D1.4

Concept for a partial automation for greenhouse air conditioning in dry-hot summer climate zone

THEGREEFA

Thermochemical fluids in greenhouse farming

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Document references

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Executive Public Summary

The project work on greenhouse climate control in hot/arid climate included the conceptualization and calculation of the system, planning of a lab greenhouse (12m²) for component testing and for an operational greenhouse (100m²). Planning included a system with main components (1) an absorber/desorber device, (2) a combined thermal and thermo-chemical storage using $MgCl_2$ as carrier material, (3) a TCF (thermochemical fluid) distribution and air distribution system. Additional components include (4) air to air heat exchanger (further cooling) and (5) solar collector (further heating). Planning started with calculation of the system using climate data from Tunis aimed at dimensioning of the components. Realisation planning included blueprints for components and entire system. Measurement and control equipment (sensors, actuators, control computer) was selected for system monitoring and control.

For the TCF material, local seawater bittern (mainly water solved $MgCl_2$ and $MgSO_4$) was investigated as a cheap and locally available material in theoretical and empirical tests.

The planning of an operational greenhouse includes a new tunnel greenhouse design with increased overall surface for improved heat removal in closed operation during day- and night-time. Design of blueprints for realization in Tunis region by local company, including dimensioning of absorbers, storage, pumps, fans, hydraulic components and air pipes.

A totally new absorber design was developed and physically tested in Berlin aimed to reduce the TCF uptake to passing air and at operation with high air- and TCF flow velocity. This included the development of blueprints for 3D printing for TCF distribution in the absorber device with several variations allowing comparison of different absorber solutions. Furthermore, a planning for an external desorber, totally based on solar thermal energy was provided.

An initial measurement and control scheme is developed for the operational greenhouse based on on/off signals to pumps and fans driving 1-6 individual absorber devices depending on temperature development in the greenhouse and motor driven storage tank supply and return connections between altering top/bottom level of the storage.

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1 Principles of sorptive air-conditioning in greenhouses and closed greenhouse application for water recuperation and CO_2 accumulation

The overall concept underpinning the project is based on an innovative use of absorption processes in the greenhouse air-conditioning (also referred as sportive air conditioning). This concept, used in several prototypes in this project, is achieved using the hygroscopic properties of fluid salt solution, here called thermo-chemical carrier fluid (TCF), which has the ability to provide multiple functions and services such as heating, cooling and de-/humidification within a single device, here called the absorber. An aqueous magnesium chloride solution ($MgCl_2$) has been resulted the more appropriate (performance/cost) for the air control in the greenhouses (see H200 project H-Disnet, (GA 695780).

When the TCF with a high concentration of hygroscopic medium gets in contact with the humid air produced by the transpiration of the plants in a greenhouse, it absorbs part of the air humidity releasing the latent heat of the humidity in form of sensible heat, appr. 1 ton of air humidity absorbed into the TCF as water, according to the phase change involved energy, it releases 680 kWh of heat (right part of Figure 1). The uptake of water dilutes the TCF.

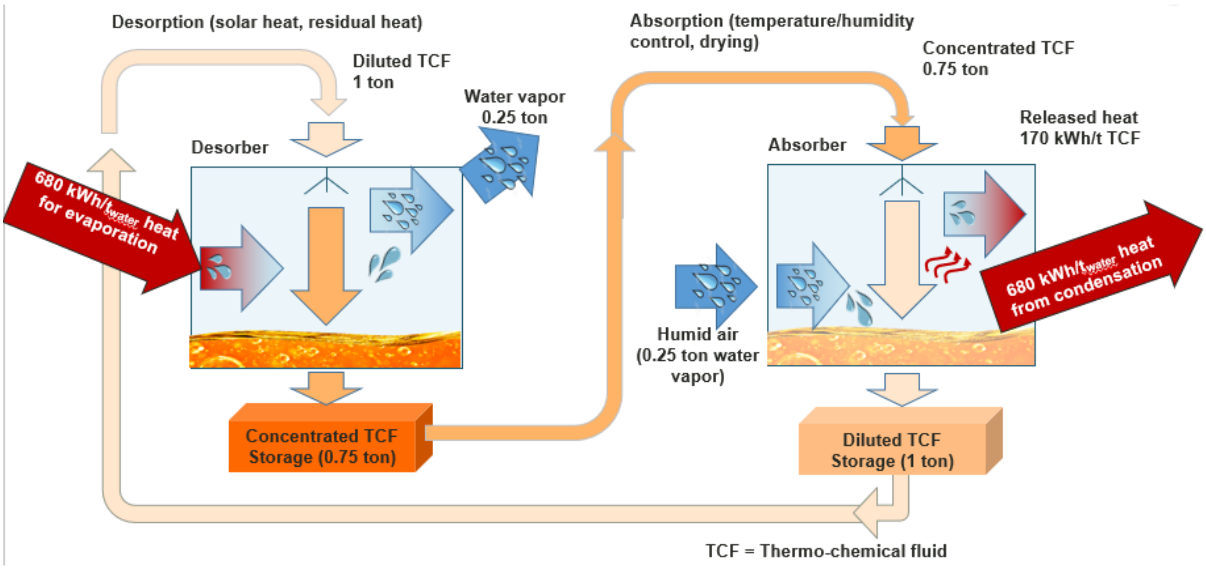

Figure 1: TCF-cycle for control of air humidity and temperature

When the TCF is diluted to a certain degree, the process cannot be continued and the TCF must be regenerated. The absorbed water must be driven out again. To do that, the same amount of energy as released by the absorption process shall be reintroduced in the system, again appr. 680 kWh/ ton evaporated water. The water is released in form of water vapour taken up by dry air (left part of Fig. 1). Heat source Temperatures below 60°C are largely enough for the regeneration process, the exact temperature depends on the phase equilibrium of pressure vapour between the TCF and ambient air.

The air conditioning in greenhouses is appropriate for this kind of applications because the plants release a large amount of humidity through the transpiration, which requires to be removed. The TCF has the function to

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remove this excess of humidity production at the same time useful heat (transformation of latent heat in sensible heat). A further advantage of the sportive air condition in the greenhouse is, that it is not any more necessary to exchange feed fresh air to control the humidity, that means that water losses can strongly be reduced (Figure 2) and water can be recycles within the system by combined evapo-condensation.

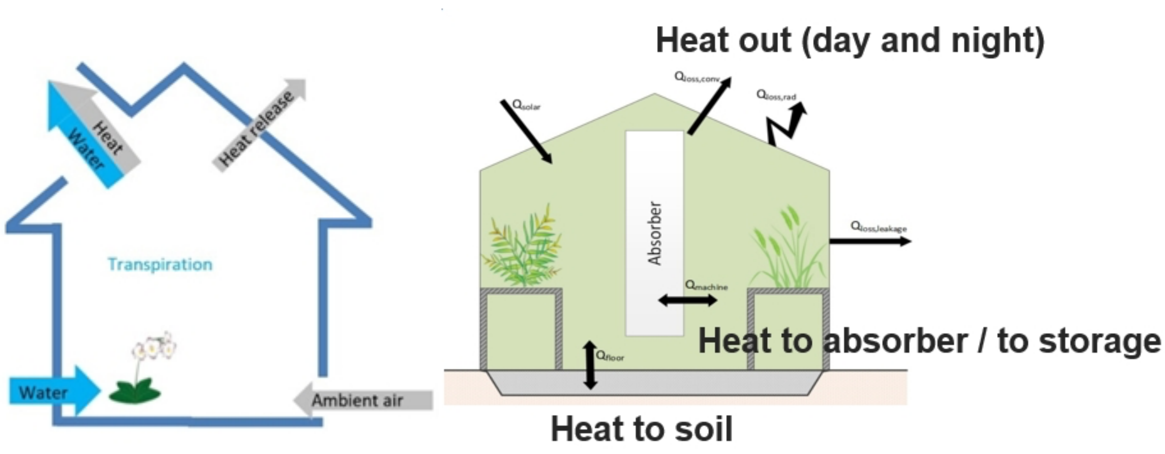

Figure 2: Energy flow in a standard greenhouse (left) and in a closed greenhouse with TCF air drying and day/night heat accumulation.

Climate control using thermo-chemical fluids allows to withdraw huge amounts of energy from the greenhouse atmosphere, using the heat pipe effect of combined evaporation (by the greenhouse plants) and absorption using the TCF for the reverse process of phase change from water vapor back to water. In this process the involved phase change energy of 680 kWh/ton of water is transferred to the TCF and can be transported to a storage. This means, the water is remaining in the system. In a night process with much lower ambient temperature and no solar radiation, the high temperature of the TCF is used to evaporate the collected water back into the greenhouse atmosphere and to condense the water on the inner surface of the greenhouse cover. Several difficulties and risks relate to this technological approach and shall be mastered by the activities in this part of the project:

- The TCF storage temperature at the end of the day must be clearly above the greenhouse air night temperature, in a way that the air becomes heated in the absorber and by this, the air relative humidity drops below the equilibrium humidity of the TCF. This is a precaution to have evaporation out of the TCF into the air. A plan B for improved regeneration is considered by external regeneration processes outside of the greenhouse atmosphere.
- The main problem of the system is over-heating. Beside the use of the absorber system, three further measures are part of the cooling concept:
    - Increase of the thermal storage capacity by increasing the water content of the soil by adding organic matter and controlled/slight irrigation of the soil.
    - Increase of the greenhouse surface. All heat energy has to be released by heat conduction through the greenhouse cover. An increased surface allows to improve the heat release during

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daytime (driven by solar energy) and nighttime (driven by heat from the thermal storage in the system)

- CO_2 accumulation is driving the productivity of the vegetation and a closed greenhouse contributes to an increased CO_2 concentration without or with only minor CO_2 losses to the ambient. Beside this advantage, CO_2 also contributes to a higher heat acceptance of the vegetation (at sufficient water supply), as closed stomata as a reaction to heat stress will still allow a sufficient supply of CO_2 for the photosynthesise. By this, the optimal growth temperature is increased and active cooling can be reduced accordingly.

2 Planning of Lab Greenhouse at INRGREF Tunis

2.1 Literature review

An extensive literature research on solutions for water recycling within greenhouses using the effect of combined evaporation and condensation was conducted during the planning phase of the project. It did lead to an overview of different technological solutions, including open and closed systems. The information has been collected as a state of art analysis, and as a fundament for the planning of the demonstrator. The results shall also be used within the capacity building process in the last year of the project. The review also contributed to a publication as part of the dissemination activities of the project. A list of relevant literature as base of the planning was created and will be continuously updated during the project.

2.2 Further development of the calculation model for the design of greenhouse prototypes

A comprehensive greenhouse model was created based on the Python programming environment in close collaboration with the work in WP2. This includes modules for solar radiation, site-specific data, a building model that contains the greenhouse geometry and the usable material properties. Furthermore, heat sinks (soil, storage), air humidity models (latent energy flows through vegetation) and the planned components for mechanical greenhouse cooling and air dehumidification are built. A model for an absorption process with the sorption solution magnesium chloride is being developed on the basis of measurement results from previous projects. This is also to be improved accordingly with measurement results from the project, that are still to be produced for further calibration.

With reference to figure 3 and 4, a simulation of the greenhouse system without climate control indicated strong overheating of the greenhouse with temperatures up to 50°C and related high heat transfer to the ambient (yellow surface). The related energy flow is indicated in the x-axis.

Secondly, a climate control system, taking out a part of the heat energy (sensible and latent heat) to a heat storage was simulated, leading to a different energy balance with lower temperatures and accordingly lower heat transfer to the environment in daytime operation. The additional heat flow to- and from the storage is indicated with the hatched surface. Unloading of the heat from the storage with higher heat transfer to the ambient is indicated during the nighttime operation.

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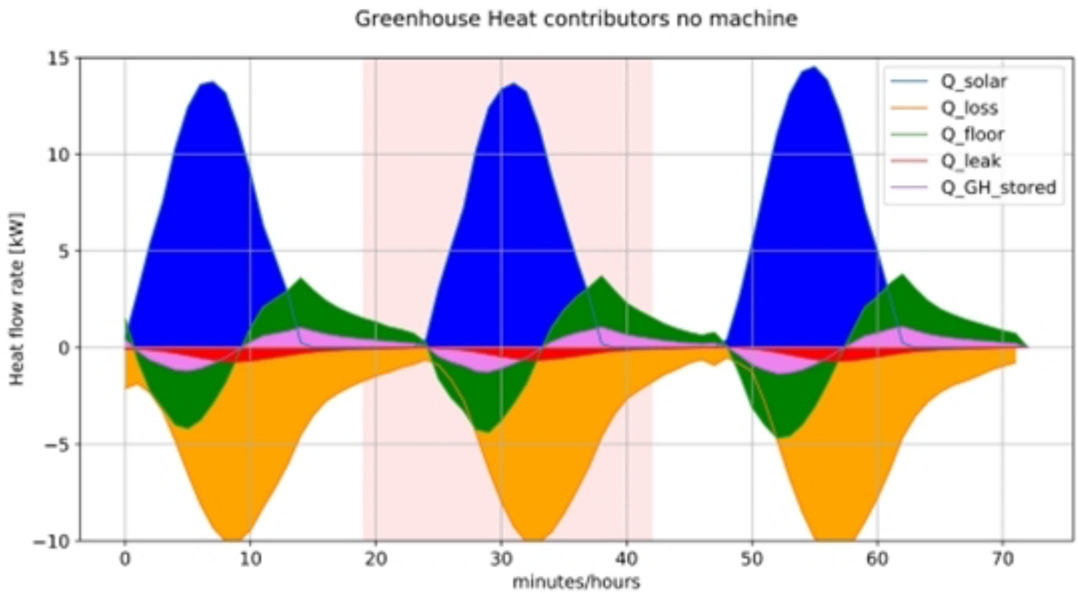

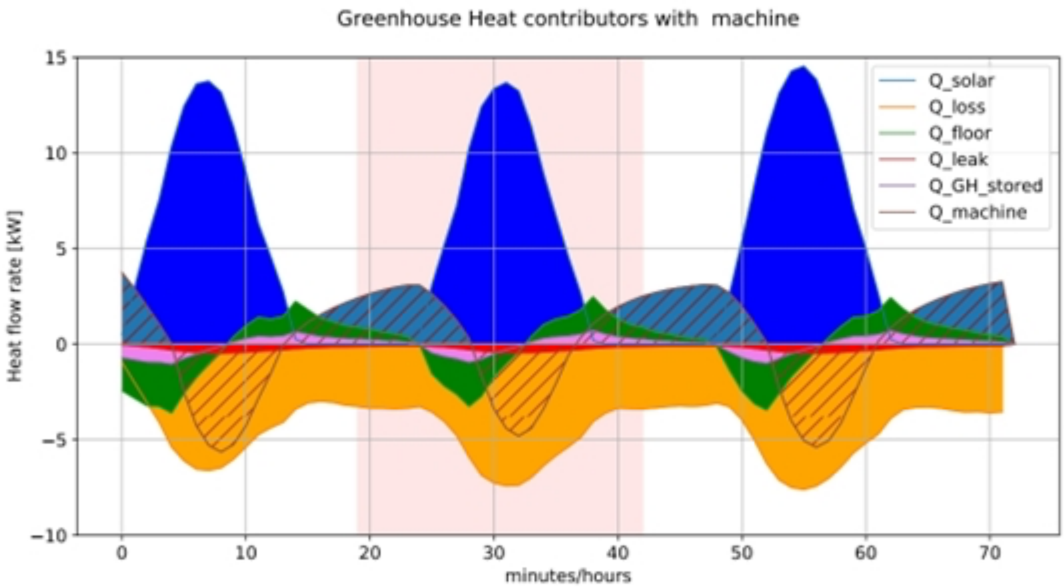

Figure 3 and 4: Modelling of closed greenhouse energy balance without cooling and with day/night heat energy storage (hatched surface in Fig. 4)

2.3 Development of the cooling concept

For the cooling of closed greenhouses, a combination of (1) an enlarged greenhouse surface for heat dissipation, (2) an improved passive day/night heat storage in the soil and a system for air cooling and air drying based on a day/night thermal storage and associated absorber elements using a TCF ($MgCl_2$ solution) was developed. In addition to the components, a simple, low-cost solar collector for heating the TCF for improved regeneration is included. The components are connected to a hydraulic system and to an air conduction system. Measurement

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and control hardware is integrated. Fig. 5 shows the main components of the system and the related placement of actuators (pumps, valves, ventilators) and sensors (air temp, air humidity, TCF temperature, Flow velocity of air and TCF).

The concept allows different experimental modes, including (1) greenhouse cooling mode with absorber and heat exchanger operation; (2) mode 1 plus solar collector operation for improved regeneration functionality (3) greenhouse cooling mode with open greenhouse only (emergency mode); (4) regeneration mode with condensation on greenhouse internal surface and condensation on heat exchanger surface and (5) regeneration mode with heat exchanger only and open greenhouse. The combination of theses modes is mainly configured for experimental studies.

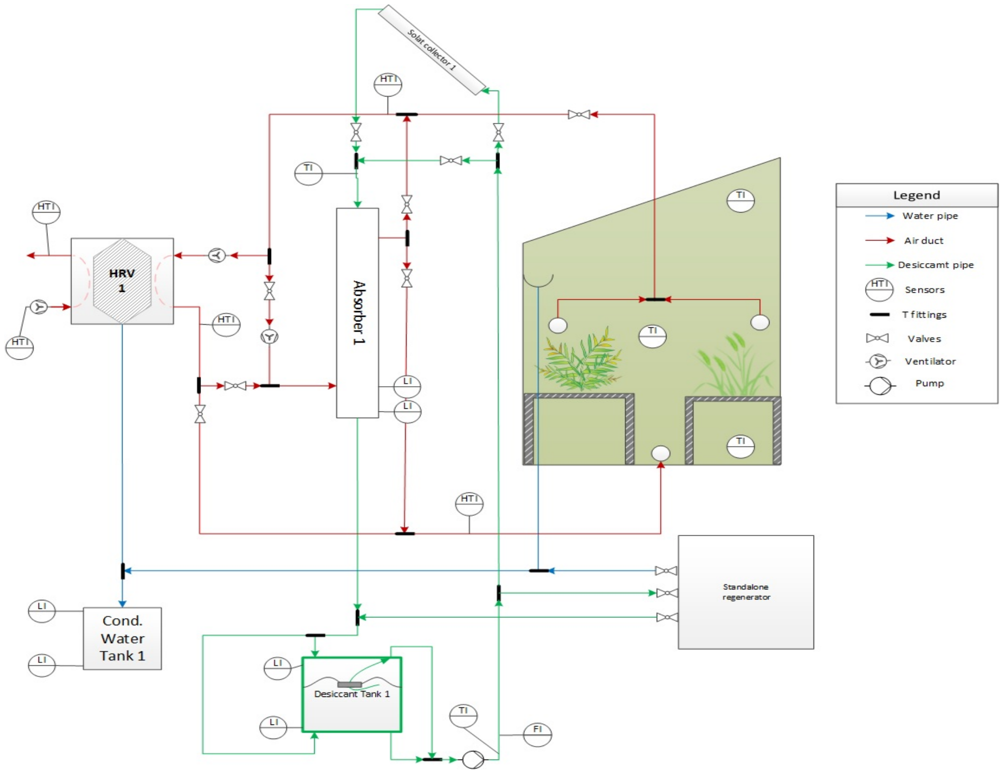

Fig. 5 Air-conditioning scheme for experimental greenhouses (TCF is called also dessicant)

For permanent operation in closed mode, an extended configuration (Fig. 6) with additional components (second absorber device and second heat exchanger) is required. Also a further mode with two separated TCF tanks has been developed. (Fig. 7). For reduction of complexity and with a clear focus on component testing in this Lab configuration and out of economic reasons, these configurations are not physically realised in this project. They shall be further examined by simulation studies, once there are enough data available from the new absorber functionality.

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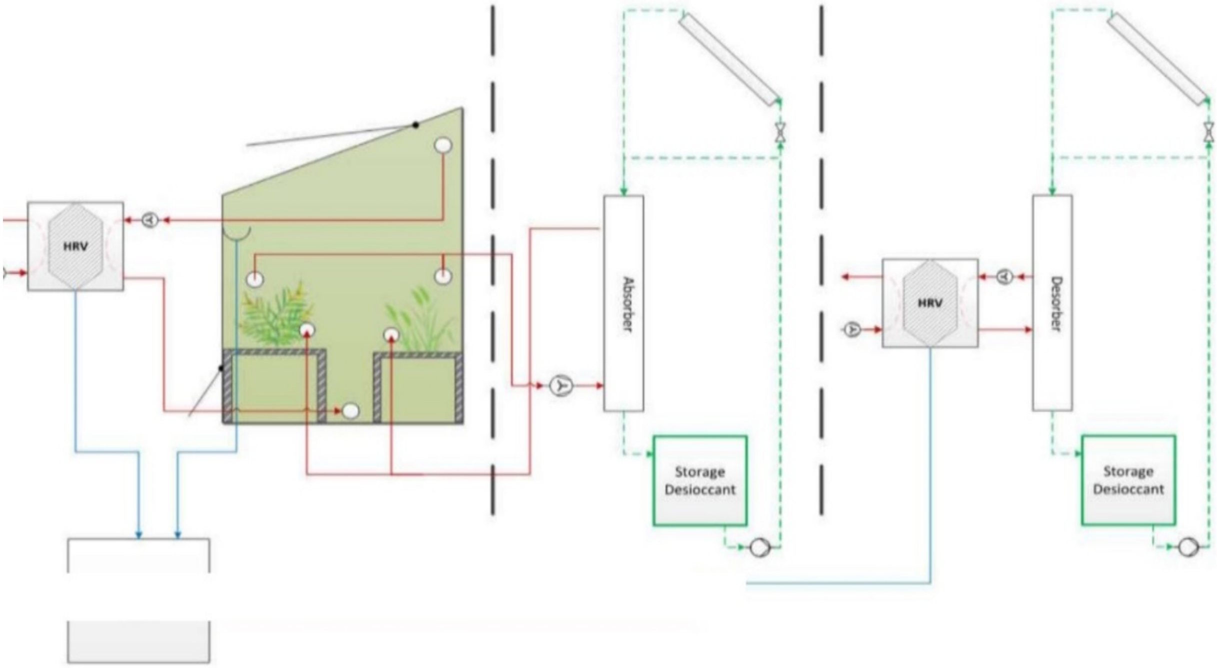

Fig.6: Parallel configuration for greenhouse cooling (absorption) and TCF regeneration (desorption)

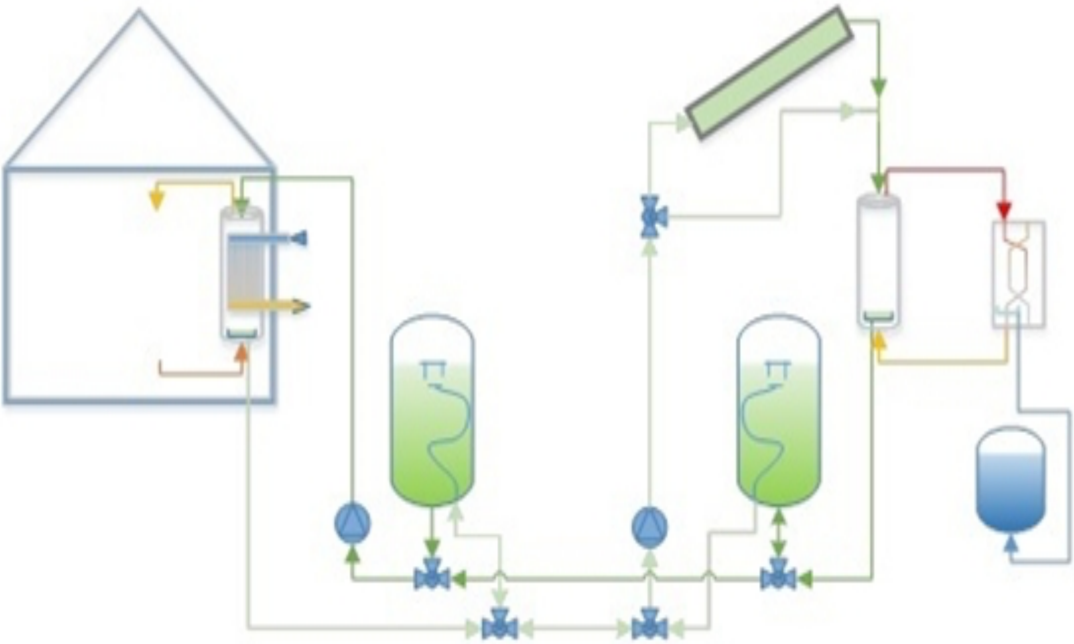

Fig. 7, Hydraulic scheme for 2 tank system in ping-pong mode

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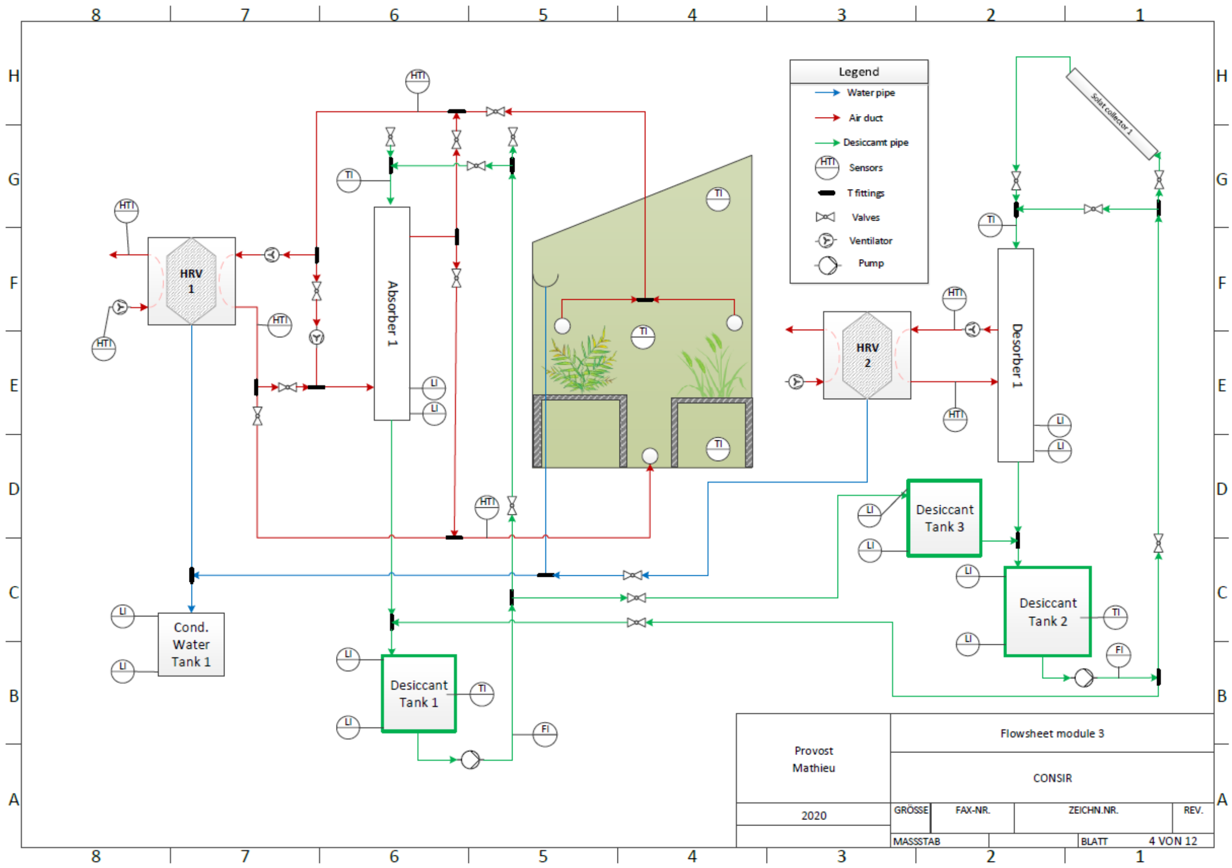

Fig.8 Greenhouse scheme including hydraulic system for air (red), TCF (green) and condensed water (blue) (TCF is called desiccant)

2.4 Realisation of lab greenhouse at INRGREF Tunis

The Tunis lab greenhouse was realized at the research facilities of INRGREF. Absorber and heat exchanger were produced and supplied from Berlin. Air distribution system was installed, allowing three different modes of air dissipation using 9 air valves for control. Air is taken from the roof area and is returned to the plant table level after a treatment/heating /cooling processes. A 2m³ TCF storage is installed and connected to the absorber by a pump and a hydraulic set up. TCF return is driven by gravity to reduce complexity of the control. For that, the absorber is installed on a platform. Measurement and control system is installed including control computer, connection to actuators (pump, fan) and sensors (Temp, humidity, CO_2, fluid velocity) in order to receive the complete information for the energy balance.

For the tests in Tunisia, two components were produced by WTG during the reporting period and sent to Tunisia: (1) an air-to-air heat exchanger and (2) a Watergy absorption column. The heat exchanger has already been installed in a greenhouse prepared for the trials. This includes an air supply line from the roof area of the greenhouse to the heat exchanger and a return line with air distribution of the cooled air in the area of the planting tables. The heat exchanger allows to add further greenhouse surface area in contact to the ambient air. On the one hand, this can be used to investigate if conventional greenhouse designs can be qualified for closed operation. On the other hand, different cooling effects adapted to the respective climatic situation can be

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created by adjusting the volume flow. This in turn is the prerequisite for closed operation and for testing further components in closed greenhouse operation.

The absorption column was shipped to Tunis in early 2021. The absorption column removes enthalpy (temperature and humidity) from the air circuit and transfers it in the form of heat to the TCF storage tank. The experiments include the adaptation of the air and TCF volume flow to the respective climatic conditions and the achievable enthalpy withdrawals. Furthermore, an energy balance is measured by monitoring the air temperature and humidity as well as the TCF temperature and TCF concentration in each case upstream and downstream of the column as well as the air and TCF volume flows. Further tests are aimed at the regeneration of diluted TCF. The extent to which regeneration can be achieved with heat transferred from the greenhouse to the storage tank during the day will be investigated. In addition, regeneration during the day is tested using additional heat from a simple plastic solar collector (so-called swimming pool collector). For daytime tests, the greenhouse is cooled via an open ventilation system, which has also already been installed, in order to simplify the set-up of the equipment.
The sensors and actuators required for the test operation are partly purchased in Berlin (temperature sensors, water level meters, TCF flow meters) as well as locally by the Tunisian partner.


Fig. 9-10, Test stand at the experimental greenhouse in Tunis with experiments on improved heat dissipation to the outside and use of the absorption system.

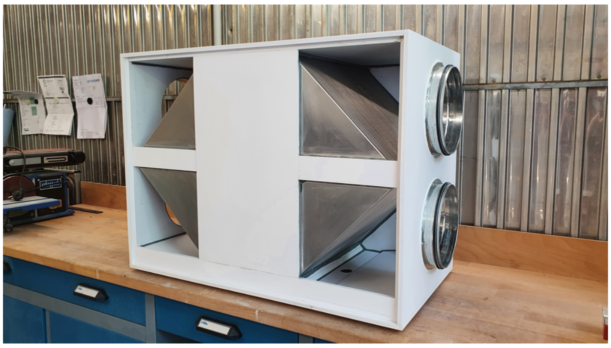


Fig. 11-12, Taylor made air to air heat exchanger with counterflow and air proof connections – a prerequisite to condensed water recycling

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Fig.13-14 Air to air heat exchanger and Watergy absorber, integrated in air distribution network

Fig. 15-16 Placement of the absorber on a platform to allow return flow of TCF to the storage (right side of the picture) by gravity

short	name	type	ammount	specifications	example
TI	temperature sensors	pt 100 or pt 1000	10	plastic (desiccant)	**Heraeus Nexensos** - W-SZK(0)
HTI	Humidity and temperature	combo sensors	7 (+2 replacement)	T [-10 ... 80°C] , Hr [0...100%]	**Driesen+Kern** - DKRF400-01-5000
FI	Flow sensors (liquid)	turbine	2	plastic (desiccant), approx Flow = 25 L/min	**Bio-Tech** - FCH-CE-PA
FI	Flow sensors (gas)	Pressure difference	1	0 - 500 Pa	**fuehlersysteme** - DMU/A-U/V1 **debimo** - DEBMK-WF -
LI	Level Sensor	digital	12	plastic (desiccant)	**Elobau** - Float switch 204KS

Tab. 1 Sensor list with examplary model of suppliers

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Fig. 17-20 Placement of sensors for air temperature and humidity in the air distribution pipes; Greenhouse control computer and related evaluation software

3 Testing of local available TCF material from Tunisian salina

Beside the absorber elements, the storage and the contained TCF material are critical factors for the future economic feasibility of the system. The chosen TCF is a $MgCl_2$ solution in water. It is inexpensive, as it can be extracted from seawater. The price on the market for large quantities and industrial quality is around 100 €/t. A high cost factor is transport and import costs. To arrive at lower costs, already at the prototype scale, the project team started investigations on local available TCF in Tunisia. A sample from the salina of Sfax included the final TCF from the salt works, which normally is pumped back to the sea, as there is no use for it. The composition measured in a water laboratory showed a mixture of $MgCl_2$ and $MgSO_4$ including some other residues. Those are the minerals in seawater with highest solubility in water. Hence, those minerals also show up with the highest hygroscopic properties. The material is easily available, actually it only produced lower transport costs from the salina to the prototype. The use of this material is an important precaution for a low budget system and for market access, using local material only

The effect of the salt solution (TCF) provided by Salina Sfax (Mare Alb) was tested by along the project under greenhouse climate conditions. Measurements have been performed for air inside a container with TCF and a container of water to compare the air temperature and humidity.

The TCF composition measured in the laboratory showed the following values:

- Density: 1,350 kg/m^3
- Magnesium Mg: 112,65 g/L,
- Sulfate SO_4: 34,09 g/L,
- Other residues (Ca, Cl, K..): 428 g/L.(of which Cl is by far the main compartment)

Fg. 21-22 Salina in Sfac, Tunisia, Measurement of air humidity in greenhouse, water container and TCF container

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The test was very successful. The result of the measurements in the TCF container showed values of more or less constant 30% rel. humidity. This relates to a very good hygroscopic property at maximum level of concentration. By this, it was decided to use the material within the Tunisian prototypes in the project.

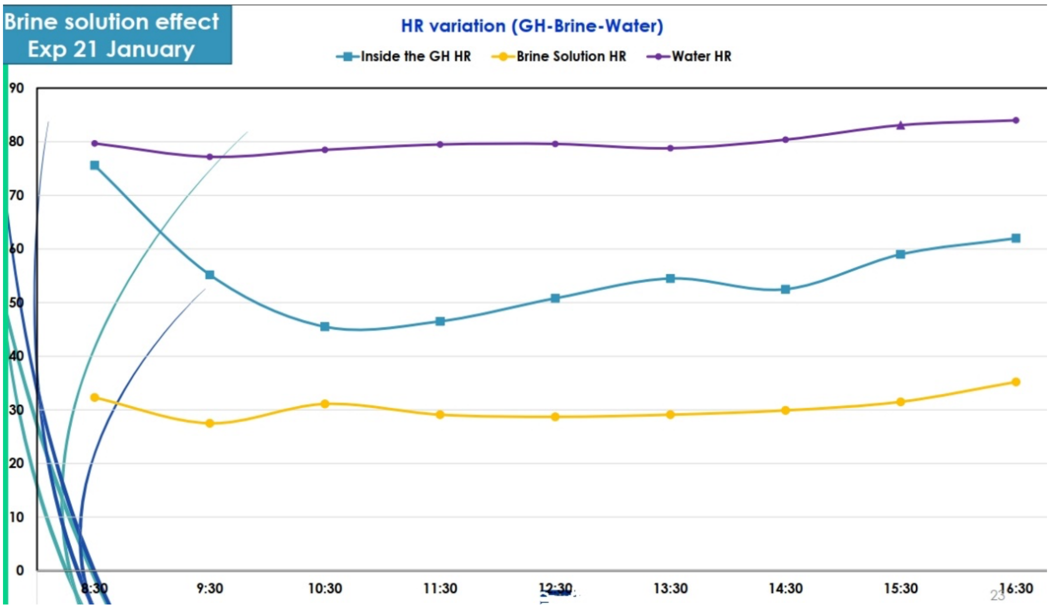

Fig. 23 Measurement of air humidity in the TCF container shows a very good and constant equilibrium humidity of ~30% using the TCF ($MgCl_2$/$MgSO_4$) from the Sfax salina in Tunisia.

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4 Upscaling, Planning for Greenhouse Prototype at Cherfech (Ariana, Tunisia)

Beside the testing activities in the Lab greenhouse, the project works on the realization of an advanced and more market ready greenhouse prototype. It is currently in process of realization.

For the operation greenhouse, a test ground was chosen on an external research farm of INRGREF about 20 km north of Tunis with good water supply and required facilities (electricity, agricultural machinery, space for storage devices etc.). A full call for tender with realization offers from three different local companies included the novel greenhouse design installation, installations for storage tank, hydraulic and air distribution as well as installation of system and control components. The work is in progress under the activity of the company chosen in the tender. Absorber and desorber devices are in production at Berlin facilities (TUB, WATERGY) and will be moved to Tunis after completion and connected to the system by the local installer.

Fig. 24 Greenhouse location in Cherfech (Ariana, Tunisia)

The planning included the identification and qualification of a demonstration location at the INRGREF Research Station in Cherfech (Ariana). The planning included an adjustment and upscaling of the technical characteristics of the Tunis lab greenhouse

The planning mainly included:

- Blueprints for the new greenhouse structure with increased surface and increased slope for droplet collection under the roof
- Blueprints for an advanced absorber design following the ongoing research for a better air- and TCF distribution in the absorber and adaptation to high volume flows through the absorber, which are required for the needed withdrawal of large quantities of heat and
- Blueprints of an advanced storage management
- The development of an initial control system with SPS device including storage loading/unloading routine

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4.1 Planning of advanced greenhouse construction for increased surface and condensed water collection

The simulations carried out in advance mainly confirmed that the bottleneck in the greenhouse cooling system is given by the size of the greenhouse's external surface. In a previous study for an experimental greenhouse in Dubai, an enlarged north wall in the form of a "zigzag" design was developed. However, this caused major constructional problems, in particular the tightness of the cover between the north wall and the roof surface was insufficient. In the first year of TheGreefa, various greenhouse constructions were therefore compared with the aim of finding a simpler construction method that would allow an enlarged surface. The so-called Caterpillar greenhouse was examined more closely. This is a tunnel greenhouse with tension ropes between the arch segments, which are used to tighten the film.

For the new greenhouse prototype, this construction principle was taken up and further developed. Significantly larger notches were made between the arches as high points and the ropes as low points, resulting in up to twice the surface area of a standard tunnel greenhouse.
This principle also creates a higher degree of stability, which is appropriate for storm and sandstorm situations in the region. The covering between the two greenhouse sidewalls can be made by only one single film segment and the sealing on the ground can be made by filling the sides with sand, thus achieving a high degree of overall tightness. Two film elements can be placed on top of each other via the clamping profiles on the arches and thus also connected tightly. In this way, greenhouse elements of any length can be formed.

The planning was made as a 3D CAD drawing by the Berlin research group (TUB WTG). The concept was agreed and explained in several Zoom meetings with INRGREF. The greenhouse will be built supported by a local construction company.

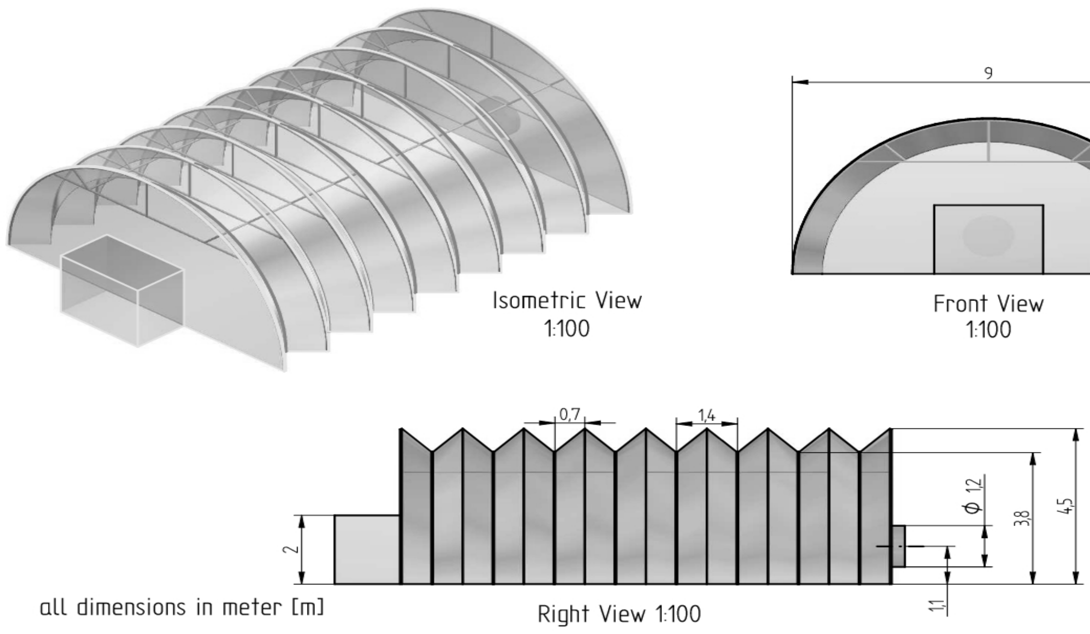

Fig. 25, Blueprints for increased overall surface of a tunnel greenhouse for improved heat conduction

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The specifications of the construction are detailed in the call for tenders:

- Tunnel Greenhouse « Accordéon » shape
- Area : 100 m^2 ; Length : 11,2 m
- Arch width on the floor : 9m and 7,6 m
- Ridge height : 4,5 m (Big arch) and 3,8 m (Small arch)
- Spacing between arches: 0,7 m
- Galvanised frame Z275
- Airlock dimensions: 2,5 m x 1,5 m x 2 m
- Cover in anti-UV Thermal Plastic , thickness > 180 µm water recovery system (Rain and condensation water)
- Irrigation system:
- Supply, assembly and start-up of irrigation equipment
- (Pumps, piping, head station, cabinet and electrical equipment, automatic programmer...)

Based on the new construction concept, the following items are included in the planning of the demonstrator:

- A backup ventilation system with supply of outside air (conventional, non-closed operation) will be included. For this purpose, a fan will be installed on the short side of the head, as well as an additional door with an insect screen to remove the air from the inside.
- A drip irrigation system will be installed.
- Installation of storage tank for the TCF solution, including a hydraulic system to connect the storage tank to the absorbers.

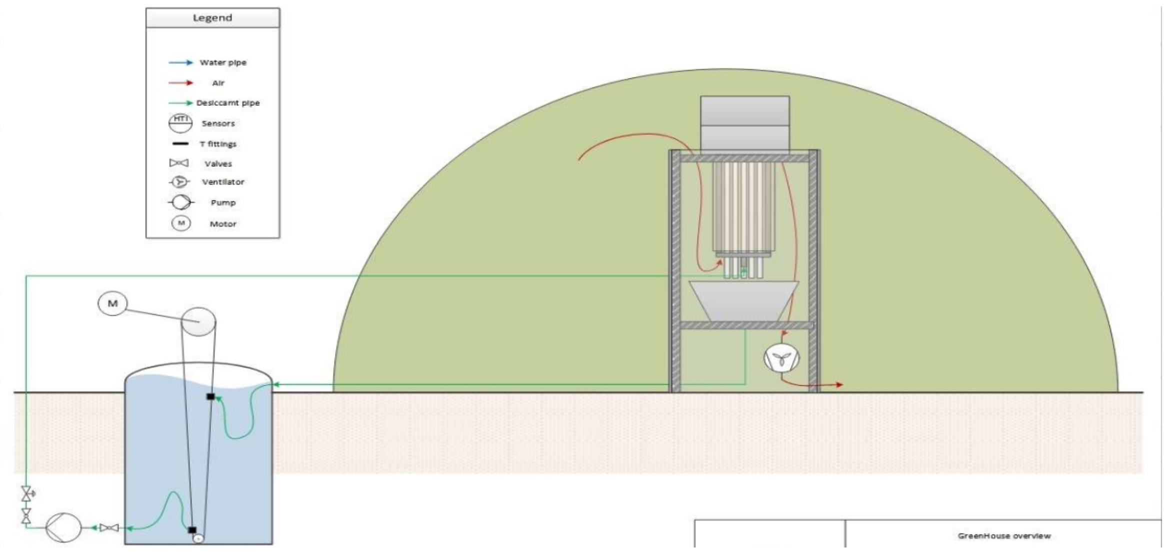

Fig. 26 Planning, Hydraulic scheme, placement of absorber andTCF storage, functioning of the storage loading/deloading with motor driven, altering top/buttom position (TCF is called desiccant)

4.2 Development and testing of novel absorber technology at TUB/WTG facilities

Due to travel restrictions in the context of the Corona crisis, some of the component tests originally planned for Tunisia were partly, and as far as possible, carried out in Berlin. The aim of the tests is to provide more mature

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elements of the greenhouse cooling and de-humidification system. The most important element for this is the absorber.

Absorption devices available on the market today, so-called air scrubbers with filled packing columns need further observation and optimisation for use in a TCF driven greenhouse system for the following reasons: (1) The dense packings generate a high pressure drop in ventilation which leads to high energy costs. (2) unlike water, falling individual TCF droplets create a discharge of salt from the unit, causing possible damage to plants and corrosion problems to the structure; (3) a droplet separator at the top of the unit can curb the problem, but leads to a considerable additional pressure loss and thus to further increased energy costs; (4) a sufficiently high TCF solution coverage of the packing element surface is only achieved with high volume flows of TCF, which in turn leads to continuously increased expenses for pumping. To solve this problem, the Berlin working group and Watergy GmbH had already developed an absorber with stretched, cylindrical textile elements in previous projects. The tests within the project on the construction of absorbers for the greenhouse are aimed at an improved version of absorption devices with the following focal points:

- Improvement of TCF distribution on a high number of textile cylinders by using 3D printing
- Tests with misting devices to optimise uniform air distribution in the absorber
- Tests with colored liquid to optimise uniform TCF distribution.

The tests revealed a number of deficits that will be taken into account when redesigning the absorbers for the greenhouse.

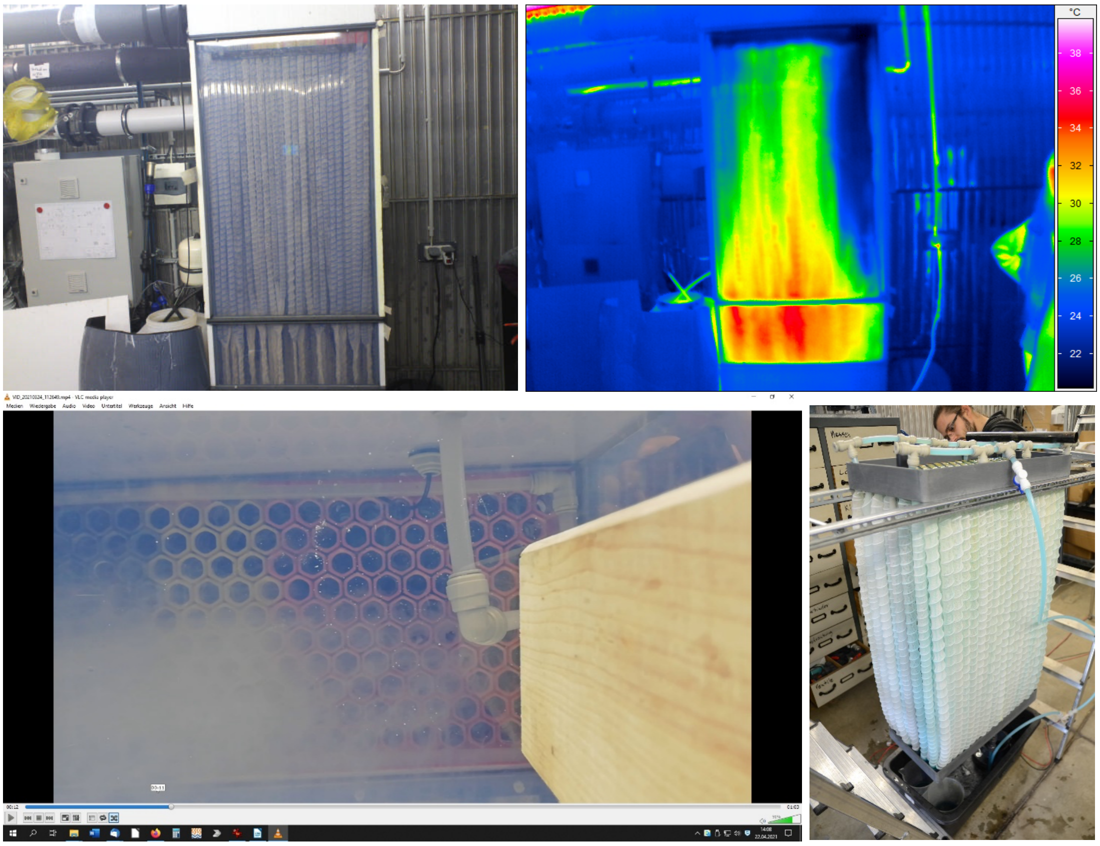

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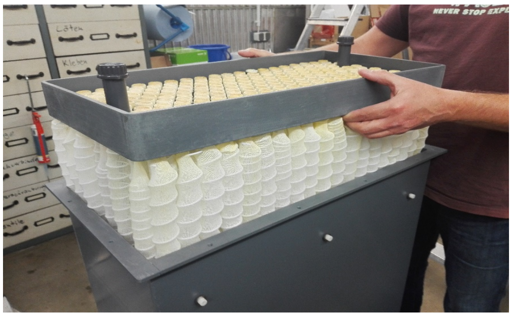
Fig. 27-30, Observation and measurement of air and TCF flows in the laboratory of TU Berlin with the help of thermography, fog experiments and with colored liquid.



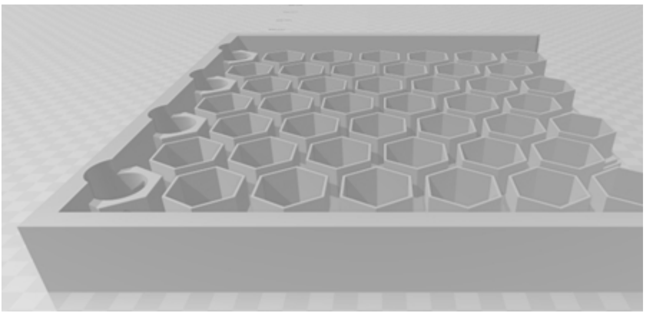


Fig. 31-32: High density interface between TCF film (on cylinders) and air; 3D Drawing of Dissipation Element

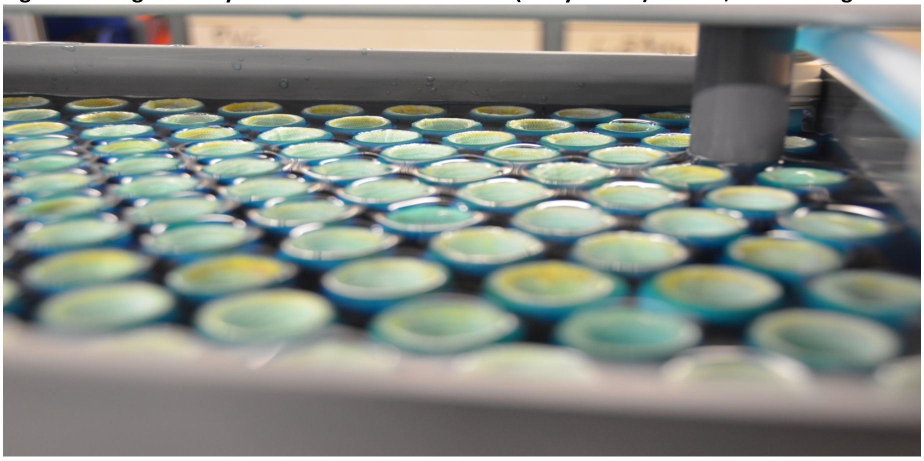


Fig. 33 Dissipation element in operation with TCF distributed through overflow tubes onto textile cylinders

4.3 Development of an adapted absorber device for the new greenhouse demonstrator

A further focus in the realisation of the greenhouse system in Tunis is the development of an absorber adapted to the system. The original idea of using an existing Watergy absorber model and pre-testing it in the Tunis greenhouse was discarded for time reasons due to Corona-related delays, but also for economic reasons: A total of at least six absorber units are needed, each of which has to be realised manually and with a high expenditure of time. Therefore, a new, simpler model was developed, which consists of a 3D printable distribution element that is installed in a ventilation box. First, an element of this is built and pre-tested in a laboratory at the TU Berlin. The main work consists of the overall planning/conception according to fluid-dynamic and functional aspects as well as the development of the 3D model for the print job. The 3D model is produced in such a way that slightly different design variants can be created using parametric inputs. It is planned to build several variants into the six absorbers and to compare their functionality later. This approach means that the creation of variants does not lead to additional work.

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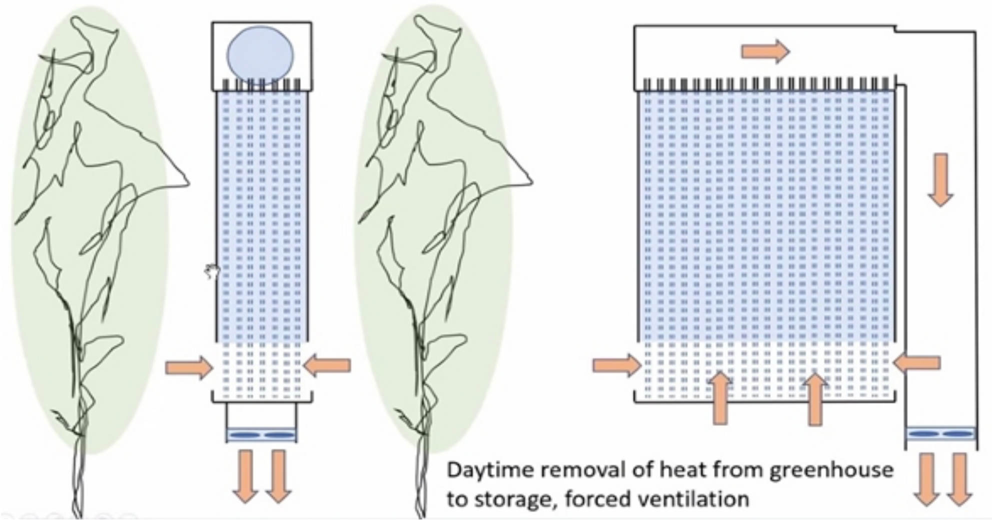

Fig. 34-35 Operation scheme for newly developed absorber with optimised air circulation in the contact area with the TCF.

The ventilation box is realised in such a way that a fan is connected via a ventilation tube, which draws in the air via the underside of the absorber at a height of about 1.5 m in the greenhouse and then distributes the cooled and dried air towards the floor level in the greenhouse. A final distribution over the entire floor level then takes place due to the higher weight of the cold air. Only when the air is warmed up again by solar radiation, it rises again back to the roof level.
A second variant in the ventilation box allows air to flow through natural buoyancy and fall due to temperature and humidity differences in the air. For this purpose, a cover is opened at the top of the box so that the air can flow in a vertical direction. This variant is intended in particular for carrying out experiments at night. In this case, fan power is saved accordingly. The thermal load on the greenhouse at night is considerably lower and the absorber is used to cool down the storage tank and regenerate the TCF. Compared to the daytime function of greenhouse cooling, the functions can be carried out with significantly lower volume flows. When using PV electricity, this also circumvents the use of electricity storage.

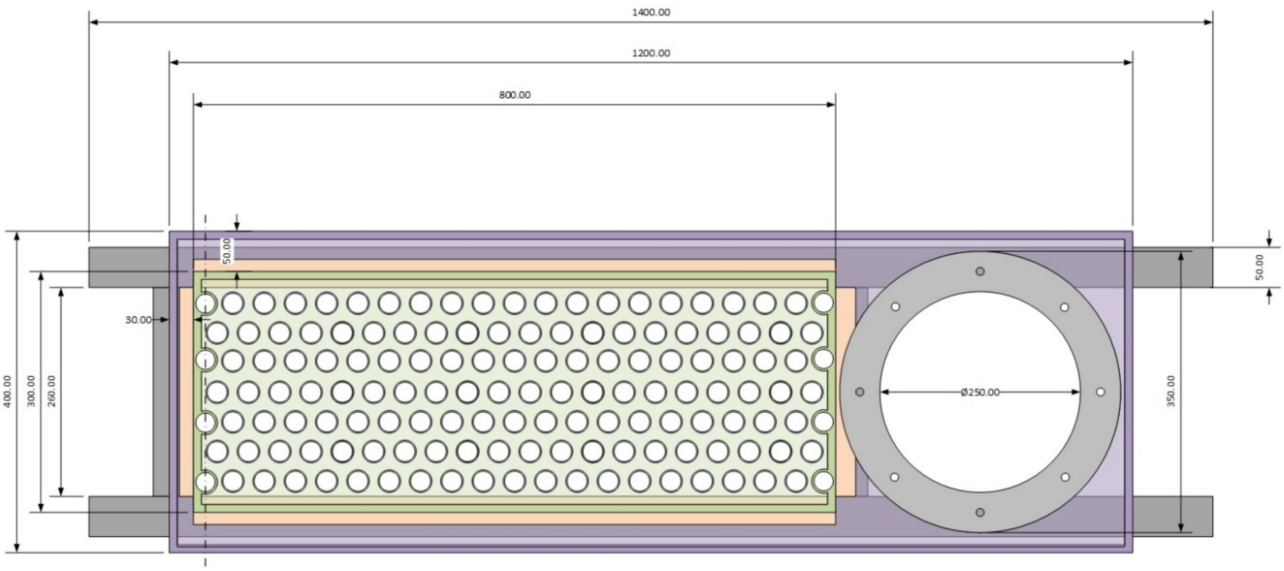

Fig. 36 Blueprint of the new absorber element

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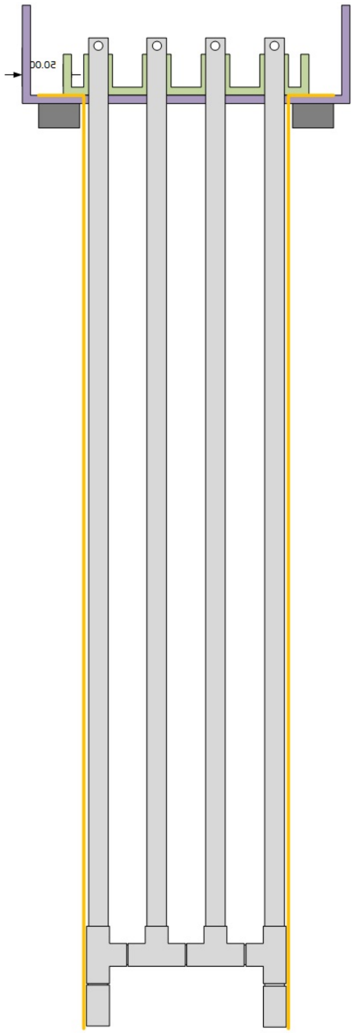


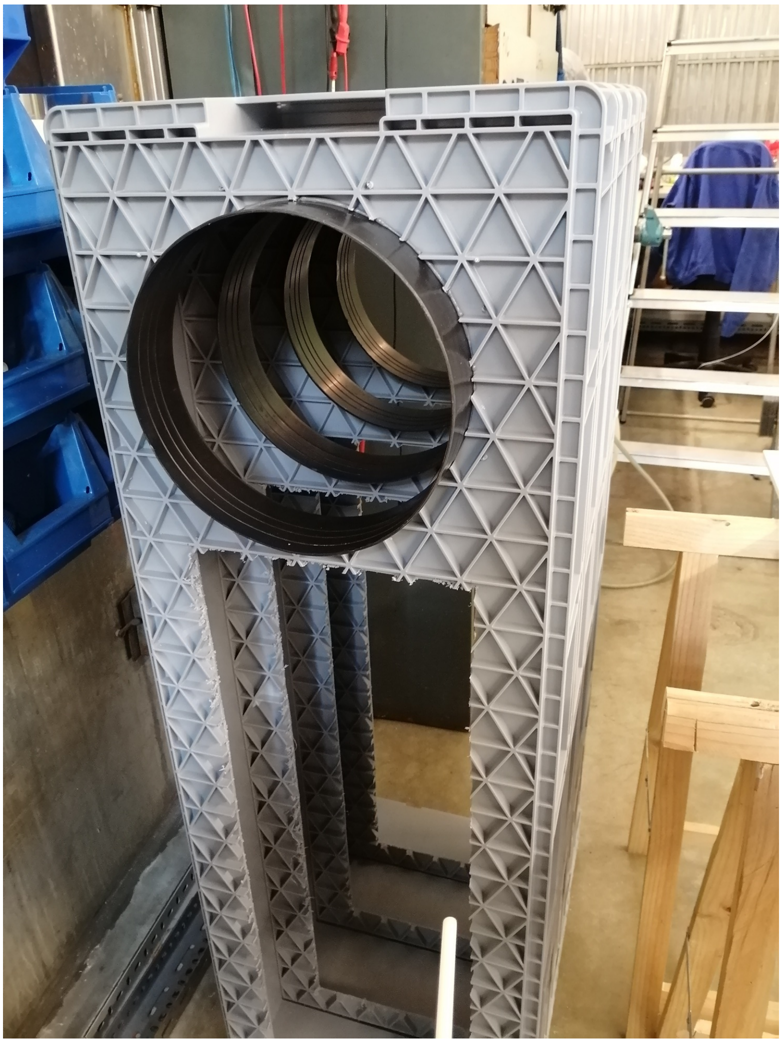
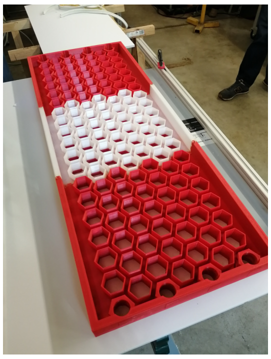


Fig. 37-38 Blueprint of the new absorber element and realisation of 6 absorbers for the CHERFECH demonstrator



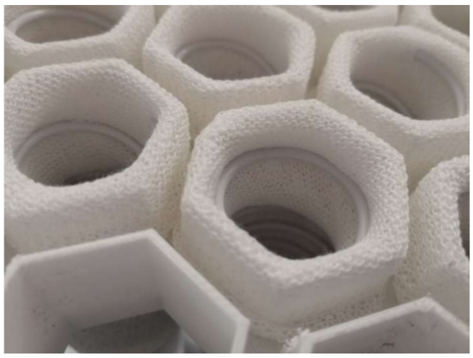


Fig. 39-41, Device for TCF dissipation to surface element (3D print), Design of TCF entry for high volume flows, detail connection of textile stripes to TCF distribution elemen

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Fig. 42-44 New developed surface area for improved air distribution in botom-up direction, Absorbers integrating low cost components (pre-fabbed materials, plastic foil…)

Workshop activities, optimising TCF distribution in the absorber using high flow velocities

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5 Conclusions

The work in this report was motivated by the idea of developing and testing a new concept for extremely water efficient and intensive production of agricultural goods in closed greenhouses. The basic idea is to keep water in a closed cycle or to use impure water (like pre-treated wastewater) in irrigation and to produce pure condensed water for external uses.

The main problem in running a closed greenhouse, especially in hot and arid climate is overheating! TheGreefa in this section works on a new cooling method, based on the heat-pipe principle, using the phase change of water for heat dissipation from the greenhouse to a day/night storage. Thermo-Chemical technology for improved heat transfer and -storage is used to solve the problem. Besides, more conventional concepts, like improving the heat storage capacity of the greenhouse soil and increase of the total greenhouse cover surface for improved heat conduction are used to support the cooling strategy.

In TheGreefa, a lab greenhouse was realized at INRGREF Tunis for testing and evaluating the principle. First tests are running and along September 2022, a first batch of test including vegetation will start. In parallel, a larger greenhouse demonstrator will be realized at the village of Cherfech in the Ariana region near Tunis. Here, learnings from the planning and testing already did contribute to technical improvements of the overall system. However, the new concept will also include elements for simplification and cost reductions using intelligent low-tech solutions and means of reducing the energy consumption, mainly in ventilation.

The tests still need more time to reach the required goals, but once the system is in an operational state and water circulation can be approved, the idea already can be demonstrated in a rather realistic environment. Dramatically rising problems in water supply for agriculture, even in Central European regions, will give a specific attention on this technology, once it will be in the envisaged demonstration mode.

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