Underground farming

Baltic Sea Underground Innovation Network (BSUIN)

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Content

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1. BSUIN project introduction

The aim of the BSUIN project is to make the underground laboratories (hereinafter ULs) in the Baltic Sea Region more accessible for innovation, business development, and science by improving the information about the underground laboratories, the operation, user experiences, and safety.

Baltic Sea Underground Innovation Network (hereinafter BSUIN) is a collaboration project between 13 partners from 8 Baltic Sea Region (hereinafter BSR) countries. Besides project partners, 17 associated partners contribute to achieving project goals.

In the project participate six (6) underground laboratories around BSR. They all will be characterized and presented to potential customers in order to attract developing innovative activities and active use of those laboratories. Six underground laboratories by name are:

1. Callio Lab, Pyhäsalmi mine, Finland
2. Äspö Hard Rock Laboratory, Oskarshamn, Sweden
3. Reiche Zeche, TU Freiberg Research and Education mine, Germany
4. Lab development by KGHM Cuprum R&D centre, Poland
5. Khlopin Radium Institute Underground Laboratory, Russia
6. Ruskeala Mining Park, Russia

The main outcome of the project is a sustainable network organization, which will disseminate the technical, marketing, operational quality, training, and other information about the BSR ULs created during the project.

The project is funded by Interreg Baltic Sea funding cooperation. Its duration is 36 months with a total budget of 3.4 M€.

2. Content of present Document

2.1 Document justification

The present document is a part of the project BSUIN work package 2.3 output, where one of the activities covers data gathering and analysis of underground production opportunities worldwide. By an underground production, we refer mostly to underground farming for scientific studies up to scaled-up industrial underground farming applications.

The purpose of work package 2 is to collect, categorize and analyze the geophysical, structural, and organizational characterization of six underground laboratories in the BSUIN project. Among that one of the activities are to collect and analyze worldwide data about underground farming possibilities and best practices that are implemented so far.

2.2 Content description

The present document gives an overview of different types of underground farming approaches and best practices worldwide. Underground farming requires a technology-based approach to food production. In principle, it can be divide into controlled-environment agriculture (CEA) and closed ecological systems (CES) approach.

Controlled-environment agriculture (CEA) aims to provide protection and maintain optimal growing conditions for example in containers and greenhouses. Ideal growing conditions are provided with hydro- or aeroponic systems where resources like water, energy, space, and capital are optimized. Controlled variables include nutrient pH, nutrient concentration, light, carbon dioxide, humidity, temperature, and pests. Temperature can be controlled in air, nutrient solution, root-zone, or leaf. Light can be studied of intervals, spectrum, duration, and intervals. In a controlled environment, different aspects of production can be studied with one changing variable at the time.

Closed ecological systems (CES) do not exchange matters outside the system. These systems can be used also as platforms to study space habitats or space stations. Closed systems require a minimum of one producer aka autotrophic (chemotrophic or phototrophic) organism.

Many of the following CEA and CES examples act as laboratories for controlled scientific studies or already as industrial production sites of underground farming. Their mission is to establish mainly local consumer-oriented farming which require much less water and land compared to the traditional field farming or conduct scientific research to understand how the human body could survive in closed ecosystems, such as in space.

The following list of examples is not definitive, but represent only a portion of fast-growing underground or indoor farming facilities globally.

It is important to note that many underground farming best practices today are carried out not in underground facilities but in indoor environments, mainly in old industrial buildings, or even in space facilities.

Therefore food production in real underground facilities, i.e in former mine sites/tunnels, especially near urban areas with stable and suitable temperatures and other parameters, are actually important alternative sources in future food production. A world population growth, urbanization, and climate change occurrences, such as desertification, water shortage, deteriorating air quality, etc, decrease most likely farming possibilities in the land in the future. Underground facilities, used for food production, can be an effective alternative to mitigate that problem.

3. Worldwide examples of controlled-environment agriculture (CEA)

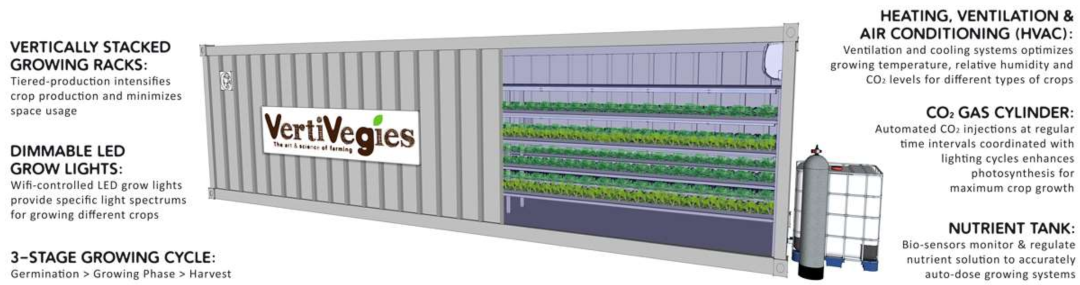
- **AeroFarms** – operating in 4 farms close to New York, U.S, and indoors in old big-scale factory buildings. Growing leafy greens and herbs in vertical controlled indoor farming with the patented aeroponic growing system. In their closed-loop system, AeroFarms uses 95% less water than field farming and with yields 390 times higher per square foot annually. Additionally, their products are pesticide-free, non-GMO, and available all year round. Since the farms locate near populated places in the United States East Coast, they also reduce harmful transportation emissions, because usually greens and herbs are grown in the United States West Coast. They have won several sustainable-related awards. More info https://aerofarms.com/

- **Growing-Underground** – growing fresh microgreens and salad leaves 33 meters below the ground in old World War 2 bomb shelters in London. Using the latest hydroponic systems and LED technology, which allows to use 70% less water than traditional open-field farming. Products are pesticides-free and available all year round. The company`s philosophy is limited food miles and keep their products consumption local, i.e reduce transport impact on the environment. More info http://growing-underground.com/

- **SananBio** – operates mainly in the United States. In vertical indoor farms growing in large variety lettuce, greens, and herbs, using their own developed RADIX grow technology. Besides plant growing company`s scientists, engineers, designers, and product developers offer consulting and research/support services in vertical farms design and construction, operations and management, and in training. Additionally, they offer novel own developed high-efficiency LED horticultural lights for plant growth, i.e the HAWK series. More info https://www.sananbious.com

- **YesHealth iFarm** – one of the biggest vertical farms in Asia operates in Taiwan and China. They grow over 30 varieties of vegetables, including arugula, ice plant, mustard leaf, etc. Their crops use less water and yield several hundred times more per unit area than traditional field farms. Their farms operate locally in order to reduce energy for transportation. Their farms don`t use pesticides, herbicides, and fungicides. More info http://www.yeshealth.com.tw/

- **VertiVegies** – develops an urban farming approach in Singapore. They have established an urban farm at Lim Chu Kang with an R&D facility center in Singapore. Besides vegetable farming, the company also offers vertical farming systems, for instance vertical farming in sea containers and smart control systems for optimizing nutrient-dosing and proper LED light intensity for instance. More info http://www.vertivegies.sg/



- **La Caverne** – an indoor urban farm in the city center of Paris, France. Operates for local consumers. Produce microgreens, endives, oyster mushrooms, shiitake, and button mushrooms. More info https://lacaverne.co/

- **Mycopolitan** – grows exotic mushrooms in Philadelphia, the United States. They sell their mushrooms to local restaurants, in retail, and in the farm. The farm locates in the warehouse basement. Uniquely their farm uses earth's thermal source to buffer temperatures so that mushrooms grow nine months out of the year with minimal energy. More info https://www.mycopolitan.com/

4. Worldwide examples of closed ecological systems (CES)

- **Biosphere 2** - The Biosphere 2 facility serves as a laboratory for controlled scientific studies, and a far-reaching provider of public education. Its mission is to serve as a center for research, outreach, teaching and life-long learning about Earth, its living systems, and its place in the universe; to catalyze interdisciplinary thinking and understanding about Earth and its future; to be an adaptive tool for Earth education and outreach to industry, government, and the public; and to distill issues related to Earth systems planning and management for use by policymakers, students and the public.

  Biosphere 2 consists of several modeled urban ecosystems, which investigate environmental and societal challenges related to water, environmental, and energy management through the design of large-scale experimentation in their ecosystems. Located in several ground facilities in Arizona, United States.More info http://biosphere2.org/

- **BIOS-3** is a closed ecosystem in Krasnoyarsk, Russia, started operation in 1972. It was established to develop closed ecosystems capable of supporting humans. The inside facility was conducted several closed experiments with one to the three-man crew. It has chambers for plant growth and the ultimate idea was to investigate how people could survive in closed systems, how it affects their health etc. Now BIOS-3 is a subdivision of the Russian Academy of Sciences and focusing on growing plants and recycling the waste in cooperation with European Space Agency.

- **European Space Agency (ESA)** – conducting research in topics such as:
  - ✓ Human health, including changes in physiology and biology during spaceflight
  - ✓ Aging
  - ✓ Plants growing for food in spaceflight conditions
  - ✓ Life support, like how we could process waste to deliver never-ending fresh supplies of oxygen, water, and food
  - ✓ Exobiology, i.e experiments exposing life to the harsh conditions of space
  - ✓ Physics and materials, i.e experiments tp produce materials of the future what are applicable for spaceflights
  - ✓ Radiation
  - ✓ Technology, e.g experiments in remote operations, energy efficiency and maritime surveillance on the International Space Station developing new technologies

  More info https://www.esa.int/Our_Activities/Human_and_Robotic_Exploration/Research/About_research_in_space

- **Lunar Greenhouse project** - NASA scientists are collaborating with a university team to develop long-term methods that could help sustain pioneers working in deep space. Lunar Greenhouse project will support ongoing research in space to grow vegetables for food and cultivating plants to sustain life support systems. More info https://www.ag.arizona.edu/lunargreenhouse/

  Addition to that, from NASA Technology Transfer program have grown several spinoff companies who now selling their product or service locally and globally, including advanced gardening services for small homes. For more info see program and spinoffs https://spinoff.nasa.gov/

5. Conclusions

It seems that underground or indoor vertical farming, with smart LED-lighting and control systems to optimize expenditures in plant growth, growing globally, especially in urban areas, where environmental resources, such as land and water, are lacking. Population growth and climate change affecting our everyday life at an accelerating pace, this has an impact on traditional field farming and might cause hunger and other occurrences. Underground farming in former mine sites/tunnels, especially near urban areas, might become a therefore important alternative source in future food production and mitigate possible food shortages.