MELiSSA MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

2022 MELISSA CONFERENCE
8-9-10 NOVEMBER 2022

CREATING A CIRCULAR FUTURE

MELiSSA PILOT PLANT INTEGRATION AND FUTURE PERSPECTIVES

Francesc Gòdia

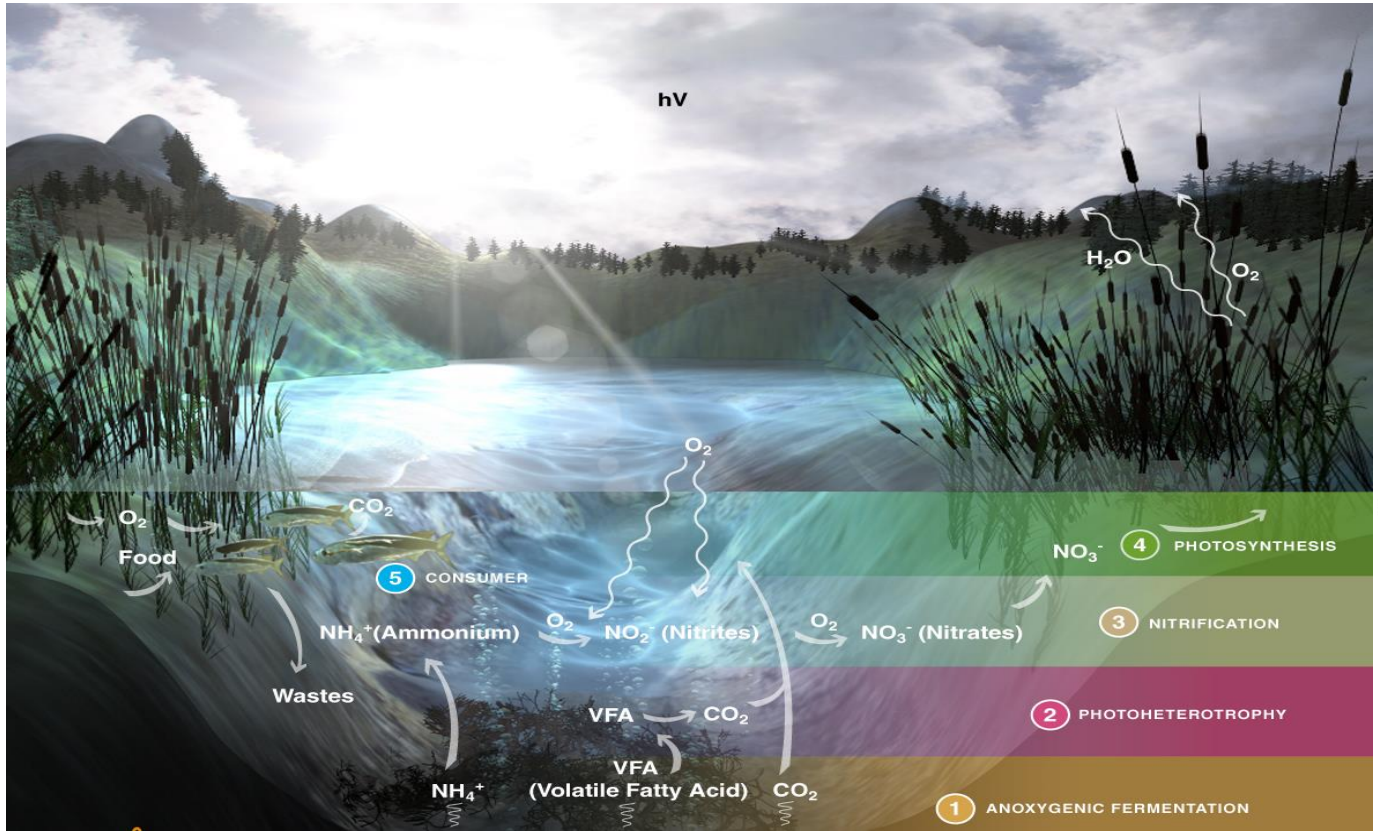
MELiSSA Pilot Plant – Claude Chipaux Laboratory, Universitat Autònoma de Barcelona

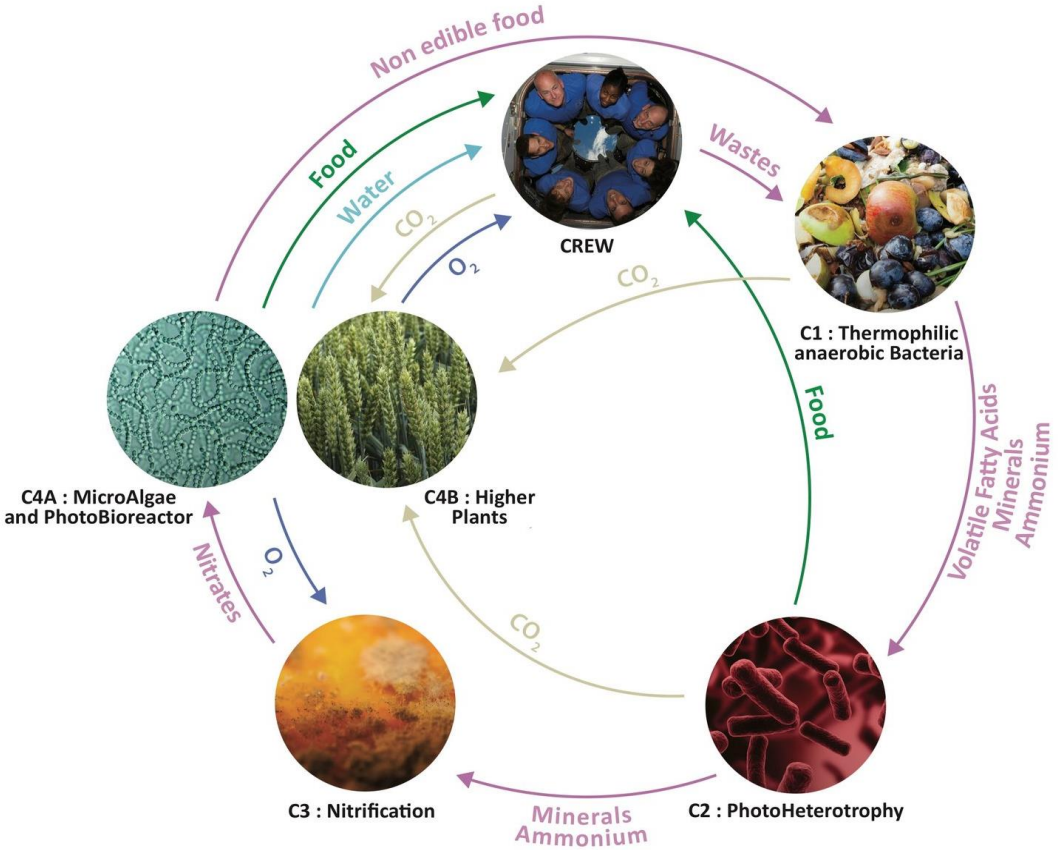
C. Arnau, D. García, C. Ciurans, E. Peiro, C.G. Dussap, L. Poughon,

O. Gerbi, B. Lamaze, Ch. Lasseur

The MELiSSA Concept

MELiSSA is inspired in a natural ecosystem to perform the most relevant biological functions in individual compartments (bioreactors and higher plant chambers), in continuous and controlled operation, to provide life support in Space in long-term human missions





The MELiSSA Pilot Plant

Main objectives

Integration and demonstration of the MELiSSA concept at pilot scale

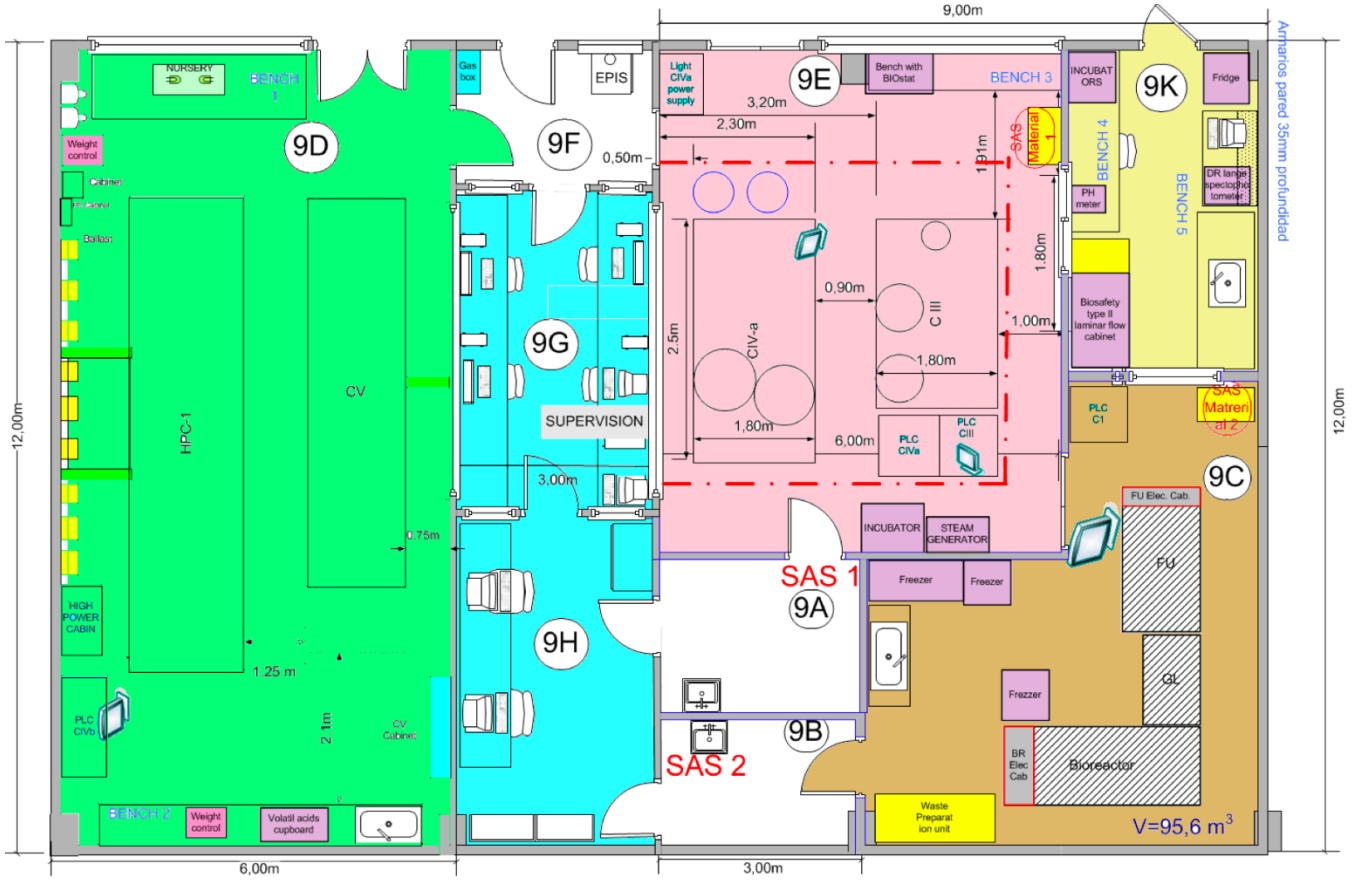
Technology demonstration:

- In ground conditions
- With an animal crew
- With industry standards
- Long-term operation
- Modelling and Control

Production of Oxygen: equivalent to one humman respiration

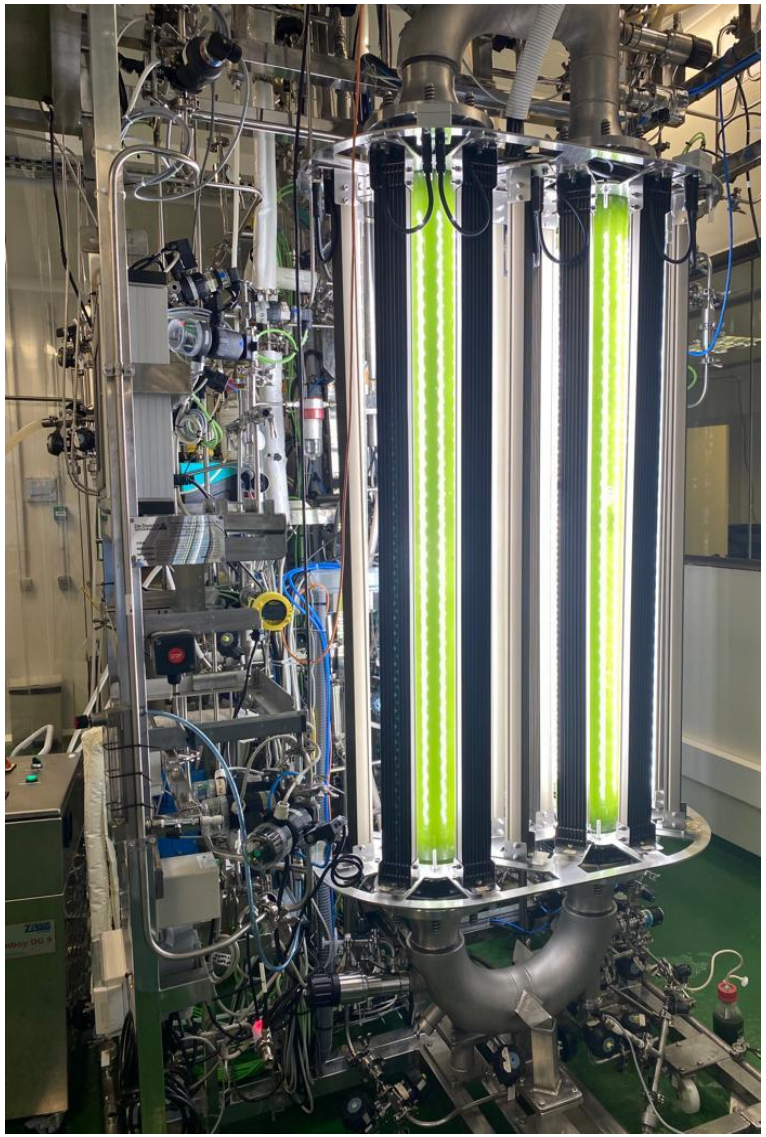
Production of food: at least 20% of a person requirements

Layout (214 m²)



Comp. 4b and 5	Comp. 3 and 4a	Control and supervision	Comp. 1 and 2	Analysis Laboratory

Quality and Systems Engineering

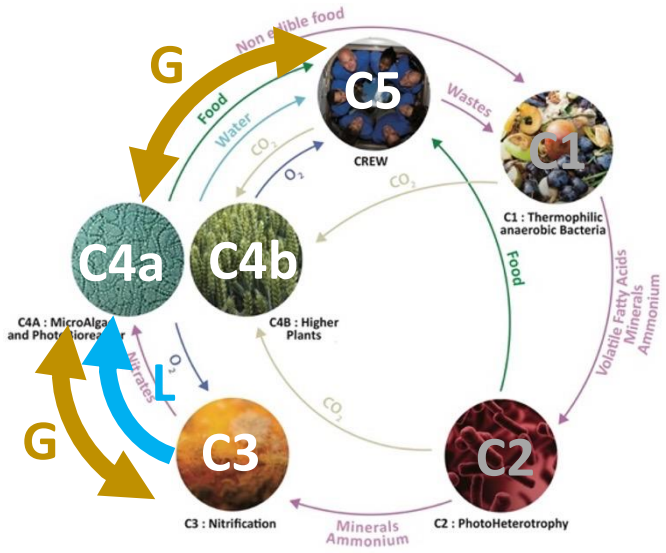


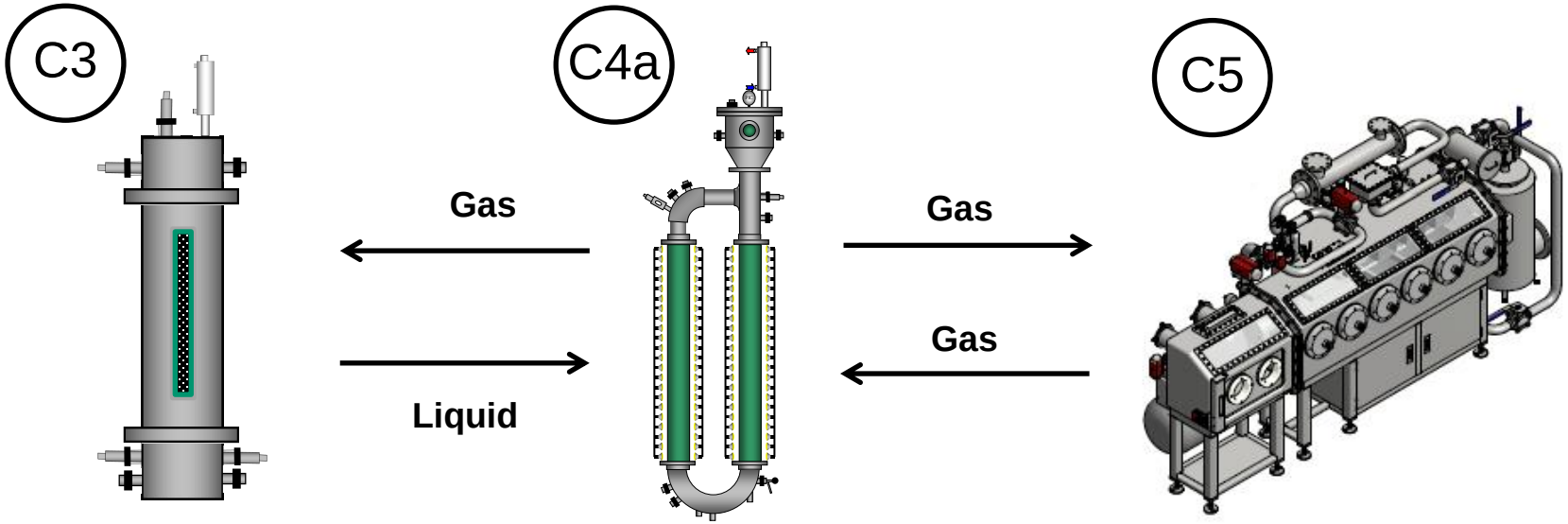
Integration Strategy: C3/C4a/C5

Top requirements for the MELiSSA Pilot Plant

- Progressive demonstration of MELiSSA concept
- Stepwise Integration
- Capitalization of knowledge

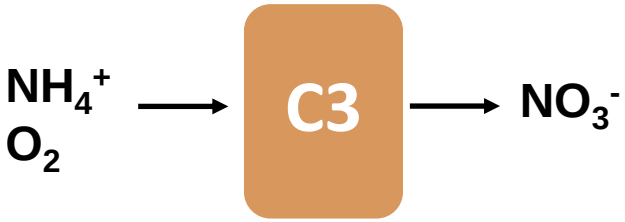
Integration logic based on the most advanced compartments in terms of knowledge, model and control

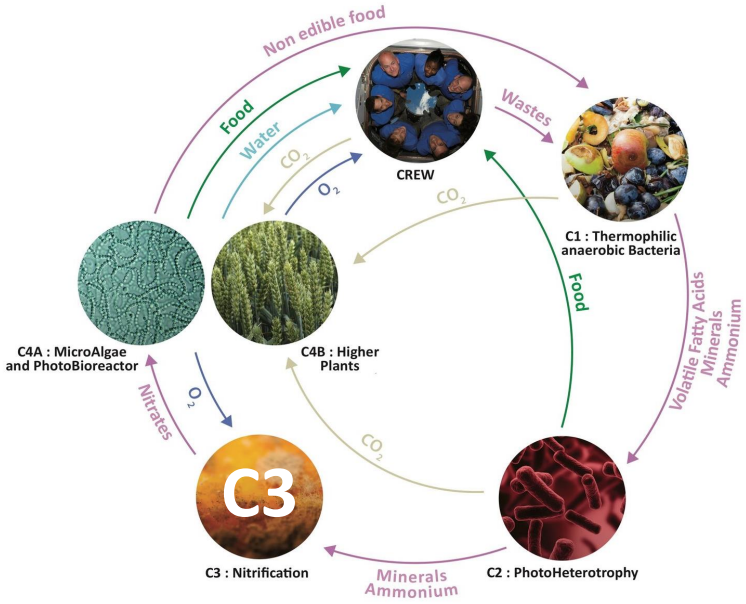




Compartment 3

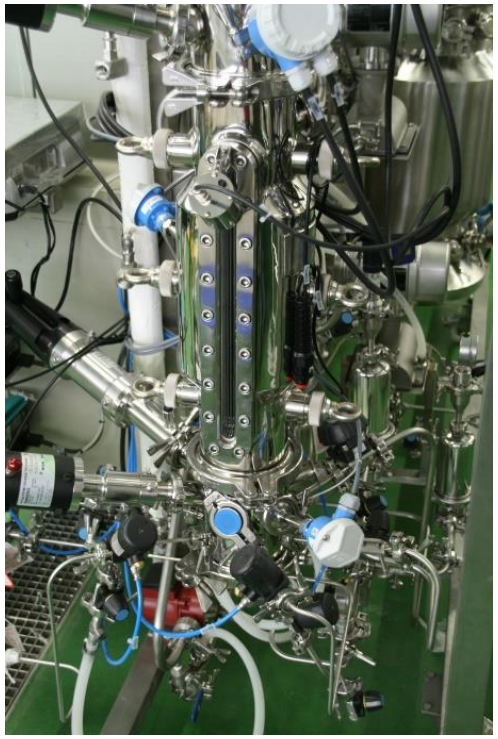
Nitrification

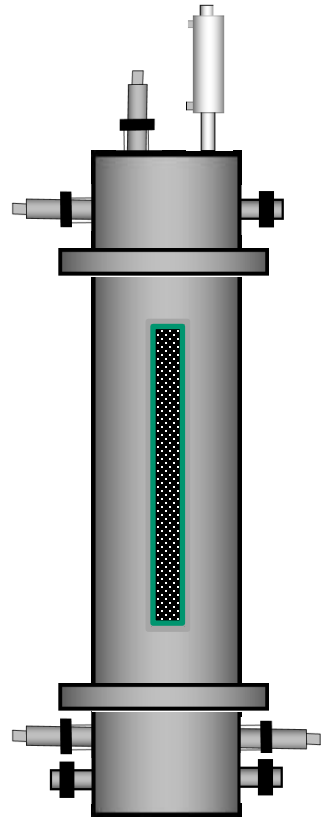




Nitrosomonas europaea and *Nitrobacter winogradsky* (axenic co-culture, aerobic)

Packed-bed bioreactor





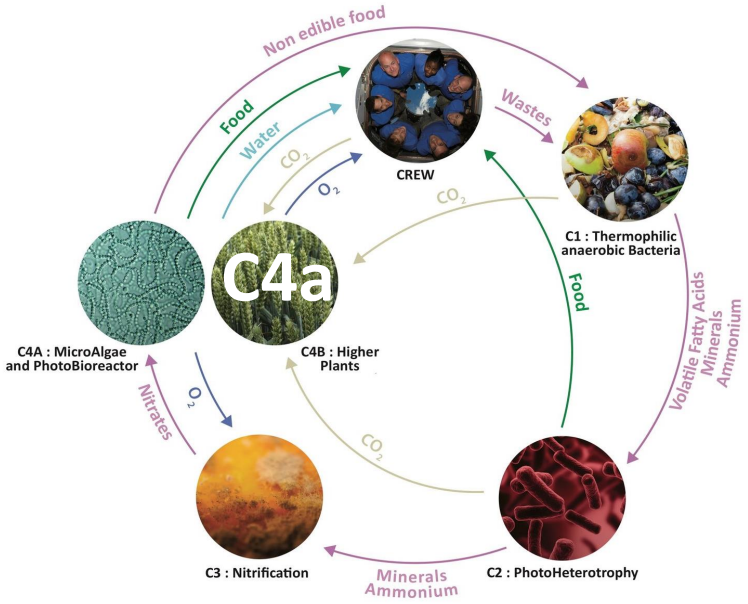
Compartment 4a

Oxygen and Food production

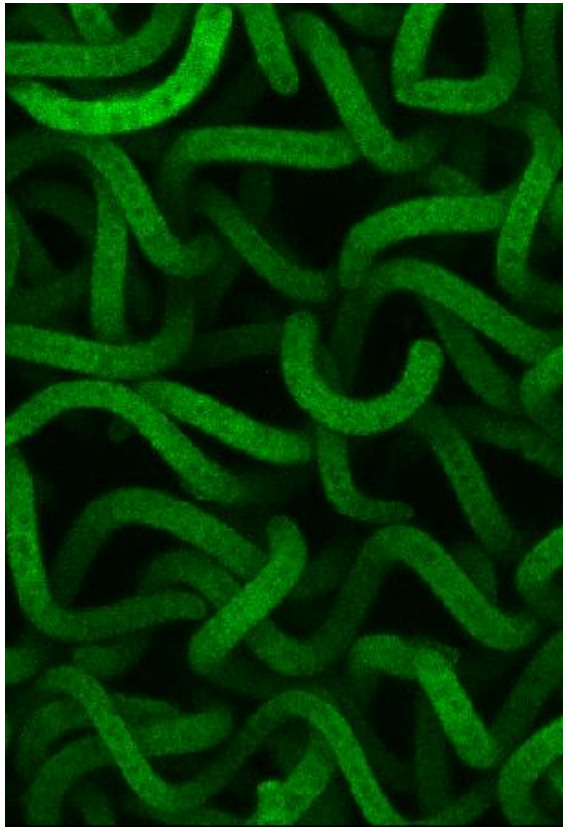
Light
CO_2

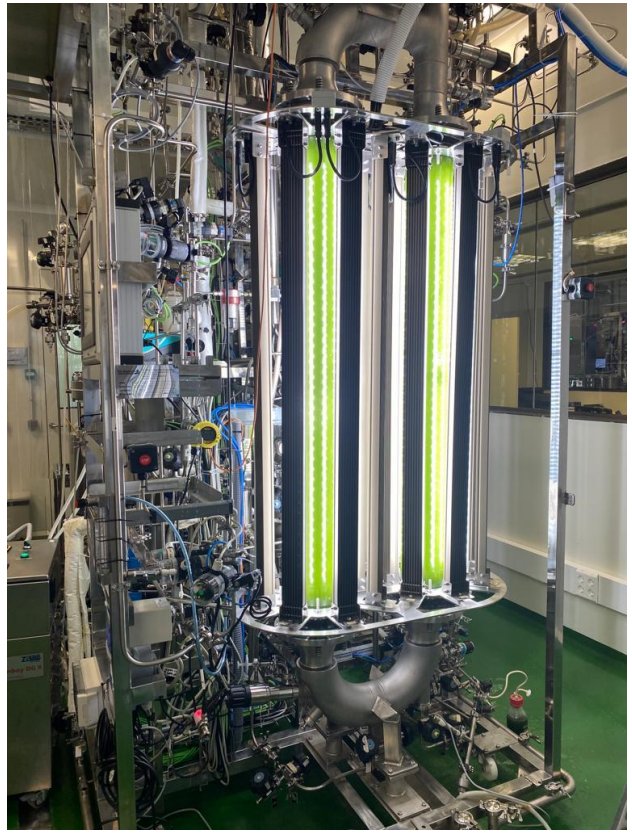
→ **C4a** →

Biomass
O_2



Limnospira indica, also known as Arthrospira platensis (axenic culture)

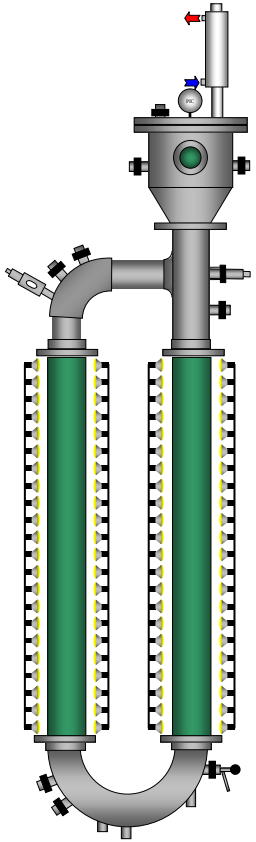




Photobioreactor

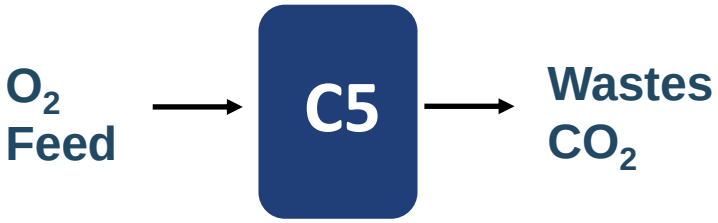
INTRAVISION

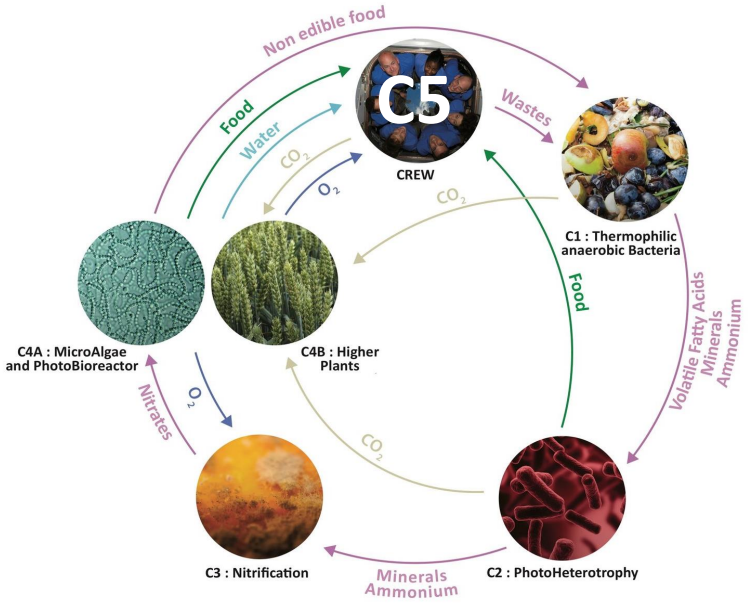
De Dietrich PROCESS SYSTEMS



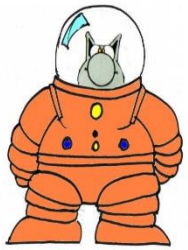
Compartment 5

Crew mock-up



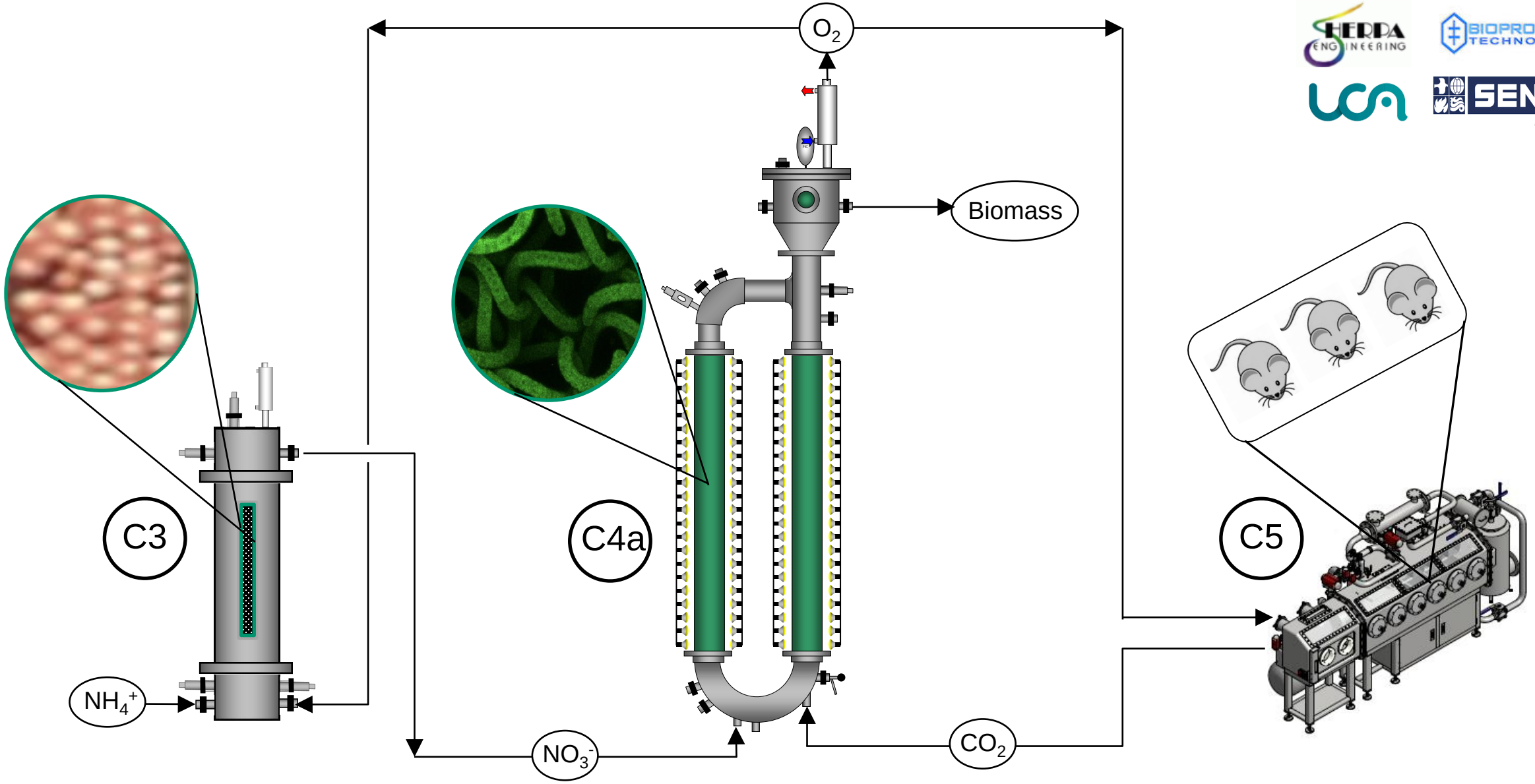


Wistar rats



Animal isolator

Integration of C3 + C4a + C5, gas and liquid

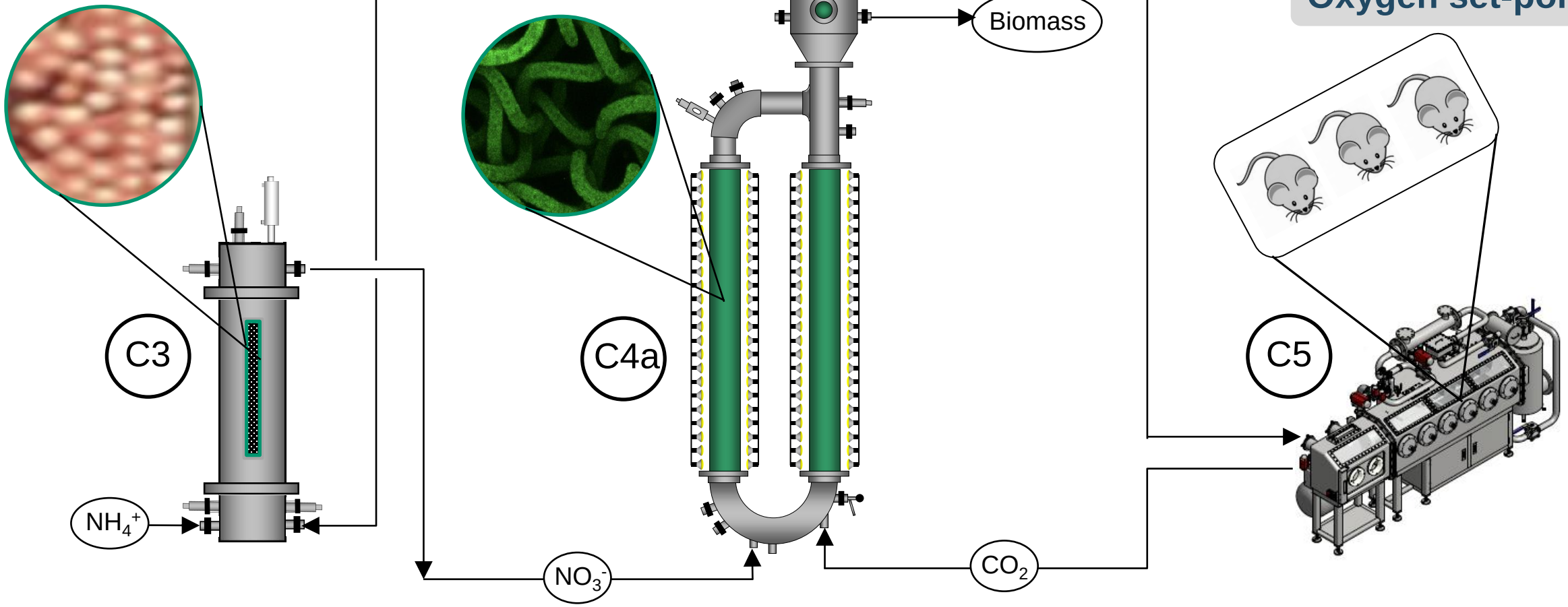


Integration of C3 + C4a + C5, gas and liquid

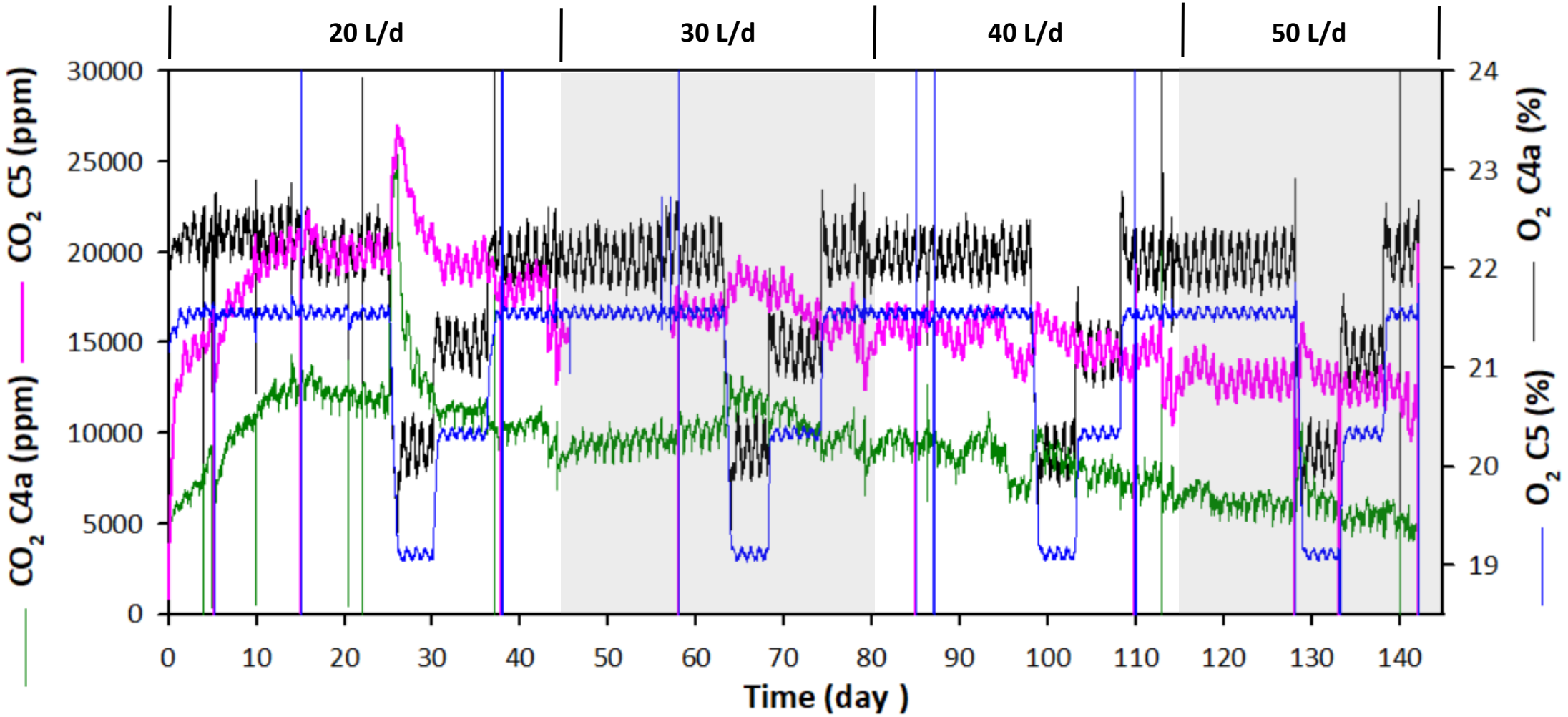
Ammonium loads:
mode 1, low
mode 2, high

Operation flow-rates

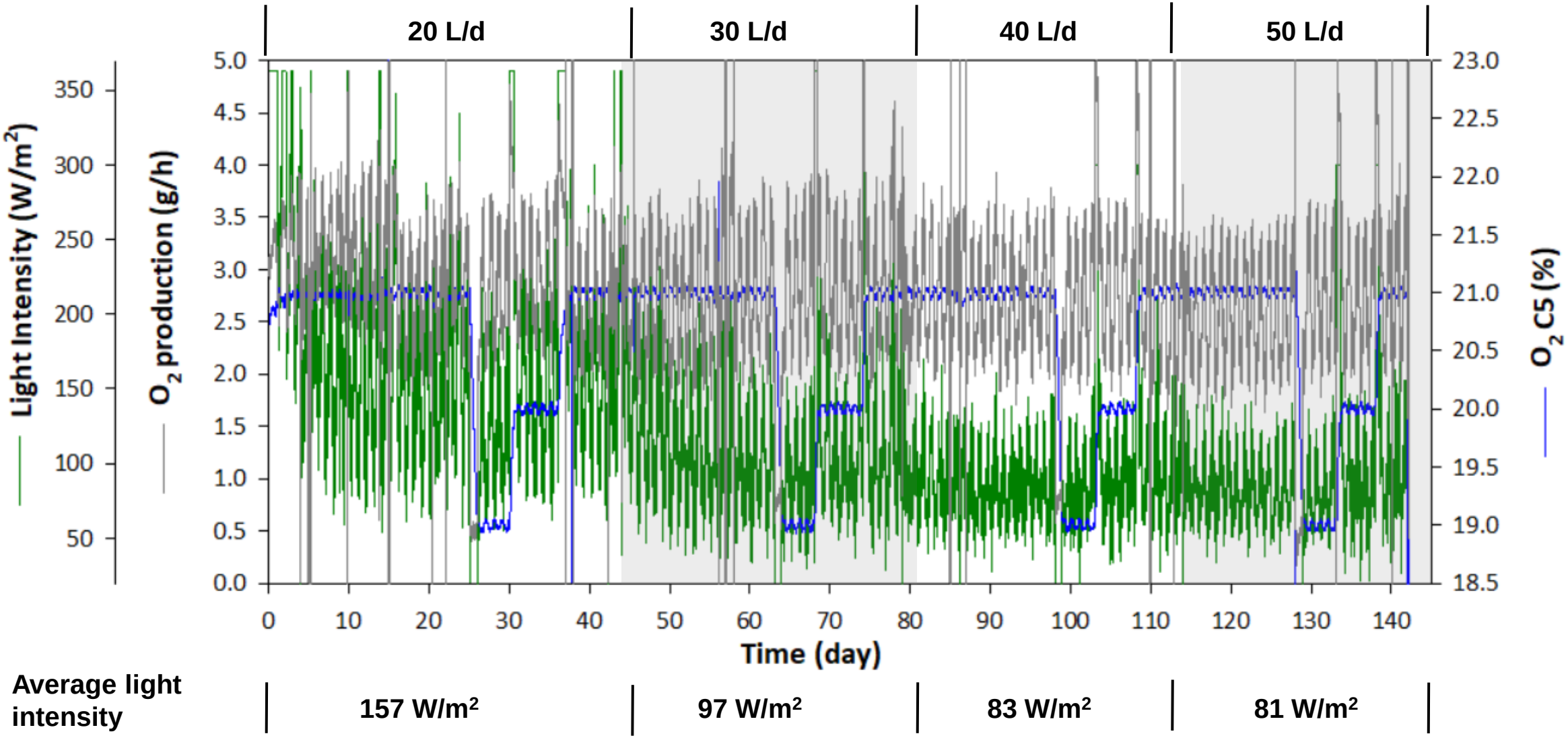
Oxygen set-points



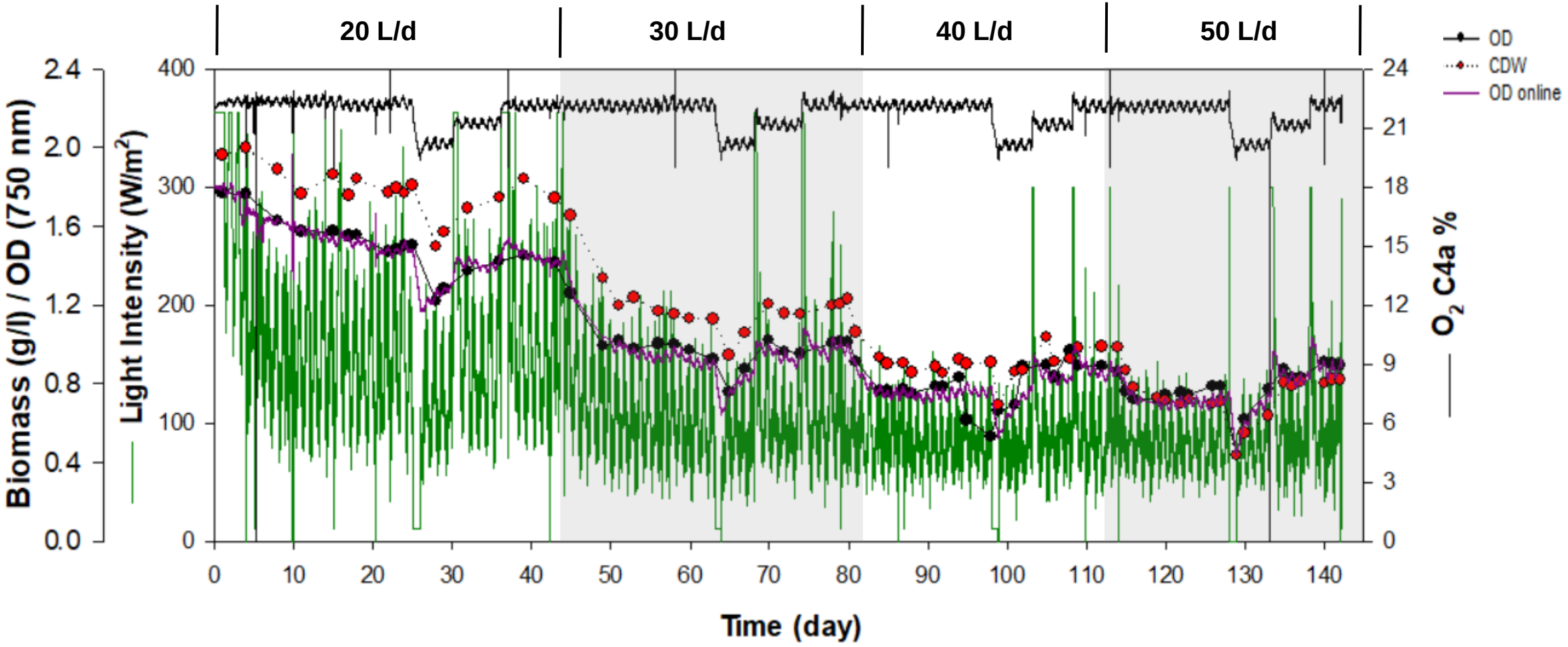
Mode 1: C4a and C5 O_2 and CO_2 in gas



Mode 1: C4 O_2 production and illumination

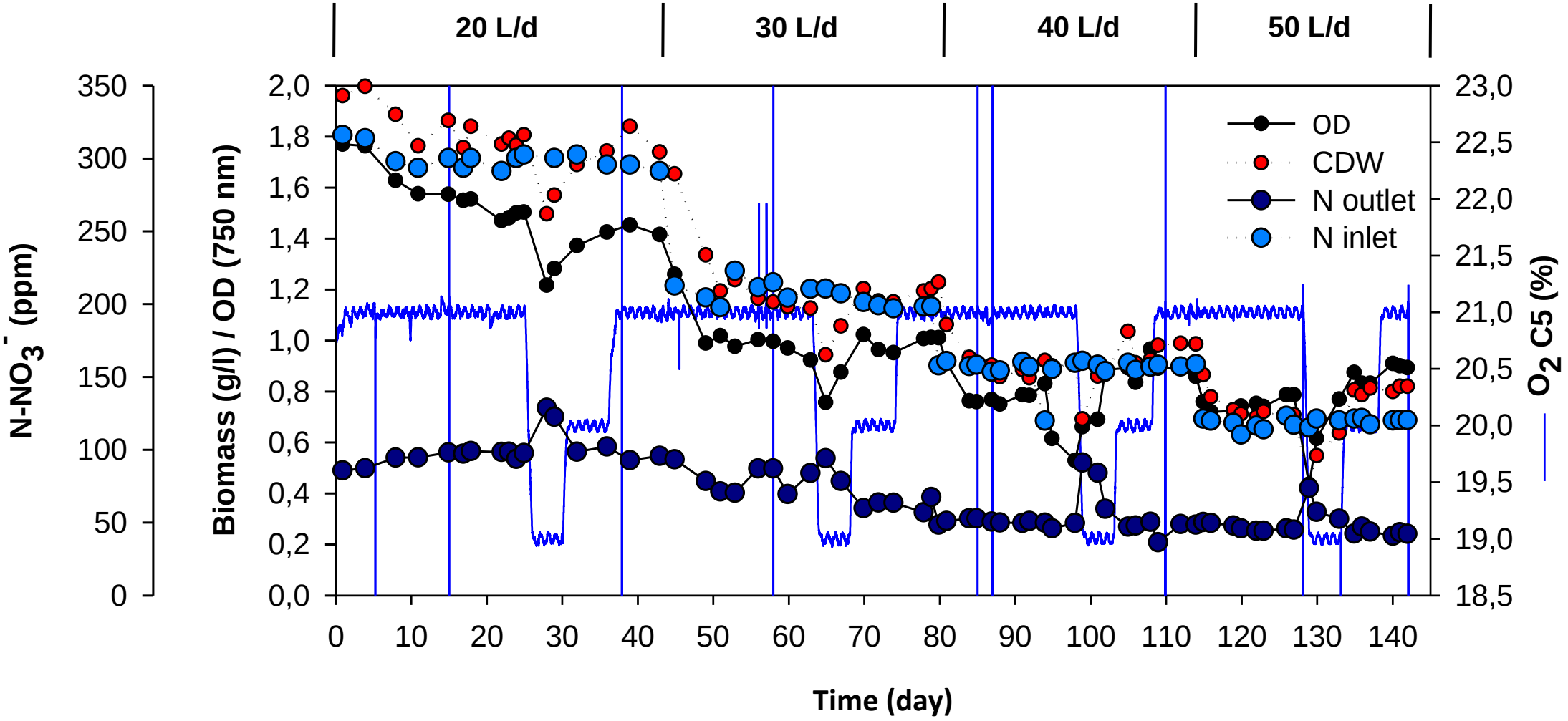


Mode 1: C4a Biomass evolution

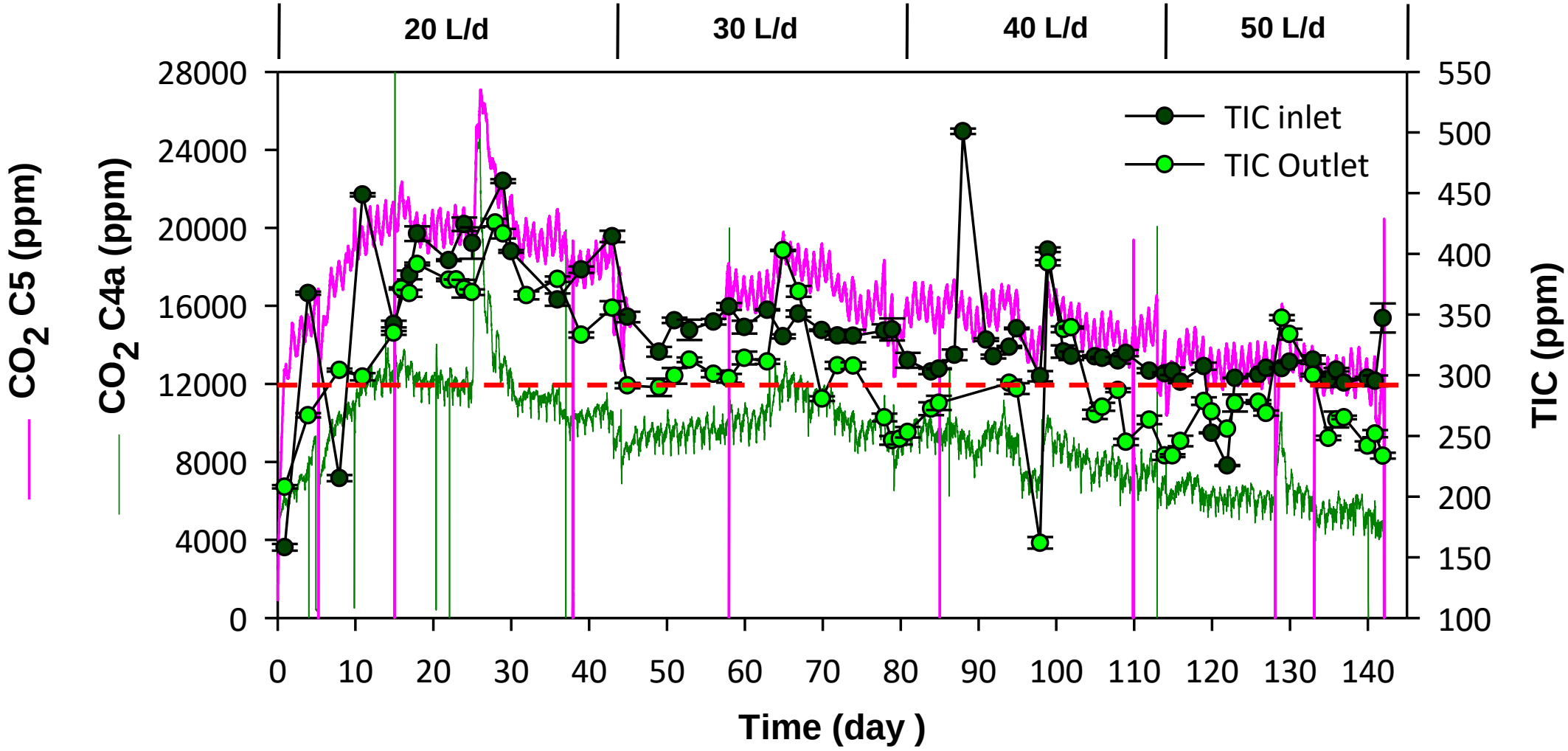


Average Biomass	1.79 g/L	1.15 g/L	0.90 g/L	0.71 g/L

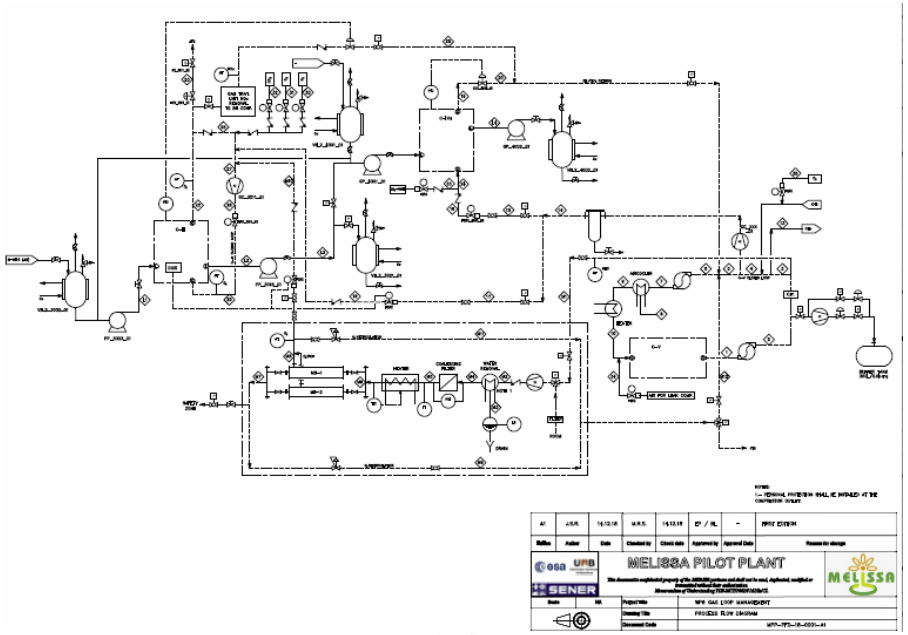
Mode 1: Nitrogen in C4a liquid

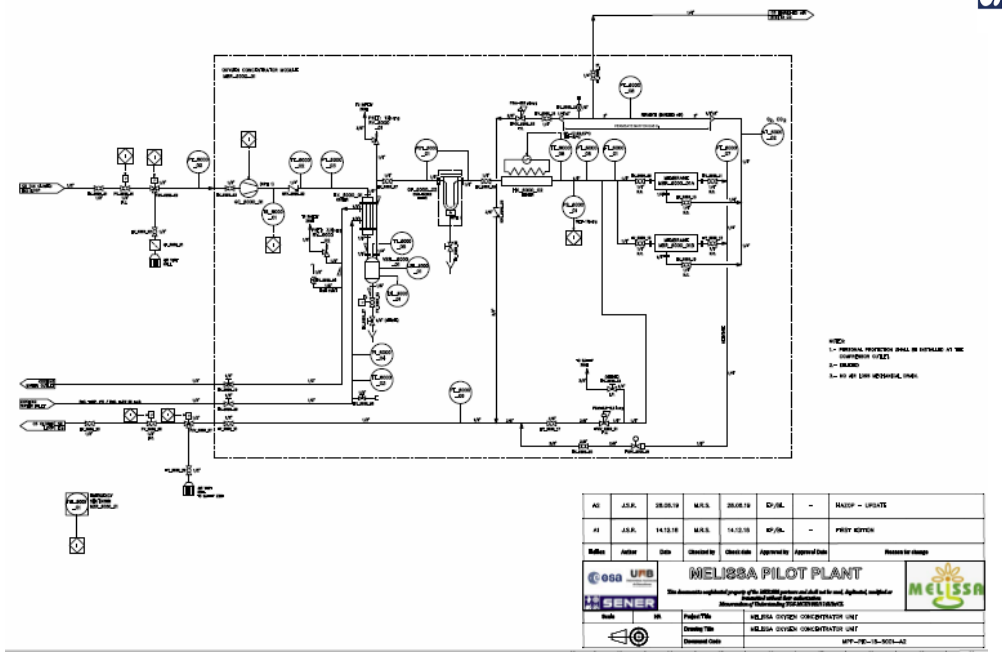


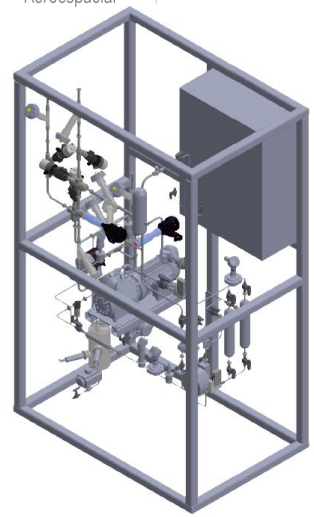
Mode 1: Carbon in C4a liquid

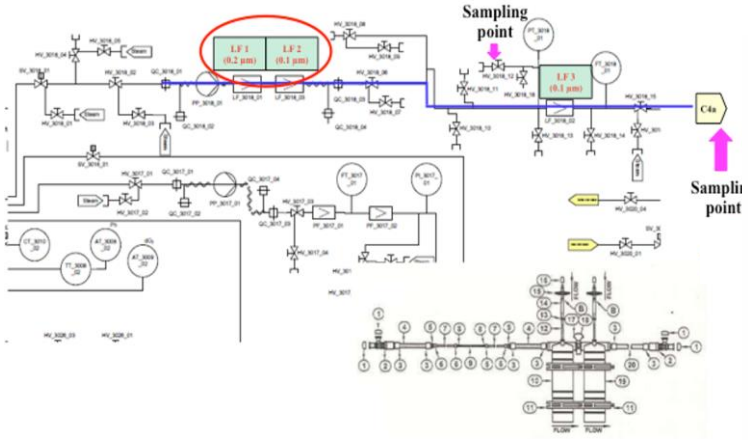


Enrichement of O_2 in gas phase for Mode 2



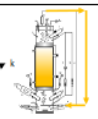






INPUTS

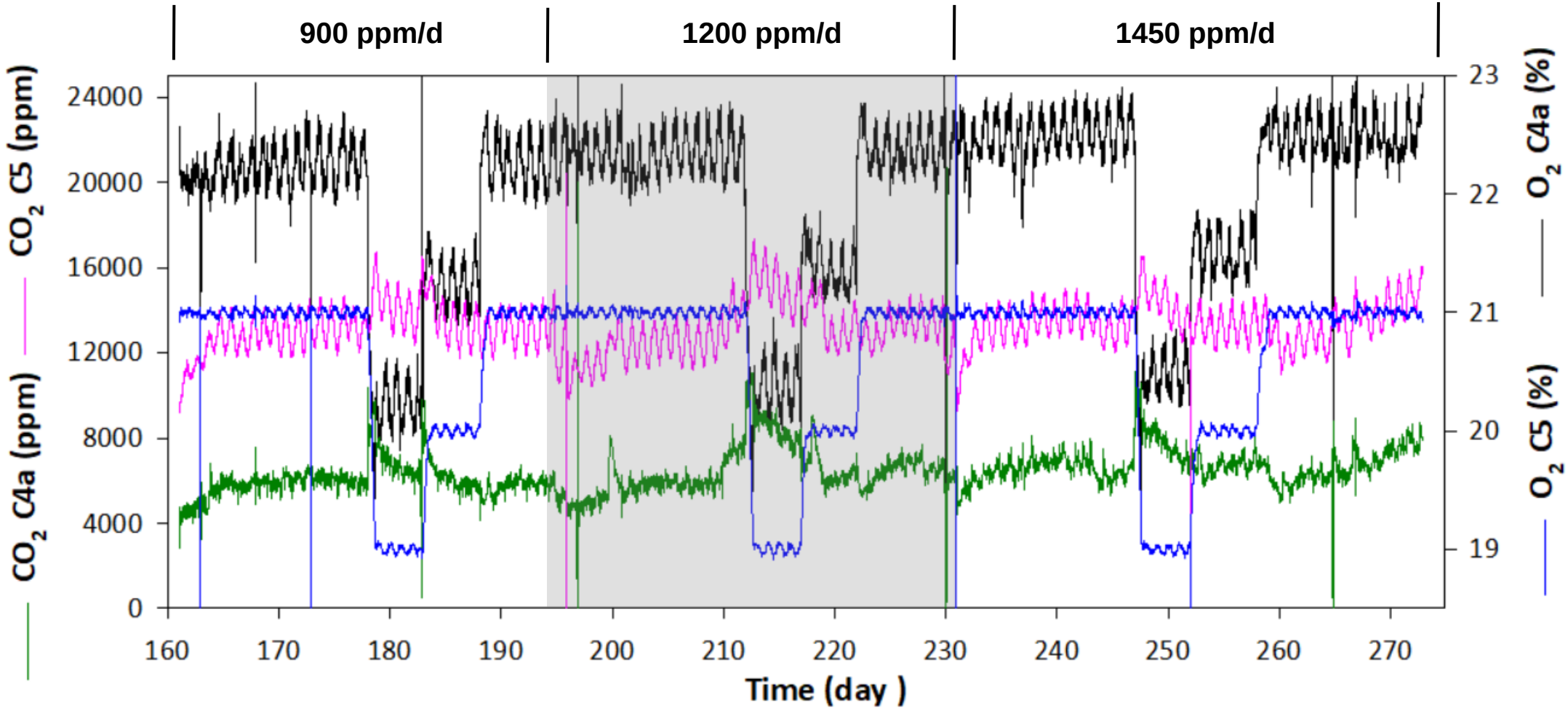
C3 Volume (L)	7
C3 Temperature (ºC)	30
C3 Pressure (mbarg)	80
C^*_{DOL} (AIR, 30ºC) (g/L)	0.00757
Weight kLa TOP Section (%)	85



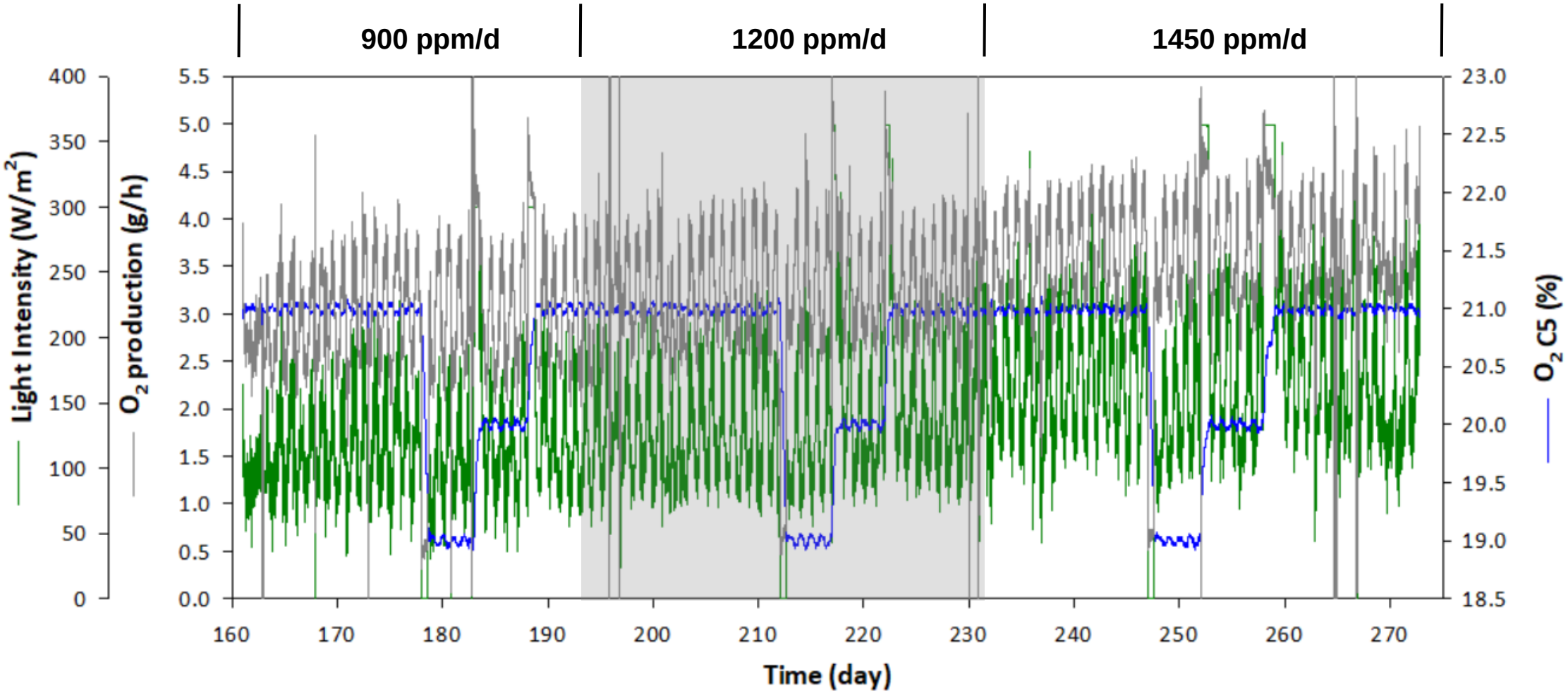
	N°	MODE *	C3 Feed Load (ppm/d)	C3 Actual Load (ppm/d) Conv.:93.3%	Total Air flowrate (L/min)	k_La TOP (1/h)	k_La LOWER (1/h)	(% mol/mol) O_2 C3 Gas Phase	C^*_{DOL} Interface Disolved O_2 equilibr. C3 (g/L)	DO %	C_{DOL} Disolved O_2 Aqueous Bulk C3 (g/L)	TOP SECTION R_{O2} O_2 transfer rate to liquid (gO_2/L.h)	TOP SECTION N_{O2} O_2 transfer flow gas to liquid ($gO2$/h)	LOWER SECTION R_{O2} O_2 transfer rate to liquid (gO_2/L.h)	LOWER SECTION N_{O2} O_2 transfer flow gas to liquid (gO_2/h)	TOTAL TOTAL N_{O2} TOTAL O_2 trans. flow gas to liquid (gO_2/h)	MATERIAL BALANCE O_2 consumption by Bacteria (gO_2/h)
NORMAL OPERATIONAL CONDITIONS	1	MODE 1	367	342	3.0	31.995	52.785	19.8	0.00800	80	0.00605	0.06245	0.37155	0.10302	0.10817	0.4797	0.4579
	2	MODE 2	608	567	3.0	31.995	52.785	24.0	0.00971	80	0.00605	0.11710	0.69675	0.19319	0.20285	0.8996	0.7593
MODE 1 DESIGN CASE	3	MODE 1	251	235	3.0	31.995	52.785	18.5	0.00742	80	0.00605	0.04372	0.26013	0.07213	0.07573	0.3359	0.3140
	4	MODE 1	486	453	3.0	31.995	52.785	21.3	0.00855	80	0.00605	0.07992	0.47554	0.13186	0.13845	0.6140	0.6062
	5	MODE 2	1286	1199	3.0	31.995	52.785	32.0	0.01288	80	0.00605	0.21847	1.29992	0.36044	0.37846	1.6784	1.6046
MEMBRANE DESIGN CASE	6	MODE 2	1714	1599	3.0	31.995	52.785	38.0	0.01520	80	0.00605	0.29264	1.74119	0.48279	0.50693	2.2481	2.1380

(*) MODE 1: LOW N LOAD MODE ; MODE 2: OXYGEN CONCENTRATION

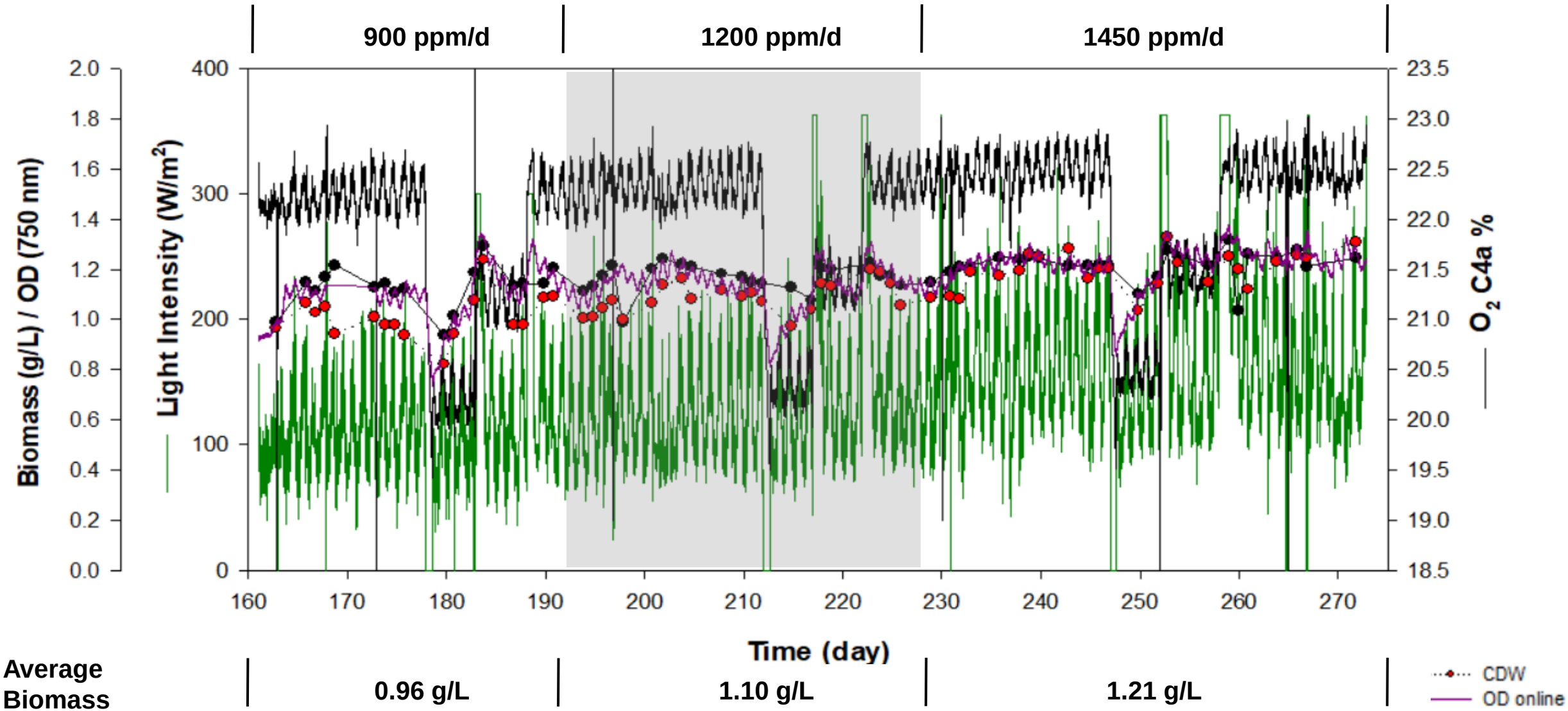
Mode 2: C4a and C5 O_2 and CO_2 in gas



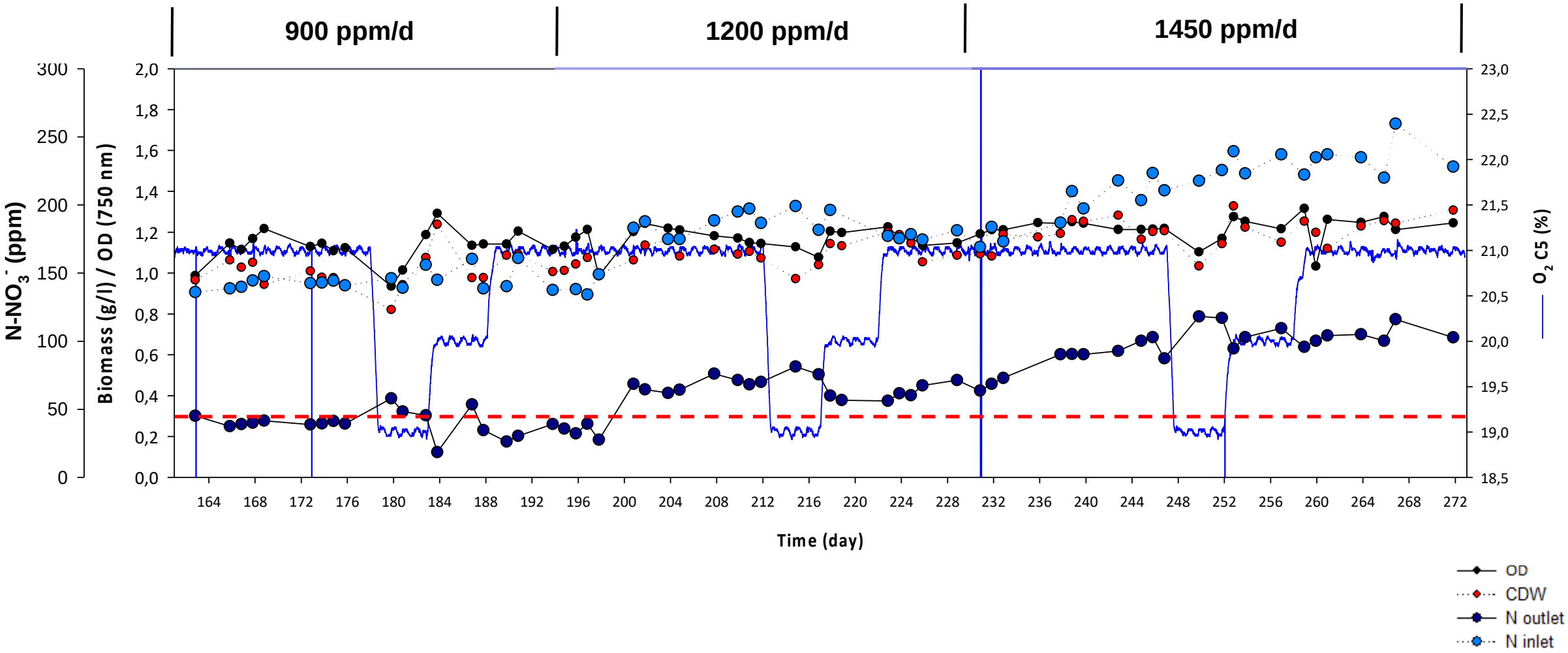
Mode 2: C4 O_2 production and illumination



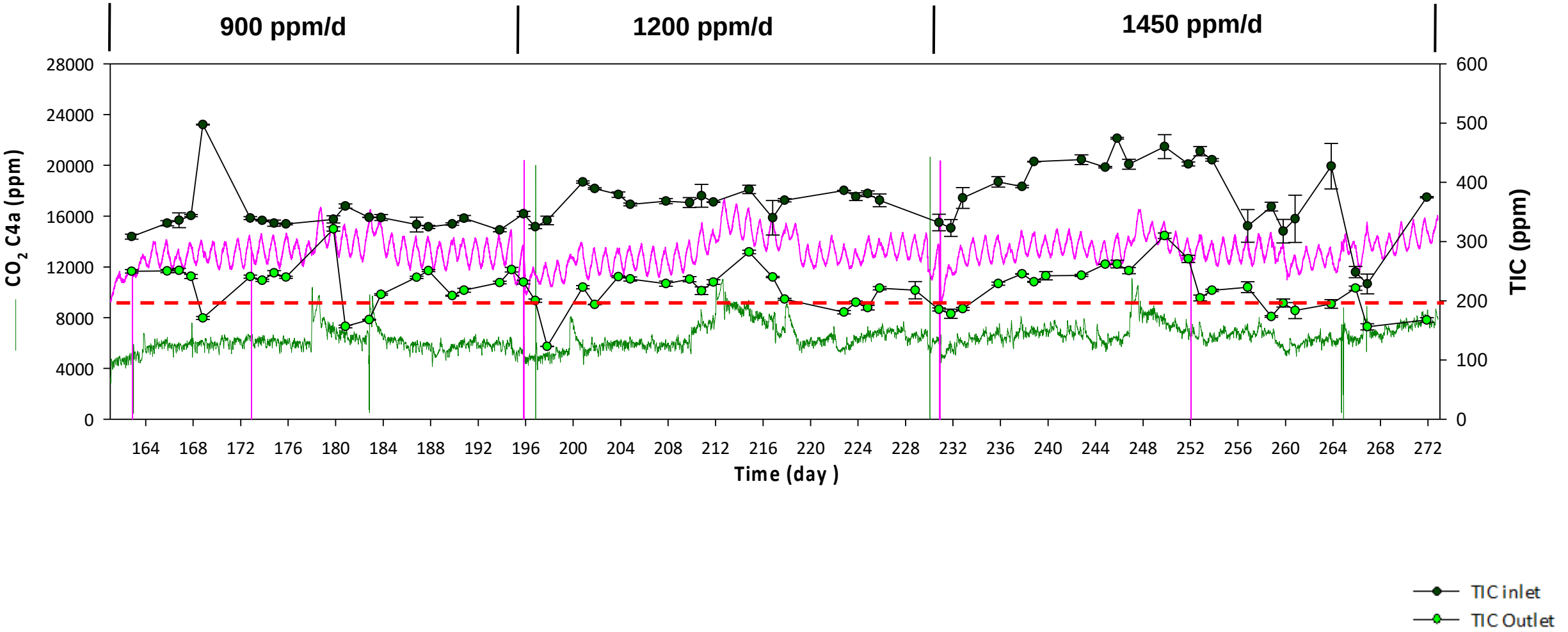
Mode 2: C4a Biomass evolution



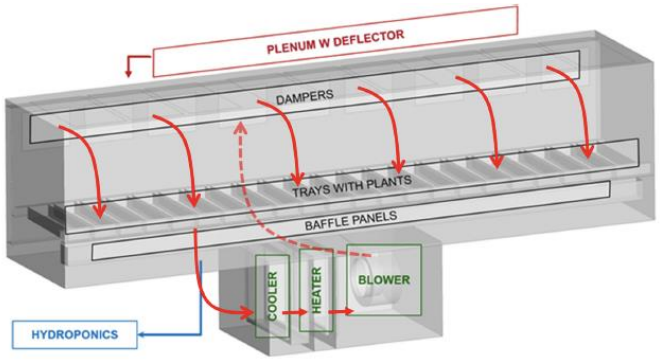
Mode 2: Nitrogen in C4a liquid

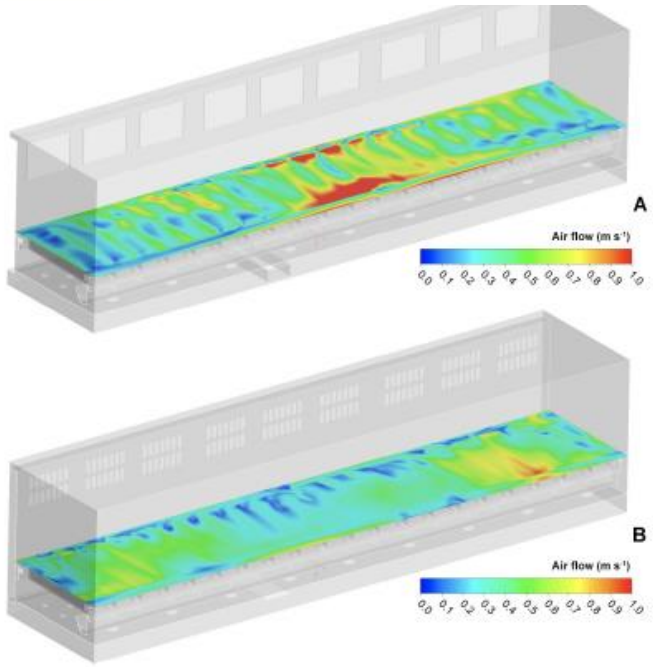


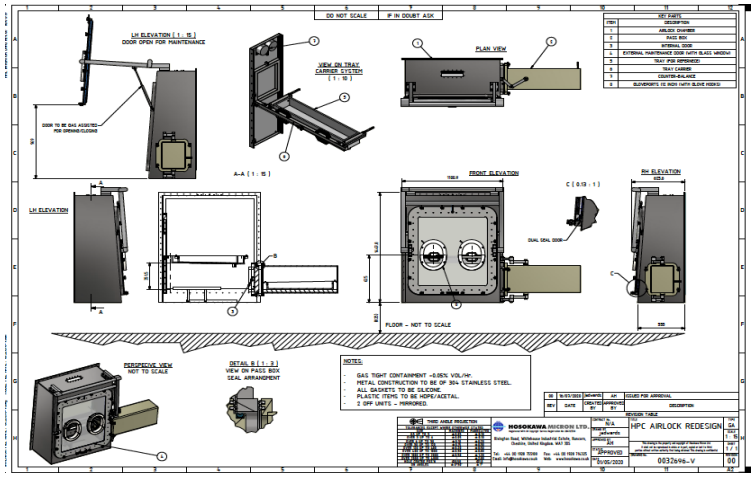
Mode 2: Carbon in C4a liquid

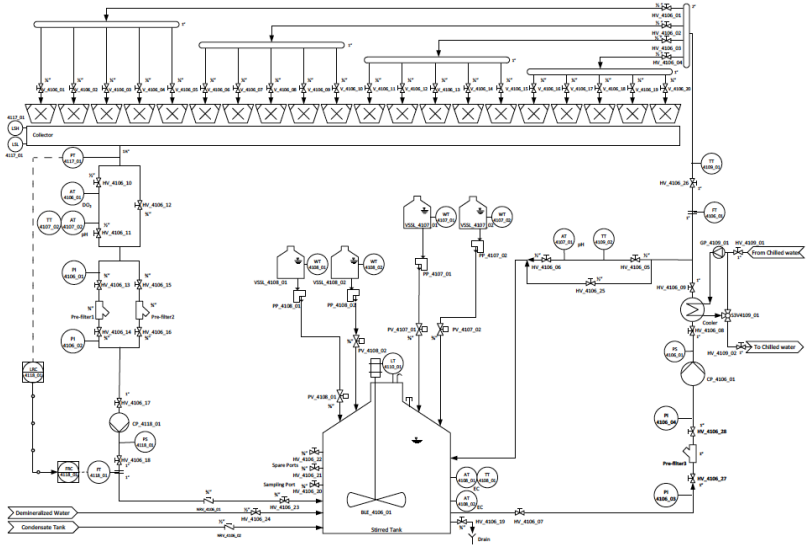


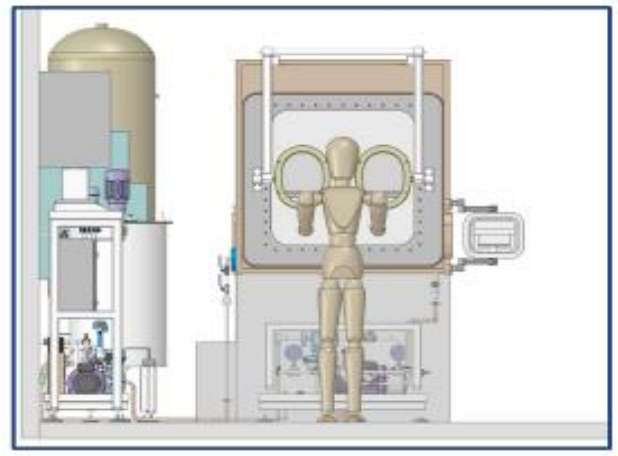
Compartment C4b upgrade

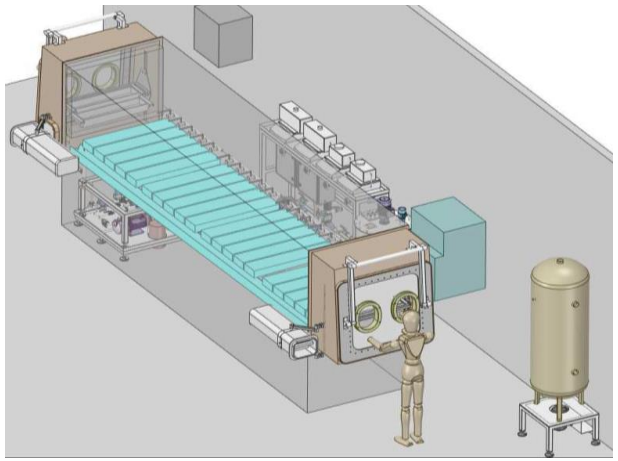




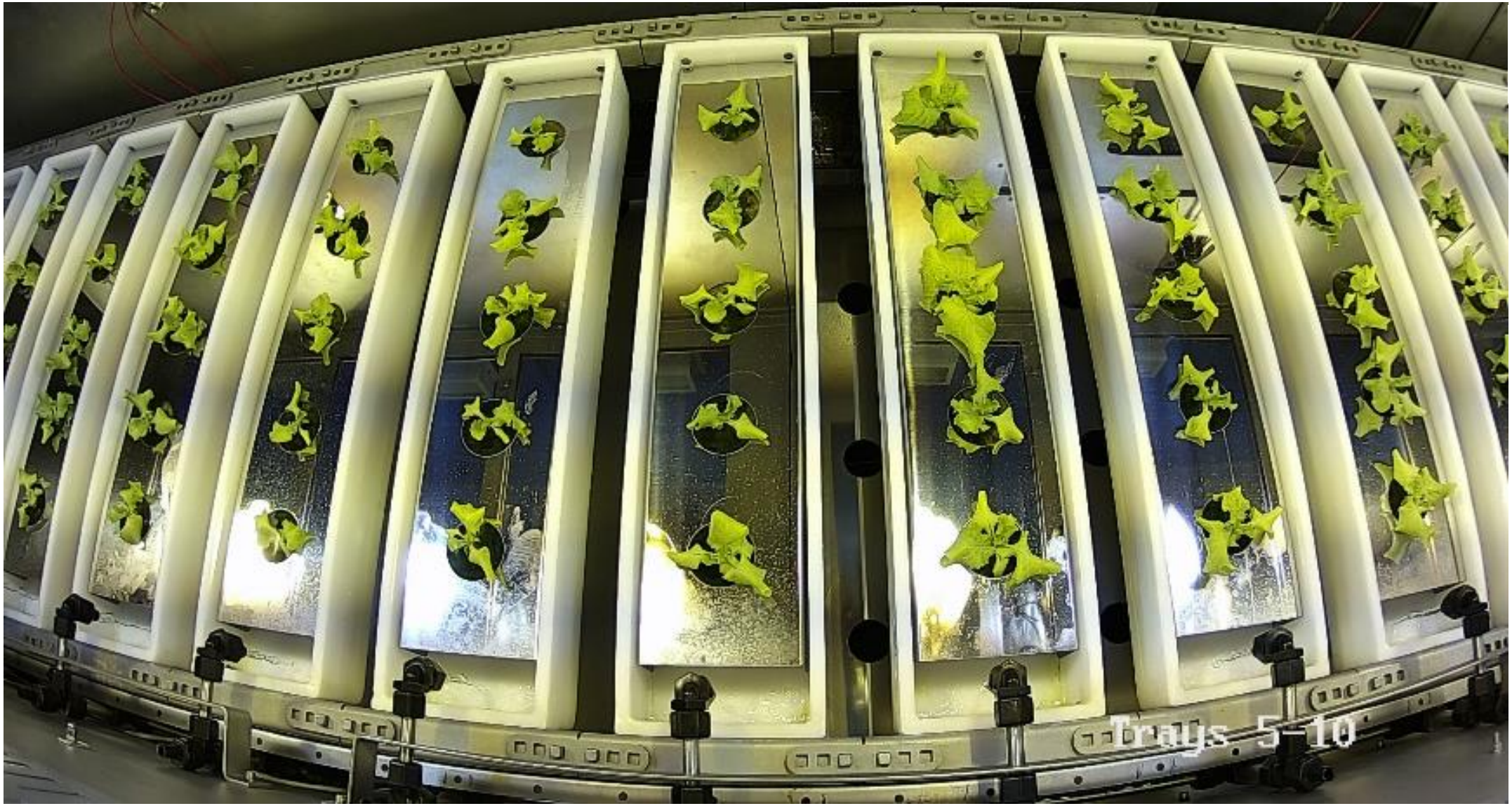








Compartment C4b: batch culture



Compartment C4b: batch culture

Compartment C4b: staggered culture

Number of days in the HPC

H/T every 7 days	7	7	7	7	7	14	14	14	14	14	21	21	21	21	21	28	28	28	28	28
	Age of plants in HPC																			
9 days old seedling	16	16	16	16	16	23	23	23	23	23	30	30	30	30	30	37	37	37	37	37

Compartment C4b: staggered culture




Carol Arnau presentation on HPC characterization (Day 2, Room 1)

Carles Ciurans presentation on HPC integration design (Day 2, Room 3)

Integration of MPP: next steps

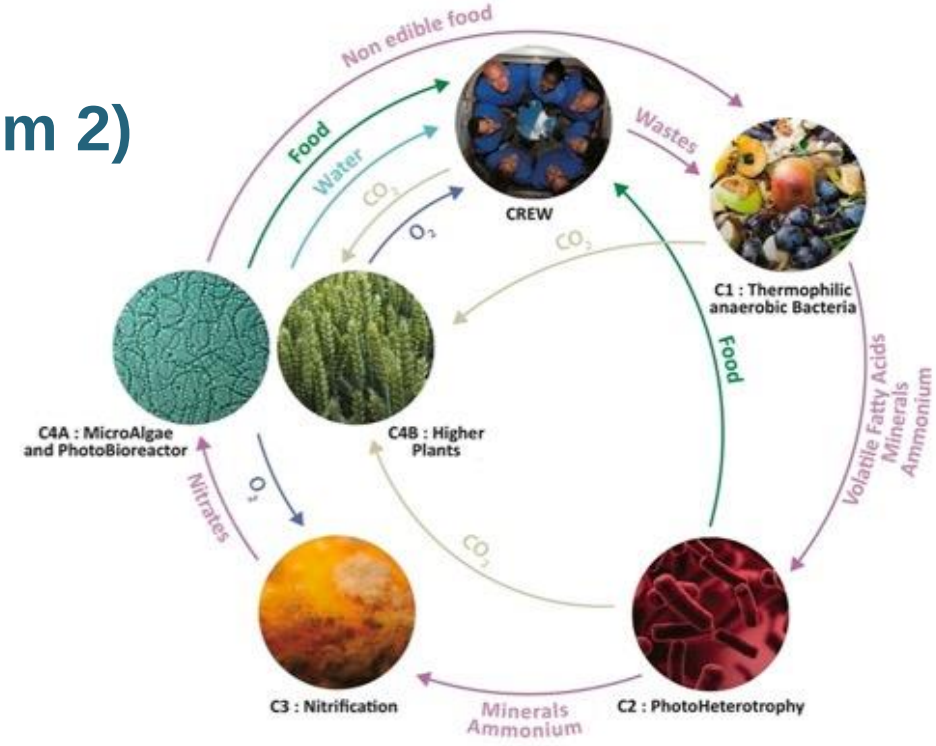
Integration of Higher Plant Chamber (gas and liquid phase)

Operation with urine (Carol Arnau, Day 3, Room 2)

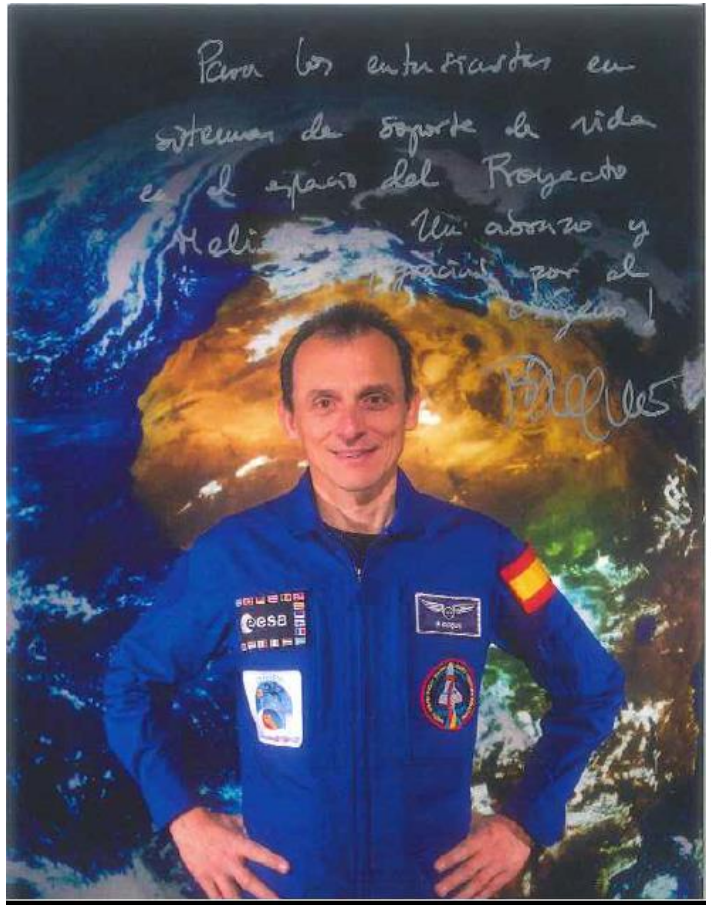
Harvest system for *Limnospira indica*

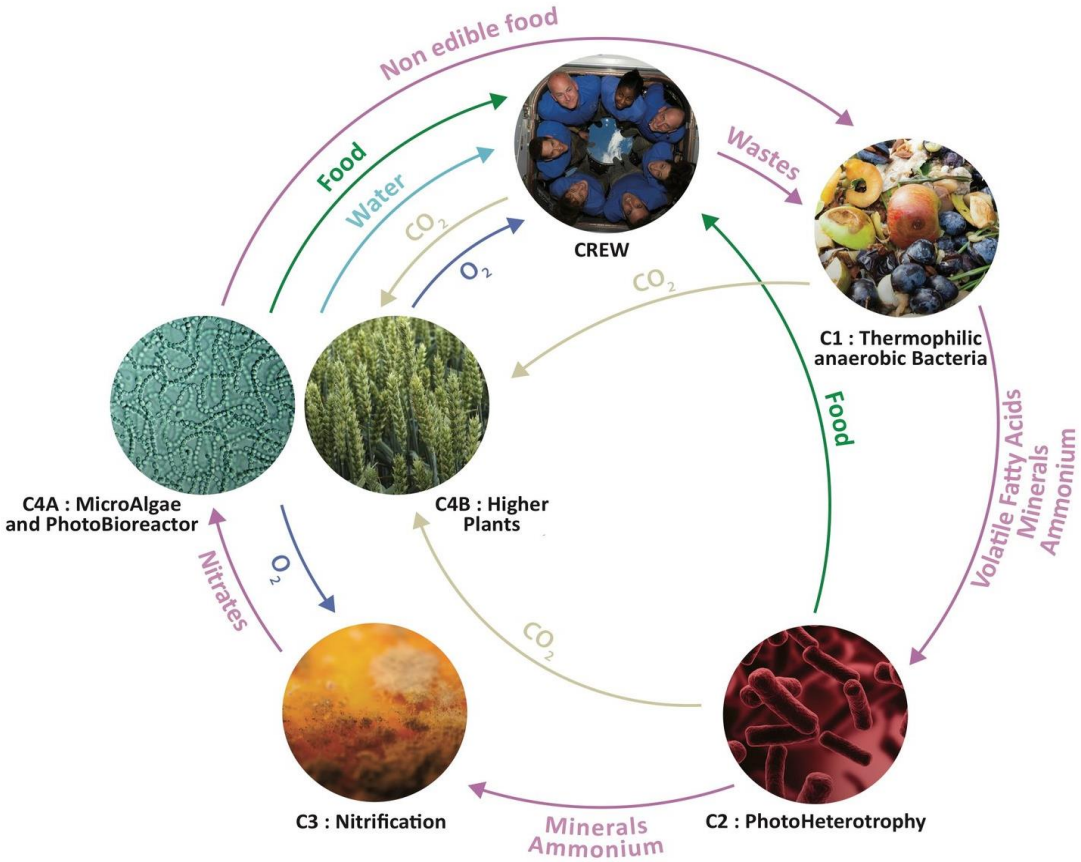
Integration of waste degradation technology

Final demonstration of the complete loop



Evolution to a Human Rated Falicity





Evolution to a Human Rated Falicity

Full demonstration of MELiSSA technology with humans in the loop

Integration and testing of additional technologies

Partnering with other relevant actors in the field

Become a reference facility for regenerative LSS ground demonstration with humans

Progressive scenarios of closure, from more simple to more complex

Safety for humans and risk assessment. Assessment by CNES experts and follow-up by an Ethical Committee

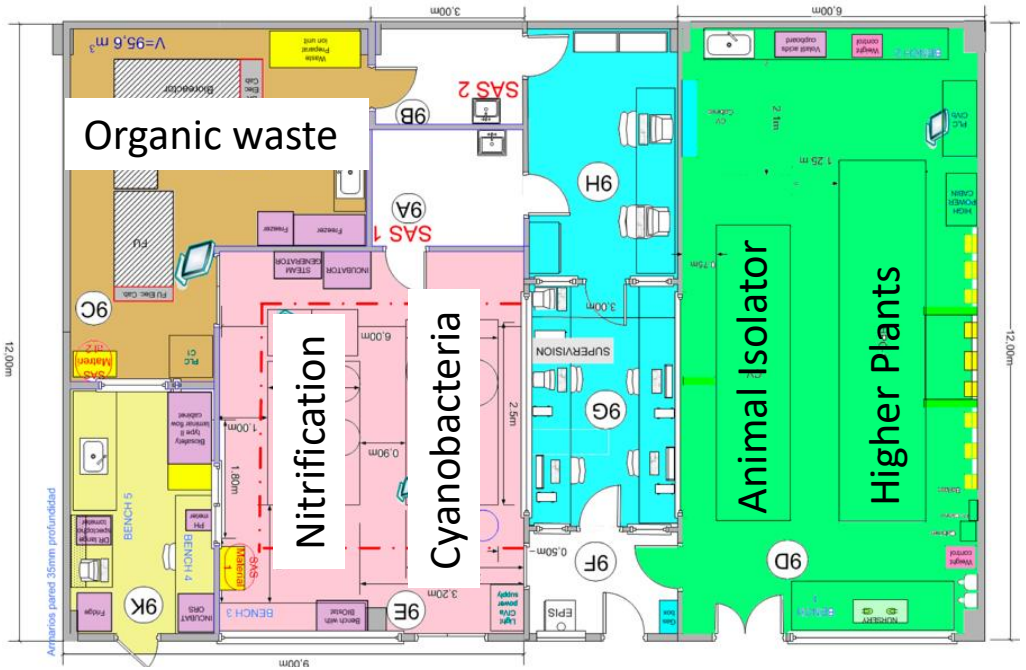
Isolation campaigns simulating the conditions of a human Space mission

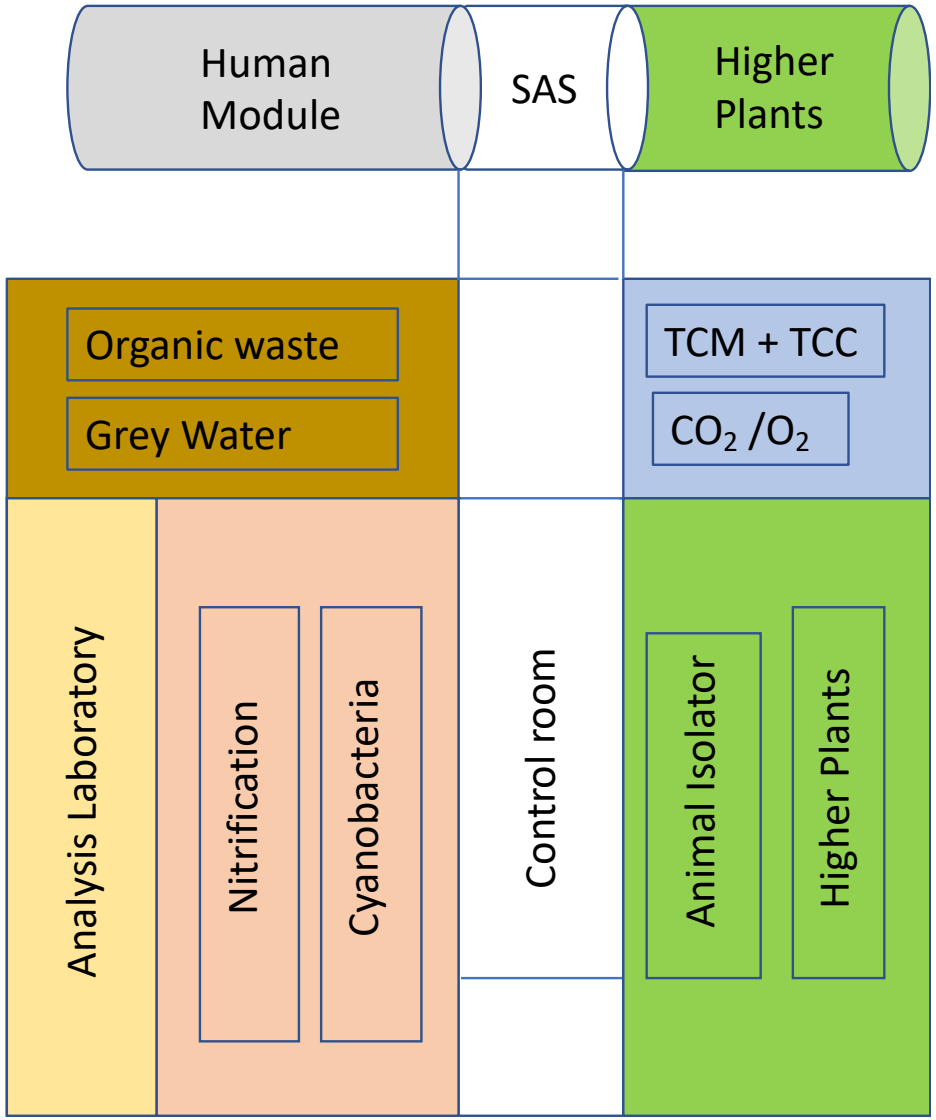
Feeding of the human based on MELiSSA recipies

Monitoring of human physiology and health

Call for “MELiSSA Astronauts”: increase public interest in MELiSSA

Evolution to a Human Rated Falicity





Evolution to a Human Rated Falicity

Schedule

Activity	Year 1		Year 2		Year 3	
Enlargement of the Pilot Plant Laboratory						
Intensification of hardware: new nitrification compartment						
intensification of hardware: new microalgae compartment						
Gas interface (O2/CO2 capture/enrichement)						
Human habitat module						
Habitat HVAC and appliances						
Higher Plants module						
Trace Contaminants Monitoring and Control						
Health monitoring						
Control and supervision system						
Interfaces with MPP core facility						

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MELiSSA Pilot Plant Team

Enrique Peiro
Beatriz Iribarren
Carolina Arnau
Vanessa García
Cynthia Munganga
Marcel Vilaplana
Carles Ciurans
Cristian Eslava
Daniella Emiliani
Arnau Vizcarra

Laia Vulart
Helen Holzke
Arman Grumel
Joanna Kuzma

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MELiSSA: from concept to a solid reality through a collaborative effort

The MELiSSA Pilot Plant was dedicated
on April 26th, 2011 to

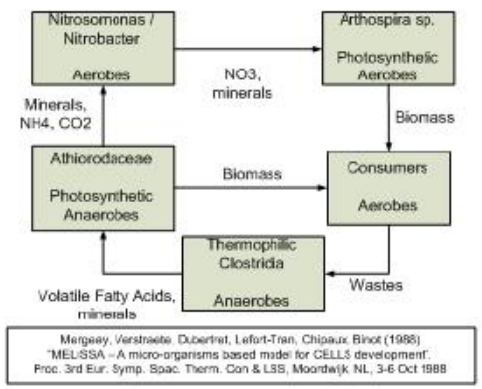
Claude Chipaux (1935-2010),

Founder of the MELiSSA Project,
As a tribute to his visionary and pioneering contribution
in the field of Closed Life Support Systems

"Sur la lune, il y a des enfants
Qui regardent la terre en rêvant.
- Croyez-vous qu'aussi loin
Il y ait des humains?"

"On the Moon are children
Who see the Earth and wonder.
- Could there be some human-kind
Far away, out yonder?"

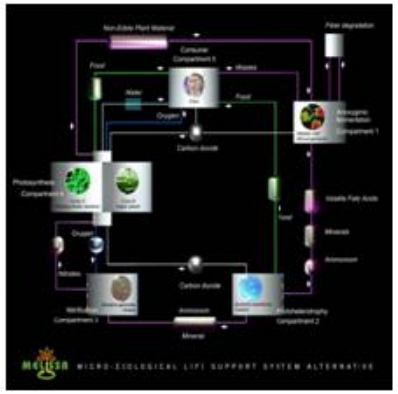
The first MELiSSA loop concept



Mergeay, Verstraete, Dubertret, Lefort-Tran, Chipaux, Binot (1988)
"MELISSA – A micro-organisms based model for CELLS development".
Proc. 3rd Eur. Symp. Space. Therm. Con & LSS, Moordwijk NL, 3-6 Oct 1988

The lake, a model ecosystem

The future MELiSSA loop...



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2022 MELISSA CONFERENCE
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THANK YOU.

Francesc Gòdia
MELiSSA Pilot Plant
Universitat Autònoma de Barcelona
francesc.godia@uab.cat

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