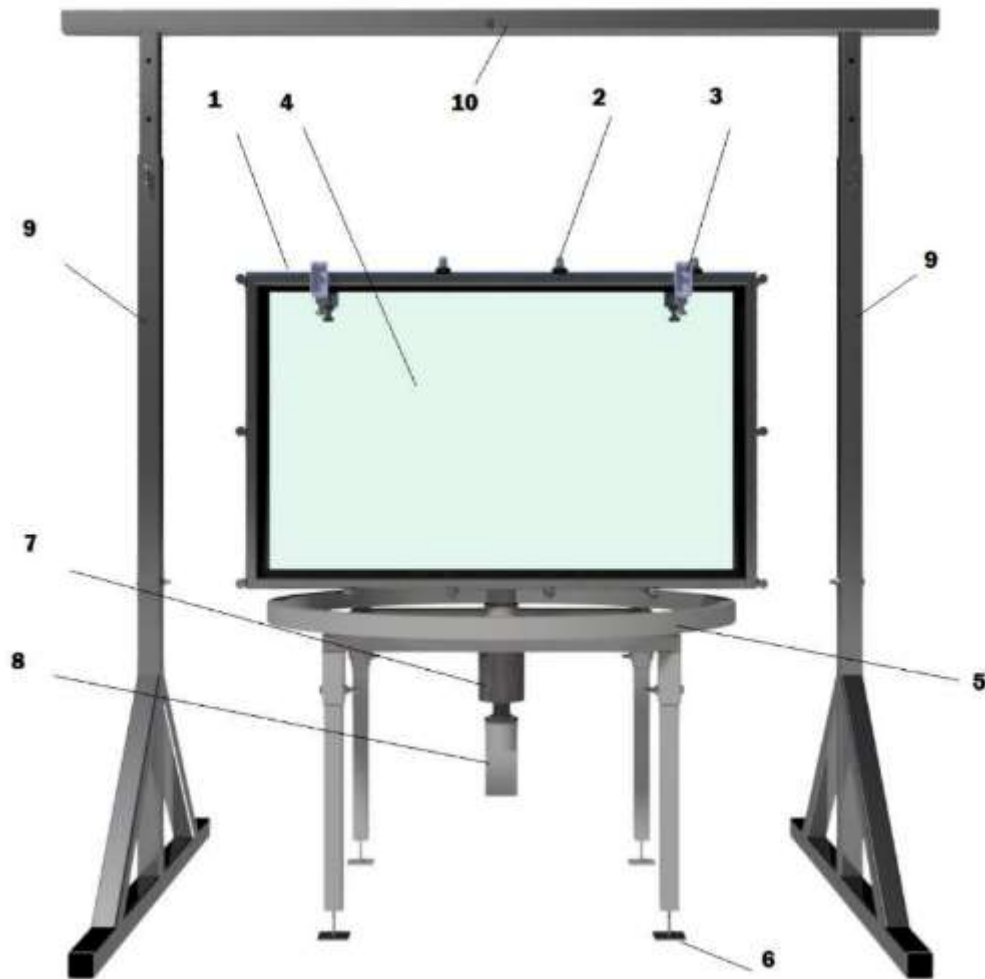
Average daylight and sunshine



Midnight sun



Rotating Flat panel PBR | Svalbard, Norway





Rotating Flat panel PBR | Svalbard, Norway





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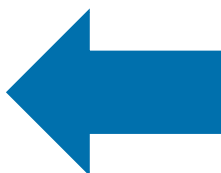
Svalbard, Norway





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Czech Republic



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Svalbard, Norway



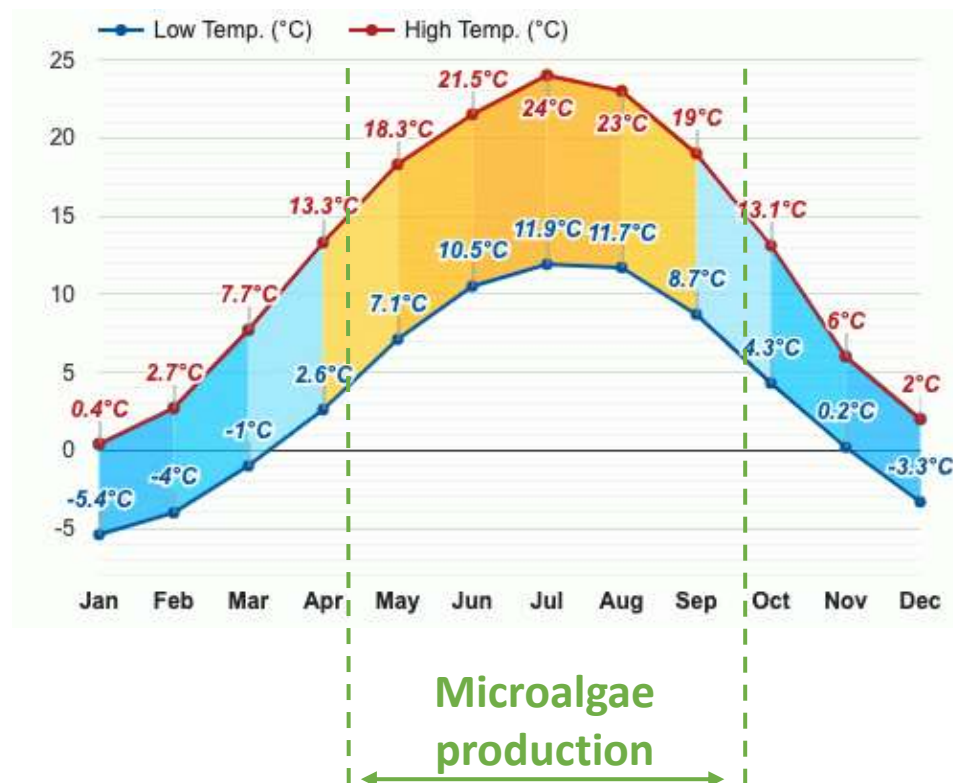


Czech Republic



Chlorella vulgaris
15-28°C

Chlamydomonas
> 2°C



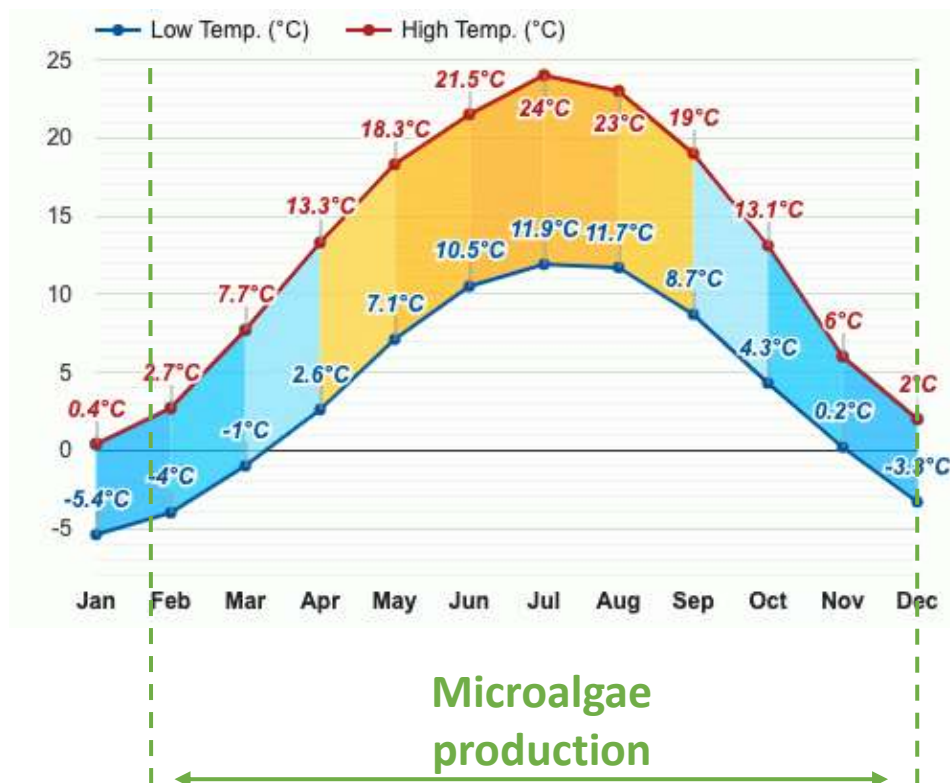


Czech Republic



Chlorella vulgaris
15-28°C

Chlamydomonas
> 2°C





Microalgal product



Biofuels



Food
industry



Pharmaceutical
industry



Chemical
industry



Biorefinery
concepts



Microalgal product



Biofuels



Food
industry



Pharmaceutical
industry



Chemical
industry



Biorefinery
concepts



Photobioreactor design





Microalgal product



Biofuels



Food
industry



Pharmaceutical
industry



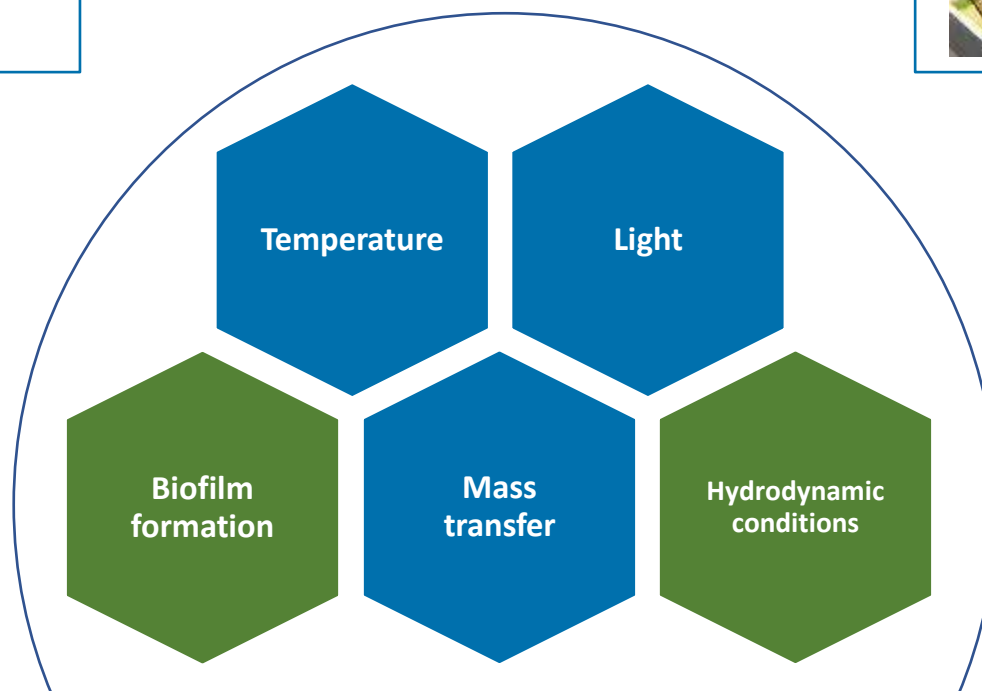
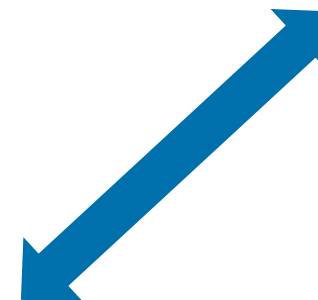
Chemical
industry



Biorefinery
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Photobioreactor design





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