

The EDEN Initiative

Abstract

In 2011, the DLR Institute of Space Systems launched a research initiative called EDEN — Evolution & Design of Environmentally-closed Nutrition-Sources. The research initiative focuses on bio-regenerative life support systems, especially greenhouse modules, and technologies for future human-made space habitats.

The EDEN initiative comprises several projects with respect to space research, ground testing and spin-offs, which are performed by a small team of enthusiastic researchers. The EDEN team has established cooperation with other European and international research groups to share research results and to work on mutual projects.

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EDEN - Space Research

ESA GHM for Space System

The goal of the ESA *Greenhouse Module for Space System* project is to design an automated production facility for higher plants, utilizing mass production principles to minimize mass and volume as well as power demands. The project is performed for the European Space Agency (=> MELISSA group).

The project will combine the different disciplines, associated with higher plant cultivation research into a solid space-proven concept taking all systems engineering aspects into account

The ESA GHM project is one part of European activities focused on developing a regenerative life support system (LSS). The cultivation of higher plants can make an essential role within a bio-regenerative LSS since it can contribute to all major functional aspects in closing different loops within a habitat.



Artist Impression of a Lunar Greenhouse Module



DLR C.R.O.P.

The research project C.R.O.P. (Combined Regenerative Organic-food Production) is a combined DLR project of the Institute of Aerospace Medicine and the Institute of Space Systems. The goal is to develop a bio-regenerative LSS with the main focal point on urine degradation, solid waste recycling and food production. Possible areas where C.R.O.P. systems can be employed are agriculture processes and in households. The C.R.O.P. project will research the following areas:

- Nitrification; the conversion of ammonia from urine to a more manageable nitrate solution
- Detoxification of completely molecules, such as hormones, antibiotics and harmful degradation products
- Cultivation of beneficial micro-organisms to improve plant growth



C.R.O.P. Prototypes

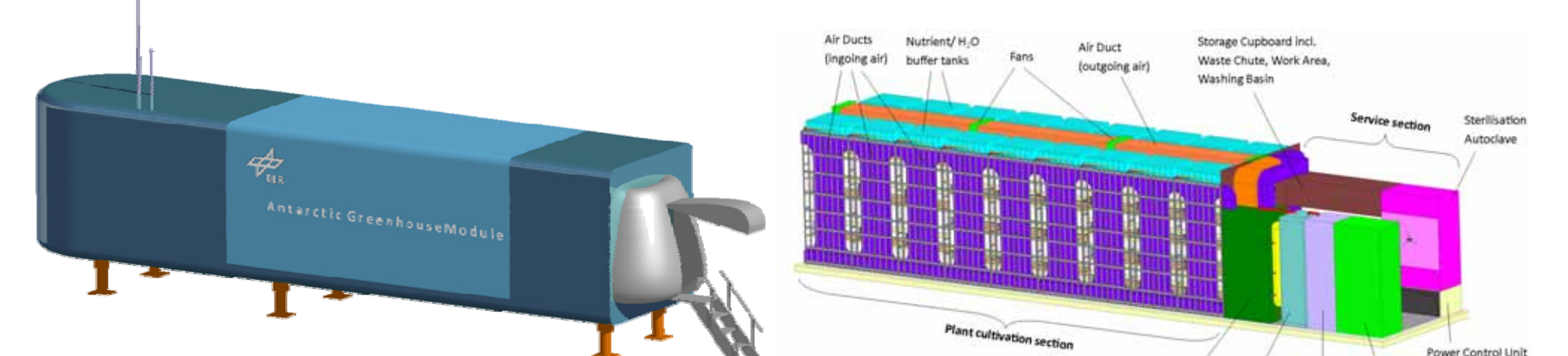


EDEN - Ground Testing

Analogue Testing @ Antarctica

ASG Antarctic Greenhouse

The Antarctic GHM (performed by the DLR Advanced Study Group) comprised all necessary system and subsystems needed for the cultivation of different crops for a remote research station at the South Pole. The focus of this investigation was the estimation of mass flows and output of an container GHM



EDEN ATS EU-Proposal

The EDEN ATS EU-Proposal aims to validate plant cultivation technologies at multiple analogue test sites (Neumayer Station III, Antarctica; Atacama Desert, Chile) to support bio-regenerative life support systems for future human space exploration. These technologies include:

- Structures, Mechanisms & Plant Compartment
- Nutrient Delivery System
- Environmental Control
- Lighting System



Neumayer Station III in Antarctica

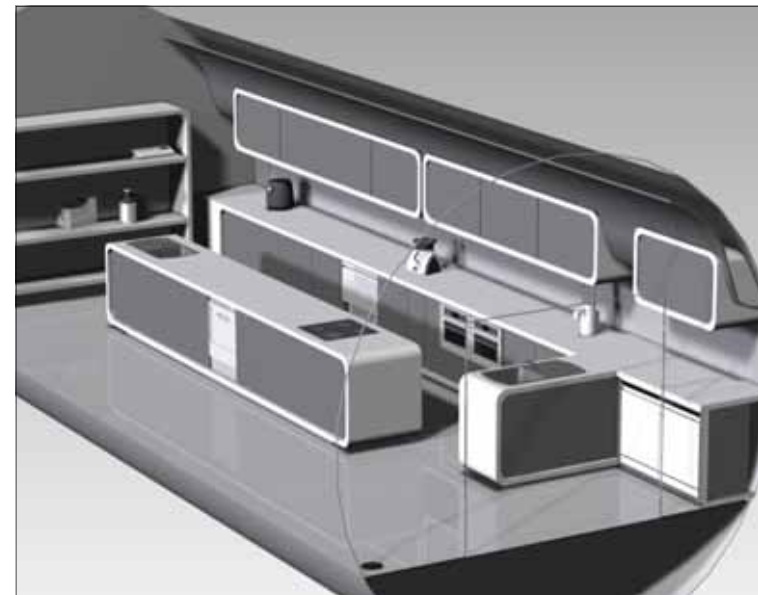
GHM Subsystem & Infrastructure Development

EDEN Laboratory

The EDEN laboratory, established in spring 2013, allows the DLR staff to experimentally investigate plant cultivation under closed environments. The research objectives are the development of customized LED panels, the creation of light recipes for different plant species and preparatory activities (e.g. plant compartment design) for a future container-shaped greenhouse module.

Food Processing Facility (FPF)

The Food Processing Facility (FPF) is the general interface between a future habitat and the greenhouse module. Analysing the post processing procedure is an essential aspect considering the overall production cycle for generating food within a closed habitat on Moon/ Mars. Within the EDEN laboratory a broadband FPF enables certain experiments considering all aspects of the different food production steps in an innovative manner (e.g. harvesting, cleaning, cutting, extracting, disinfecting, sterilizing, boiling, drying, dehydrating, packing and storing).



Design study of a Food Processing Facility (FPF), conducted by the Technical University of Berlin

CEADSE

The Controlled Environment Agriculture Development for Space and Earth (CEADSE) project intends to utilise the pull of space technology by advancing the readiness of CEA technologies within GHMs. CEADSE is funded by an International Incoming Fellowship as part of the European Marie Curie Actions.

EDEN Research Scope

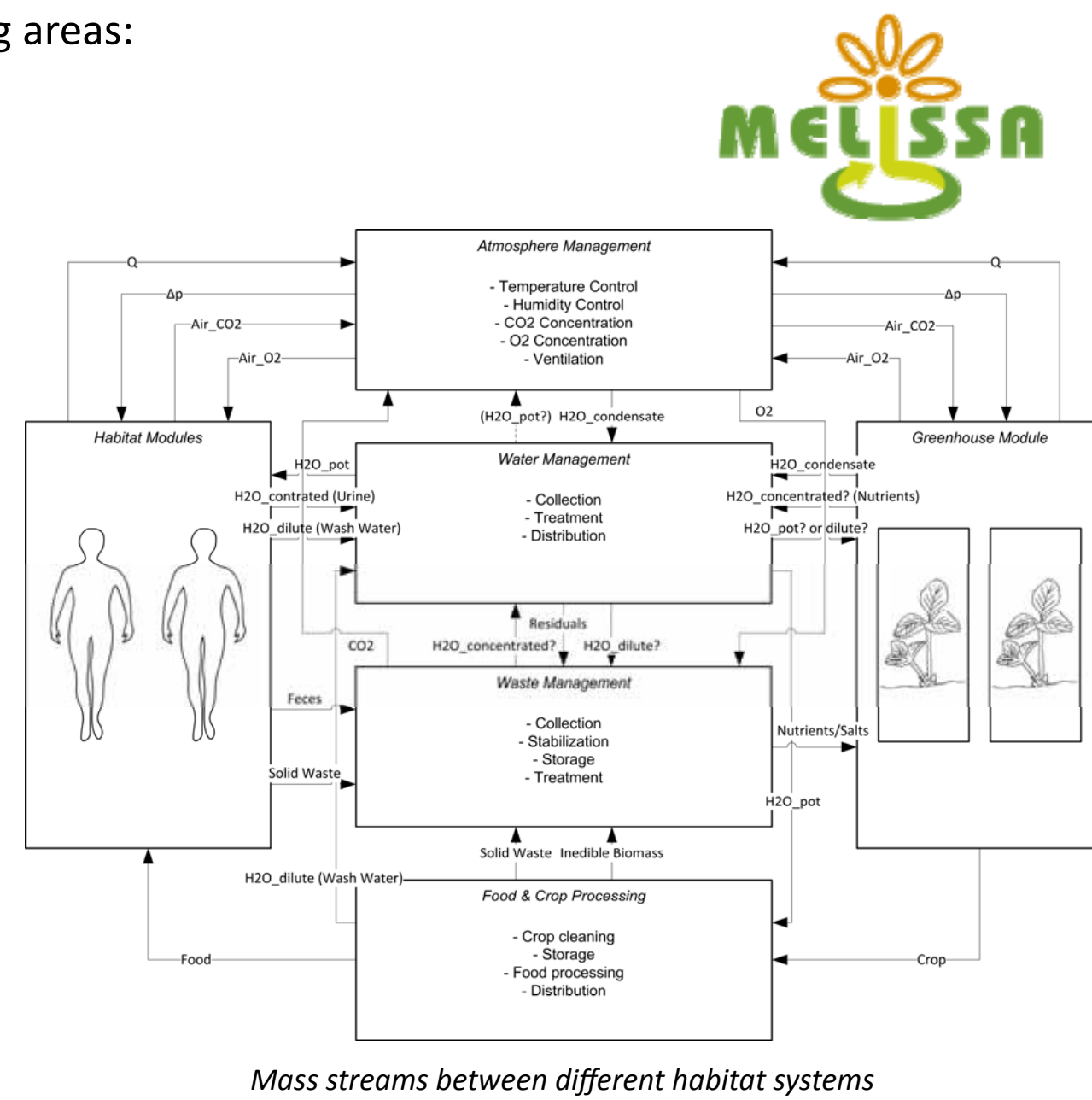
- Design of Greenhouse Modules (GHM) for future space habitats
- Development of Controlled Environment Agriculture (CEA) technologies
- GHM ground testing at Earth-analogue test sites
- Investigations in post-processing procedures
- Interface evaluations GHM <=> Habitat
- Terrestrial spin-offs, benefiting citizen on Earth

ESA National Partnership Initiative (NPI)

ESA NPI (Networking/Partnering Initiative) supports work carried out by Universities and research institutes on advanced technologies with potential space applications.

A DLR affiliated topic for the ESA NPI is the *Combination of Physico-Chemical Life Support Systems with Space Greenhouse Modules for higher loop closure at different internal pressure levels*. It will focus on the following areas:

- Improve readiness of greenhouse modules as part of LSS by taking advantage of the experience and reliability of current physico-chemical (P/C) LSS.
- Analyze proper interface and buffer methodologies between the greenhouse module and other habitat systems, and also at different internal atmospheric pressure levels.
- Investigate current analytical and mathematical models of P/C LSS, develop new models when necessary.



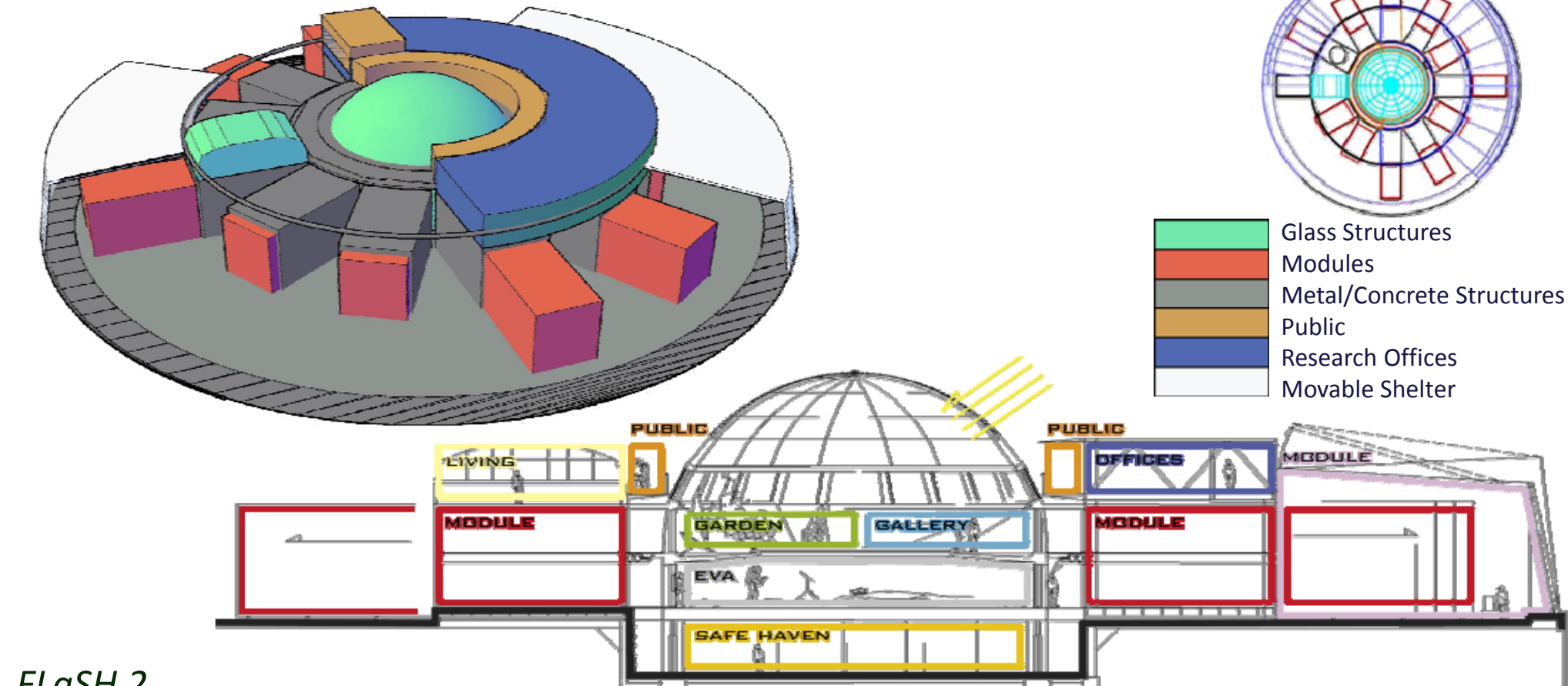
Mass streams between different habitat systems

Habitation Simulation

FLaSH

The FLaSH (Facility of Laboratories for Sustainable Habitation) study focused on the concept development of a closed-loop habitat for technology testing, with different recycling applications and In-Situ Resource Utilization (ISRU) processes.

The facility consists of an EVA terrain hall, control center, public engagement area and 12 functional modules (e.g. Air-, Water-, Greenhouse-, Sickbay-, Living-, ISRU Module). The main study points were the overall configuration, equipment-level subsystem description and the mass flow relationships between the modules.



FLaSH 2

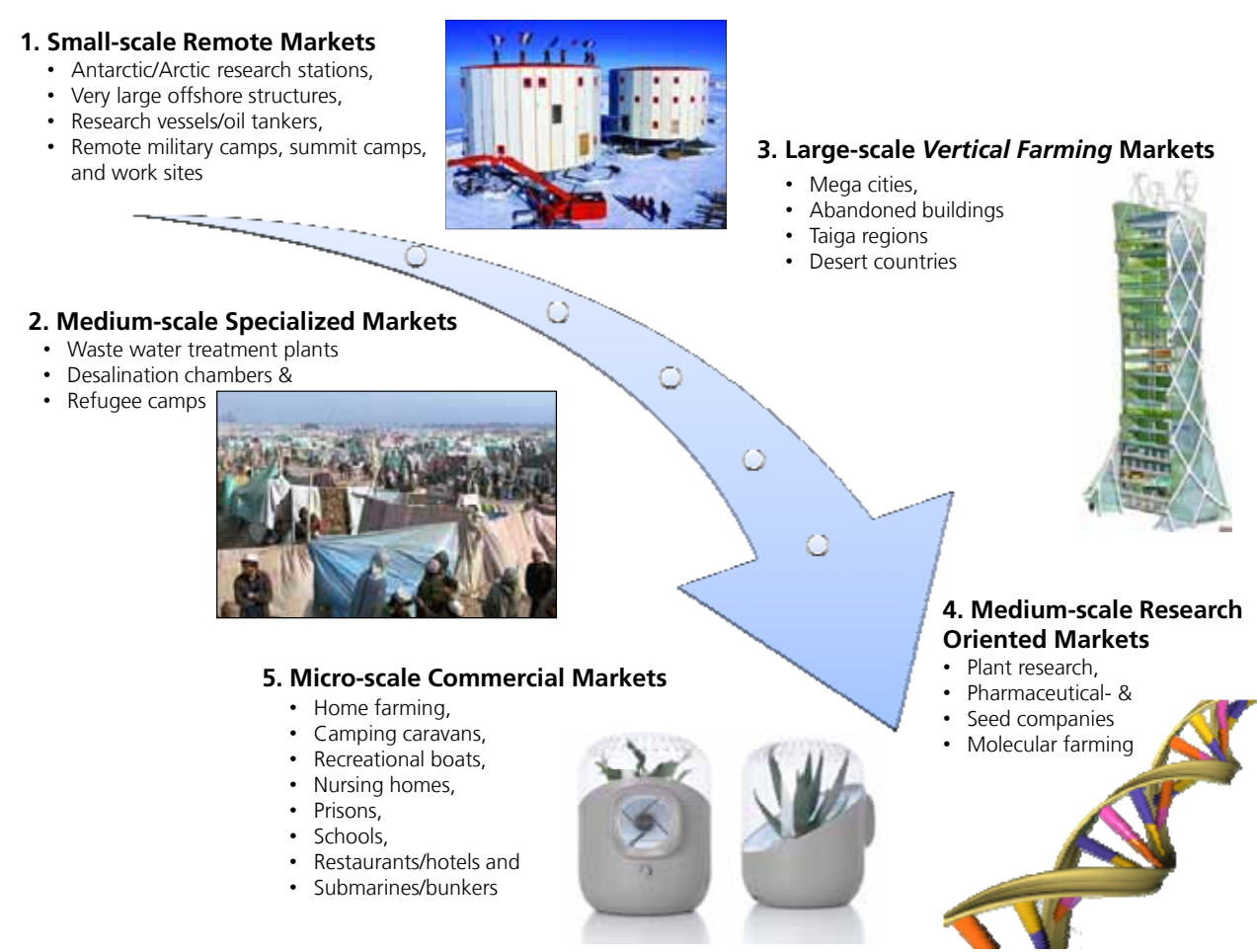
During the FLaSH 2 study, the design results of the first FLaSH will be further investigated and enhanced to achieve a detailed level ready for publication, finding of partners and acquiring of funding for additional studies and first mock-ups and models.

EDEN - Spin-offs

DLR-Technology Marketing

A detailed market analysis was performed in cooperation with the DLR-Technology Marketing (DLR-TM) department. The focal point was set on terrestrial applications, resulting from the research findings of the EDEN initiative. Five terrestrial spin-off markets could be identified (see Figure, right) and a proper market strategy was created upon these findings.

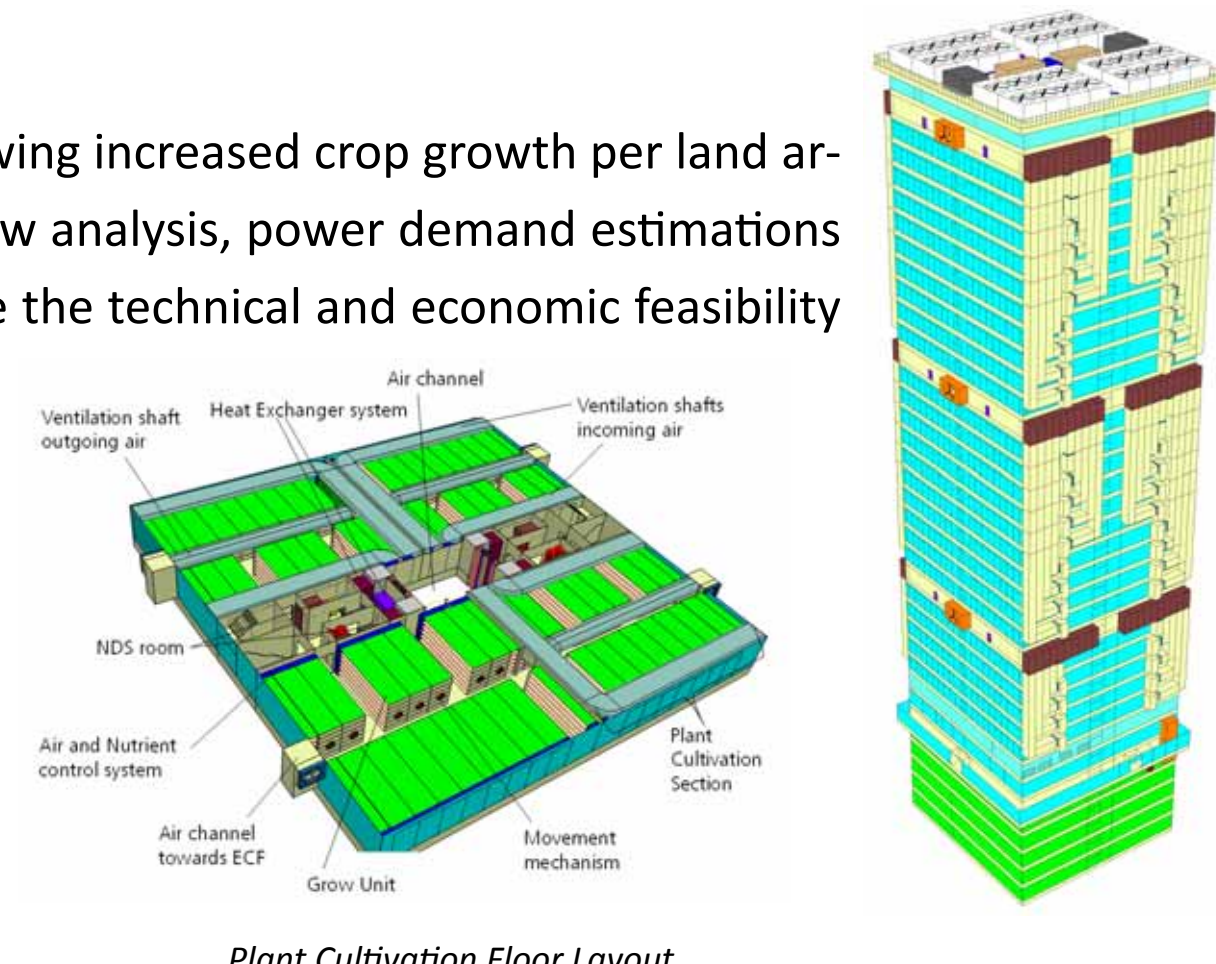
The five segments were analysed with respect to general applicability of the idea, risks and market barriers, consumer preferences and psychograms, existing market participants and projects, as well as potential market volume and potential sales volume estimates.



Vertical Farming

Vertical Farms are posited as a potential solution to the global food demand by allowing increased crop growth per land area. During a CE study, a semi closed-loop Vertical Farm focusing on input/output flow analysis, power demand estimations and detailed cost calculations was designed. The study's objective was to determine the technical and economic feasibility of a such a cultivation system.

The Vertical Farm is a 37 floor building harvesting tilapia fish and 10 varieties of fruit and vegetables. The CE study found that the Vertical Farm produces a high plant yield. In order for crops grown on agricultural land to match this yield, an area 1,100 times that of the Vertical Farm footprint would be required.



Plant Cultivation Floor Layout

EDEN - Partners

