GROWING FRESH FOOD FOR HUMANITARIAN CRISIS RESPONSE

Mobile emergency plant-growing application

MEPA

HUMANITARIAN HYDROPONICS

M.Sc. Markus Dorn (German Aerospace Center)

AGENDA

1 Project overview and objectives
2 Project history – milestones
3 Concept and design
4 MEPA operational scenario
5 Seed Cultivation Mat (SCM)
6 Automated Support Unit (ASU)
7 C.R.O.P. ®
8 Test phase (Laboratory)
9 Finale Test phases (Outdoor)
10 Outlook and conclusion

1 Project Overview

Initial Situation

- Located in Bremen, Institute of Space systems
- Based on space greenhouse technology for Moon & Mars (EDEN-ISS)
- Earth: **Humanitarian crisis scenarios** with breakdown of local agriculture
- Earthquakes, droughts, floods, hurricanes
- Political unrests

MEPA: Fresh food provision until local agriculture is restored

EDEN ISS greenhouse system in Antarctica

Deployment scenarios:

Earthquakes

Refugee camps

Droughts

Floods

1 Project Overview

Challenges

47 million

People across 54 countries are at an ‘emergency’ or worse level of hunger

333 million

People are facing acute food insecurity in 2023

23 current emergencies

Where WFP is currently responding

5 million tons

Of food delivered by WFP in 2022

USD $3.5 billion

Spend on food and delivery costs

1 Project Overview

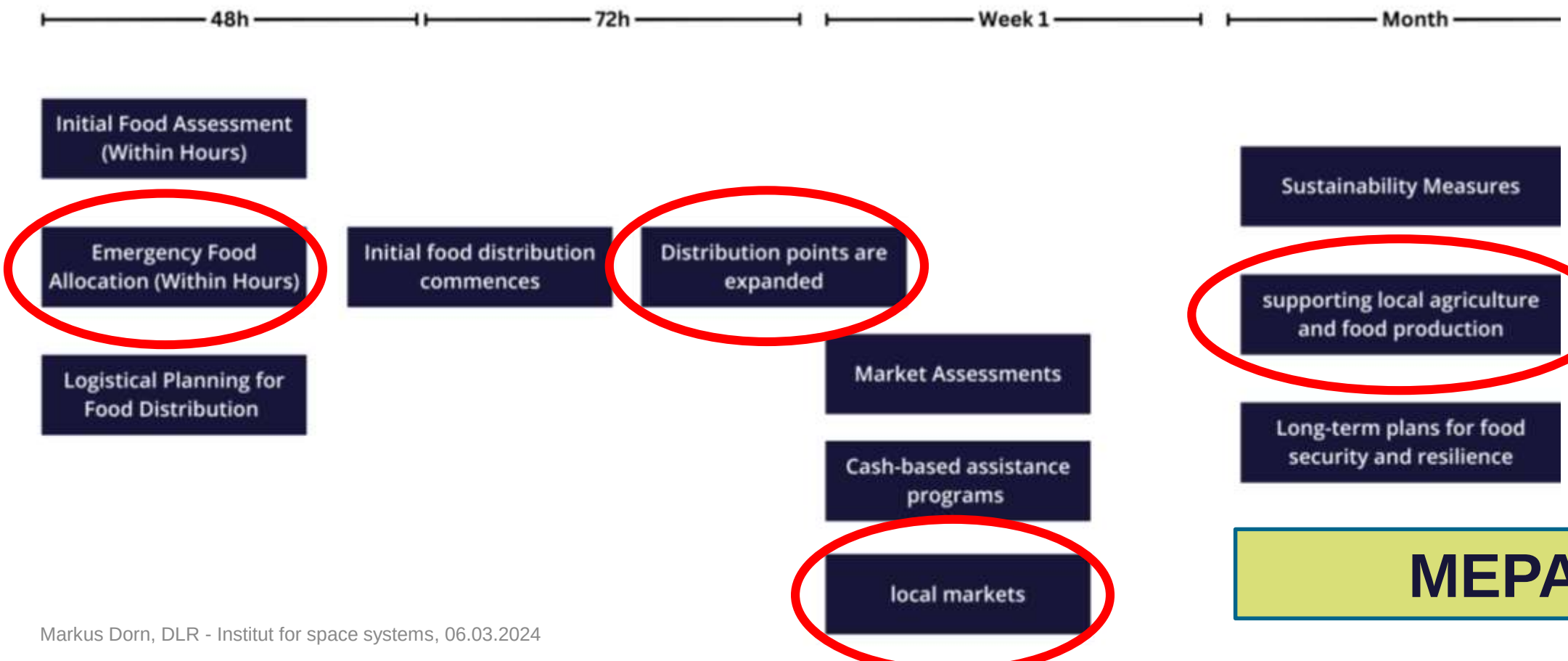
Challenges

- **Climate and natural disasters** jeopardize global food supplies
- **Political crises and wars disrupt farming,** leading to reliance on food aid
- **Food supply to refugee camps is a continuous issue**
- **Micronutrient deficiency,** lack of food variety and fresh food
- Food aid programs are in need for **new and innovative solutions for the provision of fresh food** in humanitarian crisis

1 Project Overview

Course of events

Emergency response (may vary dependent on location and situation)



MEPA

Zaatari refugee camp

Location
Jordan

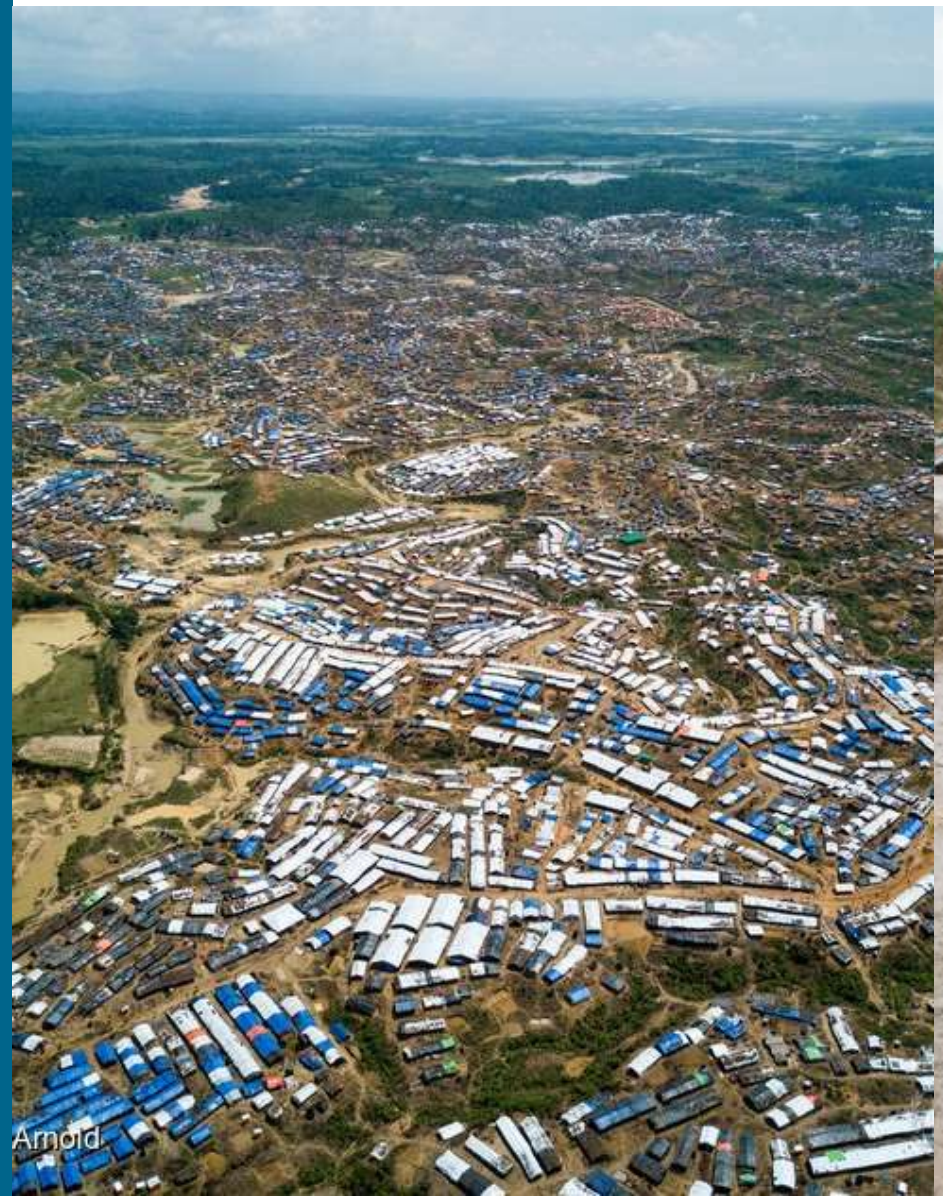
Population
80 000 (2022)

Established
2012

Occupants
Syrian refugees

Food situation
Critical

Kutupalong Expansion Site



Location
Bangladesh

Population
877 710 (2021)

Established
2017

Occupants
Primarily Rohingya refugees from the Northern Rakhine State in Myanmar

Food situation
Critical malnutrition

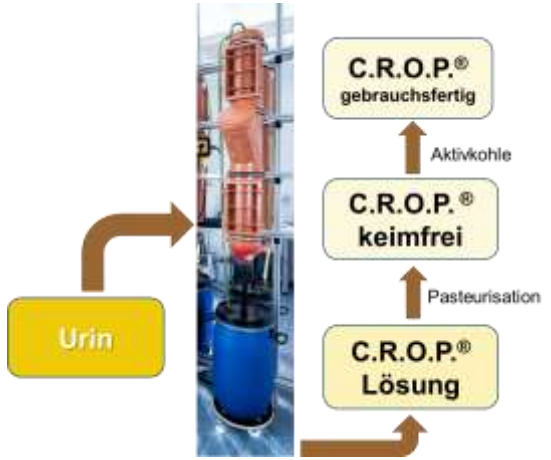
Local infrastructure continuously destroyed by natural disasters

Arnold

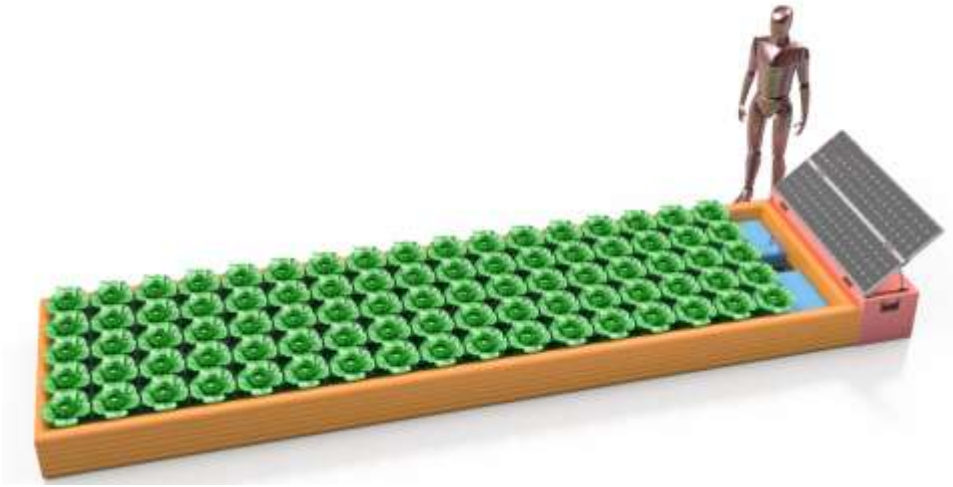
1 Objectives

Development of a semi-closed and ressource-efficient cultivation system for food production within crisis scenarios

- **Fast deployable** plant cultivation system (easy transport)
- Easy and rapid assembly; reusable ***‚Plug&Grow‘***
- **Solar powered**; independent from power grid
- Soilless cultivation (**Hydroponics**) => resource-friendly
- Integration of a **C.R.O.P.-filter** system (Nutrient recovery)
- Versatile for the production of **wide range of functional foods** (Lettuce, tomatoes, cucumbers) without cool chain => FOOD GARDENS
- Hybrid food supply (Basic food supply by WFP; **Micro nutrients and fresh food** produced by MEPA)



Urine utilization and nutrient solution by C.R.O.P.



First concept of the MEPA system (Deep-Water Culture)

2 PROJECT HISTORY

2 Project history

Overview

- „DLR HumTech Days“ (Feb.2019) in Oberpfaffenhofen with 80 participants from research, humanitarian aid organizations and funding agencies
- Fighting worldwide hunger

Focus: Global change, space, aeronautics, security, transport, digitalisation

2 Project history

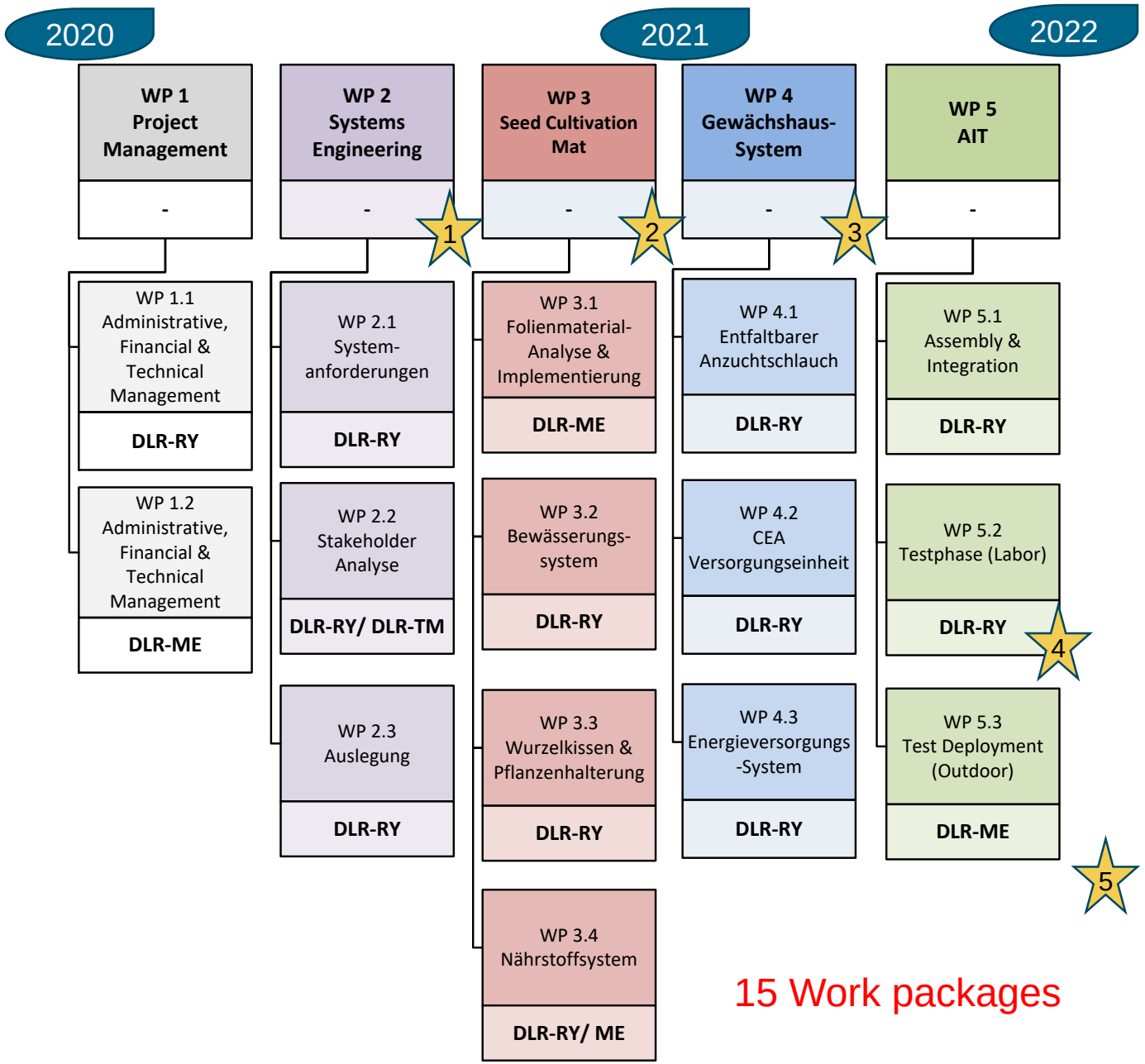
Overview

- Research area: **HumTech**
- **2-j** project duration (originally)
- Involved institutes **RY-SRS, ME-BIO**

Milestones

1. Kick-Off-Meeting
2. Preliminary Design Review
3. Final SCM Design Review
4. Test Results Review
5. Final Presentation

Work Breakdown Structure



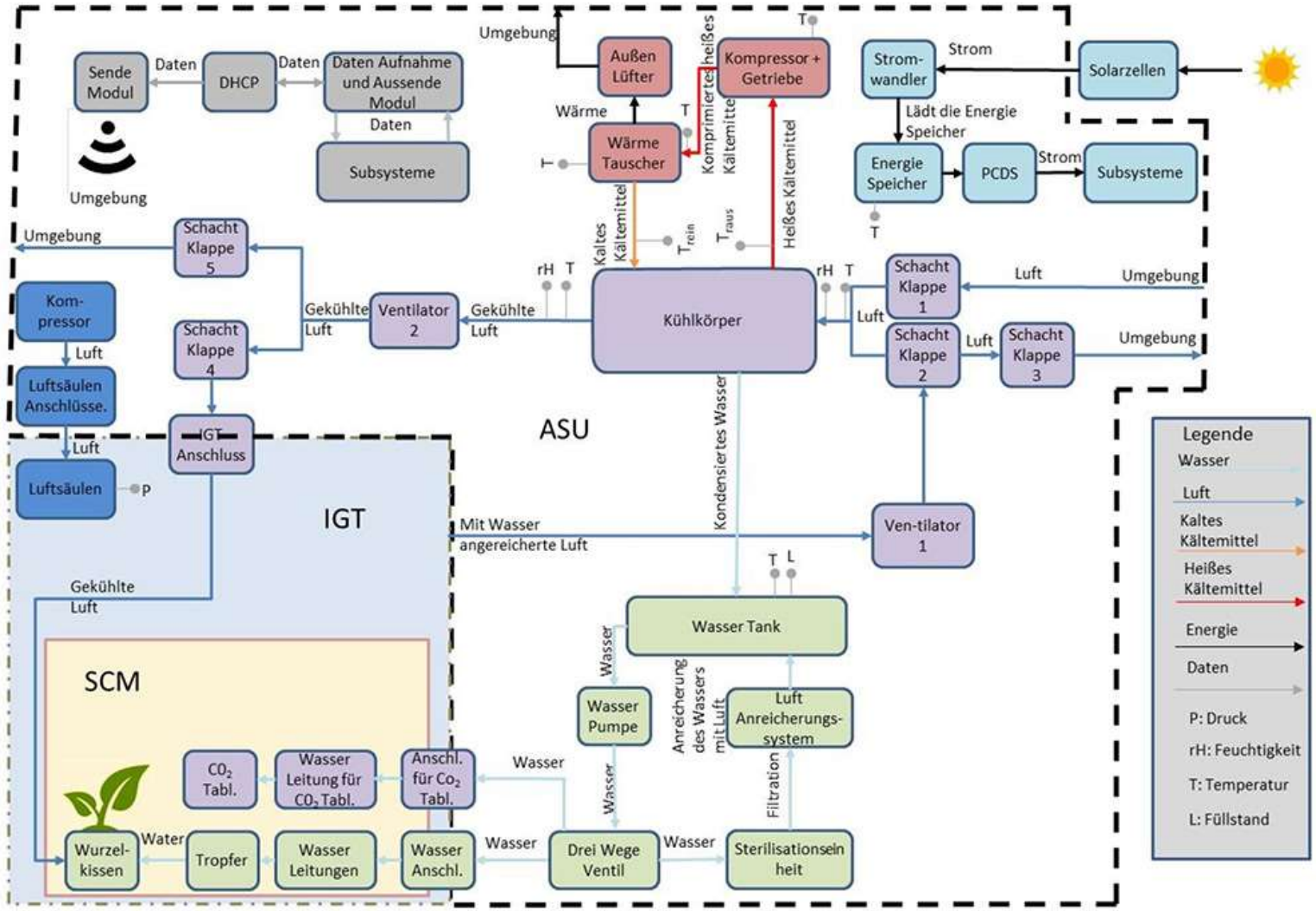
15 Work packages

3 KONCEPT AND DESIGN

3 Concept

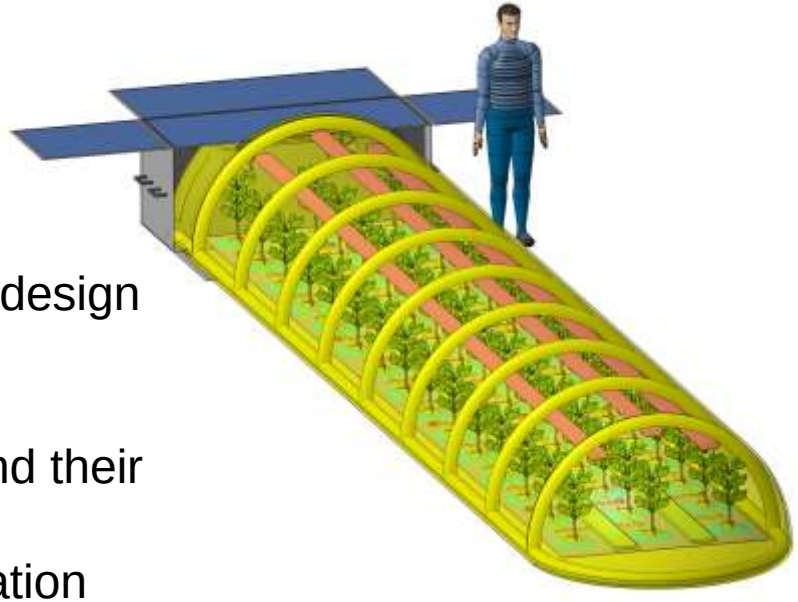
Functional overview

- DLR project start (kick-off): Jan. 2020
- Design trade-offs performed
- Detailed design work
- Material- and component analysis

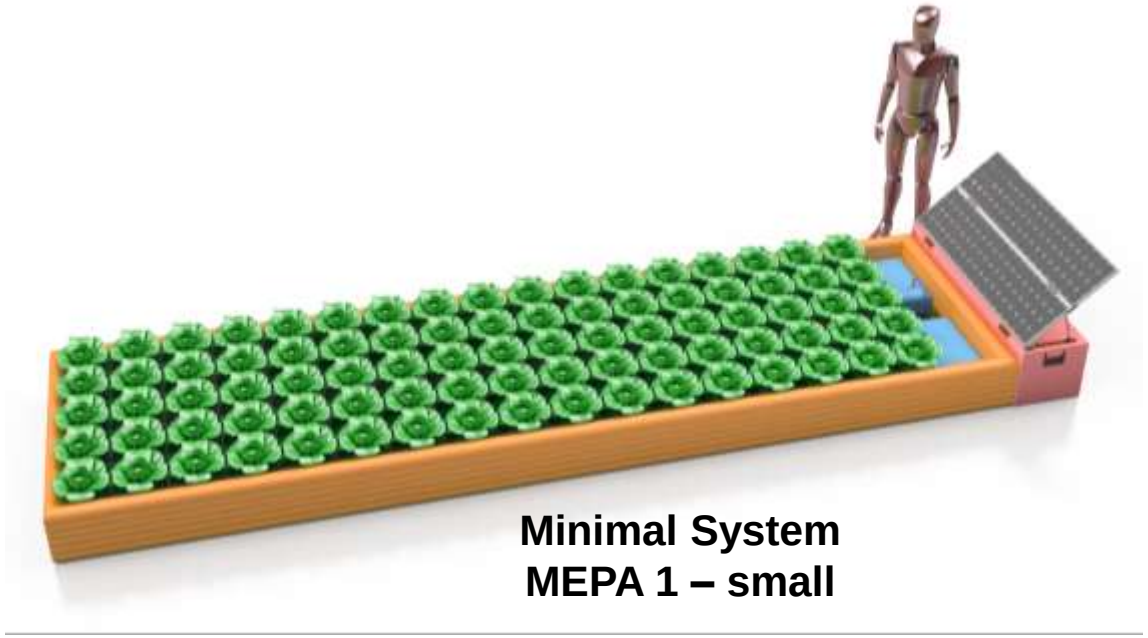


3 Concept

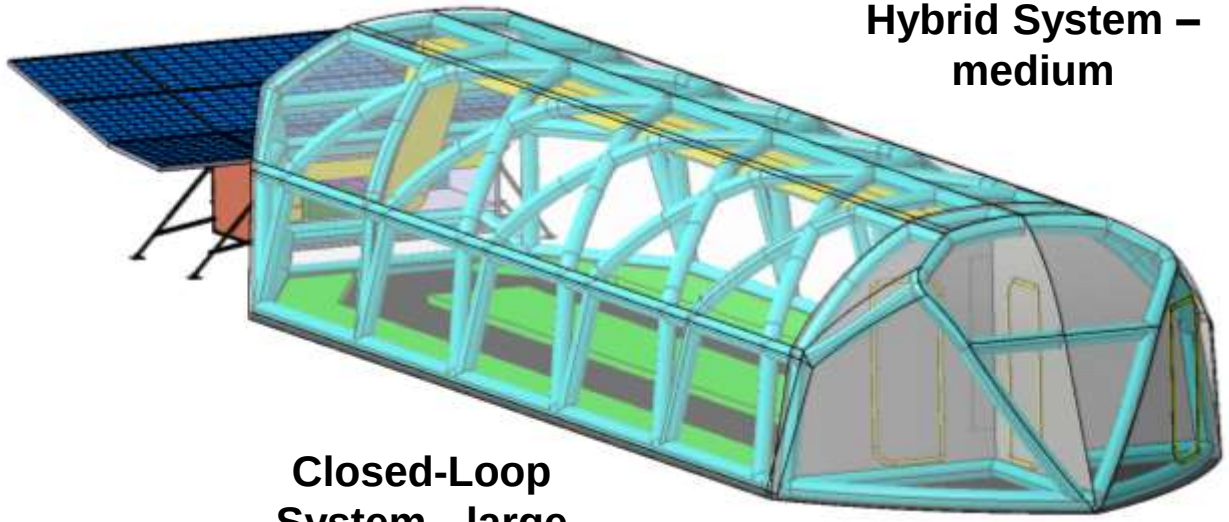
- Early concept/ design approaches
- Inclusion of components and their functions
- Space optimisation



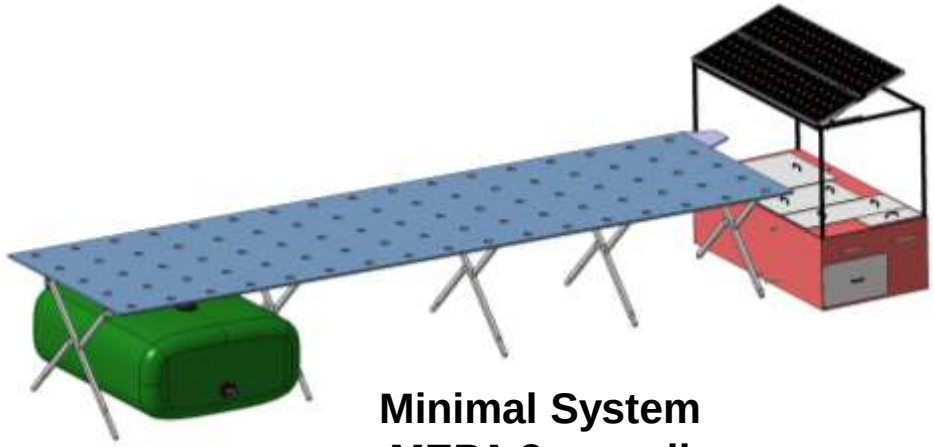
Hybrid System – medium



Minimal System MEPA 1 – small



Closed-Loop System - large



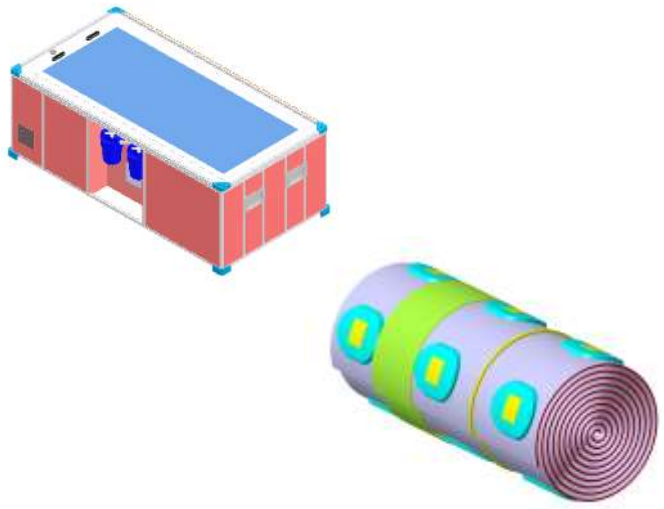
Minimal System MEPA 2 - small

3 Concept

Design approach

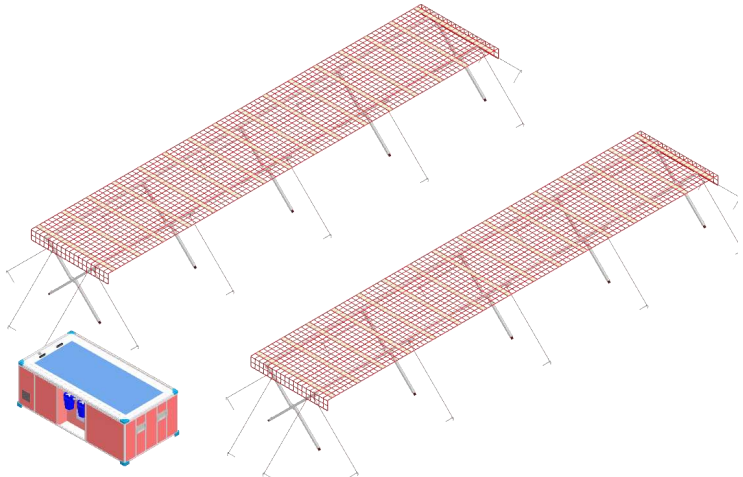
Automated support unit (ASU)

Seed-Cultivation-Mat (SCM)

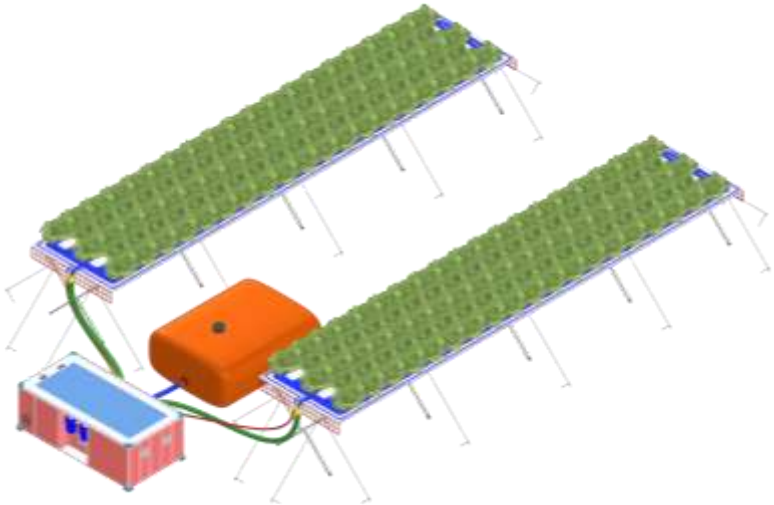


Structural elements

Production tables



Fully deployed MEPA unit

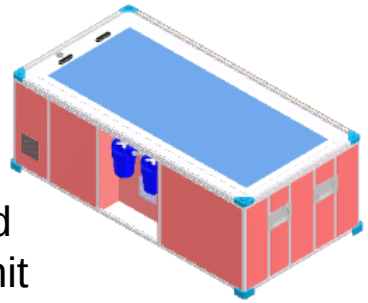


- Easy-deployment of the prototype, practicability
- Nutrient film technique (NFT, Hydroponic cultivation)
- ‚Plug&Grow‘ approach

3 Concept

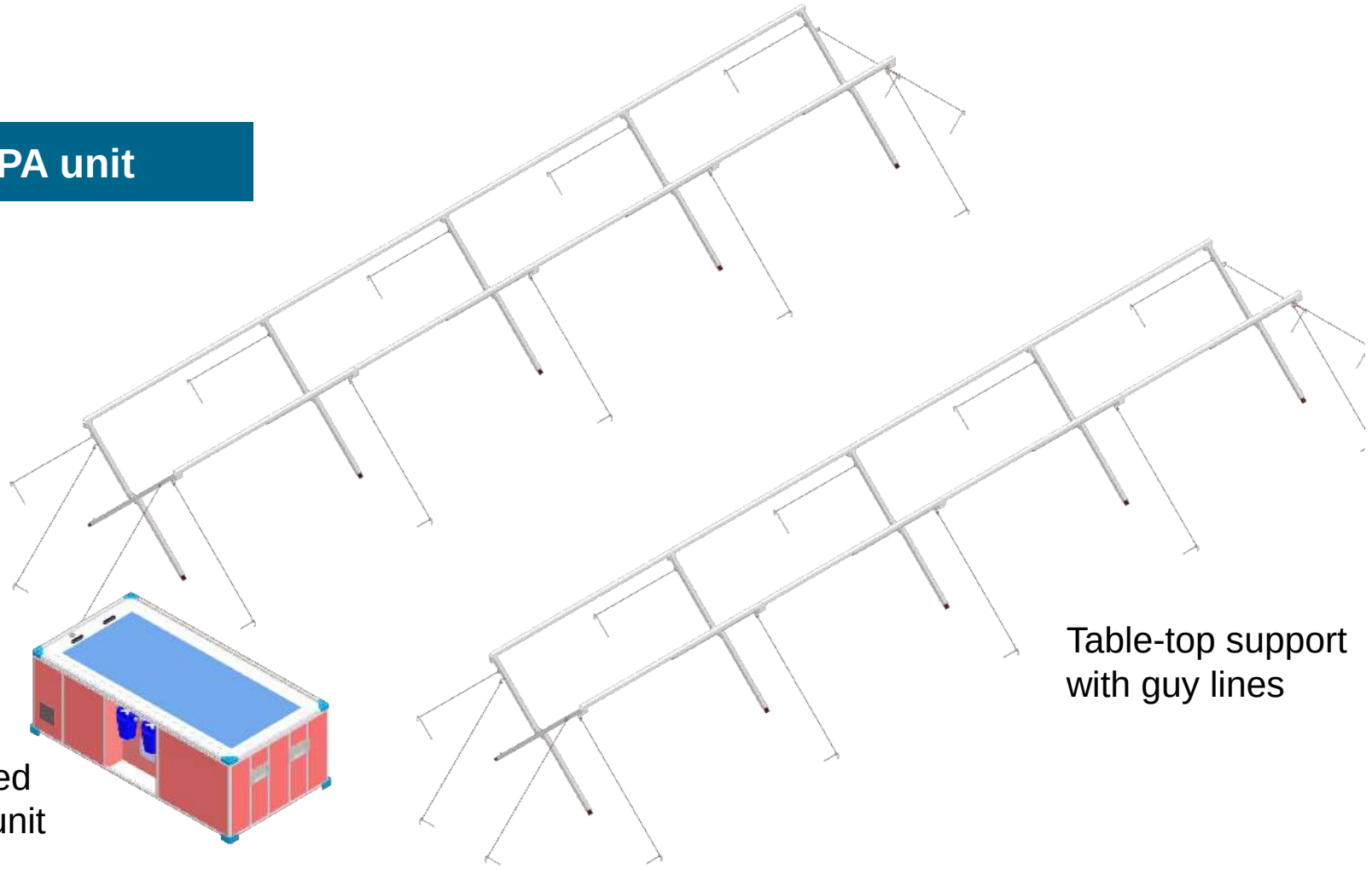
Assembly of a MEPA unit

Automated support unit (ASU)



3 Konzeption

Assembly of a MEPA unit

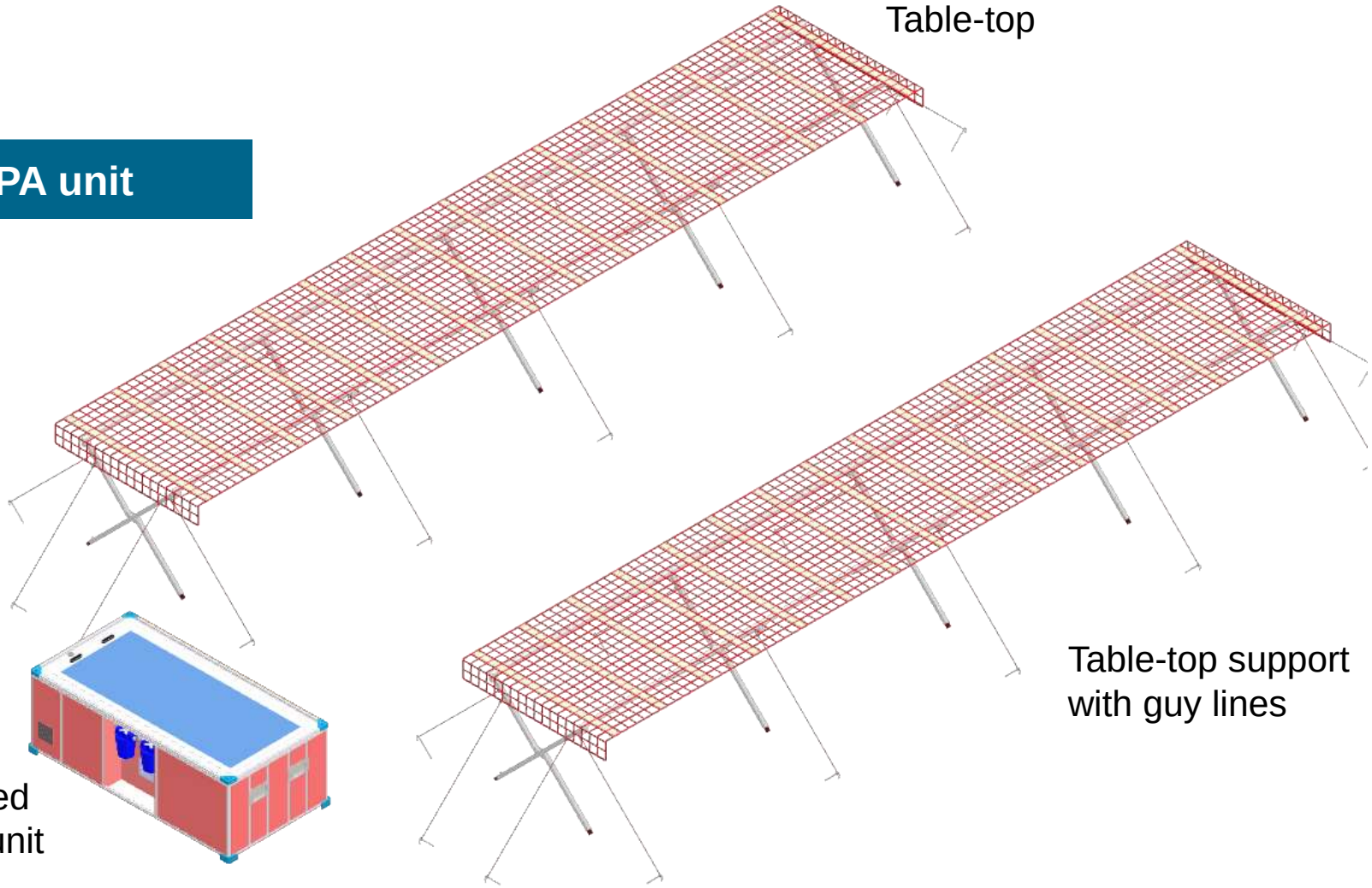


Automated support unit (ASU)

Table-top support with guy lines

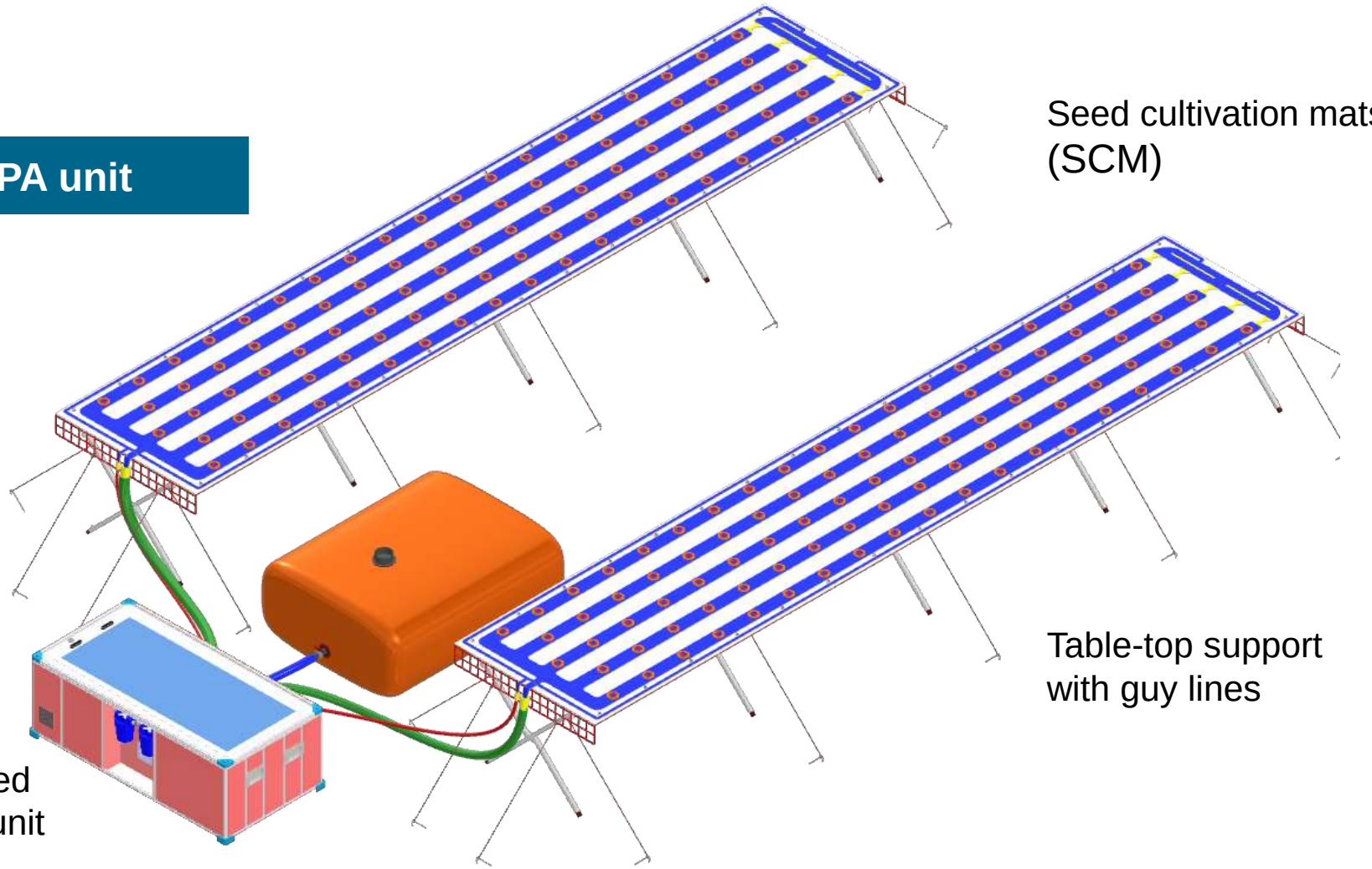
3 Konzeption

Assembly of a MEPA unit



3 Konzeption

Assembly of a MEPA unit



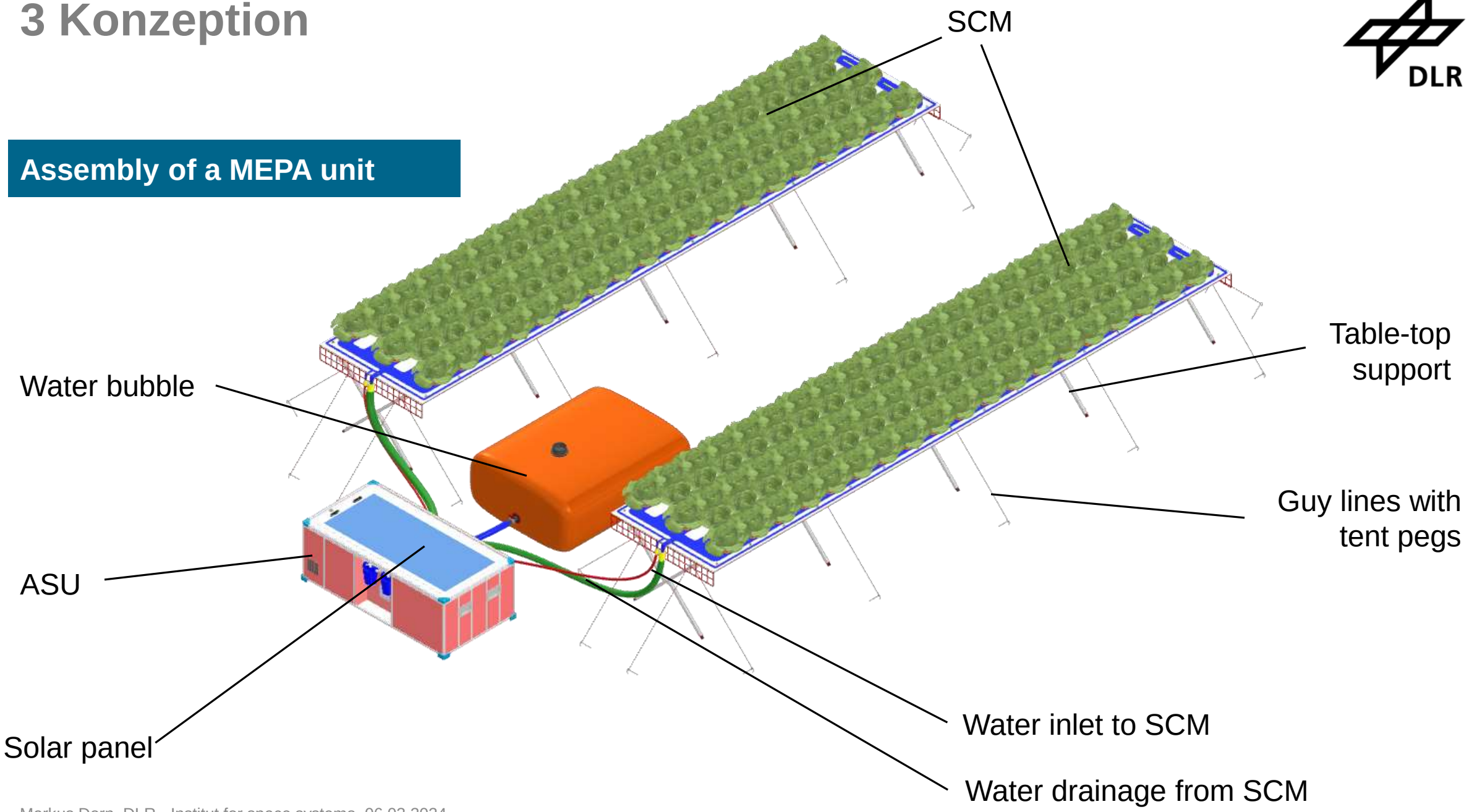
Seed cultivation mats (SCM)

Table-top support with guy lines

Automated support unit (ASU)

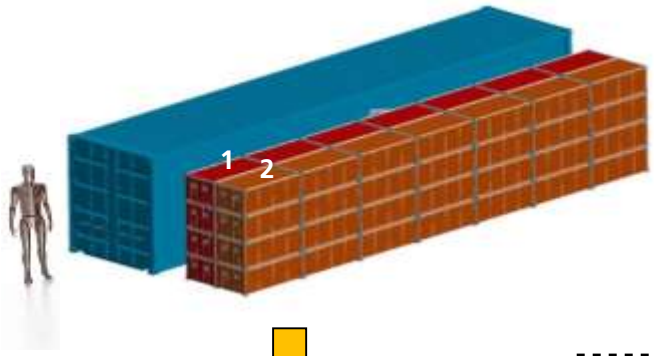
3 Konzeption

Assembly of a MEPA unit

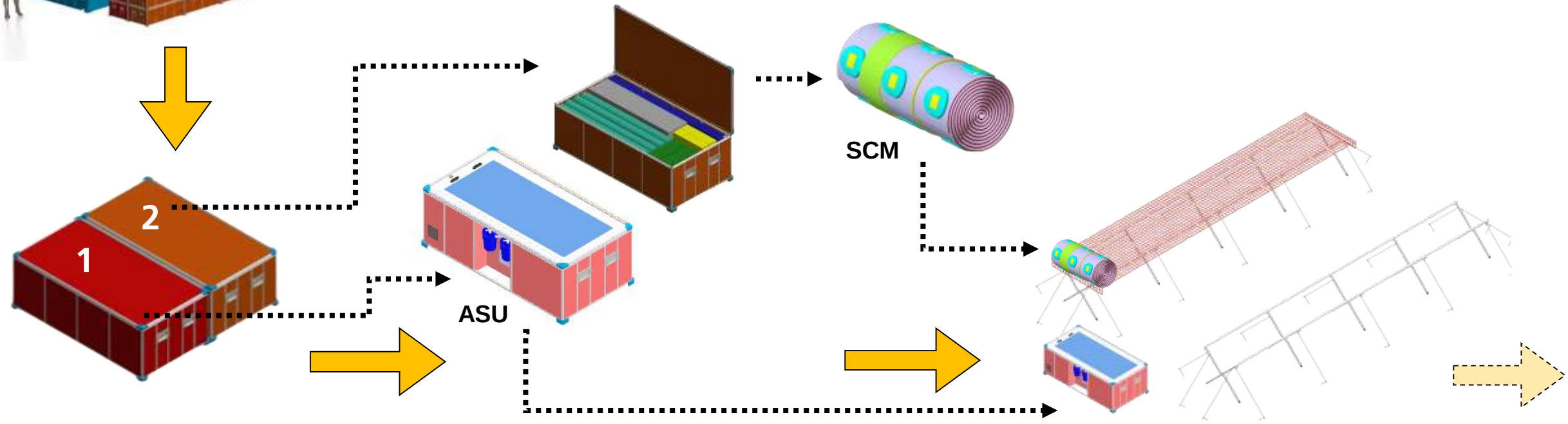


4 OPERATIONAL SCENARIO

4 Operational Scenario



28 units per 40 ft Container

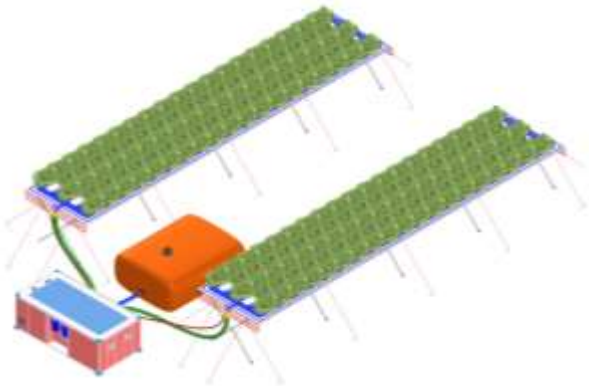


Transport mode

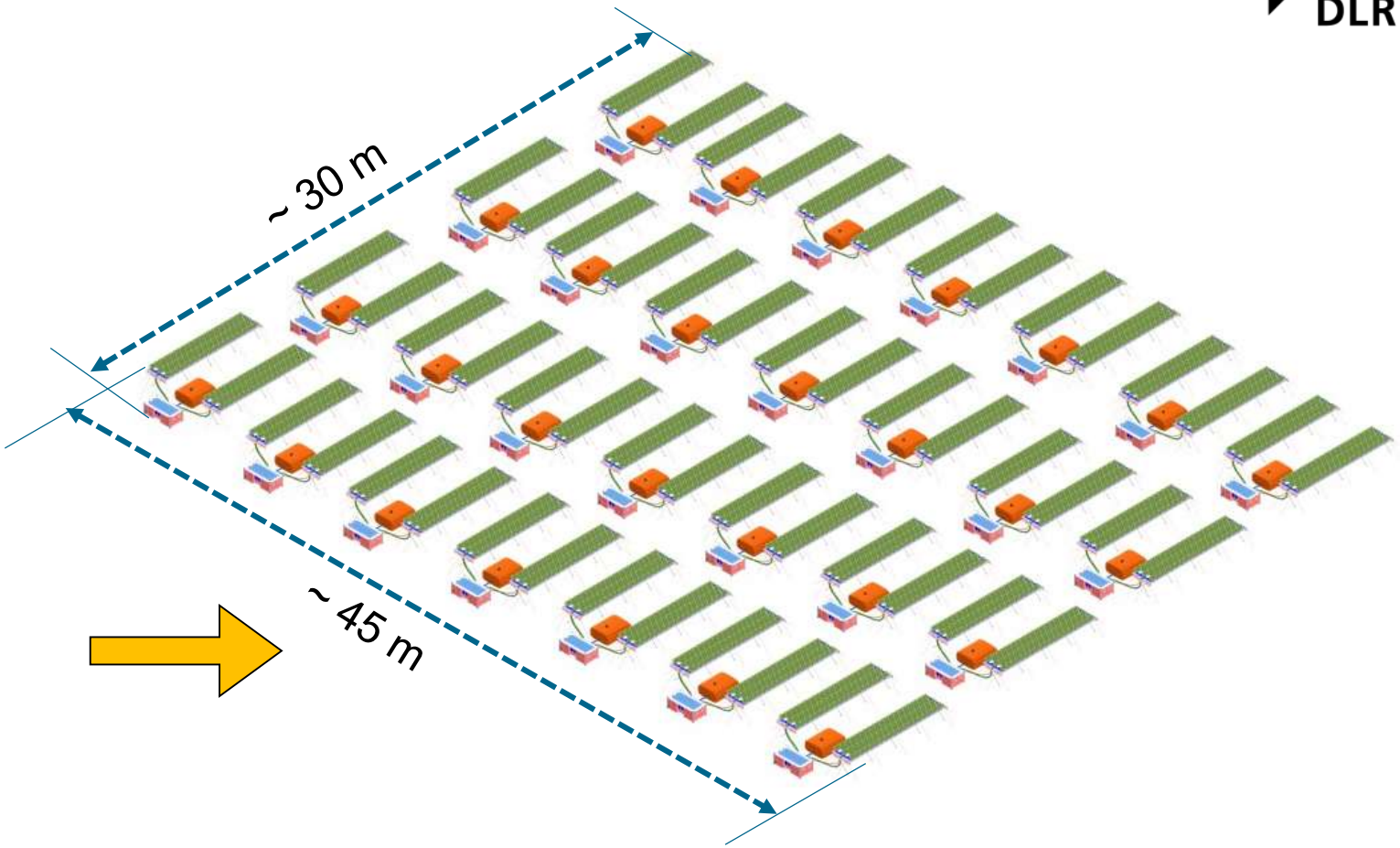
Unpacking of SCM and ASU

Assembly of structural elements

4 Operational Scenario



Fully deployed MEPA unit



MEPA units per FEU*

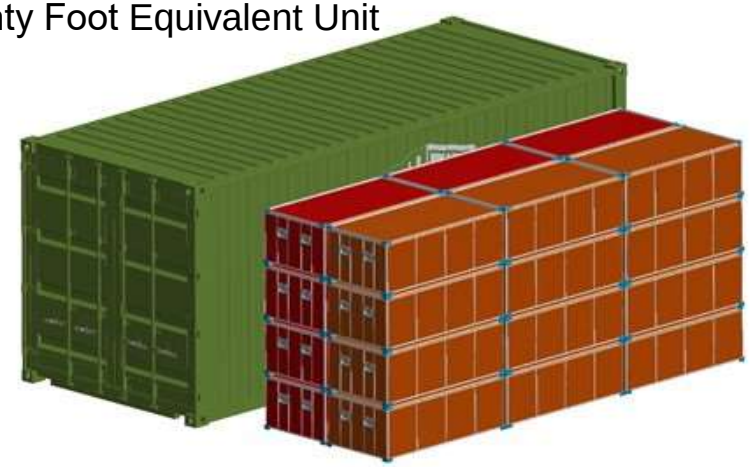
~ 400 m² tot. cultivation area (28 MEPA units)
~ 1350 m² ground area

*Forty Foot equivalent unit

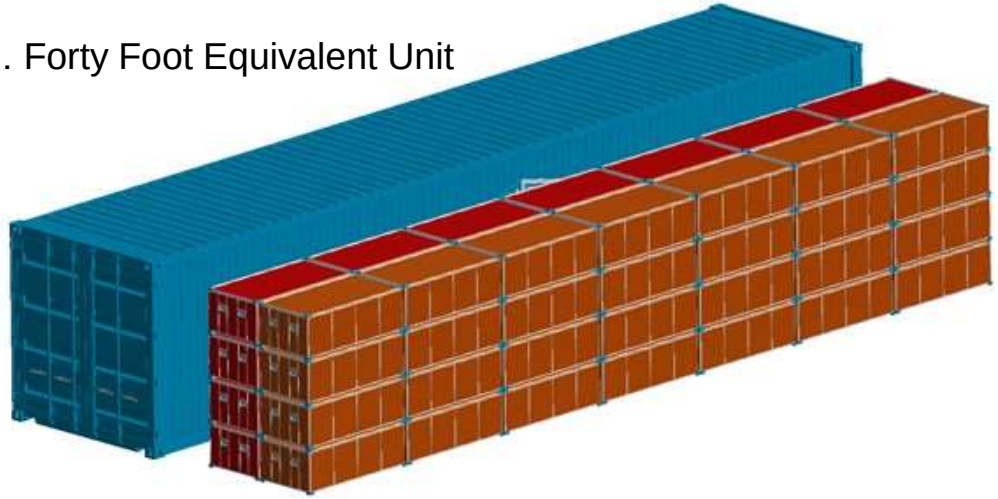
4 Operational Scenario

Vergleich 20‘ Container zu 40‘ Container

TEU … Twenty Foot Equivalent Unit



FEU … Forty Foot Equivalent Unit



Data refers to the prototype unit only. Number of tables in the final product varies.

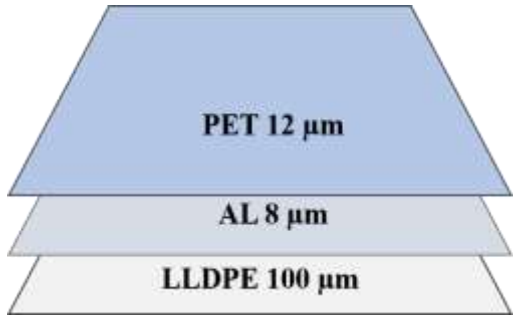
	Cultivation area [m²]	Lettuce heads (~mass [kg]) 30 cm / Lettuce; 450g / Head; ~ 6 weeks
Table	7,2	115 (52)
2 Tables (= 1 Unit)	14,4	230 (104)
TEU (= 12 Units)	172,8	2760 (1242)
FEU (= 28 Units)	403,2	6440 (2898)

5 SEED CULTIVATION MAT (SCM)

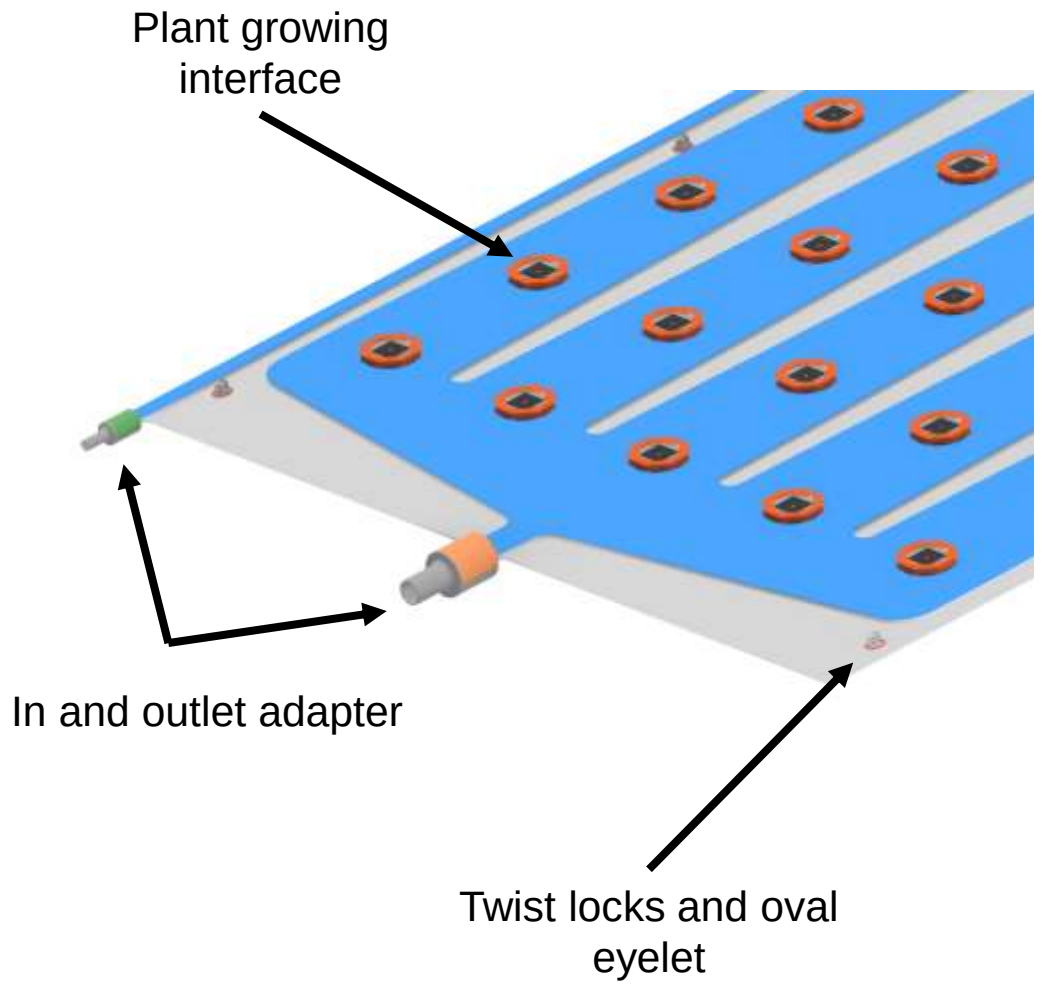
5 Seed Cultivation Mat (SCM)

Material properties

- Foil laminate made of 3 layers
- UV- and weather resistant
- Resistant to weak acids and bases
- Low stress cracking and high tensile strength due to aluminum
- High heat reflection
- Sealability inside for a tight connection



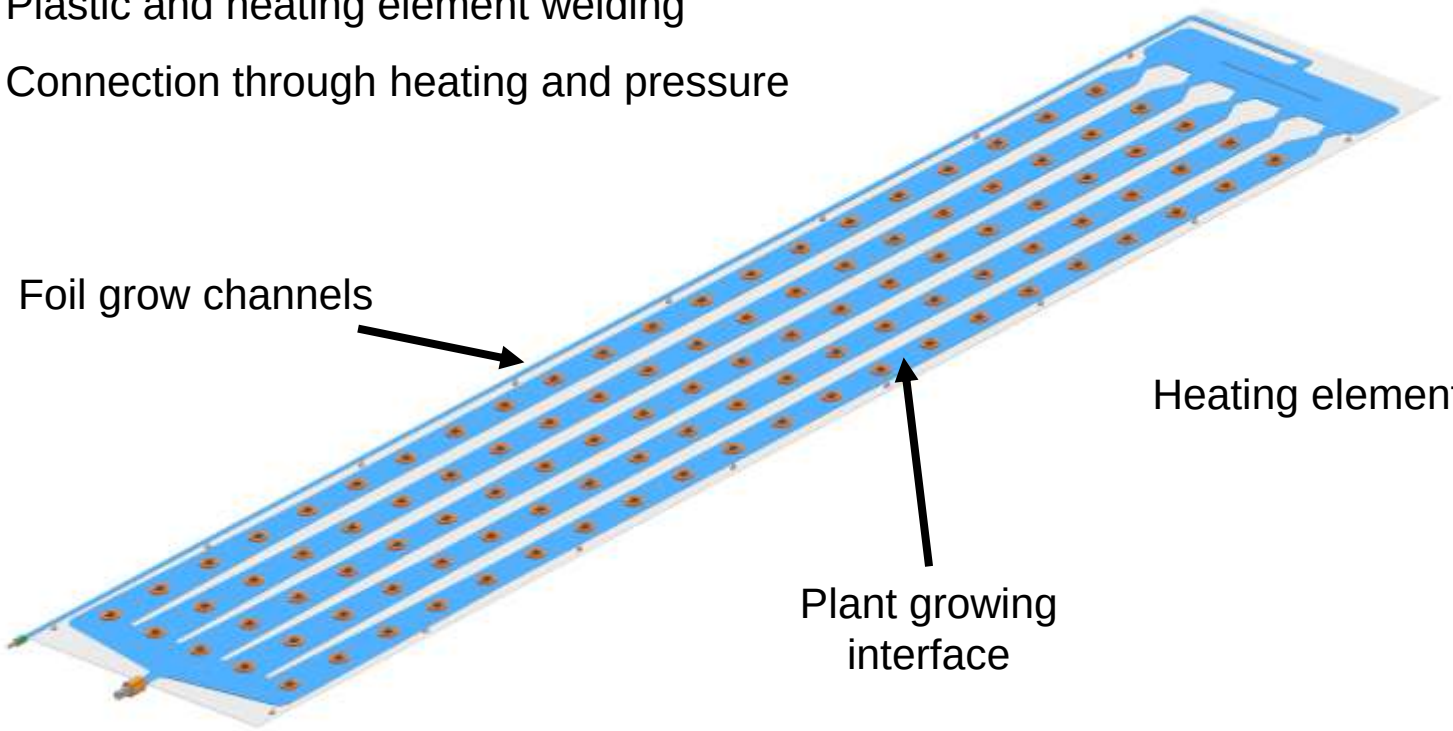
Triplex-Foil



5 Seed Cultivation Mat (SCM)

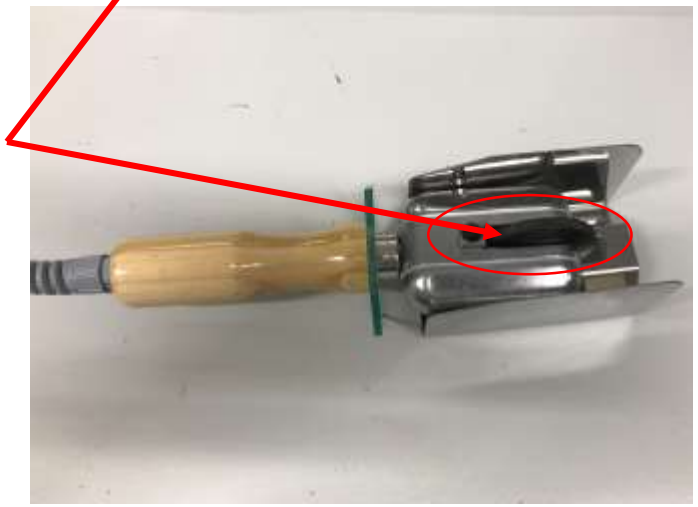
Welding process

- 2 foils placed on top of each other
- Plastic and heating element welding
- Connection through heating and pressure



Impulse welding machine

Heating element



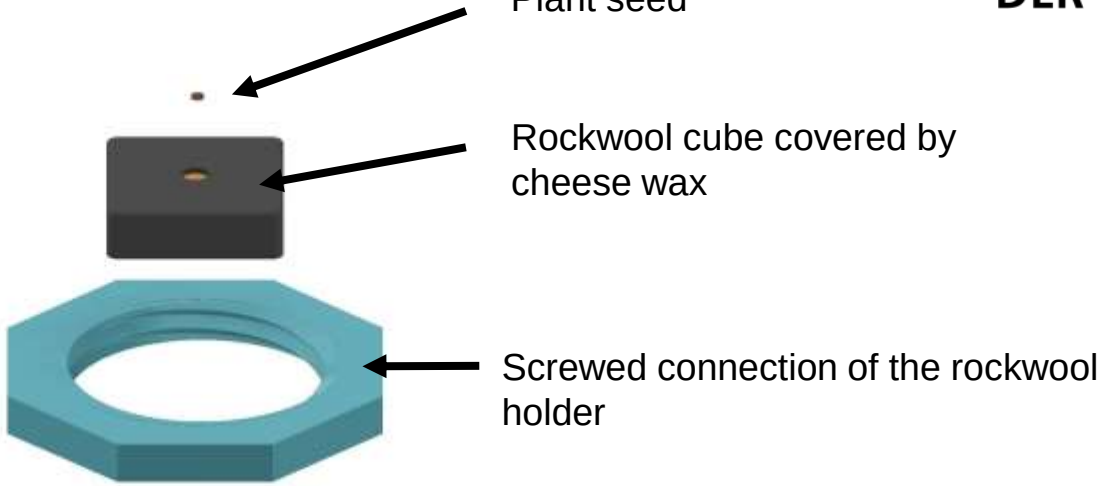
Hand rolling device

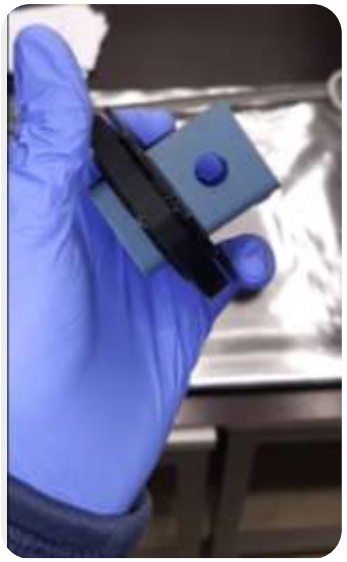
5 Seed Culivation Mat

Cultivation channel - structure

- 2 foils placed on top of each other
- Plastic and heating element welding
- Connection through heating and pressure

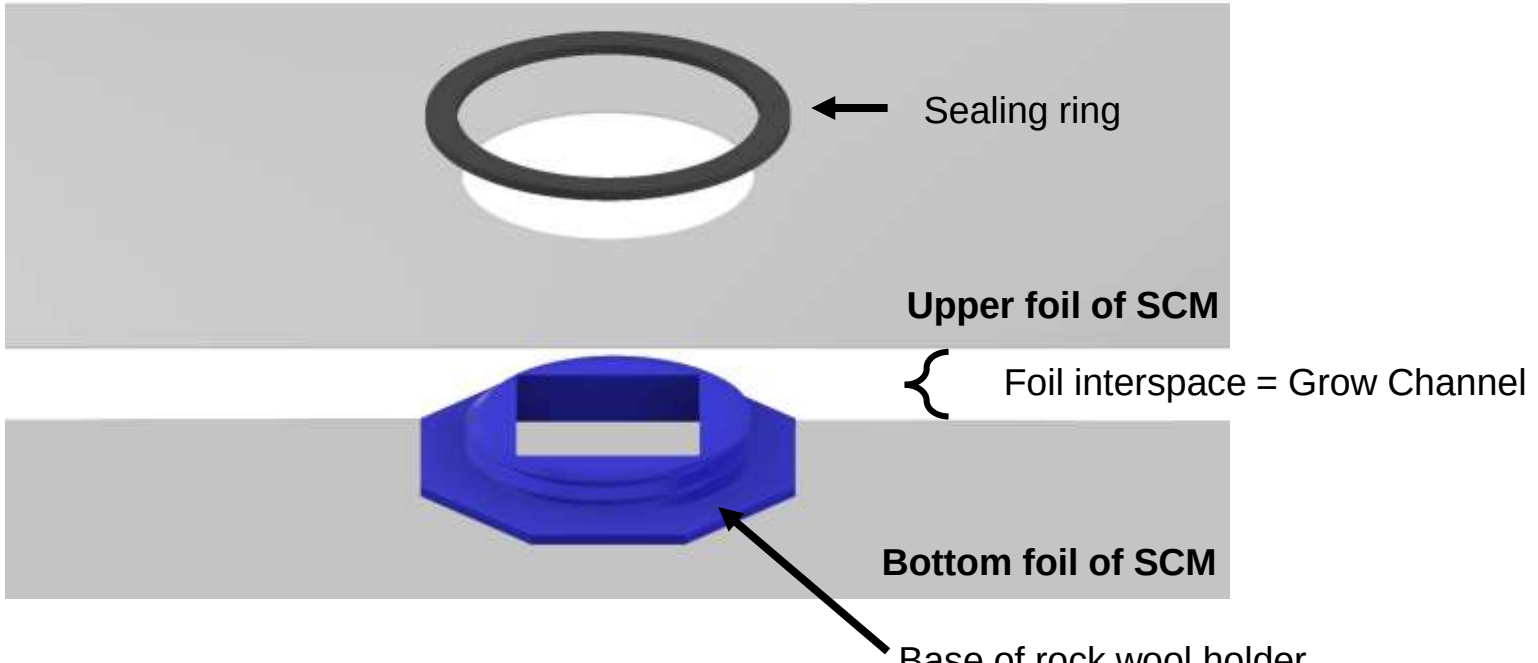
Rock wool cube
(3,6 x 3,6 x 4 cm)





3D tool for screwing

Rock wool holder



5 Seed Cultivation Mat (SCM)

Work shop activities

- ✓ Experimental set-up in the workshop
- ✓ ‚Welding‘ of different foil designs
- ✓ Functional water test
- ✓ Subsequent transfer to the clean room

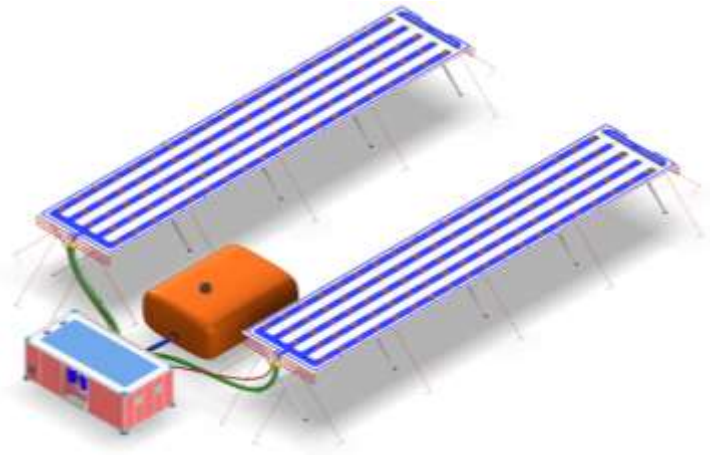
SCM foil preparation

SCM foil set up –
Water test

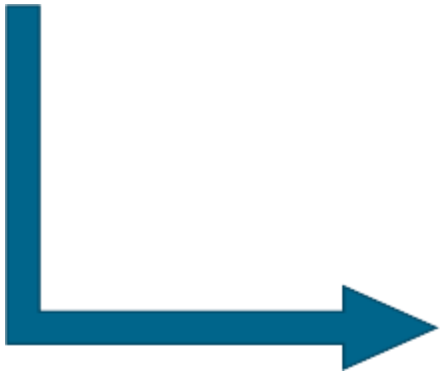
Production of first
L-size SCM

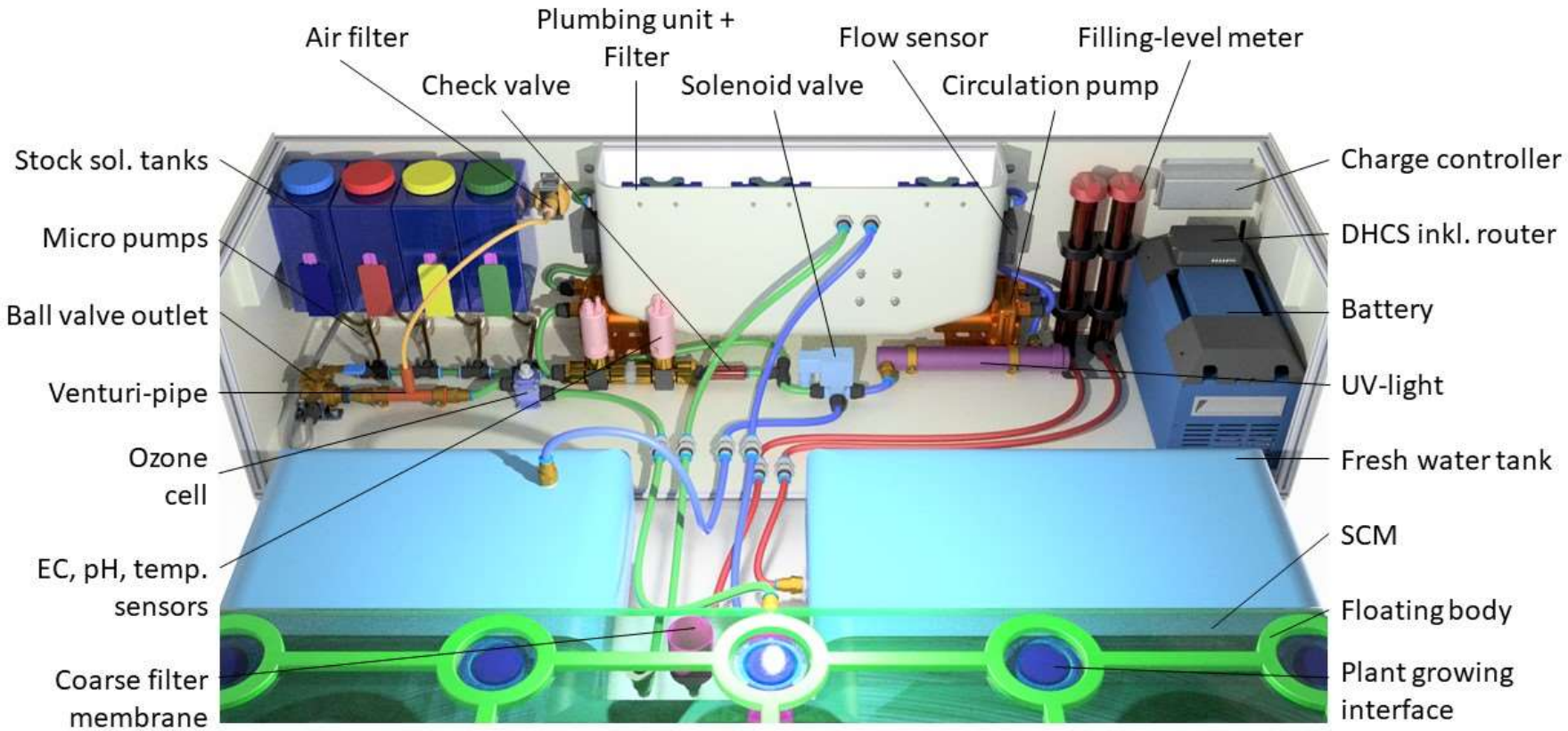
6 AUT. SUPPORT UNIT (ASU)

6 Automated Support Unit (ASU)



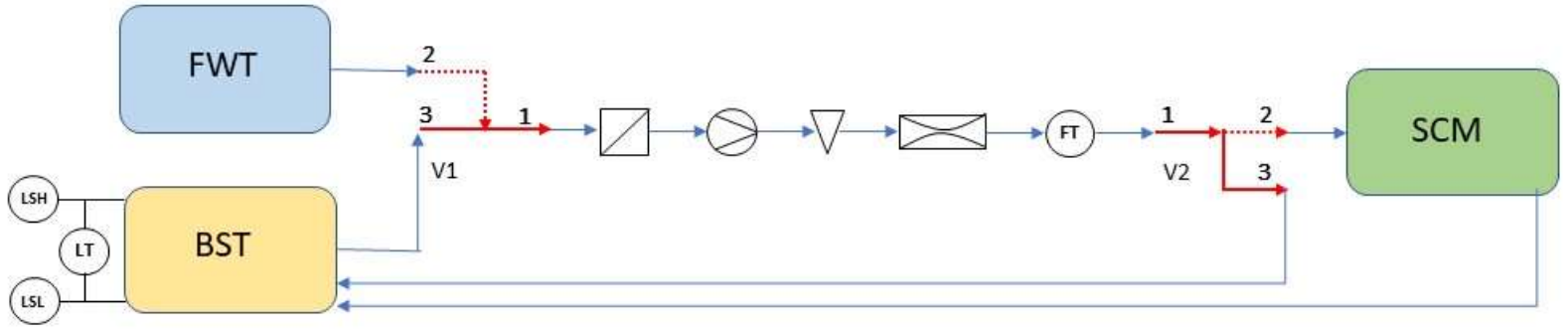
ASU





6 Automated Support Unit (ASU)

Flow Loop



Legend

BST - Bulk Solution Tank
FWT - Fresh Water Tank
SCM - Seed cultivation mat

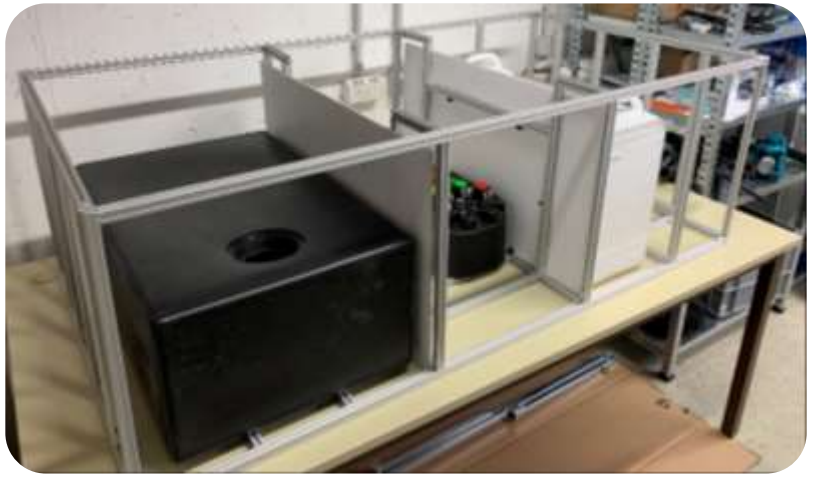
- Valve
- Filter
- Pump
- Ozone cell
- Venturi
- Flow transmitter
- Level transmitter
- Level switch high
- Level switch low

Modes of operation

- Water in
- Feritigation
- Water out
- Ozone sanitation cycle
- Nutrient Mixing

6 Automated Support Unit (ASU) 1

ITEM – structural framework



Arrangements of compartments and components

ASU during first outdoor test

Cladding the walls with Trespa-plates

Lessons learned

- No water and dustproof
- Difficult locking mechanism
- Box stability is not sufficient

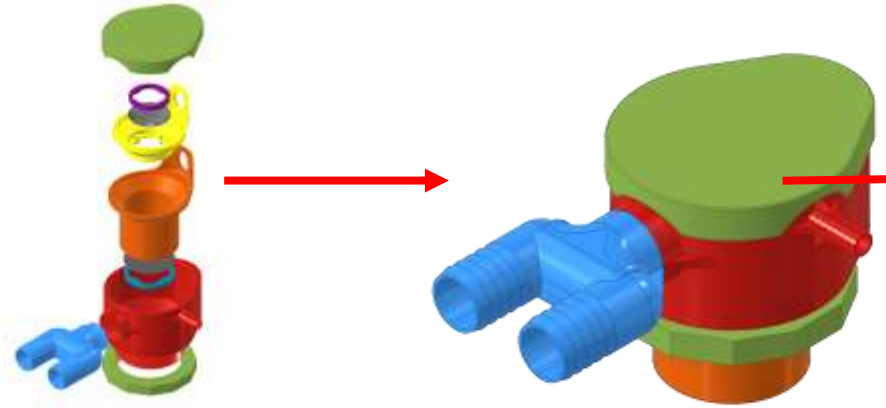
→ Search for alternative

ASU inside view during 1st outside test

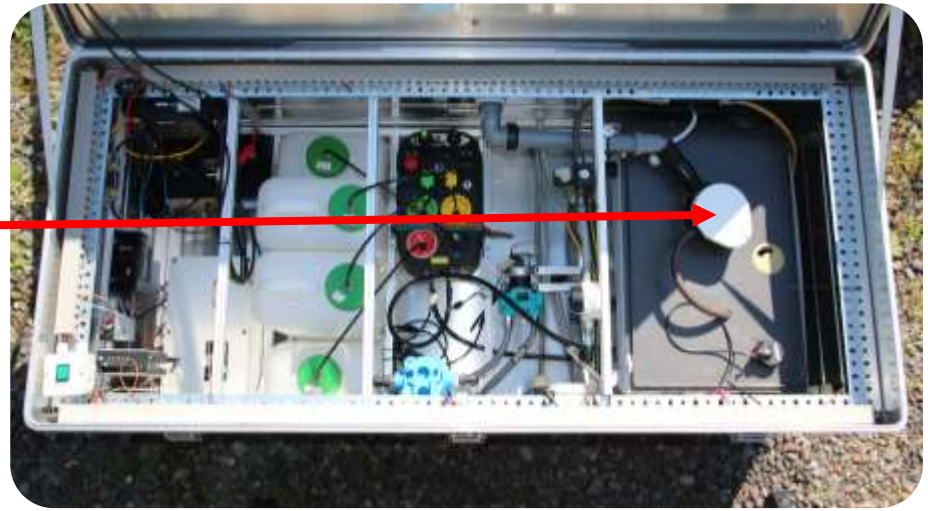
6 Automated Support Unit (ASU) 2.0

Zarges Box

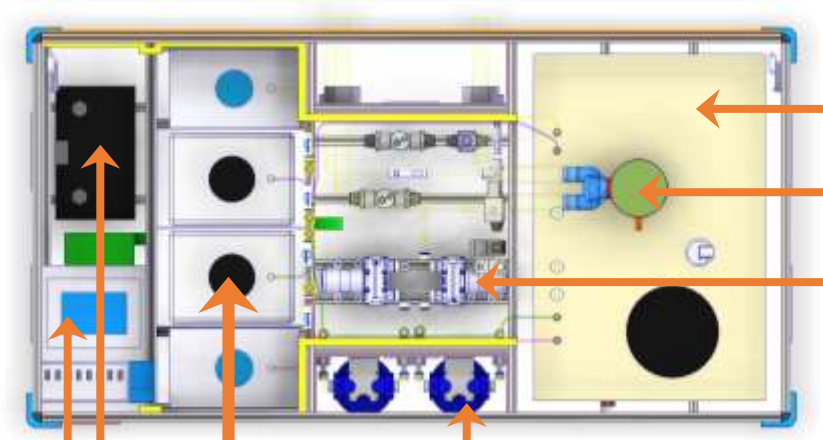
- Type: K470
- Material: Aluminium
- Dimensions: 1650 x 750 x 670mm
- Implementation of angle- and ITEM-profiles
- Open compartments



3-D printed filter in the ASU

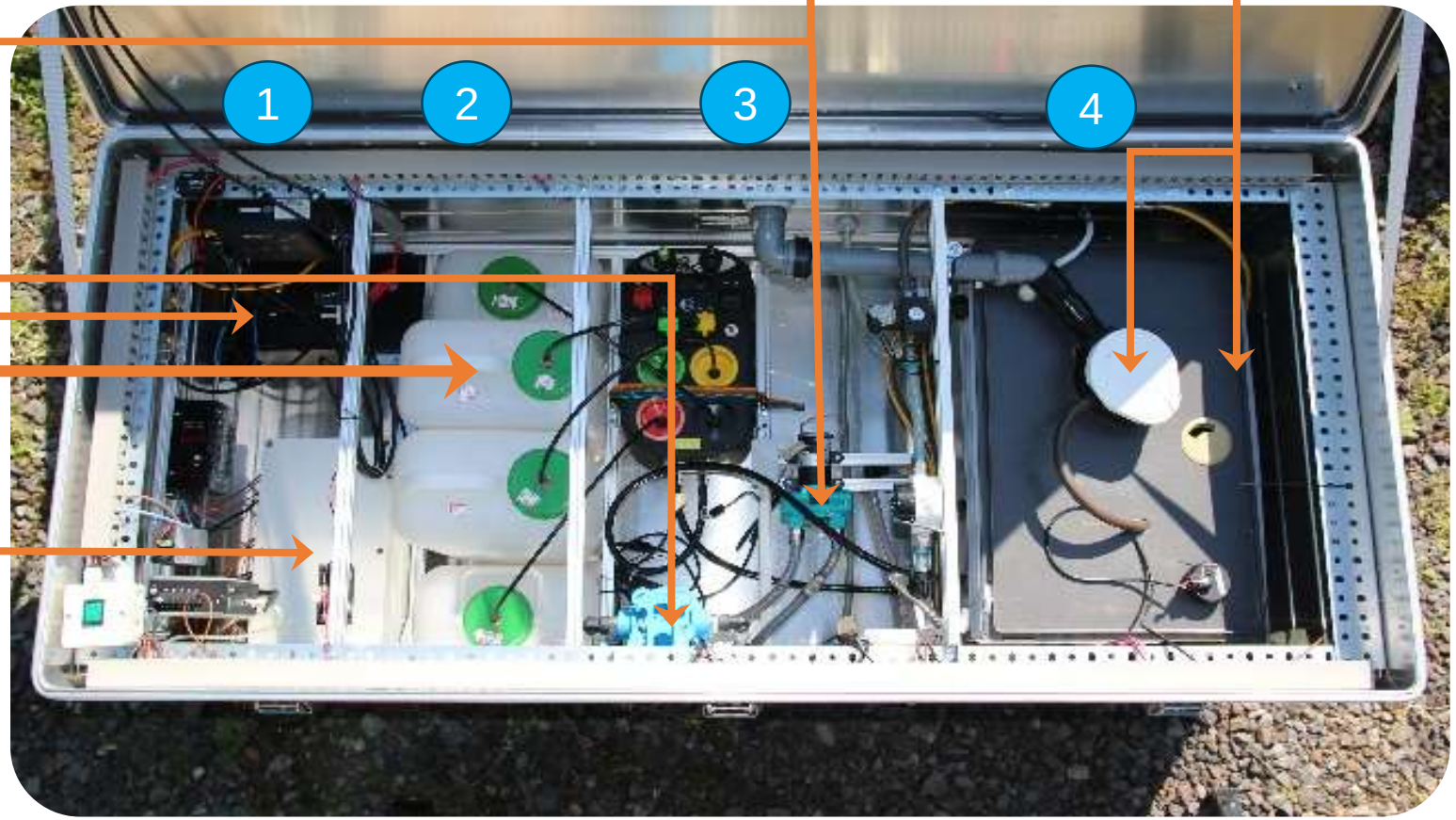


6 Automated Support Unit (ASU) 2.0



5 Nutrient tank and return filter

4 Water pump



3 Water filter

2 Stock solution tanks

1 Battery bank and DHCS


7 C. R. O. P.®
Combined Regenerative
Organic Food Production

Objectives

- Investigation of foil materials
  - Biodegradable or usable as fuel
  - Lifespan of several weeks before decomposition
  - Water and vapor proof
  - Sufficient stability and tear resistance
  - Food safe
- Urine recycling

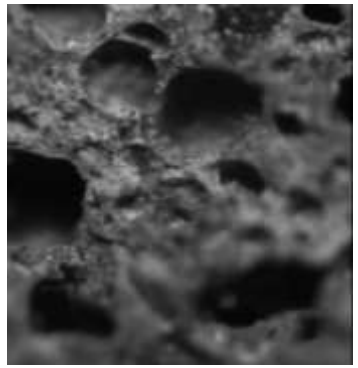

Quelle: tagesspiegel.de

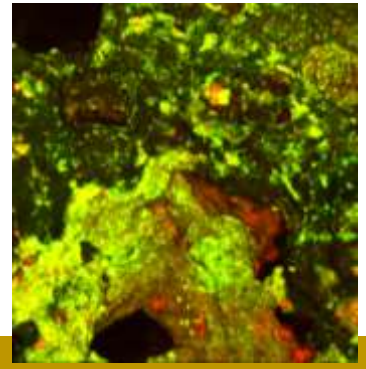
Goal: No to generate any additional plastic waste.

Solar C. R. O. P.®

Urine recycling

- Converting human urine into plant fertilizer (mainly urea and phosphate)
- Implementation in the biofilter, containing carrier material with biofilm
- Mikroorganisms convert urea into nitrate (plant available)
- Supplement for plant nutrient solution





DLR

Product: Liquid nitrogen fertilizer

Solar C. R. O. P.®

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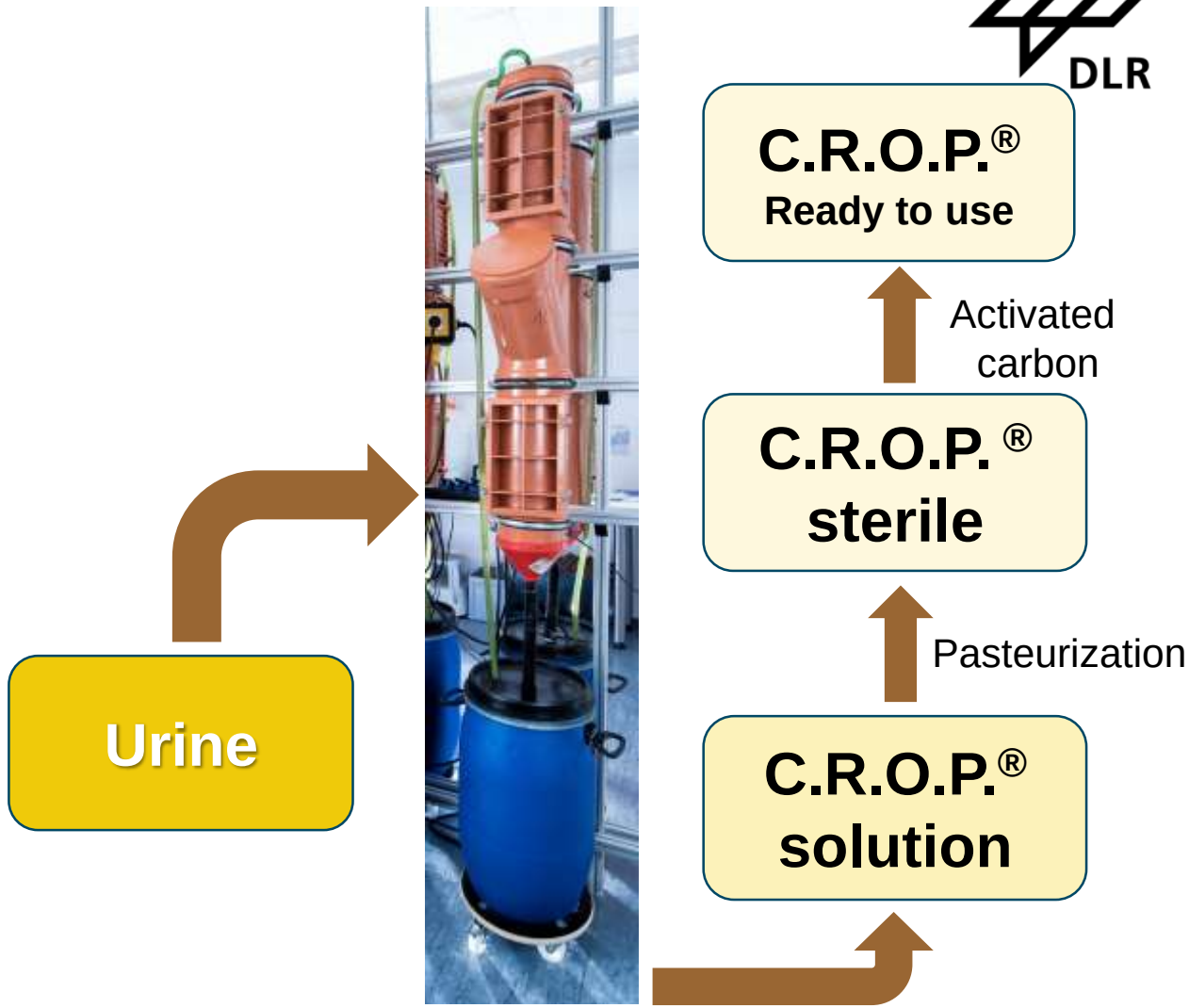


Product: Liquid nitrogen fertilizer

Solar C. R. O. P.®

Solar powered

- COTS
- PV (1000 x 600 mm, 12 V, 100 W)
- Car battery
- Up to 4 L Urine/day, N for approx. 24 m² cultivation area
- Implementation into MEPA system

DLR

Post-treatment with solar energy is being planned

8 TEST PHASE (LABORATORY)

8 Test phase (Laboratory)

Planning phase

- Light
- Nutrient Mix
- Plant varieties

Assembly/ Pre trials

- Built up of SCM-prototype
- Assembly of test stand
- Wick irrigation system/ Root pillows

Experimental - phase 1

- Monitoring of plant growth
- Calculation of harvest output

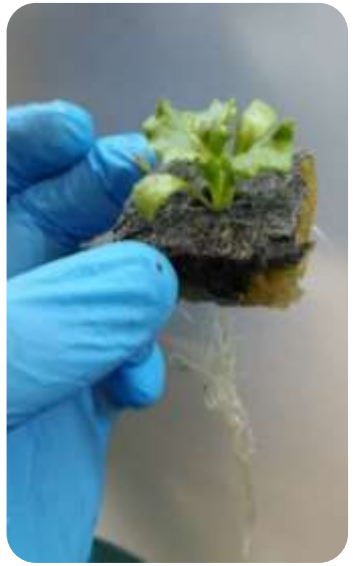
Experimental - phase 2

- Revision of the design
- Preparation of ‚Scale Up‘ and experimental phase 3

Experimental - phase 3

- Implementation of the Automated Support Unit (ASU)

8 Experimental phase no. 1 (Laboratory)



In consequence of laboratory construction works the water flow was disturbed

→ **Drought stress**

Transfer of seedlings into seed-cultivation-mat

0 d | 10 Days (d) | 12 d | 35 d | 36 d | . . .

Seedlings after sowing

Reached half of their varietal typical height

8 Experimental phase no. 1 (Laboratory)

Plugholder closed with neopren-plug;

Cleaning process

Experimental - phase 2

. . .

75 d — 81 d — 82 d

Recovery of the crop

First harvest accomplished

~ 3,7 kg (24 pl.)

~ 154 g/ plant

8 Experimental phase no. 2 (Laboratory)

Vegetative growth

1 d

18 d

46 d

New sowing

Second harvest accomplished

~ 4,2 kg (24 pla.)

~ 176 g/ plant

Experimental - phase 3

8 Experimental phase no. 3 (Laboratory)

- ✓ Extension of first experimental set up; cultivation area and variety of test crops
- ✓ e.G. bush beans, cucumber, purslane, kale
- ✓ Dimension ~ 5m length x 1,20 m width
- ✓ In total 85 plants/ large mat

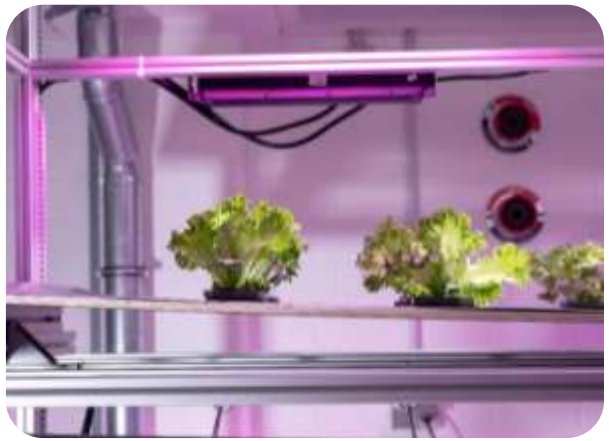
Extension of laboratory experimental set up for exp. phase no. 3

8 Experimental phase no. 3 (Laboratory)

Lettuce cv. '*Expertise*'

Climbing beans

Mixed cropping purslane, kale, lettuce



Lettuce cv. '*Expertise*'

Cucumber cv. '*Picowell RZ*'

Harvest of climbing beans

- 3 laboratory test phases with different plant varieties (Lettuce, cucumber, purslane, bean, kale)
- Data collection and risk analysis; creation of operative procedures
- Implementation of lessons learnt into the prototype and outdoor test phases

8 Experimentphase Nr. 3

- 3 laboratory test phases with different plant varieties (Lettuce, cucumber, purslane, bean, kale)
- Data collection and risk analysis; creation of operative procedures
- Implementation of lessons learnt into the prototype and outdoor test phases

9 FINAL TESTPHASES (OUTDOOR)

9 Test phase 1 (Outdoor) - 2022

Assembly of the MEPA system in an outdoor tent with first growth trials

MEPA structural elements

Winter harvest

ASU and fresh water tank

9 Test phase 1 (Outdoor) - 2023

Outdoor tent during test phase 1

- Strong snowfall lead to tent collapse
- Partly damage of test equipment
- Project realization in danger

Collapse of outdoor tent after snowfall event

9 Test phase 2 (Outdoor) - 2023

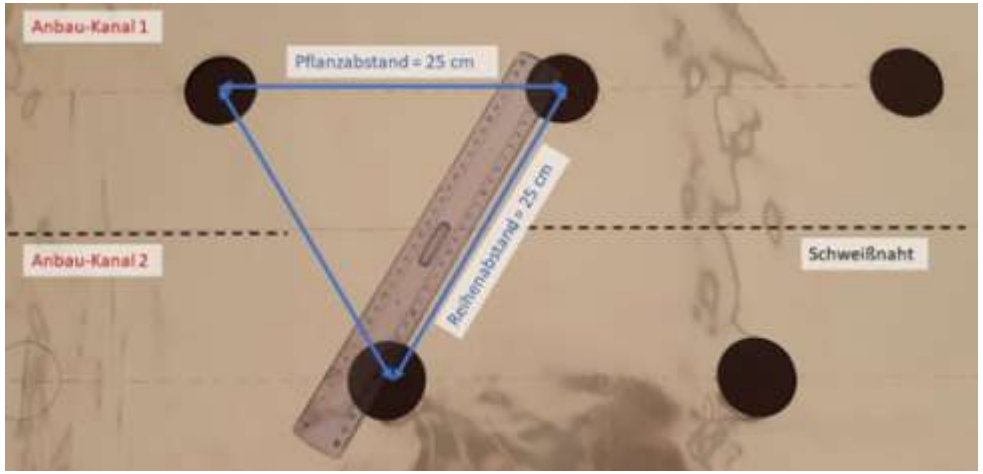
Experimental conditions

- Cultivation duration: 19.07 - 31.08.2023
- T ~15 – 32°C; rH 38 – 95%
- Natural sunlight
- EC 1,5; pH 5,8 - 6,2

Foil layout

- Planting distance: 25 x 25 cm
- Plant density: 18 Pfl./ m²
- Number of plants in total: 116 plants
- Test crop: Lettuce *‘Expertise RZ‘*

Assembly of MEPA on institutes property (RY-HB)



Plant distances on SCM

9 Test phase 2 (Outdoor) - 2023

- Start of trials and assembly: 19.07.2023
- Construction of a weather proof shelter
- Sowing in Planetary Infrastructures laboratory
- Transfer of seedlings after 10 days

Shelter and support box

Fully deployed MEPA-system

9 Test phase 2 (Outdoor) - 2023

- Satus of the lettuce heads after 25 days

9 Test phase 2 (Outdoor) - 2023

9 Test phase 2 (Outdoor) - 2023

Results

- Harvest on 31.08.2023 after 43 days
- Average harvest 17,2 Kg per SCM
- Harvest duration ca. 45 min/ SCM
- Head weight (incl. root):
  33g / **147 g** / 267 g

10 CONCLUSION AND OUTLOOK

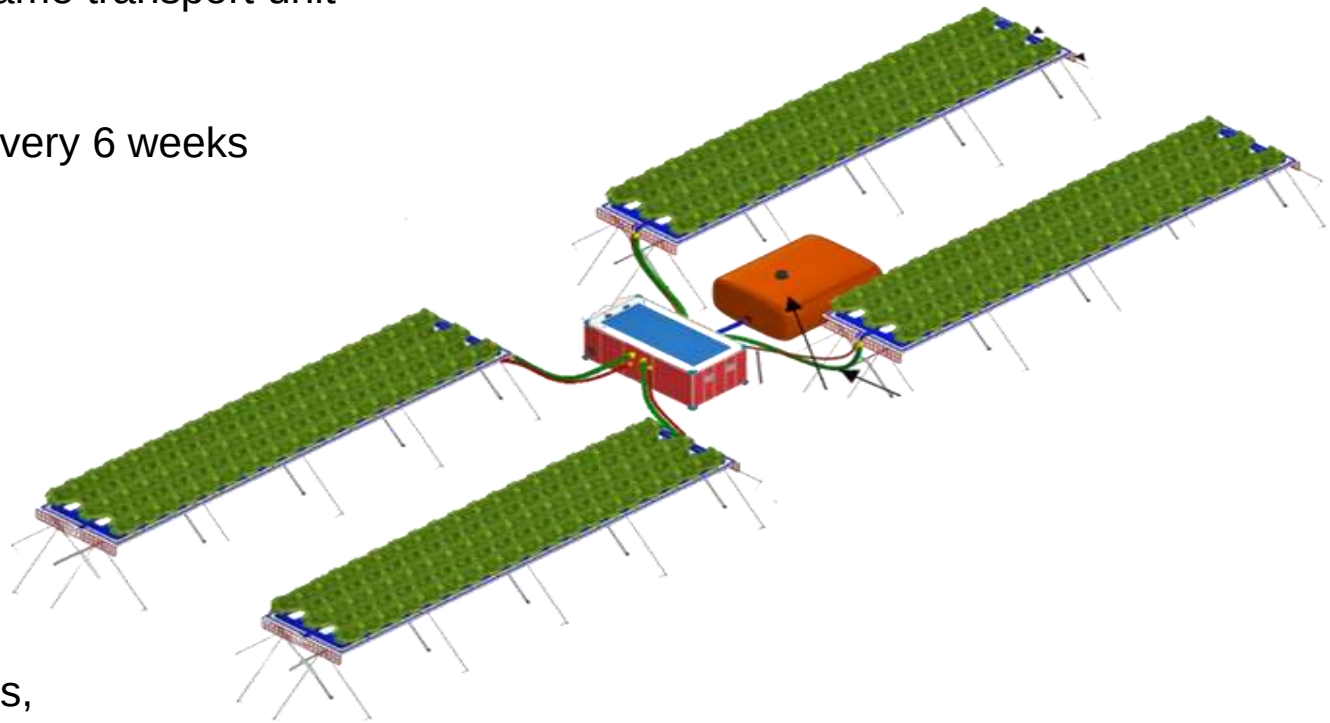
10 Outlook and conclusion

Technical extension I

- Expansion of cultivation area, lightweight foldable tables
- 4 Cultivation tables; 9m instead of 6 m; within the same transport unit (28 MEPA units per container)
- Increased cultivation area to ~1200 m² => ~ 8,7 t every 6 weeks

Technical extension II

- Adaptive control system (integration of external weather data, e.g. temp., rH, solar radiation)
- Connection Internet => Use of current weather forecasts
- Server-based networking of all units (detecting faults, alarming on-site operators)
- AI-based control & biomass optimization



MEPA 2.0 – Next Generation concept

10 Outlook and conclusion

Partnerships

- Search for mission-relevant test environment
- Plan International (=> Azraq Refugee-Camp)
- Further discussions with collaboration partners/ aid organizations

Visit of Plan International in Bremen, 30.08.2023

10 Outlook and conclusion

Development Goals/ Key Features

Compact transport=> Large cultivation area: 8,7 t of food

Independent from power grid - solar powered

Plug & Grow: Fast and easy Assembly

Dynamic control/ Implentation of weather data/ cross-linked systems

Soilless cultivation (Closed-loop/ resource-efficient)

Food supply in extreme situations; Sustainability goal No. 2 of UNO

10 Outlook and conclusion

Conclusion

- ✓ Designphases completed
- ✓ Carried out laboratory tests for evaluation of the system
- X 2 Change Notes (Corona-related extension)
- ✓ Lessons learned; Data collection and analysis
- ✓ 2 successful field trials
- ✓ First working prototype finished
- X Test in a refugee camp
- ✓ Partner network expanded (Main partner: Plan International)
- ✓ Numerous student thesis/ Invited talks/ outreach-activities
- ✓ Technology transfer project initiated / Cost analysis

10 Conclusion and Outlook

Image film MEPA

DLR

Q & A

„Growing fresh food for people in need.“

Anhang

Anhang

AI generated