Project co-financed by the European Regional Development Fund

MED Greenhouses
"Green Growth through the capitalization of innovative Greenhouses"

Training course material for stakeholders/actors on geothermal greenhouse installations

University of Thessaly - LP

Project Details:

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Contents

List of Figures

List of Tables

1. Introduction

This technical guide was designed by the institutional partners of the MED Greenhouses project (TEI of Thessaly-LP and University of Thessaly-PP1) in order to inform and familiarise the stakeholders/key actors of the greenhouse industry regarding the installation, the operation and the replication procedures of the Innovative Geothermal Greenhouse (MED Greenhouse) as well as to disseminate the essential advantages/benefits compared to the conventional greenhouses. The technical guide will be used as a training material by the Project's Partners in order to be presented in the training seminars and webinars (Del. 3.2.3) which will be organised at country level (6 in total). A shorter version of the guide will be also developed (in Power Point Format compatible with project's platform) for workshop purposes.

N/B: All the technical information, the photos and the presented results included in this guide are based on the LIFE+ Adapt2change material produced during the period 2011-2016.

2. Brief intro of the Geothermal Greenhouses

The Geothermal Innovative Greenhouse (MED Greenhouse) which was developed in the context of LIFE+ Adapt2change project (one was established in Larissa (Greece) and one in Zygi (Cyprus)) consists of distinct subsystems that can control and define the environment inside the greenhouse, achieving remarkable water and energy savings.

The greenhouse itself and each subsystems, influence specific parameters while at the same time every installed subsystem is interoperating with one or more other installed subsystems to provide the optimum conditions for cultivation.

The ultimate feature of the MED Greenhouses is the installation of air/water recycling system that it is designed to provide the capacity and potentiality to the greenhouse manager to operate the greenhouse as a closed system leading to both water and energy highest efficiency, compared even with the latest technology greenhouses.

Each subsystem is considered an independent system that operates according to specific hydro meteorological variables (temperature, humidity, etc.), being part of an integrated overall system used to control the inner environment of the MED Greenhouses.

<u>The MED Greenhouse consists of the following subsystems:</u>

- Geothermal Energy Subsystem
- Environmental control Subsystem, which is composed of the following systems:
  - Water/air recycling subsystem
  - Ventilation subsystem
  - Inlet Shutter subsystem
  - Top Windows subsystem
  - Air Heating subsystem
  - Cooling subsystem - Evaporative cooling pad
- Central Control Unit
- Hydroponics Subsystem

2.1 Equipment &Infrastructures required

This section presents the equipment and the establishments that are required for the construction of the MED Greenhouse. All subsystems are overviewed presenting their technical specifications and their role in climate adjustment.

Optimum plant growth, improved crop yields and efficient use of water, energy and other resources, parameters require appropriate environmental conditions. To achieve these conditions, the automation of the data acquisition process of various climatic parameters that govern plant growth is a prerequisite, as it allows information to be collected constantly with less labour requirements and optimized environmental and financial benefits.

2.1.1 Climate adjustment

Greenhouse temperature regulation is essential for vegetative growth. Heating requirement determination must be decided taking under consideration the minimum temperature requirements for the crop, the lowest outdoor temperature that might be expected, and the surface area of the greenhouse. Heat loss also will be affected by wind and site exposure.

Greenhouse heating installations is important to provide sufficient output to heat the greenhouse during the coldest day. The heating thermostats will be located where sunlight does not directly affect them.

Greenhouse cooling is also important for plant development considering the fact that most Mediterranean countries have hot dry summers. Evaporative cooling is a very efficient and economical way to reduce greenhouse temperature. Proper ventilation is also important not only for temperature control, but also to replenish carbon dioxide and control relative humidity. Relative humidity above 90% encourages disease problems. Roof windows used on greenhouses, provide both ventilation and cooling. Heating, cooling, and ventilation systems are controlled automatically in order to save labour and to ensure the proper conditions.

The automated data acquisition process of various climatic parameters (temperature, relative humidity etc.) that govern plant growth allows information to be collected at high constantly with less labour requirements and optimized environmental and financial benefits.

2.1.2 Geothermal Subsystem - Overview

Geothermal energy is an energy source independent from climatic conditions. It allows the creation of an energy supplying structure from local underground resources. Besides its environmental added value, since there are no expenses for fossil fuels, geothermal energy is not directly depending upon the conditions of the international energy markets. Because of these special characteristics, geothermal energy is an appropriate source for heating and cooling supply in agricultural uses and specifically greenhouses.

Geothermal energy involves the lowest specific investment cost for gas reduction in comparison to other renewable energy sources. It is available 24 hours a day irrespective of the time of the day or night, independent of weather and climate condition and it is considered a base-load energy as it offers the basis for a general energy supply from renewable sources.

Technical Specifications:

The greenhouses' energy needs for cooling, heating and conversion of water vapour are being covered by a vertical closed loop geothermal system which is built next to the greenhouses, exploiting the available shallow geothermal energy field. This system offers significant advantages over other forms of energy as it is a renewable energy source which does not burden the environment with additional pollutants, reducing carbon emissions footprint. Using common energy production methods only as an additional input, when needed, an energy source that in the future could be also provided by a renewable energy source like wind, photovoltaic panels, etc., gives the greenhouse a clean energy solution and an environmental friendly label. The credibility of this system is much greater than other systems because no combustion, in the form of chemical energy, takes place which in most cases produces residues and blocks combustion sites requiring continuous cleaning and repairs.

Based on studies and on site calculations, it is estimated that the required total power to cover the MED Greenhouse operation is 70KW. In specific, the geothermal field in the relevant area has an estimated capacity of 70W/m, therefore, 10 boreholes of 100m depth each, have been opened in order to meet the greenhouses energy needs. The distance between each hole is at least 5m to avoid thermal short circuit. The geothermal system is a closed loop; therefore, plastic pipes made of polyethylene (RE100) of diameter of 40mm are being placed into the opened holes. Finally, the boreholes are filled with quartz sand to optimize the contact of conductors with the subsoil's natural rocks maximizing the induction of heat to and from the plastic tubes.

The geothermal system uses two heat pumps which are designed for indoor operation. Together they deliver 70 KW.

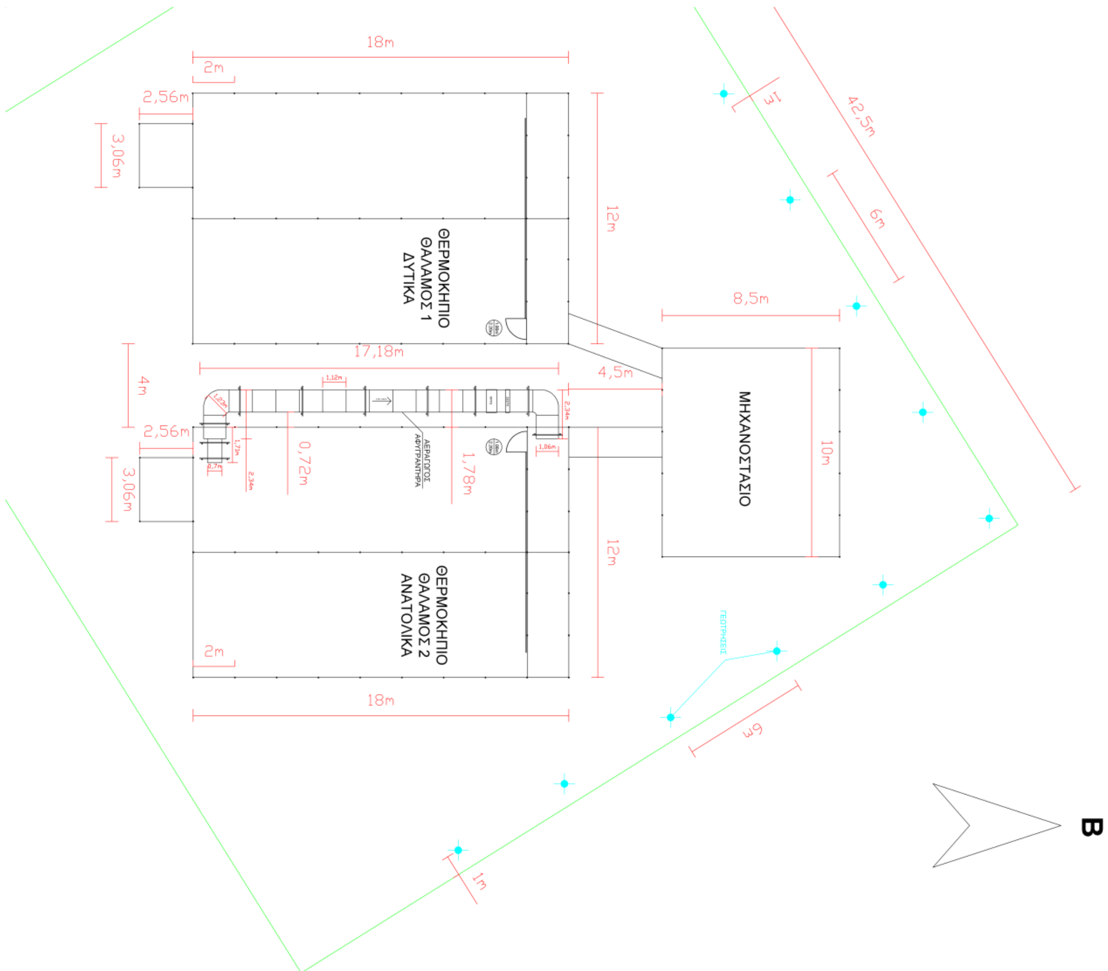


Figure 1– Top view of the MED Greenhouse installed in Larissa, including the geothermal boreholes

2.1.3 Environmental Control Subsystem

The integrated environmental control subsystem ensures that the greenhouse's internal environment is the optimum for plant growth and development. This optimum inside environment is achieved through the operation of distinct sub-subsystems which operates with the assistance of the geothermal component and in conjunction with the central control unit.

2.1.3.1 Water/air recycling subsystem

The MED Greenhouses are constructed as a closed/hybrid system equipped to capture water vapor. The purpose of this system is to minimize water consumption and optimize the indoor greenhouse environment through the application of water recycling and reusing techniques.

Technical Specifications

The water recycling system is consisted of a rectangular galvanized steel sheet airway with 1m x 1m dimensions which will be constructed outside the greenhouse. A fork-shaped tau (T-junction) with a motorized valve selection automatically selects whether to recycle or not the air by opening and/or closing the air valve, depending on the requirements of the inside environment. After branching into the airway, the first heat exchanger cools the outgoing air from the greenhouse in order to achieve its dehumidification.

At that point a special designed construction for the collection of condensate water is established with a plastic water tank with a submersed pump. The produced water is used for watering the greenhouse through the hydroponics head. The system is able to deliver 30Lt of water/hour of operation. Moreover, the necessary hydraulic system that transfers the water to the irrigation system is constructed.

After the linear demarcation of the greenhouse construction site, three trenches were opened for the installation of polyethylene water tanks. The first tank is constructed at the point of the cooling panels having 2m x 2m x 2m dimensions. The second tank is constructed beneath the collecting water way (gutter) (moisture dehumidification system) with the same as the above dimensions. The third tank is built, below the water table and it will collect rainwater and runoff of water coming from the hydroponic system that will be installed in the greenhouse. The dimensions of this trench will be 5m x 3m x 3m and it will be supported with concrete blocks having a metal structure on the top of it. All water tanks are made of high density polyethylene and have a submersible pump. Depending on the greenhouse needs for heating / cooling or watering, automatic control system will select the rate of water pumping from each tank, respectively.

Prior to entering the greenhouse, the second heat exchanger will warm (or cool the air depending the season period) the dry air that is subsequently guided in the lobby in order to finally enter the main production area through the cooling panels. The whole system will operate automatically in conjunction with the central control unit.

The main installation of the water/air recycling system which operates in order to achieve water savings is based outside the MED Greenhouse where a rectangular duct/pipeline with 1 m x 1 m dimensions will host most of the processes that contribute to the water recycling. The construction of the duct/pipeline is made of thermo galvanized steel with ten (10) years corrosion warranty. This particular pipeline receives the output of one of the four vents of the cooling system.

The pipeline was constructed in sections where each part has special hinges that allow to assembling the system with ease and speed. At the same time the insulating compounds have rubber pieces that ensure their absolute sealing, eliminating pressure loss inside the duct.

2.1.3.2 Ventilation subsystem

The exhaust fans (Munters EM30) used for the control of the inside environment, will ensure the required high airflow capacity inside the MED greenhouse. The propeller design is self-cleaning and allows the highest efficiency to be reached without human interference. The square fan housing and air conveyor (venturi) are made of a strong galvanised sheet-steel. The 6-blade propeller is statically and dynamically balanced for low noise and low vibration. It has high aerodynamic efficiency and air tightness.

Propeller and shutter

The propeller is attached to a large v-belt pulley in which a double ball is embedded bearing protection against water. The belt transmission ensures low propeller speed, which ensures high efficiency and low energy consumption as well as low noise. The shutter is made of galvanised steel, which is stronger than aluminium and plastic. The fan shutter is tightly closed when the fan is not working preventing any air leakage through the fan. The patented centrifugal system hinders the shutter from being closed by air pressure, keeping the efficiency of the fan at a peak at all times by keeping the shutter fully and firmly opened. The shutter does not have to be cleaned regularly as dust does not affect its opening and closing movement. All the plastic parts are made of acetalic plastic with UV protection.

2.1.3.3 Inlet Shutters Subsystem

The selected inlet shutters (Munters SM) are suitable for use in the MED greenhouse. In order to obtain a quick and responsive control over the fresh-air intake into a greenhouse, this type of inlet sucks the air into the greenhouse structure through an open inlet shutter by means of exhaust fans, placed in the exterior walls of the structure, or by a range of jet fans utilized to mix fresh-air with internal greenhouse air. This equipment is designed and built in a way to improve aerodynamic efficiency and reduce pressure losses.

The inlet shutter is opened by means of a strong and durable drive-motor which opens the louvers of the shutter via a reduction gearbox. The limit position, open or closed is controlled by an electromechanical limit switch, to ensure a fully open aperture or a completely sealed and closed shutter. This allows trouble free automation of the air-inlet requirement process via the specialized climate controller.

The inlet shutter housing frame is made of strong pre-coated and galvanized sheet-steel, while the shutters are made of pressed galvanised steel in order to ensure highest strength. The shutter bearing and seals are made of high resistance acetalic plastic with UV protection, and are maintenance-free. The shutter systems have been designed to be matched and balanced in a size ratio with a wide range of exhaust fans, for energy and pressure drop efficiency. The installed shutter systems are specially designed to transform circulation fans to exhaust fans while the motorized version allows simplicity with automation of ventilation inlet requirements. The shutter opening is not affected by the weight of dust deposited on the shutter blades and it presents simple and easy installation.

2.1.3.4 Top Windows subsystem

The top windows system will provide a natural source of air ventilation for regulating both the inside temperature and humidity. The top window width is1.7m, covering a width up to 2.3m wide, following the architecture of the rest of the arched construction. The movement of the cover will be linear and vertical relative to the ground, with a maximum opening range of 60cm. The top windows will be positioned in the center of each arch and will be able to be left open in winds up to 80km/h. The mechanism of the window will be staffed by a dedicated C shaped ST57 rail steel. Within the rail, nylon plastic wheels will slide driven by heavy duty double tooth, 2.5mm thickness, galvanized steel sheet. The racks will be driven in turn by a central shaft (diameter 33mm – thickness 4mm) which will slip on a special ring made of Teflon (tetrafluoroethylene).

The horizontal movement of the wheel will be converted to vertical through special articulated arms with modular connections, leading the window cover in a vertical direction. In addition, at the center of the window, there will be a third safety driver which will not allow the windows to open at very high winds for safety reasons.

The function of the window will be mechanically driven, operating with a double drive reduction system with an exit speed of 3.5 rev / min. Integrated limit switches will be , attached on the shaft, connected in double series, ensuring that the windows will stop even if some of the previous mechanisms are damaged. All the top window mechanisms will be permanently auto lubricated minimizing the need for maintenance.

Finally, the window openings will be protected from insect repellent (antiafide) net that will prevent the entrance of small insects (aphids), made of material with a guaranteed strength of ten years.

2.1.3.5 Infloor Heating

The proper control of greenhouse air temperature for the plants during the winter months will be achieved through the circulation of hot water. Plastic tubes with corrugated outer surface will ensure maximum induction of heat from the water to the plant substrate. Heating of water will be achieved by the geothermal energy system through the central pipes that will end up in the equipment chamber. The distribution of heating will be achieved with 20mm diameter spiral pipes and 6atm operation pressure.

2.1.3.6 Cooling Subsystem - Evaporative Cooling Pad

In combination with the axial fans, a cooling pad with 11m x 2m dimensions is placed in a special designed hall. The water way (gutter) and the basin of the cooling pad are made of pre-painted and galvanized steel while the paper of the cooling system is impregnated with cellulose with 10cm thickness.

The water will be circulated through a pump station and supplied to the top of the cooling pad via a distribution manifold. A distribution pad on the top of the cooling pad will ensure an even water distribution. During its operation the water will flow down the corrugated surface of the evaporative cooling pad. Part of the water is evaporated by the warm and dry air that passes through the pad. The rest of the water assists in washing the pad, and is drained back to the pump station through a gutter system. The heat that is needed for the evaporation is taken from the air itself. The air that leaves the pad is therefore cooled and humidified simultaneously without any external energy supply for the evaporation process.

The selected evaporative cooling pad (CELdek® 7090-15) is used in systems where high efficiency cooling is required. It can be used for many different cooling purposes but is particularly suitable for cooling the MED Greenhouse.

The specific green stripe pad consists of specially impregnated and corrugated cellulose paper sheets with different flute angles, one steep (60 deg) and one flat (30 deg) that have been bonded together. This unique design yields a cooling pad with high evaporation efficiency while still operating with a very low pressure drop. In addition scaling is kept to a minimum and no water carry-over occurs due to the fact that the water is directed to the air inlet side of the pad. This is where most of the evaporation takes place.

The impregnation procedure for the cellulose paper ensures a strong self supporting product, with high absorbance, which is protected against decomposition and rotting and therefore increasing longevity.

The selected installed technology provides:

- High evaporation efficiency Superb wetting properties
- Low pressure drop when wet, leading to lower operating costs
- No water carry-over
- Low scaling
- Self cleaning
- Strong and self-supporting
- Long life time

- Low running costs
- Quick and easy to install
- Environmentally friendly
- Consistent high quality

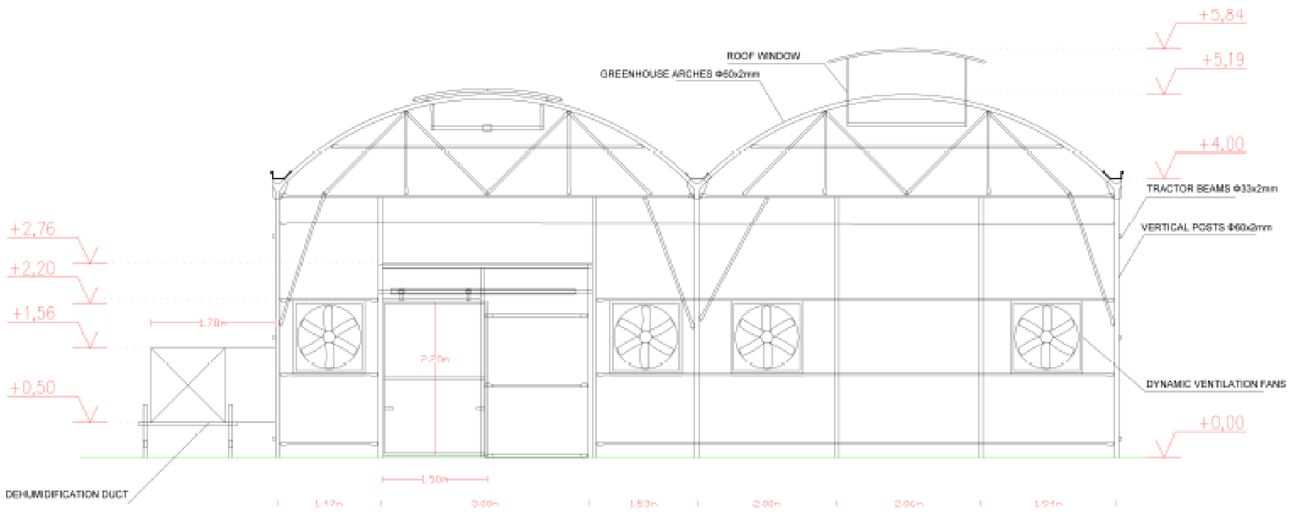


Figure 2. Environmental Control System 1

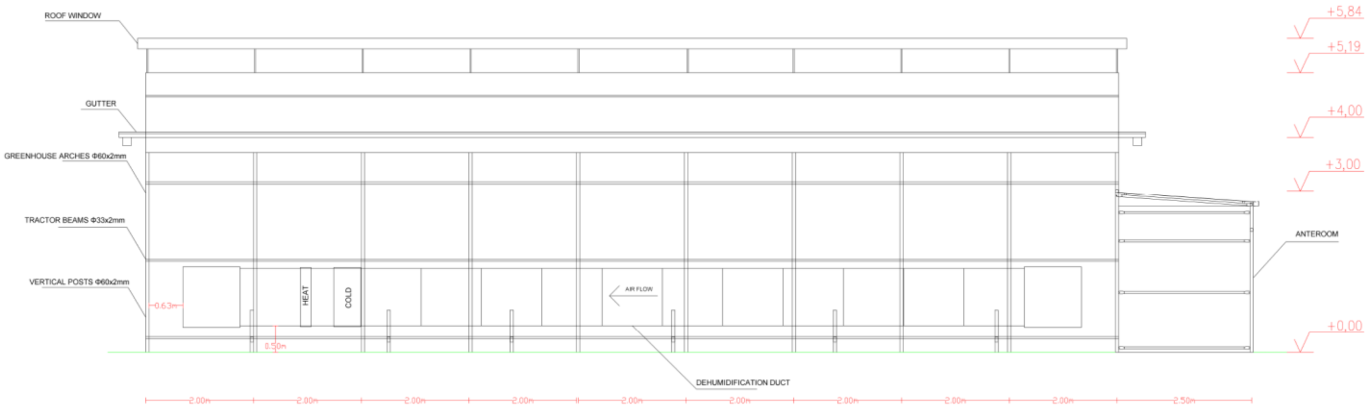


Figure 3. Environmental Control System 2

2.1.4 Central control unit subsystem

The overall performance and management of the MED greenhouse, including every subsystem, will be utilized by the central control unit (Figure 4) and specifically a programmed computer which will be able to monitor, control, evaluate and change the greenhouses operational procedures.

The central control unit will provide the greenhouse manager the ability to control every subsystem and measure its impact during the achievement of the optimum greenhouse environment by changing its operating parameters.

Through the central control unit a real time optimization will be in process, calculating and processing all incoming data from the sensors and simultaneously programming the installed subsystems.

For research purposes the central operator, will have the access to shut down any subsystem in order to log the greenhouse's performance and the capacity of other subsystems in achieving the desired environment.

The central control unit will connected to the automated sub-systems via Ethernet/Modbus Protocol and will be able interact remotely with terminal via the Internet. The control unit will provide the ability to:

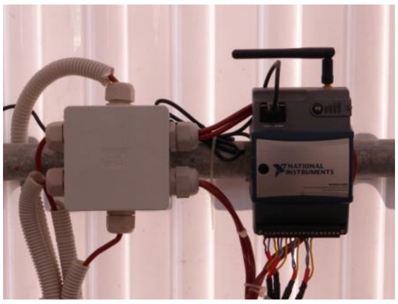
Dynamically (Real-Time) display all the measured parameters in the greenhouse(s).

- Dynamically (Real-Time) remotely configure various parameters required for the operation of greenhouses.
- Collect and storage data and provide statistic analysis.

Each central control unit will monitor and control the functions of the greenhouse. The central unit will be connected to Ethernet / Modbus peripheral PLC's that will control the operation of each subunit (external and internal climate, hydroponics system, shading system, cooling system, ventilation system, geothermal system, etc). The central unit will be able to interact remotely with the terminal device via the Internet and it will have the ability to create one or multiple crop scenarios per greenhouse. It will be able to collect data from greenhouse crops, to deliver optimal function, analyze the data and create statistical projections. The operation will be entirely graphical and absolutely friendly user. The central unit will have advanced fault detection and alert system and its operation will be controlled from a remote terminal so to minimize the cost of supervision and maintenance. Table 1 presents the main equipment that has been set on the Central Control Unit.

Table 1 – MainEquipment that can be set up to the Central Control Unit

Engine Room			
Equipment	**Units**	**Description**	**Photo**
Industrial Controller	1	Chassis with controller, 8 slots and windows embedded	
Monitor	1	Operating monitor	
Network Device Interface Unit	1	Internet access, link to PLC	

Wireless communication gateway	1	Communicating with the wireless sensors nodes	
Wireless communication nodes	2	Communicate with the wireless gateway	
Contact temperature sensors	8	Temperature measurement on heat pumps	
Temperature / humidity sensor	1	Measurement of external conditions	
Wireless communication node	1	Communicate with the wireless gateway	
Water / air temperature sensors	2	They are placed diagonally in the greenhouse	
Temperature / humidity sensor	1	It has been placed in the centre of the greenhouse	
Wireless communication node	1	Communicate with the wireless gateway	
Water / air temperature sensors	2	They are placed diagonally in the greenhouse	
Temperature / humidity sensor	1	It has been placed in the centre of the greenhouse	

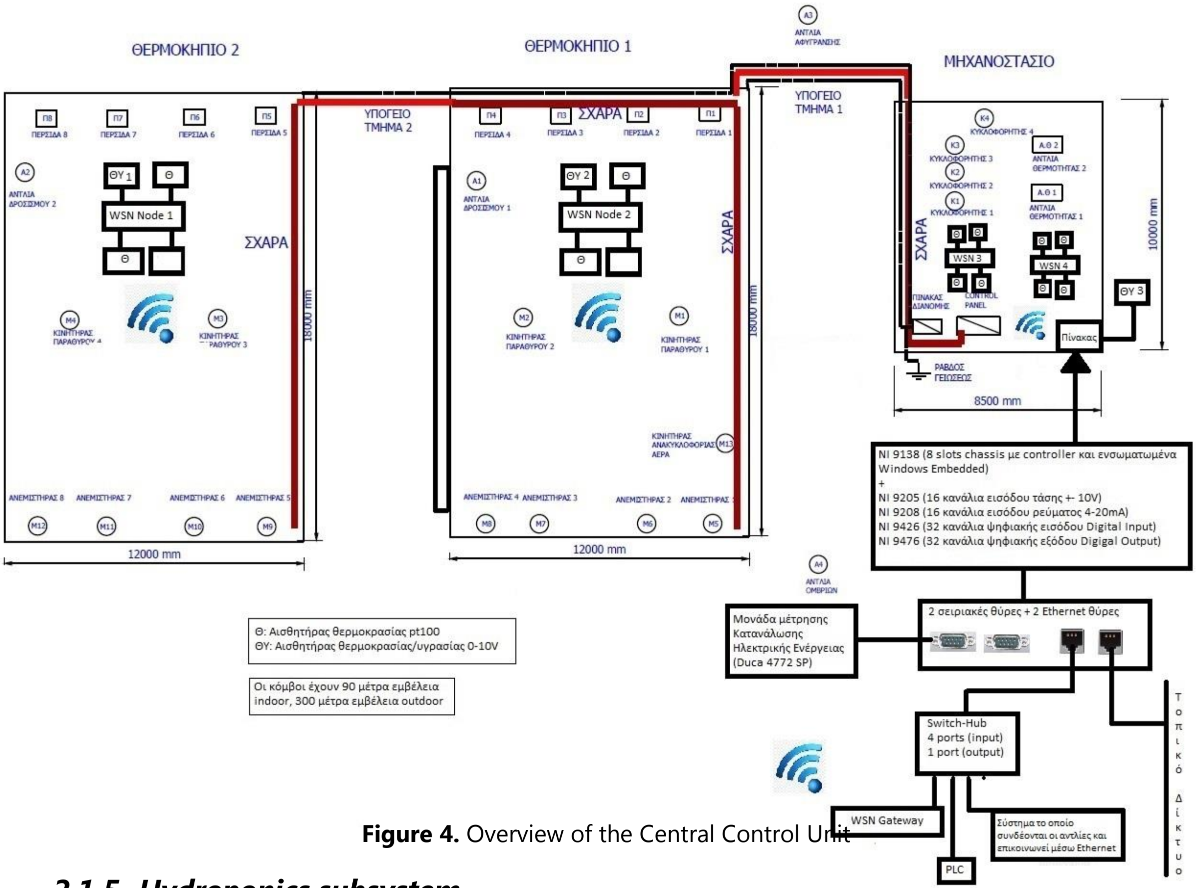


Figure 4. Overview of the Central Control Unit

2.1.5 Hydroponics subsystem

Hydroponics is hydroculture's subset and specifically the method of soilless plant cultivation using mineral nutrient solutions, in water. In hydroponics, soil is replaced by inert media such as perlite, vermiculite, horticultural rock wool, sand, or fired clay pebbles to which the necessary elements for growth are added in the form of a nutrient solution.

The inner mechanisms for the essential mineral nutrients plants absorption is the uptake of inorganic ions in water. In natural cultivation conditions, soil plays the role of the mineral nutrient reservoir. However, the soil itself is not essential to plant growth, as only when the mineral nutrients dissolve in water, plant roots are able to absorb them. The general idea of hydroponics is the artificial introduction of the required mineral nutrients into a plant's water. Hydroponics is suitable for the growth of almost any plant.

Hydroponics is an established branch of agronomy being thoroughly practical having definite advantages over conventional methods of horticulture.

There are two chief advantages of the soil-less cultivation method. Firstly, hydroponics may potentially produce much higher crop yields and secondly it can be used in places where in-ground agriculture or gardening is not possible. Most of the reasons why hydroponics is adapted in the MED greenhouse installation are the following:

- The water stays in a closed system and can be reused - thus, lower water environmental and financial costs.
- The necessary nutrition level during every plant development stage may be controlled in its entirety resulting in lower nutrition costs and significant environmental benefits in terms of the avoidance of incontrollable deposition of liquid waste. As the nutrient requirement of plants varies according to the seasons, hydroponic gardening can provide plants with optimum quantities of the necessary nutrients during the different seasons. This enables maximum growth to be achieved.
- There is no need for soil. No crop rotation is necessary as the growing medium can be reused continually, or replaced.
- High crop yields. As plants do not compete for moisture and nutrients, production in hydroponics compared with soil cultivation, in a comparable area, may be increased approximately two times. Moreover, plants are usually uniform in growth and maturity.
- Pests and diseases are easier to be monitored and confronted. Pesticide damage is diminished. The need for dangerous pesticides is largely eliminated if the plants are grown in a controlled environment. Root diseases are controlled to a greater extent.
- Harvest in hydroponics is quite easier. The labour input is less than if soil is used, once the unit is established. The work involved is generally light. Heavy manual operations associated with normal cultivation practice, such as digging weeding, and ploughing, are eliminated.

The hydroponic head will be established in the engine room along with the tanks that will have the necessary elements for the plant development.

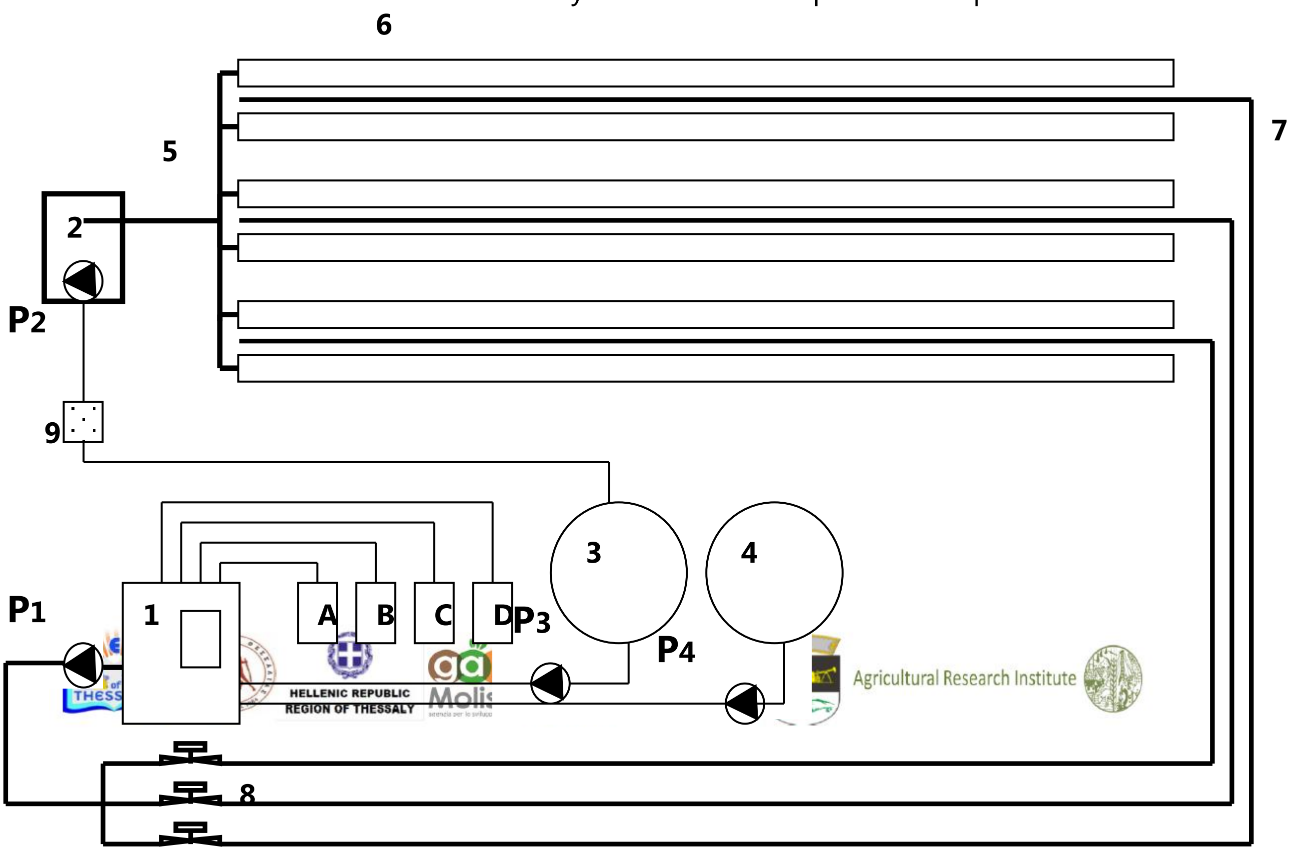


Figure 5. Schematic diagram of the Hydroponic System

2.2 How it works

In this chapter an analysis of the greenhouse operational scenarios will be illustrated. Each scenario will present the characteristics and type of greenhouse operation.

2.2.1 Semi-closed and closed greenhouses

During the last decades, engineering and technological developments in the greenhouse industry have focused on decreasing energy and water inputs and increasing yield and quality of greenhouse products. The closed or semi-closed greenhouse concept aims at covering heating, cooling and dehumidification needs of the greenhouse with minimal use of resources. In order to partly dispose of natural ventilation for temperature and humidity control, the semi-closed greenhouse must be fit with some cooling and/or dehumidifying system.
The rationale for reducing (at a cost) the need for ventilation has been mainly to lengthen the period when CO_2 enrichment of the greenhouse can be used to increase crop yield. Indeed, researches had shown that 14 kg/m^2 CO_2 were enough to maintain a year-round CO_2 concentration of > 1000 ppm in a closed greenhouse in a moderate climate whereas, in an open greenhouse, 55 kg/m^2 CO2 were required to maintain an average daytime CO_2 concentration of about 600 ppm. All other factors being the same, the increased CO_2 concentration in semi-closed greenhouses resulted in higher rates of crop photosynthesis and yield increase of about 20% or even higher. In addition to yield increase, it was observed higher primary and secondary plant compounds in tomatoes such as soluble solids and lycopene.
There are additional advantages of semi-closed greenhouses: better control of greenhouse environment; reduced water needs, reduced entry of insects and fungal spores in the greenhouse through the ventilation openings, and thus reduced pesticide use. This paper explores an under-appreciated side effect of semi-closed greenhouses: the ability to recover transpired water, thereby increasing water use efficiency. This is important in arid and semi-arid regions, where limited water resources constrain the development of sustainable horticulture. This is particularly true for the Mediterranean countries, where most of the current greenhouse area development is taking place, in spite of severe water shortages and uncertain future water availability.
The MED Greenhouses deal with one of the challenging area for global ambitions, namely the sustainable agriculture, due to the rapid turn in sustainability. Three important aspects are at the centre of attention: environmental impact (water efficiency and control), energy utilization and cost-efficiency.

To achieve optimum environmental conditions inside the greenhouses, numerous interconnected electronic control devices (subsystems) have been installed.
Furthermore, closed type greenhouse operation is being analysed, as it can be supported by the innovative establishments of the MED Greenhouse technology and it is may be an operating scenario that will be followed during the cultivation periods.
Moreover, the semi-closed greenhouse operation will be also analysed as it will be also selected whenever the optimum inside greenhouse environmental conditions cannot be achieved with the operation of all existing systems and subsystems.

2.2.2 Closed Greenhouse

The concept of the installed closed greenhouse technology is of great scientific and operational interest, since it allows reducing water and energy consumption as well as pesticides and nutrients consumption. The definition of the closed greenhouse technology, along with advantages and challenges as compared to a conventional greenhouse, is being described.
The closed greenhouse which has been constructed in Larisa and Zygi, is an innovative concept in terms of sustainable water and energy management. In principle, it is designed to maximize the utilization of geothermal energy through seasonal storage and water efficiency by creating the requirements of the closure of the water cycle inside the greenhouse and support water reuse.
During fully closed greenhouse operation all subsystems that connect the inside of the greenhouse with the outside environment remain closed (ventilation, top roof windows, etc.).
As described above, the installed closed greenhouse technology is aiming at recovering water from air and allows recycling the evapotranspirated water. The Adapt2change closed greenhouse plants are considered a climate and energy friendly system that provides the greenhouse manager with maximum control over the growth factors of relative air humidity (RH), temperature (T) and CO_2(indirectly at the beginning and directly through the establishment of a CO_2 generator in the future). Direct control of the greenhouse climate enables higher production, lower energy consumption, lower CO_2 emission and less use of crop protection agents.

2.2.3 Semi-Closed Greenhouse

As described above, the scenarios for the greenhouse operation are mainly the operation as a closed greenhouse and the operation as a semi-closed greenhouse. The semi closed operation differentiates from the closed operation because in some cases due to the extreme environmental conditions that appear in both Larisa and Zygi, the desired inside environmental conditions may not be achieved. In that case the subsystems that are related to the environmental control (top roof windows, ventilators, fans etc.) must operate in order to protect the cultivated crops.

2.3 Indicative cost for the construction and the installation of the MED Greenhouses

The construction cost of a small scale-MED Greenhouse is considered to be much higher than that of a full scale commercial greenhouse. For comparison purposes and in order to scale up the data of the current project to the scale of a commercial greenhouse, the levels of the cost of the two cases are presented hereafter.

2.3.1 Construction cost of a conventional greenhouse

The greenhouse is fully equipped with heating, ventilation and cooling systems, with a hydroponic head and fertigation system and by all auxiliary equipment for the operation in commercial conditions. The case presented is for a greenhouse of similar shape and design but for a total area of 1000 m^2.
Table2 provides the cost of greenhouse building and prices are provided per m^2 and for a unit supposing a covering greenhouse are of 1000 m^2.

Table 2 – Indicative cost for the construction of a 1000 m^2 conventional, fully equipped greenhouse.

Item	Price per m2 (€/m2)	Price (€) per unit
Structure	16,30	16.300
Reinforcements Tomato crop	0,50	500
Top Plastic Cover	1,18	1.180
Sides Polycarbonate	2,33	2.330
Insect Proof Net	0,19	190
Inside Thermal screen	2,5	2.500
Outside Thermal screen	6	6.000
Irrigations System	1,88	1.880
Drainage Collection	0,43	430
Climate Control	0.49	490
Cooling System	5	5.000
Assimilation Lights	12,42	12.420
Air Circulation Fans	0.4	400
Electrical Installation	1,42	1.420
Gas Condenser	1,8	1.800
Boilers & Burners	25	25.000
Expansion Installation		
Central Dosing CO2		
Heat Storage tank		

Item	Price per m2 (€/m2)	Price (€) per unit
Central Dosing CO2		
Transport Lines, Pipe Rail and accessories		
Part Flow Filter		
Fan Coil	1,72	1.720
CO2 Dosing System	0.4	400
Electricity Generators	1,32	1.320
Clean Water Tank	0,09	90
Ground Cover	0,97	970
Rockwool Substrate	2,03	2.030
Ground Gutters	1,34	1.340
Total price	**85.71**	**85.710**

2.3.2 Construction cost of the MED Greenhouses

Table 3 provides the cost of an MED Greenhouse building. The prices are provided per m^2 and for a unit supposing a covering greenhouse are of 1000 m^2.

Table 3 – Indicative construction cost of the MED Greenhouse

Item	Price per m^2 (€/m^2)	Price for the Innovative GH
Greenhouse unit, Control system, heating, ventilation and cooling systems, Supporting-Auxiliary building	207.17	89.500
Hydroponic system	108.8	47.000
Thermal screen andCO2 dosing system	53.24	23.000
Geothermal drillings and heat pumps	186.8	80.700
Total cost	**556**	**240.200**

3. Steps required for the audits and the installation of the MED Greenhouse

This section presents the technical audit and report process and defines the necessary steps that are being followed for the successful implementation of the MED Greenhouse. Figure 6 presents some of the major steps in a technical audit or report.

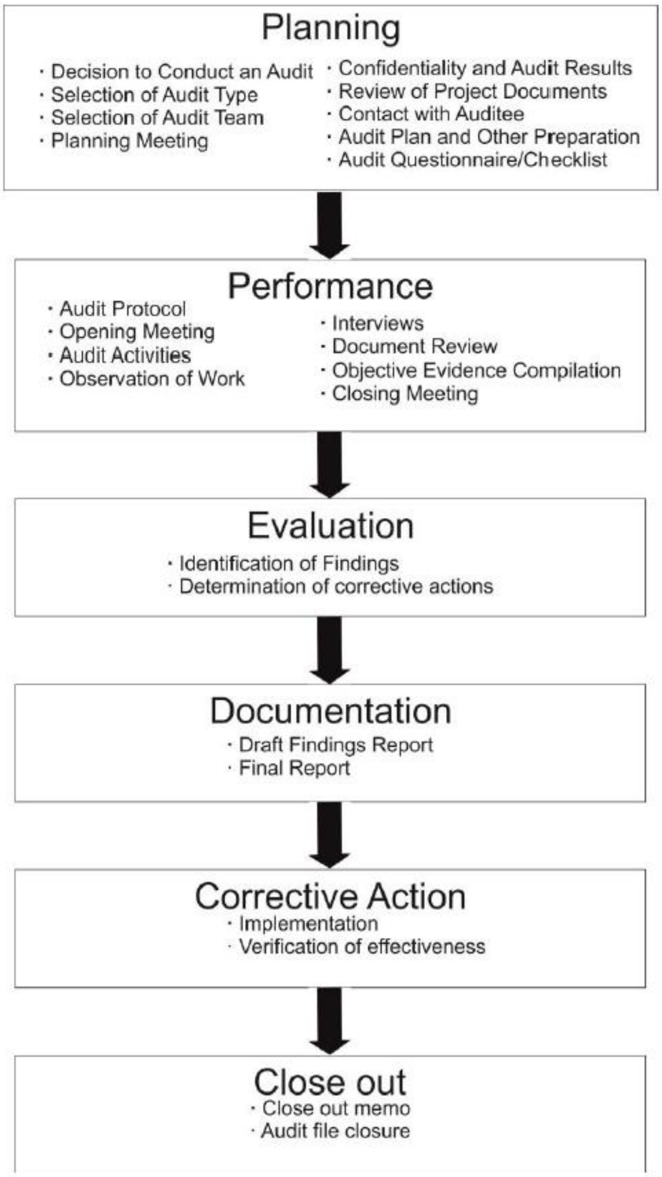


Figure 6–Flowchart of a Technical Audit

The next sub-sections present key steps that should be given attention for the construction/installation of the MED Greenhouses. The technical parts/equipment of the MED Greenhouses are presented in the sub-section 2.1.

3.1 Audit Team required

The audit teams could consist of at least two individuals the lead auditor and one supporting audit team member. However, it is expected that more than one auditor with particular qualifications will be required for the implementation of all audits.
The personnel that will utilize the audit will be qualified for this purpose and will have technical knowledge of the MED Greenhouse project establishment that will be audited. It is highlighted that personnel with different specializations will be needed for the audit and for the acceptance of specific subsystems that have been installed.
The following factors will be considered when assigning auditors and lead auditors for the utilization of the audit in the prototype greenhouses:

- the type of project(MED greenhouse)against which the audit is to be conducted,
- the type of services and products (installed systems and subsystems) and their associated regulatory requirements,
- the need for professional qualifications or technical expertise (mechanical and electrical engineers and agriculturists) in the particular greenhouse sector,
- the need for personal and communication skills and skills in managing the team (senior greenhouse manager),
- the absence of any real or perceived conflict of interest.

According to the above mentioned, the list below provides the list of the established greenhouse systems and subsystems framed by the personnel that is expected to utilize them.

- Greenhouse Frame – ***Civil Engineer***
- Geothermal Energy Subsystem – ***Mechanical Engineer***, ***Electrical Engineer, Agriculturist***
- Environmental control Subsystem, which is composed of the following systems:
- Water/air recycling subsystem – ***Mechanical Engineer***, ***Agriculturist***
- Ventilation subsystem - ***Mechanical Engineer***
- Inlet Shutter subsystem – ***Mechanical Engineer***
- Top Windows subsystem - ***Mechanical Engineer***
- Energy Curtain subsystem - ***Mechanical Engineer***
- Infloor Heating - ***Mechanical Engineer***, ***Electrical Engineer, Agriculturist***
- Cooling subsystem - Evaporative cooling pad - ***Mechanical Engineer***, ***Agriculturist***

3.2 Visual inspection and monitoring of installed equipment

The visual inspection is required to verify the integrity of the greenhouse structure and systems at any time during the greenhouse operation. All visible parts of the installation and the installed equipment will be frequently checked for cracks, malfunctions, corrosion, etc. All greenhouse parts (the identical prototype greenhouses and the installed equipment) should not present lesions, distortion or corrosion.

Particular attention is to be given to:

- Injuries at the structure of the greenhouse frame
- Injuries to the positions of the installed air/water recycling pipelines. (If found, it mandates local dismantling of piping and direct recovery of losses in accordance with the instructions of the technical experts.)
- Failure to all installed equipment.
- Use of improper materials. (If found, it mandates removal of the brace and a new anchor with appropriate materials will be provided.)

3.3 MED Greenhouse dimensions measurement

The MED Greenhouse structure is the most essential part of the overall efficient operation of the Innovative greenhouse in terms of achieving the expected results. It must withstand the external pressure and loads which are imposed by winds, rain, and everyday use. Its design characteristics should also allow the maximum possible amount of light to reach the crop, house heating and cooling systems, and comply with building codes. Figure 7 shows Larissa's MED greenhouse constructions top view.

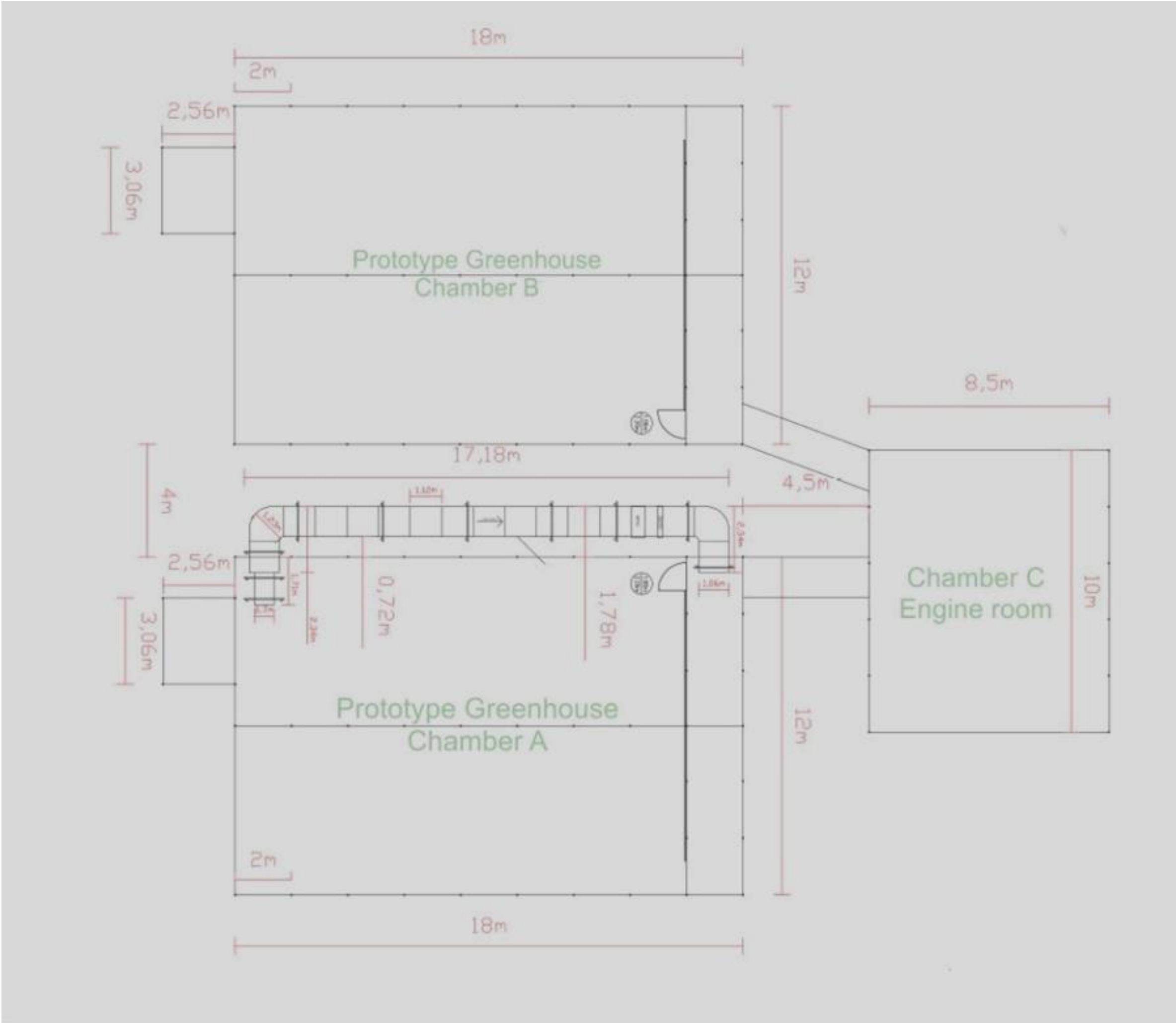


Figure 7– Top view of the MED Greenhouse in Larissa

3.4 Building components

The MED Greenhouse production structure is considered relevantly lightweight with large, exposed surface areas. Winds acting on structures of this kind can produce great uplifting forces, therefore the foundations must be designed and checked to withstand both this uplifting force and the downward gravity load of the structure. The structure must be inspected that it is securely anchored to the foundation to resist uplifting forces.
Glazing materials must transmit the maximum of amount of sunlight to the crop while also holding heat gain or loss to a minimum.

3.5 Confirmation of the specifications of all equipment that have been installed in greenhouses

A list of supporting documents is provided in this section, in order to confirm that the installed equipment is appropriate to achieve the expected results and that it is operating according to the project needs.

3.5.1 EVAPORATIVE COOLING SYSTEM

Evaporative cooling allows simultaneous lowering of temperature and vapour pressure deficit and can lead to greenhouse air temperatures lower than outside air temperature. Its efficiency is higher in dry environments.
The efficiency of the evaporative cooling pad can be greatly reduced by the compaction of cooling pads, improper operation of fans, greenhouse doors remaining open and insufficient water supply to cooling pads. Whenever the efficiency of evaporative cooling is reduced, the air temperature inside the greenhouse increases. In terms of equipment maintenance, major factors are to be considered in any maintenance and care program for the installed evaporative cooling pad.

3.5.2 VENTILATION SYSTEMS

For an area like Thessaly, Greece, where during the critical summer period, values of outside solar radiation exceed the value of 900 W m^{-2}, a ventilation rate of about 0.06 m^3 s^{-1} m^{-2} (which corresponds, for a greenhouse with a mean height of 3 m, to an air-exchange of 60 h-1) is needed in order to maintain a ΔT between outside and inside of about 4ºC. By natural ventilation an air exchange rate of about 40 h^{-1} could be obtained. For higher ventilation rate forced ventilation would be necessary.
For effective ventilation, ventilators should, if possible, be located at the ridge, on the side walls and the gable.
Total ventilator area equivalent to 15–30% of floor area is recommended for natural ventilation. Above 30%, the effect of additional ventilation area on the temperature difference is very small.
When not limited by too low external wind speed, natural ventilation may be more appropriate as it creates a more humid and cooler environment, although less homogeneous, around the canopy.
With roof ventilators, the highest ventilation rates per unit ventilator area are obtained when flap ventilators faced the wind (100%), followed by flap ventilators facing away from the wind (67%). The lowest rates of roof ventilation are obtained with the rolling ventilators (28%).
Forced ventilation by fans is the most effective way to ventilate a greenhouse, but it consumes electricity. It is estimated that the annual needs for electrical energy for

greenhouse ventilation, for a greenhouse located in the Mediterranean are about 70000 kWh per greenhouse ha.

Ventilation fans should develop a capacity of about 30 Pa static pressure (3 mm on a water gauge), should be located on the leeside or the lee end of the greenhouse and the distance between two fans should not exceed 8-10 m. Furthermore, an inlet opening on the opposite side of a fan should be at least 1.25 times the fan area. The velocity of the incoming air must not be too high, in the plant area; the air speed should not exceed 0.5 m s^{-1}. The openings must close automatically when the fans are not in operation.

With fan cooling alone (no evaporative cooling) little advantage could be derived from increasing airflow rates beyond 0.05 m^3 m^2 s^{-1}.

The operating efficiency of a ventilation fan can be reduced 30-50% by the deposition of dust on fan blades or by shutters that do not operate freely. Regardless of how well the prototype greenhouse ventilation system has been designed and installed, the system will not function properly without the proper maintenance. The result of a poorly efficient ventilation system may be stagnant air, inadequate cooling from evaporative cooling pads, high heating expenses, heavy condensation in winter, reduced life and reliability of ventilation equipment, and high repair cost.

4. Replicability procedures

There is no significant geographical limit to outcome geothermal energy for covering heating and cooling demands, since the ground surface temperature is used without any geographical restriction. However, even in direct use geothermal systems that work by taking the advantage of the higher temperatures performed in depth, ground is not the limit but the investment and functional cost demanded to drill to depth and the accessibility in innovative technologies needed for producing geothermal heat.

Aspects that affect the drilling procedure, therefore, among others, is the geology, hydrology and land availability. Ground synthesis (rock or soil) and its properties act on heat transfer rates and therefore need to be taken into consideration for designing geothermal systems, while the quality of the ground and surface water define the style and the effectiveness of the ground loop. The size and layout of the land, landscaping, location of sprinkler systems, etc., determine the design of the geothermal system as well. Additionally, ignoring the high cost required in any geothermal project, the most significant aspect limiting the integration of geothermal technology in greenhouses is the competition for land-use between the need of intense cultivation and the energy systems themselves. In this sense, although geothermal energy is promising for greenhouse application, it is only possible at sites with suitable geothermal resources that can be developed.

An access to the spatial distribution data, therefore, of the area in which geothermal technology intended to be transferred will aid the experts to clarify the feasibility of the system in the specific area. The use of specialized software for maps (such as Arc-GIS) may supply more accurate spatial information. Otherwise, maps in JPEG format could aid to determine in more details the interested territory. Orientation to the geothermal maps, if such maps are available, facilitates even more the process, since it is provided on where to explore to reduce the risk and ensure a higher likelihood of drilling success.

In support of transferring geosciences data, the subsurface temperature, fluid and permeability of the new region should be defined, while the need for an additional heating or cooling function for the pump can be assessed. By studying how much heating or cooling is demanded in that particular geographical location using heating and cooling "degree day" data will adjust the system in the current greenhouse needs.

Overall, during the process of transferring technology from one region to another, it should be carefully considered if the system design properties meet the specifications defined by the responsible ministry authority of the area concerned. An effective, efficient, fair and common system for regulating exploration of geothermal in

Mediterranean regions is a critical first step to encouraging geothermal energy progress. One approach for transporting geothermal energy technologies to another countries easily is to create a single window based on specific guidelines about system adjustments in technical inputs, financial and reporting requirements, so that the investors does not have to apply to separate authorities for different permits. Likewise, a plain language version should be developed that outlines for stakeholders the regulations for geothermal energy exploration and development, and opportunities for public consultation.

5. Pros & cons compared to Conventional Greenhouses

5.1 Advantages& Disadvantages

The following table presents the main advantages / results that can be achieved by using the MED Greenhouses instead of a conventional or open-field cultivation.

Table 4 -Main Benefits / advantages of the MED Greenhouses

Main advantages of MED Greenhouses	
Water efficiency	▪ Working as a closed hydroponic system the prototype reduced greenhouse water consumption by up to 45% compared to the conventional greenhouse; ▪ This reduction can reach 70%, compared to open filed cultivation practices. ▪ Considering the additional water retention systems installed inside the prototype greenhouses (i.e. rain-water re-circulation systems), the water re-use reached was, in some cases, 100% ▪ The cooling system installed in the greenhouses (capacity of 150 W m-2) has the potential to increase the water use efficiency by up to 75%, compared to a conventional greenhouse.
Energy efficiency	▪ The mean energy reduction (Kwhe) for 6 cultivation periods can by up to 67% comparing the prototype greenhouse with the conventional greenhouses.
Environmental benefits	▪ The mean CO_2 emissions reduction for 6 cultivation periods was ranged between 46-52% comparing the prototype greenhouses with the conventional greenhouses. ▪ The use of fertilizers was reduced by approximately 30% compared to an open hydroponic system; this reduction can reach and surpass 60% compared to open cultivation practices.

The main disadvantages compared to a conventional greenhouse or open-field cultivation could be:

- The up-front high capital cost in order to establish the MED Greenhouse. Although such investment seems profitable, the need for drilling and installing this innovative technology increase the cost of the construction/investment. Overall, it is worth-wile to invest in large scale geothermal greenhouses, payback.
- A drawback of applying geothermal energy in greenhouse operation is, additionally, the extended land required for drilling and exploitation. Generally, the geothermal unit delivers the maximum capacity, as less is the

distance between the greenhouse and installed point of the drilling wells. That makes geothermal systems hard to be applied in already established greenhouses, unless a vertical ground source heat pump is used.

- MED Greenhouses require experts and well trained operators to establish and monitor the whole system, while proper education and training of the users is also required for its operation.

5.2 Comparative analysis

This section presents a comparison between the performances of the MED (Prototype) Greenhouse, the Control (conventional) Greenhouse and the open field cultivation. The comparison is undertaken in the following categories:

1. Energy requirements
2. Water requirements
3. Crop Yield

N/B: the comparison study – analysis was undertaken in Zygi of Cyprus which was the 2nd area where the MED Greenhouse was constructed, installed and operated/tested in the context of LIFE+ Adapt2change project.

5.2.1 Energy Requirements

The performance of the two greenhouses regarding the Energy requirements is presented in Table5.

Table 5 - Energy requirements of the MED Greenhouses vs Control GH per cultivation period

Cultivation Number	Growing Period	Energy Consumption						Total Energy Consumption		Total Reduction of Energy consumption in Prototype (%)	Reduction of Heating Energy consumption in Prototype (%)
		Heating				Ventilation					
		Prototype (kWhe)	Contol (oil liters)	Control kWhth	SEER	Prototype (kWhe)	Contol (kWhe)	Prototype (kWhe)	Control (kWhth)		
1	Winter 2013/2014 , 27/11/2013 - 13/05/2014	6268	2026	24109.4	3.27	1018	549	7286	24658.4	70.45	74.00
2	Summer 2014, 23/05/2014 - 25/08/2014	0	0	0		2679	2192	2679	2192	-22.22	
3	Winter 2014/2015, 5/11/2014 - 8/04/2015	7731	2247	26739.3	2.94	287	136	8018	26875.3	70.17	71.09
4	Summer 2015, 20/4/2015 - 22/07/2015	0	0	0		1990	1630	1990	1630	-22.09	
5	Winter 2015/2016, 16/11/2015 - 21/04/2016	6554	1899	22598.1	2.93	1450	966	8004	23564.1	66.03	71.00

The energy consumption comprised mainly in heating requirements and for ventilation needs, for the operation of the exhaust fans of the greenhouses and the cooling system. It is obvious that heating is required only during the winter cultivations. Heating was done in the MED Greenhouse using the Geothermal Heat Pump and in the Control Greenhouse using the fuel oil burner. For comparison, the heating oil was transformed in equivalent KWh (1 Liter of Heating Oil is equivalent to 11.9 KWh thermal).

The average reduction in heating energy requirements of the MED Greenhouse, compared to the Control GH, is around 72%. The Total energy consumption (Heating plus Ventilation) was reduced by 68.9%. This is due to the increased ventilation requirements of the MED Greenhouse that operated in a semi-closed mode for humidity control purposes and thus the need for forced ventilation was increased compared to the Control Greenhouse by about 22%.

5.2.2 Water requirements

The water requirements of the MED Greenhouse and the Control Greenhouse are presented in Table6, according to the growing season.

The number of plants in a greenhouse and the growing seasons are different from the open field cultivation and that makes it difficult to compare the two methods regarding the water requirements and crop yield. The calculation way is shown in the following.

Table 6 - Comparison of the Water consumption of the MED Greenhouse and the Control Greenhouse per Growing Period

Cultivation Number	Growing Period	Water Consumption												
		Fresh water (Liters)		Reused Water (Liters)	% reduction on fresh water in Prototype	Total Number of Plants per GH	Fresh water per plant (Litres)		No. of Growing Days	Fresh water per plant (Litres/day/plant)		Field Cultivation Average Water needs (Litres/day/plant)	Water Saving compared to Field Cultivation (%)	
		Prototype	Contol	Water Saved in Prototype			Prototype	Contol		Prototype	Contol		Prototype	Contol
1	Winter 2013/2014 , 27/11/2013 - 13/05/2014	48437	62917	14480	23.01	381	127.13	165.14	167	0.76	0.99	2.5	68.93	59.64
2	Summer 2014, 23/05/2014 - 25/08/2014	46087	86936	40850	46.99	397	116.09	218.98	64	1.81	3.42	2.5	25.97	-39.64
3	Winter 2014/2015, 5/11/2014 - 8/04/2015	34807	52576	17769	33.80	373	93.32	140.95	154	0.61	0.92	2.5	75.27	62.64
4	Summer 2015, 20/4/2015 - 22/07/2015	44543	56311	11768	20.90	373	119.42	150.97	93	1.28	1.62	2.5	47.59	33.75
5	Winter 2015/2016, 16/11/2015 - 21/04/2016	30034	62853	32819	52.22	374	80.30	168.06	156	0.51	1.08	2.5	78.99	56.03
				Average (%)	35.38							Average (%)	59.35	53.02

The number of growing days is calculated by subtracting the days elapsing from planting until first fruit harvesting from the total growing days.

Crop	Tomato	Pepper	Cuccumber	Eggplant
Days from planting to harvest	45	40	50	50

The Water requirements of the different crops are shown in Table7 and represent values given in the Norm Input-Output Data for the Main Crop and Livestock Enterprises in Cyprus. The data represent average values.

Table 7 - Norm Data for the Water requirements of the different crops used in the Experiments

Crop	Water Requirements per Month						Total (m3/ha)	Water Requirements per Plant (Litres/Year/Plant)	Requirements per Plant (Litres/Day/Plant)
	April	May	June	July	August	September			
Tomato	150	750	1500	1680	1680	780	6540	545.0	3.0
Pepper	150	430	1000	1680	1680	620	5560	231.7	1.3
Cuccumber	150	750	1700	2160	1800	1000	7560	630.0	3.5
Eggplant	150	430	1000	1680	1680	780	5720	357.5	2.0
								Average	2.5

The calculations regarding the open-field cultivations are also based on the crop yield and number of plants in a ha (=10,000 m^2) given in the Norm and down sized to a da (=1000 m^2) to be compared to greenhouse cultivations.

Table8 - Norm Data for Yield and Plant Numbers of the different crops used in Open-Field cultivations.

Crop	Yield (tons/ha)	Plants per ha	Yield/plant (Kg/plant)
Tomato	45	12000	3.8
Pepper	35	24000	1.5
Cuccumber	30	12000	2.5
Eggplant	60	16000	3.8

From Table 6, it is shown that the average water saving in the MED Greenhouse, compared to the open-field cultivation is around 59%, whilst the water saving in commercial greenhouses operating as the Control greenhouse is around 53%. For the comparison of the Control Greenhouse, the value estimated for the 2nd cultivation period (Summer 2014) was excluded from the calculation of the average value because it seems that there is an error in the recording of the fresh water consumption in that case. The value was there for considered as an outsider. Comparing the water consumption in the two greenhouses the water saving in the MED Greenhouse amounts to an average value of 35.4%.

5.2.3 Crop Yield comparisons

It is difficult to compare precisely the crop yield between a greenhouse and an open-field cultivation, due to differences in plant density, growing seasons and cultivation duration. Since normally the cultivation of vegetables in Cyprus extends to 9 months in a year, that is 270 days, the comparisons are made considering this growing season. The results are shown in Table 9.

The crop yields measured during the experiments are shown analytically per growing period for each crop separately and the average yield values are calculated for the MED Greenhouse to be:

For Tomato 8.7 kg/plant, for Pepper 3.2 for Cucumber 17.0 and for Eggplant 10.8 kg/plant.

The respective values for the open-field cultivation for the same crop duration and using the Norm Data for Cyprus, are:

For Tomato 3.75 kg/plant, for Pepper 1.46 for Cucumber 2.50 and for Eggplant 3.75 kg/plant.

The results were up-scaled to an Area of 1000m^2 (1 da) using again the Norm values for plant density:

Greenhouse Area (m2)	1000
Number of plants in GH	2500
Cultivation Days (9-Months)	270
Crop	**Open field plants /da**
Tomato	1200
Pepper	2400
Cuccumber	1200
Eggplant	1600

Table 9 -Up-scaling crop production per plant from Experimental Data to 9-month cultivation.

Cultivation Number	Period	Crop Yield (kg per greenhouse (192 total active m2))								Plants Production (kg /active day/plant)				9-Month cultivation 270 active days (kg/plant)			
		Prototype				Control				Prototype				Prototype			
		Tomato	Pepper	Cuccumber	Eggplant	Tomato	Pepper	Cuccumber	Eggplant	Tomato	Pepper	Cuccumber	Eggplant	Tomato	Pepper	Cuccumber	Eggplant
1	Winter 2013/2014 , 27/11/2013 - 13/05/2014	1471.3			589.3	1604.6			678.0	0.0423			0.0525	11.4			14.2
2	Summer 2014, 23/05/2014 - 25/08/2014	490.2	146.5	475.8	217.6	474.4	149.6	434.2	252.8	0.0540	0.0174	0.1049	0.0735	14.6	4.7	28.3	19.8
3	Winter 2014/2015, 5/11/2014 - 8/04/2015	511.9	59.3	301.8	117.2	584.1	61.9	326.0	130.9	0.0252	0.0029	0.0297	0.0173	6.8	0.8	8.0	4.7
4	Summer 2015, 20/4/2015 - 22/07/2015	281.9	136.1	525.9	147.1	274.6	136.4	512.3	134.0	0.0230	0.0111	0.0883	0.0359	6.2	3.0	23.8	9.7
5	Winter 2015/2016, 16/11/2015 - 21/04/2016	352.6	142.4	294.0	148.7	444.1	185.8	315.1	160.8	0.0171	0.0069	0.0286	0.0217	4.6	1.9	7.7	5.9
													Average Prototype Yield	8.7	3.2	17.0	10.8
													Average Open Field Yield	3.75	1.46	2.50	3.75

Thus, comparing the Prototype Yields with those in Open-Field cultivation it is shown that a greenhouse operating in conditions similar to the MED Greenhouse would produce considerably higher Yields for all Crops tested. The results are shown in Table 10.

Table 10 - Comparison of Crop Yields between a greenhouse operating in Prototype Mode and an Open-Field Cultivation.

Cultivation	Average Production 9-Month cultivation under Prototype conditions 270 active days (kg)	Average Production 9-Month cultivation in Open Field 270 active days (kg)	Yield difference (%)
Tomato	21,818	4,500	79.4
Pepper	7,947	3,500	56.0
Cuccumber	42,428	3,000	92.9
Eggplant	27,117	6,000	77.9

Bibliography

- Adapt2change (December 2012): PROTOTYPE – GEOTHERMAL STUDY
- Adapt2change (December 2012): PROTOTYPE GREENHOUSE DRAWINGS
- Adapt2change (December 2012): WATER RECYCLING & HYDROPONIC SYSTEM
- Adapt2change (December 2012): Prototype Automation Design Plan
- Adapt2change (April 2015): Practical Guide for the Greenhouse Design
- Adapt2change: Geothermal finalisation plan
- Adapt2change: Water recycling dimensioning
- Adapt2change: Comparison of the performance of the Prototype vs the Control Greenhouse of the Project and Open-Field Cultivations
- Adapt2change (August 2016): Guide for Automated Control Unit
- Adapt2change (March 2016): Economic Assessment Report
- Adapt2change (August 2016): Environmental achievements guide
- Adapt2change (August 2016): Layman's Report