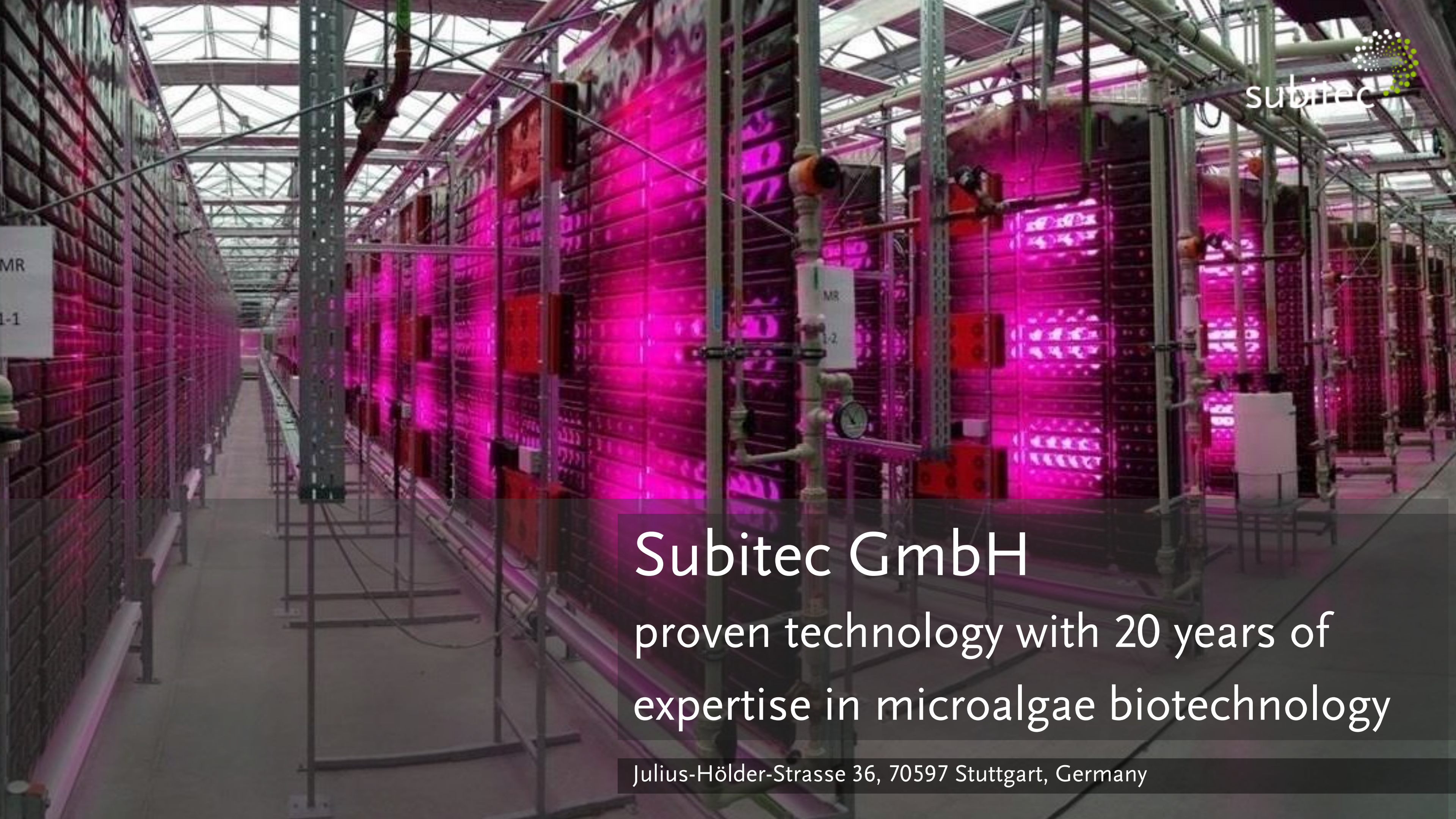


Subitec GmbH

proven technology with 20 years of expertise in microalgae biotechnology

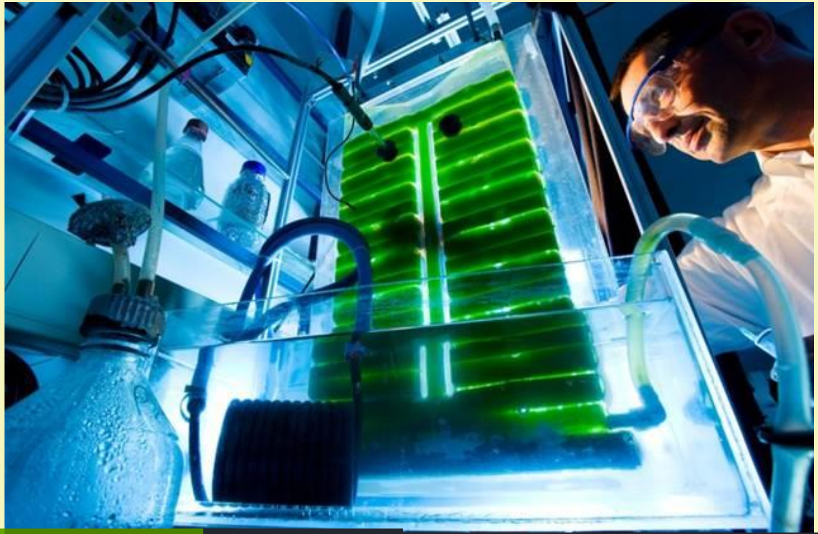
Julius-Hölder-Strasse 36, 70597 Stuttgart, Germany

Established in 2000 as a spin-off from the Fraunhofer Institute

More than 20 years of experience with microalgae

Process engineering and supply of cultivation equipment

Located in Stuttgart, Germany



Subitec in Brief

Our Technology – The FPA Photobioreactor

The Subitec FPA reactor brings the algae to the light

Efficient light utilization

No chemical/gaseous gradients

Excellent process reproducibility

Straightforward process control

➡ High volumetric productivity
➡ High biomass concentration

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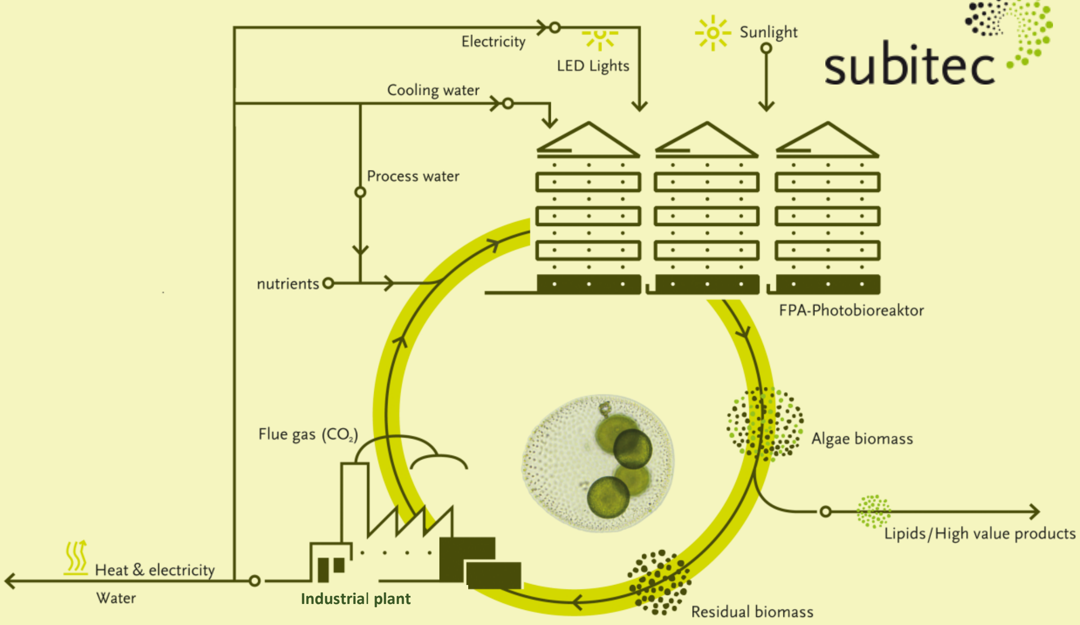
Proven Technology

Expert Services



Products and Services

Manual, semi-automatic, fully automatic cultivation systems

Proven cleaning and decontamination routines

Supplied also with single-use or sterilised reactors

Laboratory Cultivation Equipment

< 1 kg Biomass / Month with 6 Liter Reactor Capacity

Manual, semi-automatic, fully automatic cultivation systems

Proven cleaning and decontamination routines

Also supplied with single-use, sterilised reactors

Equipment for Scale-Up and Small Scale Production

< 5 kg Biomass per Month, 28...168 Liter Reactor Capacity

Indoor, greenhouse, outdoor

Integrated media preparation and harvesting systems

Exact represetnation of production conditions

Pilot Plants for Simulating Production Conditions

1…100 kg Biomass / Month with 180…3000 Liter Reactor Capacity

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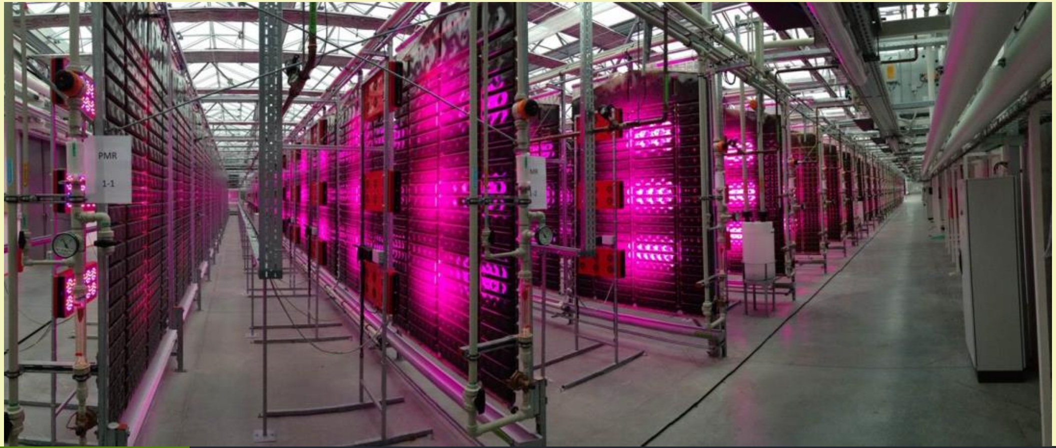
Indoor, greenhouse, outdoor

Automatic process control

Integrated cleaning and decontamination



Production Plants

1…100 Mta Biomass / Month with >10 m^3 Reactor Capacity

(Pre-)feasibility studies

Cultivation studies, process development and optimization

research and development

Supply of equipment and associated technical support

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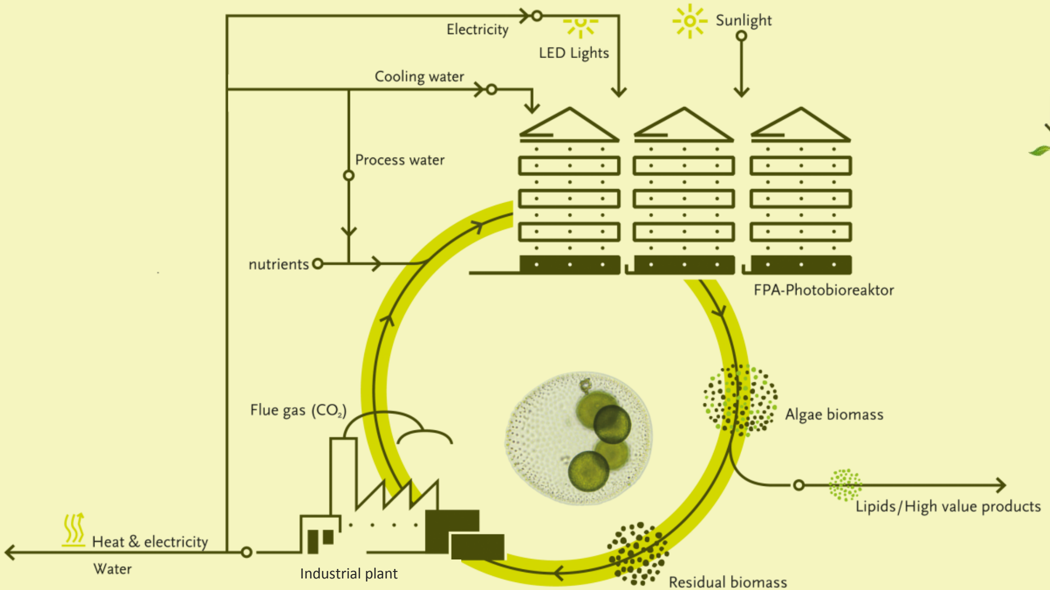
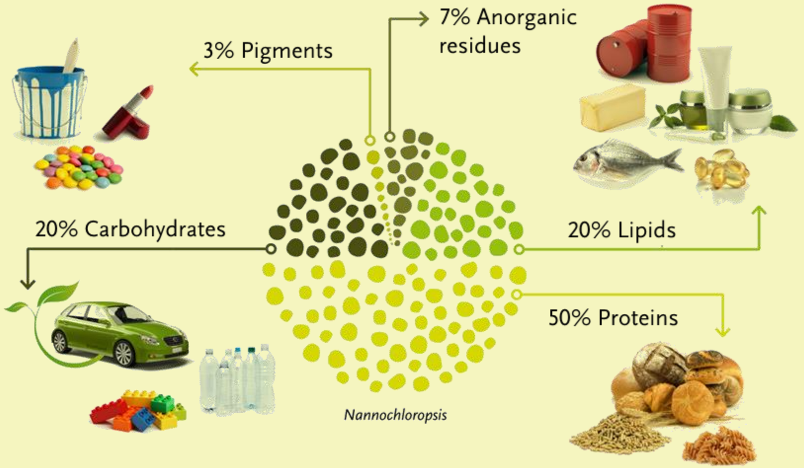
Services and Expertise

Your partner in developing your ideas to commercial applications

CONCEPTION – PROCESS AND FPA DESIGN VARIABLES

Application and economic production





User Requirements

- Application and algae
- Production requirements
- Regional and site specific requirements
- Process development and testing requirements
- Schedule and budget requirements

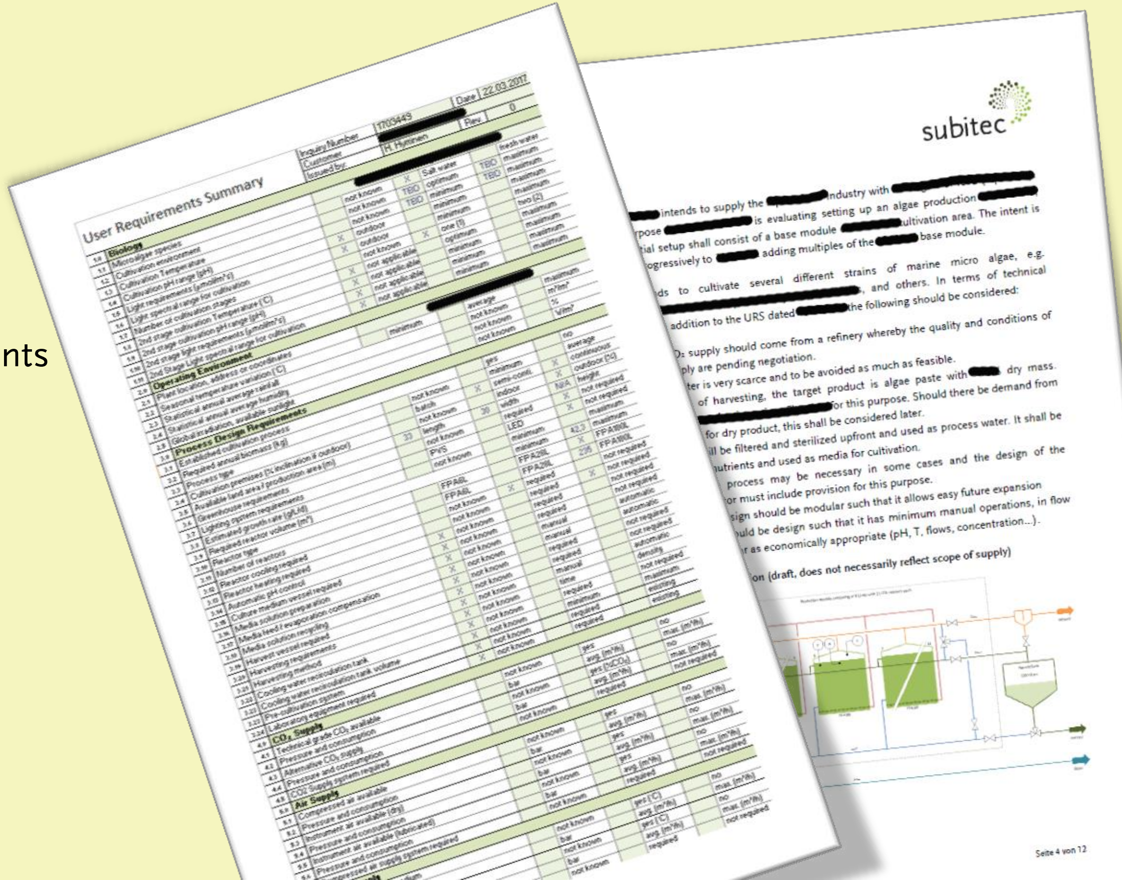
Form a common understanding of :

➡ the project goals

➡ the project scope

➡ the process requirements and,

➡ technical and other constraints



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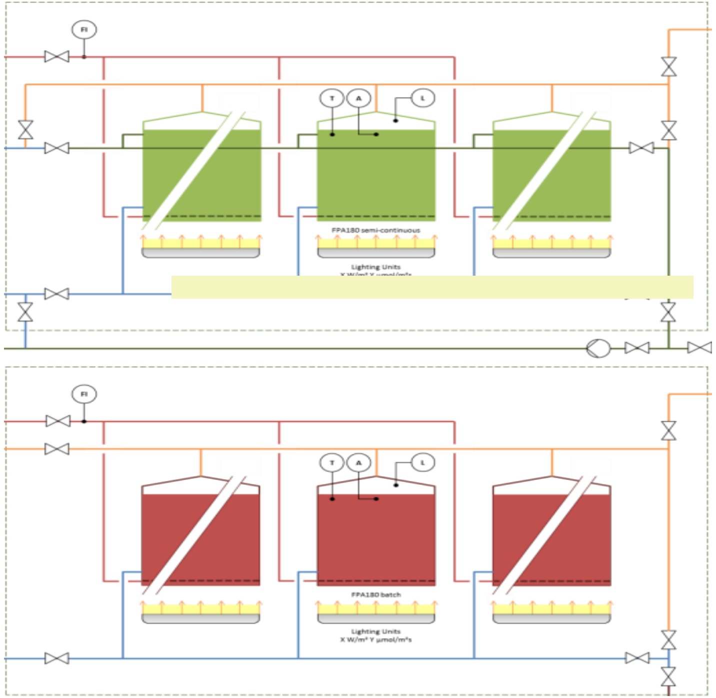
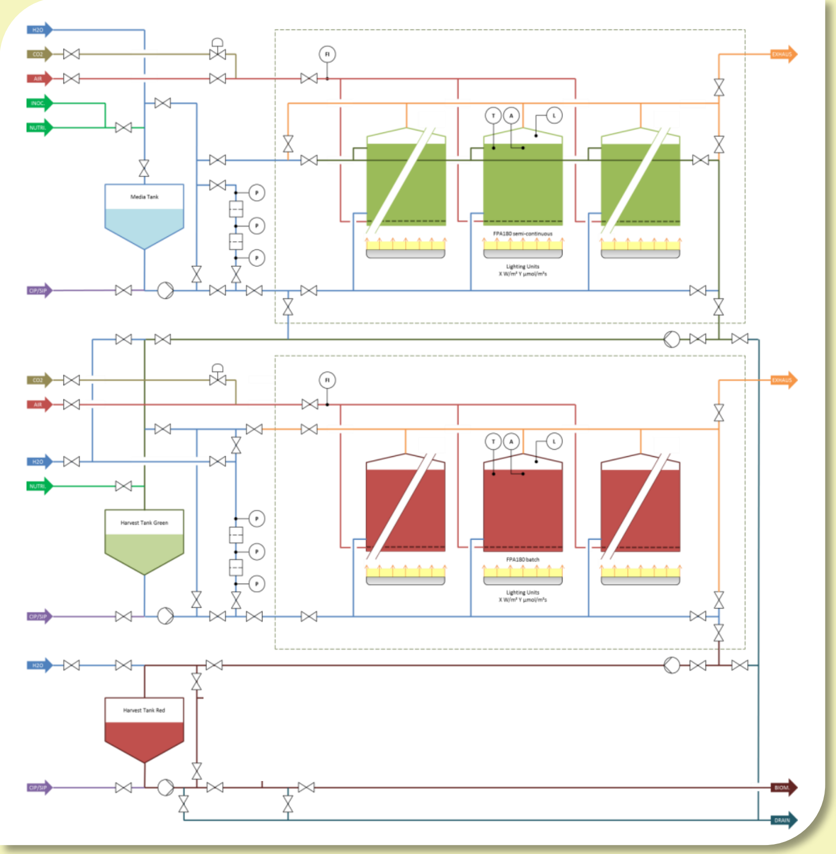
Process Design – Reactor System

- Alga specific productivity data, number and type of reactor modules, number or reactors in module, single or two stage process
- Number and type of lighting units, light intensity, static or variable intensity and spectrum, light controls, light distribution, light pollution prevention
- Gas supply and distribution, air and CO_2 source and quality, filtration and preconditioning, automatic or manual flow control and exhaust
- Temperature control: culture temperature, lighting system, environment



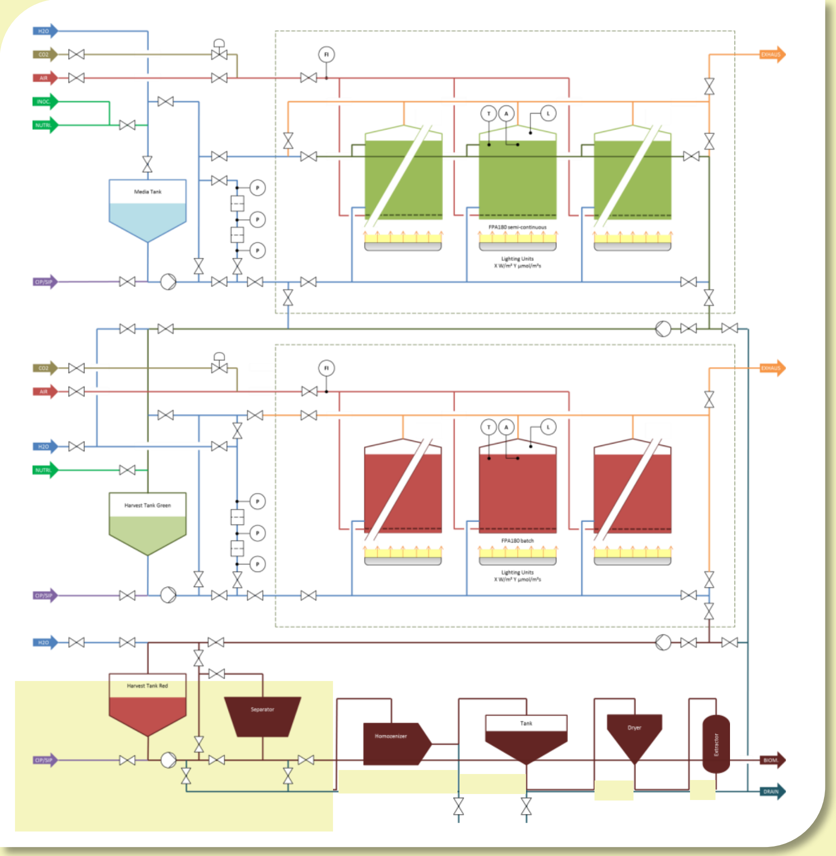
Process Design – Process and Utilities

- Inoculation system, pre-and starter culture holding, scale-up chain, process integrity upon culture transfer
- Media feed system, capacity, manual or automatic media preparation, filtration, feed, one or multiple media consistencies, cleaning and disinfecting.
- Harvesting system, method i.e. time or OD, automatic or manual e.g. sampling, harvest collection and transfer, harvest tank capacity.
- Cleaning and disinfection system, manual or automatic, chemical cleaning process, frequency and cleaning and disinfecting agents, sterilization – i.e. single-use technology available for axenic processing.
- Drainage and waste management, recycling?



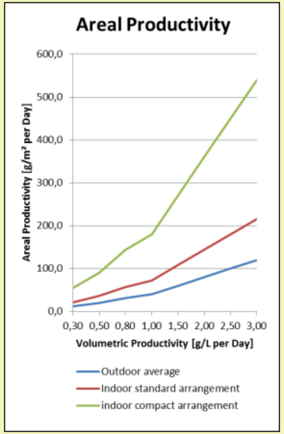
Process Design – Downstream

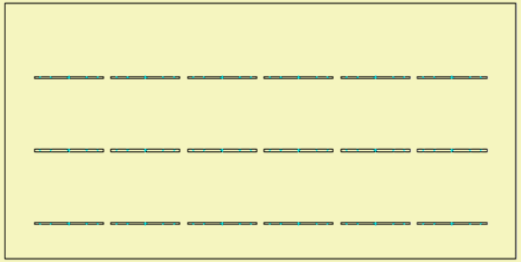
- Downstream processing dependent on required end product e.g. paste, dried product or extract
- Inhouse or outsourced to contract partners
- If outsourced, clarify product quality required for successful contract downstream processing e.g.
  - cell rupture
  - dried product moisture content
  - purity and content of desired ingredients
  - moisture content etc…
- Packaging and logistics
- Quality assurance



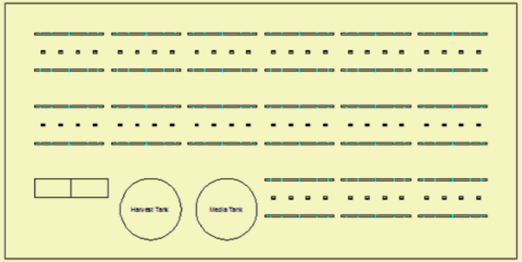
Layout Design

- Efficient utilization of available area, maximize area productivity
- Communicate and define interfaces with all parties involved, minimize risk of conflicts
- Well thought material and personnel flow improves safety and reduces risk of contamination
- Easily accessible operating areas and operator interfaces, keep walking distances short
- Provide sufficient service and maintenance access and areas to all equipment

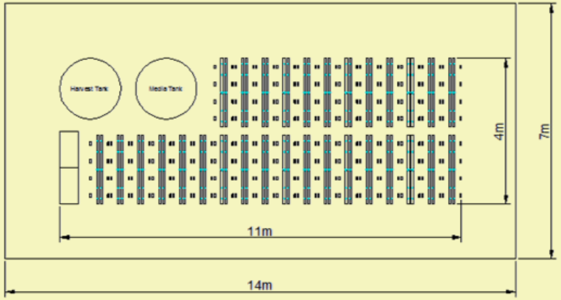




3,3m³ reactor volume
outdoor arrangement

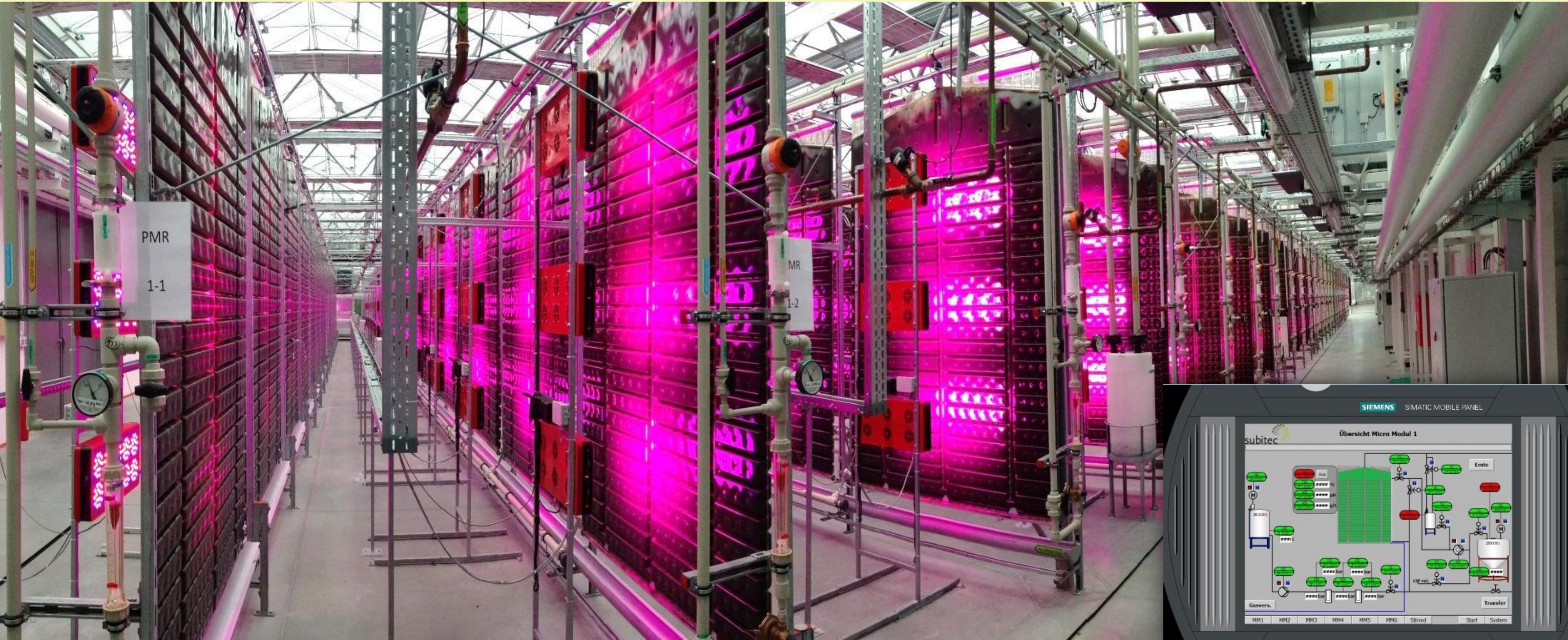


5,4m³ reactor volume
greenhouse, indoor



10,8m³ reactor volume
indoor, compact

Automation



PMR
1-1
MR
1-2
SIEMENS
SIMATIC MOBILE PANEL
subitec
Übersicht Micro Modul 1
Ernte
Gasvers.
Transfer
MM1
MM2
MM3
MM4
MM5
MM6
Stirred
Start
System

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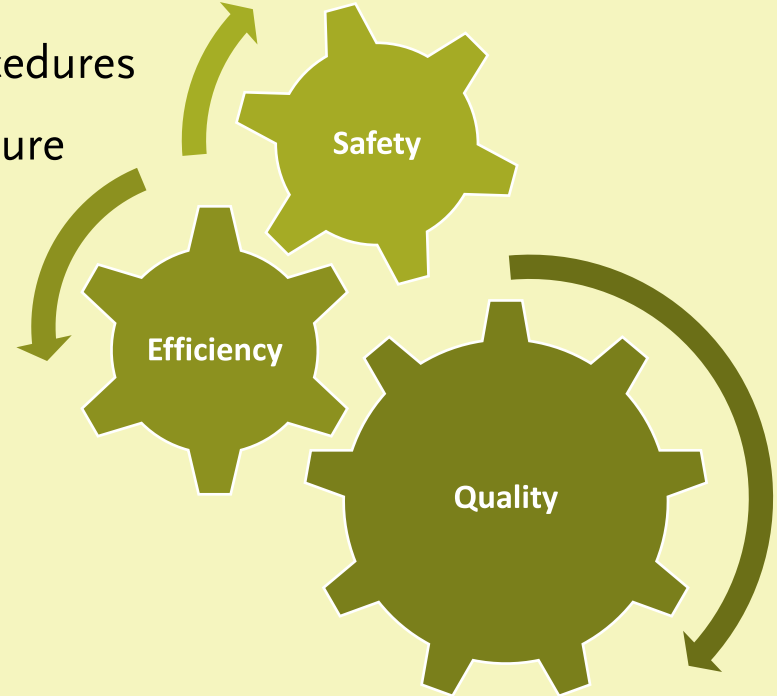
Electrification and Automation

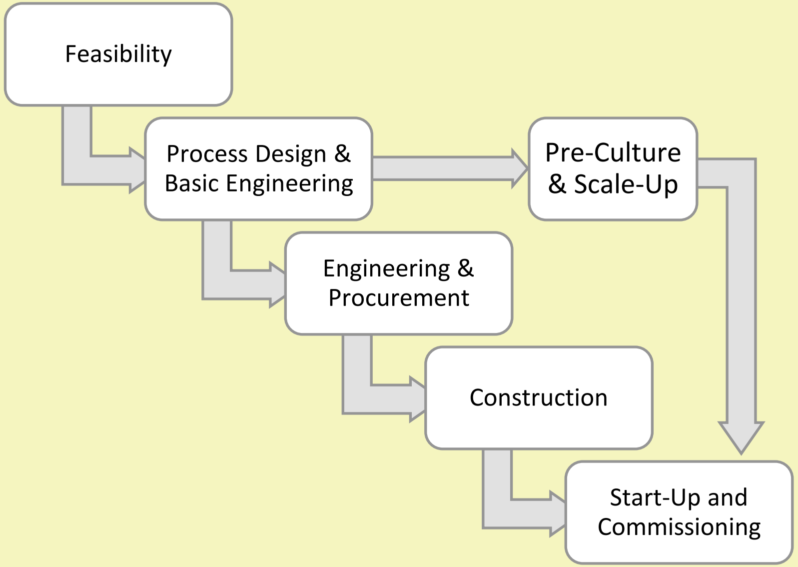
- Functional Design Specification describing all processes, manual, semi-automatic, automatic operations, alarms and operator functions
- Electrical design and control system architechture describing power supply and distribution, process automation platform and operator interfaces
- Process visualization and reporting
- Data recording requirements
- Security and access
- INTERFACES!!!

Interfaces, Handshakes, Integration

- Alarms, plant safety systems and emergency procedures
- Building, climate control, facilities and infrastructure
- Sub processes, utilities and process inflows
  e.g. air, CO_2, process- and cooling water etc…
- Downstream processing
- Waste management



Scheduling



- Include sufficient time in plan for review and approval of critical design documents
- Ensure transparency so that all parties work on the same schedule basis
- Prep scale-up culture to allow efficient commissioning after start-up
- Include contingency both in budget and schedule for the unexpected

CONSTRUCTION

Construction

Week 14 | Week 15 | Week 16

Receipt of major components

Move-in and Placement

Receipt of FPA reactors

Construction

Week 16 | Week 17 | Week 18

Site prep

Start Frame work and pipe runs

FPA Assembly

Construction

Week 19

Week 21

Week 23

Begin Electrical Installation

Framework and piping done

Mechanical and Electrical installation completed

Construction

Week 24

Week 30

Week 42

Cleanup and prep for Start-up

Start-up and Testing Completed

Commissioning completed

Summary

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- Thorough clarification, consultation and understanding of the user requirements is the basis for a feasible and satisfying outcome of any project. This can and should be formalized in writing.
- Uncertainty can be minimized by testing e.g. cultivation studies, process development and testing of different dewatering and drying techniques, extraction methods etc…
- In addition to formal training, the start-up and testing phase should be used as an opportunity to familiarize and train the users operation and maintenance staff on the equipment.
- Critical design documents e.g. process flow diagram, layout, functional design specification, electrical design and control system architecture should be reviewed and approved by the user or a qualified representative of the user. Once approved, any change or revision shall be subject to approval.
- Good project management practices and policies, open communication, transparency and documentation of project execution helps avoid costly pitfalls for all parties e.g. interfaces.

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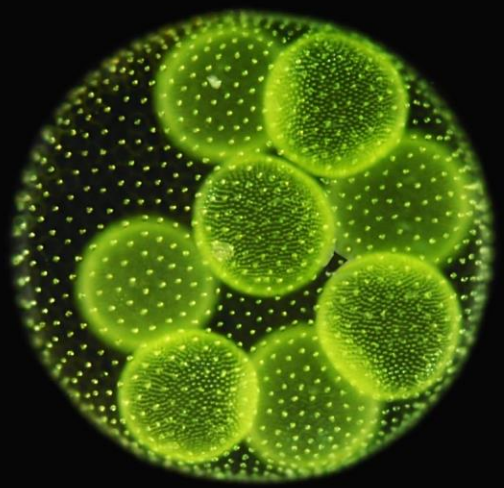
YES, IT'S PLASTIK – AND IT WORKS FINE!

- UV resistance, e.g. PMMA
- Light transparency as glass
- Excellent scratch resistance
- Light weight easy installation and service
- **Can be formed to optimize performance**

Thank you for your kind attention!

Questions?



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