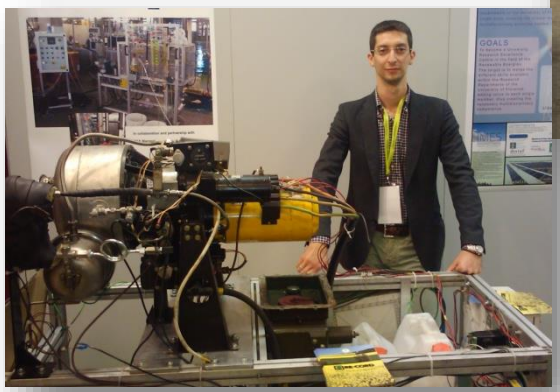
RE-CORD ACTIVITIES ON ALGAE FIELD

Matteo Prussi

*(direttor **RE-CORD**)*

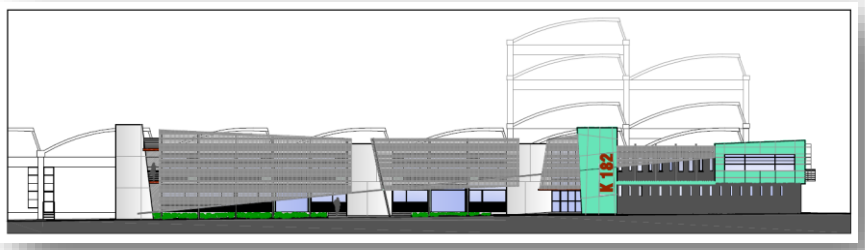
Who we are…



UNIVERSITÀ DEGLI STUDI FIRENZE

RE·CORD

RE-CORD MEMBERS



CREAR
University Research Center

Villa Montepaldi
University Farm

RE·CORD

Pianvallico SpA
Mugello Land Devel. Company

Spike Renewables SrL
Engineering and R&D SME

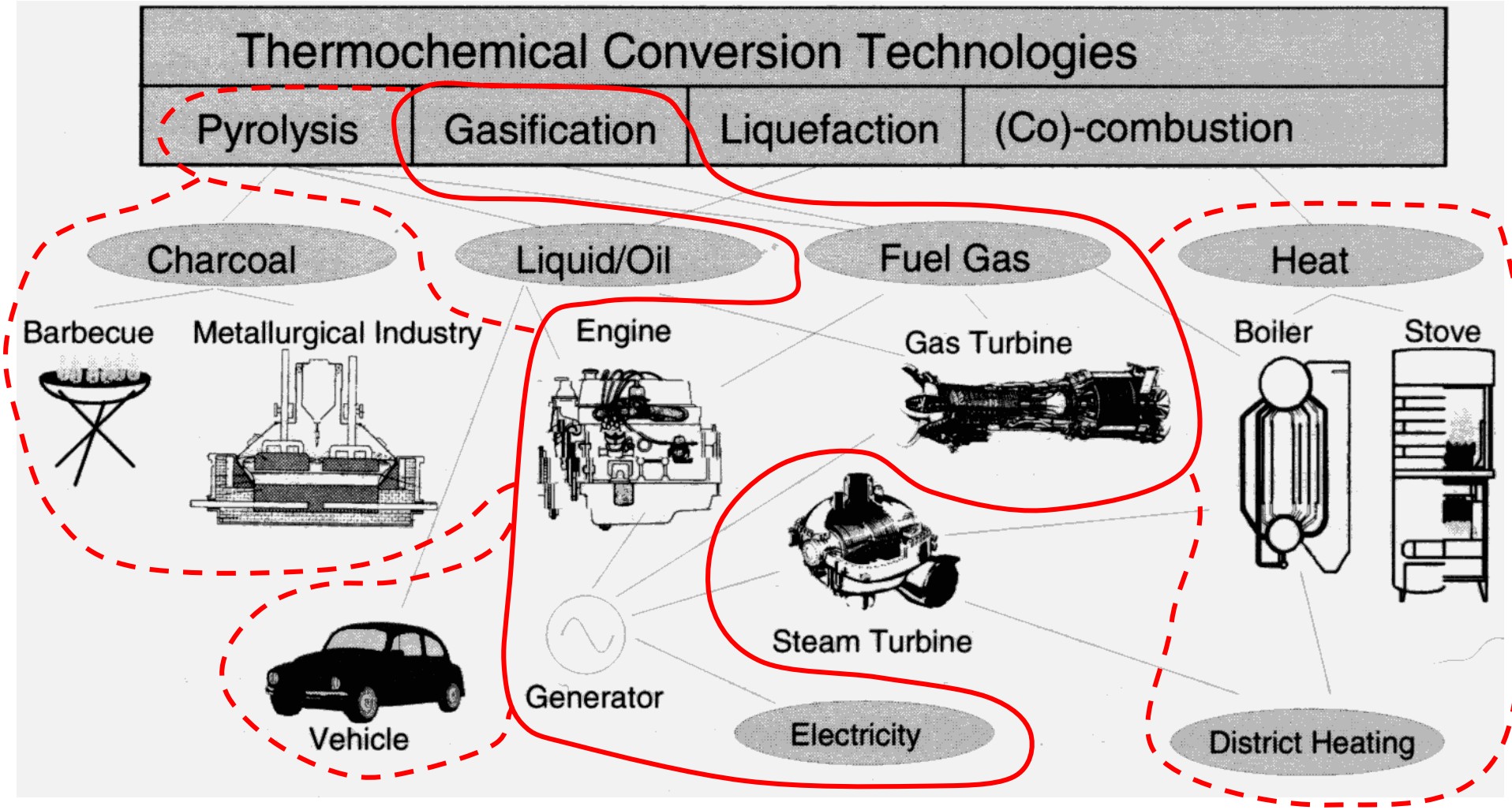
➢ RE-CORD – Renewable Energy Consortium for R&D

- **Chemical laboratory fully** dedicated to Bioenergy/Biofuels and Renewables (**Pianvallico** area)
- Various equipments for **Solar** and **Wind** energy assessments
- **1 ha fenced experimental area** at the **Villa Montepaldi** Farm (300 ha University farm)
- **Preliminary and detailed engineering skills** through **Spike** Renewables SrL
- Academic **R&D skills** through **CREAR**/Dept. of Energy Engineering/Dept.s of Agriculture
- Various Renewable Pilot Plants

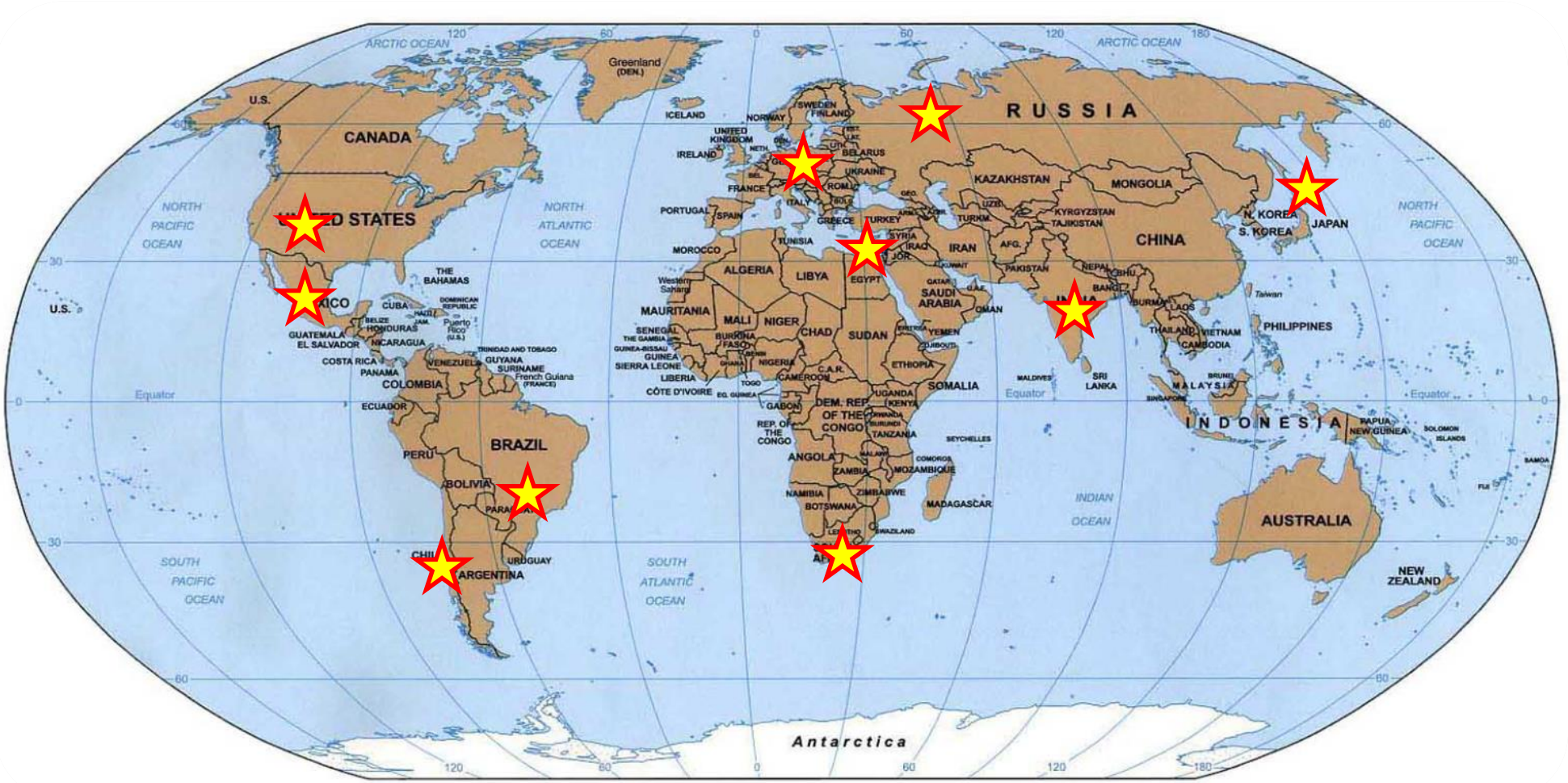
Pilot and Demo plants RE-CORD

- **Brichettatrice** (100 kg/h)
- Impianto di **pirolisi intermedia catalitica** (1.5 kg/h)
- **Gassificatore** open-top twin-fire (70 kWe)
- **Gassificatore** downdraft di Imbert (10 kWe)
- **Impianto pilota di Torrefazione/Carbonizzazione** (in realizzazione)
- **Reattore pilota di metanazione** (in realizzazione)
- **Microturbina** Capstone convertita a biofuels (30 kWe)
- **Microturbina** Garret convertita a biofuels grezzi (20 kWe, 40 HP)
- **Turbina a combustione esterna a biomassa/NG gas turbine** (50-100 kWe)
- **Microcogeneratore a olio vegetale puro** (5 kWe/10 kWth)
- **Motore ad olio vegetale puro** (7 kWe)
- Impianti pilota per coltivazione di **alghe** (in collaborazione con DIBA/F&M)
- **Digestori anaerobici** per prove di laboratorio

Fields of interest



Reti, scambi, progetti…

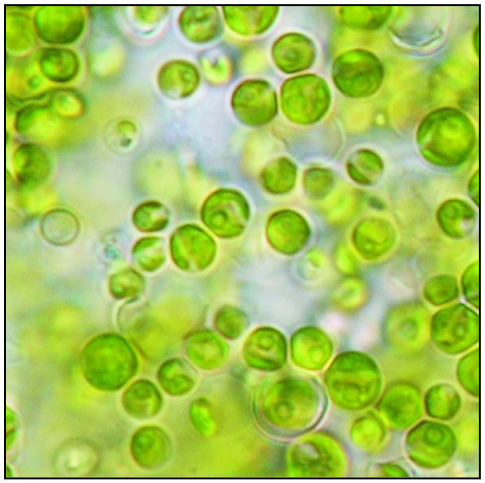


The Biomass LAB

GENERAL OVERVIEW OF RE-CORD LAB INTERESTS

Vegetable oil

Lignin

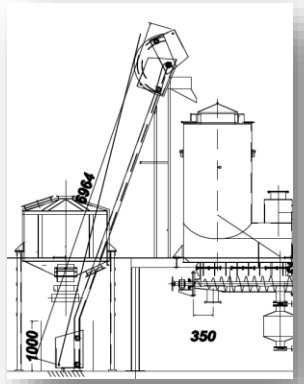


Algae

RE·CORD

Pyrolysis oil

Biogas



Gassificazione

UNIVERSITÀ DEGLI STUDI FIRENZE

RE·CORD

OUR EFFORT ON ALGAE SECTOR

RE-CORD and Algae

RE-CORD is **leading** the **desing** of several plants.

Among the other, the most relevant activities are in two large project:

- **BIOFAT** (FP7-EU)
- **ALGAEFUELS** (Chile)

BIOFAT
BIOfuels From Algae Technologies

BIOFAT PROJECT
PILOT plant in ITALY

Eng. Matteo Prussi, PhD

BIOFAT
BIOfuels From Algae Technologies

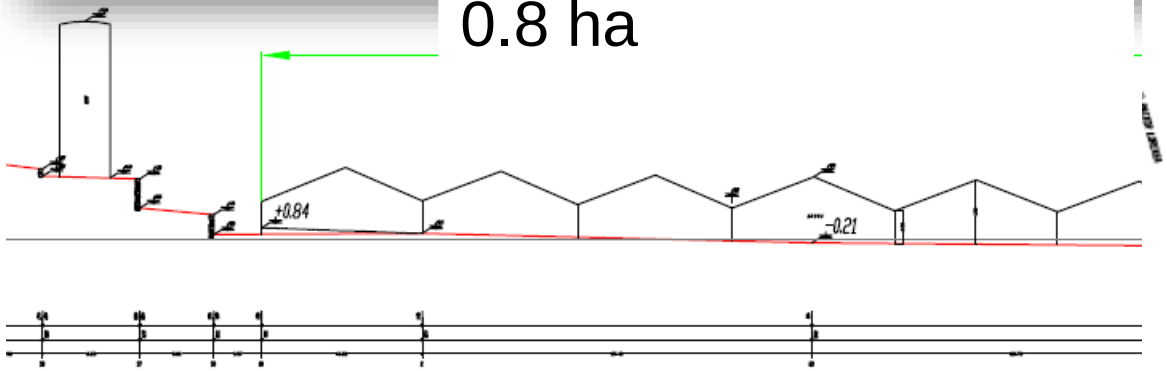
FP7 supported project

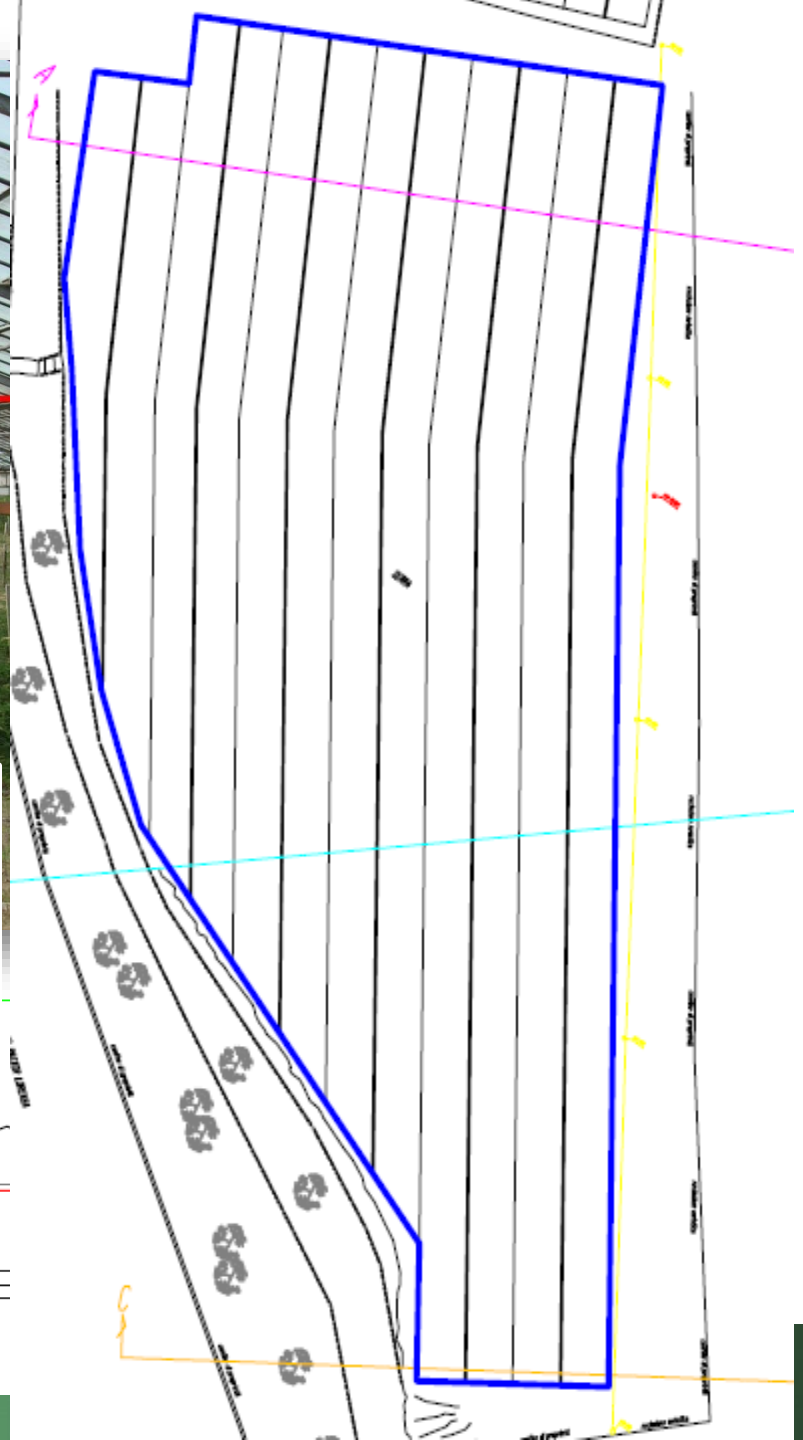
Aim of the project is to **demonstrate** the **algae** feasibility for biofuels **production**.

Target:

- 1 ha pilot plant
- 10 ha demo plant
- 90 ton/yr of biomass

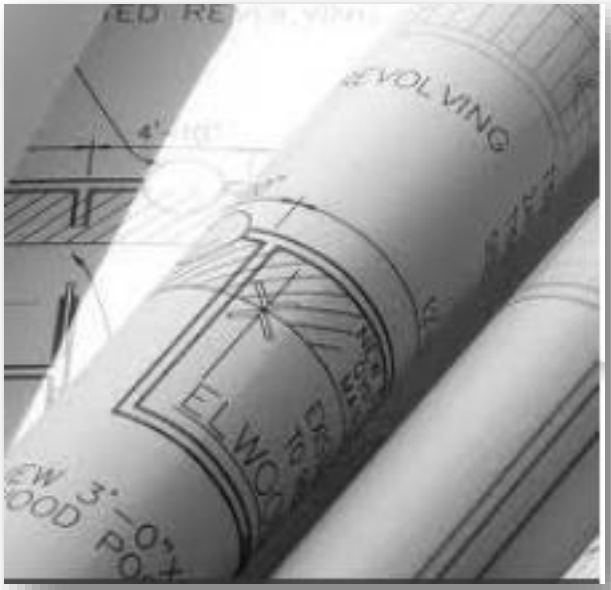
Camporosso (IM – Italy) GreenHouse – 0.8 ha





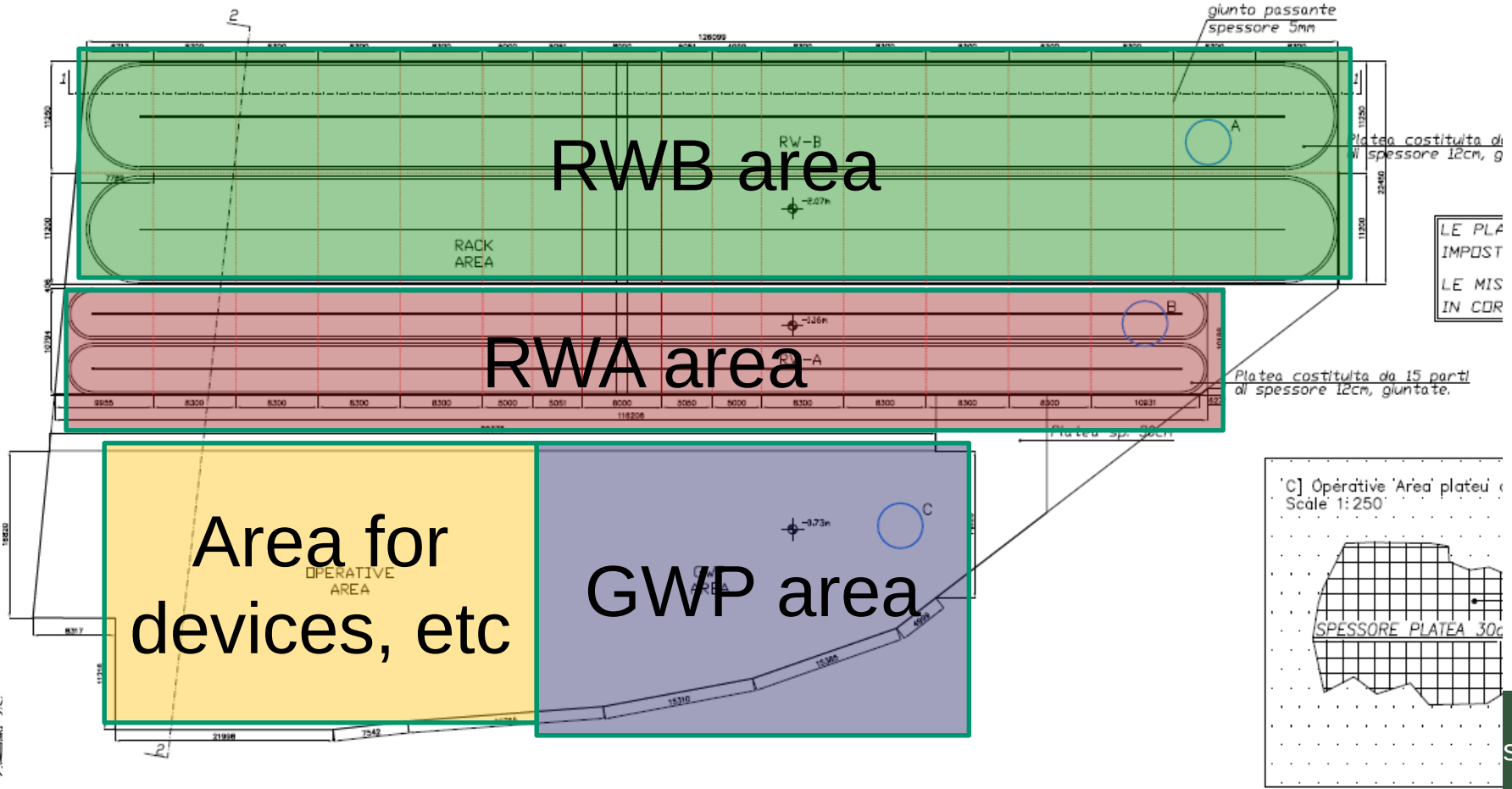
GreenHouse demolition works

Design of the Plant



The plant is divided in 4 main sectors:

1. GWP – Inoculum section
2. RWA – First growth stage
3. RWB – Second growth stage
4. Area for devices: centrifuges, pumps, storages, etc.



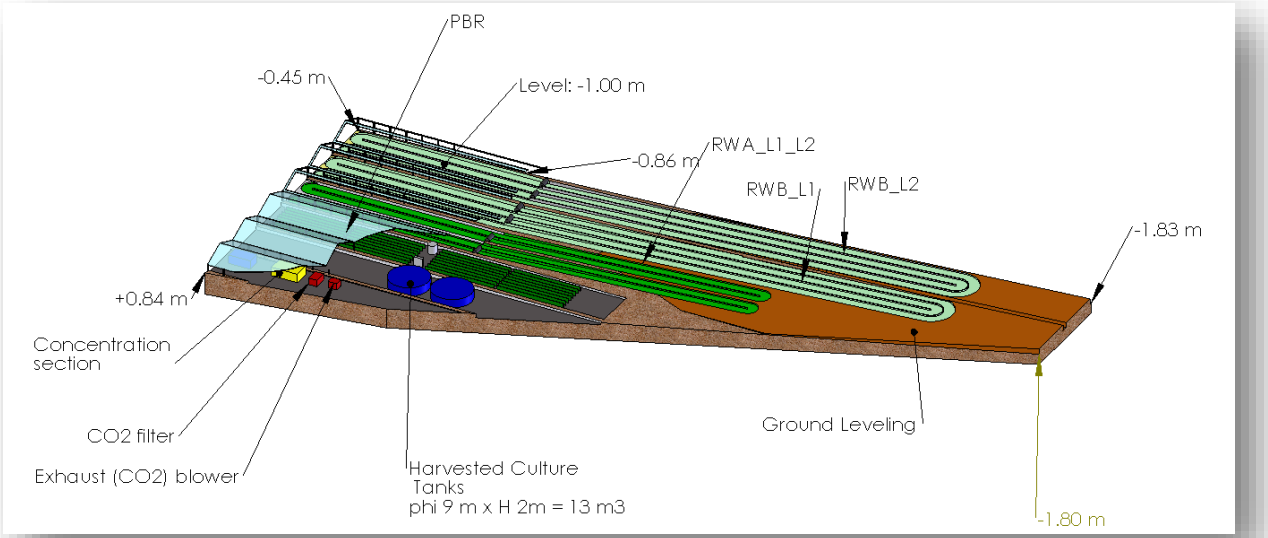
Because each section is complex and made of several devices, a further subdivision has been defined to classify the plant sub-systems:

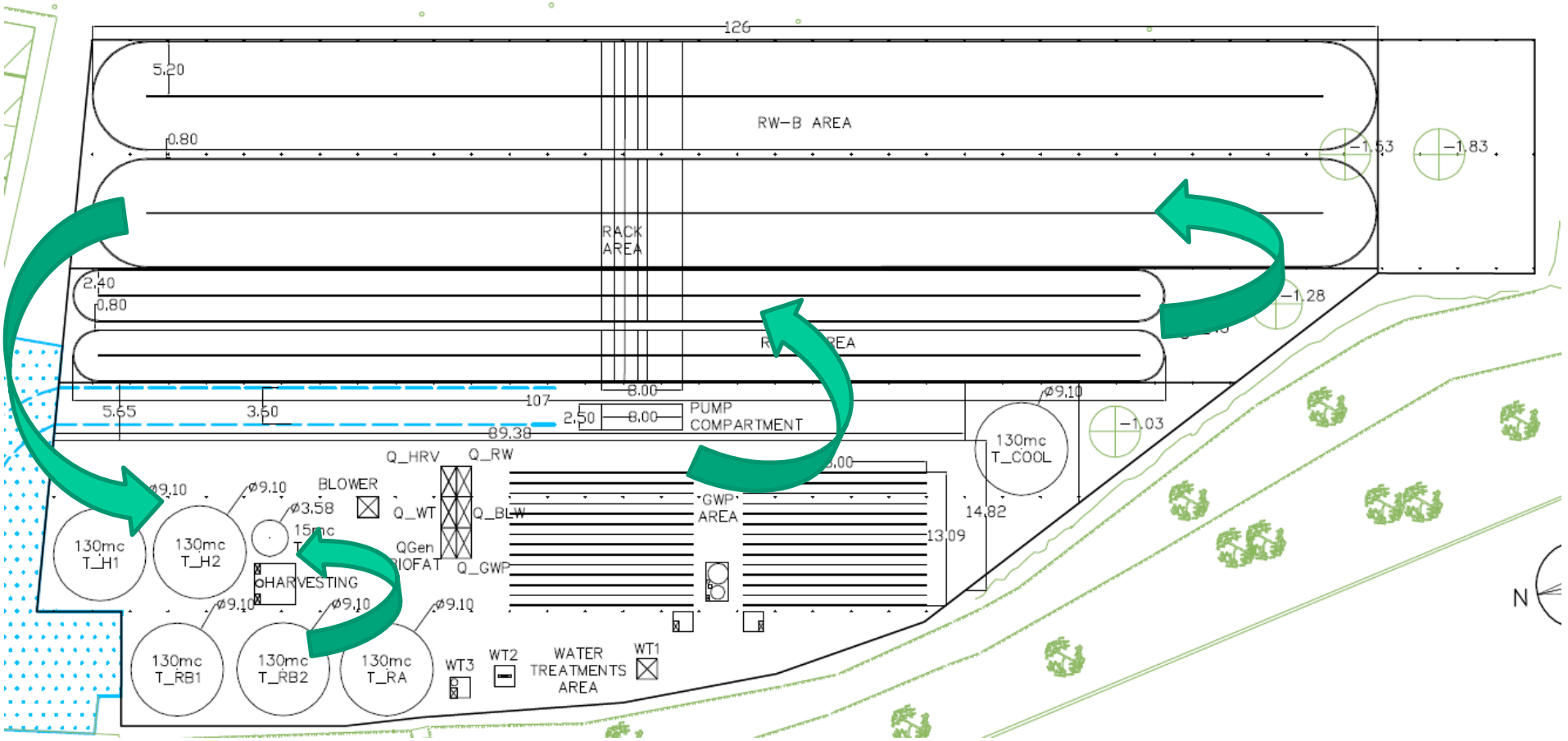
100	**Nutrient preparation**
200	**CO_2 supply**
300	**Brackish water supply**
400	**Inoculum section (GWPs area)**
500	**Growing section (RWA)**
600	**Oil/Carbohydrates accumulation section (RWB)**
700	**Harvesting system**
800	**Water treatment section**
900	**General control board**

For each sub-section, the main parts have been dimensioned:

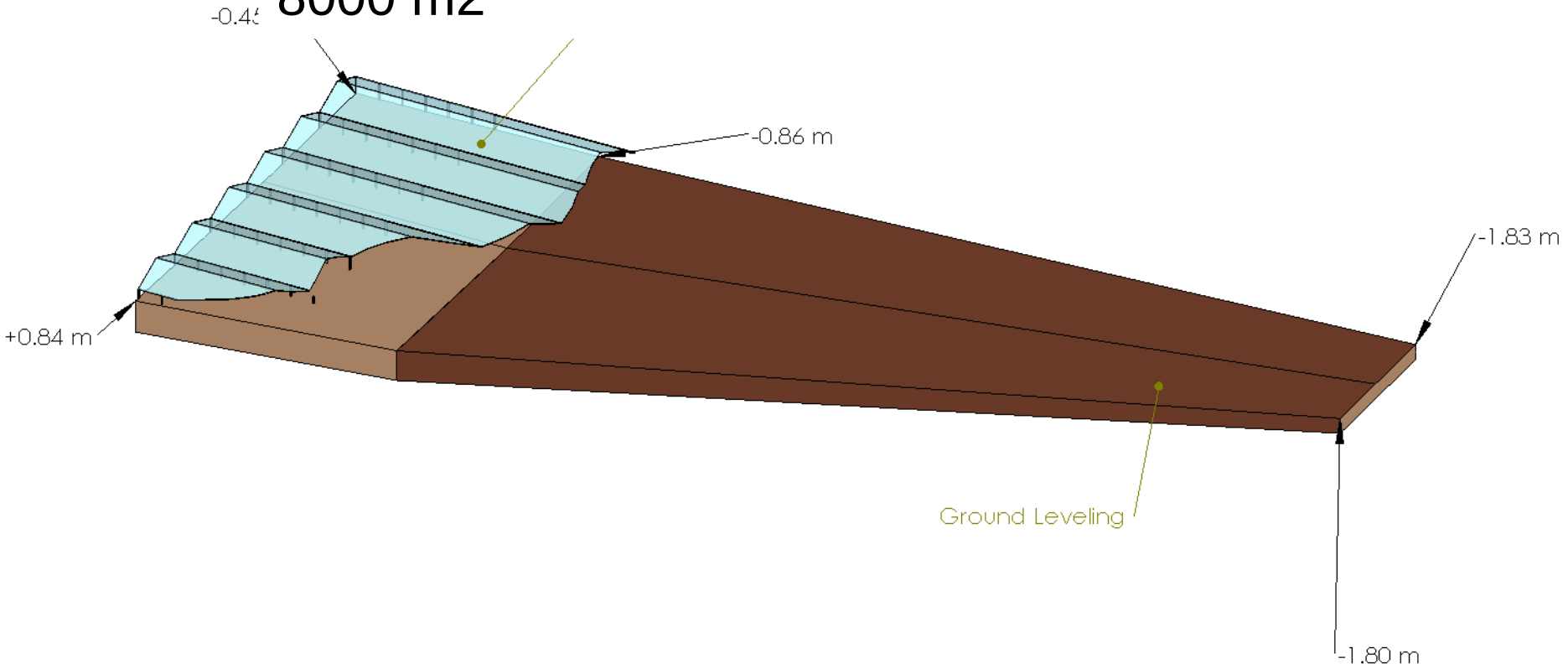
500	**Growing section (RWA)**
501	Layout and position
502	Geometry and specifications
503	Operative parameters (conc, water speed, etc)
510	Supply boards specification
511	Electrical supply
512	Water supply
513	CO_2 supply and distribution
514	Nutrients
…	….
522	Geometry and position
523	Energy requirements
530	Storages
540	Control devices
541	Water level
542	pH
543	Turbidity
544	Electrical conductivity (salinity)
545	Temperature

General Plant layout

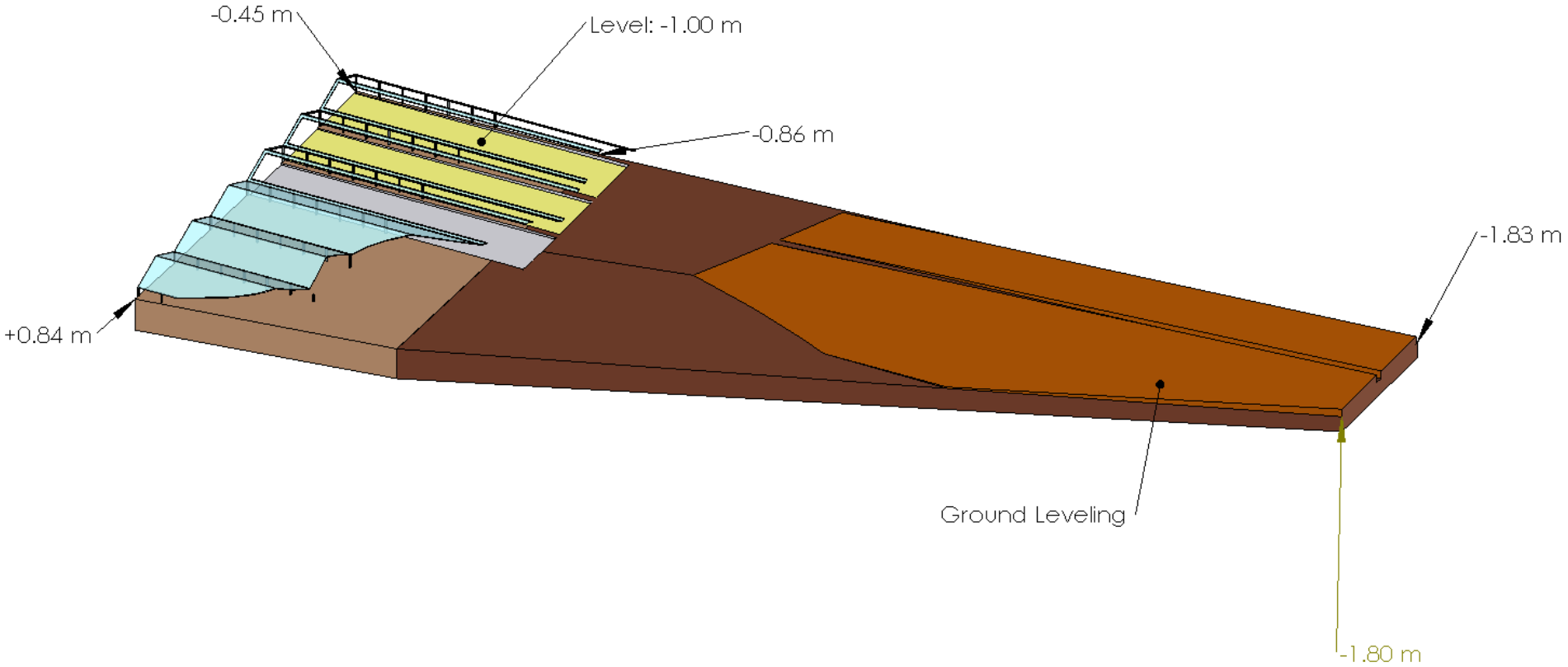



126
5.20
0.80
RW-B AREA
RACK AREA
2.40
0.80
8.00
107
5.65
3.50
2.50
8.00
PUMP COMPARTMENT
89.38
Q_HRV
Q_RW
BLOWER
Q_WT
Q_BLW
Q_GWP
QGen BIOFAT
GWP AREA
130mc T_H1
130mc T_H2
HARVESTING
130mc T_RB1
130mc T_RB2
130mc T_RA
WT3
WT2
WATER TREATMENTS AREA
WT1
130mc T_COOL
14.82
13.09
N

Camporosso (IM – Italy) GreenHouse – 8000 m2

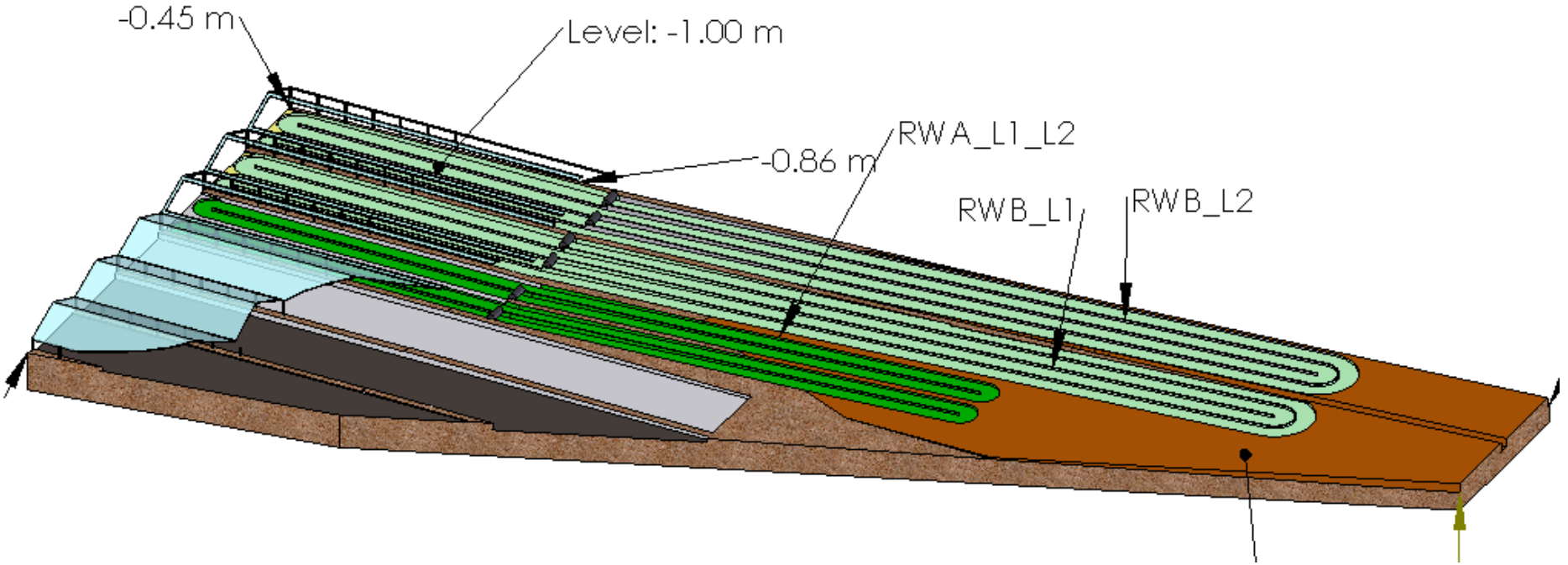


Camporosso (IM – Italy) GreenHouse – 8000 m2

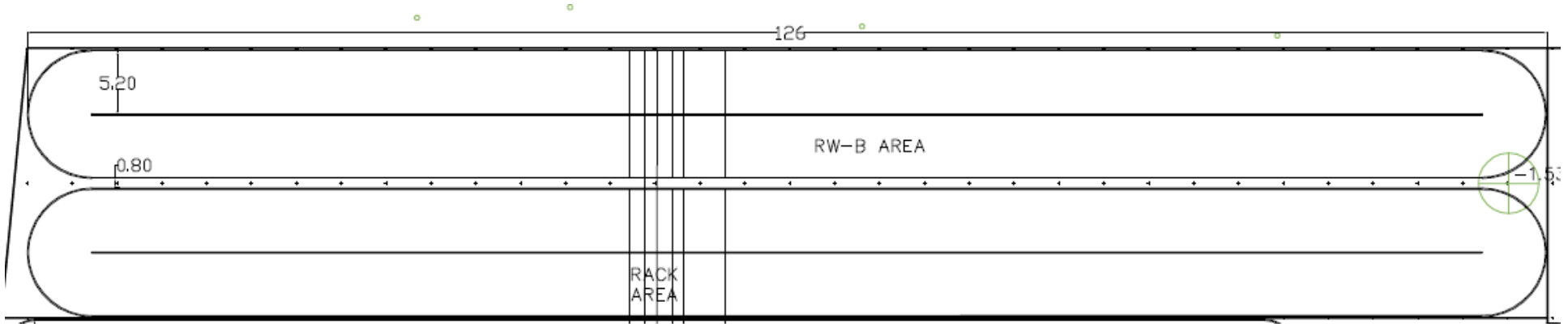


Ground leveling works and glasses substitution

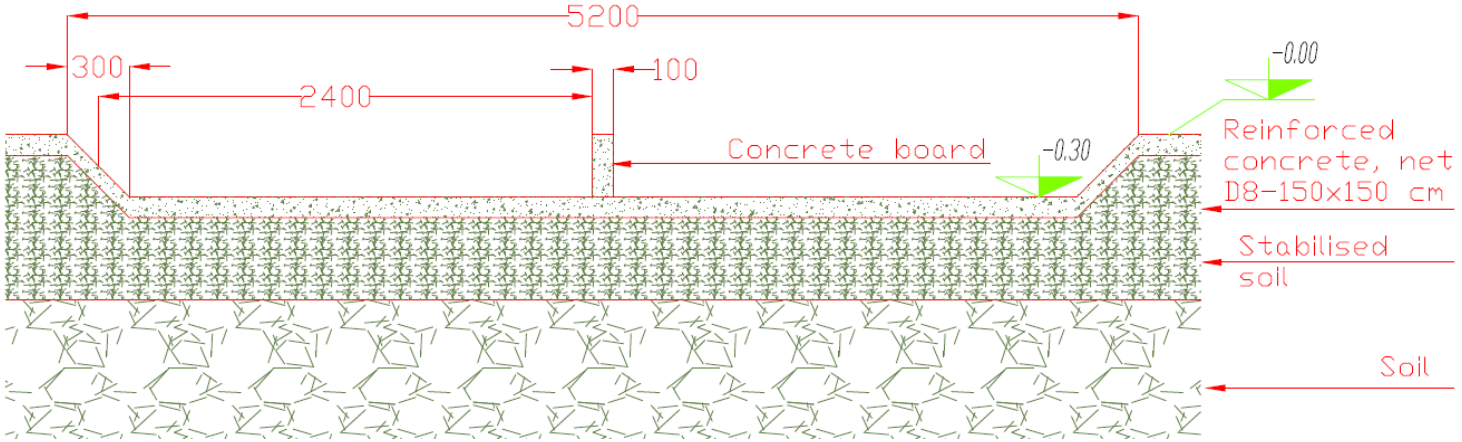
Camporosso (IM – Italy) GreenHouse – 8000 m2

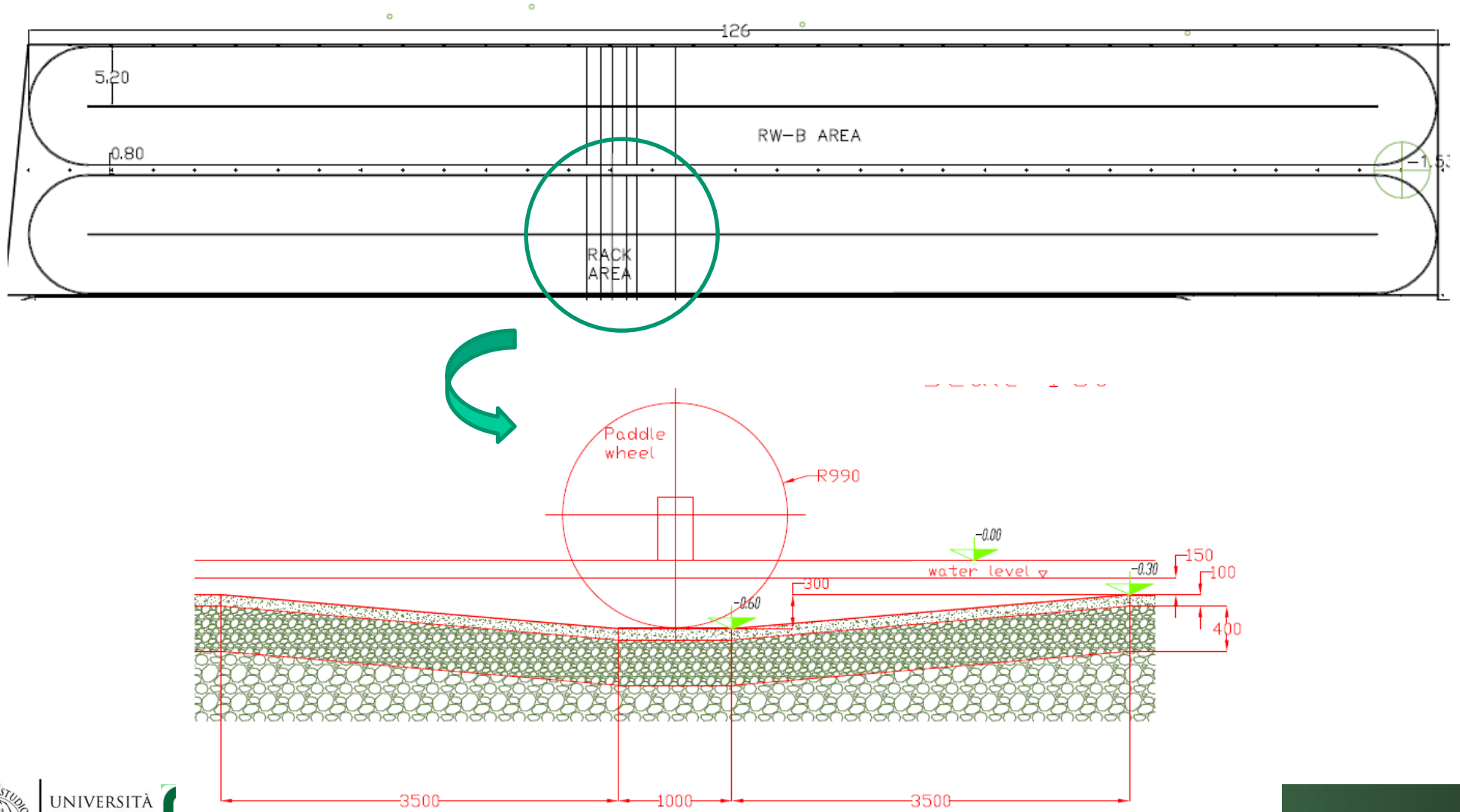


RWP A and B for both L1 and L2



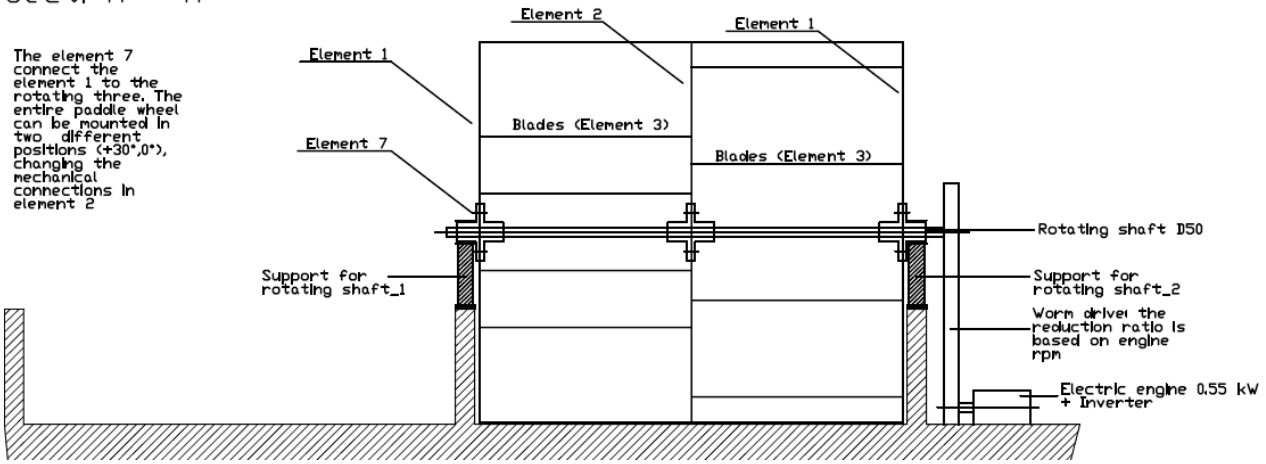
500 m² pond desing



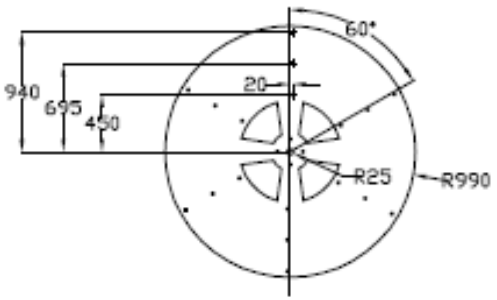

126
5.20
0.80
RW–B AREA
RACK
AREA
Paddle
wheel
R990
-0.00
water level
-0.30
-0.60
150
100
300
400
3500
1000
3500

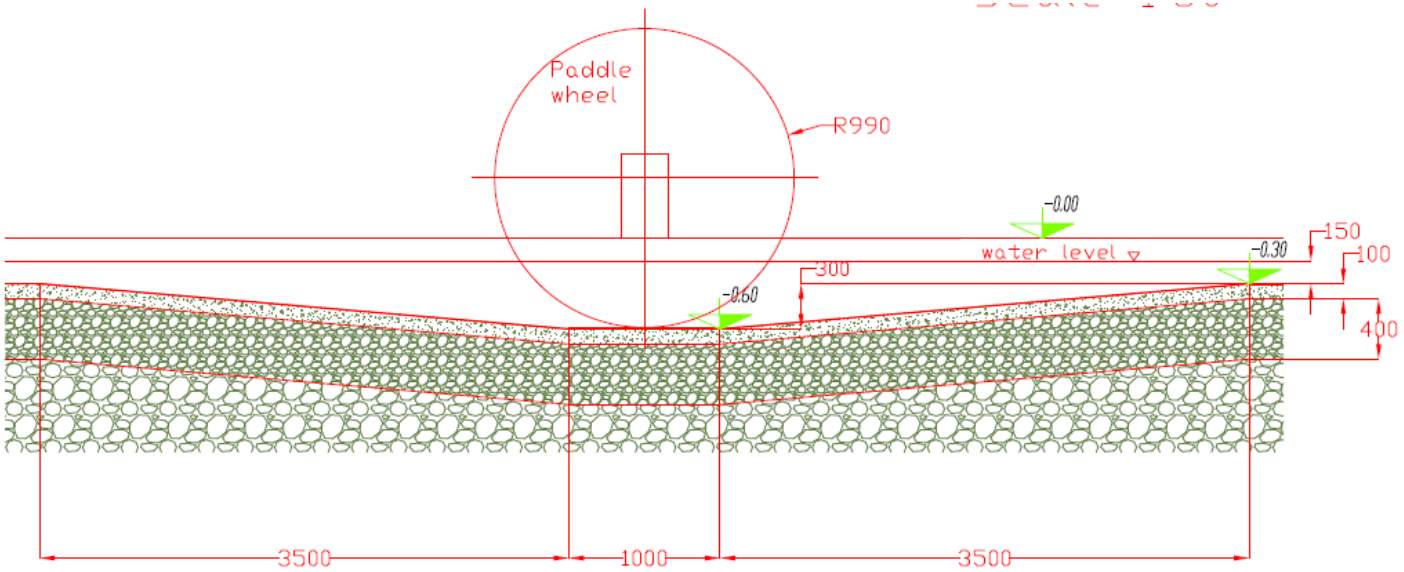
RWA
Sect. A – A'

The element 7 connect the element 1 to the rotating three. The entire paddle wheel can be mounted in two different positions (+30°,0°), changing the mechanical connections in element 2

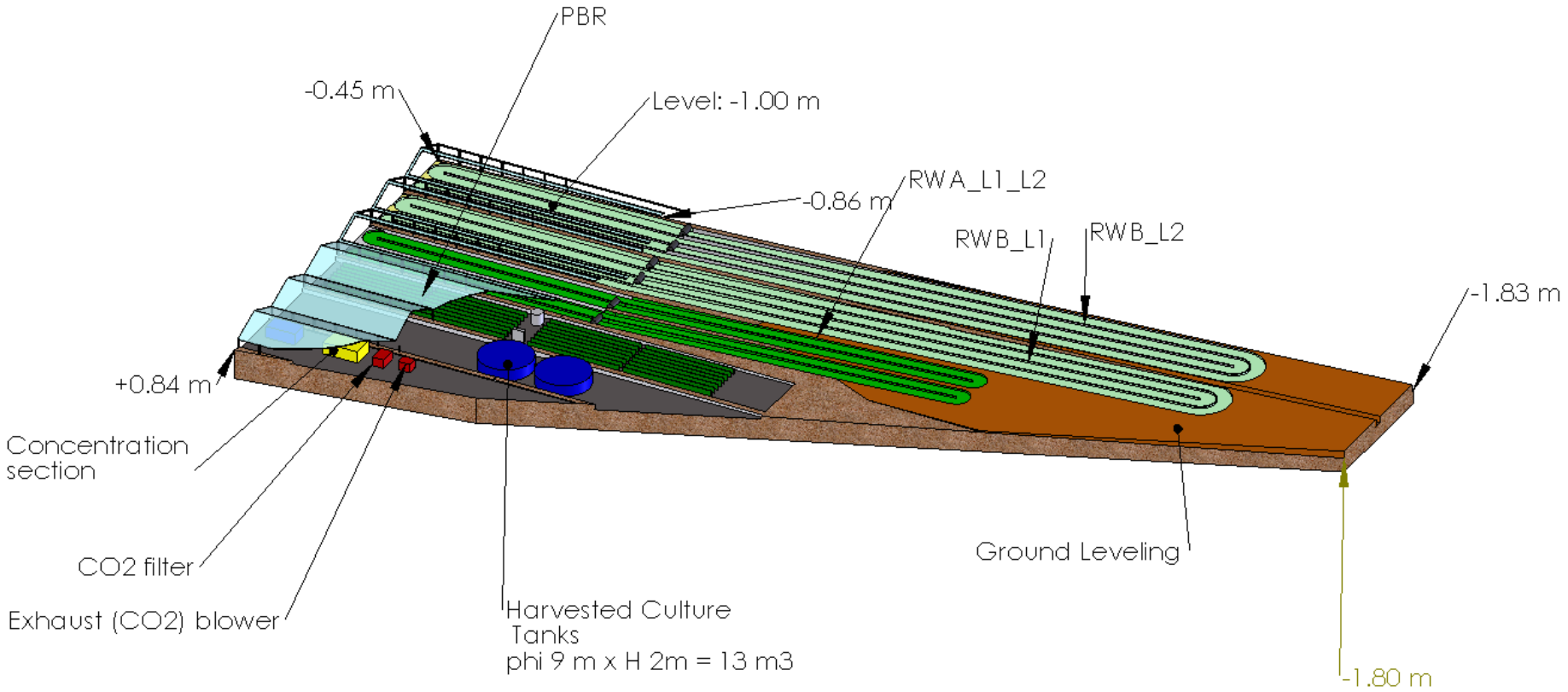


Element 5 – RWB n. 4



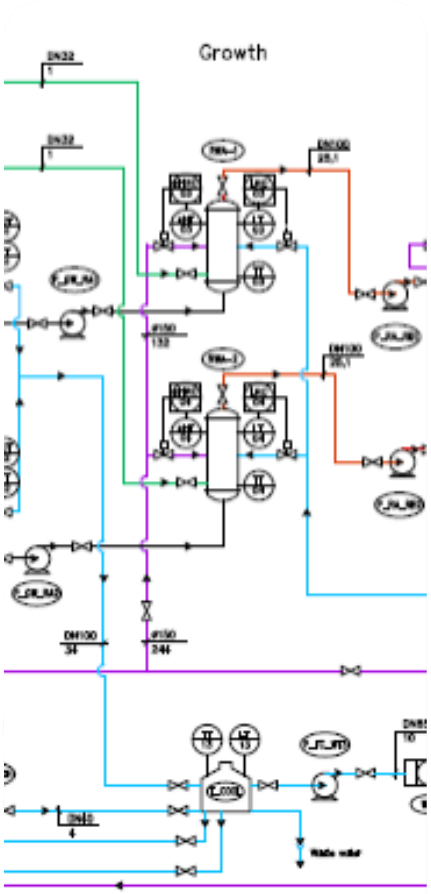


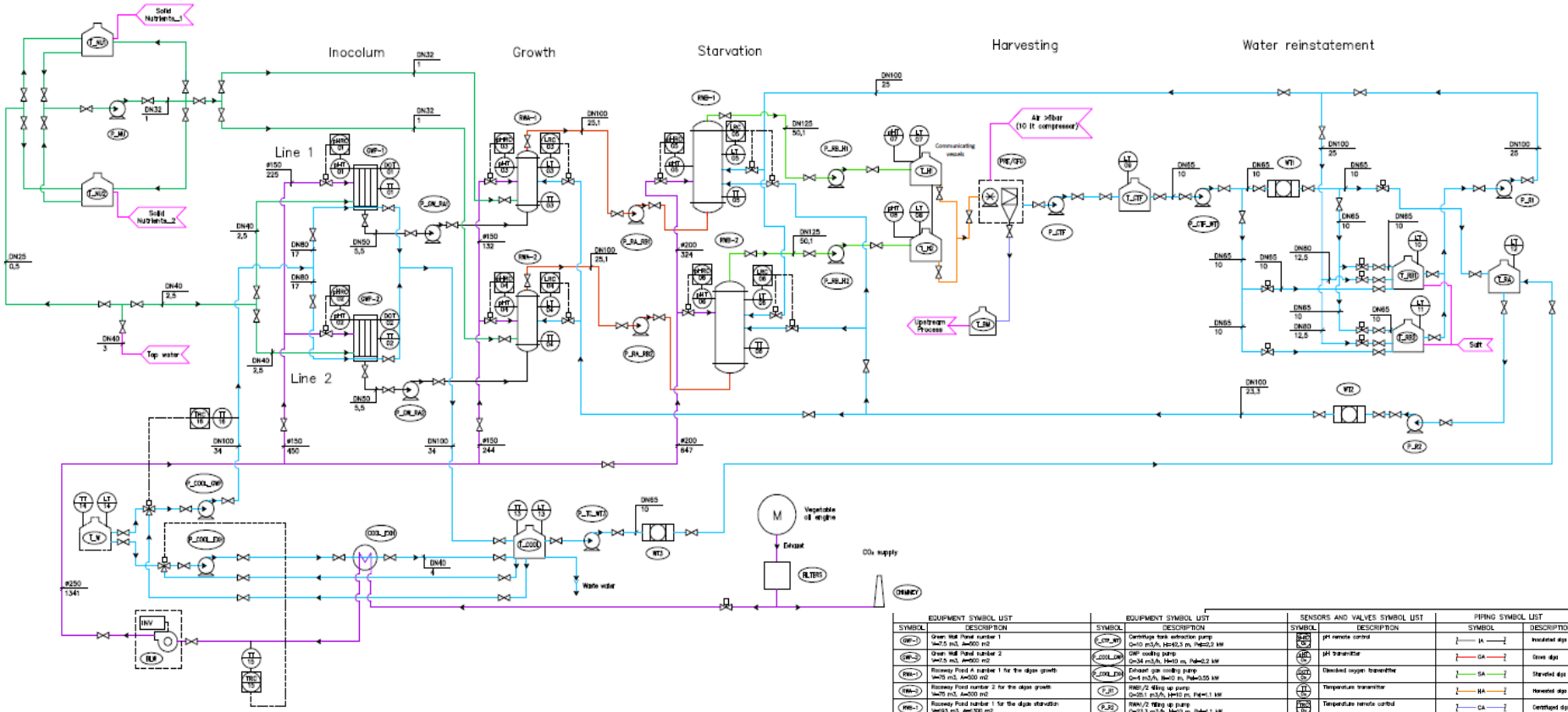
Camporosso (IM – Italy) GreenHouse –



Concentration section and starved culture tanks

P&ID



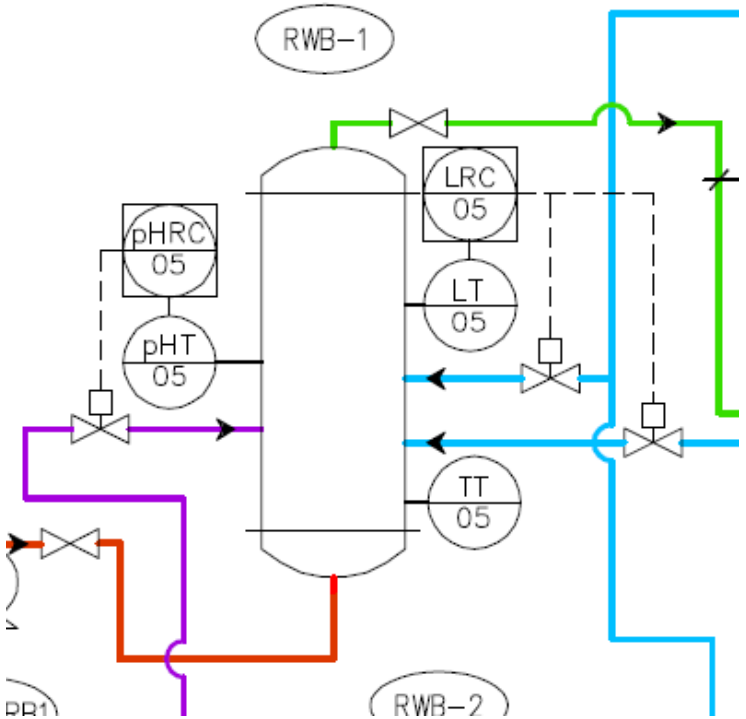


EQUIPMENT SYMBOL LIST		EQUIPMENT SYMBOL LIST	
SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
GWF-1	Green Wall Panel number 1 V=7.5 m3, A=500 m2	T_CTF_NT	Centrifuge tank extraction pump Q=10 m3/h, H=42.3 m, Pel=2.2 kW
GWF-2	Green Wall Panel number 2 V=7.5 m3, A=500 m2	P_COOL_GWF	GWF cooling pump Q=34 m3/h, H=10 m, Pel=2.2 kW
RWA-1	Raceway Pond A number 1 for the algae growth V=75 m3, A=500 m2	P_COOL_EXH	Exhaust gas cooling pump Q=4 m3/h, H=10 m, Pel=0.55 kW
RWA-2	Raceway Pond number 2 for the algae growth V=75 m3, A=500 m2	P_FI	RWB/2 filling up pump Q=25.1 m3/h, H=10 m, Pel=1.1 kW
RWB-1	Raceway Pond number 1 for the algae starvation V=93 m3, A=300 m2	P_FI2	RWA/2 filling up pump Q=23.3 m3/h, H=10 m, Pel=1.1 kW
RWB-2	Raceway Pond number 2 for the algae starvation V=93 m3, A=300 m2	P_TL_WT2	Water Softener pump Q=10 m3/h, H=42.3 m, Pel=2.2 kW
HE/CPE	Centrifuge Q=7 m3/h, Pel=15 kW	P_NT	Nutrients tanks pump Q=1.5 m3/h, H=10 m, Pel=0.25 kW
BLW	Blower Q=1341 m3/h, Pel=30 kW, P=300 mbar	T_HT	Harvesting Tank 1 V=130 m3
WT1	Ultra filtration Q=10 m3/h	T_HT	Harvesting Tank 2 V=130 m3
WT2	Ultra-violet Water Treatment Q=23.3 m3/h	T_BM	Biomass storage tank V=0.5 m3
WT3	Water softener Treatment Q=10 m3/h	T_CTF	Centrifuge tank V=15 m3
COOL_EXH	Exhaust gas cooler Tg_in=93 °C, Tg_out=20 °C, Tw_in=17 °C, Tw_out=27 °C	T_WT	Treated water tank 1 V=130 m3
P_GW_RA1	GWF-1 extraction pump Q=5.5 m3/h, H=10 m, Pel=0.55 kW	T_WT	Treated water tank 2 V=130 m3
P_GW_RA2	GWF-2 extraction pump Q=5.5 m3/h, H=10 m, Pel=0.55 kW	T_FA	Purified water tank V=130 m3
P_RA_RB1	RWA-1 extraction pump Q=25.1 m3/h, H=10 m, Pel=1.1 kW	T_NT1	Nutrients tank 1 V=0.5 m3
P_RA_RB2	RWA-2 extraction pump Q=25.1 m3/h, H=10 m, Pel=1.1 kW	T_NT2	Nutrients tank 2 V=0.5 m3
P_RB_H1	RWB-1 extraction pump Q= m3/h, H=10 m, Pel=3 kW	T_COOL	Cooling water tank V=130 m3
P_RB_H2	RWB-2 extraction pump Q= m3/h, H=10 m, Pel=3 kW	T_W	Brackish water tank
P_CTF	Centrifuge extraction pump Q=7 m3/h, H=10 m, Pel=0.75 kW	All pumps are to be considered as one working and one stand-by	

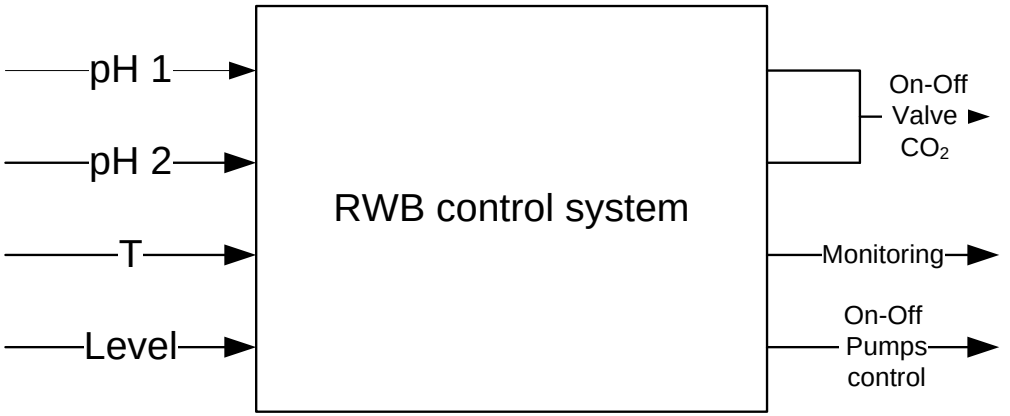
SENSORS AND VALVES SYMBOL LIST	
SYMBOL	DESCRIPTION
pHC 06	pH remote control
pHT 06	pH transmitter
DOT 04	Dissolved oxygen transmitter
TT 03	Temperature transmitter
TRC 10	Temperature remote control
LT 11	Level transmitter
LRC 11	Level remote control
	Ball valve / Throttle
	Automatic valve

PIPING SYMBOL LIST	
SYMBOL	DESCRIPTION
IA	Inoculated alga
OA	Grown alga
SA	Starveted alga
HA	Harvested alga
CA	Centrifuged alga
WW	Wet water
TW	Top water
CO2	Carbon dioxide
EXT	External input
PIPE SIZING SYMBOL	
DN50 250	Pipe diameter [mm] / Volumetric flow [ml/h]

RWB area

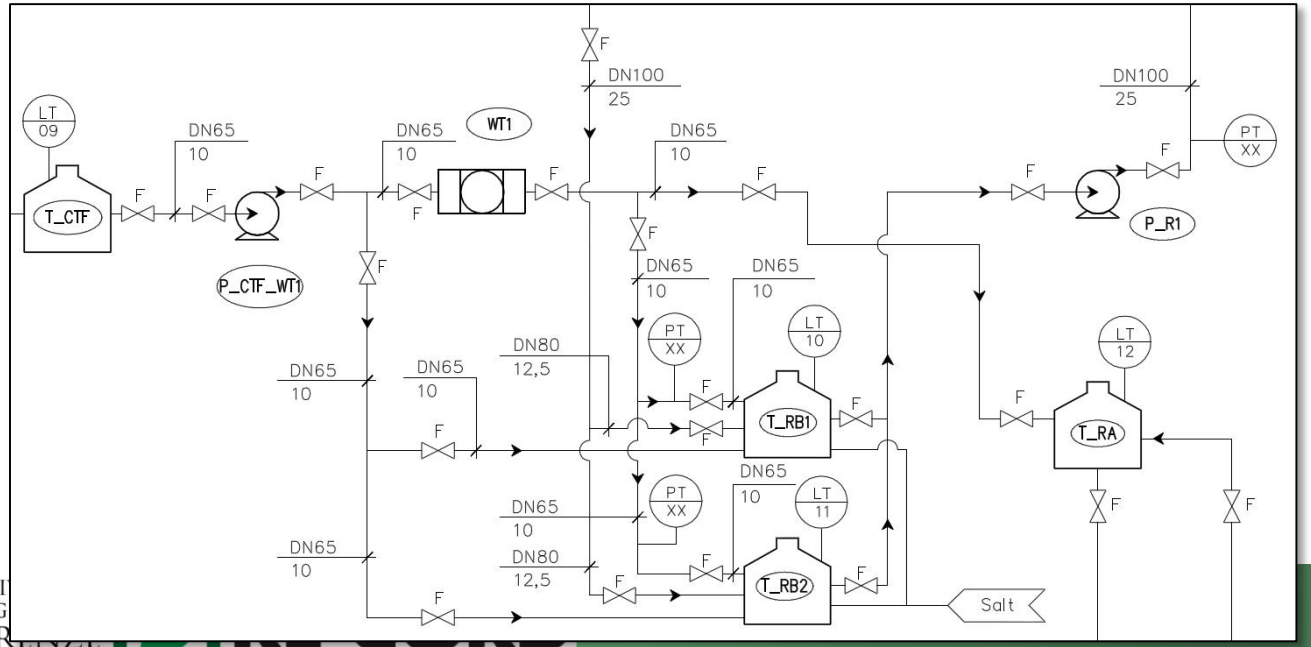


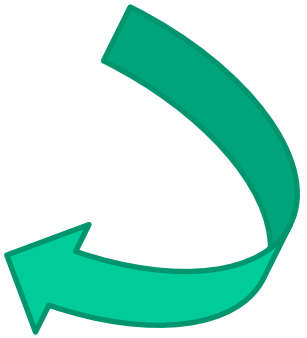
A supply board will be designed in order to guarantee all the specifications of the RWPs area.



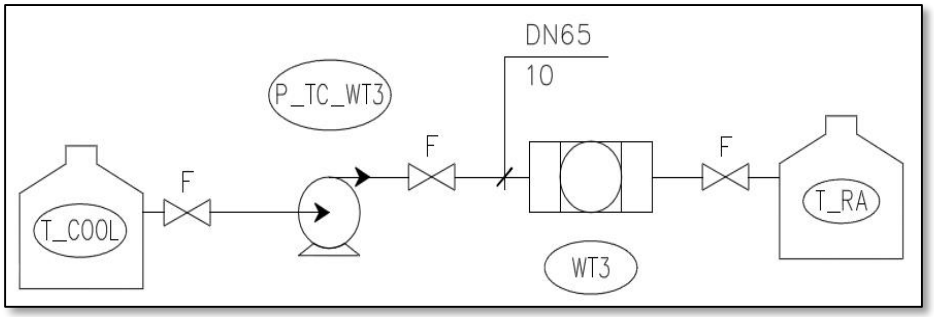
Water management

20:00	21:00	22:00	23:00	24:00	01:00	02:00	03:00	04:00	05:00	06:00
Emptying RWB										
				Emptying RWA						
							Emptying GWP		Filling up GWP	
				Filling up RWB						
							Filling up RWA			

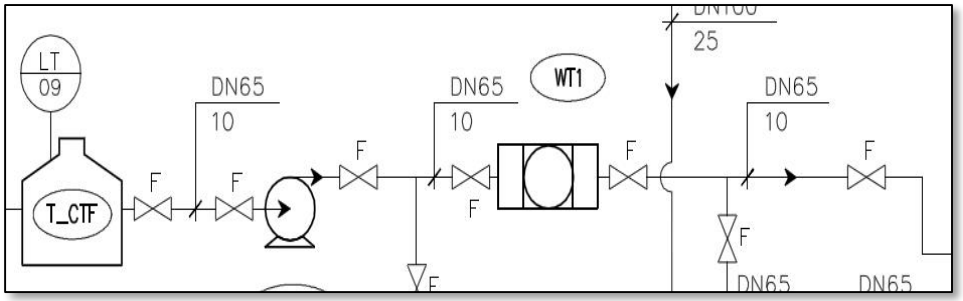




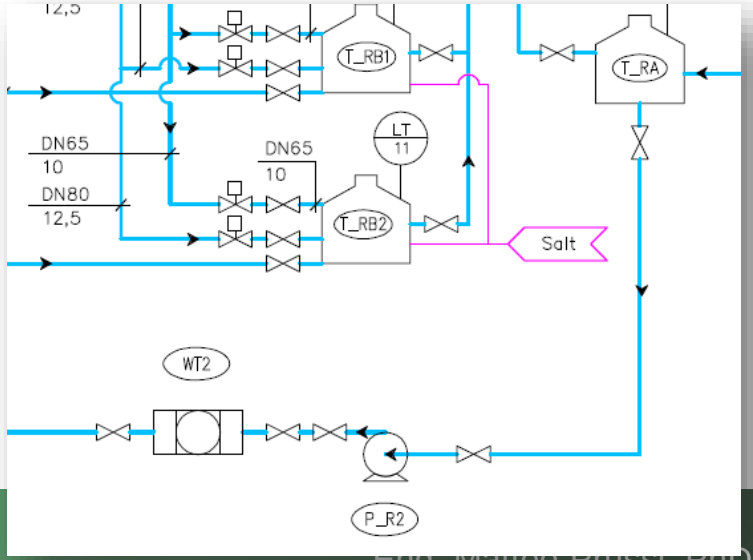
Water treatments



Brackish water treatment :
WT3 softener process



Water from centrif: WT1 - Ultra-filtration



Water for RWA:
WT2 - UV Lamps

OBJECTIVES

Testing the ultrafiltration membrane on the output of the centrifuge:

- asses the pilot (up to 9 m3/h) performance;
- estimate the energetic performance;
- evaluate the better membranes cleaning strategy.

GENERAL FIRST CONCLUSIONS

The first tests at CAMPOROSSO show that:

- **GOOD RESULTS WITH BIOFAT ALGAE STRAINS (Tetra and Nanno)**
- **CARBONATE SALTS CAN BE AN ISSUE FOR UF**

CO2 Supply

To regulate the CO_2 flux will be used:
- pH meter (two for every production unit, both pond or panel);
- electric valve (one for every pHmeter and one to control the opening of the chimney);
- flow meter (one before every production unit and one after the blower);
- inverter.

Line	Nominal CO_2 request	Seasonal Factor	
		T_{out} = 15°C	T_{out} = 35°C
	kgCO2/h	m³/h	
GWP	13.9	215	231
RWA	27.8	431	463
RWB	59.2	917	985
Total	101.0	1563	1679

ROBUSCH

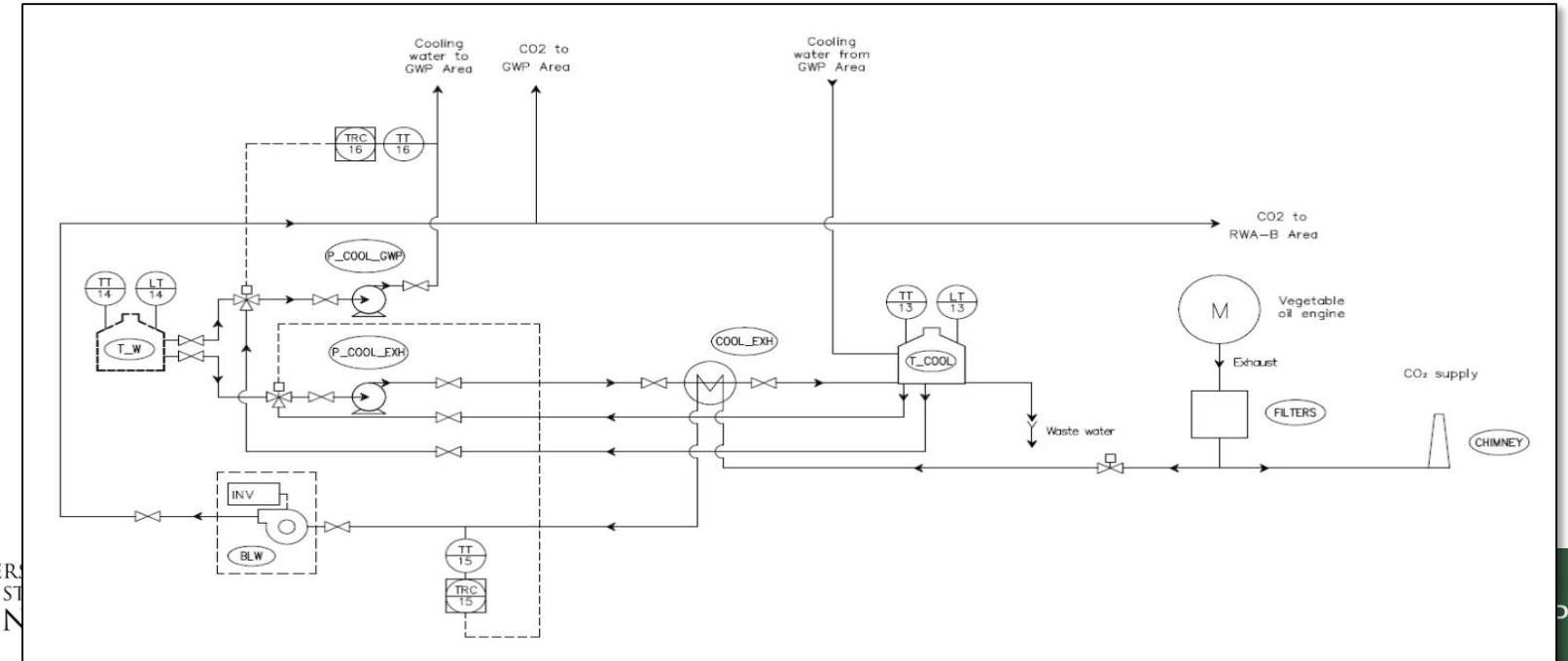
RBS 66
Funzionamento in pressione

DP (mbar)	Poli	4			2						
	rpm	1500	1800	2200	2600	3000	3600	4000	4400	4600	4800
300	Q1 m³/min	8,6	10,9	14,0	17,1	20,2	24,8	27,9	31,0	32,5	34,0
	DT °C	33	32	30	29	28	28	27	27	27	27
	Nsof kW	6,0	7,3	9,1	11,1	13,2	16,7	19,3	22,1	23,6	25,1
	Nmot kW	7,5	11	11	15	15	22	22	30	30	30
	Lp(A) sc	78	81	85	89	91	95	97	99	100	101
	Lp(A) cc	<70	<70	<70	<70	<70	73	75	77	78	79
400	Q1 m³/min	8,1	10,5	13,5	16,6	19,7	24,3	27,4	30,5	32,0	33,6
	DT °C	47	44	41	40	39	38	37	37	37	36
	Nsof kW	7,9	9,6	11,9	14,4	17,0	21,3	24,4	27,7	29,5	31,3
	Nmot kW	11	11	15	18,5	22	30	30	37	37	37
	Lp(A) sc	79	83	87	90	93	97	99	100	101	102
	Lp(A) cc	<70	<70	<70	<70	71	75	77	78	79	80

Eng. Matteo Prussi, PhD

COOLING

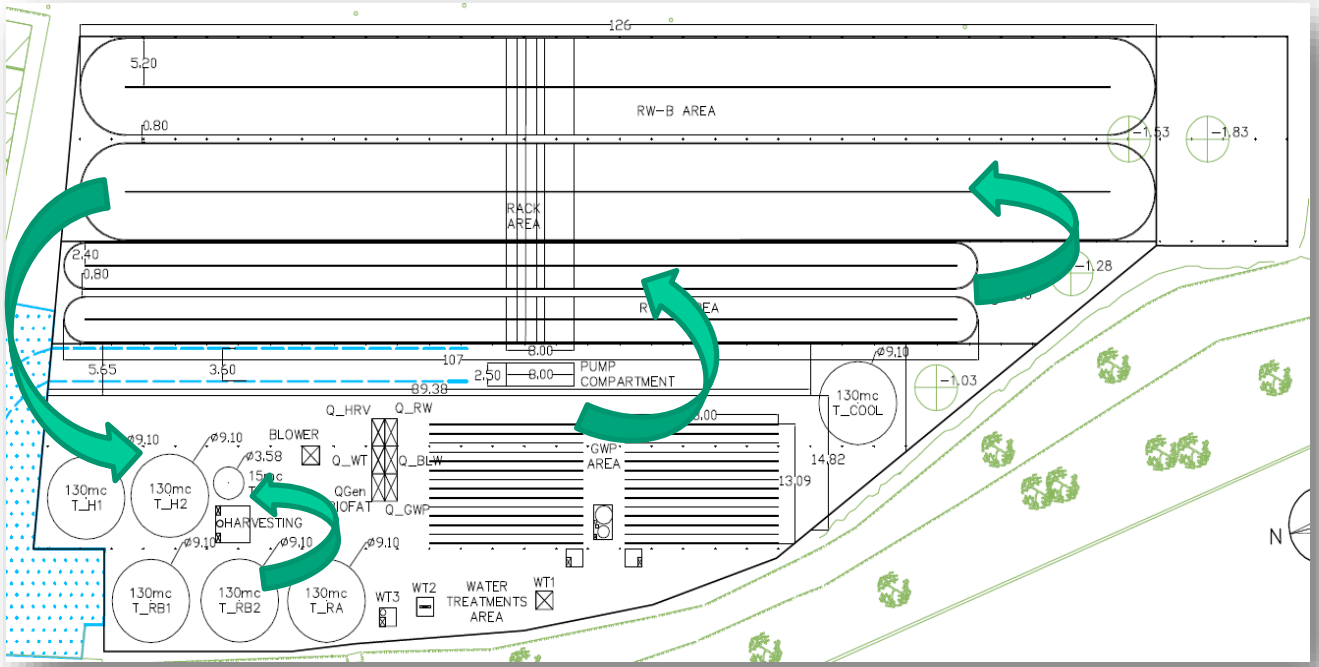
Brackish water, from the T_W, is used to cool of the exhausts and of the GWPs.
Once the water passes through the GWP it is sent to the T_COOL storage. The same line is designed to cool the exhaust gasses form the engine; this is required by the blower specifications.
In order to optimize the water consumption, the coolant flow works in a closed cycle between T_COOL and T_W. Night time temperatures are naturally used to dissipate part of the heat.
If the temperature of the T_COOL increases too much, new water is introduced in the system from the T_W.



Preliminary energetic assessment

PRELIMINARY ENERGY ASSESSMET

- Nominal Power of each device;
- Operational period for each device;
- Avaerage Energy consumption per cycle of production.



PRELIMINARY ENERGY ASSESSMET

COMPONENT ID	BOARD	DEVICE	Nom.POWER	h_funz 2days cycle	h daily	Average Power	Energy Consumpt.
PWA_1	RWP	Paddle wheel					
PWA_2		Paddle wheel					
PWB_1		Paddle wheel					
PWB_2		Paddle wheel					
P_RWA		Pump					
P_RWB		Pump					
Moduli GWP	GWP	Area GWP					
P_GW_RA_1		Pump					
P_GW_COOLING		COOL					
CTF_2	Harvesting Area	Centrifuge					
COMPR		Compressor					
		Pump					
WT3	W_TREAT	PUMP WT2					
		Cool CO2					
PR_1		Pump_Stor_R1					
PR_2		Pump_Stor_R2					
		UF					
WT2		UV_Lamp					
BLW_1	BLOWER	Blower					
GCB	C_BOARD						

PRELIMINARY ENERGY ASSESSMET

COMPONENT ID	BOARD	DEVICE	Nom.POWER	h_funz 2days cycle	h daily	Average Power	Energy Consumpt.
			kW				
PWA_1	RWP	Paddle wheel	0.55	48	24	0.75	
PWA_2		Paddle wheel	0.55	48	24	0.75	
PWB_1		Paddle wheel	1.10	48	24	0.75	
PWB_2		Paddle wheel	1.10	48	24	0.75	
P_RWA		Pump	1.10	3	1.5	1	
P_RWB		Pump	3.00	4	2	1	
Moduli GWP	GWP	Area GWP	0.76	48	24	1	
P_GW_RA_1		Pump	0.55	2	1	1	
P_GW_COOLING		COOL	2.20	6	3	1	
CTF_2	Harvesting Area	Centrifuge	15.00	36	18	0.85	
COMPR		Compressor	1.00	30	15	0.25	
		Pump	0.75	30	15	0.5	
WT3	W_TREAT	PUMP WT2	2.20	8	4	1	
		Cool CO2	0.55	24	12	0.75	
PR_1		Pump_Stor_R1	1.10	5	2.5	1	
PR_2		Pump_Stor_R2	1.10	2	1	1	
		UF	2.83	36	18	0.25	
WT2		UV_Lamp	0.75	3	1.5	1	
BLW_1	BLOWER	Blower	25.00	20	10	0.55	
GCB	C_BOARD		3.00	48	24	0.2	
			64.19				

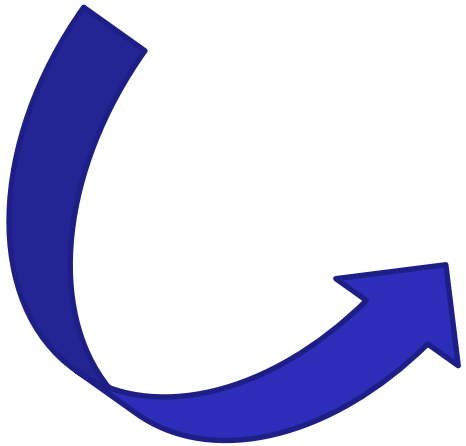
PRELIMINARY ENERGY ASSESSMET

COMPONENT ID	BOARD	DEVICE	Nom.POWER	h_funz 2days cycle	h daily	Average Power	Energy Consumpt.	
			kW				kWh/day	%
PWA_1	RWP	Paddle wheel	0.55	48	24	0.75	9.9	1.9
PWA_2		Paddle wheel	0.55	48	24	0.75	9.9	1.9
PWB_1		Paddle wheel	1.10	48	24	0.75	19.8	3.8
PWB_2		Paddle wheel	1.10	48	24	0.75	19.8	3.8
P_RWA		Pump	1.10	3	1.5	1	1.7	0.3
P_RWB		Pump	3.00	4	2	1	6.0	1.2
Moduli GWP	GWP	Area GWP	0.76	48	24	1	18.2	3.5
P_GW_RA_1		Pump	0.55	2	1	1	0.6	0.1
P_GW_COOLING		COOL	2.20	6	3	1	6.6	1.3
	Harvesting Area							0.0
CTF_2		Centrifuge	15.00	36	18	0.85	229.5	44.6
COMPR		Compressor	1.00	30	15	0.25	3.8	0.7
		Pump	0.75	30	15	0.5	5.6	1.1
WT3	W_TREAT	PUMP WT2	2.20	8	4	1	8.8	1.7
		Cool CO2	0.55	24	12	0.75	5.0	1.0
PR_1		Pump_Stor_R1	1.10	5	2.5	1	2.8	0.5
PR_2		Pump_Stor_R2	1.10	2	1	1	1.1	0.2
		UF	2.83	36	18	0.25	12.8	2.5
WT2		UV_Lamp	0.75	3	1.5	1	1.1	0.2
BLW_1	BLOWER	Blower	25.00	20	10	0.55	137.5	26.7
GCB	C_BOARD		3.00	48	24	0.2	14.4	2.8
			64.19				514.65	kWh/day

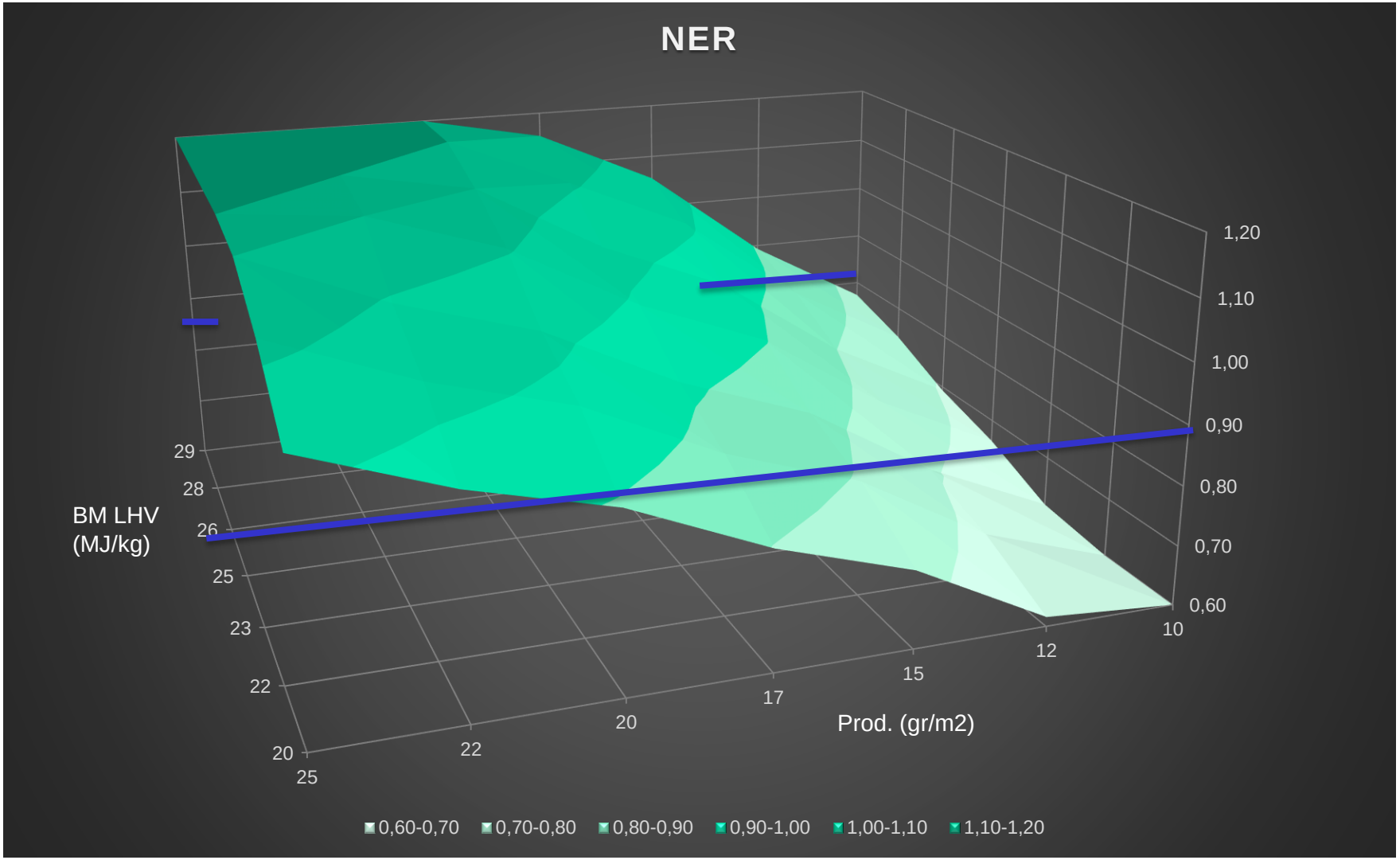
PRELIMINARY ENERGY ASSESSMET
Net Energy Ratio

Once the plant energy consumptio is known it is possible to evaluate the Net Energy Ratio:

$$\boldsymbol{NER} = \frac{E_{OUT}}{E_{IN}} = \frac{Productivity \times LHV}{\sum Device.Cons}$$



$$\boldsymbol{NER}\ f(Prod, LHV, E_{IN})$$
$$\boldsymbol{Rel}\ (Prod, LHV)$$
$$\boldsymbol{E_{IN}}\ f(Productivity)$$

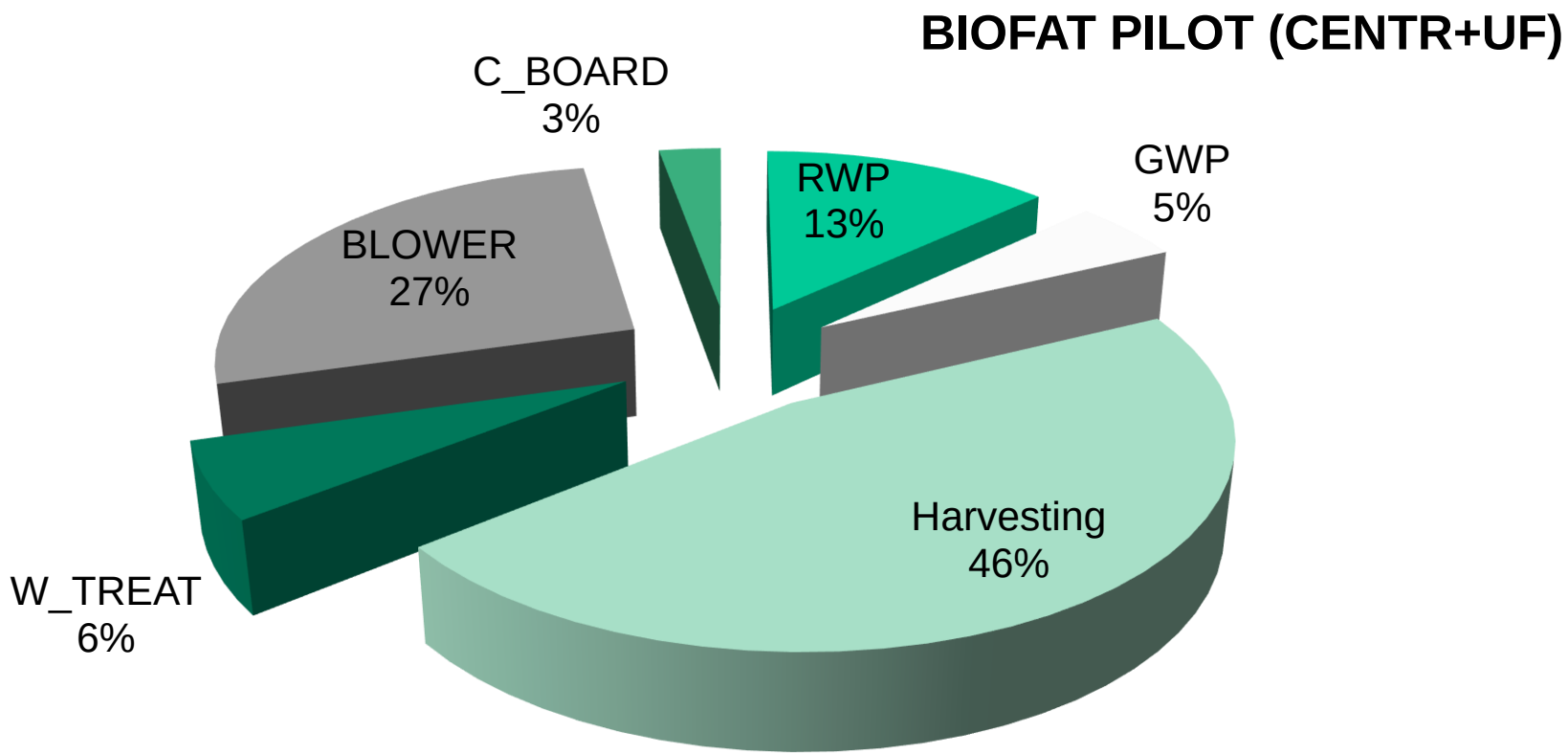

NER
BM LHV (MJ/kg)
29
28
26
25
23
22
20
25
22
20
17
15
12
10
Prod. (gr/m2)
1,20
1,10
1,00
0,90
0,80
0,70
0,60
0,60-0,70
0,70-0,80
0,80-0,90
0,90-1,00
1,00-1,10
1,10-1,20

PRELIMINARY ENERGY ASSESSMET

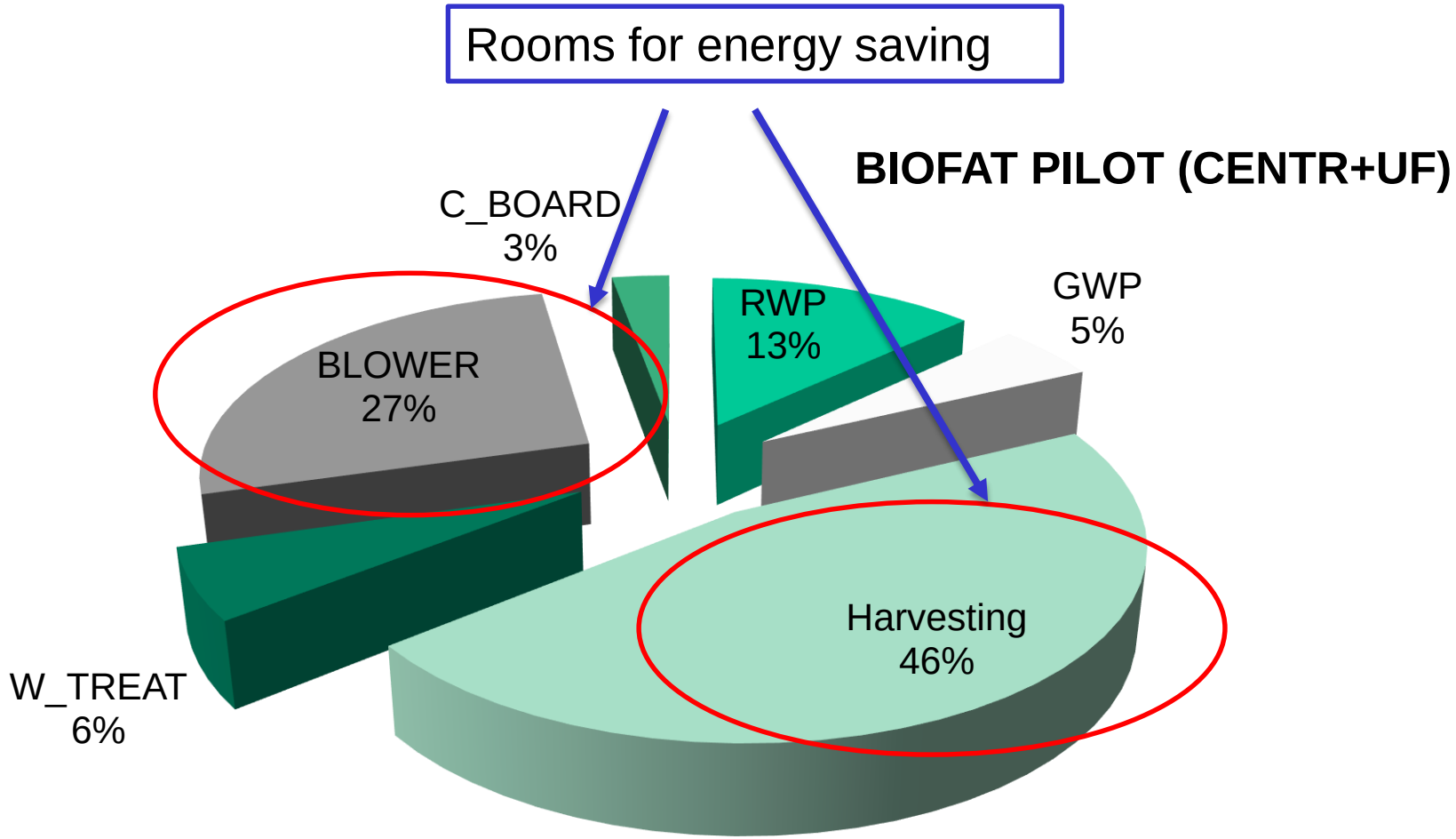
CAMPOROSSO – layout nr. 1

BIOFAT		
Area	4500 m2	%
RWP	67.05	13.0
GWP	25.35	4.9
Harvesting Area	238.88	46.4
W_TREAT	31.48	6.1
BLOWER	137.50	26.7
C_BOARD	14.40	2.8
TOTAL CONS.	514.65	
BM_PROD	54.00	kg/day @ 12 gr/m2/day
LHV_algae	7.78	kWh/kg (28 MJ/kg)
NER (Eout/Ein)	0.82	

PRELIMINARY ENERGY ASSESSMET



PRELIMINARY ENERGY ASSESSMET



PRELIMINARY ENERGY ASSESSMET
ENERGY SAVING

Energy Saving can be achieved by:

- Increase the CO_2 content in the flue gas;
- Increase the carbonation efficiency;
- Increase the blower efficiency by smart grid control;

- Pushing on UF as system for pre-concentration (not only water treatment);

- Smart Paddle Wheels speed regulation f(Irrad, Tamb);

- Investigate the other parasitic costs;

CO_2

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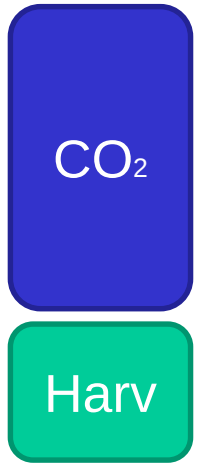

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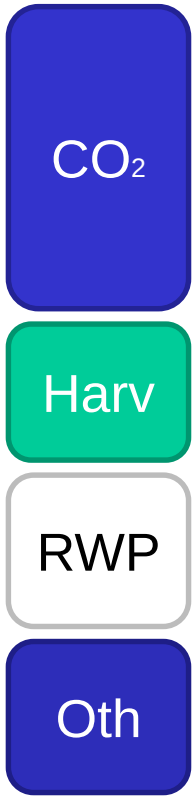


ALGAEFUELS Project

Chile

AlgaeFuels Project

Plants and **targets**:

- **Mejillones** (Antofagasta)
  - 0.7 ha plant for biofuels production

- **El Carmelo** (Iquique)
  - 1 ha plant for fish feeding and proteins production

Mejillones plant

Location:

E-Cl (suez GDF) power plant. Coal supply.

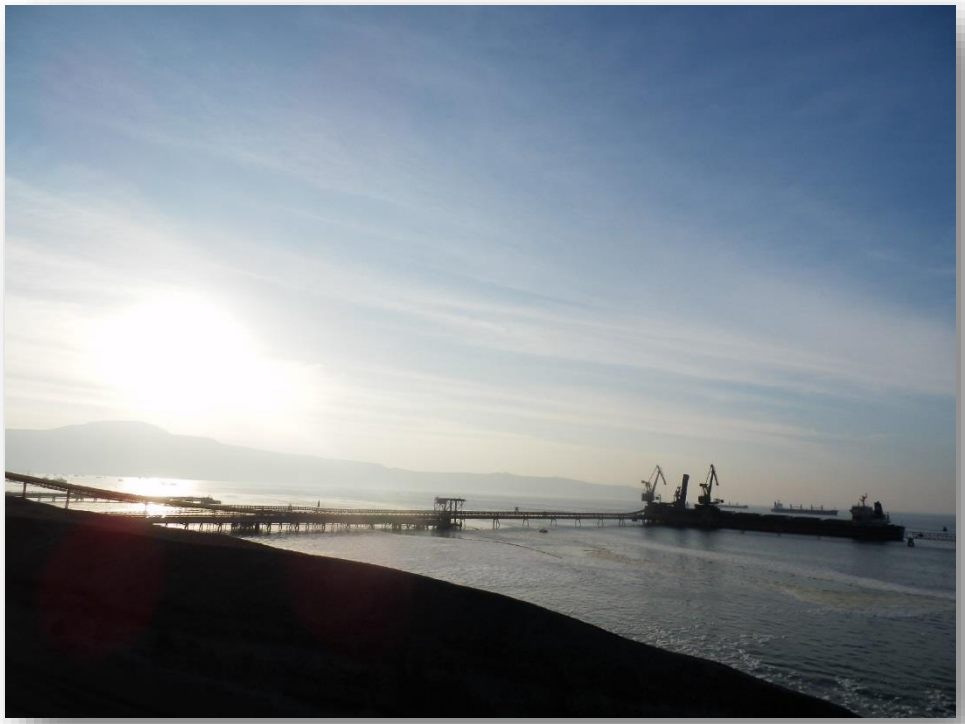
Source of CO_2:

Power plant feed by coal.

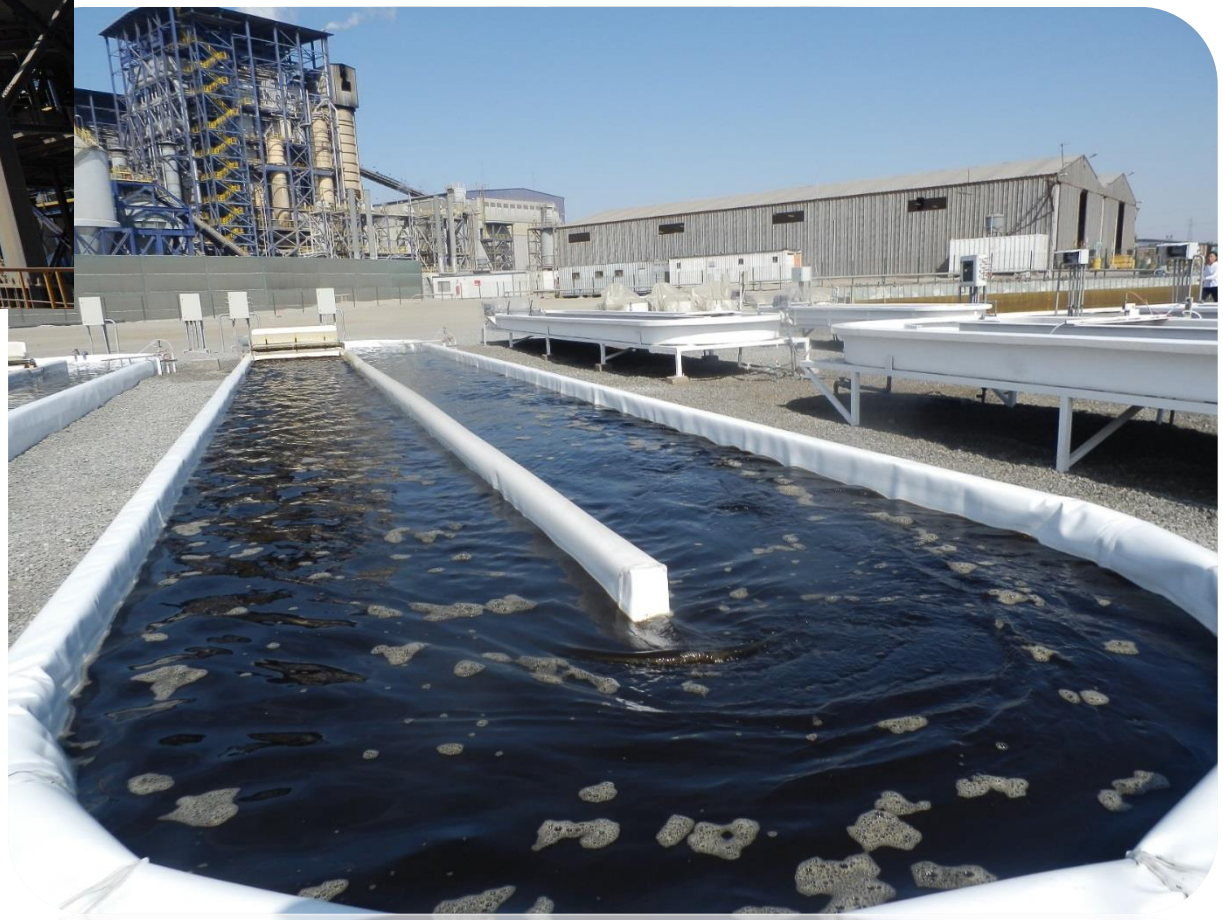
Target:

Reduce CO2 impact rom power production.

Biofuels production.



Mejillones plant



Plant
Optimization
needed

El Carmelo plant

Location:

La Tirana (Iquique)

Desert Area @ 1000 m.a.s.l.

Source of CO_2:

Energy production for algae process

Target:

1. Proteins
2. Nutraceutical products
3. Fish feed.

El Carmelo plant

Location:

La Tirana (Iquique)

Desert Area @ 1000 m.a.s.l.

Source of CO_2:

Energy production for algae process

Target:

1. Proteins
2. Nutraceutical products
3. Fish feed.

Thanks for your attention