GOhydro

A smart-sensing AI-driven platform for scalable, low-cost hydroponic units

D2.4 Integrated Multi-modal Sensor

DELIVERABLE NUMBER	D2.4
DELIVERABLE TITLE	Integrated Multi-modal Sensor
RESPONSIBLE AUTHOR	Eleni Makarona (NCSR-D)

GOhydro is part of the ERA-NET Cofund ICT-AGRI-FOOD with funding provided by national sources [i.e., General Secretariat for Research and Innovation in Greece, Ministry of Environment and Food in Denmark, Federal Ministry of Food and Agriculture in Germany and the Executive Agency for Higher Education, Research, Development and Innovation Funding in Romania] and co-funding by the European Union's Horizon 2020 research and innovation program, Grant Agreement number 862665.

PROJECT ACRONYM	GOhydro
PROJECT FULL NAME	A smart-sensing AI-driven platform for scalable, low-cost hydroponic units
STARTING DATE (DUR.)	01/03/2021 (24 months)
ENDING DATE	28/12/2023
PROJECT WEBSITE	https://www.gohydro.org/
COORDINATOR	Panagiotis Zervas
COORDINATOR EMAIL	panagiotis@scio.systems
WORKPACKAGE N. | TITLE	WP2 | Multi-modal sensor kits
WORKPACKAGE LEADER	NCSRD
RESPONSIBLE AUTHOR	Eleni Makarona (NCSR-D)
RESPONSIBLE AUTHOR EMAIL	e.makarona@inn.demokritos.gr
DATE OF DELIVERY (CONTRACTUAL)	31/05/2022
DATE OF DELIVERY (SUBMITTED)	15/06/2022
VERSION | STATUS	1.0 | Final
NATURE	Demonstrator
DISSEMINATION LEVEL	Public
AUTHORS (PARTNER)	Niklas Galler (nr21 DESIGN), Alexandros Salapatas (NCSR-D), Pythagoras Karampiperis (SCiO)
CONTRIBUTORS	Niklas Galler (nr21), Pythagoras Karampiperis (SCiO)
REVIEWER	Antonis Koukourikos (SCiO), Panagiotis Zervas (SCiO)

VERSION	MODIFICATION(S)	DATE	AUTHOR(S)
0.8	Initial version	28/05/2022	Eleni Makarona (NCSR-D)
0.9	After input from nr21	08/06/2022	Niklas Galler (nr21 DESIGN)
1.0	After review from reviewers and WP2 Leader	15/06/2022	Eleni Makarona (NCSR-D)

PARTICIPANTS		CONTACT PERSON
SCiO P.C. (SCiO, Greece) **Coordinator**		Panagiotis Zervas Email: panagiotis@scio.systems
Department of Plant and Environmental Sciences, University of Copenhagen (UCPH, Denmark)		Bhim Bahadur Ghaley Email: bbg@plen.ku.dk
Holisun SRL (Holisun, Romania)		Oliviu Matei Email: oliviu.matei@holisun.com
nr21 DESIGN GmbH (nr21 DESIGN, Germany)		Niklas Galler Email: niklas.galler@nr21.com
Institute of Nanoscience and Nanotechnology, National Centre for Scientific Research “Demokritos” (NCSR-D, Greece)		Eleni Makarona Email: e.makarona@inn.demokritos.gr
Department of Technical and Soil Sciences, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca (USAMV, Romania)		Teodor Rusu Email: trusu@usamvcluj.ro

ACRONYMS LIST

BB-MZI	Broad-band Mach-Zehnder Interferometry or Interferometer
CHSK	Crop-Health Sensor Kit
CSU	Communications and Storage Unit
DIY	Do it yourself
MMSK	Multi-modal Sensor Kit
NCK	Nutrient-Content Kit

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EXECUTIVE SUMMARY

One of the main technical objectives of the GOHYDRO project is the development of a Multi-modal Sensor Kit (MMSK) capable of monitoring at pre-determined intervals the environmental factors affecting the hydroponic cultures of microgreens, the quality of the water feeding the plants as well as the nutrient content of the microgreens. This kit has as a main task to collect information about the cultivation conditions and the quality of the microgreens and communicate the relevant information to the e-agronomist mobile application that will notify the user about the health of the crops and provide suggestions about necessary condition arrangements. Towards that end the MMSK is divided into 3 major components: **(1) the Crop Heath Sensor Kit (CHSK)** responsible for monitoring the temperature, humidity, light intensity at the installation as well as the electroconductivity and pH of the water in the tank (indicating the quality of the watering), (**2**) a photonics-based kit that will determine the **nutrient content** of the microgreens through their pulps (**Nutrient-content Kit, NCK**)., and (3) **the communications and storage unit (CSU)** that stores and transmits the data collected by the kits to the GOHYDRO data-driven platform. The MMSK is developed through a dedicated work package (WP2), which has received input from WP1 "Nutrient and environmental needs for microgreens" with regards to the specific parameters that must be monitored for a successful hydroponic installation.

This deliverable is the description of the prototype of the Integrated MMSK and is the first targeted outcome of Task 2.4. Even though the actual deliverable D2.4 is a DEMONSTRATOR, this report is an accompanying explanatory document describing the main activities that led to the integration and a concise summary of the various components and design aspects of the MMSK. This version is an intermediate one due to small deviations from the foreseen workplan. The deviations were due to 2 reasons: (1) the delay in funding of NCRS-D and SCiO which has put a corollary delay in the procurement of kits components and of the 3d-printer required for the fabrication of the housings, (2) the more rigorous design constraints of the kits' housings that became evident during Tasks 2.1-2.3; the consortium has opted to delay the fabrication in favor of a better design, which can meet all the stringent requirements of a hydroponic installation, but which at the same time can be produced in a DIY manner. The delays are expected to be quickly absorbed within the next 3 months of the project without affecting the final outcomes.

All relevant design specifications and requirements were covered in D2.1 "Multi-modal Sensor Kit Specifications and Requirements" (M3), the design details in D2.3 "Crop-health kit prototype" (M12) and the preliminary results of the high-risk photonic component in deliverable D2.2 "Nutrient-content kit prototype" (M12). All these achievements are briefly re-visited in Chapter 1. Chapter 2 analyzes the fabrication iterations of the CHSK, while Chapter 3 presents the updated design and fabrication details of the CSU. Chapter 4 shows the current version of the NCK, which will pave the way for the final NCK design and fabrication. The deliverable is completed with a summary of the conclusions in Chapter 5.

1 CURRENT STATUS OF MULTI-MODAL SENSOR KIT

GOhydro as a whole aims at developing a cost-efficient smart-sensing ICT platform capable of monitoring the crops' health and nutrient content of hydroponically cultivated microgreens in order to optimize the cultivation process and allow the harvest of the best possible products in an urban setting. GOhydro aspires to culminate in the production of a platform that will be a shifting paradigm of how AI-driven technological innovation can become an affordable, accessible-by-all tool, applicable to all forms of urban farming. With this aim in mind, the GOhydro platform has a "dual core", one that consists of the platform's hardware and one that consists of the AI component. The former, collectively described as the MMSK, is the core that in essence monitors, collects and transmits the data pertinent to the health and nutrient content of the hydroponically cultivated microgreens and can be envisaged as the "front-end" of the GOhydro platform responsible for the continuous monitoring of all parameters for the successful cultivation of plants at the hydroponic installation (Fig.1.1). Towards that end, the MMSK is divided into 3 major components: **(1) the Crop Heath Sensor Kit (CHSK)** responsible for monitoring the temperature, humidity, light intensity at the installation as well as the electroconductivity and pH of the water in the tank (indicating the quality of the watering), **(2) a photonics-based kit** that will determine the nutrient content of the microgreens through their pulps **(Nutrient-content Kit, NCK)**, and (3) **the communications and storage unit (CSU)** that stores and transmits the data collected by the kits to the GOhydro data-driven platform.

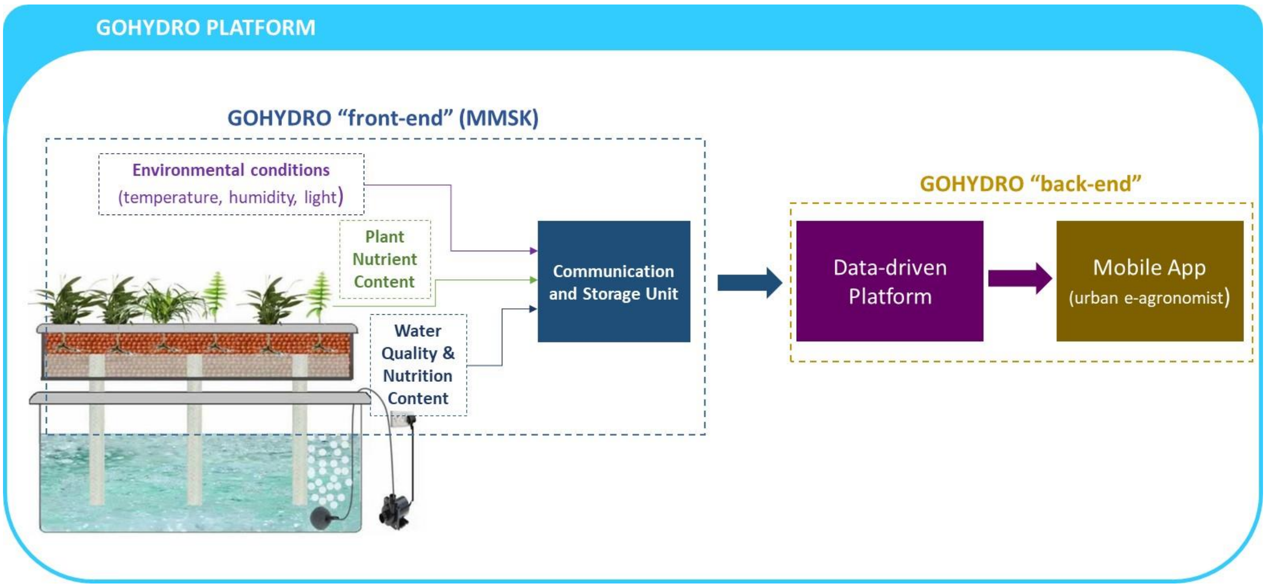


Figure 1.1 Schematic Representation of the GOhydro platform concept. The MMSK, which is essentially the front-end of the platform is shown on the left-hand side with respect to the hydroponic installation in the dashed blue frame. The "back-end" consisting of the AI data-driven platform and the e-agronomist mobile app are shown in the yellow dashed frame.

At the very core though of the GOhydro concept lies one mandate: the MMSK design must be such that the GOhydro platform can be addressed to all, allowing any user to construct and implement themselves an affordable hydroponic culture at their urban setting of choice (home, garden, office, communal buildings, schools etc.). Therefore, the MMSK design should first and foremost obey **three basic requirements**: **(1)** low cost, **(2)** ease of installation, and **(3)** ease of use (mostly in terms of maintenance, like re-charging). Deliverable 2.1 was based on these three requirements, which dictated the entire set of specifications and requirements compiled therein with the underlying idea that all components of the "commercial" sub-units (CHSK and CSU) can be purchased online and that their housing (aka can be fabricated via 3d printing). As far as the NCK is concerned, which is based on a very novel idea to be proven as a concept within the duration of the project, its components are knowingly non-trivial and as a kit it can be used as a supplementary tool of a higher cost that can be shared within a community. Due to the novelty of the idea, it was opted to first test and assess it as a tool for the nutrient-content determination, define all measurement protocols, and then proceed with final housing design that can accommodate appropriate ergonomic aspects allowing ease-of-use. For the moment the NCK is being tested in a preliminary housing and configuration (details in D2.2 and Chapter 3) mostly fit for laboratory use.

The CHSK and CSU are currently been integrated by the lead partner nr21, while SCiO has received the designs from nr21, has installed a 3d-printer and has commenced the fabrication of the housings at its premises. Once completed, the CHSK and CSU will be installed at the hydroponic unit to start the pilot trials with new crops of basil and broccoli. At the same time, NCSR-D will be evaluating the NCK with the same crops and finalize the measurement protocols. The NCK results will be compared to golden standard measurements with LC/MS with regards to the total phenolic content of the microgreens, as defined by WP1. The LC/MS will be performed at the Agricultural University of Athens.

The details of the 3 MMSK sub-units are presented in the following chapters.

2 CROP-HEALTH SENSOR KIT & COMMUNICATION AND STORAGE UNIT

The CHSK is one of the three major components of the MMSK and has as its main task the measurement of the environmental parameters along the water quality and nutrition content. Its design concept was based on two basic pillars:

1. The identification of environmental and nutrient parameters that must be monitored and are essential for the successful hydroponic cultivation of 3 microgreens (basil, broccoli and Brussels sprouts). These parameters were determined by the findings of WP1 "Nutrient and environmental needs for microgreens" and in particular Task1.1 "Review on nutrient and production parameters and light requirements"
2. The basic concept of GOhydro is the development of an efficient and cost-efficient tool that can allow anyone to create his/her own hydroponic installation and have a personalized monitoring tool. As such, all components must be of low cost, off-the-shelf, and easily accessible (i.e. can be directly ordered through e-commerce), while the entire installation and kits (except the NCK) can be assembled in a DIY fashion. With these two basic prerequisites the monitoring parameters were selected and the components specified in D2.1 "Multi-modal Sensor Kit Specifications and Requirements", which was concluded within Task 2.1 "Sensor kits specification and requirements" while receiving continuous input from Task 1.1. "Review on nutrient and production parameters and light requirements".

Several design sprints were organized supported by the tri-weekly progress meetings during which the entire consortium contributed to the design and selection of individual features starting from the ideation prepared by nr21 all the way to the final fine-tuning of all design aspects. As a result, the CHSK –which initially included two separate sub-units- ended up with a more elegant and efficient **all-in-one design** that allows the collection of environmental and water quality parameters from a single unit hanging in the middle of the hydroponic installation (details can be found in D2.3). The final design is depicted in Fig. 2.1.

Figure 2.1. Visualizations of the matured All-in-one Sensor Kit concept ready for 3D printing.

Based on experiences, a virtual overall concept was first developed with the help of CAD tools (Fig. 2.2). The goal was to keep the number of parts low while achieving a functional and attractive structure and shape. The assembly process was designed in order to be as simple and convenient as possible. Based on this, we decided to screw the printed circuit boards onto the corresponding plates, which in turn are then inserted into the housing using a locking mechanism. The sealing of the housing was solved with the help of available standard off-the-shelf parts (e.g. O-rings). The tolerances were adjusted according to the selected 3D printing process (FDM print) in an iterative process. The final CAD designs of the CHSK and CSU units are shown side-by-side in Fig. 2.3 to better demonstrate their relative sizes. The two accompanying documents of D2.4 show the design briefs of the CSU.

Figure 2.2 Preliminary visualizations of the CSU (left) and final design, as a desktop version (right).

Figure 2.3 Final CAD designs of the CSU (left) and CHSK (right) as desktop versions

With the FDM printing process, care must be taken to ensure that the geometries do not require a support structure. This would otherwise have a negative impact on the surface quality. The geometries must therefore be optimized in such a way that the component can be built up layer by layer and no "free-hanging" parts are created in the printing process. All these points were taken into account in the finalized model. The CSU design was initially thought to have less stringent requirements than the rest of the MMSK sub-units and an initial design was completed by M12 of the project and its components underwent a first prototyping fabrication round (Fig. 2.5).
The assembly structure of the current development status works now we are going to optimze the last details for the sensor components now. The following pictures below show parts of the MMSK and CSU prototypes Figs. 2.4-2.5).

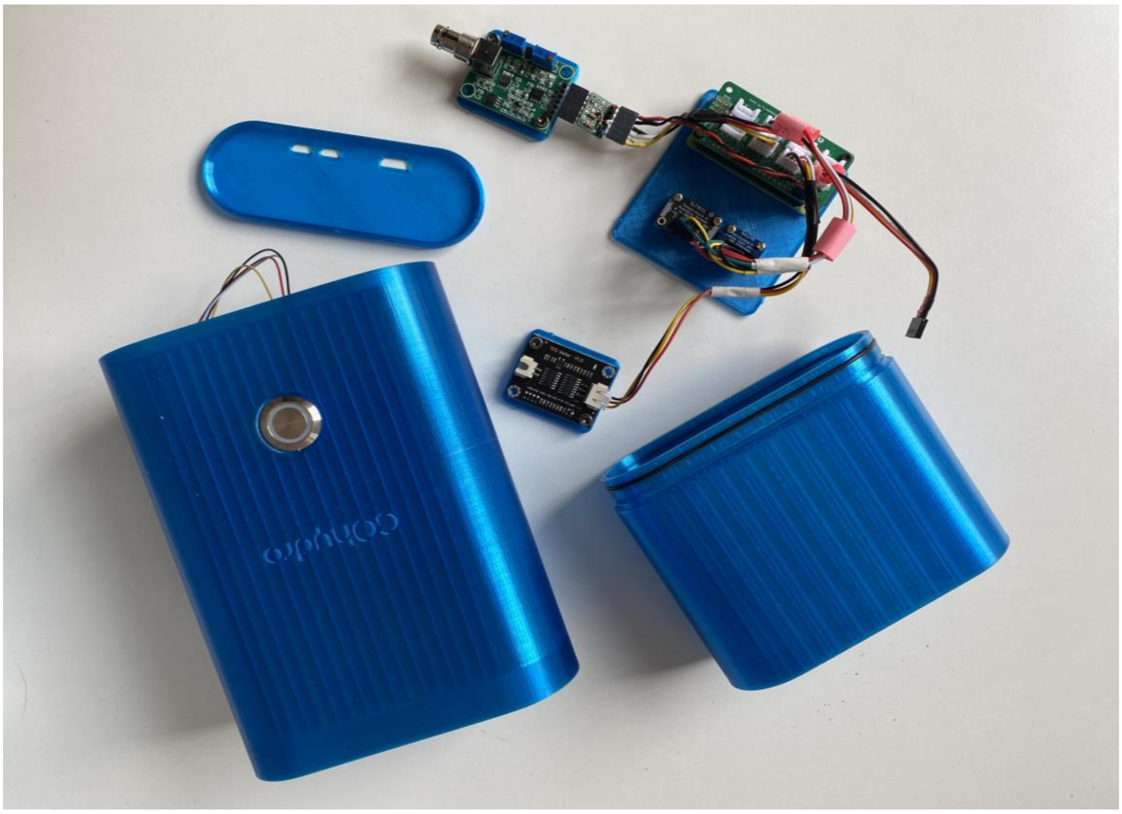


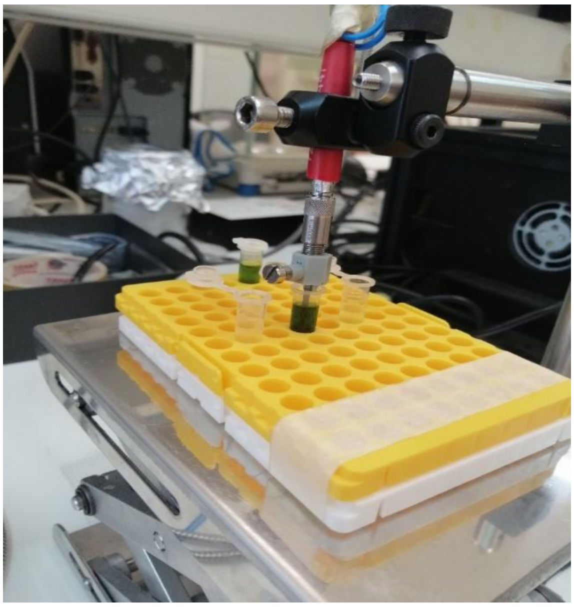
Figure 2.4. Photograph of 3d-printed CHSK parts with the sensors attached

Figure 2.5 3d-printed version of the CSU casing

3 NUTRIENT CONTENT KIT

As already mentioned the NCK is still being tested as a proof-of-concept. A preliminary, laboratory-oriented version of it is being currently tested to evaluate the concept and to fine-tune the measurement protocols (Fig. 4.1 and details in D2.4). Despite its preliminary design, the NCK has a portable reader (Fig. 4.1a). After the assessment of the new crops and the correlation to the LC/MS data that will be obtained, a new design round will commence for its housing within M13-M15. All the design updates and fabrication will be included in a new version of D2.4 after their completion.

(a)



(b)

Figure 4.1. Photograph of (a) the current version of the NCK reader, which even at this stage has a portable format, and (b) the photonic-end of the NCK during a measurement of the extracted basil liquids. The sample being measured is the short-leaf basil, which is darker in colour, while in the background the second sample from the wide-leaf basil can be seen distinguished by its lighter colour

4 CONCLUSIONS

D2.4 has progressed satisfactorily. The current version of the deliverable comprises the designs and first prototypes of the CSU and MMSK units. The printing processes were verified, and a first unit set was constructed successfully.

Regarding the design of the NCK unit, it was decided to slightly shift it in time in order to incorporate the user experience of this high-risk component, which is currently tested in its laboratory version. The final version of D2.4 will be submitted by the end of M15, comprising the prototypes and presenting the final design of all units.