D6.1 - Market analysis and technology database report

prepared for

WP 6.1 - Terrestrial Applications

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Executive summary

Within the EDEN-ISS project, a lot of technologies were implemented into the Future Expoloration Greenhouse (FEG) for the analogue mission on Antarctica. Most were existing technologies that had been developed within previous “space related” projects and some were derived from existing high-tech greenhouse production technology.

This document analyses the potential for spin-offs to other applications, particularly of the technologies that were either new or modifications of existing technologies, that is: the E-nose for the microbial detection; the water-cooled LED luminaries for plant lighting; the online, continuous control of the spectrum of the luminaries and the plant health monitoring system.

Whereas the potential for application of the modified E-nose is particularly in hospitals and related places, the potential for the other three systems is particularly in high-tech, fresh vegetable production, such as high-tech greenhouses or Vertical Farms. Indeed, given the size of such markets, the potential for each system is certainly high. This document also gives a preview of the improvements/adaptations of each system, which would improve the penetration in the potential market.

The findings were fine-tuned through a workshop aimed at companies operating in the sector, that is, both growers and technology providers. The programme and invitation of the workshop is: https://www.wur.nl/en/activity/Greenhouses-in-space-down-to-earth.htm

A short film has been produced for reference about the workshop and the most advanced participating companies and their vision, and it can be found here:

https://vimeo.com/332985950/bfa904937d

The Food Quality and Safety activity produced a large data set that were communicated to students and professionals of the food area in a workshop organised by CNR and LIT in Parma (Italy) as part of the Cibus OFF event. The workshop was advertised by the press office of Cibus OFF and by the press office of the CNR

https://www.cnr.it/it/nota-stampa/e-16225/cibo-spaziale-per-una-terra-che-cambia

and was on national media.

https://parma.repubblica.it/cronaca/2019/04/02/news/cibus_off_al_via_il_programma-223109009/

A video interview was produced during the workshop by the national newspaper “Repubblica” that made it available on line

https://www.youtube.com/watch?v=rsTdjeJP5S8

Table of contents

1 Introduction

Within the EDEN-ISS project, a lot of technologies were implemented into the Future Expoloration Greenhouse (FEG) for the analogue mission on Antarctica. Most were existing technologies that had been developed within previous “space related” projects and some were derived from existing high-tech greenhouse production technology. It could be expected that technology innovation and implementation during the analogue mission could lead to advances with broad applications, particularly in Controlled Environment Technologies, such as computer-controlled, automated greenhouses and/or Vertical Farms.

The purpose of WP 6 “Terrestrial applications” was to analyse the potential for spin-offs to such other applications, particularly of the technologies that were either new or modifications of existing technologies.

2 Own assessment of potential

For this purpose, at the end of the project all partners were asked to answer a series of questions in order to assess: a. the potential market (other than "space") and b. the adaptations possibly needed to enter the other market(s).

In fact, most partners did not answer the questions, which probably means that they did not see any other possible applications. In other cases (particularly some of the technologies related to the plant fert-irrigation system), the responsible partner chose to "play safe", that is to implement proven technologies, already in use in high-tech greenhouses, so that it was the application within this project that was a spin-off and not the other way around.

Nevertheless, a few of the technologies that were developed (or modified) and then implemented into the FEG, do have potential for application in other fields. A short summary is given in Table 1.

Table 2: Self-evaluation of the technologies that were developed/modified for the analogue mission, that were deemed to have a potential for application elsewhere

	Microbial detection
Name of the technology	E-Nose
What it did within EDEN-ISS	Measurement of microbial contamination
Short evaluation of the performance within EDEN-ISS	The measurements are matching with the controls (Q-Tips)
Who/which company is the owner	Sensor System: Airsense Entire Application: Airbus DS
List of possible other applications	Monitoring of contaminations in hospitals/planes Phenotyping
List of required adaptation/improvements for the other applications/markets	Sample taking unit to be modified Dedicated odour database training to be performed
Rough estimate of the market size	If regulations for hospitals given, the market is >1000 units/year

	Water-cooled LED Luminaries for Plant Production
Name of the technology	Water-cooled LED Luminaries
What it did within EDEN-ISS	Specificity of sealed environment of FEG required development of water-cooled-LED luminaries to assure high level of thermal control
Short evaluation of the performance within EDEN-ISS	The example of EDEN ISS shows that water-cooling system allows to maintain operation temperature of LED lights on a stable low level. It has a positive effect on quantum efficiency of luminaires as well as extends the expected life span. Low operating temperature prevents plant canopy getting damaged when growing very close to luminaire surface. However faultless operating of water-cooled luminaires requires investment in good quality heat exchange system
Who/which company is the owner	Heliospectra AB
List of possible other applications	Plant factories; all applications requiring high level of thermal control and high level of control over growth conditions as e.g. production of plants with low thermal requirements, cloning, reproduction of demanding species, growing plants for extraction of chemicals, herbivore insect breading
List of required adaptation/improvements for the other applications/markets	Development of robust heat exchange system
Rough estimate of the market size	The total market for horticulture lighting in 2017 was estimated to 3.8 billion USD. As more applications are added and LED grow lights are gaining increasing market shares, the market is expected to grow to 8.6 billion USD

	in 2022, representing an average increase of 18% per year. The establishment of vertical growth modules, which makes the use of space more efficient in growing environments, is then expected to double the market value between 2022 and 2027 to 17,2 billion USD. (Yole Development, November 2017)

	Dynamic LED Light Strategies for Closed Environment Plant Production
Name of the technology	Dynamic LED Light Strategy
What it did within EDEN-ISS	Tuneable LED luminaries produced by Heliospectra which were used during the EDEN-ISS project allow high level of regulation of light intensity and light quality. WUR had developed a general lighting strategy (including light spectrum and photoperiod), which was used for successful growth of wide variety of plant crops in FEG. The application of reduced light intensity at the beginning and the end of photoperiod can help reduce plant stress, increase light interception, and extend photoperiod with reduced amount of energy (when compared with static lighting)
Short evaluation of the performance within EDEN	The results of research conducted during EDEN-ISS project shows that dynamic light intensity during the photoperiod is beneficial for plant growth
Who/which company is the owner	Heliospectra AB owns the rights to the controllable LED luminaries as well as to the software controlling the light settings. The specific lighting strategies can be developed in cooperation or independently by any user of the luminaries
List of possible other applications	The basic versions of dynamic light strategies (photoperiodic) have application in plant factories and greenhouses with limited natural light particularly in production of lettuce, other leafy greens and other crops of low or intermediate light requirements. The application of dynamic light spectra can be extended by application of light sensors and a plant growth monitoring system to stabilize light condition during plant growth allowing high level of control over production cycle. By controlling light level and temperature a high level of repeatability of quality of produced crops can be achieved. Furthermore, certain level of control over crop production (i.e. possibility to speed up or slow down harvest, following e.g. market requirements) is gained. Application of dynamic light strategies in greenhouses helps to save energy (when compared to static on-of light control) Dynamic light spectrum control can be used in enhancing production of certain phytochemicals including those responsible for plant taste, smell and coloration (for example year-round consistent production of aromatic oils). Controlled light spectra can be used to influence behaviour of animals (chickens, cows, bees etc., as well as humans staying in environments of limited amount of daylight)
List of required adaptation/improvements for the other applications/markets	Although the idea of lighting strategies tailor-made to requirements of different crops is not new, it still requires dedicated research. Lighting strategies (including duration of phases of different light intensity and light quality) have to be optimized or developed for separate plant varieties, individual goals of growers (e.g. for rooting, flowering, increased shelf life etc.) as well as specific growth conditions. Development of robust, low-cost sensors will accelerate the use of dynamic lighting strategies
Rough estimate of the market size	The market for SMART greenhouses (LED lighting, irrigation systems, control systems, sensors etc.) was valued at 1,26 billion USD in 2018, with an expected annual growth of 12,6% to the year 2023, leading to an expected market value of 2,28 billion USD. (Smart Greenhouse Market – Global forecast 2023)

	Plant health monitoring
Name of the technology	Crop monitor
What it did within EDEN-ISS	Automated screening of a large number of RGB images taken with cheap cameras. Automated comparison with previous images of the same spot a. detected anomalies that required human intervention; b. predicted remaining days to harvest and c. evaluated crop performance.
Short evaluation of the performance within EDEN	The system did what it was meant to do, although the good conditions in the FEG made it redundant there
Who/which company is the owner	Wageningen Plant Research, Greenhouse Horticulture Unit
List of possible other applications	Vertical farms/plant factories High-tech greenhouses
List of required adaptation/improvements for the other applications/markets	To increase intelligence of the system, in order to minimize human intervention. Evaluation in more challenging conditions of the quality of the predictor and of the crop performance evaluator.
Rough estimate of the market size	Labour is about 30% of greenhouse production costs, in high- as well as low tech greenhouses. Qualified labour (the green-finger grower) is ever scarcer. A relatively cheap yet reliable system that decreases need for (qualified) labour has a huge potential. Obviously, first applications will be at the high-end of the market (plant factories) and then in high-tech greenhouses.

3 Workshops

In order to have a kind of "reality check" of the estimated potential of the technologies aimed at high-tech plant production, an "innovation workshop" was organised where consortium partners and external market participants (both growers and technology providers) were invited.

The program of the workshop and the invitation can be found here:

https://www.wur.nl/en/activity/Greenhouses-in-space-down-to-earth.htm

Indeed, there was a general agreement that protected horticulture is evolving towards ever more control of the growing conditions and ever less labour requirement. In addition, it was observed that there is a growing interest in the application of artificial intelligence also in this field. In short, the companies see potential in what has been developed within the EDEN-ISS project and tentative appointments are being made about future collaborations.

A short film has been produced about the workshop and the most advanced participating companies, and it can be found here:

https://vimeo.com/332985950/bfa904937d

Figure 1: Photo of some participants and attendants at the WUR-organized workshop

To communicate the results of the food quality and safety activities CNR and LIT organized the WORKSHOP "Cibo spaziale per una terra che cambia -Space food for a changing earth" (https://www.iret.cnr.it/images/News/cibo_spaziale_programma.pdf).

The workshop was organized in collaboration with:

- ALMA (https://www.alma.scuolacucina.it/);
- the School of Advanced Studies on Food and Nutrition of the university of Parma (http://www.advancedstudies.unipr.it/?lang=en);
- Cibus OFF (http://turismo.comune.parma.it/en/thematic-channels/events/events-and-initiatives/multiple-events/cibus-off?set_language=en)
- and with the kind contribution of the Italian Space Agency (https://www.asi.it/en).

ALMA is a world recognized top quality school for students that aim to become top quality chefs. Cibus OFF is an initiative linked to the Cibus event, which is one of the most famous events, related to food and food service business, which was held in the workshop week in Parma.

ALMA and Cibus OFF took care of press coverage, availability of the location (the historical city council palace "Palazzo del Governatore") and all technical necessities for the event. The press office of the Cibus OFF initiative launched a press alert, fully reported by the national newspaper Repubblica, about the Cibus event that contained our workshop as one of the events on the agenda.

(https://parma.repubblica.it/cronaca/2019/04/02/news/cibus_off_al_via_il_programma-223109009/)

The alert of the event was also released by the CNR press office.

(https://www.cnr.it/it/nota-stampa/e-16225/cibo-spaziale-per-una-terra-che-cambia)

The national newspaper Repubblica, sent one journalist, from the Parma office, who carried out a video interview with speakers at the meeting. The interview was used to realize a video that was published by Repubblica TV, and linked by several newspapers sites and web-based information platforms.

ALMA included the event as part of its school activity in the event day, ensuring the presence of more than 30 students. Other participants (more than 50 in total) were from the general public and included some qualified members of the scientific school editorial sector (Zanichelli spa).

A video interview was produced during the workshop by the national newspaper "Repubblica" that made it available on line

https://www.youtube.com/watch?v=rsTdjeJP5S8

Figure 2: Photo of some participants and attendants at the CNR- and LIT-organized workshop