AlgaeBioGas

Algal treatment of biogas digestate and feedstock production

D2.2

Assembly and Startup Report

PUBLIC

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1 Summary

Set-up of the demonstration centre is one of the central activities of the AlgaeBioGas project. This report documents Task 2.2 the assembly and setup phase of this activity. This activity followed the design and planning phase (task 2.1, reported in D2.1 Design of the Demonstration centre). This report presents brief description of the status of the Demonstration centre and then details deviations between initial design reported in D2.1 and final constructed centre. In its second part this report describes procedures that we used to startup the demonstration centre. This description should be a template for description of such activity in replicated projects.

This deliverable is the result of work under task 2.2. Demonstration centre planning.

Editorial note

Deliverables in AlgaeBioGas project necessary build on and refer to previous deliverables. Our aim is to make them self-contained readable documents which necessary involves some replication of contents of previous deliverables, either as verbatim or summarized quotes. We are aware that such text is annoying to someone reading deliverables in series, so we have decided to set such text in lighter colour.

Thus, if you are reading just this text, please find contextual and reference information in lightly set sections; if you are acquainted with the project context (like a reviewer), please ignore the text set in light typeface.

Previous deliverables (partially) quoted in this document:

- DoW Description of work (Annex I of the Grant Agreement)
- D2.1 Design of the Demonstration centre

2 Project description & Design objectives

AlgaeBioGas project is focused to market introduction of algal-bacterial treatment of biogas digestate. Using algae we can recycle CO2 emissions and nutrients contained in the biogas digestate. Excess heat can also be productively used. Treated digestate is of such quality that it can be reused or released to the environment. Resulting biomass can be used as biogas substrate, possibly after extraction of specific components in biorefinery.

Classical biological (bacterial) waste water treatment successfully reduces the quantities of organic substances at the cost of significant CO2 emissions and significant energy consumption for aeration. Mineral nutrients, flushed with the liquid phase of digestate, are lost in the bacterial sludge which is frequently deposited, incinerated or discharged to the environment.

Algae hold a great potential because of their high growth rate, easy production, better utilization of sunlight compared to conventional plants, shorter lifecycles and independence from fertile agricultural land. Biogas plants are rich sources of mineral nutrients, CO2 and heat. By algal recycling we can close material cycles, provide feedstock for bio-refining various high value products and decrease competition between biogas and food use of agricultural crops.

The project aims to set-up the first application as a demonstration centre and prepare all prefabricated technology, organization and marketing tools to market replication projects. The technology demonstration centre is not only be able to demonstrate the technology in full size at a demanding customers site, but also provides on-site support for customer's testing, analysis, evaluation, training and other activities required as part of a complex project.

3 Task description

Description of demonstration centre from DoW (Annex I):

Objective

The objective of this work package (WP2) is to construct the demonstration centre from the planning to the commissioning phase.

Preliminary structure of the demo installation at the KOTO site:

- Algal-bacterial pond
  - Construction and ground works
  - Lining and shaping
  - Mixing equipment
    - Motor, variable frequency control
    - Paddlewheel with mounting
  - CO2 introduction with pH regulation
  - Heat exchange piping
  - Monitoring and control system
    - Sensors: pH, DO, ORP, EC, NH4, optical density, Chlorophyll, several flow and level sensors
    - Weather data including insolation and PAR sensor
    - Logging, alerting and control equipment
    - Networking, remote access and control
    - Video surveillance
- Greenhouse (an off-the-shelf (OTS) greenhouse will be used for demo, but we plan to develop a specialized pond cover later – for efficiency and scalability)
  - Temperature control with filtered ventilation
- Separator / Clarifier
  - OTS unit will be used
  - Piping, plumbing, pumping and monitoring will be custom made
- Flocculant preparation
  - Tank and dosing pump
- Inoculation photobioreactor
  - A small inoculation unit will be built or bought
  - Includes mixing, control and dosing equipment
- Infrastructure
  - Connections for digestate supply, CO2 supply and heat supply
  - Pumps and dosing equipment
  - There is an existing dewatering facility, but it may prove to be inadequate, so we may be forced to install a new separation facility
  - Power, clean water and sewage connections
- On-site working room
  - Sample storage, on-site monitoring, equipment installation

- A transportable solution (that may be later used as a portable demo) will be investigated

Detailed design was made in task 2.1, site preparation and component selection, manufacturing, testing, assembly, system test and start-up are being done as task 2.2.

Task 2.1. Demonstration centre planning

Detailed plans for the demonstration centre had been done under this task. Several technical decisions had been made. The planning included construction planning, electrical and piping installations, sensors and control system. Item list of all the components had been compiled. Component suppliers and or manufacturers were selected. All necessary permits (construction, land use) were requested.

Task 2.2. Construction, assembly and start-up

Selected equipment and materials from the equipment list were purchased. Site preparation work has been done and individual components for demo centre were produced (pond, sedimenter, inoculation photobioreactor ...).

Equipment installation was done under this task. This includes unit acceptance and testing. The equipment includes piping, covers, set up of pumps, mixing system, CO_2 and digestate supply system, heating, sedimenter, sensors and control system. Preparation of inoculation culture of algae in the inoculation photobioreactor was started and testing of the equipment was performed. Any changes needed in planning are reported as change order in the plans in this report.

Algal culture has been introduced to the pond and system has been started. All calibrations were made at this step and all basic operating modes of the system were tested at this stage.

4 Status summary

Demonstration centre has been constructed and started as described in the above description.. The detailed design that was prepared under task 2.1 was the basic blueprint for the construction. During construction some of the improvements and modifications were made and we are describing these in section 5.

As a general guideline we wanted to setup the essential parts of the demonstration centre as soon as possible to take advantage of the summer season. For this reason we have prioritized basics and delayed more advanced and time consuming features. Net result is that the centre was operational in August 2014, but will still need to implement improvements in sensors, monitoring and control system. These activities will continue for next six months and we expect to prepare an updated version of this report at the end of this period. A brief list of pending activities is in section Error! Reference source not found..

5 Demonstration centre by components

This section describes the constructed demonstration centre by components roughly corresponding to the structure defines in DoW (section 3)

5.1 General situation

Demonstration centre has been built within KOTO's industrial yard in the area between the biogas plant and biofilter (a large area used to biologically filter air for odour). Main part of the demonstration centre consists of a greenhouse and two equipment containers.

Figure 1 Location of Demonstration centre and related facilities (image © Google)

The demonstration centre is connected to:

- Biogas plant for digestate input
- Gas motor for supply of exhaust gases, heat
- WWT plant for output water

Details of these connections are more complex and will be detailed in further text.

Figure 2 Demonstration centre area before start of construction

5.2 Algal-bacterial pond

5.2.1 Construction and ground works

Main design decisions made before start:

- Due to relatively small size of the pond we have opted for simple geometry of the pond. For a larger pond, the mid section of the raceway would have to be shaped for better mixing efficiency.
- We plan to use water level at 30 cm, but we have built the pond to accommodate water levels up to 50 cm to enable testing with larger proportion of dark/light volume.
- We have built ample thermal insulation, heating and cooling piping under the pond to be on the save side for any weather conditions; observed performance will enable significant optimizations.
- We opted for classical/proven paddlewheel mixing; better energy efficiency would be possible if we used different mixing technology (slow propeller), but energy efficiency is not of primary concern at this pond size.

Ground works were started in May 2014. Construction and ground works were quite demanding since the terrain used for the demonstration centre was previously filled by tissue from biofilter which resulted in soft terrain. Soft material had to be removed and we opted for very solid foundation. Pond bottom was made of:

- concrete slab
- 5 cm expanded polystyrene plates (Styrodur) for insulation
- pipes for underfloor heating
- concrete floor screed
- PEHD membrane

Figure 3 Concrete slab, walls from concrete blocks and under-floor heating pipes

Pond walls are made from concrete block. Walls are hydro-insulated on the outside, inside curves are made from EPScrete (expanded polystyrene concrete). Curves are at least 10 cm thick, so they also function as thermal insulation on vertical sections.

Figure 4 Hydro-insulation and models for the curves

5.2.2 Lining and shaping

We have selected a PEHD membrane that is oversized for this kind of pond. The only off-the shelf solution that we were able to find was intended for land-fill lining with very stringent demands regarding permeability and welding, The membrane is 3 mm thick and certified for land-fill applications. Membrane is doubly welded and all welds are pressure certified. The contractor also provided certificate for the whole layout.

This kind of membrane required that all edges are rounded with minimal radius of 50 cm. The membrane also forms "blisters" with changing temperature when not loaded. Although the membrane surface seems to be very smooth thus preventing attachment of algae, this is not true for the welds. This thick membrane has to be attached on vertical surface above water level and cannot integrally cover the horizontals of the pond. Attachment is done with screwing metal profile to the concrete; the corrosion resistance of these metal profiles will have yet to be proven.

The solution we used with the membrane is not really scalable. We did consider epoxy paint instead of membrane; the concrete at the bottom and the curves made of EPScrete are of sufficiently good quality to be painted, but we made a conservative decision to use this kind of membrane.

Figure 5 Curves made of EPScrete and PEHD membrane

Each pond has one draining pit where we can drain it. Draining pits are prefabricated installation shafts made of PP. Draining pipes are connected to the pits. We can also use a submersible pump within the pit to completely drain the pond.

5.2.3 Mixing equipment

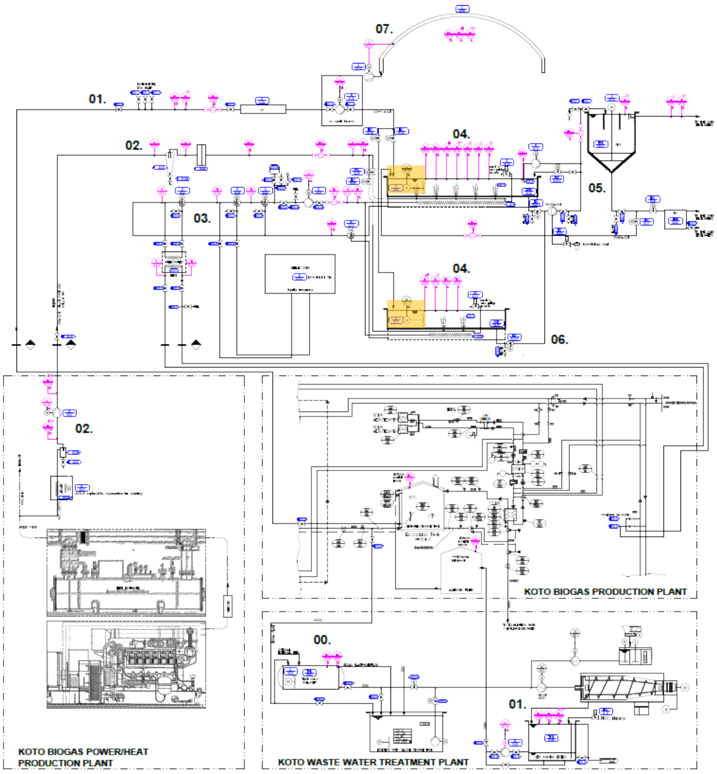


Figure 6 Mixing equipment (full size chart in appendix)

Initially we intended to use a paddlewheel that was available from previous use in AlgEn's spirulina ponds. It turned out that we had to rebuild all the paddles due to deeper pond. The paddlewheel diameter is now 140 cm, which makes it a very large structure. The existing gear proved to have to low ratio due to larger diameter of the wheel so we replaced it together with the motor. Finally only the shaft and one bearing remained from the original paddlewheel.

Paddlewheel motor is driven by a variable frequency controller allowing for the water speeds between 20 and 50 cm/s. Some torsional vibration was observed in the paddlewheel which may require some reinforcements.

Mixing in the inoculation pond is implemented by a vertical mixer. It was made from welded stainless steel, equipped with a geared motor and mounted on a metal beam across the circular pond. This metal beam also serves as a fixture for CO_2 diffuser and digestate inlet.

Figure 7 Paddlewheel and vertical mixer in inoculation pond

5.2.4 CO2 introduction with pH regulation

CO2 introduction is implemented as introduction of exhaust gases from the gas motor.

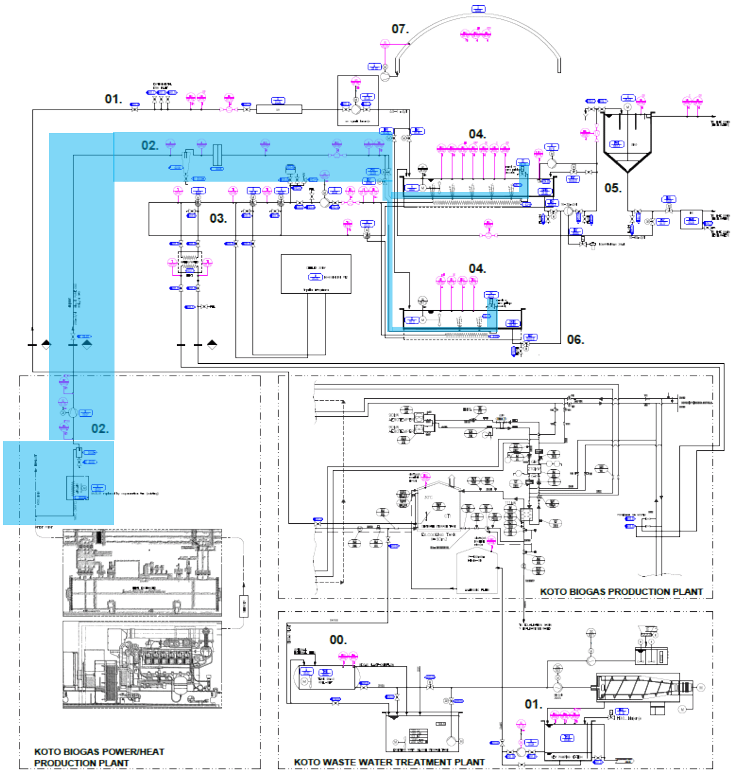


Figure 8 CO_2 subsystem (full size chart in appendix)

Exhaust gases are captured from the gas engine chimney and led through heat exchanger that was made of copper pipe and mounted in front of the cooling fans of the gas engine. The air coming from the gas engine container is not really cold, but airflow is huge and heat exchanger works very efficiently. Exhaust gases contain approx 10% of water vapour so large amounts of condensate are expected. We installed drains at several places, the first and most important one is next to the heat exchanger.

Exhaust gas comes at two temperatures: 480°C when the steam generator is off and 180°C when steam generator is working, so the function of heat exchanger is very important. Negative pressure is provided by a blower that provides the pressure to drive 150m line from the gas engine to the pond. Pipe is an insulated PE-RT/Al/PE-RT pipe; on all vertical sections we installed drains to discharge the condensate.


Figure 9 Flue gas heat exchanger and blower with the drain

We measure temperatures of the gas at several places and control the gas flow to the constant temperature at the pond's end. We keep the gas temperatures above 30°C to prevent freezing of the condensate along the pipe during winter.

At the pond-end we are using an of-the shelf air filter with drain and control gas flow to the ponds by electrically controlled valves.

Blower position close to the motor end of the pipeline ensures that any leaks in the pipe just present loss of flue gases and do not introduce air into the pipe.

Pond gas diffusers are made differently for the two ponds. The round inoculation pond has drain pit in the centre, so we used a punctured pipe in S configuration at the bottom of the pit as a diffuser. Just above the diffuser the mixing blade induces radial movement, so we can expect that significant part of gas bubbles will get dissolved in water.

In the large raceway pond a counter-flow diffuser was made. It consists of a transparent grooved plate mounted slanted against the water current. Exhaust gasses are blown from the punctured pipe at the bottom of the slanted plate, so that the bubbles form on the plate. When everything is right the bubble of average size remain still under the plate, so the dissolving time of a bubble is maximized.

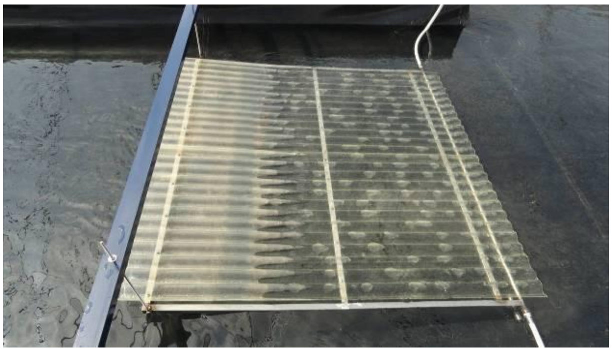


Figure 10 CO_2 diffuser in raceway pond

Introduction of exhaust gases to the ponds will be controlled by a pH regulator in the control system.

5.2.5 Heat exchange piping

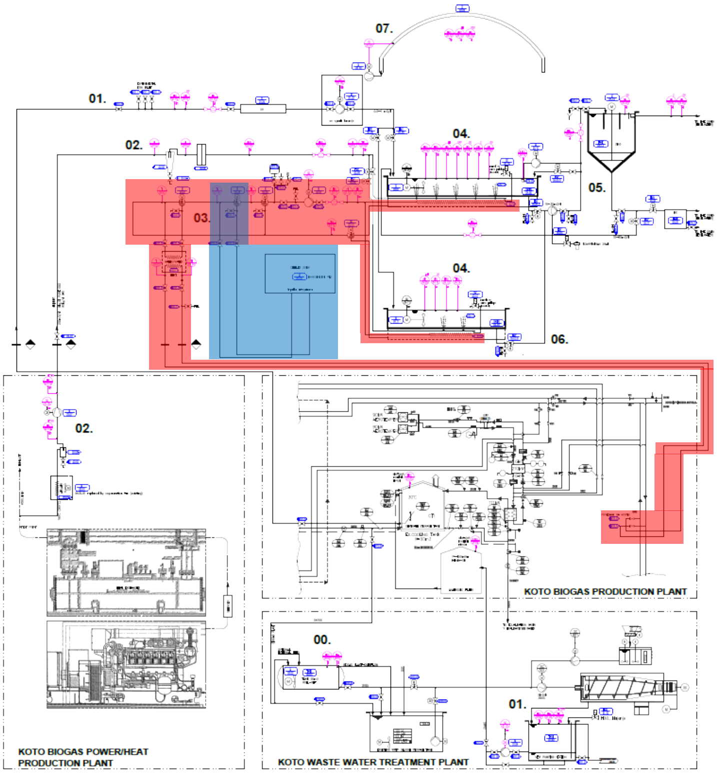


Figure 11 Heating and Cooling system (full size chart in appendix)

As described in section 5.2.1 the ponds have an under-floor piping installed for heating and/or cooling. Pipes are installed as a single piece under the pond and several sections are terminated in a pit next to the pond.

Heat transfer pipes are connected to a classical hot water / chilled water distribution system very similar to usual central heating installation. Heating and cooling is regulated using 3-way valves including or bypassing heat exchanger or chiller in the circuit. The system is separated from KOTO's company-wide district heating system with a heat exchanger to provide safety for the rest of the system. Chiller has internal heat exchanger to transfer the heat from the pond to the chilled water. Flow and temperature sensors enable us to calculate exact energy consumption of the system. Control system automatically regulates the operation mode (heating/cooling) considering the actual conditions in the pond.

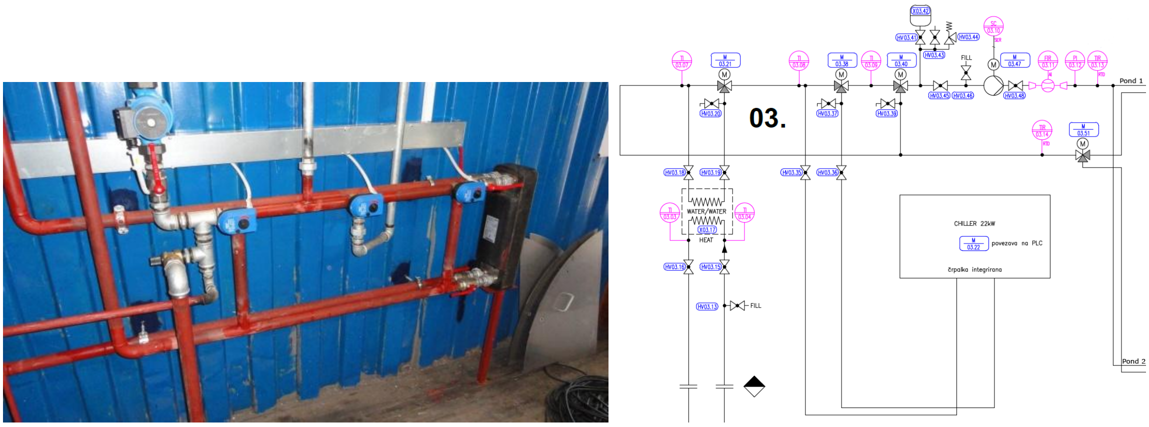


Figure 12 Heating & cooling implementation and circuit schematics

We used existing water chiller and we have installed it as a safety measure. Regular temperature control ought to be achieved by forced ventilation of the greenhouse, but availability of the chiller adds flexibility to the system. Chiller is able to extract 20kW of heat from the ponds which is less than half of expected solar thermal flux at peak hours. Chiller already includes heat exchanger and all ordinary valves, so it is a self contained subsystem that was easy to integrate.

Figure 13 Chiller mounted in front of the equipment containers

5.3 Monitoring and control system

Control system for the demonstration centre is distributed as there are three locations that host equipment of the demonstration centre: WWTP for digestate storage and separation, biogas engine for exhaust gas cooling and pumping and demonstration centre itself for all other equipment.

At the WWTP an electrical cabinet already existed, so we installed a small PLC unit with all necessary controls there. At biogas engine, we have installed a small cabinet with a PLC and other logic needed at the location (Figure 15).

Main PLC and most of the control electronics is installed in cabinets in the office container next to the greenhouse. PLC selection was done congruent with other such equipment at KOTO: Siemens S7 components are used. The system is networked and thus allows integration of data in control into the unified factory system.

All actuators (valves, motors) are installed and connected. Each actuator can be controlled manually or by software. Installed PLC has ample spare inputs and outputs for future extension.

Sensor network is being installed. We have opted for lower cost chemical sensors as we expect that such a sensor set will have to be installed for each pond in the replicated installations. We are designing a dedicated hardware solution that will act as a pond-hub. It will include all sensors needed at one pond and be networked into a centralized control system. This unit will have very low cost as it is replicated for each pond; the cost of centralized part of control system is much less important.

The dedicated hardware solution is not complete yet, so we are working on interim solution to connect the final sensors with some level adaptors to the existing PLC. This solution should be installed in few weeks.

Some of the sensitive (digestate) flow sensors are still not delivered.

Initial set of sensors per pond are the following:

- T, pH, DO, conductivity
- level (pressure)
- optical density (immersed light sensor at three depths).

Such unit will be networked into galvanically insulated RS485 network.

A low cost weather station is being tested and will be integrated into the system in next weeks. A PAR (photosynthetically active radiation) sensor is being installed and will be interfaced to analog input of PLC.

CO_2 concentration sensors have not been selected yet, some tests are underway.

Chlorophyll fluorescence and optical flow-through sensor are still being designed. A prototype system is available in the lab and will most likely be brought to the demonstration centre to get some experience on meaning of measured values.

PLC system at present is capable of controlling all units and logging all measurements. The control and sequencing software is being developed. After basic controls will be operational, a user interface panel will be developed.

Networking access is available with existing tools used in KOTO. Read only access will be granted to outside access; VPN access is available but at this time we intent to prevent any control inputs from remote locations for security reasons.

Video surveillance has been used during construction to prepare a time-lapse video of the construction. The camera is still mounted at the biogas plant and we are considering its mounting in the greenhouse (without any final decision due to environmental conditions in the greenhouse).

Figure 14 Electrical cabinets at the demonstration centre

Figure 15 Remote cabinet at the gas-engine and panel at the pond

5.4 Greenhouse

Greenhouse is an off-the-shelf greenhouse with double layer of UV resistant PE foil. It has sidewall openings for temperature control which we covered by insect nets. Roof segments and all sidewalls except the opening are doubly covered for thermal insulation with a blower controlling the distance between the two foils. All sidewall foils end below the external soil level, so the greenhouse is essentially insect proof.

The inoculation pond within greenhouse has additional level of insect net to avoid insect cross-contamination between inoculation and main pond.

Figure 16 Greenhouse - final set-up outside and inside

For the main cooling we will install a filtered fan and a filtered opening on the opposite end sides of the greenhouse. These are not yet installed as we are measuring the thermal behaviour of the system for proper dimensioning. The fan will be installed before next hot season. Forced air cooling and environmental sensors are connected to the central control system. An independent of-the-shelf CO_2 and CO concentration alarm will also be installed in the greenhouse to monitor potentially hazardous levels coming from the exhaust gases.

5.5 Separator / Clarifier

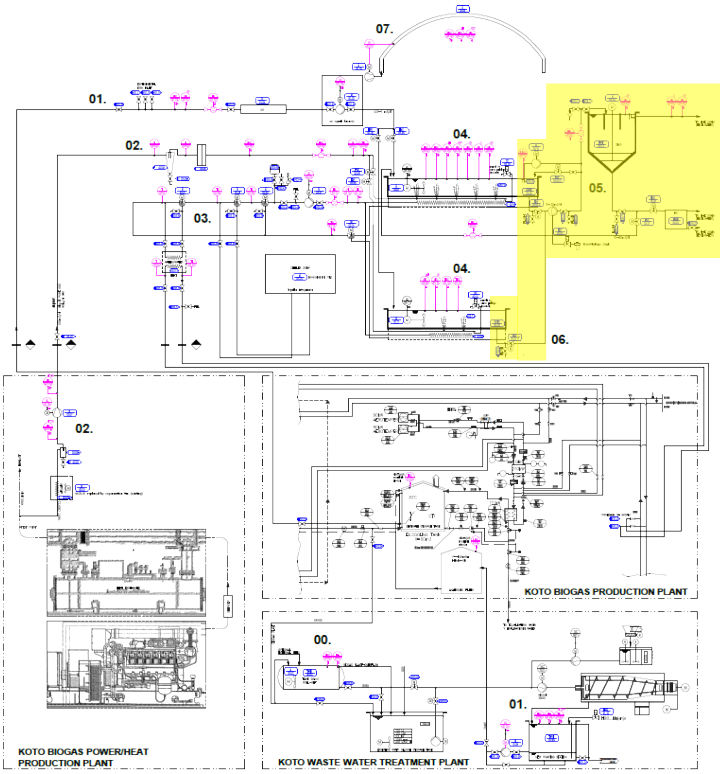


Figure 17 Sedimentation and recycling subsystem (full size chart in appendix)

Sedimentation/clarifying is done in a small clarifier positioned in the hydraulic container. We studied a number of designs before choosing a relatively simple design with the idea to modify it later, based on the achieved performance. Clarifier includes a scrubber rotating at 1 RPM based on the experience with previous sedimenters. Sedimenter was made from an existing stainless steel tank with minimal modifications and this design remains to be subject of future improvements.

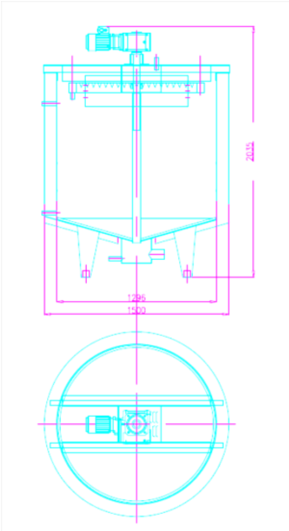



Figure 18 Sedimenter / clarifier

The clarifying system consists of a pneumatic recirculation pump that can be used also to pump inoculation culture to the main pond and to drain both ponds. This piping will also be used for fresh water addition if needed, but initially the valves of this part are not motorized as we have to gain some experience on how much how frequently such additions will be needed. Sedimented sludge may also be removed from the system using automated valves and led to an external IBC container. Clarifier geometry is partially adjustable to allow optimization for the best sedimentation results.

Flow and OD sensors are not yet installed in the sedimentation and recycling system. Software for the sequencing of operations in sedimentation and recycling system still needs improvement (based on real sedimentation performance).

Figure 19 Pneumatic membrane pump used for sedimentation & recycling

We have not (yet) built the flocculant addition system as existing experience shows that bioflocculation alone is very good. Flocculant preparation is already available at the digestate separation station (decanter/centrifuge) so we have a ready supply for testing the impact of flocculant addition. If required, the system will consist of small peristaltic dosing pump and a supply container with level switch. Both can easily be installed in the hydraulic container if/when needed. We also plan to add a small electro-coagulation unit to the sedimentation cycle, but this will be subject of WP 4.2. Piping of the sedimentation and recycling subsystem is ready for easy modifications of this type and control system provides additional inputs and outputs for easy integration into the system.

5.6 Inoculation photobioreactor

In the design phase we have opted for a simple round pond as an inoculation photobioreactor. It is housed next to the main pond within the same greenhouse. Next to the inoculation pond we have left some additional space in the greenhouse for any additional types of inoculation PBRs that we might want to install later.

To isolate inoculation pond from insect contamination from main pond we have installed separate insect net over the inoculation pond.

Mixing of the inoculation pond is described in 5.2.3, CO2 introduction is described in 5.2.4 and heating / cooling is available with the same system as for the main pond (described in section 5.2.5).

Major source of nutrients for the inoculation pond will be digestate. It is supplied from the same system that supplies it to the main pond. We anticipate additional filtering for the inoculation pond, but until we get enough experience with the new digestate quality, we are just using the ordinary digestate and monitoring the quality visually.

Control system is able to control all parameters (mixing, heating/cooling, CO_2) of inoculation pond separately from the main pond, so we can assure conservative conditions optimized for algae growth.

5.7 Digestate supply

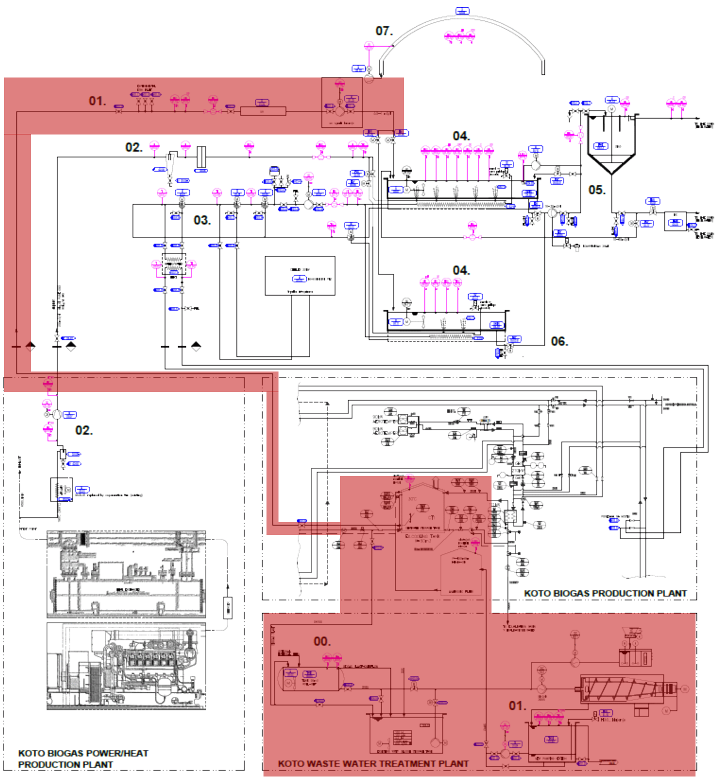


Figure 20 Digestate subsystem (full size chart in appendix)

At the time of writing DoW, digestate supply was thought to be so simple that it did not have a separate item as a subsystem. In implementation this turned to be the most complex subsystem. This subsystem has also changed most between design in D2.1 and present implementation.

Main objective of the digestate subsystem is to separate solid and liquid phase of the digestate so that the liquid phase (centrate) is as clean as possible. The two important attributes of the centrate are COD (Chemical Oxygen demand) and its colour. COD determines how much oxygen has to be produced by algae to oxidize the organic and inorganic content of the centrate. This is directly related to amount of algal biomass that has to be grown which is a function of lighted area (and productivity). Input COD thus determines how much of pond area we need to tread the digestate. Digestate colour on the other side reduces the efficiency of light use for algal growth, which also indirectly impacts needed area.

Centrate that we have been using in the tests for last two years had COD in the range 15 g/L and very dark colour. These figures are high compared to some other digestates that we had tested. In order to make demonstration centre relevant for other biogas operators we had to move to more common ranges of 10 g/L and lighter colour, which means that solid liquid separation had to be improved.

Before the start of the project, digestate was collected in a common equalization basin together with the sludge from WWT and then led to a centrifuge (decanter). The centrate was simply returned to the WWT.

The initial design was straight forward: we planned to collect the digestate from biogas plant (A, see Figure 21) in a separate buffer tank (a roll-off container B), drive it to the centrifuge (C) which is now time-shared between digestate and WWT sludge, collect it in equalizer tank (D) and use existing digestate cooling tank (E) to store the centrate before it is fed to the demonstration centre (F).

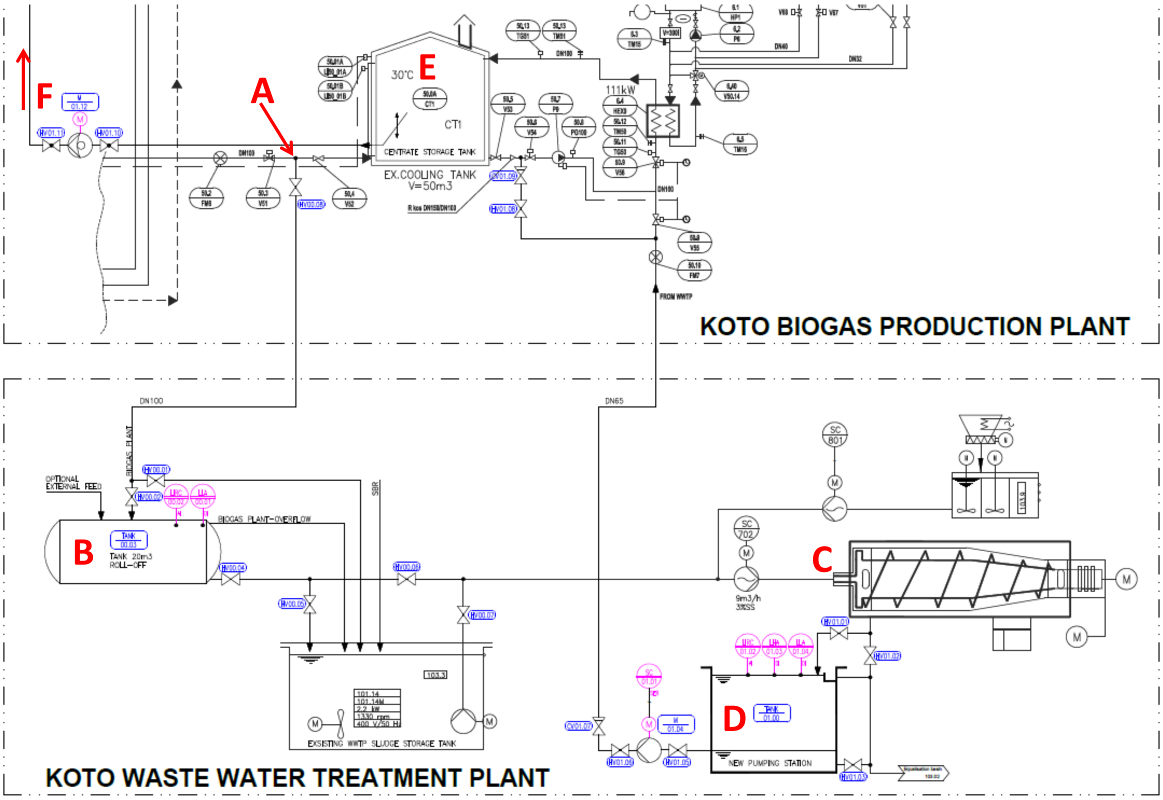


Figure 21 Digestate separation and equalization as designed in D2.1

We implemented the following improvements:

- Part of the Biogas plant is an Anaerobic Filter (AF) that was previously used to treat the wastewater. For a year this filter was not used due to some leakage problems and during final maintenance stages KOTO decided to use it as an additional anaerobic treatment of centrate. Benefits include:
    - The temperature conditions in the anaerobic filter are even (compared to wastewater),
    - Additional treatment step results in cleaner and brighter centrate which is very desirable also for the algal treatment,
    - Biogas production in AF is higher,
    - Centrate brought into WWTP has lower COD & BOD; foaming in the SBR reactor of the WWTP is reduced (this is relevant for the part of centrate that bypasses the AlgaeBioGas demonstration centre).
    - This setup did not incur any extra cost.
- Before entering the equalization tank (roll-off container) digestate is coarsely treated by a Press Screw Separator (PSS). Benefits include:
    - Most of the solids are removed before entering the tank thus reducing the need for sediment removal from the tank,
    - Press Screw Separators are common equipment of biogas plants and they are the only separation device in many of them; having two options for separation makes the demonstration centre more relevant for the common cases.
    - We used existing unit that was not used before and the extra cost was just required piping and integration of the unit into the control system.

Final implementation of the digestate subsystem:

- Digestate is intercepted close to the previous digestate cooling tank (CT1). It is fed through new DN100 stainless steel pipe to the vicinity of the equalization pond of the WWTP. Any excess digestate or overflows can be put directly into the equalization pond.
- Digestate is led into Press Screw Separator (PSS) via flexible tubing; separated solids are collected in a mud bin and removed.
- Liquid phase from PSS is stored in the digestate equalization tank that was implemented as a roll-off container (20 m^3) next to the existing equalization pond for the WWTP. Roll-off container was used since it is common equipment in KOTO and to avoid any issues with construction permits, It is also very convenient for cleaning of sediments. All piping around the container is flexible and allows easy temporary operation without the container.
- Roll-off container may be used also to accept foreign digestate for testing in case it needs the solid-liquid separation phase.

Figure 22 Press Screw Separator and roll-off digestate equalization container

- Digestate is fed to centrifuge / decanter with capacity 9 m3/h that is time shared between digestate processing and WWTP sludge processing.
- Centrate (liquid phase of the centrifuge output) is buffered in a small equalization tank close to the centrifuge. From this tank it is pumped back to the biogas plant (via existing DN65 pipe) and routed to Anaerobic Filter.

Figure 23 Centrifuge / decanter (WWTP) and Anaerobic filter (biogas)

- Output from anaerobic filter is fed into the centrate storage tank (CT1) for equalization and cooling from where we use it at the demonstration centre. There are two outputs from CT1 to the algae pond to allow for some sedimentation of centrate. Excess centrate is fed through existing piping to the equalization basin of the WWTP.

Figure 24 Centrate storage tank (CT1) (ex digestate cooling tank)

- The demonstration centre has provision to alternatively use foreign centrate in IBC containers.
- Digestate is led through UV disinfection and electric valves to both ponds.

Figure 25 UV sterilizer

5.8 Infrastructure

Digestate, CO2 and heat supply has been described in previous sections. Other necessary infrastructure for the demonstration centre consists of power take-off, clean water supply, drain (sewage) connection and network connection

The required heat energy for under-floor pond heating is acquired from the existing district heating pipeline near biogas plant (Figure 26). Heat is generated in the genset and distributed to the biogas plant, so it's available around the clock. Pipes connecting the demonstration centre and district heating pipeline are laid underground.

Electrical power is provided by a tap from existing Biogas plant. Inside cabinet MCC0 + P1 we added separate circuit breaker for the demonstration centre (Figure

27). Remote equipment located at WWTP and next to the gas engine is powered directly from those two units.

Ethernet connection for general use is also done from Biogas plant MCC0 +P5 and it is used also for PLC communication with other systems and dislocated PLC-s (Figure 27).

Water supply and sewage connection are provided by existing connections next to the biogas plant. Large capacity water supply (pond filling) is available from nearby biogas plant. There are two water supplies available within the facility: public clean water and proprietary well water.

Sewage connection is connected to the technological sewage system that leads the sewage to the WWTP equalization tank. This connection will also be used for clean water exit from sedimenter and for any pond draining,

Sedimentation and recirculation pump is pneumatic, so a compressed air connection was provided from the biogas plant.

Figure 26 Connection to the district heating pipeline

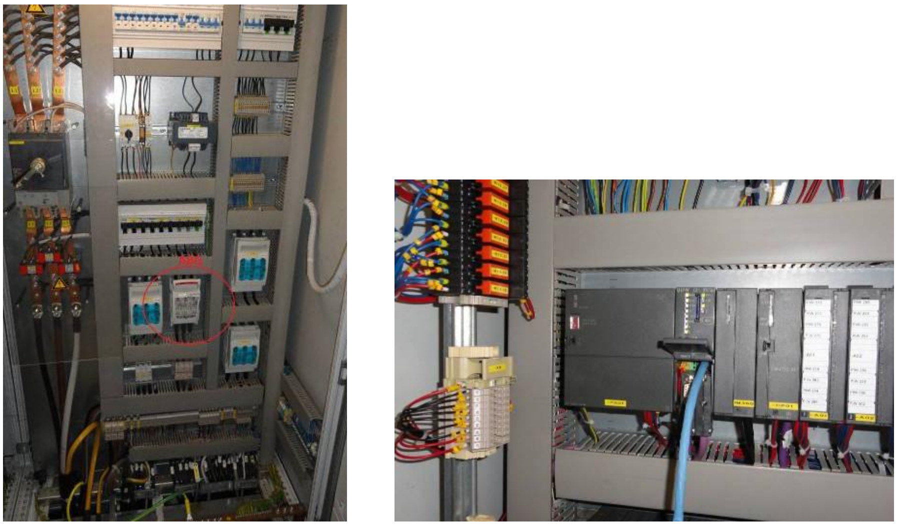


Figure 27 Power and Ethernet connections for the demo centre (biogas plant)

5.9 On-site working room

Next to the greenhouse two containers were installed, referred to as hydraulic and office container. Hydraulic container contains All piping (digestate, CO_2, heating/cooling) and sedimenter are installed in hydraulic container. Electrical equipment is installed in two cabinets in the office container. Rest of the space is available as the working space. Chiller is installed outside of the containers and there is space for up to three IBC containers for foreign digestate testing and/or collection of ALBA biomass.

Figure 28 Workplace at the office container

6 Start-up

Start up procedures consisted of many tests of isolated subsystems and an integral test that is running for most of the August 2014.

6.1 Subsystems tests

Subsytems that were separately tested:

- All construction materials were subject to ordinary construction tests.
- All piping for under-floor heating/cooling was pressure tested.
- All other piping was pressure tested.
- Lining and all welds of the PEHD foil were tested for leaks and certified according to land-fill lining requirements.
- Greenhouse double foil cover was tested for leaks.
- CO2 (exhaust gas) piping was pressure tested. Heat exchanger was tested for temperature for both low- and high-temperature output of exhaust gases. Exhaust gas blower was tested for temperature increase from compression.
- All network connections were tested for connectivity between PLC units and connectivity into the industrial network in KOTO.
- All power installation was tested for connectivity and ground resistance.

- All metal piping was tested for ground connection.
- Both CO_2 diffusers were tested for performance.
- Mixing in both ponds was tested for performance (water speed in main pond).

6.2 Inocculation

Inoculation pond was inoculated with algal culture from pilot installation that is running on KOTO biogas digestate at Biotechnical faculty in Ljubljana (hydroponics tests). Culture from the pond was filtered using 80μm filter to prevent transfer of insect larvae. Filtering was done twice in an interval of 7 days.

Inoculation pond was filled with 1000 L of water and 50 L of filtered culture. Mixing was set to lower intensity and 1 L of *Algen Chlorella Ultimate Nutrient mix* was added. After a week the culture was in excellent condition (although we had some precipitation of limestone) and we added additional 1000 L water and 100 L of digestate. Culture is approaching full density after a week.

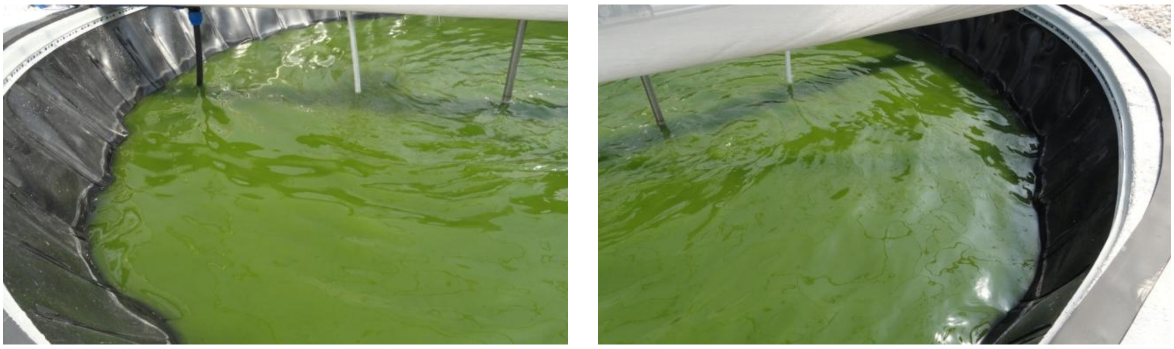


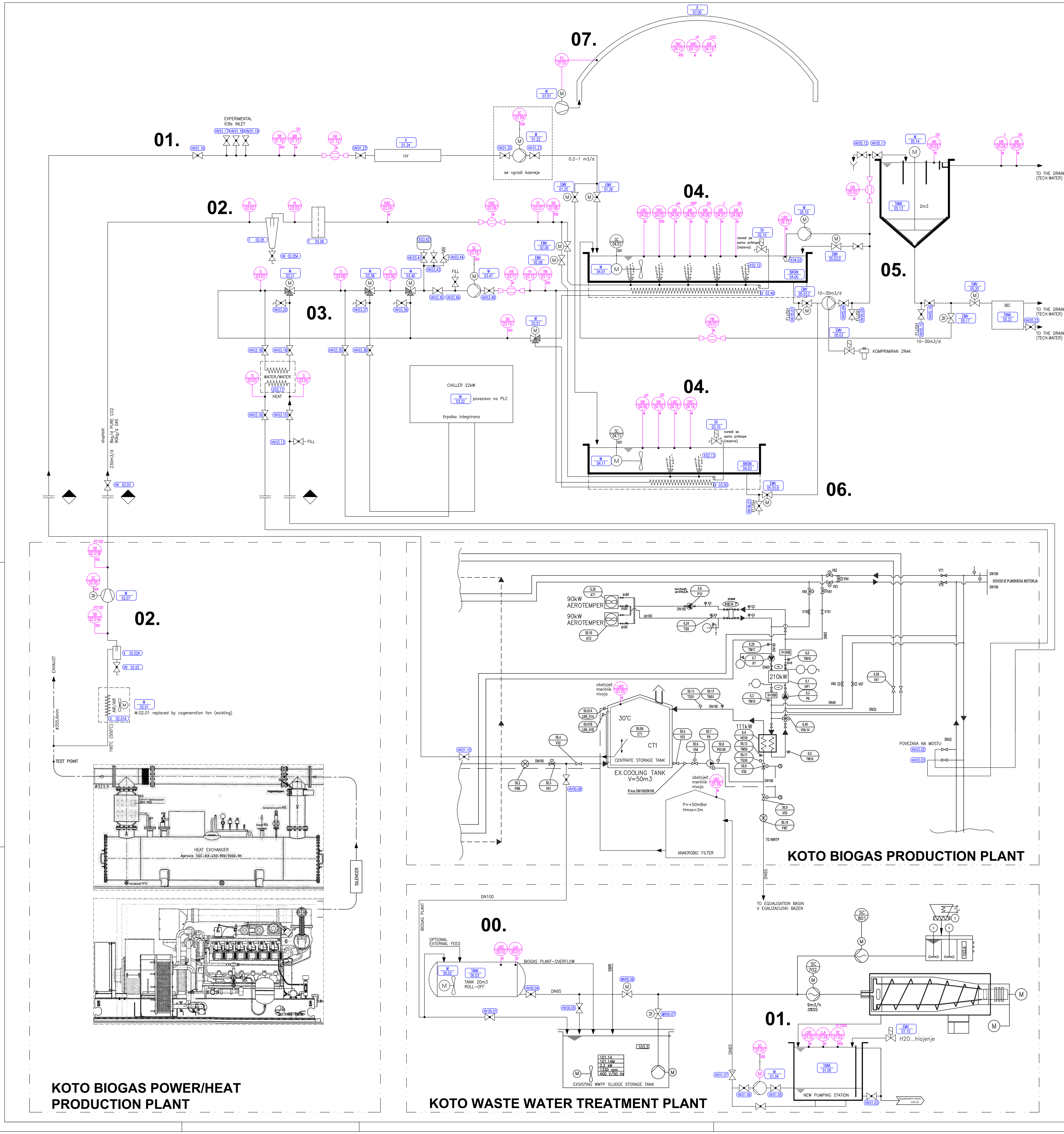
Figure 29 Inoculation pond one week after inoculation

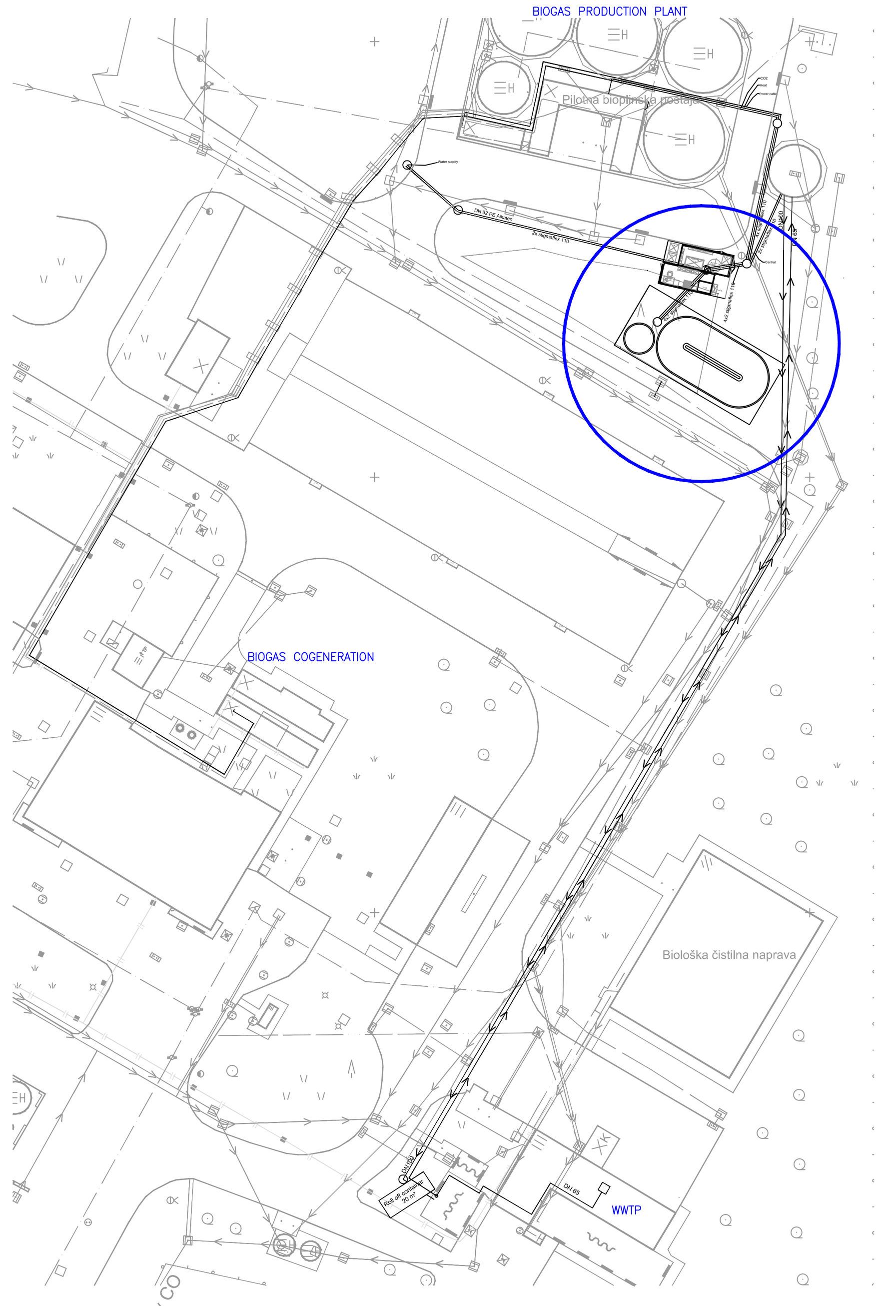
Main pond was tested with naturally occurring culture for two weeks with minimal mixing and no CO_2 addition. After that, main pond was drained, cleaned and CO_2 diffuser was installed. At the time of writing, tests of CO_2 diffuser are on-going and inoculation of the main pond is scheduled for September 1st.

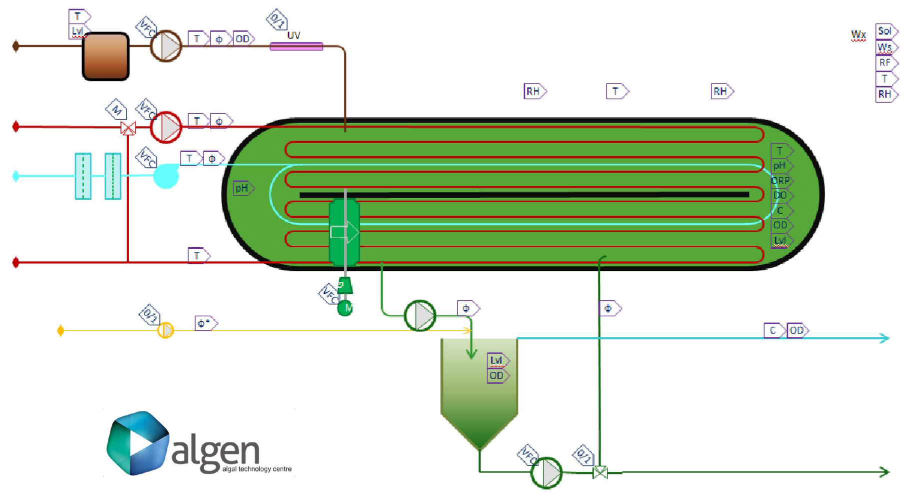
A protocol for daily measurements of temperature and pH was introduced until the pH regulation is automated.

7 Conclusion

Establishment of the Demonstration centre is one of the three main expected outcomes of the project. The Demonstration centre has been built and put in operation and we believe it will serve *to demonstrate the technology in different working regimes, measure the operating characteristics of the system, measure environment impacts, provide the LCI data in a realistic set-up, and above all show the installation to the potential customers to enable repeated installations* [quoted from DoW]. Some of the construction and improvement activities shall continue, but the basic operation was successfully started.







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