Table S1. List of documents published on algal cultivation in outdoor PBRs.

Title	DOI	Authors	Reference
Outdoor Cultivation of Temperature-Tolerant *Chlorella* sorokiniana in a Column Photobioreactor	10.1002/bit.24603	Bechet et al. (2012)	[39]
A Model for Light Distribution and Average Solar Irradiance Inside Outdoor Tubular Photobioreactors for the Microalgal Mass Culture	10.1002/(SICI)1097-0290(19970905)55:5<701::AID-BIT1>3.0.CO;2-F	Fernandez et al. (1997)	[89]
Improvement of mass transfer characteristics and productivities of inclined tubular photobioreactors by installation of internal static mixers	10.1007/s00253-002-0940-9	Ugwu et al. (2002)	[58]
Biomass and Lipid Production of *Dinoflagellates* and *Raphidophytes* in Indoor and Outdoor Photobioreactors	10.1007/s10126-012-9450-7	Fuentes-Grünewald et al. (2012)	[47]
Pilot-scale outdoor photobioreactor culture of the marine dinoflagellate *Karlodinium* veneficum: Production of a karlotoxins-rich extract	10.1016/j.biortech.2017.12.101	López-Rosales et al. (2018)	[73]
Passive temperature solar control of an outdoor photobioreactor	10.1016/j.renene.2007.11.004	Gutierrez et al. (2008)	[126]
Evaluation of *Chlorella* sorokiniana cultivated in outdoor photobioreactors for biodiesel production	10.1080/17597269.2020.1763094	Menegazzo et al. (2020)	[59]
Outdoor cultivation of *Ulva* lactuca in a recently developed ring-shaped photobioreactor: effects of elevated CO_2 concentration on growth and photosynthetic performance	10.1515/bot-2018-0016	Sebök et al. (2018)	[127]
Chlorella for protein and biofuels: from strain selection to outdoor cultivation in a Green Wall Panel photobioreactor	10.1186/1754-6834-7-84	Guccione et al. (2014)	[124]
Productivity of Outdoor Algal Cultures in Enclosed Tubular Photobioreactor	10.1002/bit.260400917	Lee and Low (1992)	[55]
Dynamic modeling of temperature change in outdoor operated tubular photobioreactors	10.1007/s00449-017-1765-3	Androga et al. (2017)	[104]
Biomass Accumulation of *Chlorella* Zofingiensis G1 Cultures Grown Outdoors in Photobioreactors	10.3389/fenrg.2018.00049	Huo et al. (2018)	[64]
Prediction of Volumetric Productivity of an Outdoor Photobioreactor	10.1002/bit.21319	Bosma et al. (2006)	[75]
An Interactive Tool for Outdoor Computer Controlled Cultivation of Microalgae in a Tubular Photobioreactor System	10.3390/s140304466	Dormido et al. (2014)	[33]
Airlift-driven external-loop tubular photobioreactors for outdoor production of microalgae: assessment of design and performance	10.1016/S0009-2509(00)00521-2	Fernhndez et al. (2001)	[90]
Eicosapentaenoic acid production from *Nannochloropsis* oceanica CY2 using deep sea water in outdoor plastic-bag type photobioreactors	10.1016/j.biortech.2017.12.102	Chen et al. (2018)	[78]
A novel horizontal photobioreactor for high-density cultivation of microalgae	10.1016/j.biortech.2015.09.030	Dogaris et al. (2009)	[77]
Outdoor Cultivation of the Microalga *Chlorella* vulgaris in a New Photobioreactor Configuration: The Effect of Ultraviolet and Visible Radiation	10.3390/en13081962	Lopes et al. (2020)	[61]
Lipid accumulation and growth of *Chlorella* zofingiensis in flat plate photobioreactors outdoors	10.1016/j.biortech.2011.08.109	Feng et al. (2011)	[65]
Comparison of Microalgae cultivation in Photobioreactor, Open raceway Pond, and a Two-stage hybrid system	10.3389/fenrg.2016.00029	Narala et al. (2016)	[121]
Outdoor Helical Tubular Photobioreactors for Microalgal Production: Modeling of Fluid-Dynamics and Mass Transfer and Assessment of Biomass Productivity	10.1002/bit.10543	Hall et al. (2002)	[91]
Irradiance optimization of outdoor microalgal cultures using solar tracked photobioreactors	10.1007/s00449-012-0790-5	Hindersin et al. (2013)	[62]
Energy efficiency of an outdoor microalgal photobioreactor sited at mid-temperate latitude	10.1016/j.biortech.2011.03.098	Hulatt et al. (2011)	[107]
Outdoor Growth Characterization of an Unknown Microalga Screened from Contaminated *Chlorella* Culture	10.1155/2017/5681617	Huo et al. (2017)	[123]

Effects of Environmental Factors on the Growth, Optical Density and Biomass of the Green Algae *Chlorella* Vulgaris in Outdoor Conditions	10.4314/jasem.v20i1.16	Fatemeh and Mohsen (2016)	[63]
Enhanced Oil Production by the Tropical Marine Diatom *Thalassiosira* Sp. Cultivated in Outdoor Photobioreactors	10.1007/s12010-017-2421-8	Kusumaningtyas et al. (2017)	[122]
Modeling Microalgae Productivity in Industrial- Scale Vertical Flat-Panel Photobioreactors	10.1021/acs.est.7b05545	Endres et al. (2018)	[38]
Operational Strategies for Cost Effective Mass Cultivation of Halophilic Microalgal Strain *Pseudanabaena* limnetica in 1000 L Flat-Panel Photobioreactor	10.4172/2157-7463.1000380	Sampat and Arun (2018)	[37]
Outdoor Large-Scale Cultivation of the Acidophilic Microalga *Coccomyxa* onubensis in a Vertical Close Photobioreactor for Lutein Production	10.3390/pr8030324	Fuentes et al. (2020)	[153]
Design tool and guidelines for outdoor photobioreactors	10.1016/j.ces.2013.11.014	Lee et al. (2014)	[25]
Nannochloropsis production metrics in a scalable outdoor photobioreactor for commercial applications	10.1016/j.biortech.2012.04.073	Quinn et al. (2012)	[82]
Prediction of Dissolved Oxygen and Carbon Dioxide Concentration Profiles in Tubular Photobioreactors for Microalgal Culture	10.1002/(SICI)1097-0290(19990105)62:1<71::AID-BIT9>3.0.CO;2-T	Rubio et al. (1999)	[103]
Comparison of four outdoor pilot-scale photobioreactors	10.1186/s13068-015-0400-2	De-Vree et al. (2015)	[85]
Design scenarios of outdoor arrayed cylindrical photobioreactors for microalgae cultivation considering solar radiation and temperature	10.1016/j.algal.2019.101515	Huanga et al. (2019)	[129]
Process of outdoor thin-layer cultivation of microalgae and blue-green algae and bioreactor for performing the process	Patent Number: US5981271A	Doucha et al. (1999)	[135]
PHOTOBIOREACTOR SYSTEMS AND METHODS FOR GROWING ORGANISMS	Patent Number: US 2009/0203067 A1	ECKERLE et al. (2009)	[154]
Selection of microalgae for biodiesel production in a scalable outdoor photobioreactor in north China	10.1016/j.biortech.2014.10.008	Xia et al. (2014)	[69]
Techno-economics of algae production in the Arabian Peninsula	10.1016/j.biortech.2021.125043	Schipper et al. (2021)	[36]
Outdoor performance of *Chlorococcum* littorale at different locations	10.1016/j.algal.2017.08.010	Cabanelas et al. (2017)	[66]
Maximizing the solar to H_2 energy conversion efficiency of outdoor photobioreactors using mixed cultures	10.1016/j.ijhydene.2009.11.030	Berberoglu and Pilon (2010)	[53]
Use of concentric-tube airlift photobioreactors for microalgal outdoor mass cultures	10.1016/S0141-0229(98)00103-3	Camacho et al. (1999)	[92]
Outdoor production of *Phaeodactylum* tricornutum biomass in a helical reactor	10.1016/S0168-1656(03)00101-9	Fernandez et al. (2003)	[93]
Production and monitoring of biomass and fucoxanthin with brown microalgae under outdoor conditions	10.1002/bit.27657	Gao et al. (2021)	[94]
Developing microalgal oil production for an outdoor photobioreactor	10.1007/s10811-021-02374-7	Norsker et al. (2021)	[26]
Theoretical Investigation of Biomass Productivities Achievable in Solar Rectangular Photobioreactors for the Cyanobacterium *Arthrospira* platensis	10.1002/btpr.1540	Pruvost et al. (2012)	[22]
Microalgae for Oil: Strain Selection, Induction of Lipid Synthesis and Outdoor Mass Cultivation in a Low-Cost Photobioreactor	10.1002/bit.22033	Rodolfi et al. (2009)	[86]
Seasonal variation of biomass and oil production of the oleaginous diatom *Fistulifera* sp. in outdoor vertical bubble column and raceway-type bioreactors	10.1016/j.jbiosc.2013.11.017	Sato et al. (2014)	[70]
Design scenarios for flat panel photobioreactors	10.1016/j.apenergy.2010.12.037	Slegers et al. (2011)	[34]
Evaluation of a vertical flat-plate photobioreactor for outdoor biomass production and carbon dioxide bio-fixation: effects of reactor dimensions, irradiation and cell concentration on the biomass productivity and irradiation utilization efficiency	10.1007/s002530000550	Zhang et al. (2001)	[117]

Photosynthetic performance of a cyanobacterium in a vertical flat-plate photobioreactor for outdoor microalgal production and fixation of CO_2	10.1023/A:1026737000160	Zhang et al. (2001)	[125]
Feasibility of biodiesel production by microalgae *Chlorella* sp. (FACHB-1748) under outdoor conditions	10.1016/j.biortech.2013.03.169	Zhou et al. (2013)	[60]
Indoor and outdoor cultivation of *Chlorella* vulgaris and its application in wastewater treatment in a tropical city—Bangkok, Thailand	10.1007/s42452-019-1704-9	Sarker and Salam (2019)	[10]
Design of batch algal cultivation systems and ranking of the design parameters	10.1007/s40974-020-00149-3	Sarker and Salam (2020)	[35]
Exploring the potential of wastewater reclamation by means of outdoor cultivation of microalgae in photobioreactors	10.1007/s40974-021-00207-4	Sarker (2021)	[54]
Comparative analysis of the outdoor culture of *Haematococcus* pluvialis in tubular and bubble column photobioreactors	10.1016/j.jbiotec.2005.11.010	Lopez et al. (2006)	[72]
A closed solar photobioreactor for cultivation of microalgae under supra-high irradiance: basic design and performance	10.1023/A:1023849117102	Masojídek et al. (2003)	[109]
Production of Spirulina Biomass in Closed Photobioreactors	10.1016/0144-4565(86)90021-1	Torzillo et al. (1986)	[108]
Temperature as an Important Factor Affecting Productivity and Night Biomass Loss in *Spirulina* platensis Grown Outdoors in Tubular Photobioreactors	10.1016/0960-8524(91)90137-9	Torzillo et al. (1991)	[110]
Effect of temperature on yield and night biomass loss in *Spirulina* platensis grown outdoors in tubular photobioreactors	10.1007/BF00003691	Torzillo et al. (1991)	[111]
Use of chlorophyll fluorescence to estimate the effect of photoinhibition in outdoor cultures of *Spirulina* platensis	10.1007/BF02185901	Vonshak et al. (1994)	[112]
Productivity of Spirulina in a strongly curved outdoor tubular photobioreactor	10.1007/s002530050642	Carlozzi and Torzillo (1996)	[113]
Hydrodynamic aspects and Arthrospira growth in two outdoor tubular undulating row photobioreactors	10.1007/s002530000355	Carlozzi (2000)	[50]
Lutein production by *Muriellopsis* sp. in an outdoor tubular photobioreactor	10.1016/S0168-1656(00)00380-1	Campo et al. (2001)	[76]
Transient analysis and performance studies of two tubular photobioreactors for outdoor culture of *Spirulina*	10.1002/er.4440190603	Prakash et al. (1995)	[114]
Light and oxygen stress in *Spirulina* platensis (cyanobacteria) grown outdoors in tubular reactors	10.1111/j.1399-3054.1996.tb00494.x	Vonshak et al. (1996)	[115]
Effect of Photobioreactor Inclination on the Biomass Productivity of an Outdoor Algal Culture	10.1002/bit.260380906	Lee and Low (1991)	[56]
Absorber Tower as a Photobioreactor for Microalgae	10.1023/A:1026663329682	Petkov (2000)	[128]
Production of *Chlorella* Biomass in Different Types of Flat Bioreactors in Temperate Zones	10.1016/0144-4565(86)90062-4	De-Ortega and Roux (1986)	[57]
A new tubular reactor for mass production of microalgae outdoors	10.1007/BF02186235	Richmond et al. (1993)	[49]
Biomass production and studies on *Rhodopseudomonas* palustris grown in an outdoor, temperature controlled, underwater tubular photobioreactor	10.1016/s0168-1656(01)00280-2	Carlozzi and Sacchi (2001)	[105]
Production of eicosapentaenoic acid by *Nannochloropsis* sp. cultures in outdoor tubular photobioreactors	10.1016/S0079-6352(99)80122-2	Zittelli et al. (1999)	[87]
Growth characteristics of *Rhodopseudomonas* palustris cultured outdoors, in an underwater tubular photobioreactor, and investigation on photosynthetic efficiency	10.1007/s00253-006-0550-z	Carlozzi, et al. (2006)	[106]
Invention of outdoor closed type photobioreactor for microalgae	10.1016/j.enconman.2005.06.010	Sato et al. (2006)	[52]
A Two-Plane Tubular Photobioreactor for Outdoor Culture of Spirulina	10.1002/bit.260420714	Torzillo et al. (1993)	[116]
A vertical alveolar panel (VAP) for outdoor mass cultivation of microalgae and cyanobacteria	10.1016/0960-8524(91)90147-C	Tredici et al. (1991)	[48]
Efficiency of Sunlight Utilization: Tubular Versus Flat Photobioreactors	10.1002/(SICI)1097-0290(19980120)57:2<187::AID-BIT7>3.0.CO;2-J	Tredici and Zittelli (1998)	[51]
Productivity of *Nannochloropsis* oceanica in an industrial closely spaced flat-panel photobioreactor	10.1016/j.algal.2019.101632	Norsker et al. (2019)	[79]

Neochloris oleoabundans oil production in an outdoor tubular photobioreactor at pilot scale	10.1007/s10811-021-02400-8	Norsker et al. (2021)	[67]
Fucoxanthin production from *Tisochrysis* lutea and *Phaeodactylum* tricornutum at industrial scale	10.1016/j.algal.2021.102322	Pereira et al. (2021)	[95]
Effect of temperature on growth, photosynthesis and biochemical composition of *Nannochloropsis* oceanica, grown outdoors in tubular photobioreactors	10.1016/j.algal.2020.101923	Carneiro et al. (2020)	[80]
Industrial production of *Phaeodactylum* tricornutum for CO_2 mitigation: biomass productivity and photosynthetic efficiency using photobioreactors of different volumes	10.1007/s10811-019-1750-0	Quelhas et al. (2019)	[96]
Operation Regimes: A Comparison Based on *Nannochloropsis* oceanica Biomass and Lipid Productivity	10.3390/en14061542	Guerra et al. (2021)	[81]
A validated thermal and biological model for predicting algal productivity in large scale outdoor cultivation systems	10.1016/j.algal.2021.102224	Greene et al. (2021)	[71]
Scale-up and large-scale production of *Tetraselmis* sp. CTP4 (Chlorophyta) for CO2 mitigation: from an agar plate to 100-m3 industrial photobioreactors	10.1038/s41598-018-23340-3	Pereira et al. (2018)	[120]
Comparing EPA production and fatty acid profiles of three *Phaeodactylum* tricornutum strains under western Norwegian climate conditions	10.1016/j.algal.2017.12.001	Steinrücken et al. (2018)	[97]
Oil and Eicosapentaenoic Acid Production by the Diatom *Phaeodactylum* tricornutum Cultivated Outdoors in Green Wall Panel (GWPW) Reactors	10.1002/bit.26353	Rodolfi et al. (2017)	[98]
Productivity and biochemical composition of *Tetradesmus* obliquus and *Phaeodactylum* tricornutum: effects of different cultivation approaches	10.1007/s10811-016-0876-6	Buono et al. (2016)	[99]
Shear stress tolerance and biochemical characterization of *Phaeodactylum* tricornutum in quasi steady-state continuous culture in outdoor photobioreactors	10.1016/S1369-703X(03)00072-X	Mirón et al. (2003)	[100]
Turbidostat operation of outdoor pilot-scale photobioreactors	10.1016/j.algal.2016.06.006	de-Vree et al. (2016)	[88]
Seasonal Variation of Lipids and Fatty Acids of the Microalgae *Nannochloropsis* oculata Grown in Outdoor Large-Scale Photobioreactors	10.3390/en5051577	Olofsson et al. (2012)	[83]
Productivity and biochemical composition of *Phaeodactylum* tricornutum (Bacillariophyceae) cultures grown outdoors in tubular photobioreactors and open ponds	10.1016/j.biombioe.2013.03.016	Benavides et al. (2013)	[101]
Photoacclimation of *Phaeodactylum* tricornutum (Bacillariophyceae) cultures grown outdoors in photobioreactors and open ponds	10.1080/09670262.2012.683202	Torzillo et al. (2012)	[102]
Productivity and photosynthetic efficiency of outdoor cultures of *Tetraselmis* suecica in annular columns	10.1016/j.aquaculture.2006.08.011	Zittelli et al. (2006)	[118]
Energy balance of algal biomass production in a 1-ha "Green Wall Panel" plant: How to produce algal biomass in a closed reactor achieving a high Net Energy Ratio	10.1016/j.apenergy.2015.01.086	Tredici et al. (2015)	[119]
Marine microalgae for outdoor biomass production—A laboratory study simulating seasonal light and temperature for the west coast of Sweden	10.1111/ppl.13412	Cheregi et al. (2021)	[84]
Production of Microalgal Slow-Release Fertilizer by Valorizing Liquid Agricultural Digestate: Growth Experiments with Tomatoes	10.3390/app10113890	Jimenez et al. (2020)	[74]

Table S2. List of documents published on algal cultivation in outdoor PBRs.

Title	Inventors [Reference]	Patent number	Country	Year	Current Assignee
Impianto perfezionato per la coltura in strato laminate sottile dei microgranismi fotosinetetici.	M. R. Tredici, D. Mannelli, and R. Materassi [48]	9357 A/88 - CNR	Italy	1988	-
Process of outdoor thin-layer cultivation of microalgae and blue-green algae and bioreactor for performing the process	Jiri Doucha, Karel Livansky [135]	US5981271A	Czech Republic	1999	Mikrobiologicky Ustav Akademie Ved Ceske Republiky
Photobioreactor with improved supply of light by surface enlargement, wavelength shifter bars or light transport	Walter Trösch, Ulrike Schmid-Staiger, Armin Zastrow, Alexander Retze, Franz Brucker [155]	US6509188B1	Germany	2003	SUBITEC GmbH
Reactor for industrial culture of photosynthetic micro-organisms	Mario Tredici, Liliana Rodolfi [156]	EP1599570A2	Italy	2004	Universita degli Studi di Firenze
Photobioreactor systems and methods for growing organisms	Matthew W. Eckerle, Thomas W. Chalberg, JR., Cheryl A. Hackworth, Michael B. Fertik [136]	US20090203067A1	USA	2009	New American Energy, Inc. (U.S.)