GEOFOOD - RAS and heating installation in The Netherlands

Half-yearly update report no. 1 - May 2019

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January 21st 2019 marked the start of the construction of the RAS- and aquaponic research facilities for the GEOFOOD project. The new aquaponic system was built within the existing greenhouse research facilities of Wageningen University & Research which are located in Bleiswijk, the Netherlands. This report summarizes the design choices and construction process that preceded completion of the facilities in May 2019.

1 Aquaponic system description

The overall aquaponic system consists of a recirculating aquaculture system (RAS) that is originally designed for pike-perch and a greenhouse compartment equipped with a deep water culture system (DWC) for hydroponic cultivation of leafy greens and herbs.

1.1 RAS facilities

Figure 1 shows an overview of the RAS that was fitted within an existing greenhouse compartment of 144 m^2. The system has a total water volume of about 55 m^3 of which 36 m^3 are fish tanks. System flow reaches 60-80 m^3/h and retention time in the fish tanks is 30-60 minutes. Figure 2 shows a layout indicating all major components such as the fingerling tanks (1), on-growing tanks (2), grow-out tanks (3), drum filter (4), nitrifying biofilter (5), CO_2 degasser (6), heat exchanger (7), circulation pumps (8), oxygen cone (9), ozone generator (10), pH dosing pump (11), denitrification reactor (12) and mineralization reactor (13). A full description of the RAS can be found in the design report by Landing Aquaculture, 2019.

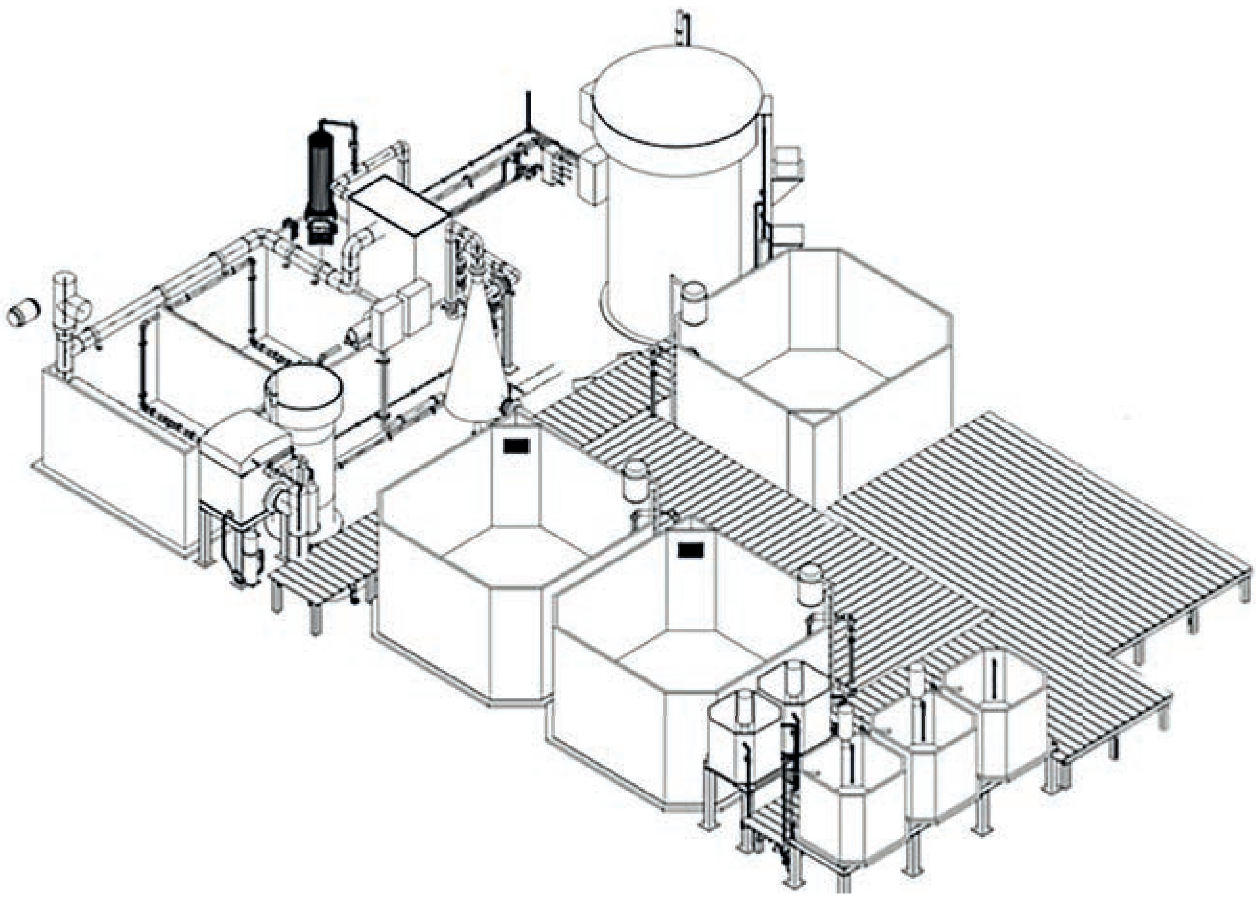

Figure 1 *Overview of the research recirculating aquaculture system for the GEOFOOD project. Source: Adapted from Landing Aquaculture.*

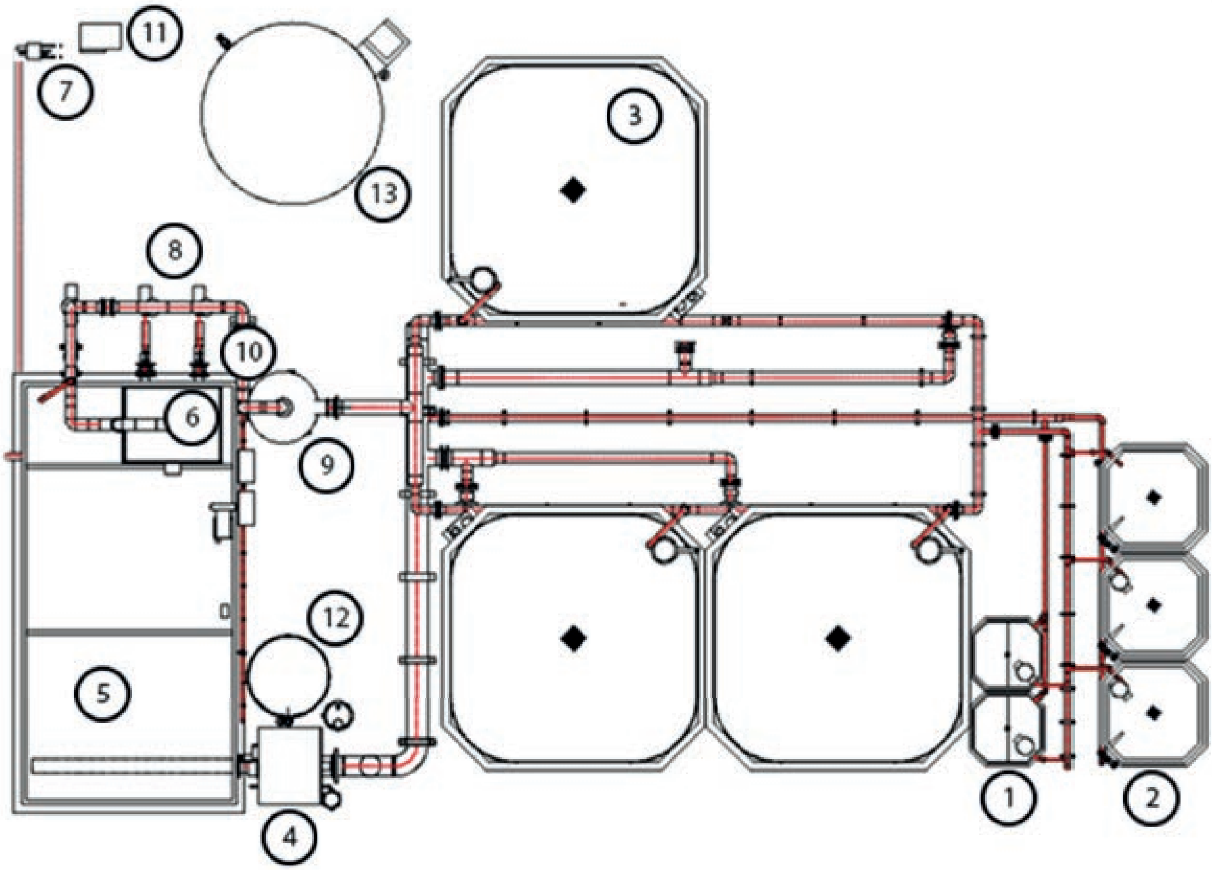

Figure 2 *Layout of all major system components of the RAS for the GEOFOOD project; fingerling tanks (1), on-growing tanks (2), grow-out tanks (3), drum filter (4), nitrifying biofilter (5), CO2 degasser (6), heat exchanger (7), circulation pumps (8), oxygen cone (9), ozone generator (10), pH dosing pump (11), denitrification reactor (12) and mineralization reactor (13). Source: Adapted from Landing Aquaculture.*

Figure 3 shows a photo of the completed RAS. A time-lapse video of the construction phase can be found on the project website www.geofoodproject.eu.

Figure 3 *The completed RAS, constructed by Landing Aquaculture within the greenhouse research facilities of Wageningen University & Research.*

1.2 Greenhouse facilities

For the hydroponic plant cultivation component of the aquaponic system a second greenhouse compartment of 144 m^2 was prepared. Figure 4 shows a photo of the greenhouse which is equipped with a total of 10 containers suitable for deep water culture (DWC) and floating rafts. The nutrient solution for each container can be controlled separately and each unit has a circulation pump to ensure water quality throughout the container remains homogenous. Greenhouse climate is controlled using sensors, a climate computer and equipment such as automated vents, pipe heating, LED lighting, screens, fogging and CO_2-dosing. Once the RAS effluents contained enough nutrients, trials were started growing lettuce.

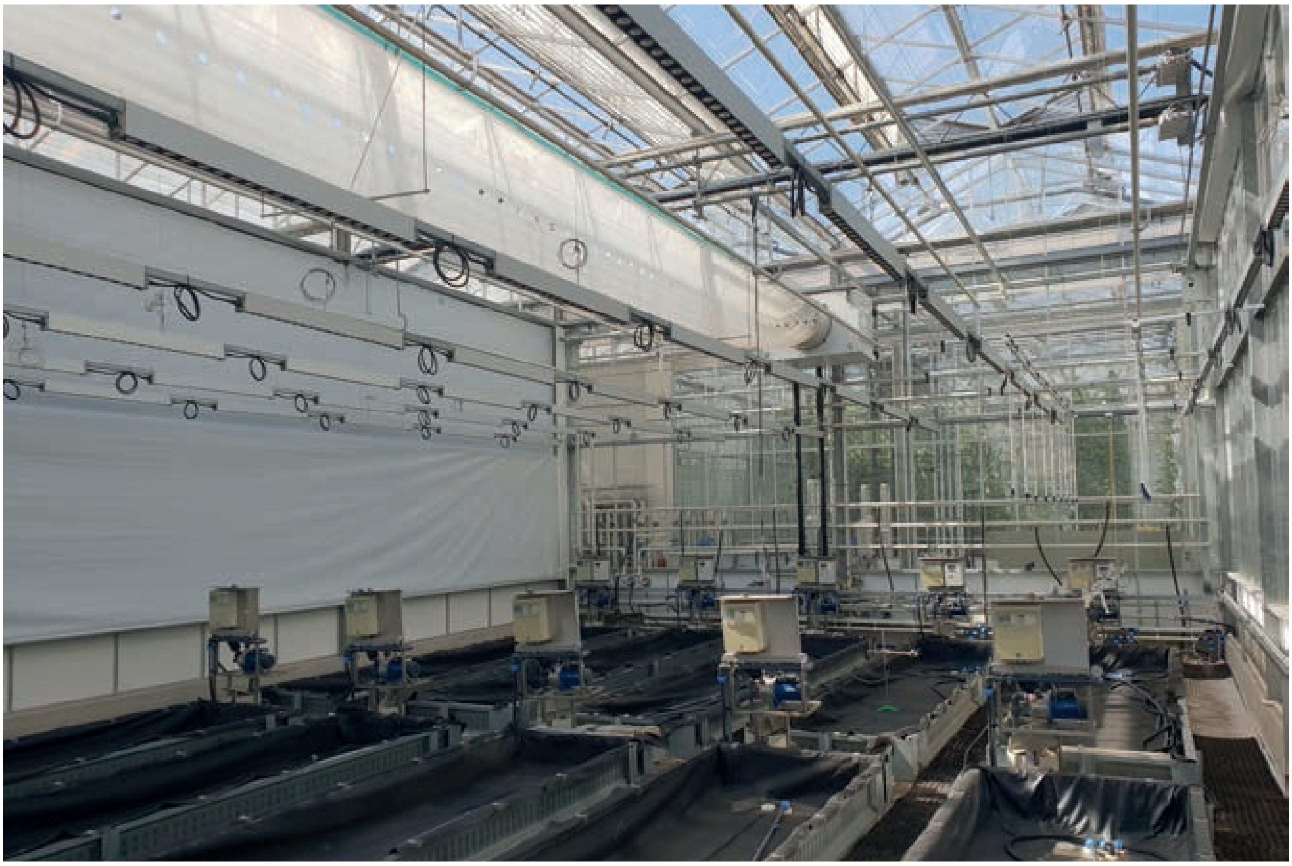

Figure 4 *Greenhouse compartment connected to the RAS for the GEOFOOD project.*

1.3 Aquaponic fertigation system

The system is set up as decoupled aquaponics since water and nutrients flow from the fish production to the plants, but water does not cycle back from the greenhouse to the RAS. Instead, any drain water from the DWC is recirculated within the greenhouse. This way optimal water conditions can be achieved for both fish and plants.

The RAS is designed to provide two separate flows of effluent for hydroponic cultivation: 1) water from the biofilter which contains mainly nitrogen (NO_3^-) and 2) water from the mineralization reactor which has a higher concentration of other macronutrients (i.e. phosphorus, potassium, calcium, magnesium and sulphur). Each outflow of effluent can be regulated with valves in order to mix a fertigation batch based on the nutrient profile of each flow. The mixing sump that holds the batch is not only connected to the RAS but also to the nutrient mixing system of the entire greenhouse facilities. Therefore, additional nutrients or pH-regulators can be added before the water is used as fertigation in the DWC containers.

As the fish grows, the feed load increases. This in turn requires larger water exchanges per day in order to keep nitrogen accumulation at an acceptable level. The greenhouse production area is too small to process all the water. To minimize the loss of water and nutrients to the sewage, a denitrification reactor is therefore included in the RAS. This unit is designed to remove nitrate from the RAS utilizing the faecal carbon produced by the fish. All in all, the resulting aquaponic system very much reflects the multi-loop aquaponic system as proposed by Goddek *et al.* 2016. Figure 5 shows a schematic of the water flows in such a system.

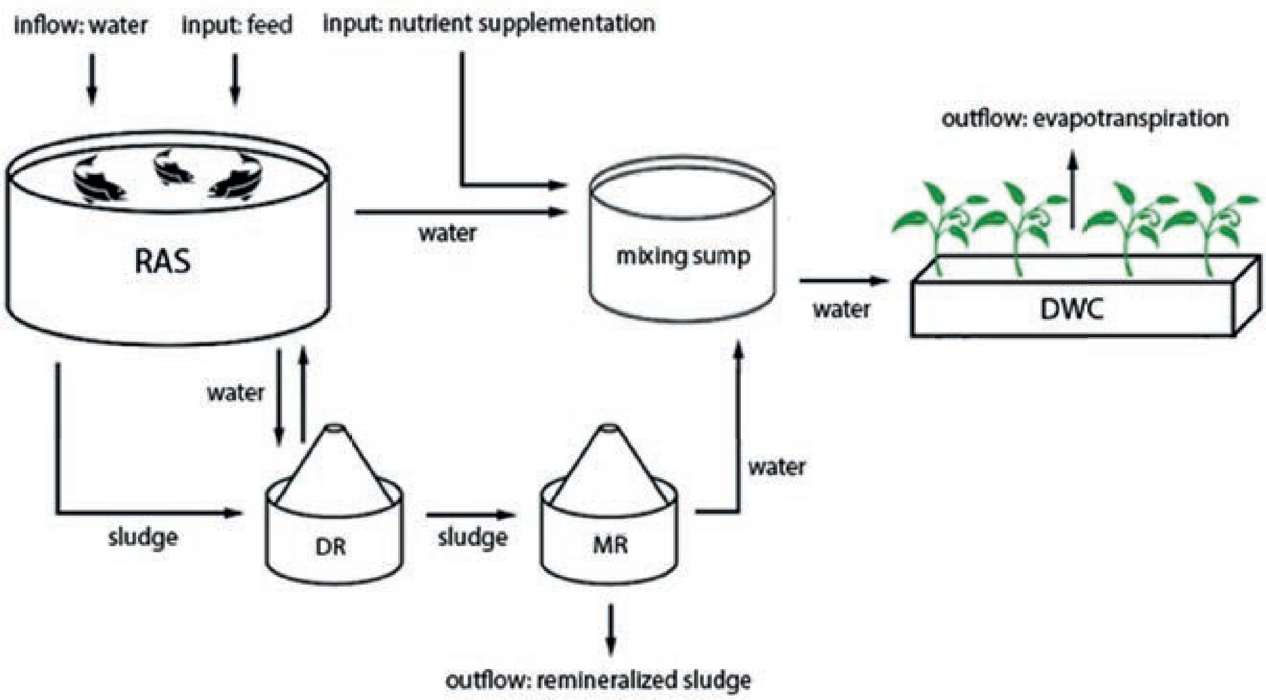

Figure 5 *Schematic overview of the decoupled aquaponic system using nutrient supplementation, active denitrification (DR) and mineralization (MR). Source: Adapted from Goddek et al., 2016.*

2 Heating system

One of the main objectives for the RAS facility is to gather data on the energy flows of the system in order to validate a model describing geothermal aquaponics. At the greenhouse facilities in Bleiswijk there is no geothermal source, but the existing heating system was extended to mimic different strategies that could increase geothermal energy use efficiency: 1) by using low-temperature residual heat from a greenhouse pipe heating system (35 – 40°C) as input for a RAS, and 2) by using high-temperature geothermal heat (70 – 85°C) directly for a RAS.

Figure 6 shows a schematic of the water-to-water heat exchanger that was designed to connect the RAS and the greenhouse pipe heating system. On one side of the heat exchanger the RAS water is continuously circulated with a flow of 11 m^3/h. On the other side the greenhouse pipe heating water is circulated of which the temperature can be controlled using a mixing valve. The maximum heating capacity of 26 kW at an input temperature of 35°C was calculated using the RAS energy model that has been developed within the GEOFOOD project and is described in detail by Boedijn *et al.* 2019.

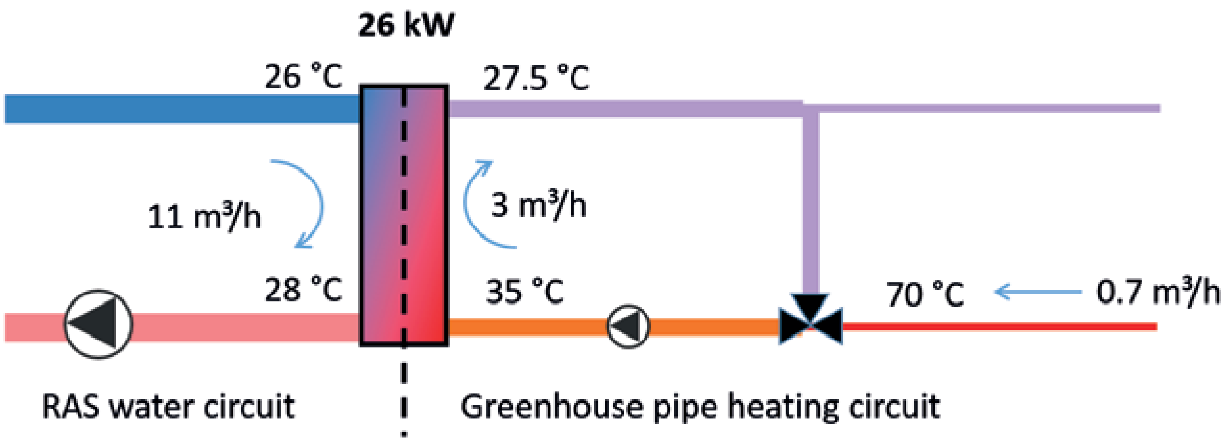

Figure 6 *Schematic overview of the implemented RAS heating system.*

To control the heating system a sensor that is connected to the greenhouse facility climate computer continuously measures RAS water temperature. The RAS water temperature functions as an input for the climate computer software to control the mixing valve. Within the RAS compartment a second pipe heating network is present which can be used to heat the compartment air if the heating capacity of the heat exchanger proves to be insufficient to reach the target RAS water temperature of 28°C.

3 Sensor network and data management

To monitor energy flows going in and out of the RAS a network of sensors has been installed. Each sensor provides data that is required to calculate several components of the system's energy balance:

$$Q_{demand} = Q_{building\ loss} + Q_{water\ exchange} + Q_{evaporation} + Q_{ventilation} - Q_{fish} - Q_{equipment}$$

Q_{demand}	: overall heat demand of the RAS facility	[W/m^2]
$Q_{building\ loss}$	: heat loss from the building	[W/m^2]
$Q_{water\ exchange}$	: heat demand due to water exchange	[W/m^2]
$Q_{evaporation}$	: heat loss due to evaporation	[W/m^2]
$Q_{ventilation}$	: heat loss due to ventilation	[W/m^2]
Q_{fish}	: heat produced by the fish	[W/m^2]
$Q_{equipment}$	: heat produced by the equipment	[W/m^2]

Table 1 contains an overview of the type of sensors, where they are installed in the RAS and how the data contributes to calculating energy flows for model validation. All of the sensors are connected to a datalogger that automatically sends out the data every day to be stored on a server. After that the data is processed and added to a database on a regular basis. Besides the input from the sensors, the GEOFOOD database is supplemented with data from the weather station that belongs to the greenhouse research facilities in Bleiswijk. Another source of data is the greenhouse climate computer that provides for instance vent- and screen positions as well as pipe temperatures. If needed, measurements will be performed by hand to determine the air flow in the ventilation pipe.

The only energy balance component that is not measured directly or indirectly is the heat produced by the fish. This energy flow will be estimated according to methods in literature and information from the daily management of the RAS such as the number of fish, total weight of the fish population and feeding loads.

Table 1
List of installed sensors and their application for the validation of the aquaponic energy model.

Sensor	Description	Input for energy balance component
Energy meter	Installed at the pipe heating system	Q demand
Air temperature	Measures the temperature of the air within the RAS compartment	Q building loss, Q evaporation
Relative humidity	Measures the relative humidity of the air within the RAS compartment	Q building loss, Q evaporation
Water flow meter	Installed at the supply water pipe	Q water exchange
Water temperature	Installed at the supply water pipe	Q water exchange
Water flow meters	Installed at all water output pipes (i.e. fertigation and sewage)	Q water exchange, Q evaporation
Water temperature	Measures RAS water temperature and also functions as input for heating system control	Q water exchange, Q evaporation
Air temperature	Measures the temperature of the air within the CO2-degasser ventilation pipe	Q ventilation
Relative humidity	Measures the relative humidity of the air within the CO2-degasser ventilation pipe	Q ventilation
Energy counters	Installed at all electrical groups for equipment (e.g. pumps and drum filter)	Q equipment

4 Integrating RAS into existing greenhouse facilities

One of the scenarios that is investigated within the GEOFOOD project is to turn greenhouse production into aquaponic production by integrating a RAS. If the RAS can be placed within the existing greenhouse structure this could save investments in new infrastructure. However, the construction phase in Bleiswijk proved that integrating a RAS into existing greenhouse facilities is not a straightforward process and needs proper preparation.

As is described in the previous chapters, the RAS and the greenhouse have to be connected to fertigation and heating systems. This requires a design and engineering phase because certain equipment (e.g. buffer tanks, mixing units, piping) must be able to support two production systems with different requirements.

Since most fish are influenced by or sensitive to daylight, the greenhouse needs to be equipped with blackout screens. LED lamps with an appropriate spectrum can then be installed to control light intensity and photoperiod, depending on fish species and life stage.

Once the fish tanks and biofilter are filled up with water they weigh between 1-2 tonnes per m^2. The carrying capacity of the greenhouse floor needs to be considered to avoid subsidence that could result in ruptured tanks or pipework.

RAS are usually actively ventilated to avoid build-up of CO_2 and moisture. High CO_2 concentrations are undesirable with respect to working conditions and efficiency of CO_2 stripping. High humidity levels can affect equipment or cause a building to rot and rust. Though moisture affects a greenhouse structure much less than it does a building, the greenhouse still needs to be adapted to facilitate ventilation ducts, especially when active CO_2 stripping is applied.

Energy loss from a greenhouse is usually higher than from an insulated building. A RAS placed within a greenhouse will therefore most likely have a higher energy use. In summertime solar radiation can cause greenhouse air temperature to rise above 35°C, especially since the greenhouse windows cannot provide much ventilation when a blackout screen is permanently deployed. Cooling may even be necessary to keep the system water temperature below acceptable thresholds for fish.

Fish feed needs to be stored in a cooling cell. However, due to its strong smell, storing it together with fresh produce from a greenhouse may affect the quality of the produce.

Literature

Boedijn, A., Romero, E. B., & Poot, E. (2019).
GEOFOOD - Energy model of geothermal greenhouse aquaponic systems, Part I: Model description and applications.

Goddek, S., Espinal, C. A., Delaide, B., Jijakli, M. H., Schmautz, Z., Wuertz, S., & Keesman, K. J. (2016).
Navigating towards decoupled aquaponic systems: A system dynamics design approach. *Water (Switzerland)*, *8*(7), 1–29. https://doi.org/10.3390/W8070303

Landing Aquaculture. (2019).
Design report on the research recirculating aquaculture system for the validation of the GEOFOOD energy model.

To explore the potential of nature to improve the quality of life

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The mission of Wageningen University and Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 5,000 employees and 12,000 students, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.