HSLU Hochschule Luzern

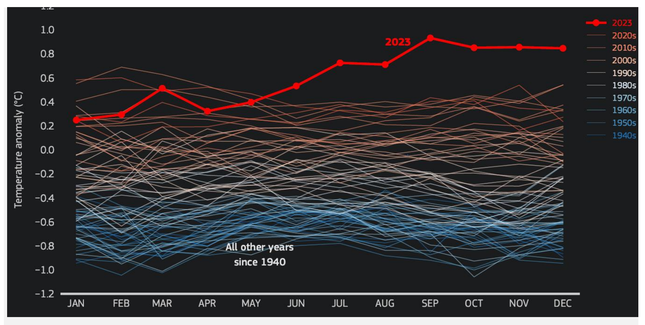
**Technik & Architektur**

Energy and Environment
Master Thesis

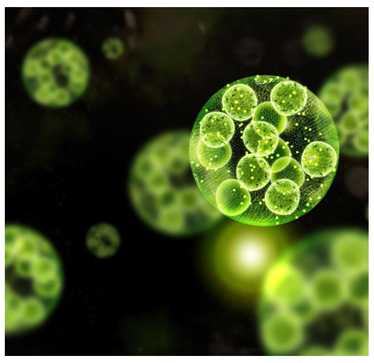
**Master Thesis**

# Theoretical and Experimental Characterization of a Lab Scale Thin-Layer-Cascade Photobioreactor for Carbon Dioxide Removal

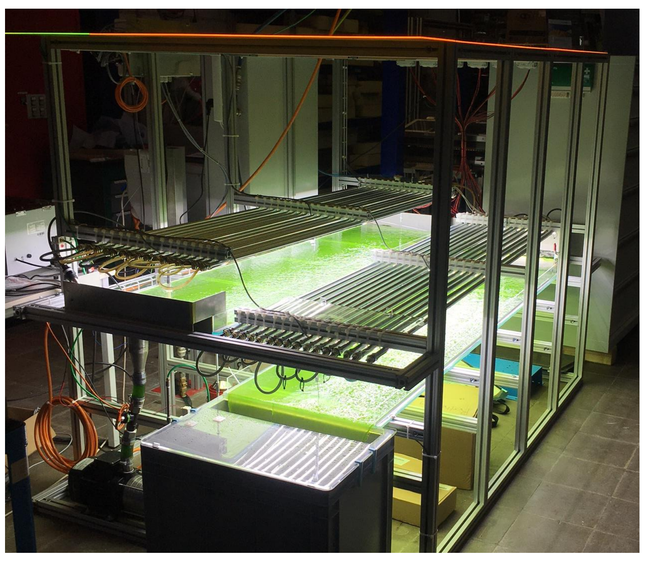
Microalgae, Photosynthesis, Chlorella Vulgaris, Hydrodynamic, Biomass Productivity




Average Global Temperatures



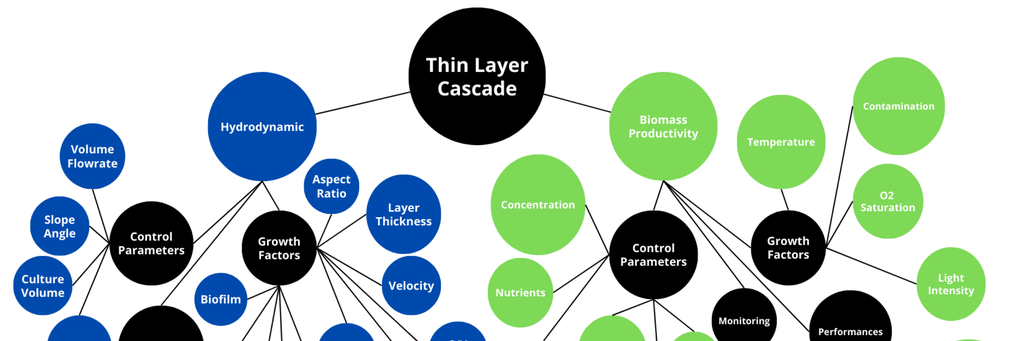
Chlorella Vulgaris



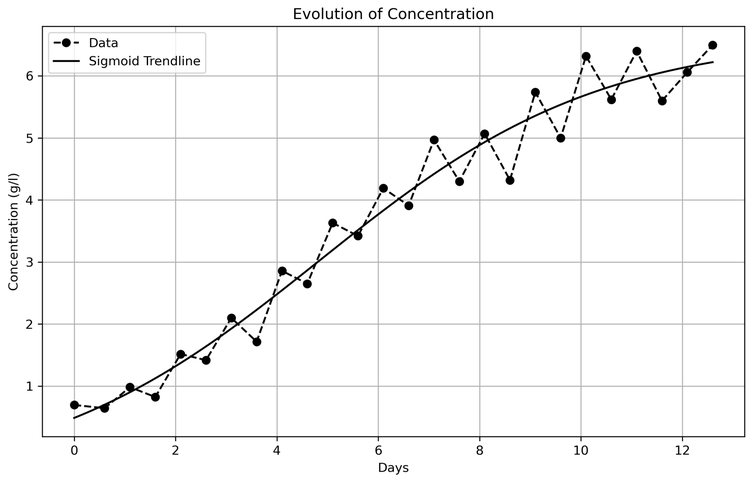
Lotus Mini



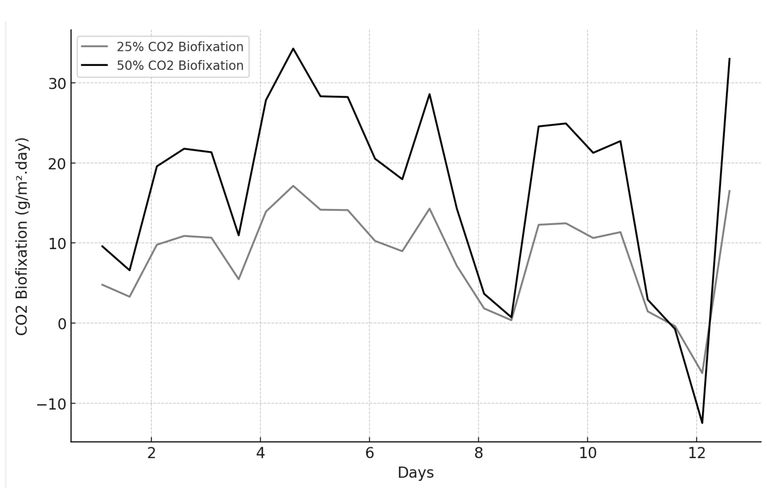

Principles of Microalgal Cultivation




Nexus of Parameters : Carbon Capture in a Thin Layer Cascade




Evolution of Concentration




Daily CO2 Fixation

First Generation Thin Layer Cascade

**Problem Statement**

To combat anthropogenic climate change, it is imperative not only to reduce CO2 emissions but also to deploy Negative Emission Technologies (NET) on a large scale. Switzerland committed to a net-zero target for 2050, necessitating long-term Carbon Dioxide Removal (CDR) from the atmosphere. Achieving net zero means that by 2050, any remaining CO2 emissions must be balanced by removing an equivalent amount from the atmosphere using natural and engineered storage solutions. NET includes various methods such as afforestation, ocean fertilization, and the replacement of concrete and metals with wood, among others, with microalgae photobioreactors emerging as a highly efficient approach.

Arrhenius AG is exploring Thin-Layer Cascade reactors for microalgae cultivation, starting with the 2 m² lab-scale reactor: Lotus mini. TLC reactors are characterized high photosynthetic efficiency, low energy consumption, and enhanced production rates.

**Solution Concept**

This work aims to understand the Lotus mini's behavior across various parameters to identify weaknesses and optimize its design and operations for efficient large-scale CDR. Initially, hydrodynamic characterization is performed with fresh water, followed by biomass productivity analysis using Chlorella Vulgaris.

**Results**

The initial characterization with fresh water demonstrated decent hydrodynamic and mixing performances of the Lotus mini, with a layer thickness of 4.8 mm, an average velocity of 51 cm/s, and a Photosynthetic Photon Flux Density (PPFD) of 1000 µmol/m².s. Calculations showed the importance of increasing the Surface to Volume (S/V) ratio to enhance performance.

The subsequent biomass growth evaluation using Chlorella Vulgaris demonstrated the Lotus mini's capacity to effectively grow microalgae, with results comparable to literature despite being lower than expected. The maximum concentration reached 6.5 g/l, with an average net areal productivity of 9.3 g/m².day, an average Photosynthetic Efficiency (PE) of 4.2%, and a CO2 biofixation rate ranging from 8.5 to 17.1 g/m².day, peaking at 34.3 g/m².day.

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