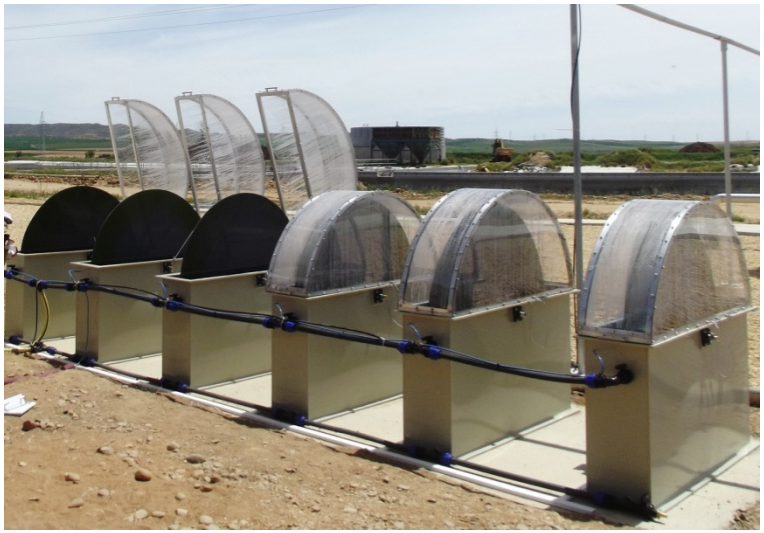
ALGADISK –Novel algae-based solution for CO_2 capture and biomass production

12 November 2014, Brussels, Belgium
Open Algae Workshop, EUBIA Office, Brussels



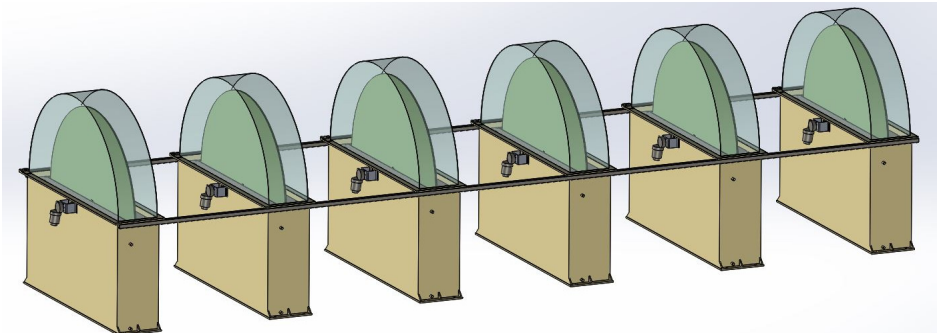
INTRODUCTION TO ALGADISK TECHNOLOGY

The aim of the ALGADISK project is to develop a modular, scalable and automatic bio-film reactor for algae biomass production, with low operational and installation costs.

Building the Algadisk prototype

ALGADISK Operation concept

- Vertically oriented disks increase the useful surface area of the reactor
- Disks are continuously rotating
- Half of the disks are in shade in the medium, while the other half is exposed to light in air phase, this way light staturation can be avoided
- Temperature of liquid is kept below a certain point with a heat exchanger
- pH is controlled by addition of flue gas, which is the source of CO_2 as well
- Due to closed modules, biofilm is protected from extrem weather conditions, contaminations and high CO_2 level can be reached in air phase
- Half automatic harvesting



WHY ALGADISK?

Conventional PBR Technologies	ALGADISK - Innovative design
Expensive maintenance required (unexpected biofilm formation, pumping systems, sterilization)	Low operation cost and easy maintenance. Easy construction procedure.
Low CO_2 efficiency (bubbling through the liquid phase)	Increase in CO_2 capture efficiency (buffer tank mixing)
High water required (raceway ponds, PBR)	Low water required
Harvesting is difficult, time consuming and inefficient (High Costs)	Automatic and semi-continuous harvesting
Scale-up problems	Easy scalability trivial
Difficult to design at flexible scale	Modulable units.
High land use footprint	low footprint - 20g/mq day of dry algae

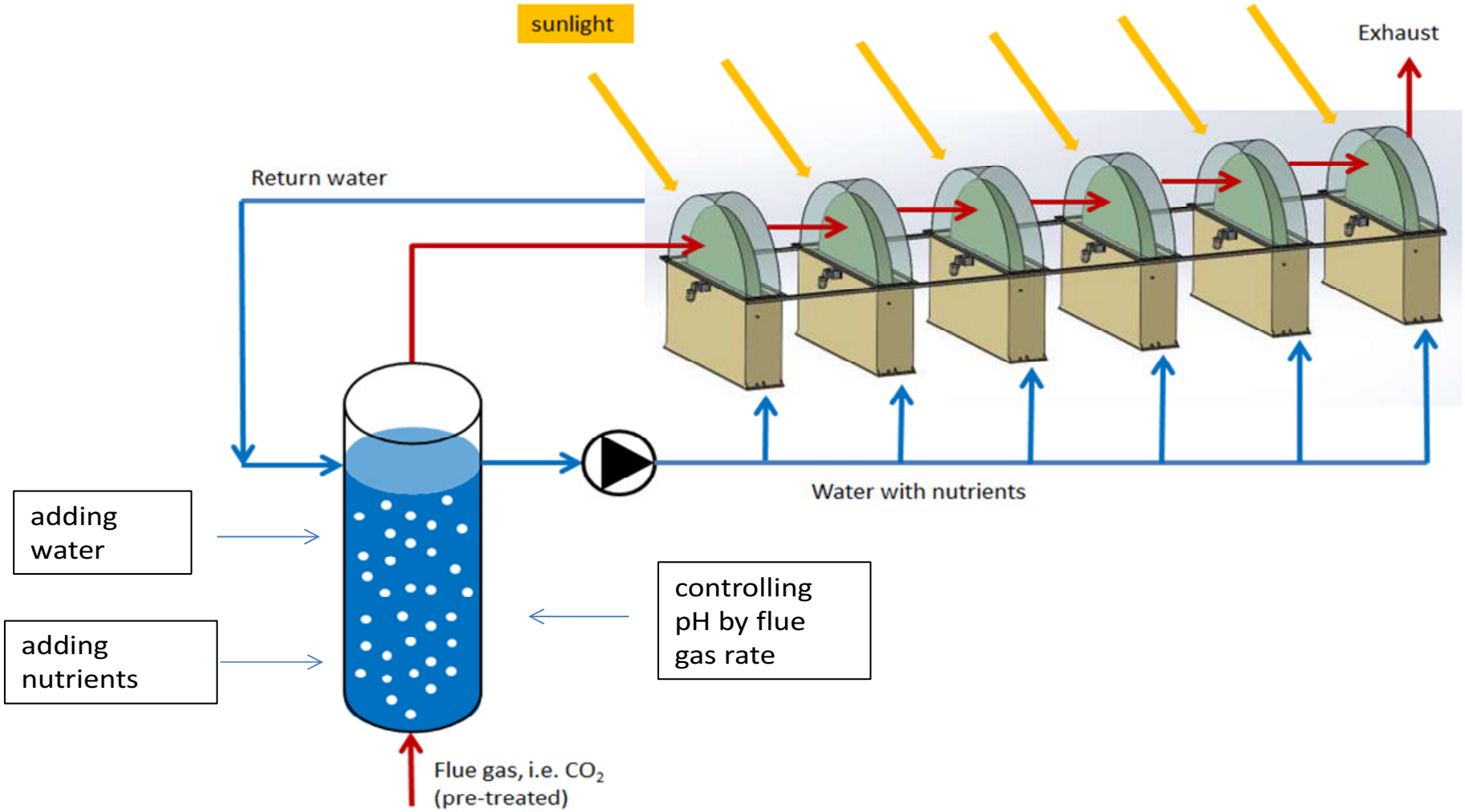
ALGADISK Sensor and control system

Sensors:

- pH electrode
- Dissolved oxygen electrode
- Conductivity probe
- Brightness sensor
- PAR sensor
- Temperature sensors
- Foam sensor
- Liquid level sensor

Controlled parameters:

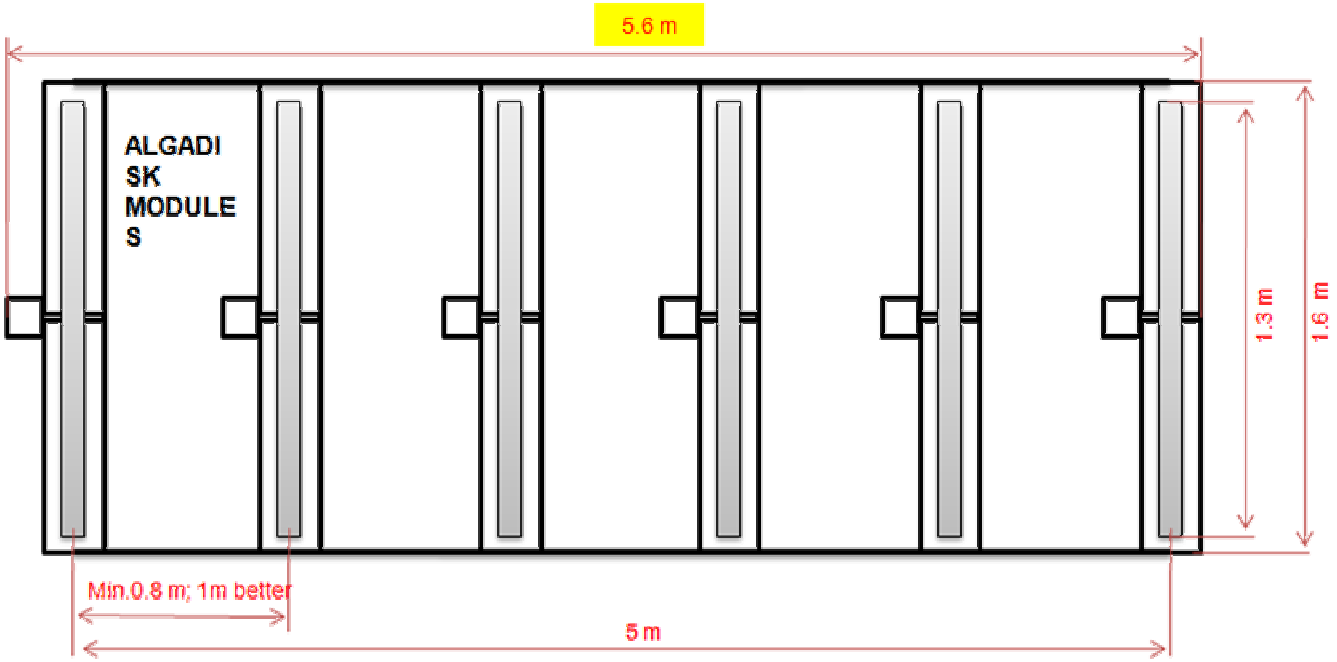
- pH kept below a set value by addition of flue gas
- Temperature of medium by a heat exchanger
- Foam formation reduced by addition of antifoam agents
- Liquid level by addition of water
- Disk rotation speed
- Nutrient concentration


sunlight
Exhaust
Return water
Water with nutrients
adding water
adding nutrients
controlling pH by flue gas rate
Flue gas, i.e. CO_2 (pre-treated)

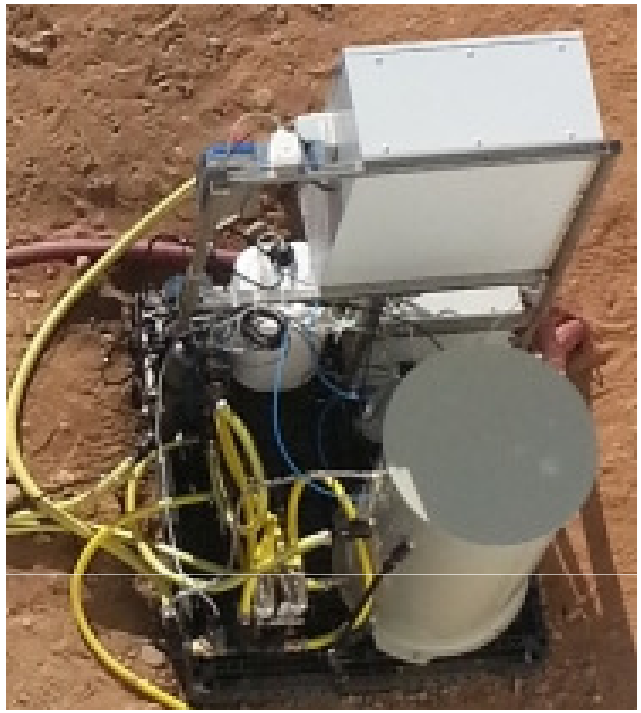
The Algadisk pilot plant in Almazan (Spain)

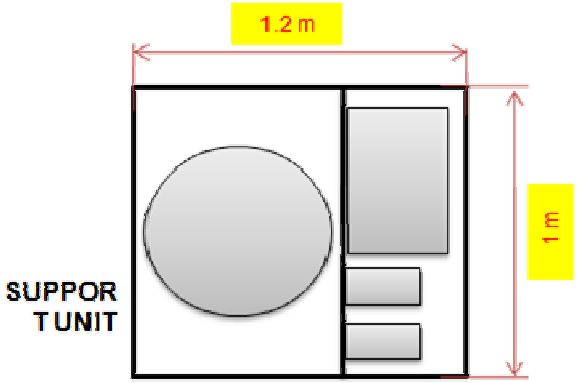
Overview on components, logistic and expected results

ALGAE GROWTH PILOT PLANT. REACTOR UNITS

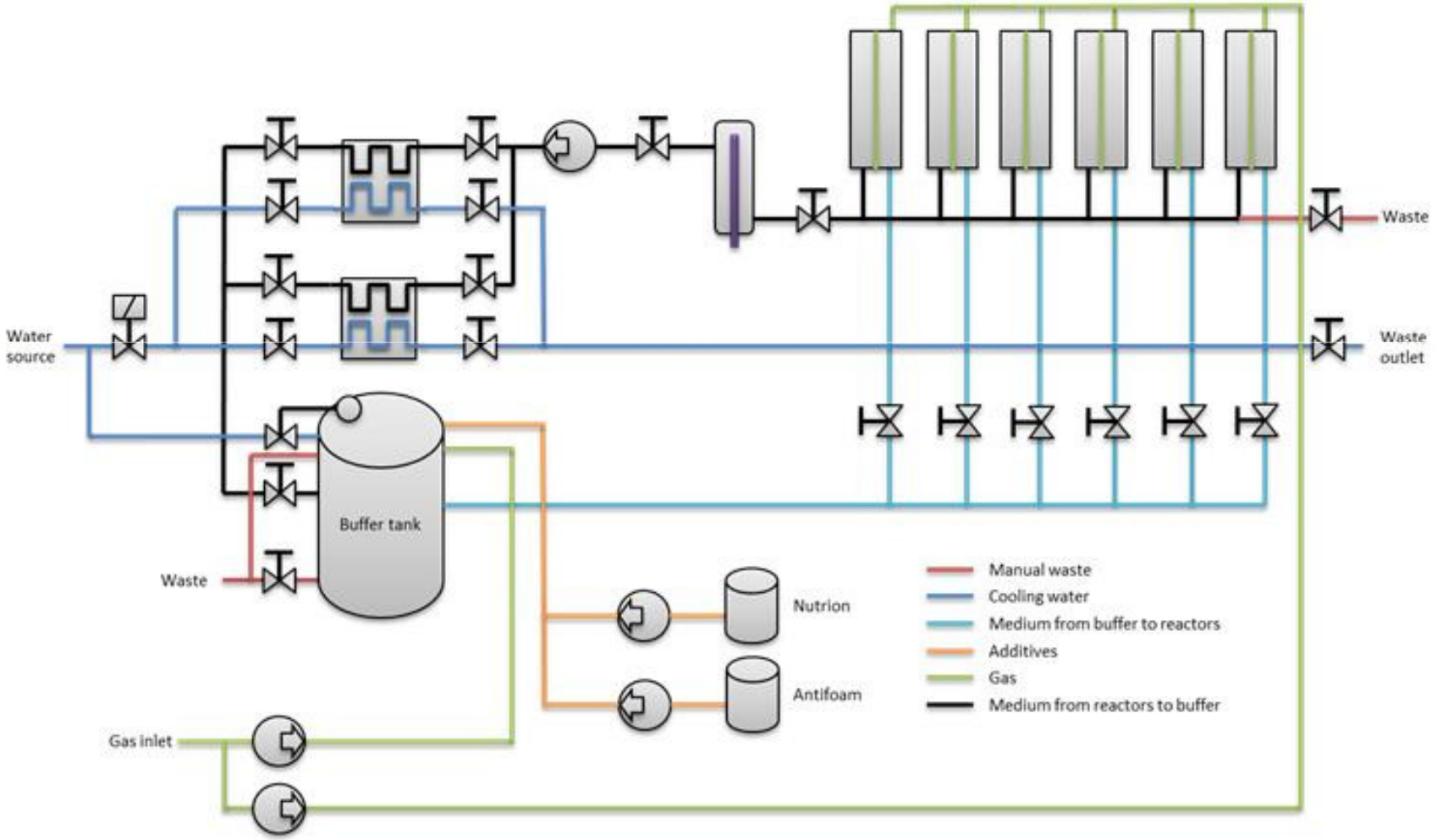


ALGADISK PILOT PLANT. CONTROL UNIT





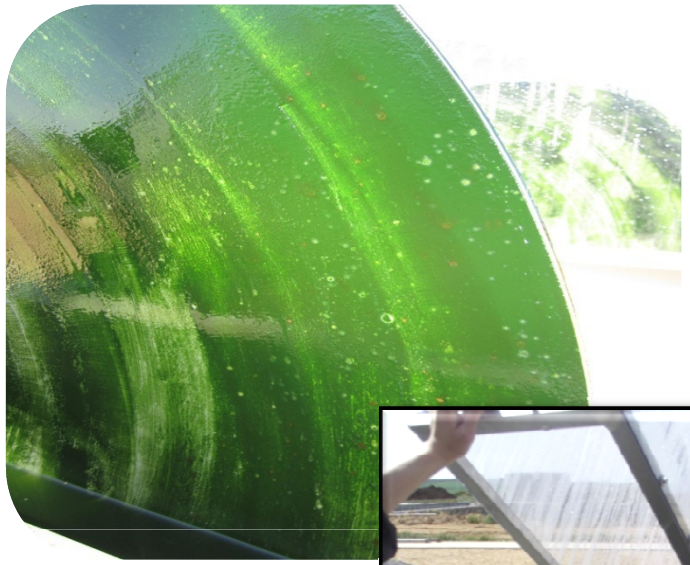
Algadisk pilot plant logistic flow scheme

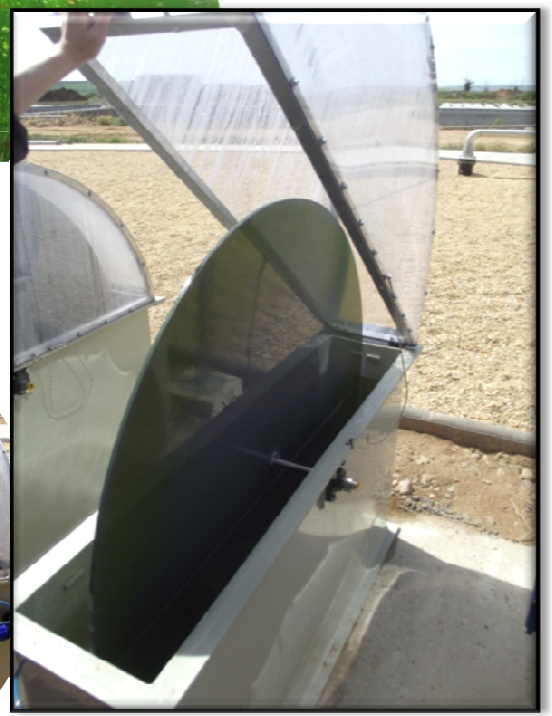


ROTATING DISKS

Surface, material, dimensions.

- Rotating disks units: every disk of this pilot plant is in PVC
- Dimension: 1,3m diameter
- Different coatings to improve the disk roughness are under evaluation
- Rotational speed with electric engine (0,12kW, used usually at 20%)
- Disk rotation speed of 3 rpm

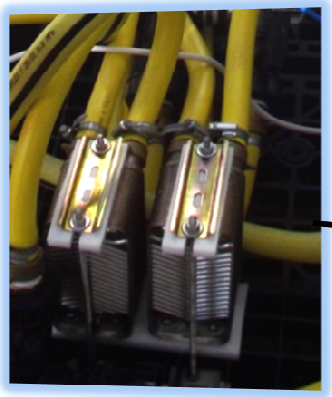


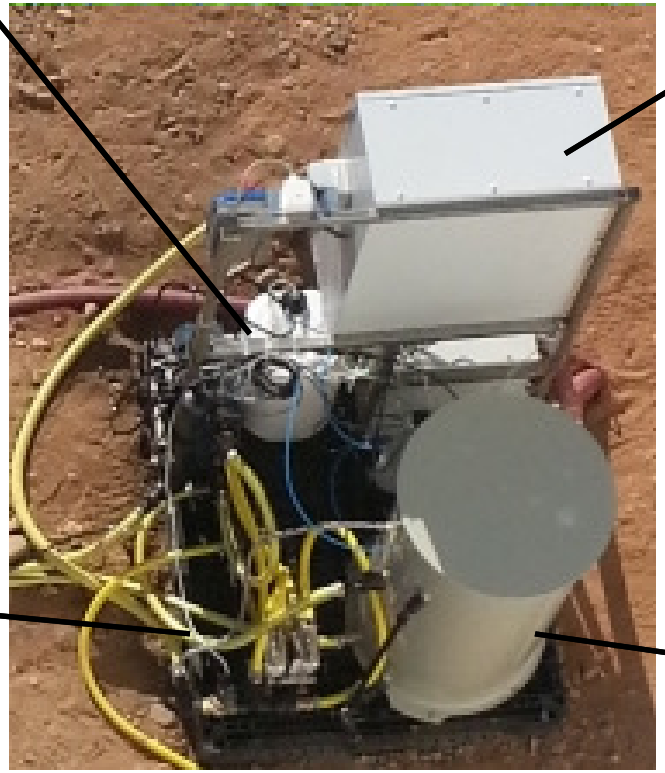


ALGADISK CONTROL UNIT

Control System and sensor

Heat Exchanger





Buffer tank (CO_2, water, nutrients)

Function of control system:

- Pumps for flue gas from Biogas engine
- CO_2 on demand by pH (regulated on 6.7)
- Daily antifoam addition
- Max temperature of 35ºC
- Control electronics (disks rotation engines, water pumps..)
- Nutrient Semicontinuous feed - Based on conductivity
- Bi-weekly harvest

ALGADISK Estimated Energy Consumption per day

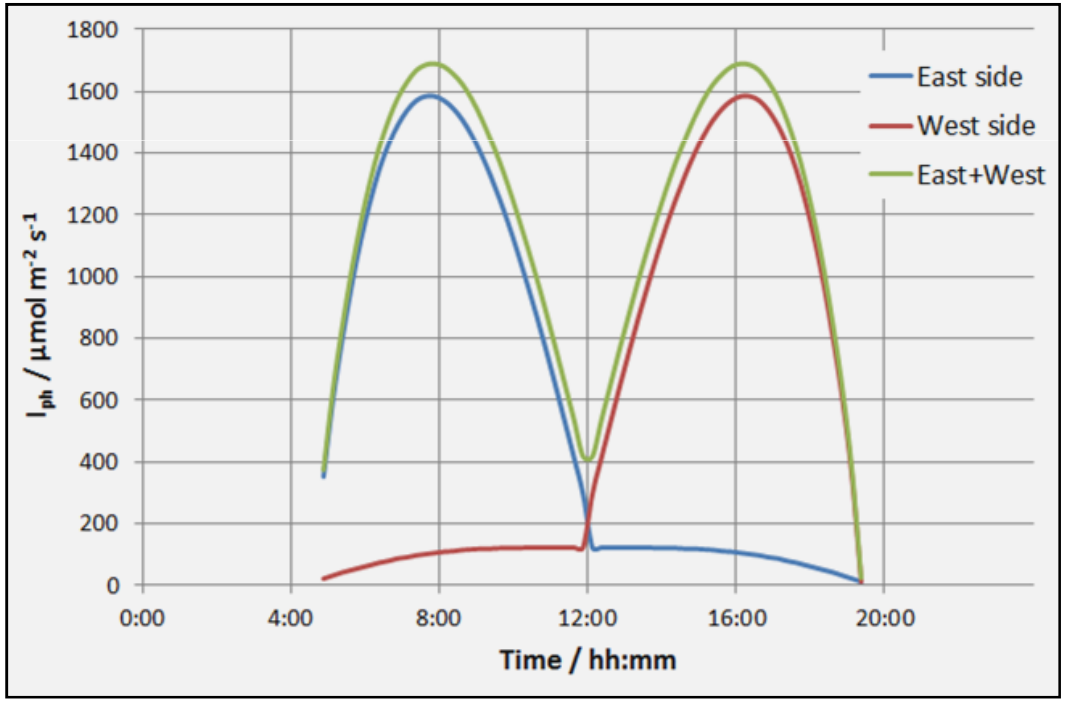
	Power (W)*1	Power (W)*2	Hours	Energy (kWh)*1	Energy (kWh)*2
Cooling flue gas	120	0	18	2,16	0
Gassing of buffer tank	40	5	18	0,72	0,09
Liquid pumping between buffer tank and disk-units	90	75	18	1,62	1,35
Liquid pumping through heat exchanger	90	75	18	1,62	1,35
Disk rotation	120	120	24	2,88	2,88
Other auxiliaries	60	45	24	1,44	1,08

*1_Energy consumption for pilot plant
*2_Energy consumption estimated for commercial plant

FIRST TESTS and EXPECTED FUTURE RESULTS

Daily Irradiation tested in june

CO_2 absorption efficiency / %	Flue gas requirement Peak / $Nm^3 h^{-1}$	Day / $Nm^3 d^{-1}$
20	0.96	12
40	0.48	6.1
60	0.32	4.0
80	0.24	3.0
100	0.19	2.4

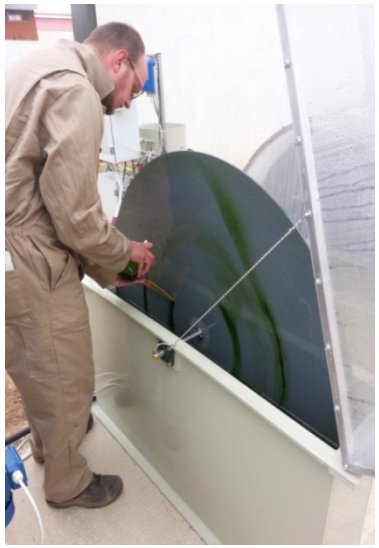


FIRST TESTS AND EXPECTED FUTURE RESULTS

Algae biomass yield in Laboratory

June daily rates (per day):

Biomass productivity	$7.57\ mol_x\ d^{-1} = 182\ g\ d^{-1} \Rightarrow \underline{5.4\ kg\ mth^{-1}}$
Carbon (CO_2) consumption	$7.57\ mol_C\ d^{-1} = 0.170\ Nm^3_{CO2}\ d^{-1}$ (1)
Nitrogen (N) consumption	$1.06\ mol_N\ d^{-1} = 14.8\ g_N\ d^{-1}$
Phosphorus (P) consumption	$0.083\ mol_P\ d^{-1} = 2.58\ g_P\ d^{-1}$



Biomass production efficiency calculation:

June biomass yield: 21,8 g dry algae/m^2 day

Average biomass yield estimated per day: 166 g/day

Average biomass yield : 18 - 20 g dry algae /m^2 day (6-7 months)

ALGADISK First Trials results:

	Harvest kg wet	f dry/wet g/kg	dry harvest g	P disk surf g/m2/d	P area g/m2/d	cycle time days
cycle (June)	11.9	88	1055	4.7	12.0	14
cycle (July)	7.8	76	593	2.7	6.7	14
cycle (September)	7.9	58	459	2.1	5.2	14

- Harvest in optimal condition has not been provided yet due to issues in CO2 supply.
- The most interesting yield has been collected in June, with good weather, however, CO2 supply issues limited the yield of the reactor.
- Further steps, logistic strategies and technical solution will be investigated in the next months.

System risks 1: Disk Rotation blockage

When:

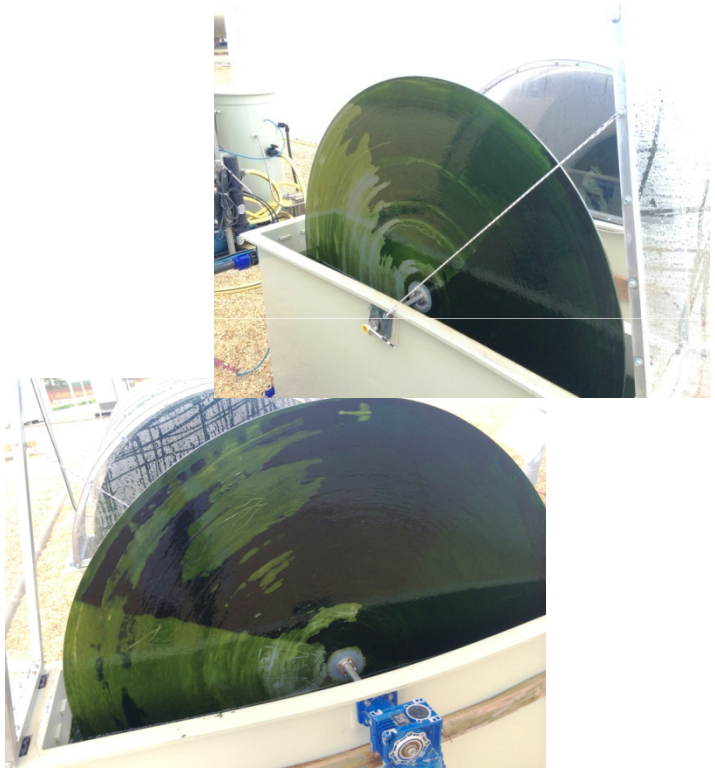
- Power failure
- Axel failure

Result

- Drying of the biomass
  - Biomass loss
  - Biomass death

Solutions:

- Battery or back up power for rotation
- Metal bars



System risks 2: PH drop in photobioreactor

When:

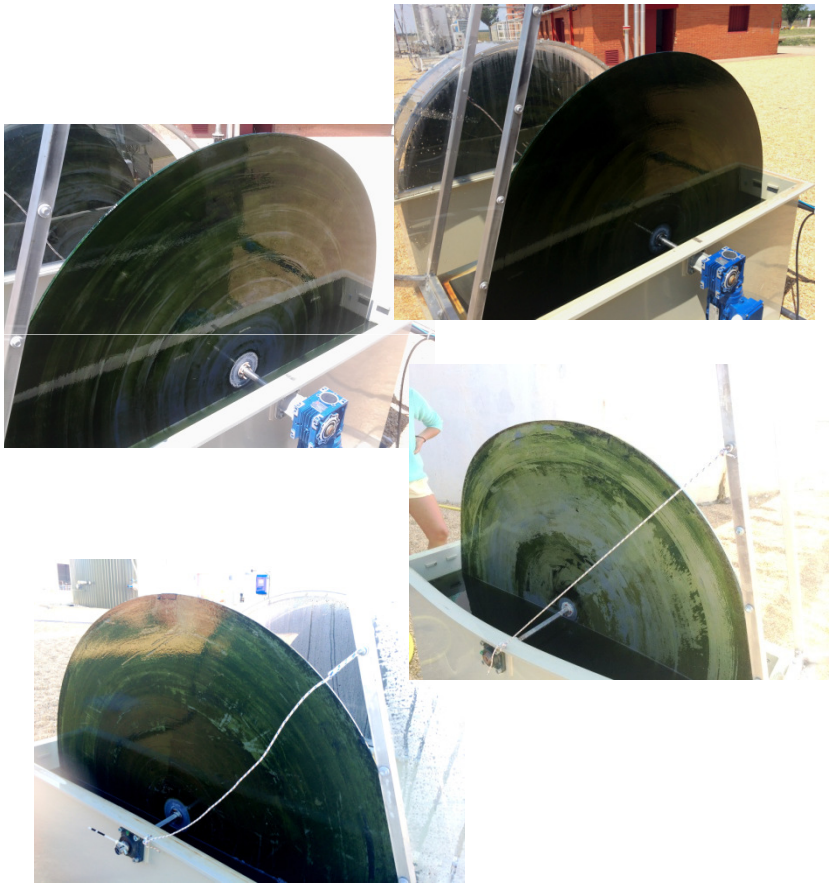
- Decaying biomass

Result

- pH drop
- Biomass loss and death

Solutions:

- Reactor cleaning
- Sodium carbonate addition



System risks 3: Low CO_2 supply

When:

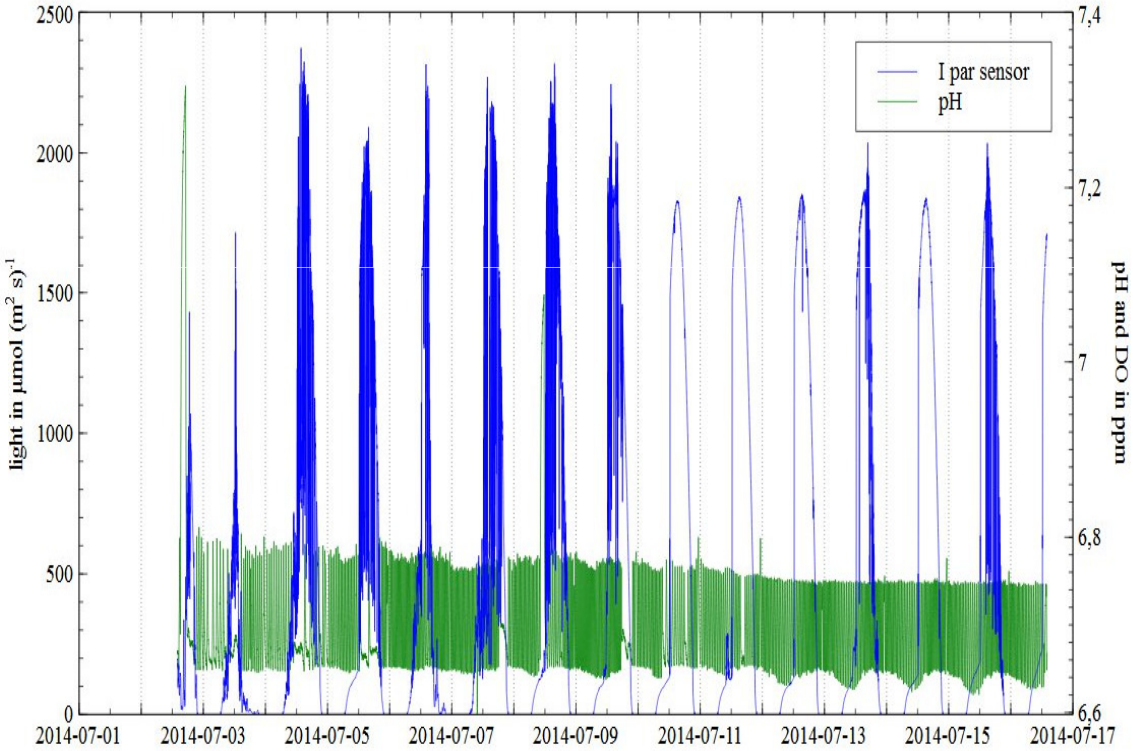
- Gas engine BFC is off
- Low biogas production

Result

- pH rise
- CO_2 limitation

Solutions:

- Bottle of CO_2
- More biogas



FIRST TESTS AND EXPECTED FUTURE RESULTS

ALGADISK SCALE UP STRATEGIES AND FUTURE ACTIVITIES

- More efficient automatic Harvesting System for reducing energy consumption (under patenting)
- Scale up ALGADISK concept improving the sensors and control system unit
- Investigating on new algae species suitable for ALGADISK (ongoing)

- Business plan in under evaluation takes in account following aspects:

- Algae market price, Energy cost, nutrient recovery, CO2 supply system, maintenance

- ALGADISK prediction software will be provided to SMEs to evaluate the economic feasibility of ALGADISK reactor installation

THANK YOU FOR YOUR ATTENTION!

Andrea Salimbeni
The European Biomass Industry Association
Andrea.salimbeni@eubia.org
www.eubia.org