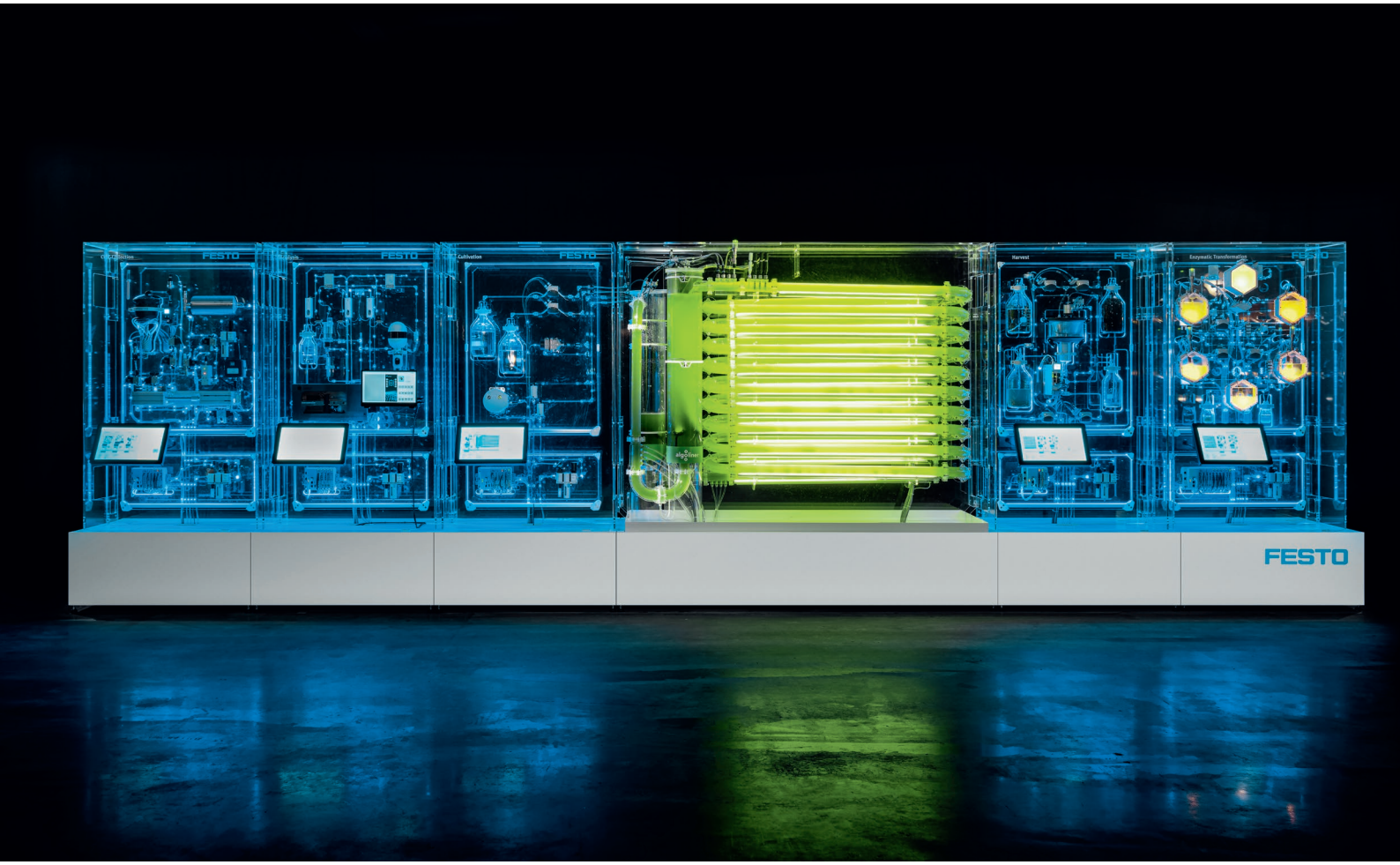
BionicCellFactory

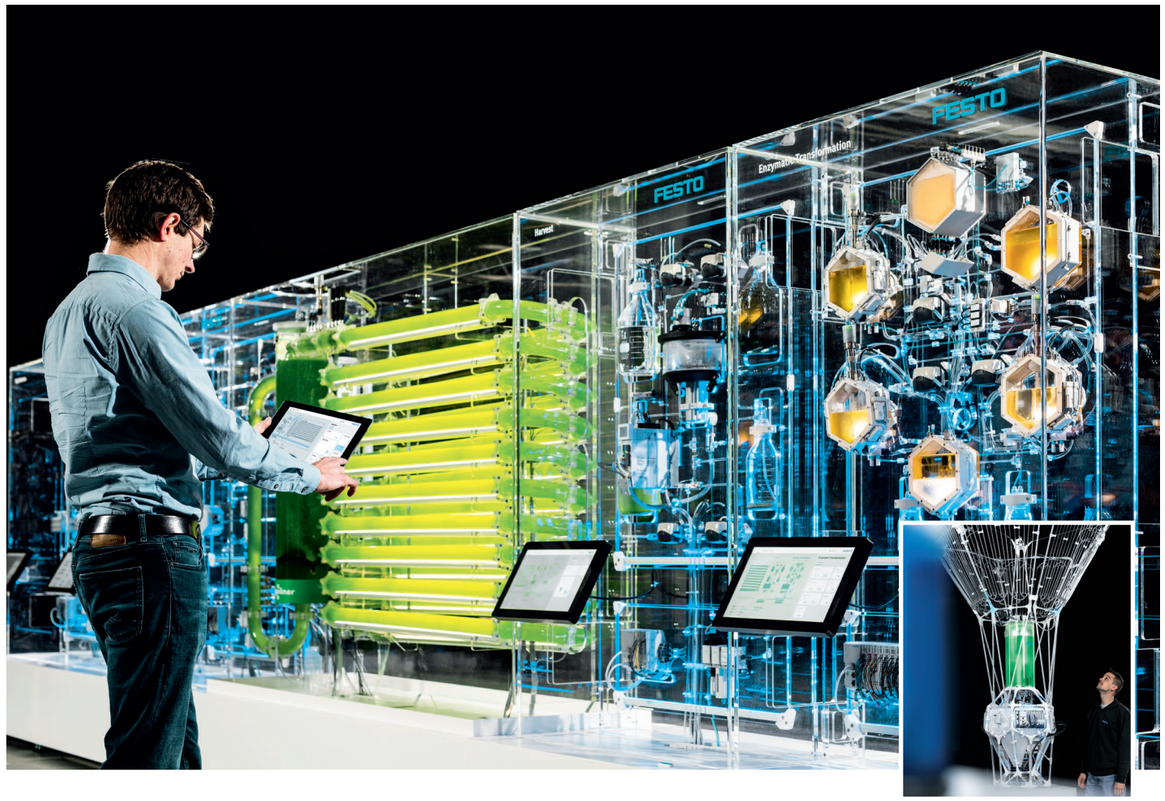
Cultivation of biomass on an industrial scale

FESTO



01: **BionicCellFactory:** Holistic bioprocess in five modules

02: **PhotoBionicCell:** Our first bioreactor with a capacity of 10 litres for the automated cultivation of algae.



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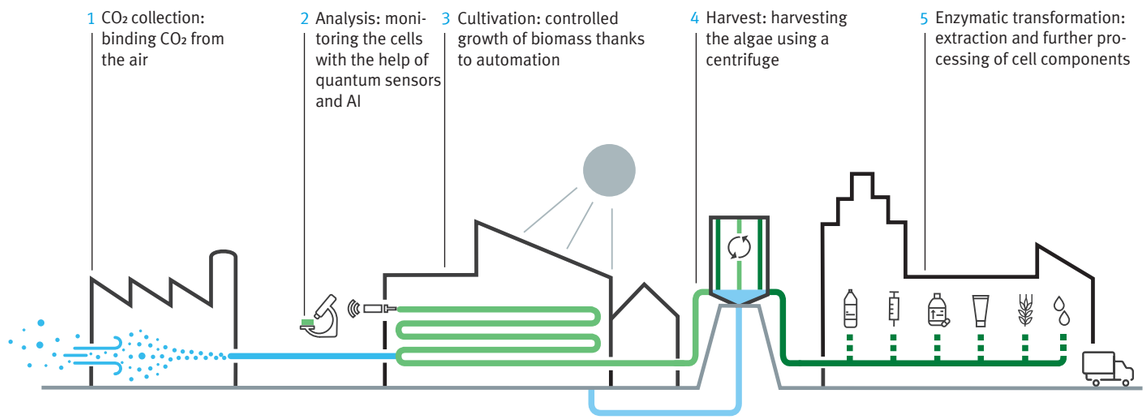


Production systems of the future
As a model factory, the BionicCellFactory is the universal blueprint for holistic production systems of the future. With the help of our automation technology, it can be scaled to any size. In order to meet future demand for renewable raw materials, bioreactors with a capacity of several thousand litres are needed. Expertise in process automation is required to ensure that the plants can reliably produce the desired quantities of biomass.

Biological transformation portfolio
Together with its customers, Festo develops intelligent control cabinet solutions for bioreactors and continues to expand its portfolio. We ensure stable and precise process control with maximum productivity.

This includes optimised fumigation and feeding strategies, control algorithms, soft sensors for real-time biomass determination, and system concepts for bio-based production processes. We will also support plant operators with remote diagnostics, maintenance and control via the cloud.

Robust value creation processes and easy operation of the system modules will be important if a large number of modular production units for the extraction of raw materials and carbon fixation are to be built and operated around the world in the future.

New job profiles for new technologies
However, highly qualified technical staff and biotechnologists are not available everywhere. To this end, our experts at Festo Didactic are already analysing the new knowledge requirements in order to define interdisciplinary links and establish innovative apprenticeships, degree programs and additional qualifications in the fields of biomechatronics, biointelligence and sustainability. The paradigm shift affects future-oriented business areas and professional requirements in equal measure.

That's why we are already holistically setting the course for the biological transformation of the economy towards an environmentally friendly circular economy. After all, it is only through the interplay of technology and education that the global challenges of the 21st century can be tackled responsibly.

Climate and resource protection are two of the great challenges of our time. How can we extract CO_2 from the atmosphere and actively contribute to climate protection? How can we reduce our material consumption, recycle more materials and at the same time access alternative raw materials?

At Festo, we have been dealing with these questions for some time and are breaking new ground: we transfer our expertise in automation technology to biological processes. Here, too, nature is our great paragon. It teaches us about resource efficiency, because in nature there is no waste or wastage. We scale and accelerate solutions from the laboratory format and bring them to industrial application through the interplay of biological and technical processes.

The cell as a factory
Living cells are the smallest factories in the world. Algae's chloroplast cells photosynthesise to convert sunlight, carbon dioxide and water into oxygen and chemical energy sources – or valuable organic matter.

Optimised growth conditions thanks to automation
With our automation technology, biomass can be cultivated in a closed cycle in a highly efficient, resource-saving way and on a large scale. Everything that we currently produce from crude oil creating immense CO_2 emissions can also be obtained sustainably from algae. They are small planet protectors because they absorb ten times more CO_2 than land plants. This value can be increased by a factor of ten through automated cultivation in bioreactors. The biomass obtained can be used in the chemical, food or pharmaceutical industries.

Holistic process all the way up to harvesting and refinement
With the PhotoBionicCell project, we presented our first bioreactor for the automated cultivation of algae in 2022. This year, we're going even further. With the BionicCellFactory, we are demonstrating a holistic bioprocess – from the optimised cultivation of the algae on a large scale with continuous monitoring and analysis through to harvesting and the further processing and refinement of the various components.

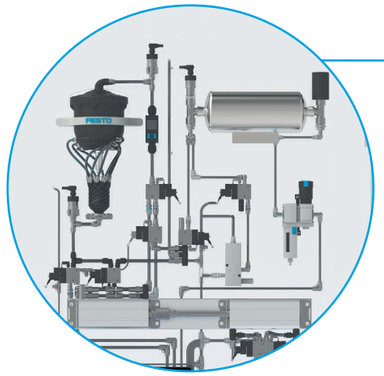
BionicCellFactory

The cell factory is divided into five modules in which nature and technology coalesce in different ways. In doing so, we present the BionicCellFactory as a tool for the biological transformation moving towards an environmentally friendly circular economy. In contrast to chemical processes, we manage without high temperatures, high pressures and toxins.

Module 1:

CO_2 collection: binding CO_2 from the air

Algae grow best at a CO_2 concentration of around two per cent. However, as our ambient air contains far less than one per cent, the CO_2 collection module enriches the algae with a higher concentration: it filters the required gas from compressed air by blowing it into a chamber with CO_2-binding granules. The granulate consists of a polymer that can absorb or release CO_2 depending on the prevailing conditions. Once the granulate has absorbed sufficient CO_2, it is heated to a temperature of 90 degrees Celsius to release the gas again. The concentrated CO_2 is then cooled in an intermediate storage tank and blown into the bioreactor via an aeration element.

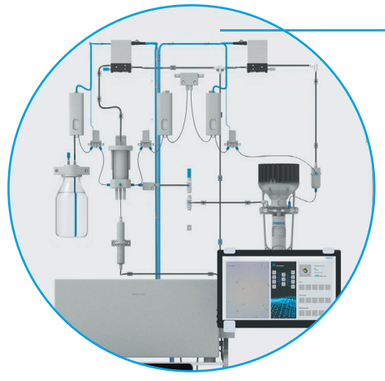


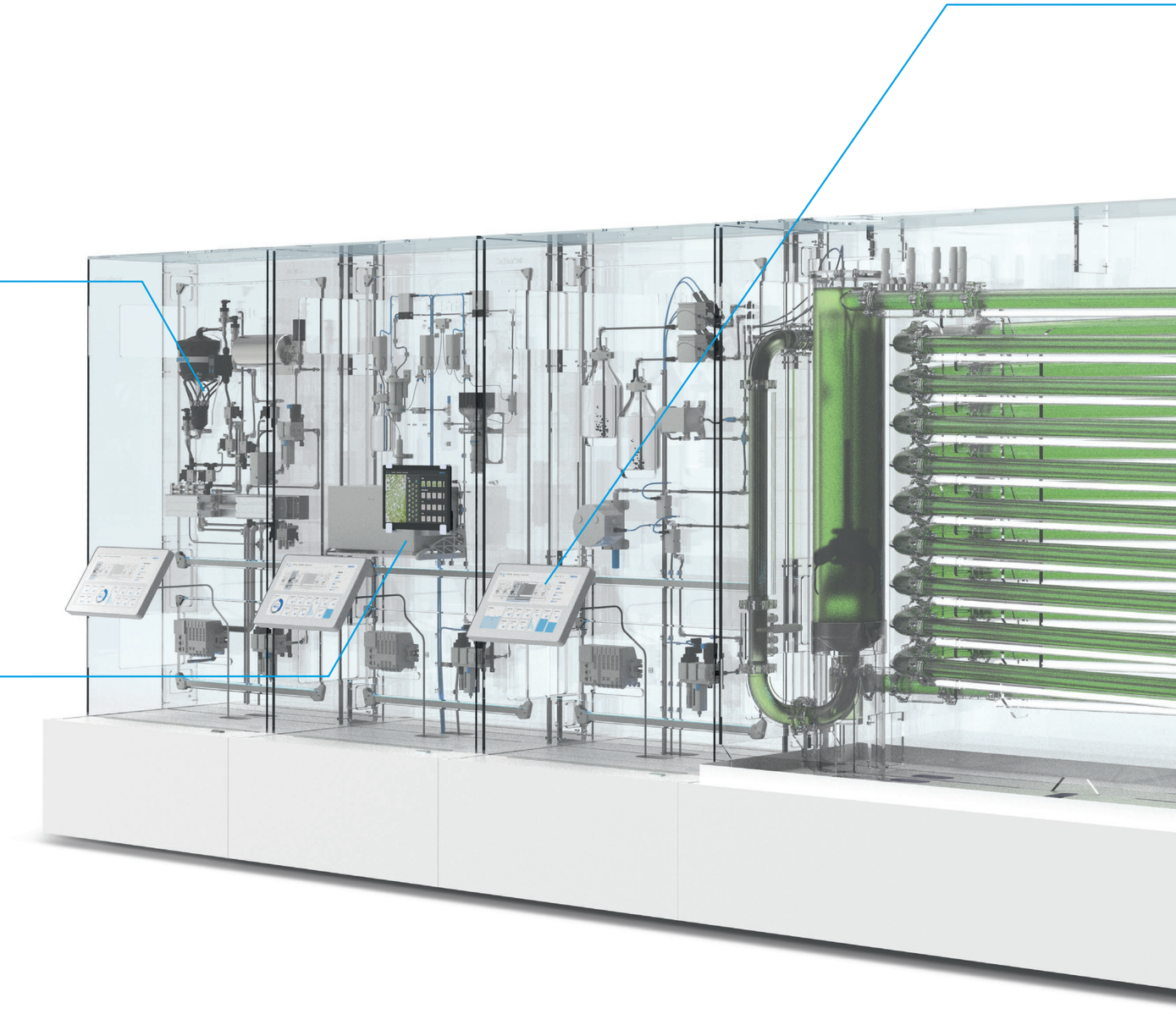
Module 2:

Analysis: monitoring cells using quantum sensors and AI

A major challenge for bioreactors is determining the amount of biomass. In the analysis module, we use an optical method based on microscopy and AI, as well as quantum technology. The digital microscope continuously delivers images that are analysed by AI. Through training images, it learned to recognise the algae cells.

For the quantum-based particle sensor, a precision pump transports the algae cells from the cultivation system. Using a precise valve system, they are fed to a mixing container where they are diluted with water for optimal analysis conditions. The pressure-over-liquid principle enables a uniform flow rate and directs the mixture to the quantum sensor. The sensor – developed by the start-up Q.ANT – delivers huge amounts of data, which can consist of the size and number of algae as well as foreign bodies. These analyses make it possible to react to process events in advance and intervene in a regulatory manner.

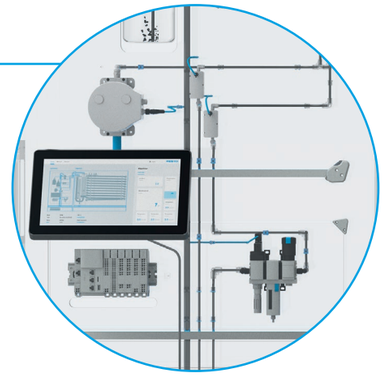


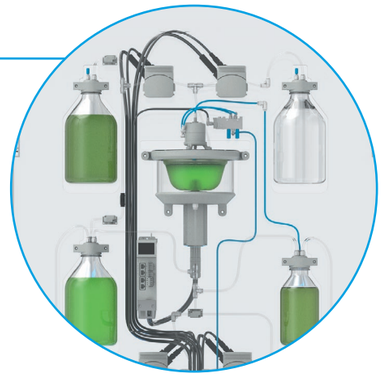


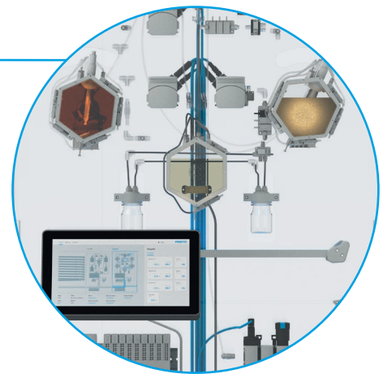
Control architecture

The modular structure of the BionicCellFactory is also reflected in the control architecture: each module is controlled by a CPX-E controller from Festo. This means that the five process steps can be put into operation both in combination and separately and can be easily replaced in the event of production changes.

Using dashboards on the respective control panel, experts can monitor and modify individual parameters of the process steps. Data exchange between the modules takes place via OPC UA and enables efficient control of the entire BionicCellFactory.







Module 3:

Cultivation: controlled growth through automation

The heart of the BionicCellFactory is a 45-metre-long tube system from Algoliner with a capacity of 80 litres. In this transparent, illuminated photo series, the algae cells perform their photosynthesis under optimal growth conditions. Sensors continuously measure conductivity, pH, oxygen and CO_2 concentration as well as the temperature.

Depending on the algae's needs, the system supplies nutrients such as potassium, phosphorus and nitrogen. A heat exchanger ensures the right temperature. The mass-flow control and innovative piezo valve technology enable precise dosing of the air. Up to 20 litres per minute are supplied via a ventilation element. The resulting fine air bubbles ensure the optimum exchange of CO_2 and O_2 between algae and the environment.

Module 4:

Harvest: harvesting the algae using a centrifuge

The Harvest module is the interface between production and enzymatic transformation of biologically grown material. A centrifuge ensures that the biomass is harvested continuously: at a speed of 10,000 revolutions per minute, the algae cells are separated from their aqueous environment and pushed to the edge; the water is fed back into the process. The algae are then fed to the next module via a pump for further processing. The timing and quantity of the harvest are regulated in such a way that the vitality of the algae remains at the optimum level and the right amount of biomass is available for transformation in the next step.

Module 5:

Enzymatic transformation: extraction and further processing of cell components

Five transformation cubes with individual tasks create the ideal conditions for refining the algae with enzymes. They are biological catalysts that are fed in a targeted manner. This way, they support the gradual transformation, which requires no heavy metals at all.

In order to extract individual components from the harvested algae, molecular scissors cut open the cell walls and thus reach the ingredients: starch, proteins, dyes and the algae oil we want. This requires hardly any energy, as the environmentally friendly process takes place in mild – automatically controlled – ambient conditions of 40 degrees Celsius and a pH of five. The algae oil obtained can now be used as a food supplement and for the manufacture of cosmetics or further processed into energy sources or bioplastics. The algae residues can be used as feed or fertiliser.

Integrated components from Festo
Use the QR code to access our product selection for the automation of bioreactors.

Project participants

Project initiator: Dr Wilfried Stoll, managing partner, Festo Holding GmbH
Project team: Sebastian Schrof, Adrian Eilingsfeld, Cornelius Pflumm, Michael Jakob, Florian Zieker, Andreas Ulmer, Sandra Lichtenberger, Andreas Häckh, Charlotte Tesch, Ralf Kapfhamer, Julia Heidingsfeld, Dr Elias Knubben, Xiaojia Yao, Micha Purucker, Alexander Müller, Isabel Lamich, Nenja Rieskamp, Vanessa Bader, Philipp Steck, Dr Nina Gaißert, Philipp Eberl, Festo SE & Co. KG
Cooperation partners: Algoliner GmbH & Co. KG
Q.ANT GmbH

Technical data

- Technical data: 7 metres
- Cultivator capacity: 80 litres

Integrated components for algae cultivation:
- EMMT-AS servo motor
- VFOE one-way flow control valve
- VZWD and VZWF solenoid valves
- VEAB proportional pressure regulator valve
- VEMD proportional flow control valve
- VYKA media-separated solenoid valve
- SFAH flow sensor
- Quantum-based particle sensor from Q.ANT
- Tube system from Algoliner

Integrated components for enzymatic catalysis:
- DRVS semi-rotary drive
- VUVG solenoid valve
- VFOE one-way flow control valve
- VYKB media-separated solenoid valve

Integrated components for handling gases:
- ADN compact cylinder
- VUVG solenoid valve
- GRxA and GRxZ one-way flow control valve
- VFOE one-way flow control valve
- VPPM proportional pressure regulator valve
- SFAB flow sensor
- CRVZS air pressure reservoir

Components for control and compressed air preparation:
- CPX-E automation system
- MSB4 service unit

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