

ADVANCES IN PHOTOBIOREACTOR DESIGN UNDER EUROPEAN CLIMATIC CONDITIONS

DEPARTMENT OF PROCESS ENGINEERING

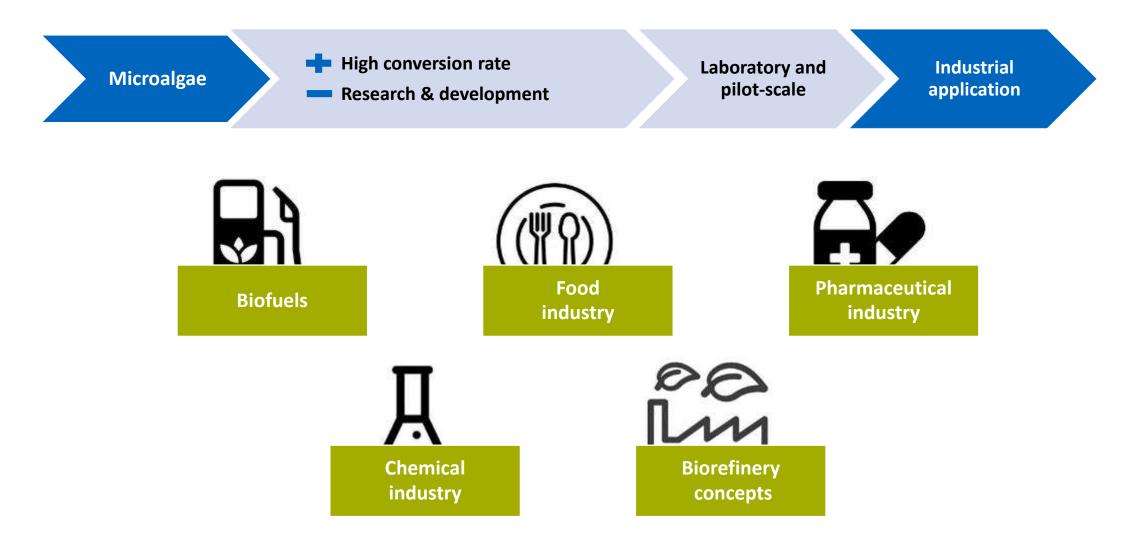
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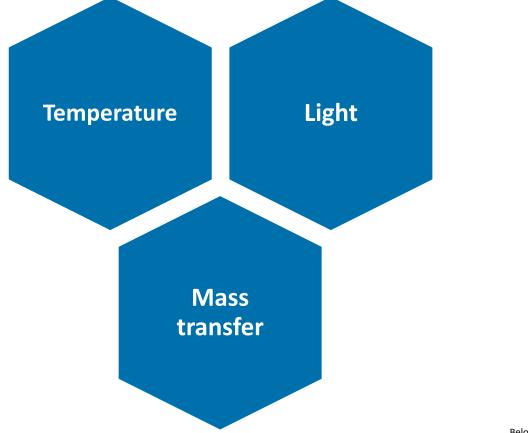


Introduction | Microalgae cultivation and utilization





Introduction | Key cultivation factors





Belohlav, V., Jirout, T., Kratky, L. (2018). Possibilities of implementation of photobioreactors on industrial scale. Chemické Listy, 112 (3), 183–190.





Hybrid tubular PBR | Barcelona, Spain





Hybrid tubular PBR | Barcelona, Spain





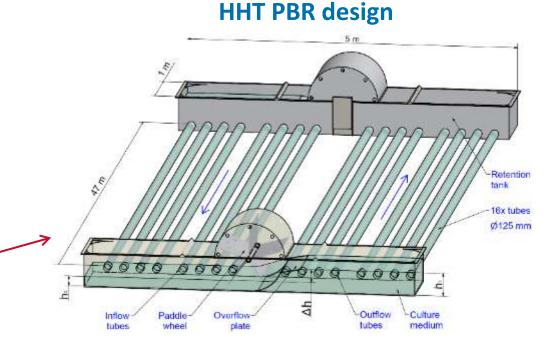






Hybrid tubular PBR | Barcelona, Spain

Process flow diagram of biorefinery concept Agricultural General run-off by-pass General M 1 by-pass PV-411 2 P-101 E C PBR-3 HT-102 FW-X PBR-2 PBR-1 2 IP-104 TK-103 P-304 TK-301 -(3) -Xt Domestic DONTRO (3) wastewater 5a P-308 -6.31 TK-302 EN 5b X .7 TK-401 5c P-206 General 0.8 TK-303 by-pass ∑ P-310

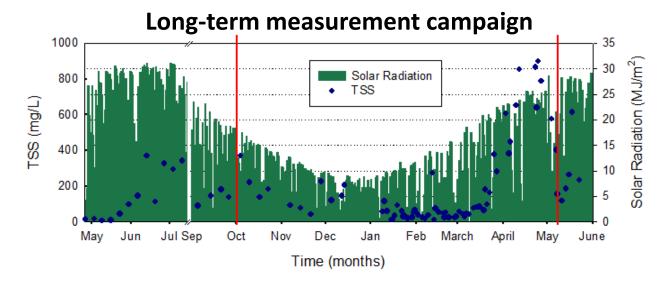


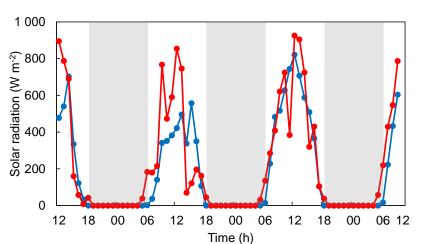


García, J., Ortiz, A., Álvarez, E., Belohlav, V., García-Galán, M. J., Díez-Montero, R., Álvarez, J. A., Uggetti, E. (2018). Nutrient removal from agricultural run-off in demonstrative full scale tubular photobioreactors for microalgae growth. Ecological Engineering, 120.

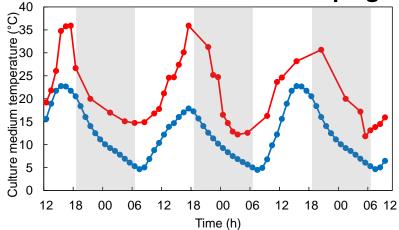


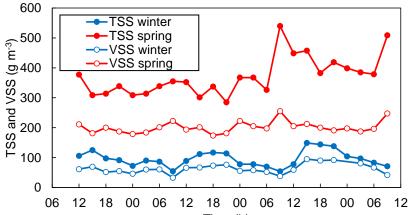
Hybrid tubular PBR | Barcelona, Spain





Intensive measurement campaign





Time (h)

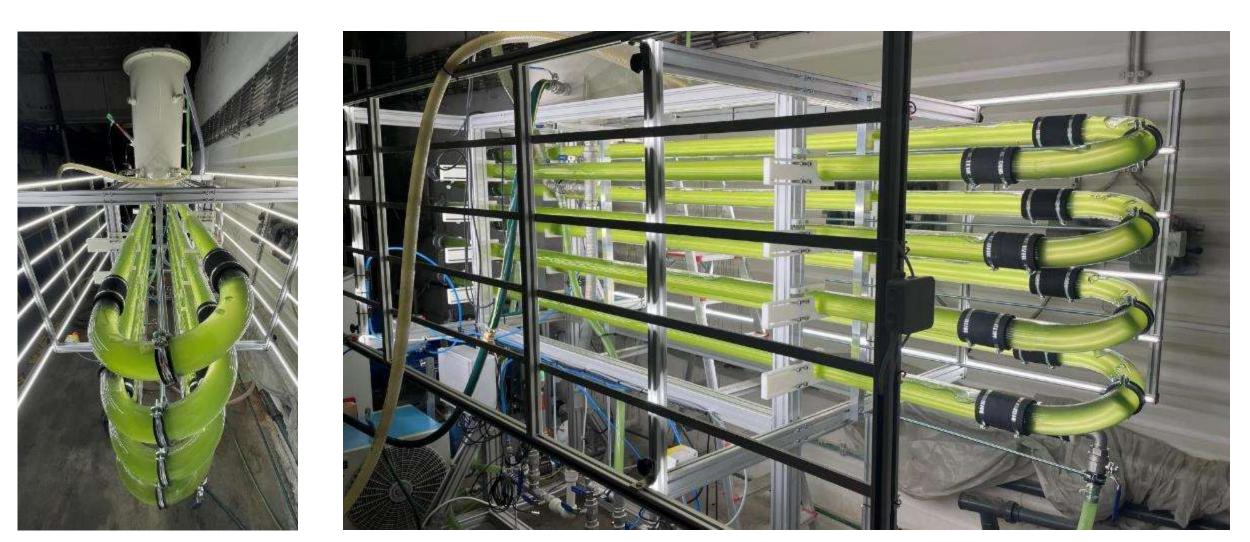


Biofilm formation | Barcelona, Spain





Tubular PBR | Prague, Czech Republic





Biofilm formation | Prague, Czech Republic





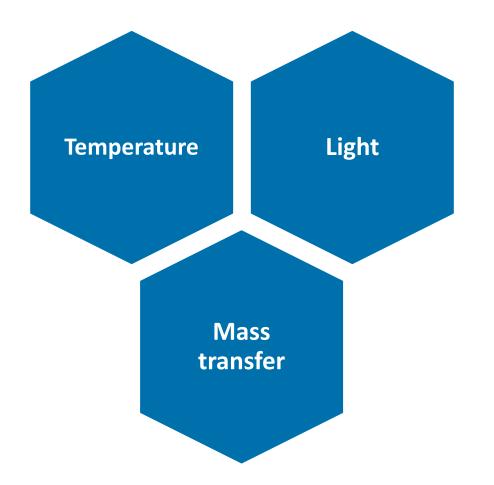


Biofilm formation | Prague, Czech Republic



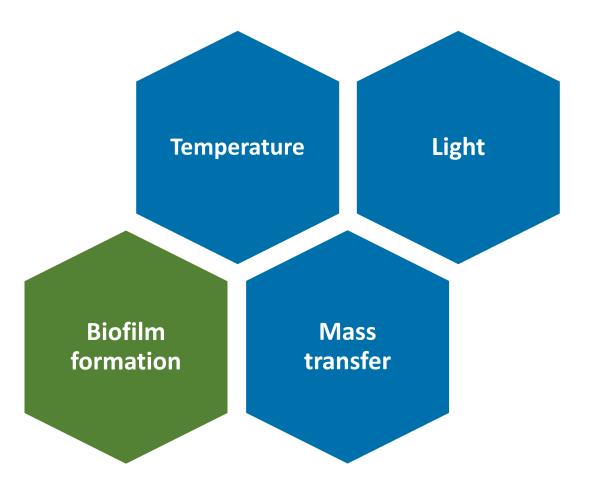


PBR | Key cultivation factors



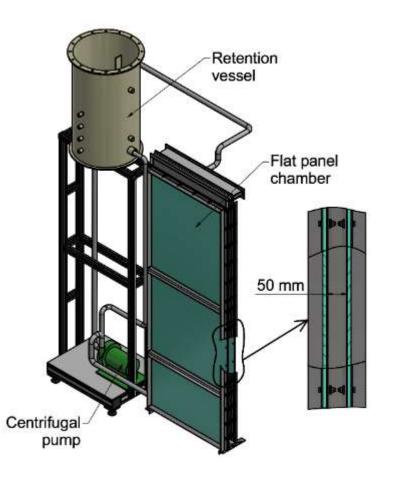


PBR | Key cultivation factors





Flat panel PBR | Prague, Czech Republic











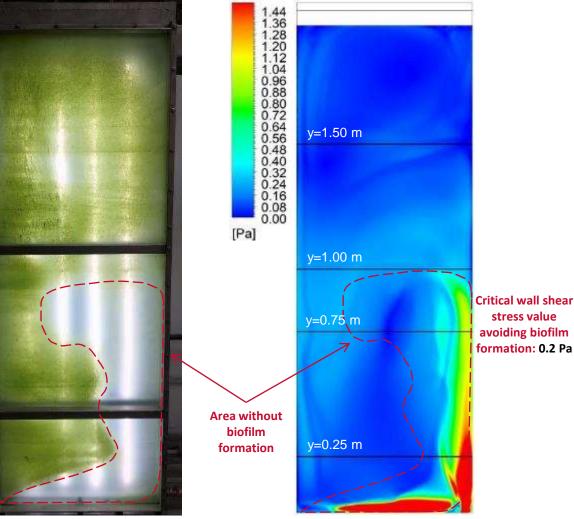
Flat panel PBR | Prague, Czech Republic



Biofilm fixed in FP PBR

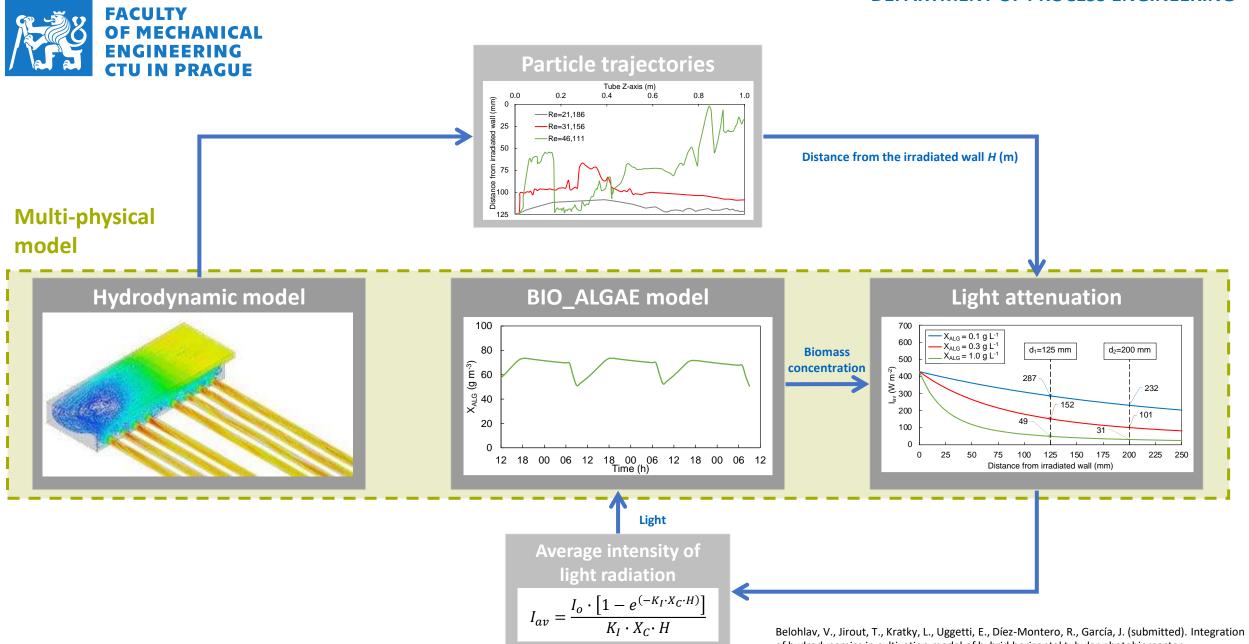


Shear stress bellow the critical value formed 70 % of the total transparent area of FP PBR



Fixed biofilm on transparent walls

Wall shear stress distribution



of hydrodynamics in cultivation model of hybrid horizontal tubular photobioreactor.



Hydrodynamics | Light conditions and Microalgae production -Re=23,700 Re=31,200 Re=46,200 (⁷ 500 € 400 ≥ 300 _[≈]200 Time (h) Re=23,700 Re=31,200 Re=46,200 X_{ALG} (g m⁻³) Time (h)



Flat panel PBR | Intensification of mixing

50 mm 5 mm 50 mm mm 100 mm mm 3 mm m 8 mm 45 mm

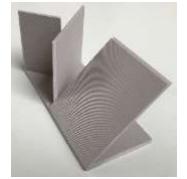
Utility model: Jirout, T., Belohlav, V. Static mixer, especially into a plate reactor chamber, U1 34 865 CZ, Feb 23, 2021. European patent: Jirout, T., Belohlav, V. Static mixer, especially into a plate reactor chamber, Application No.: PCT/IV2021/058296

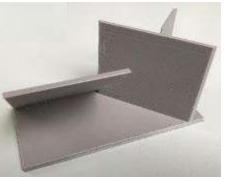
Static mixer in FP PBR chamber





3D printed static mixer element

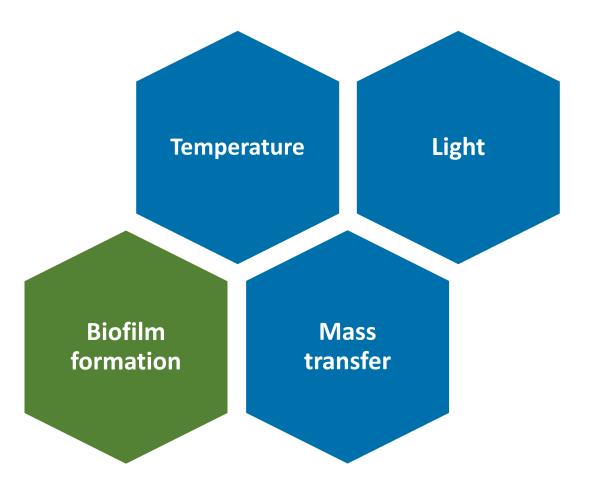




Dimensional scheme and 3D model

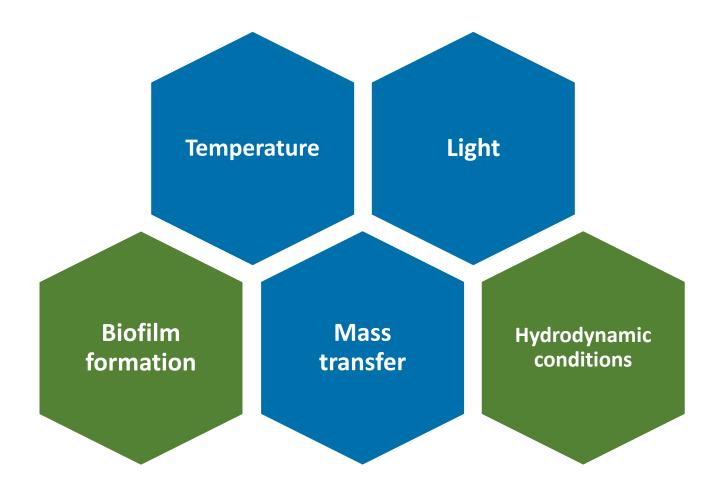


PBR | Key cultivation factors

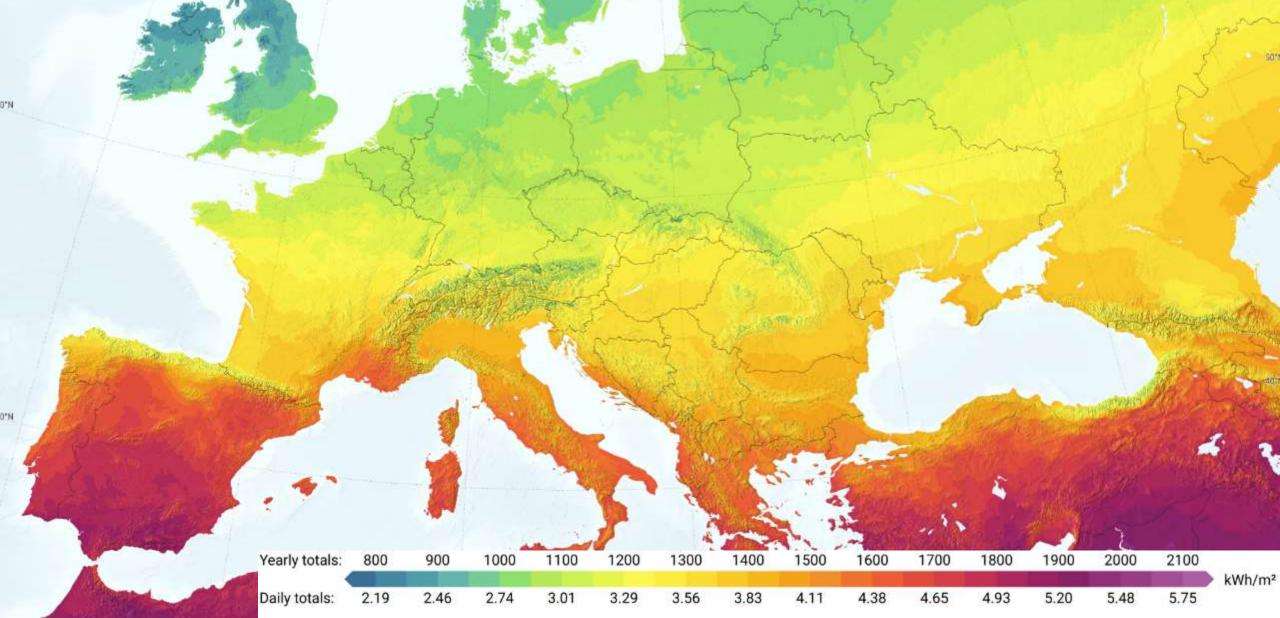




PBR | Key cultivation factors



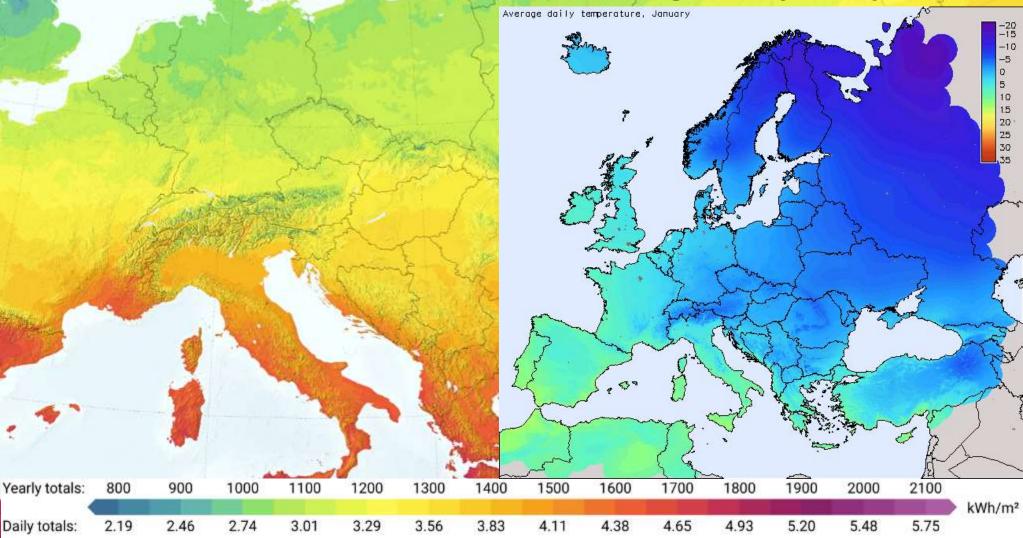
Global horizontal irradiation



20.44

Global horizontal irradiation

Average daily temperature

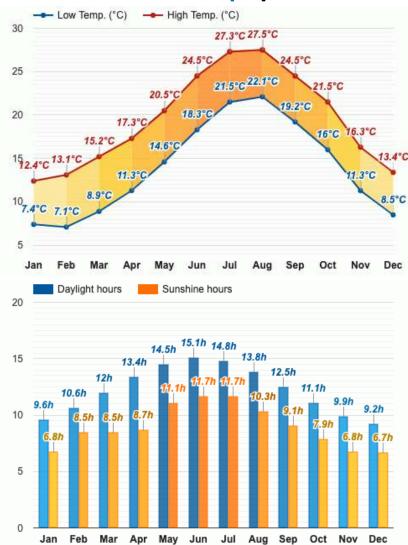


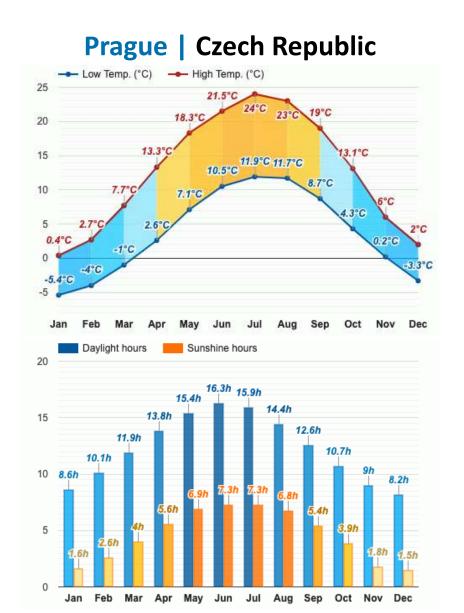
20 W

0"N



Barcelona | Spain



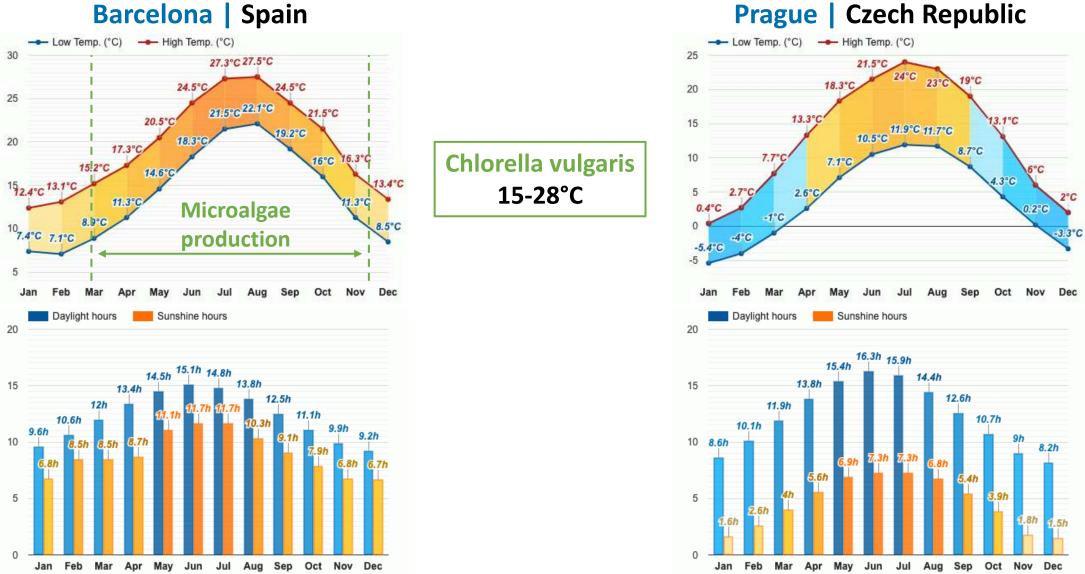




Barcelona | Spain Prague | Czech Republic --- Low Temp. (°C) --- High Temp. (°C) --- Low Temp. (°C) --- High Temp. (°C) 30 25 27.3°C 27.5°C 21.5°C 24°C 19°C 23°C 24.5°C 18.3°C 24.5°C 20 25 21.5°C 22.1°C 21.5°C 13.3°C 20.5°C 13.1°C 10.5°C 11.9°C 11.7°C 15 19.2°C 20 18.3°C 17.3°C 8.7°C **Chlorella vulgaris** 16.3°C 10 7.7°C 16°C 7.1°C 15.2°C 6°C 14.6°C 4.3°C 1512.4°C 13.1°C 13.4°C 15-28°C 5 2.7°C 2.6°C 2°C 11.3°C 11.3°C 0.4°C 0.2°C -1°C 8.9°C ¹⁰7.4°C 7.1°C 0 8.5°C -3.3°C -4°C -5.4°C 5 Oct Nov Dec Jan Jul Aug Oct Nov Dec Jan Jun Jul Aug Sep Jun Sep May Daylight hours Sunshine hours Daylight hours Sunshine hours 20 20 16.3h 15.9h 15.4h 14.5h 15.1h 14.8h 14.4h 15 13.8h 15 13.8h 13.4h 12.6h 121 11.9h 11.1h 10.7h 10.6h 10.1h 9.6h 9.2h 10 8.6h 10 5h5h8.2h 7.3h 7.3h 5 5 3.9h .5h 0 0 Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

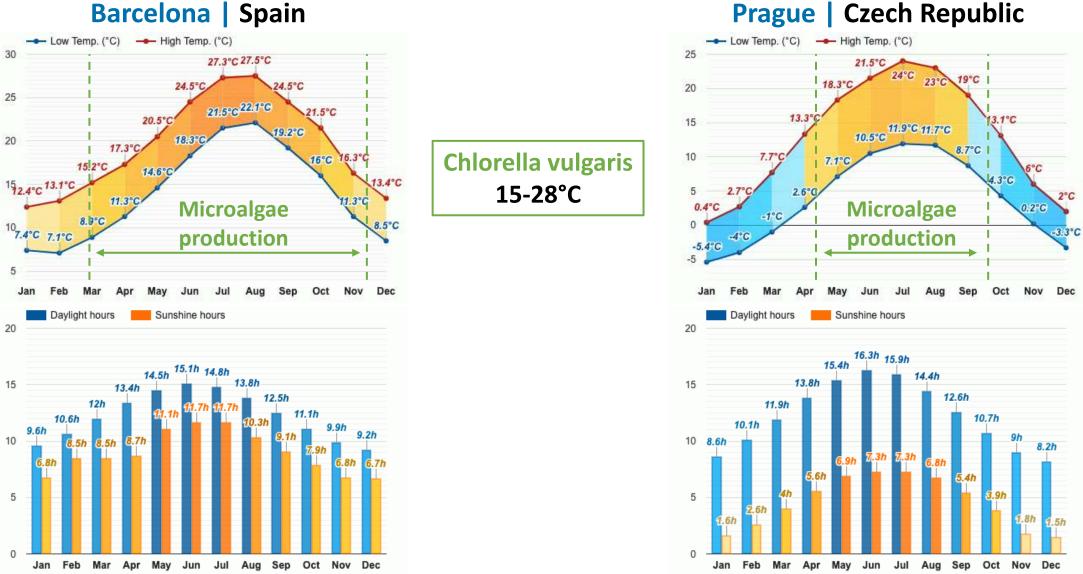


Barcelona | Spain





Barcelona | Spain





Snow microalgae | Svalbard, Norway

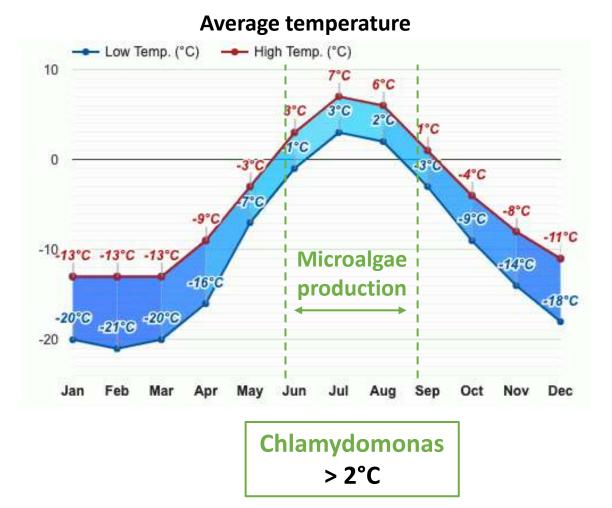


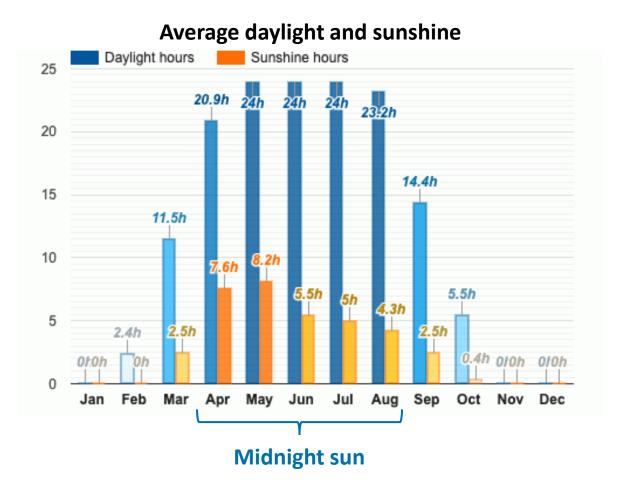
Snow microalgae | Svalbard, Norway





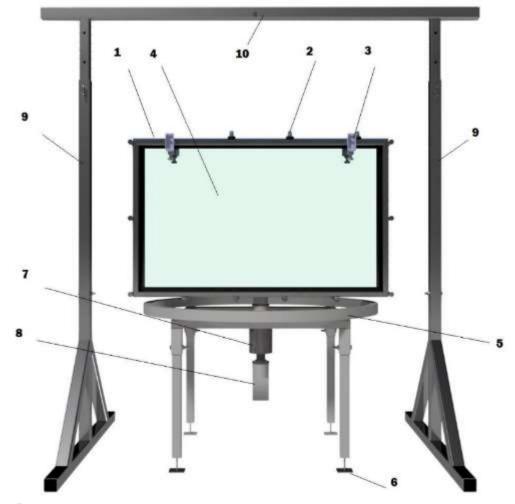
Snow microalgae | Svalbard, Norway







Rotating Flat panel PBR | Svalbard, Norway



Utility model: Šnokhous K., Bělohlav V., Jirout T., Krátký L., Elster J., Kvíderová J., Liška J., Lukavský J., Nedbalová L., Rotary flat panel reactor, especially for microalgae cultivation, U1 36 383 CZ, Nov 4, 2022.





Rotating Flat panel PBR | Svalbard, Norway





Svalbard, Norway



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Czech Republic



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Svalbard, Norway

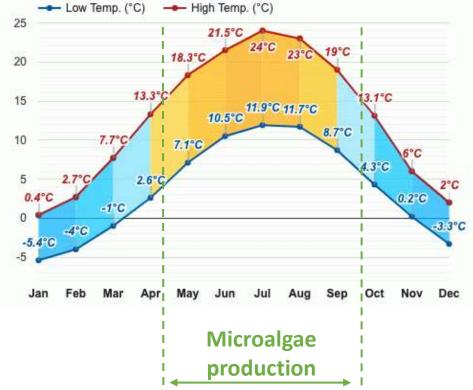




Czech Republic





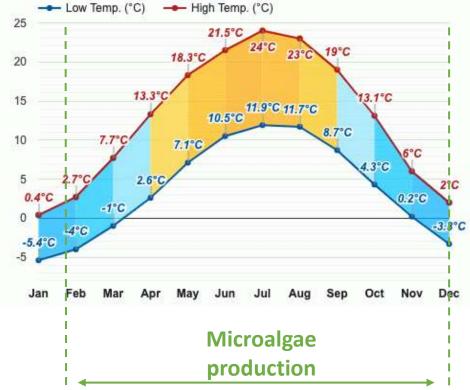




Czech Republic







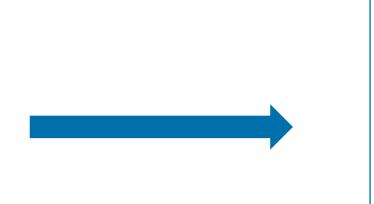


DistributionBiofuelsFood
industryFood
industryDistributionDi

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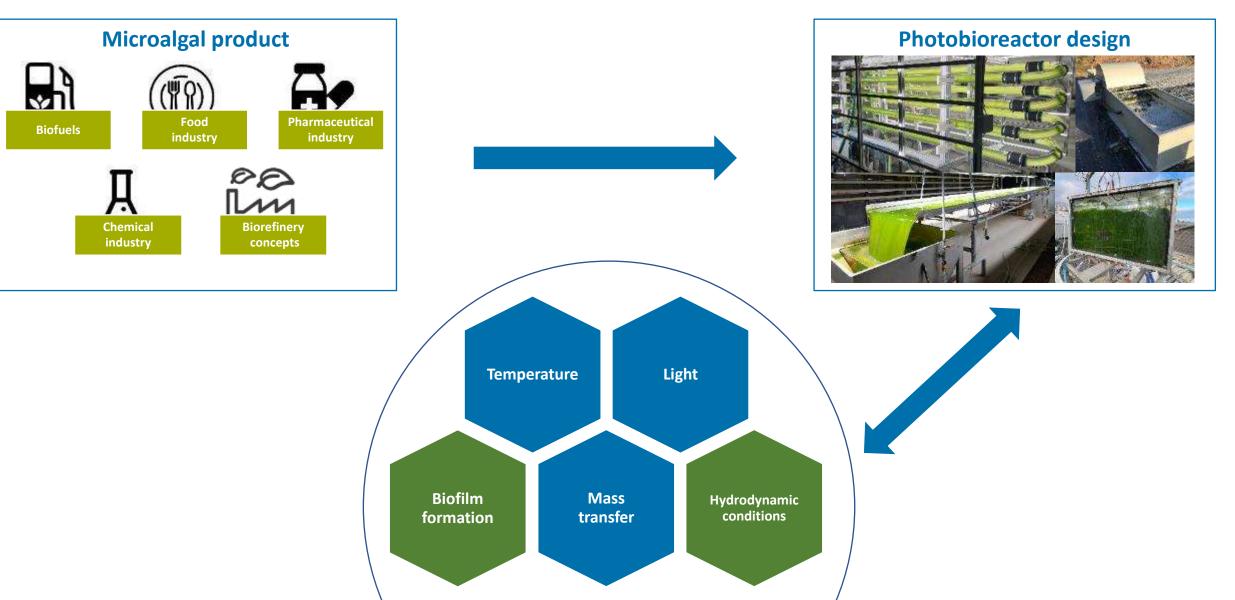


Microalgal productBiofuelsImage: Colspan="2">Image: Colspan="2" Image: C











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