MELISSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

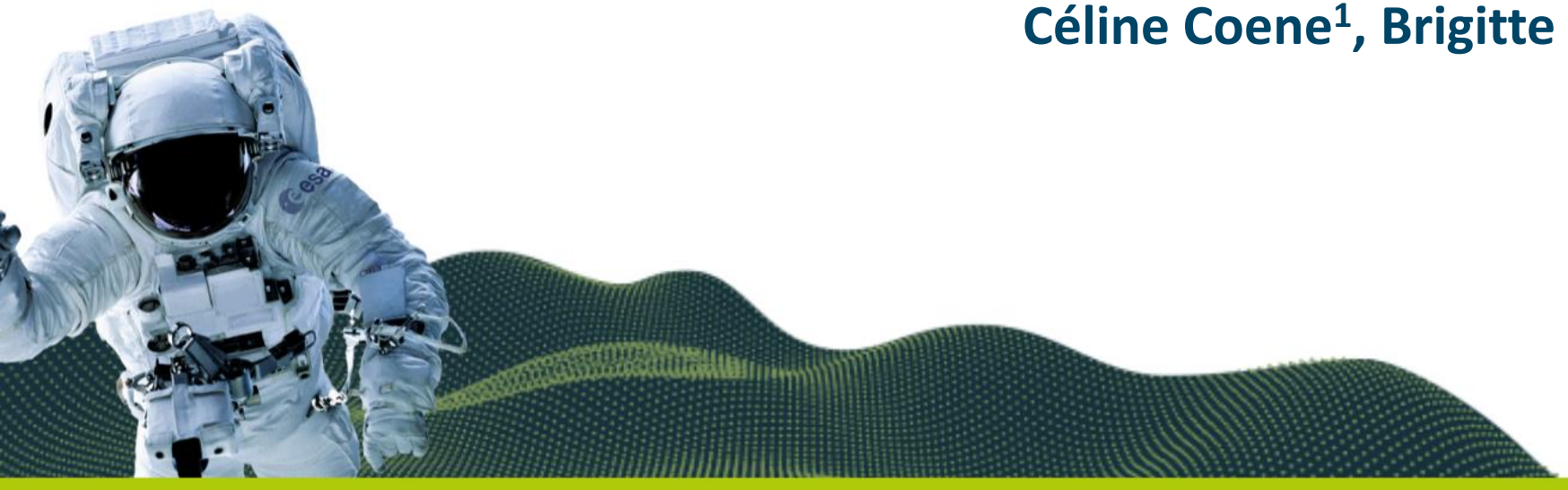
2022 MELISSA CONFERENCE
8-9-10 NOVEMBER 2022

CREATING A CIRCULAR FUTURE

Implementation of an automated process for a continuous *Limnospira* harvesting and the recycling of the culture medium for space applications

Dries Demey[1], Estelle Couallier[2], Jordan Tallec[2], Marie Vandermies[1], Céline Coene[1], Brigitte Lamaze[3], Christel Paille[3]

1. QinetiQ
2. GEPEA/Capacités
3. ESA



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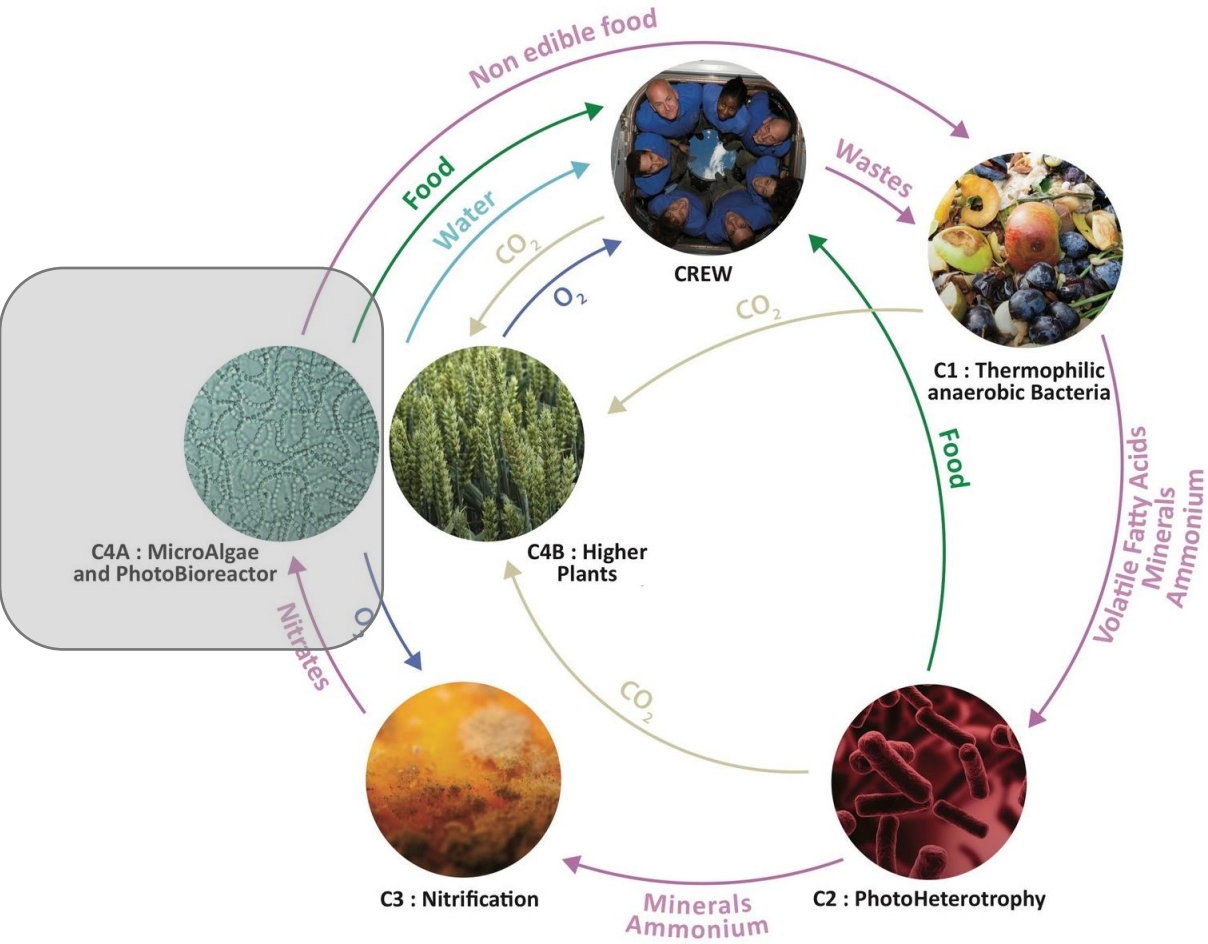

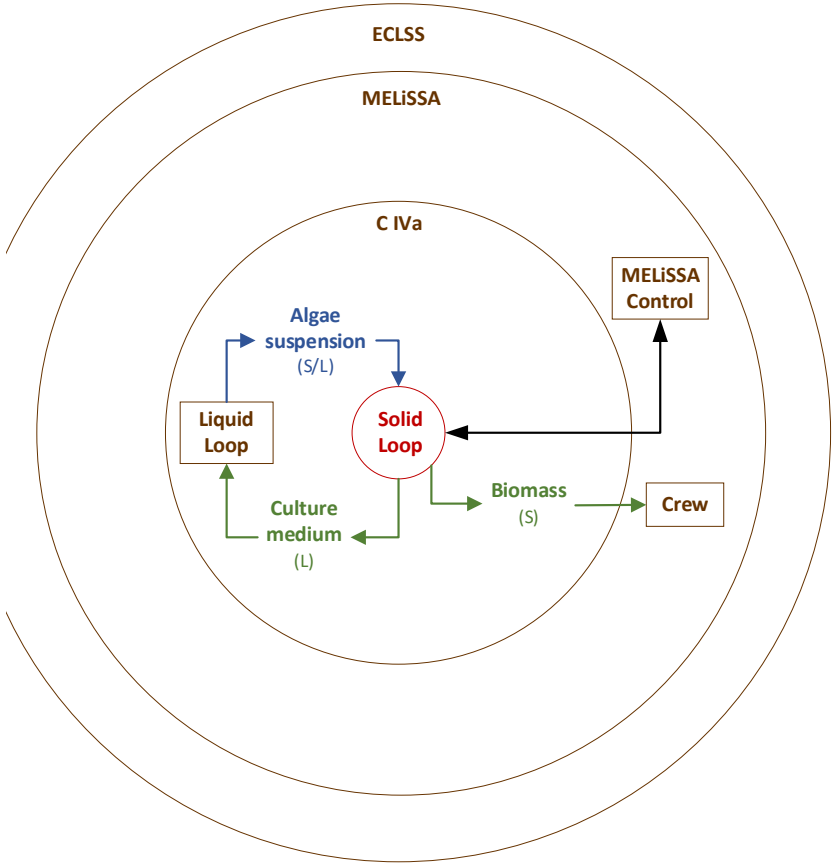

LEGEND

- System of interest
- Interacting system
- Input
- Output
- (L) Liquid
- (S) Solid

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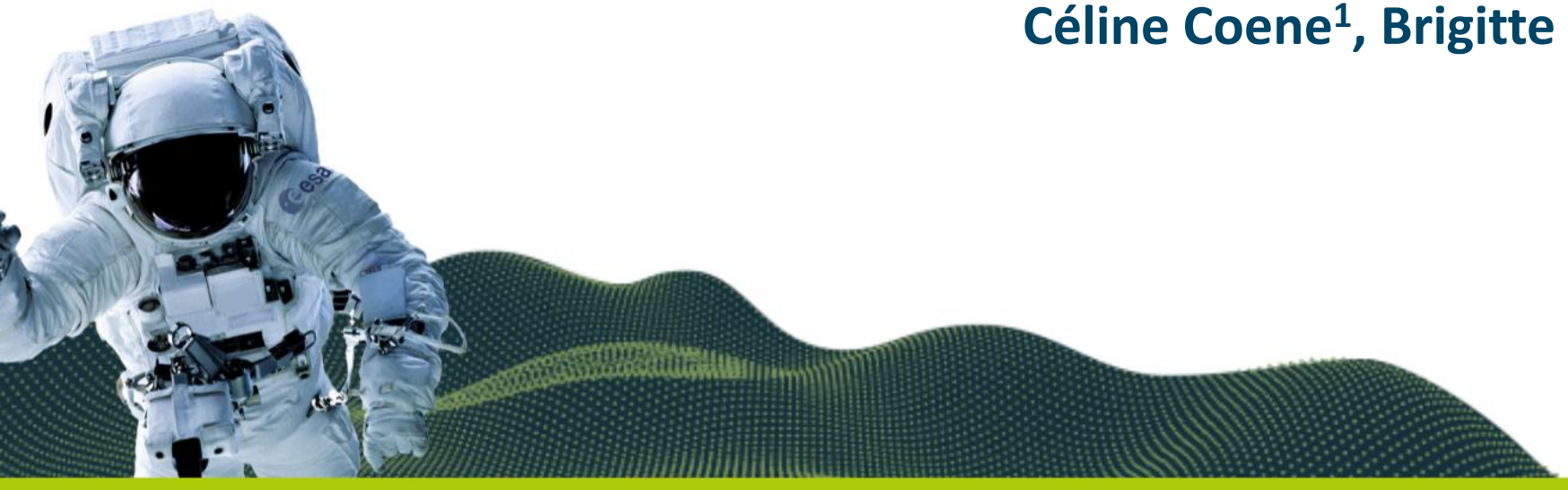

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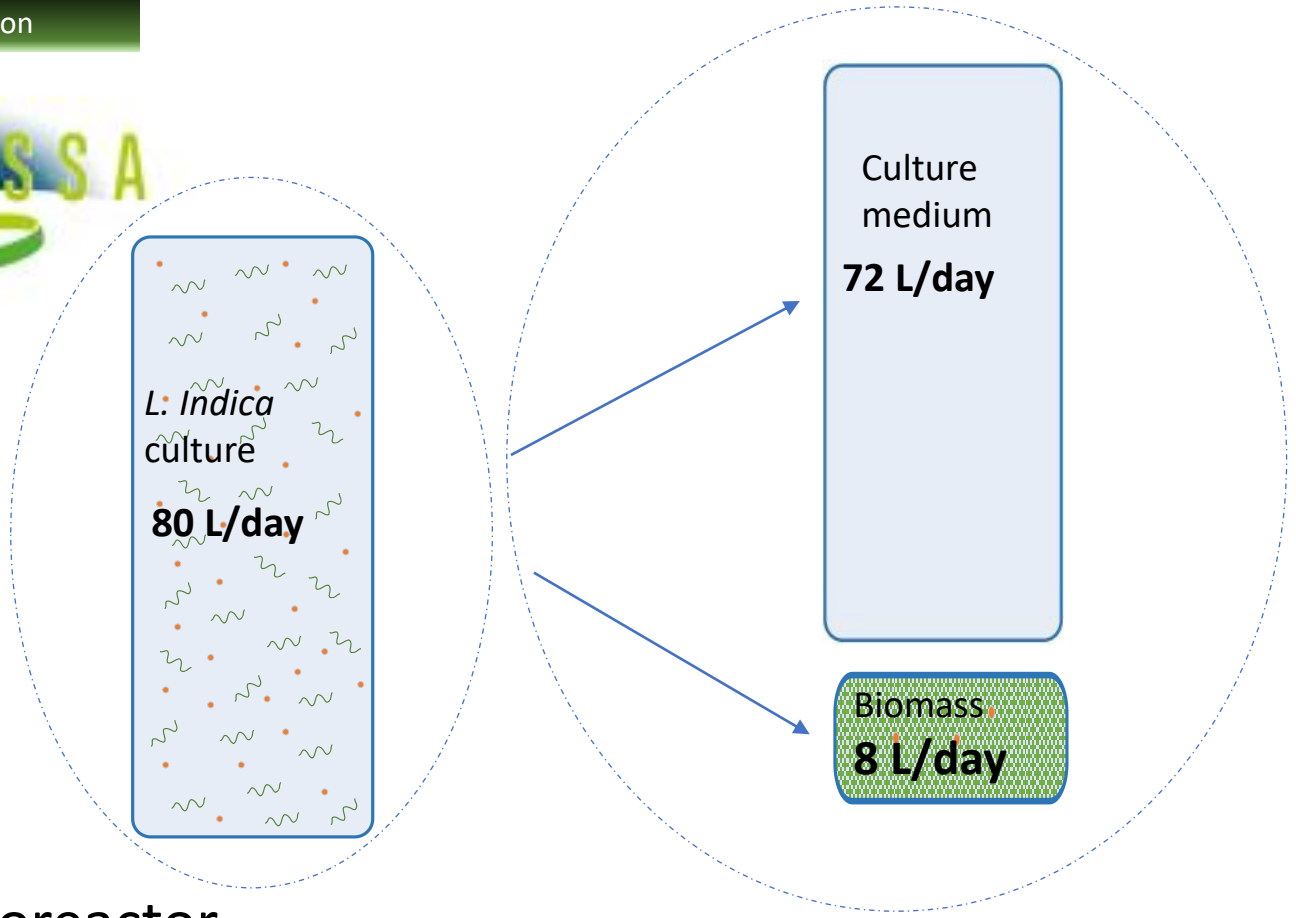
Plan

2. Requirements identification



Photobioreactor

- Culture and process conditions of MELiSSA research
- 80 L/day

Separation and harvesting system

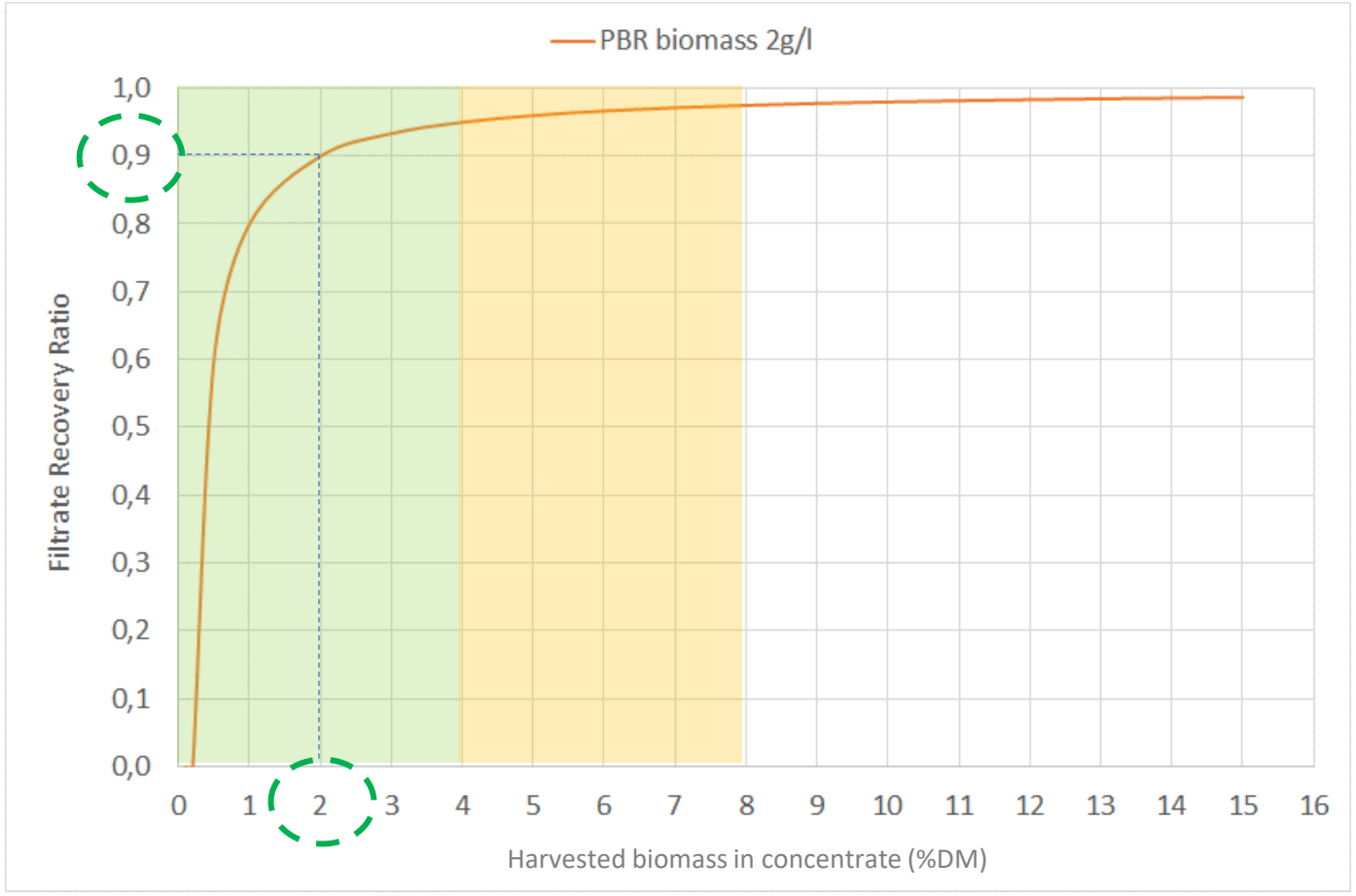
- Separate and harvest biomass under space conditions
- **Recover > 90% of the culture medium**
- Continuous life test period of 40 days
- Axenicity

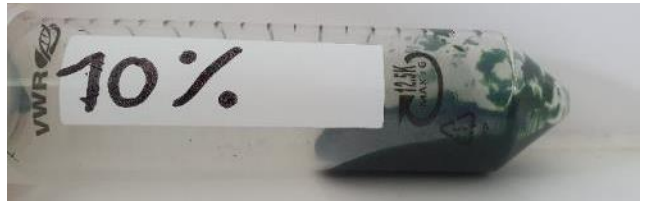
Control system and electronics

- Automated process

Recover > 90% of the culture medium

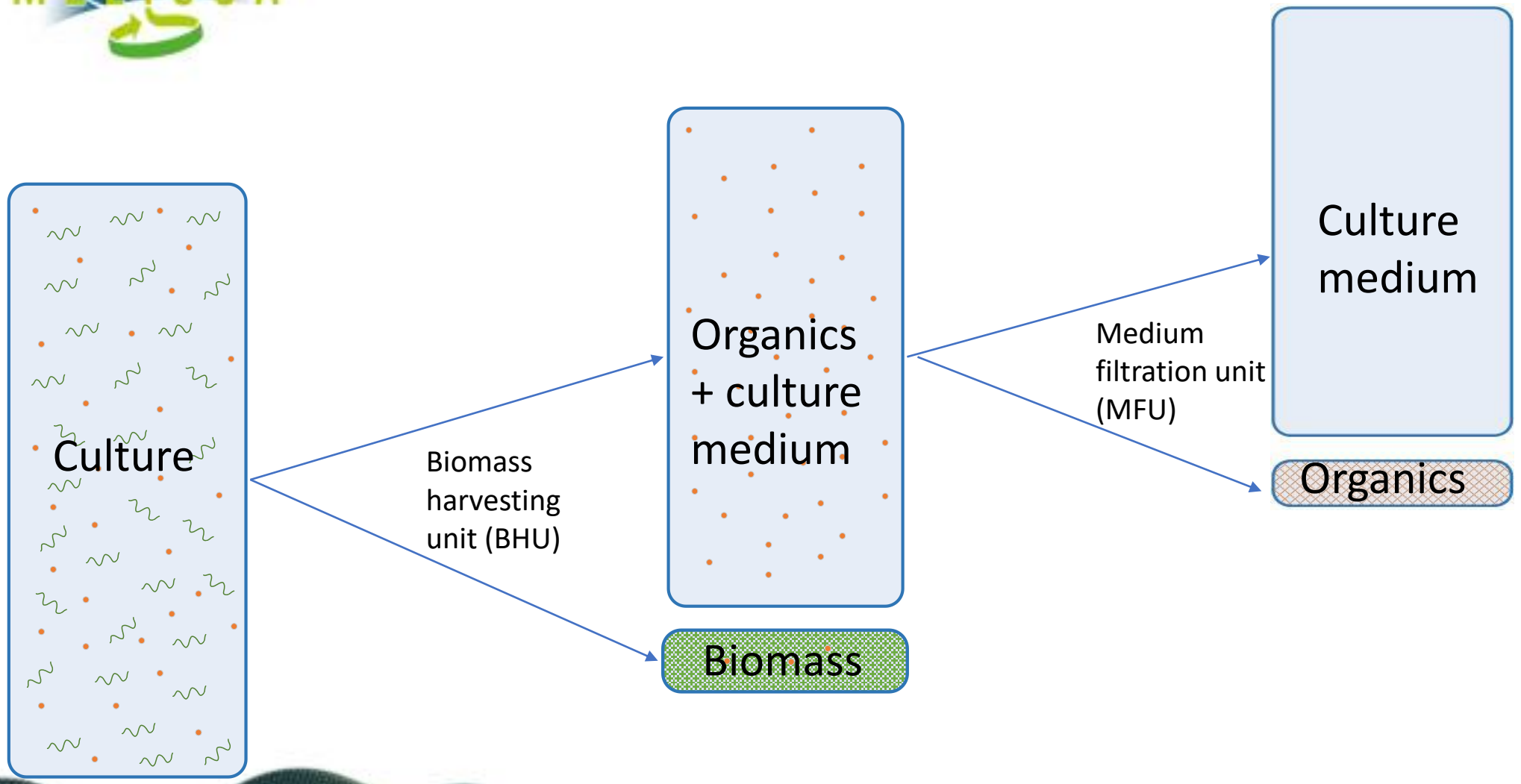
Filtrate recovery & solids in concentrate/cake



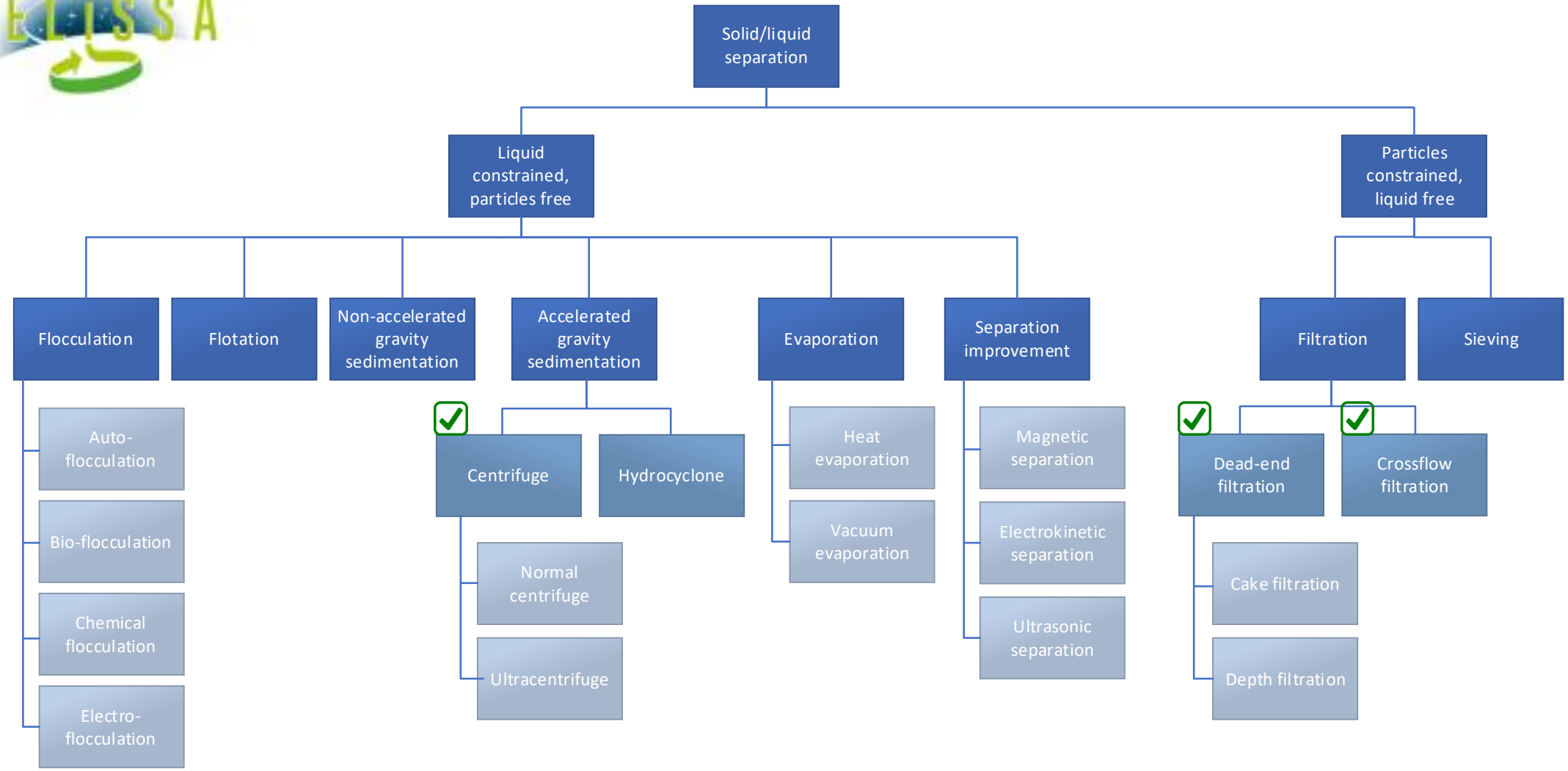


3. Technology trade-off

A two step separation

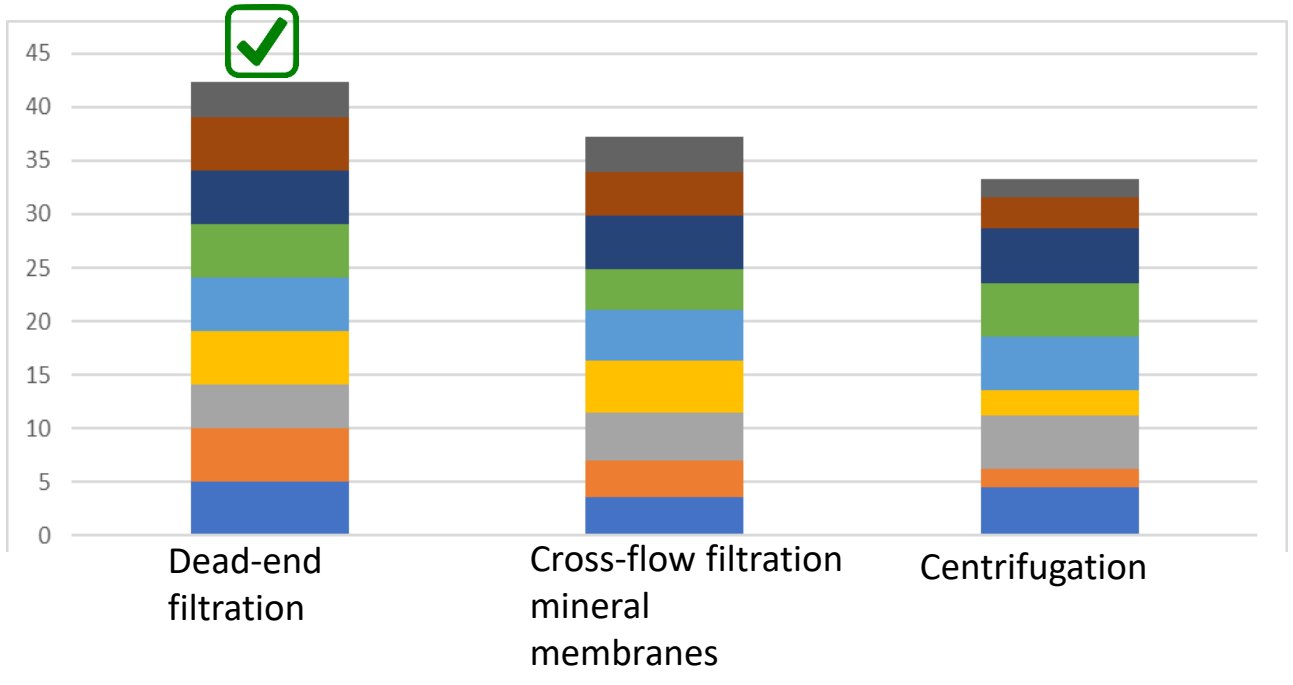


Filtration technologies

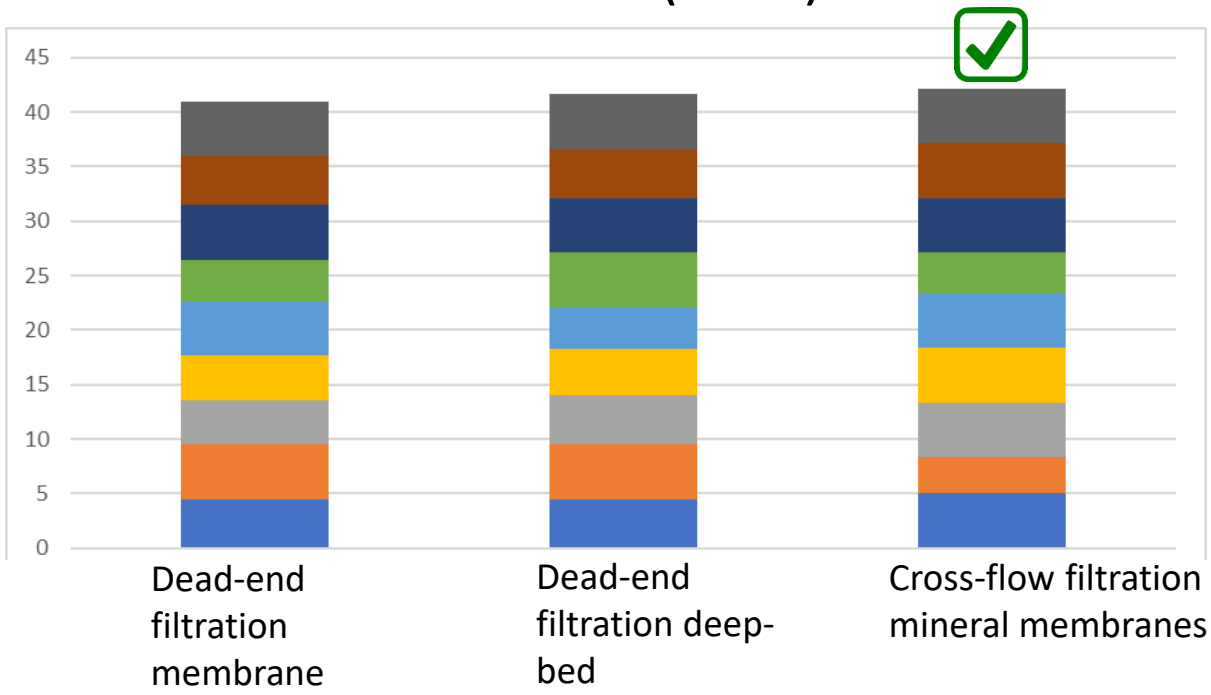


ALiSSE Criteria

Biomass harvesting unit (BHU)



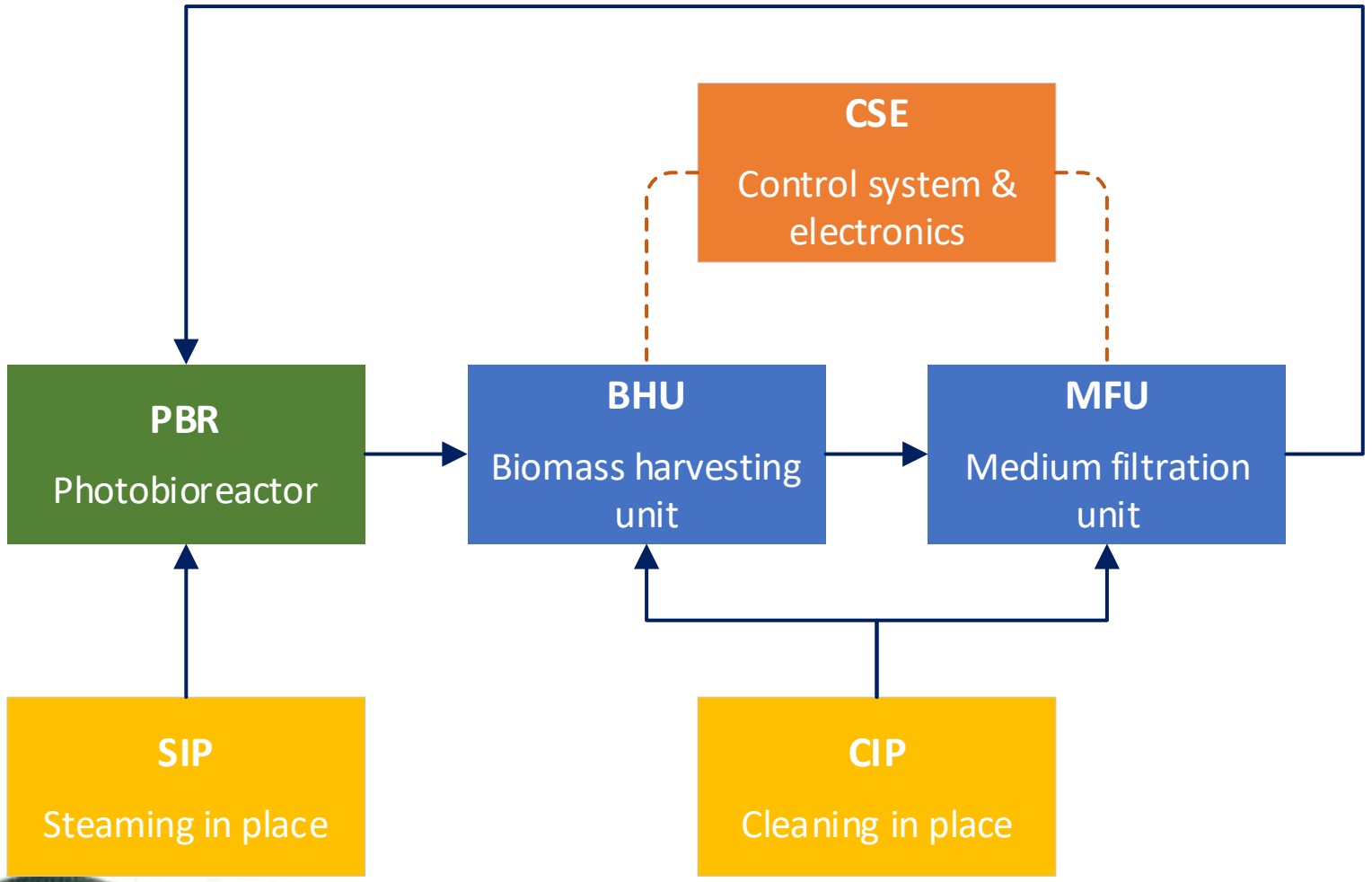
Medium filtration unit (MFU)



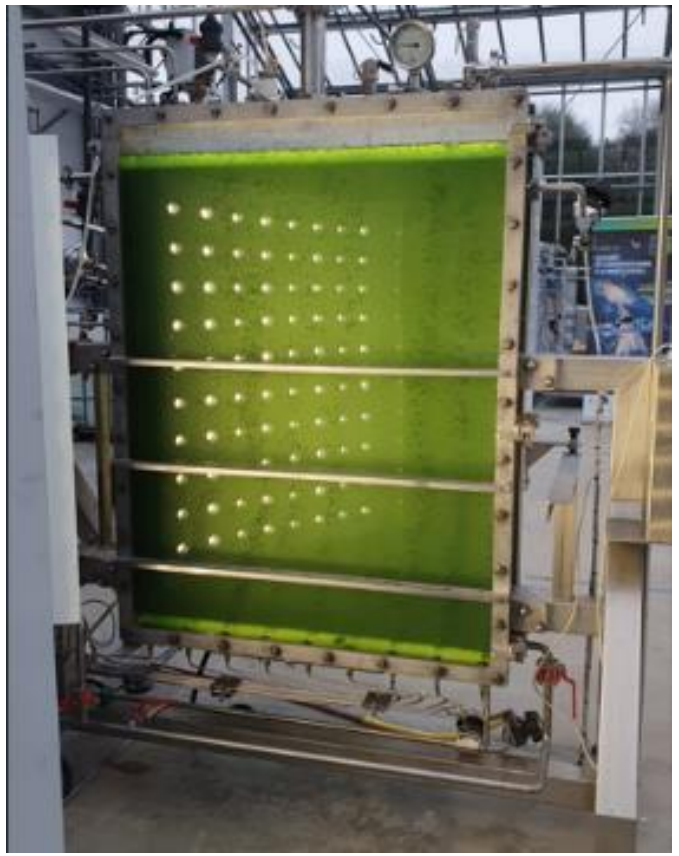
Physical mass | Energy and power | LSS crew time | Efficiency | Risk for human
Reliability | Readiness | Sustainability | Life cycle cost

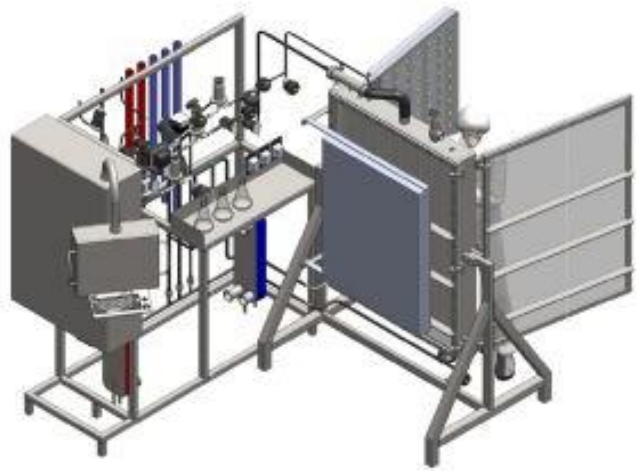
4. Breadboard configuration

Overview of the sub-systems



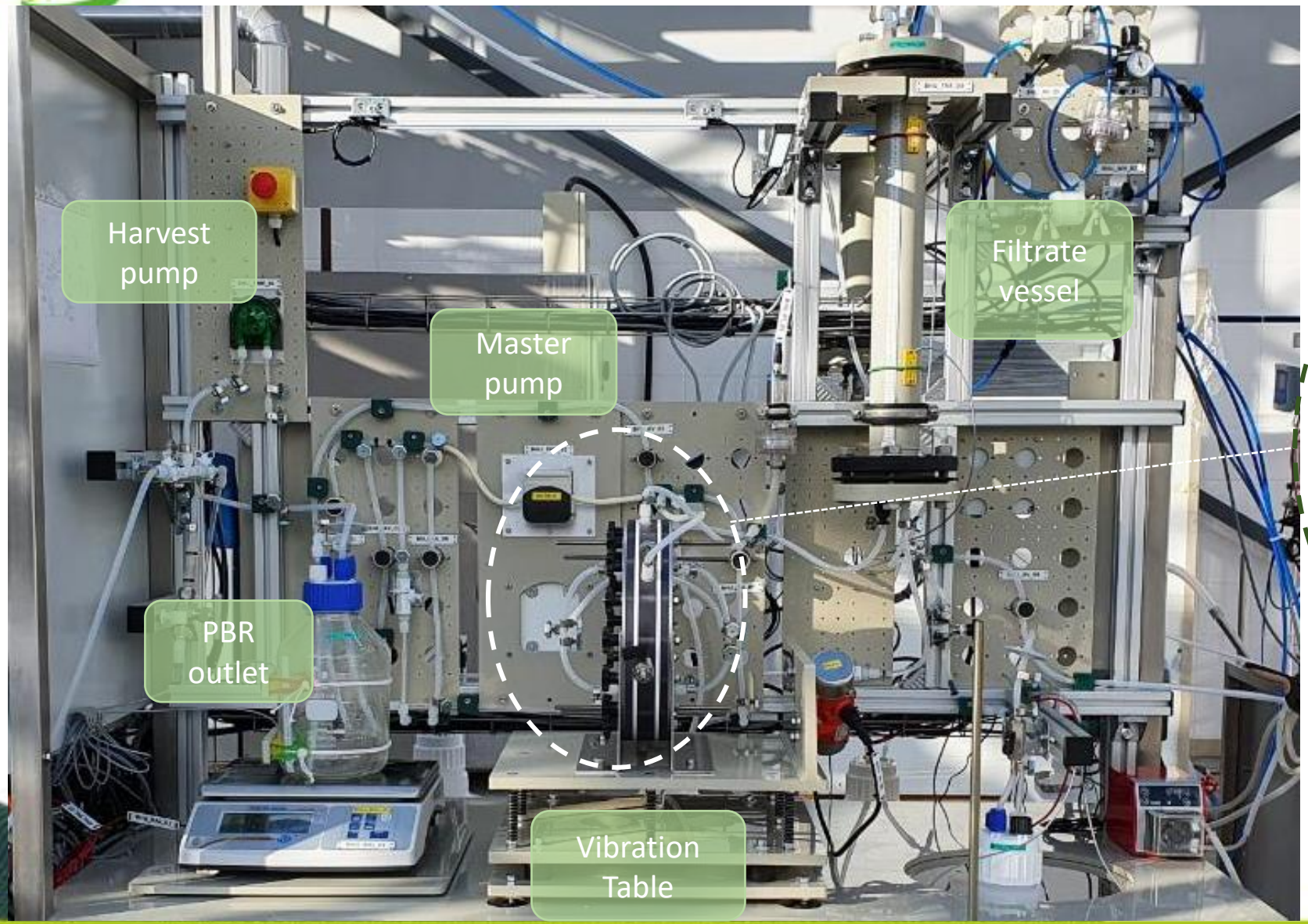
Photobioreactor

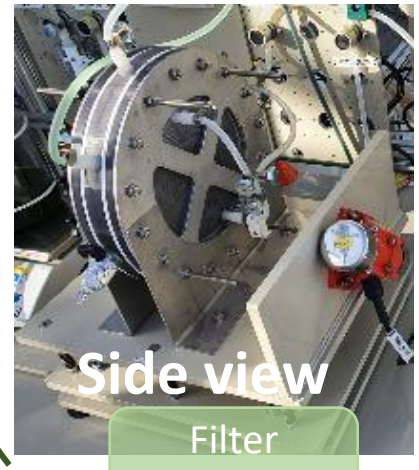




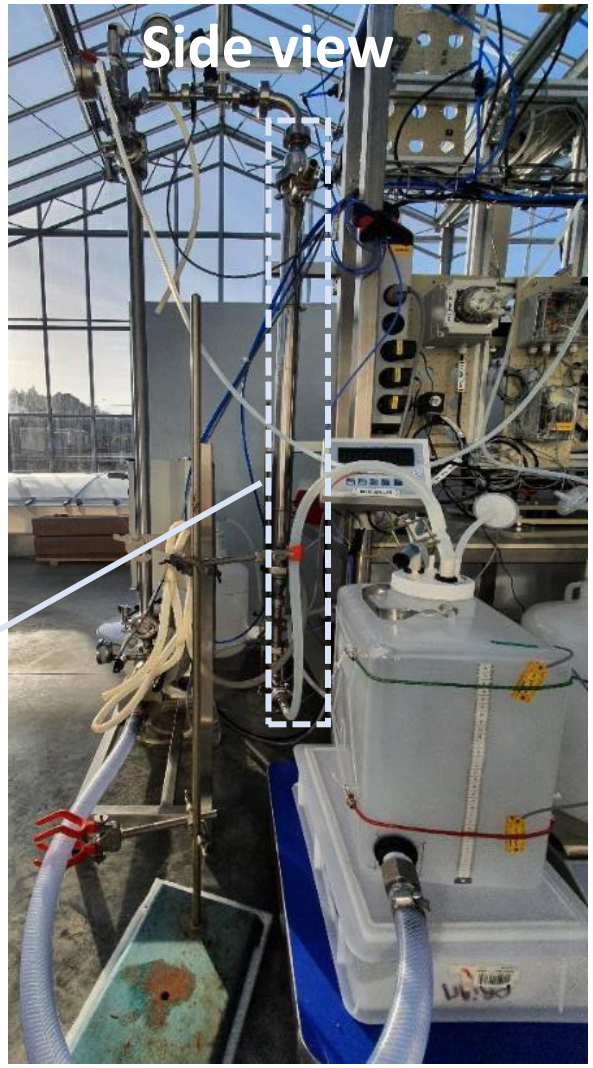
Closed system fully automated

Biomass harvesting unit (BHU)

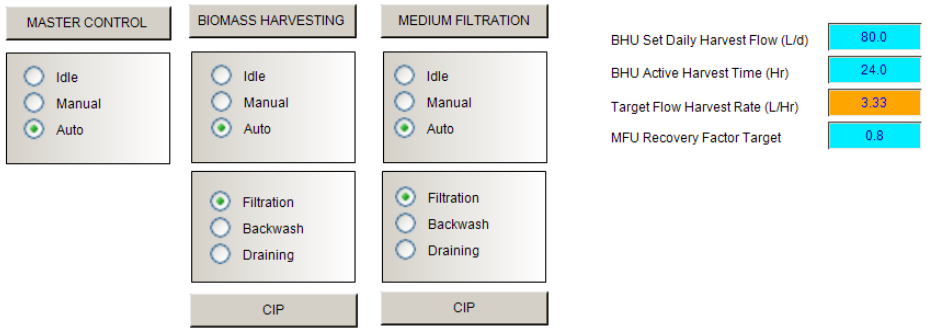


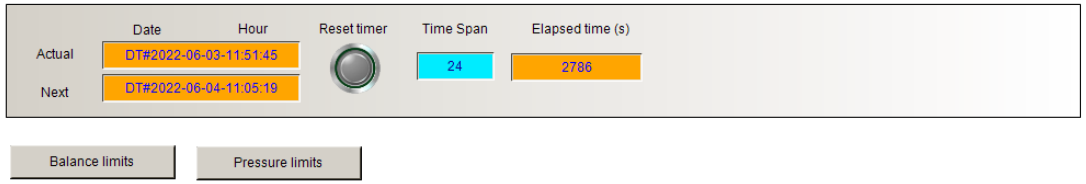


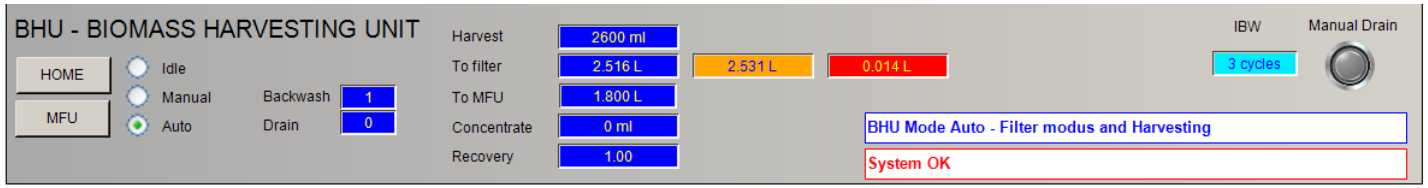
Medium filtration unit

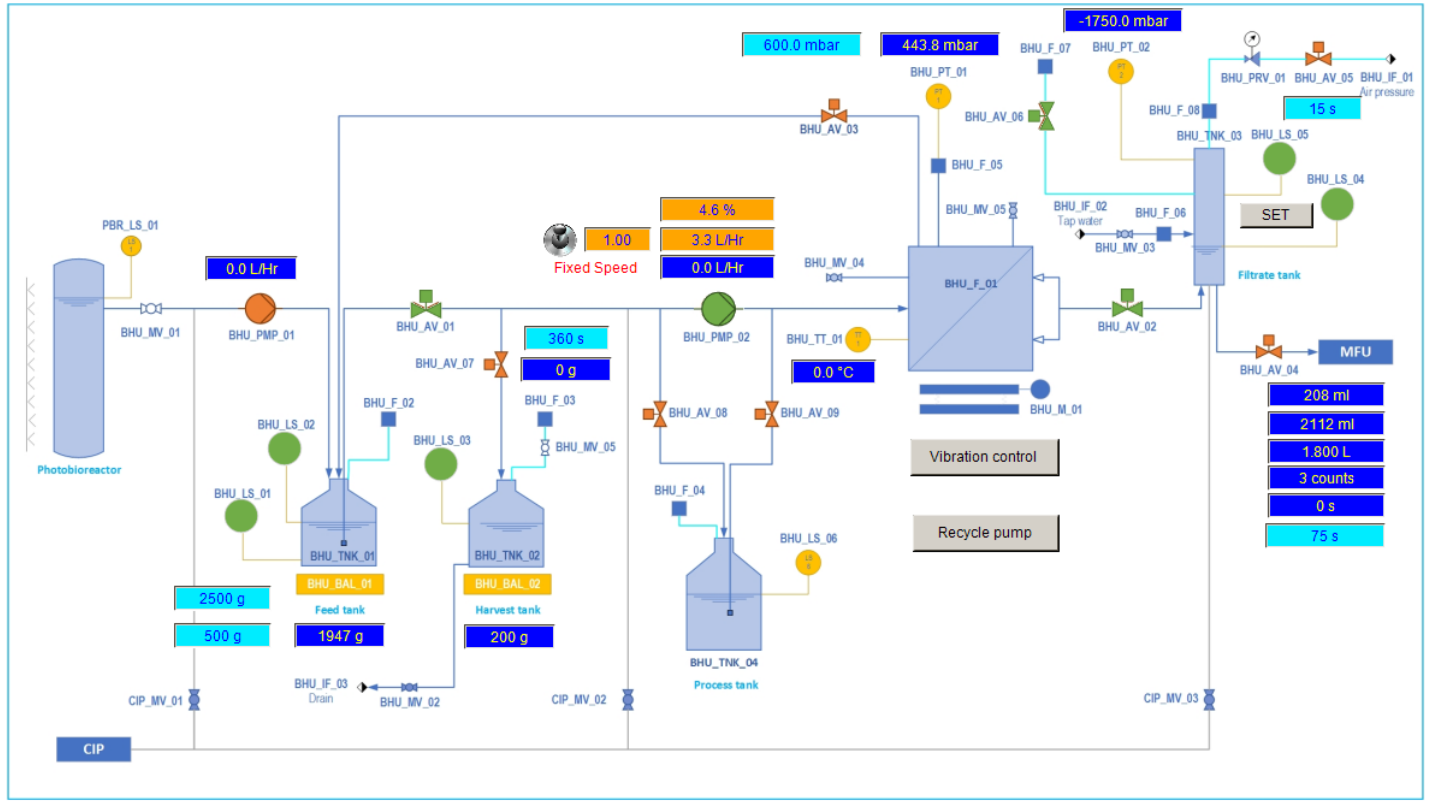


Human Machine Interface









5. Tests

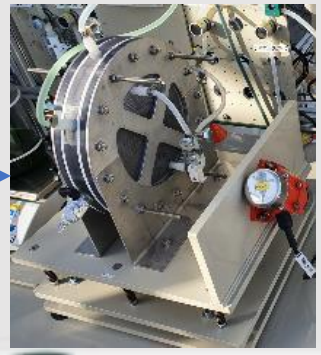
Organization of the experiments

- 2 scales of experiments :
  - Lab scale → Feasibility tests *(membrane selection, process sizing…)*
  - Pilot scale → Demonstration tests *(scale up, test of robustness…)*

- 2 process studies :
  - Biomass Harvesting Unit (BHU) → Dead-end filtration
  - Medium Filtration Unit (MFU) → Cross flow filtration

BHU lab unit
Filtrate flow
0,2-0,5 L/h

BHU pilot unit
Filtrate flow
3-6 L/h



MFU lab unit
Permeate flow
0,2-0,5 L/h

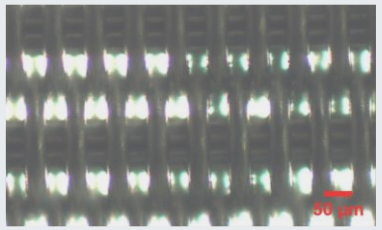
MFU pilot unit
Permeate flow
5-10 L/h

BHU feasibility test

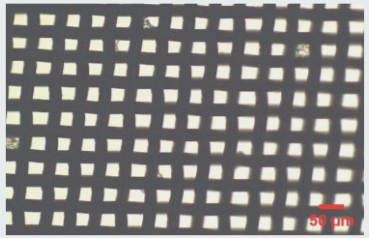
Objective : Select the most efficient membrane cut-off in terms of separation performance and filtrate productivity

Different mesh was tested :

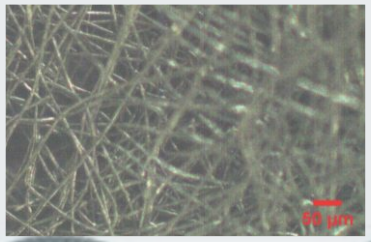
40µm



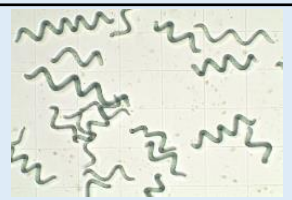
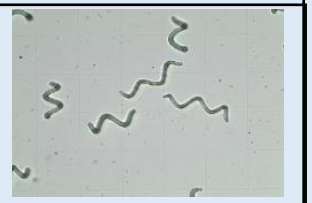
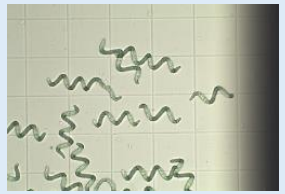
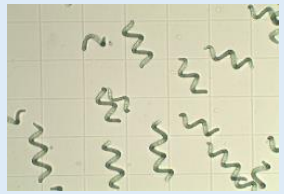
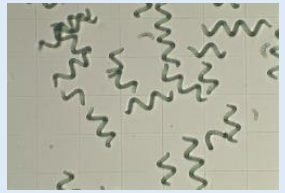
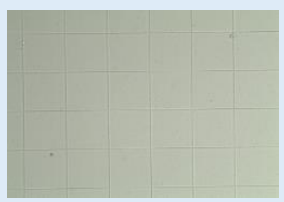
25µm



5µm

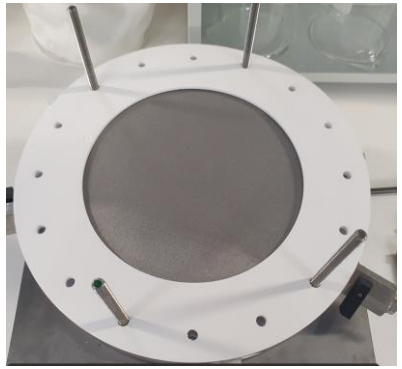


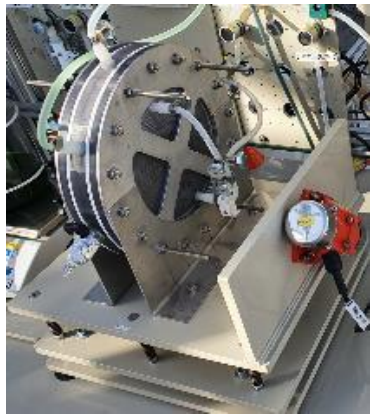
Microscopic observation:

	INITIAL	FILTRATE
40µm		
25µm		
5µm		

5µm is the most efficient

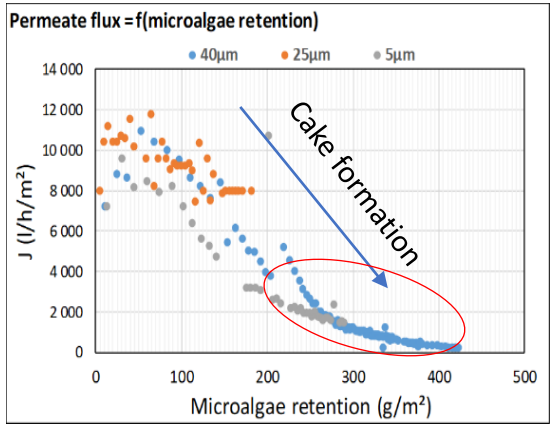
Is used for scale up



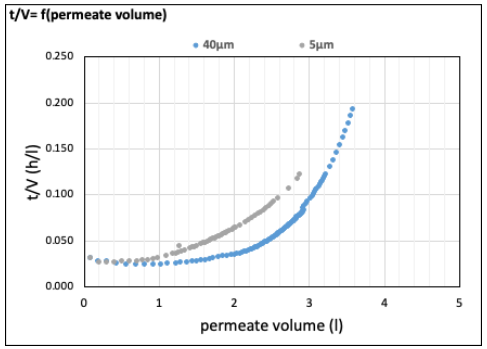


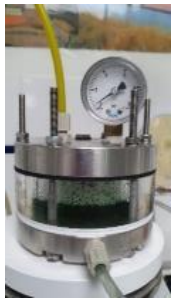
BHU feasibility test

Filtrate productivity



Cake resistance analysis





In dead-end filtration, the accumulation of organic material (=cake formation) decreases the permeability

How can we avoid cake formation ?

Vibrating sieve

Addition of a vibrating table

Vibrating system

Dead end filtration → Cake formation

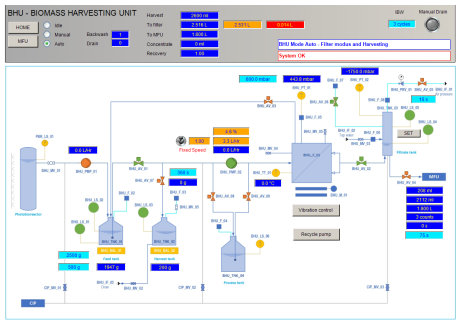
~~Clogging~~ → vibrating

BHU pilot implementation

BHU Feasibility test

- 5 µm
- Vibration system

Control system and electronics



Automatic procedure and control to manage dead end filtration :

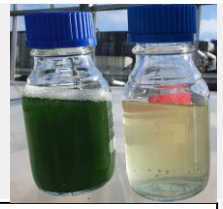
- **Step 1 : Cycle of filtrate production**
- **Step 2 : Periodic backwash cycle**
- **Step 3 : Drain cycles of concentrated biomass**

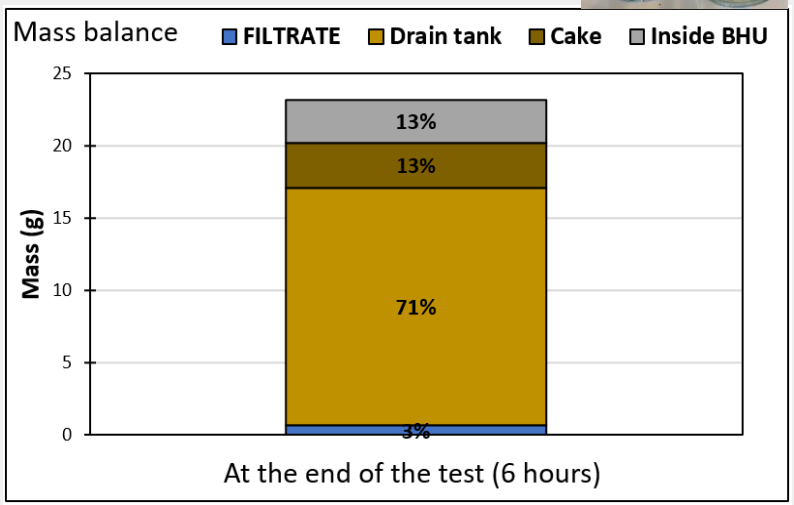
BHU demonstration test

Objectives of the **B**iomass **H**arvesting **U**nit :

1. Separate microalgae from culture media,
2. Working in continuous mode,

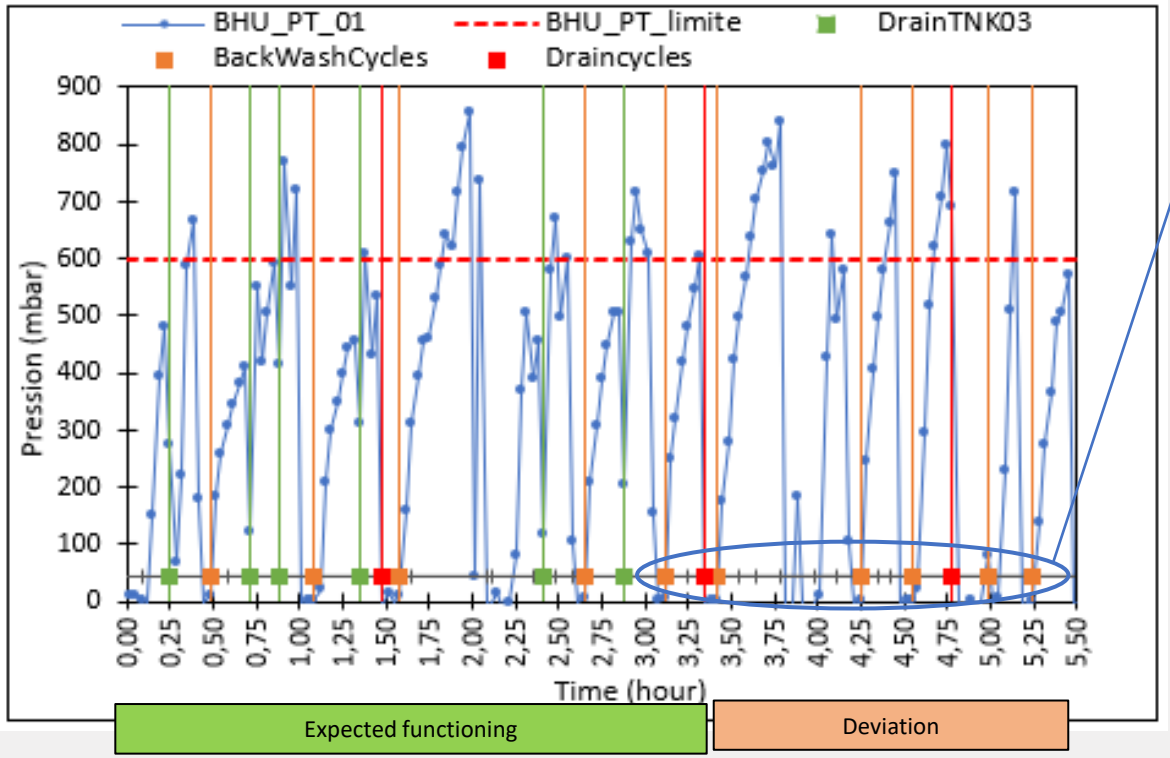
1. Separation performance :





only 3% of the initial suspended matter passed the membrane

2. Filtrate productivity through the time

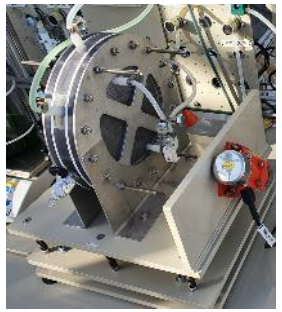


Deviation of the system in infinite backwash loops after several hours

Needs Improvement

BHU optimization and limits

Optimization tests



Optimizing vibration time, frequency and operating procedures to reduce cake resistance

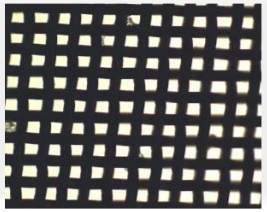
→ ↗the filtrate volume by 6
But system deviation still present

Limitation of the actual BHU design and perspectives

Optimization of the filter unit design to prevent cake formation

Investigate link between *Limnospira* culture properties and filtration performance

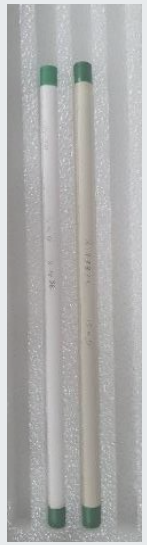
Filter material selection to minimize biomass adherence

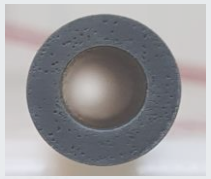


MFU Feasibility test

Objective : Validate experimentally the results from the literature review in order to size the pilot scale system

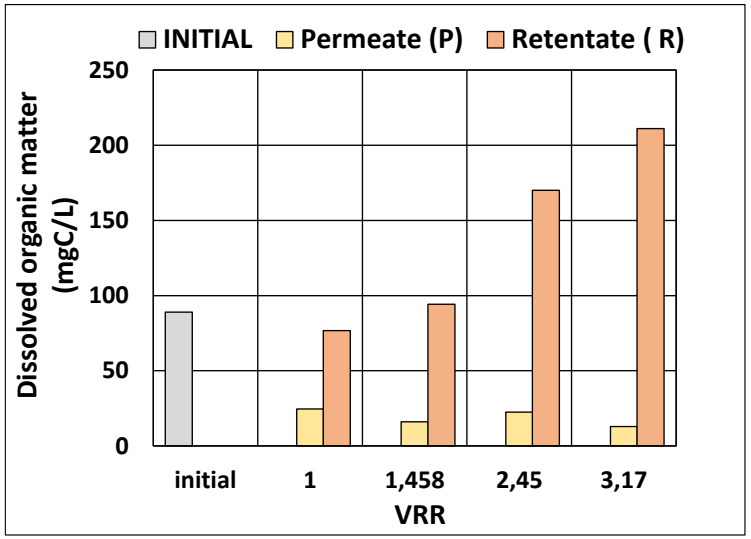
Ceramic membrane
15kDa
0,005m²





Organics separation performance

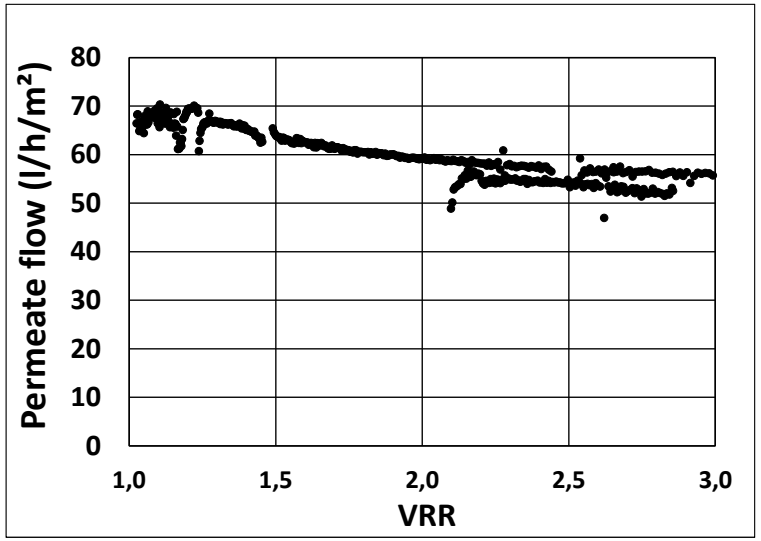
15kDa – T=30°C – PTM=0,8bar – v=2,6m/s



- Retention of the organic carbon
- Migration of the inorganic molecules

Permeate productivity

15kDa – T=30°C – PTM=0,8bar – v=2,6m/s



- Range of permeate flow : J = 50 – 70 l/h/m²

15kD cut off + Permeate flow range → Used for MFU pilot scale sizing

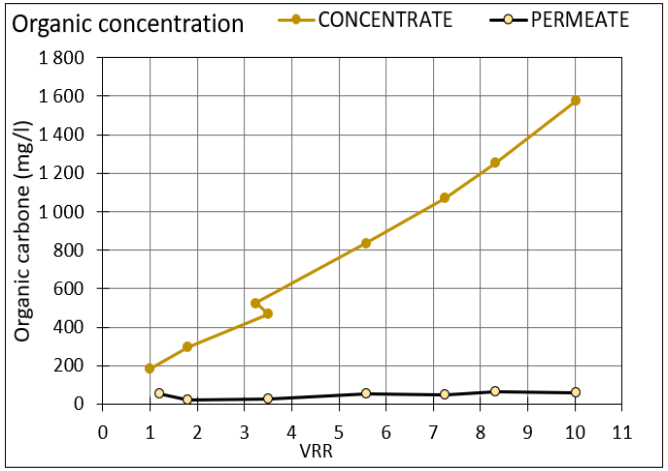
MFU demonstration test

Objectives of the MFU **:**

1. Separate dissolved organics from culture medium,
2. Concentrate organics,

Ceramic membrane
15kDa
0,11m²

1. Separation performance :

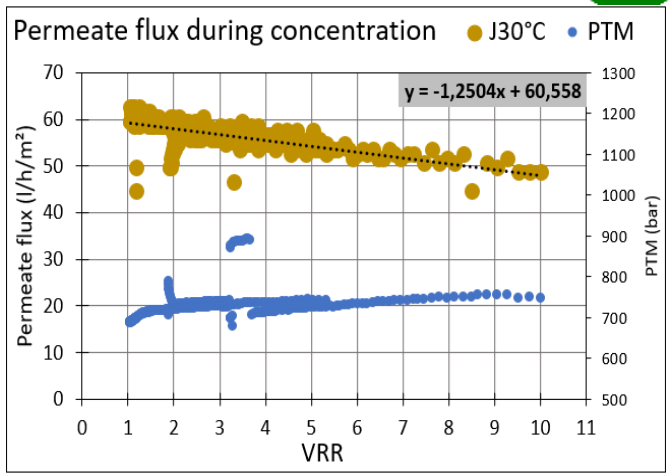


Initial

Concentrate

Permeate

2. Permeate productivity



Through the VRR, the permeability flux keep a good performance

- VRR 1 : 61 l/h/m²
- VRR 5 : 55 l/h/m²
- VRR 10 : 50 l/h/m²

6. Conclusion

Conclusion and future work

- Objective: Implementation of an automated process for a continuous *Limnospira* harvesting and the recycling of the culture medium for space applications
- An automated two step separation process
  - Biomass harvesting unit (BHU)
  - Medium filtration unit (MFU)
- Results
  - Batch mode: good results
  - Continuous mode: good separation performance but continuous operation to be optimised at BHU level
- Future work
  - Characterisation of the strains and culture properties
  - Optimisation of the filter unit (BHU) to prevent cake formation

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Céline Coene
QinetiQ
celine.coene@qinetiq.be

Jordan Tallec
GEPEA/Capacités
jordan.tallec@capacites.fr

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