SHERPA engineering

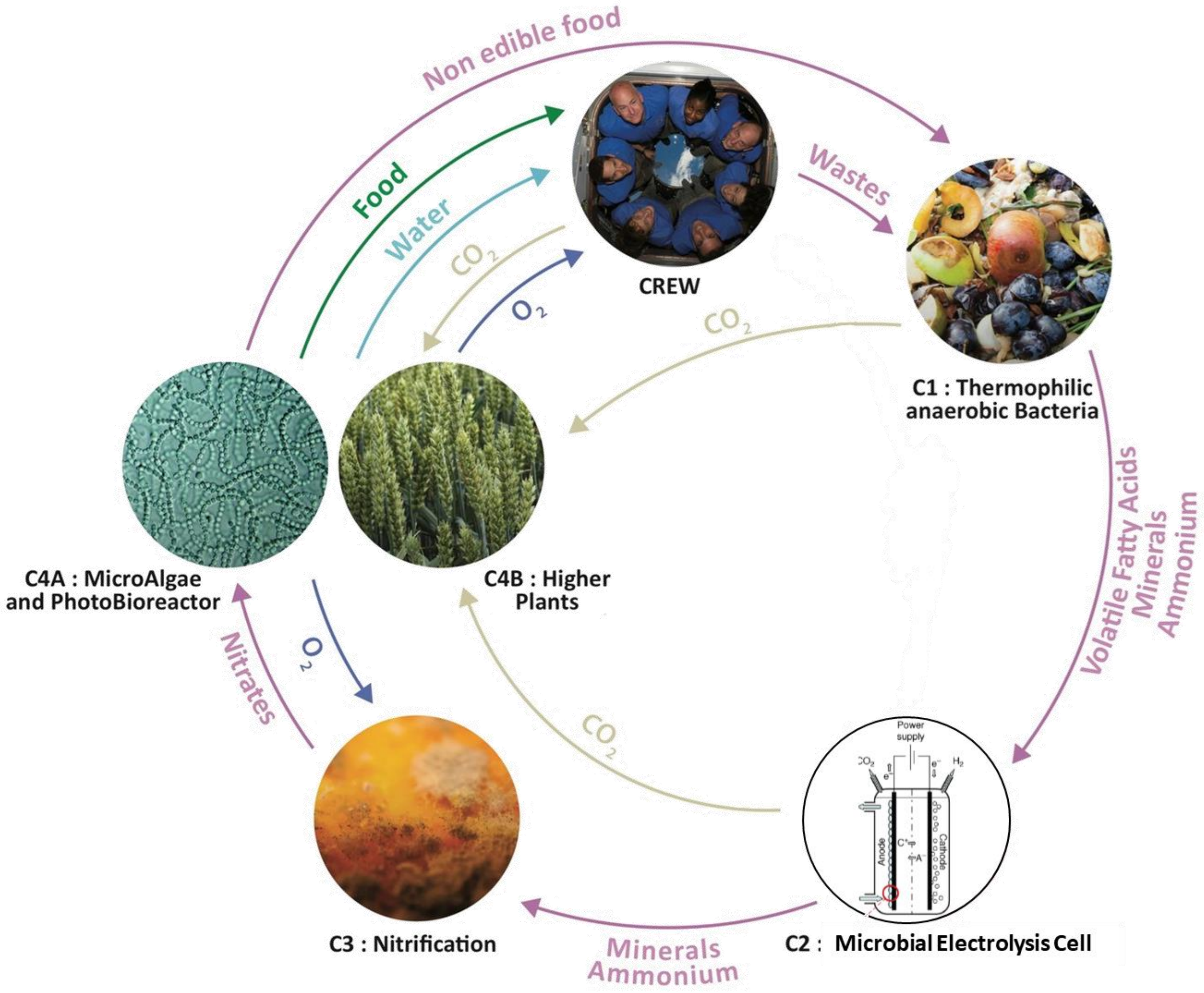
MELiSSA

Design of the MELiSSA loop control strategy

B. Thiron, P. Fiani, O. Gerbi, C. G. Dussap,
L. Poulet, L. Poughon, L. Bucchieri, M. Gatti

Context : MELiSSA loop

- MELiSSA loop :
  Degrade organic waste into food, water and oxygen for human



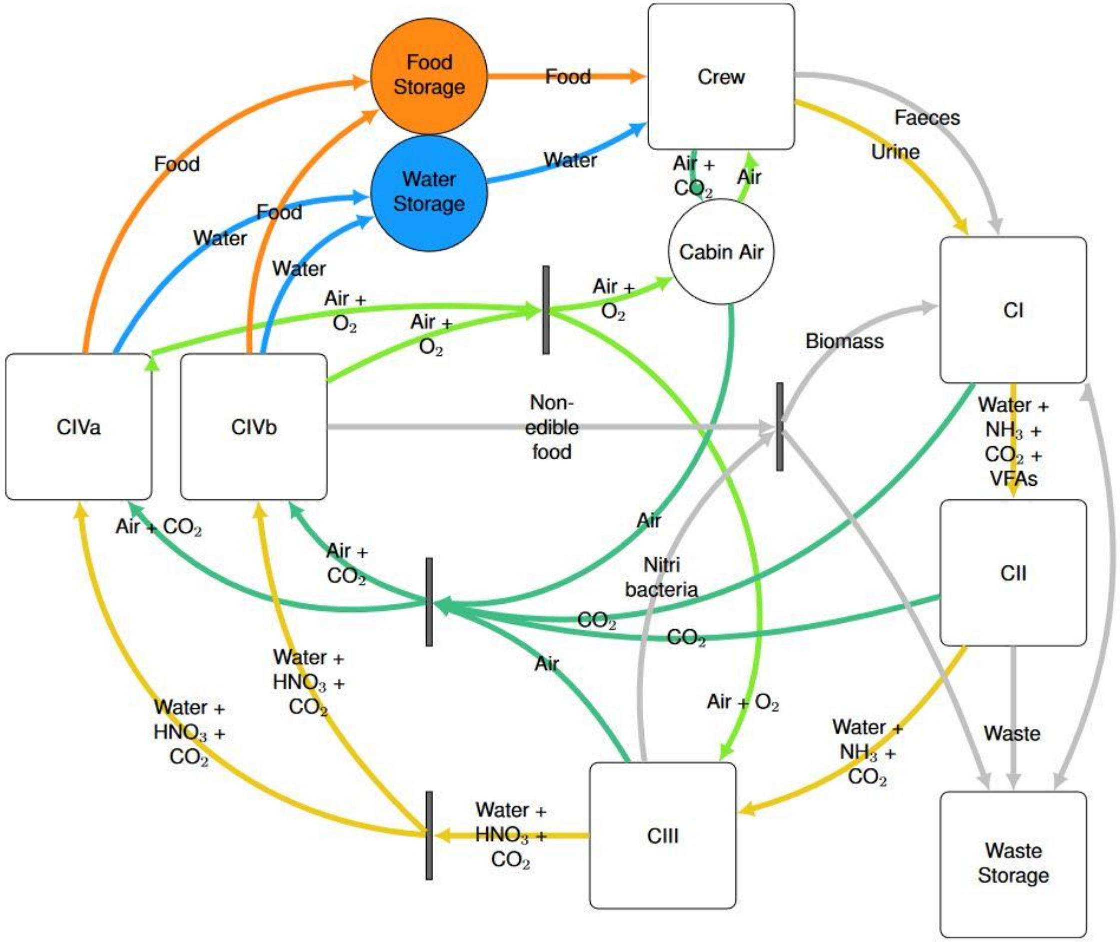
Context : Control strategy ?

- Elaborate a flow control strategy :

  To determine the choices for distributing the flows between the various entities of the MELiSSA loop.

  - What to send?
  - Where?
  - When?

- Two goals:
  1) Ensure the crew survival
  2) Optimality



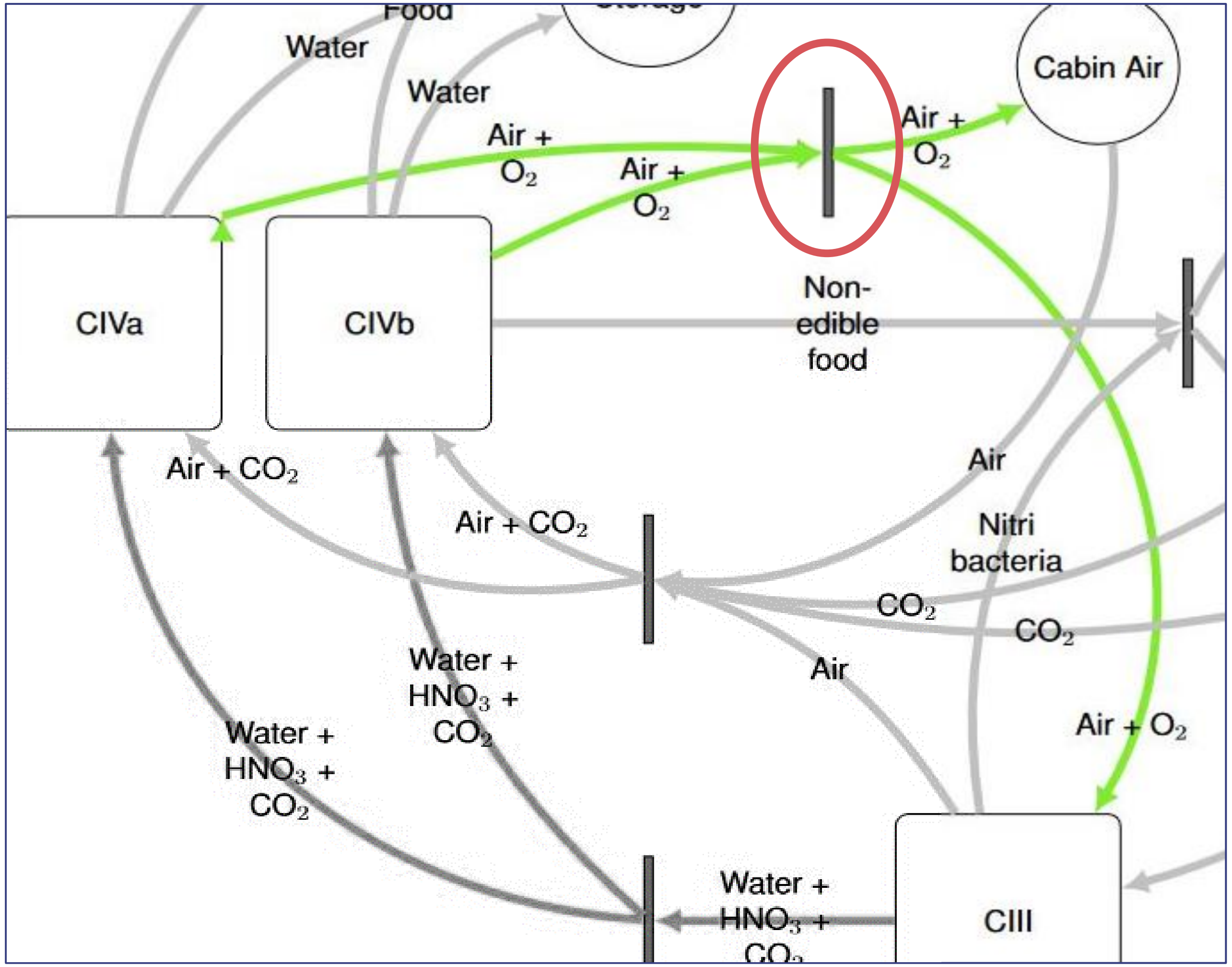
Degrees of freedom (1/2)

Degrees of freedom 1st type :

Choices in the flow distribution

Example for O2 distribution :

- How much from C4a/C4b ?
- How much to C3/C5 ?



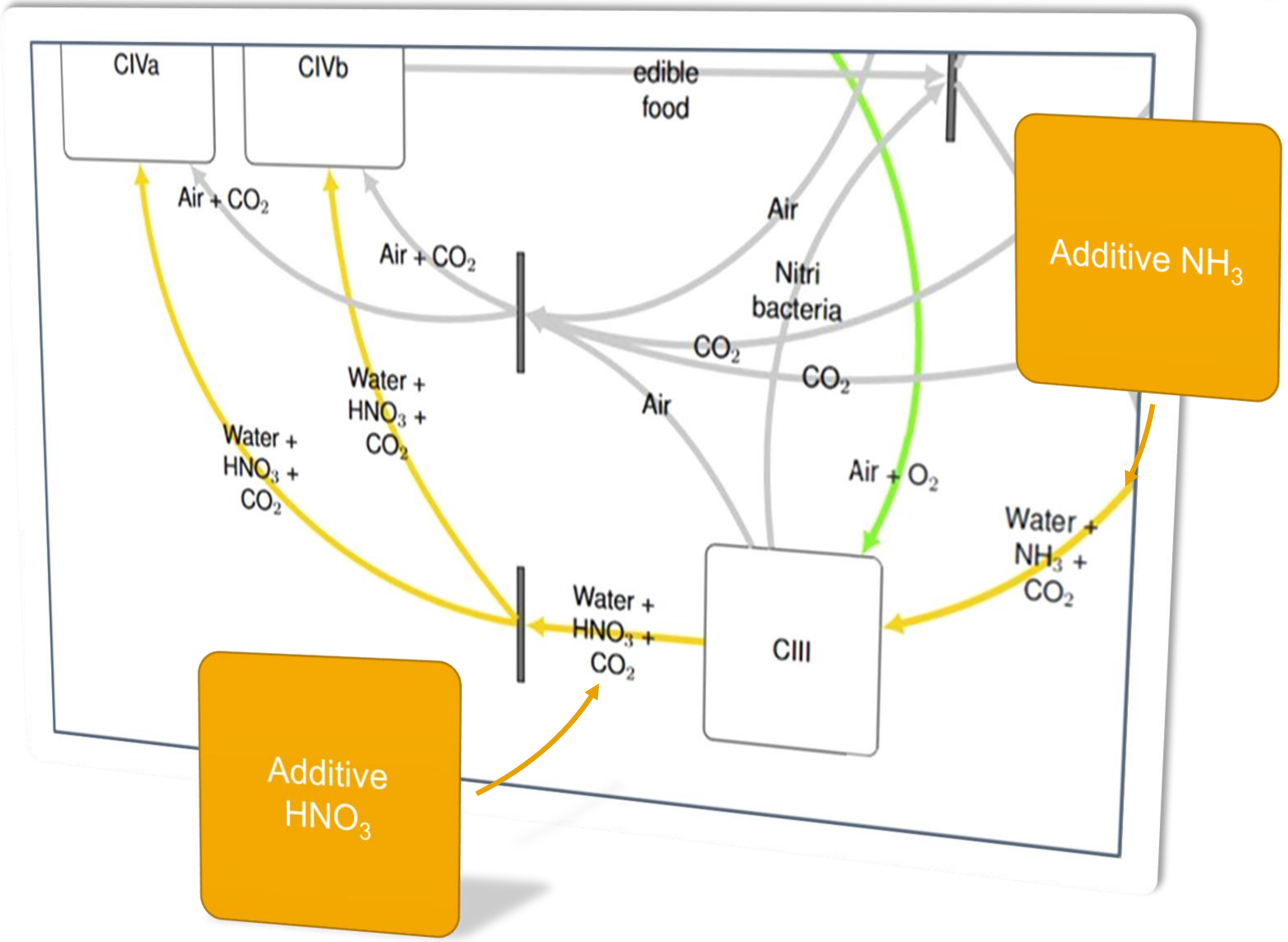
Degrees of freedom (2/2)

Degrees of freedom 2nd type :

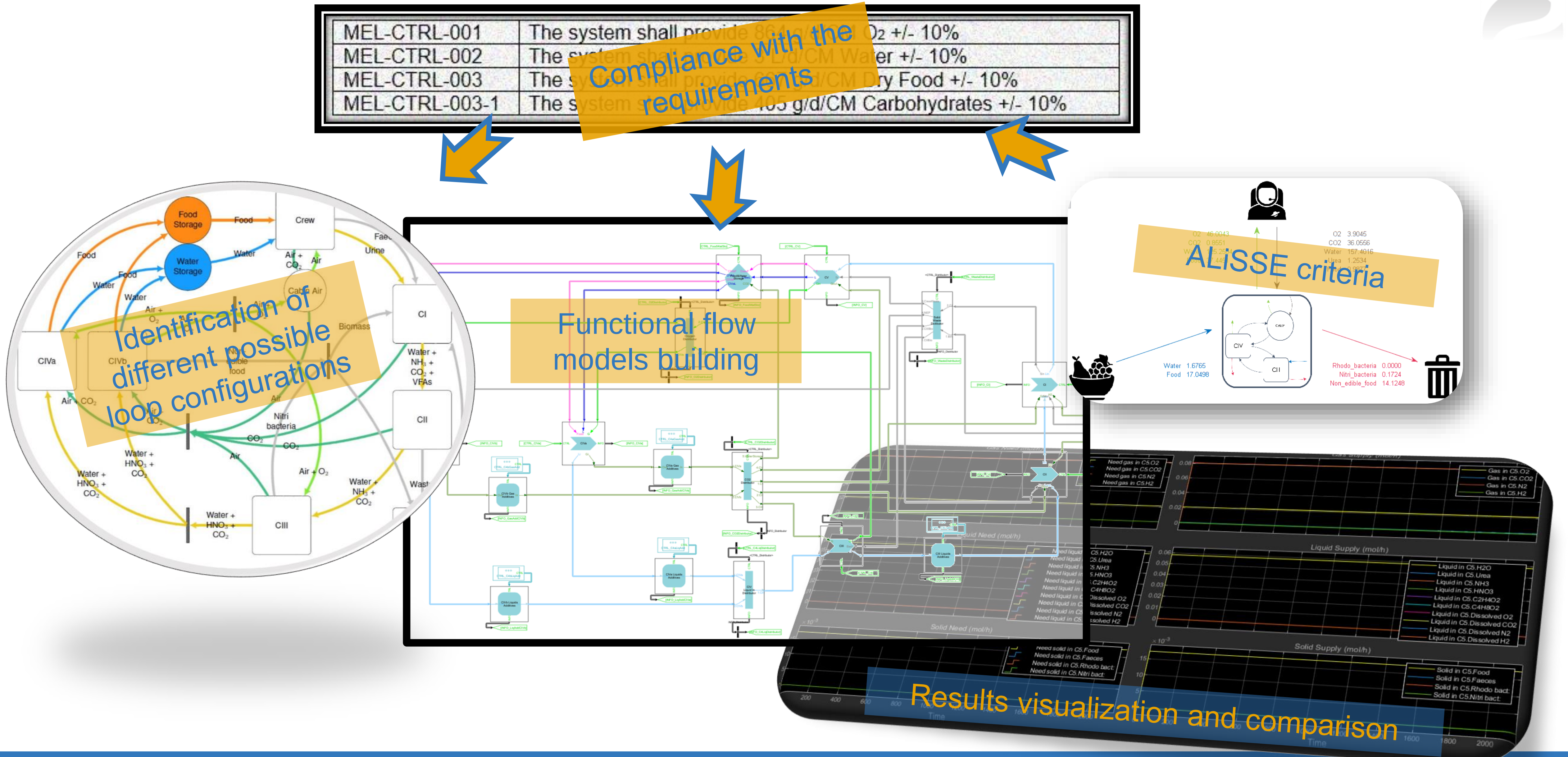
Choices in the chemical components addition

Example for N addition :

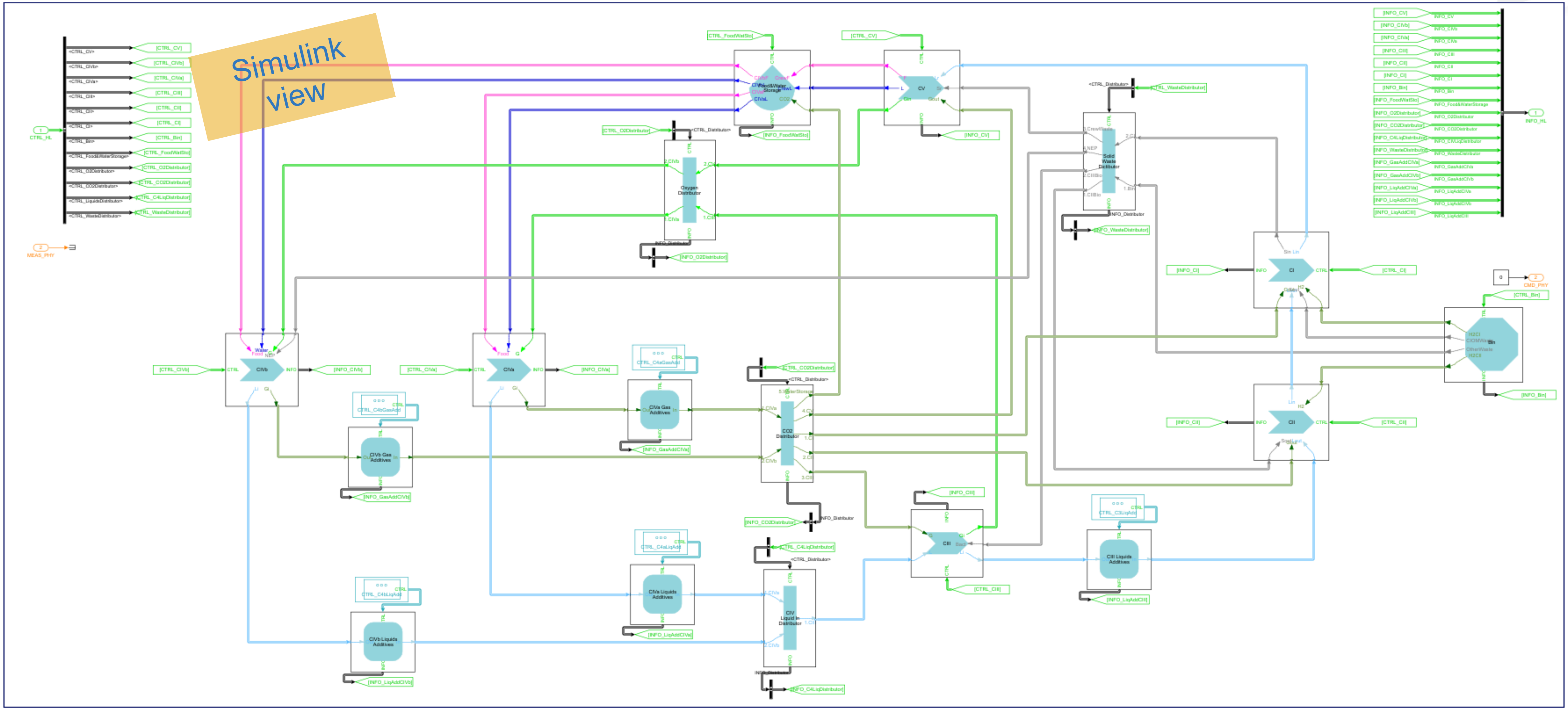
- The most efficient ?
- The most robust ?



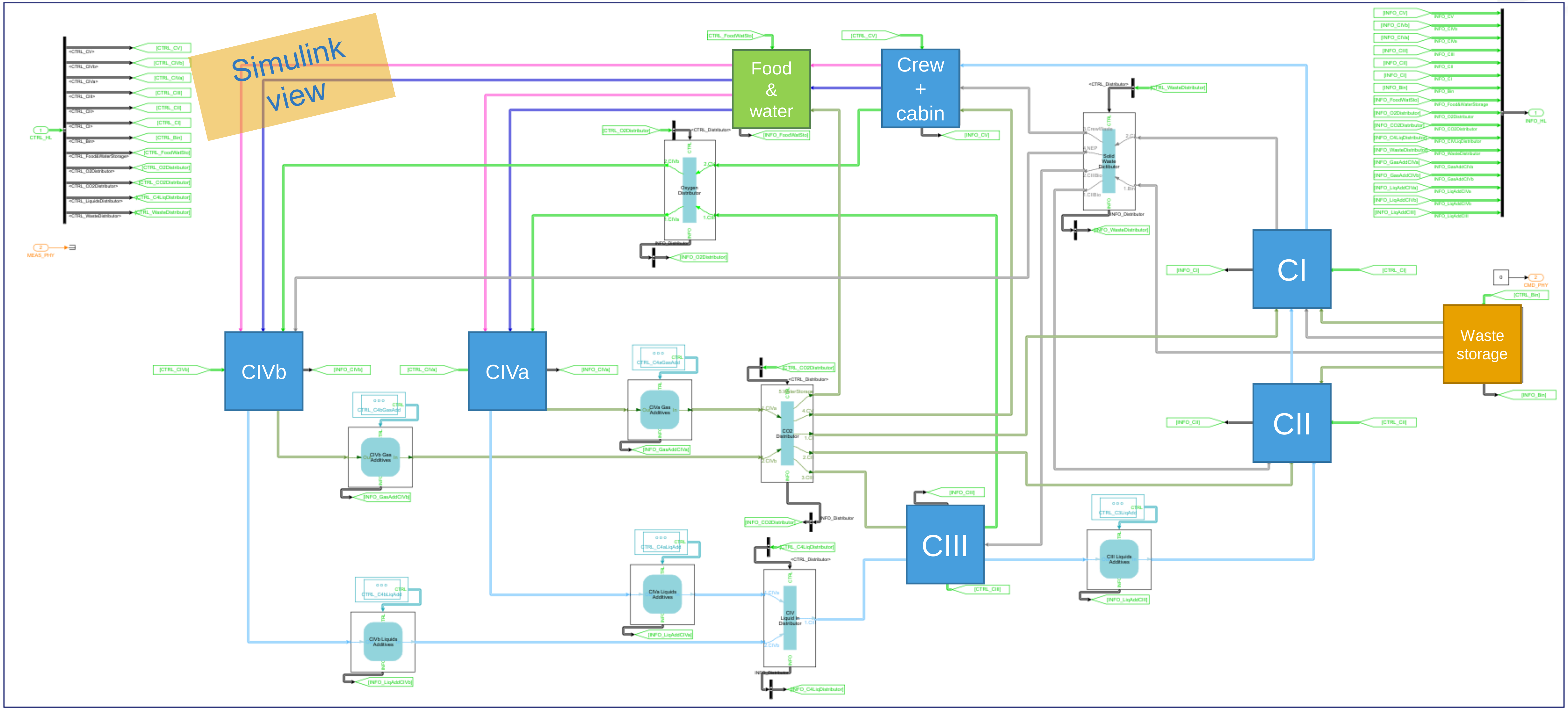
Elaboration of the control strategy



Models of the loop



Models of the loop



Scenario and requirements

- Life on Mars surface : **3 years** mission
- Typical crew week schedule

1 normalized astronaut

667 g/day
of dry food :
- 405 g/day of carbohydrates
- 103 g/day of fats
- 122 g/day of proteins
- 37 g/day of fibres

Food requirements :
- mass of spirulina < 5% of the crew diet

3 L/day of
drinking water

864 g/day
of O_2

Air requirements :
- 19% < O_2 level < 23%
- CO_2 level < 5000 ppm

Scenario and requirements

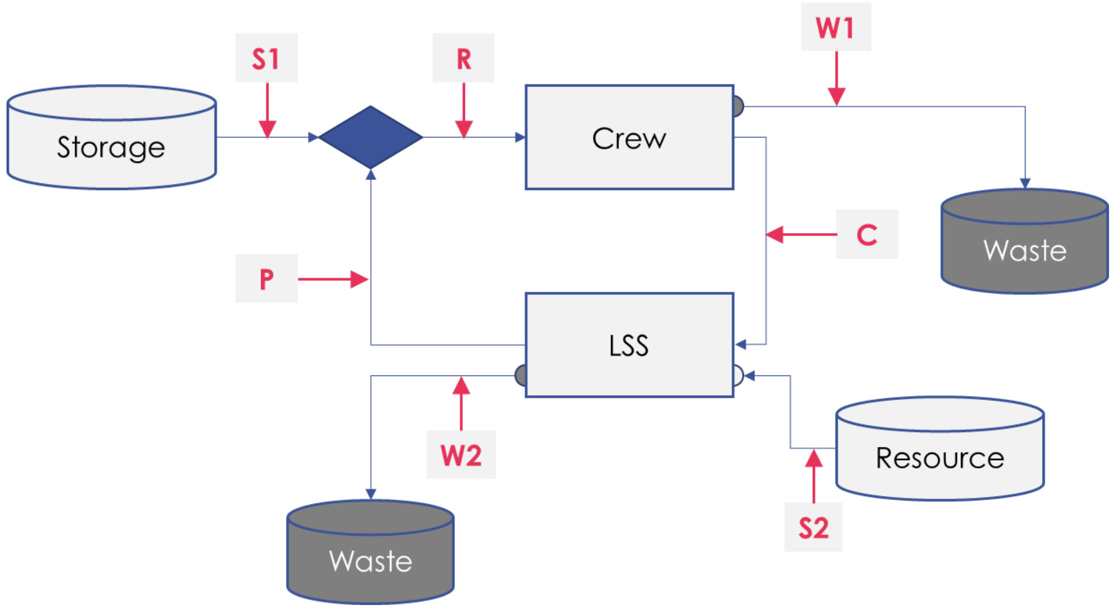
- 7 failure scenario (designed by ESA)
- Objective : **study and compare the robustness** of the different configurations

	ESA scenario proposal
1	"Crew is sick. Urine and faecal matter cannot be used for 1 week. Only CO_2 and grey water/humidity condensate can be used during that time"
2	"Ammonium sensor fails, ammonium concentration in C1 cannot be measured. Methane production cannot be inhibited"
3	C3 failure
5	Photobioreactor lighting in C4a can only reach 70% efficiency
6	Harvesting system in C4a harvests too much biomass, biomass production remains nominal.
7	Excess O_2 in MELiSSA loop (e.g. sudden change of crew composition)
9	Protein stock on-board is decreasing. The MELiSSA loop shall provide 80% of the protein needs for the mission.

Evaluation criteria

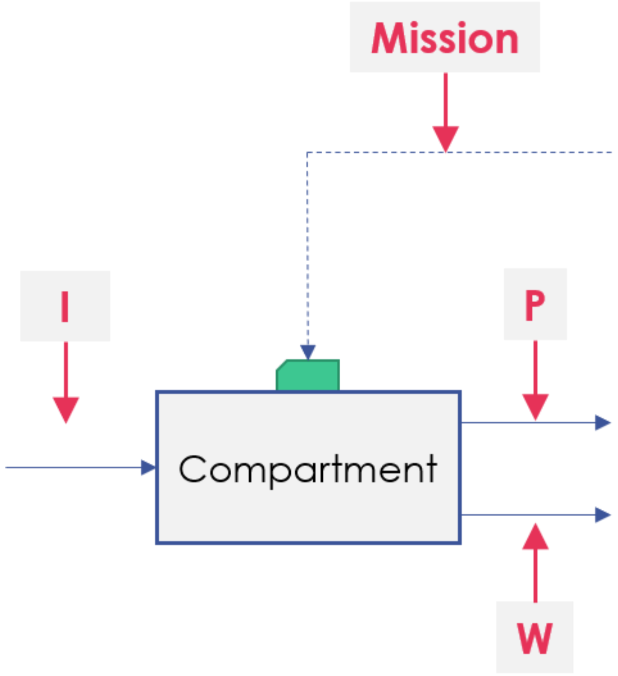
At the loop level

Criteria	Expression
Autarky	P/R
Production cost	$(S_1+S_2)/R = (W_1 + W_2)/R$
Resource intensity	$(C + S_2)/P$



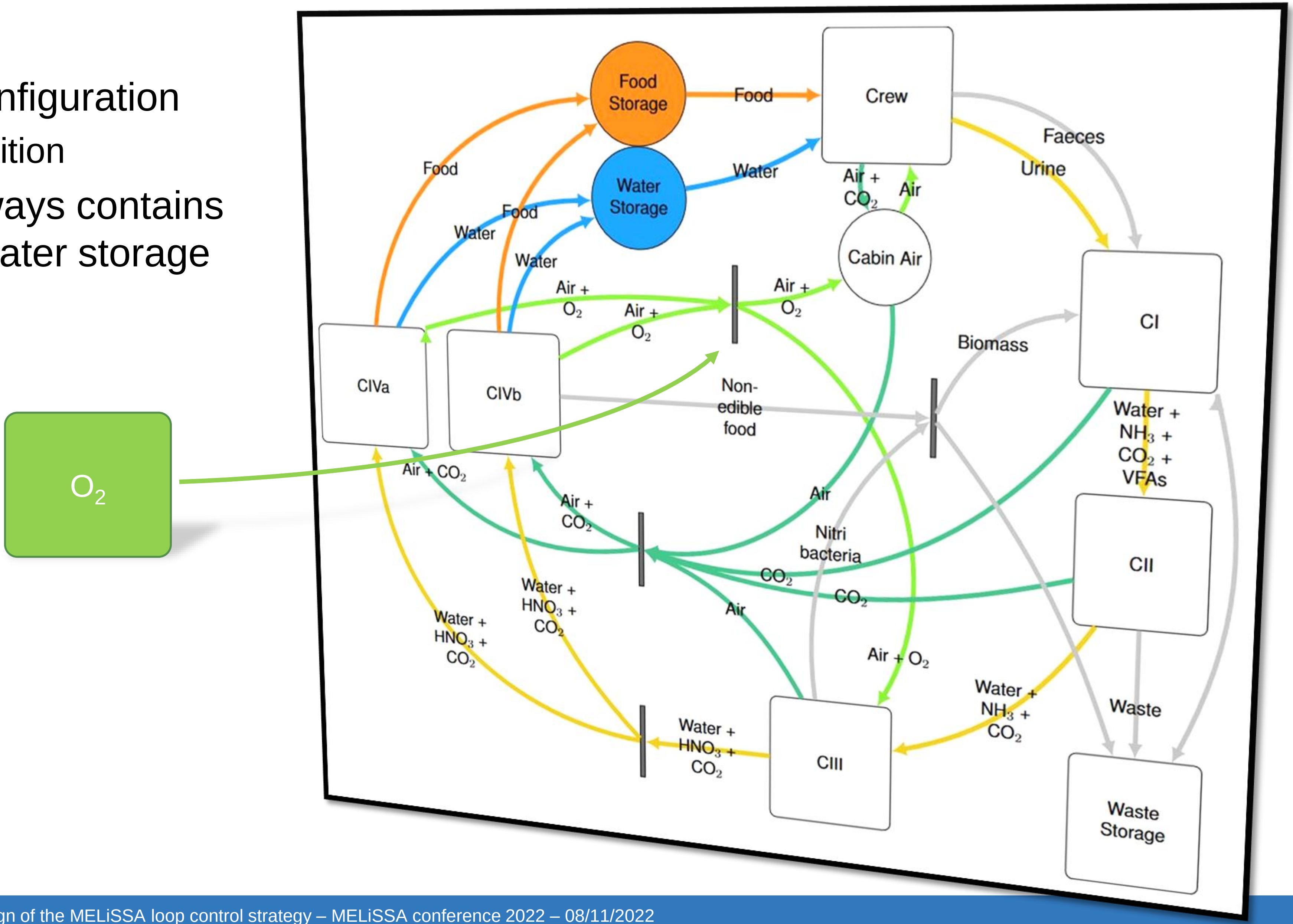
At a compartment level

Criteria	Expression
Coverage	$P/Mission$
Efficiency	P/I



Example : configurations

- Basic configuration
  - O_2 addition
- Loop always contains food & water storage

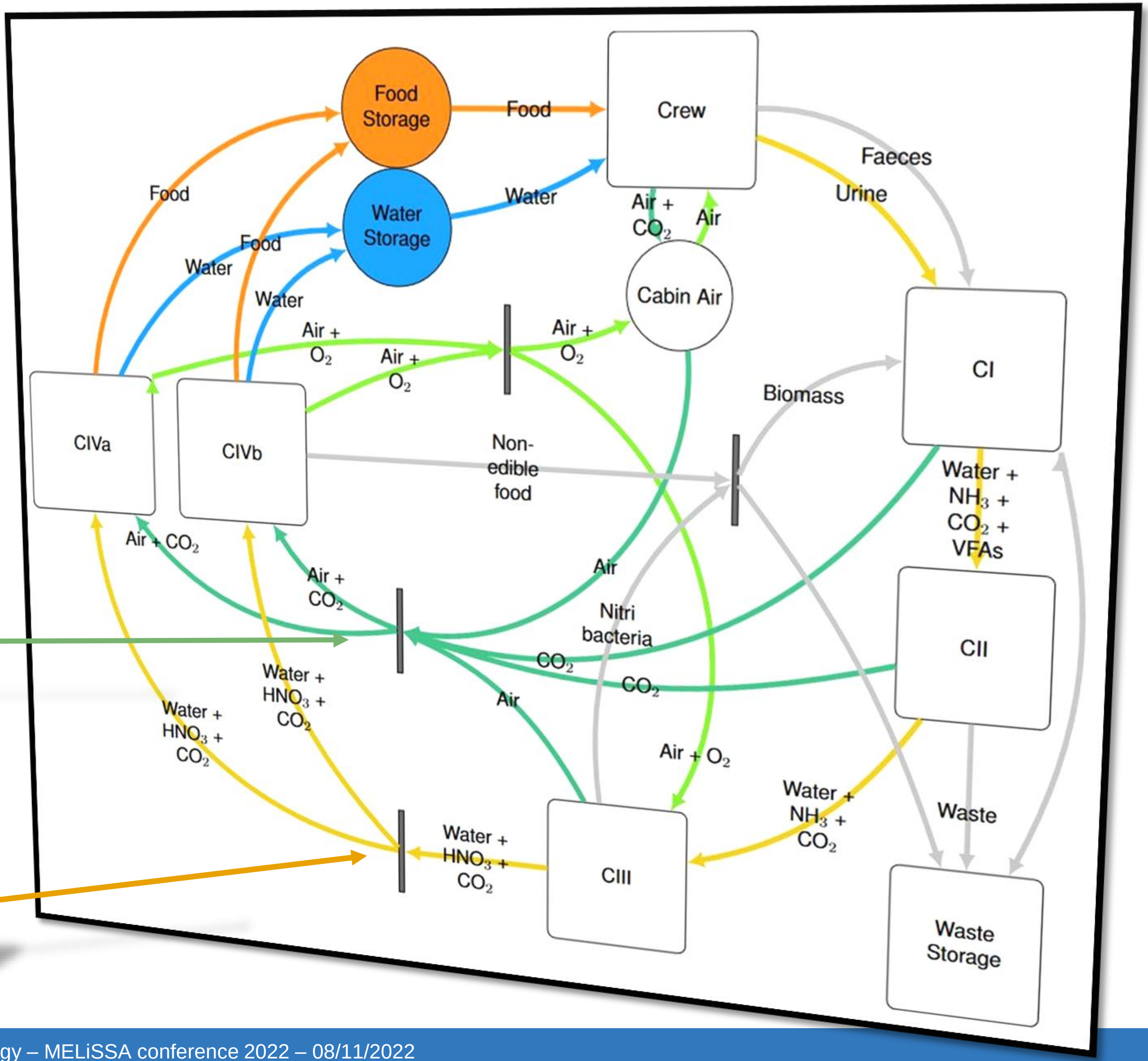


Example : configurations

- Configuration 1 :
  - C4 enrichment
    - HNO_3 & H_2SO_4 addition
    - CO_2 addition

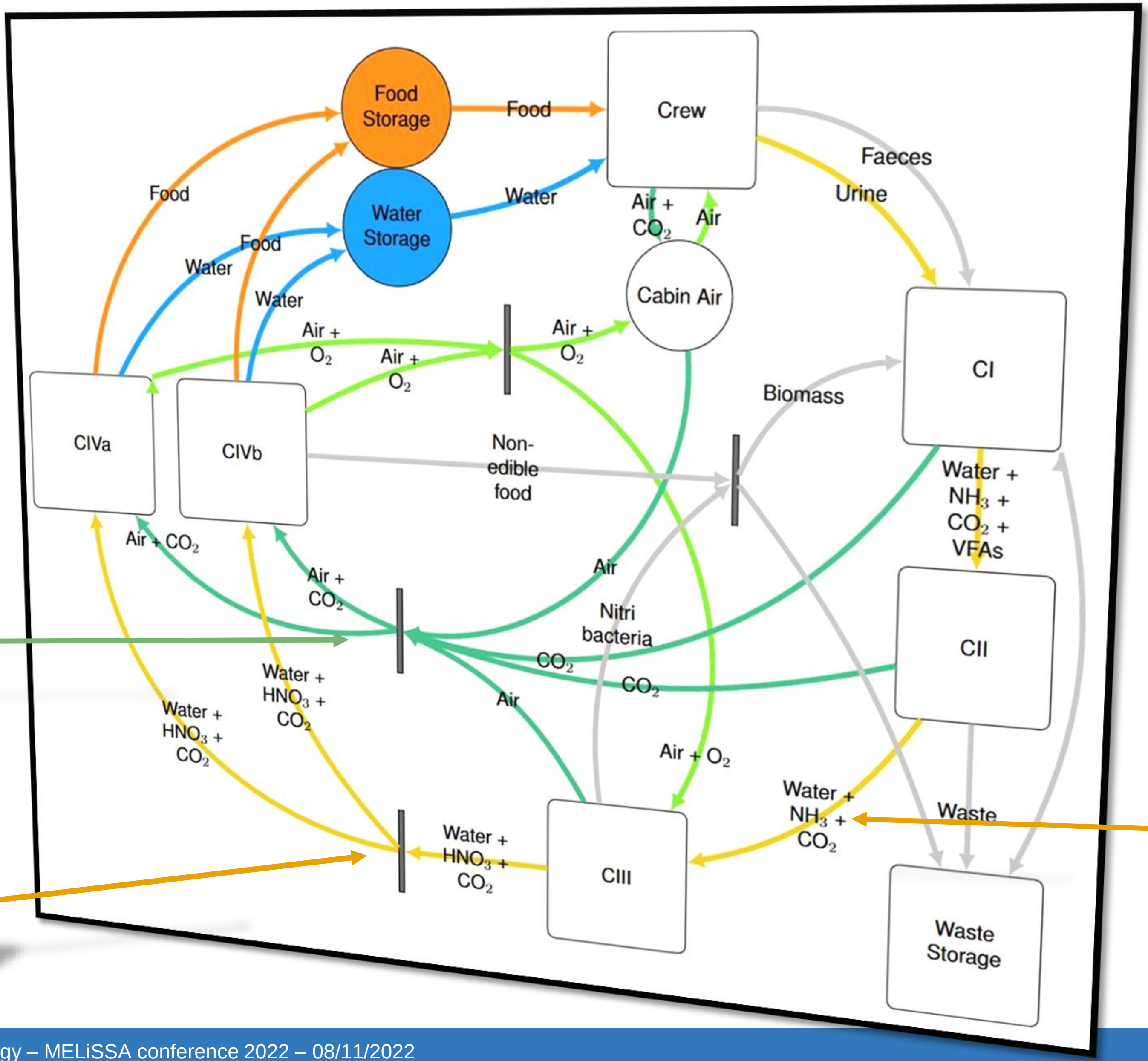
CO_2

HNO_3 & H_2SO_4



Example : configurations

- Configuration 2 :
  - C4 enrichment
    - H_2SO_4 addition
    - CO_2 addition
  - C3 enrichment
    - NH_3 & H_2SO_4 addition



CO_2

H_2SO_4

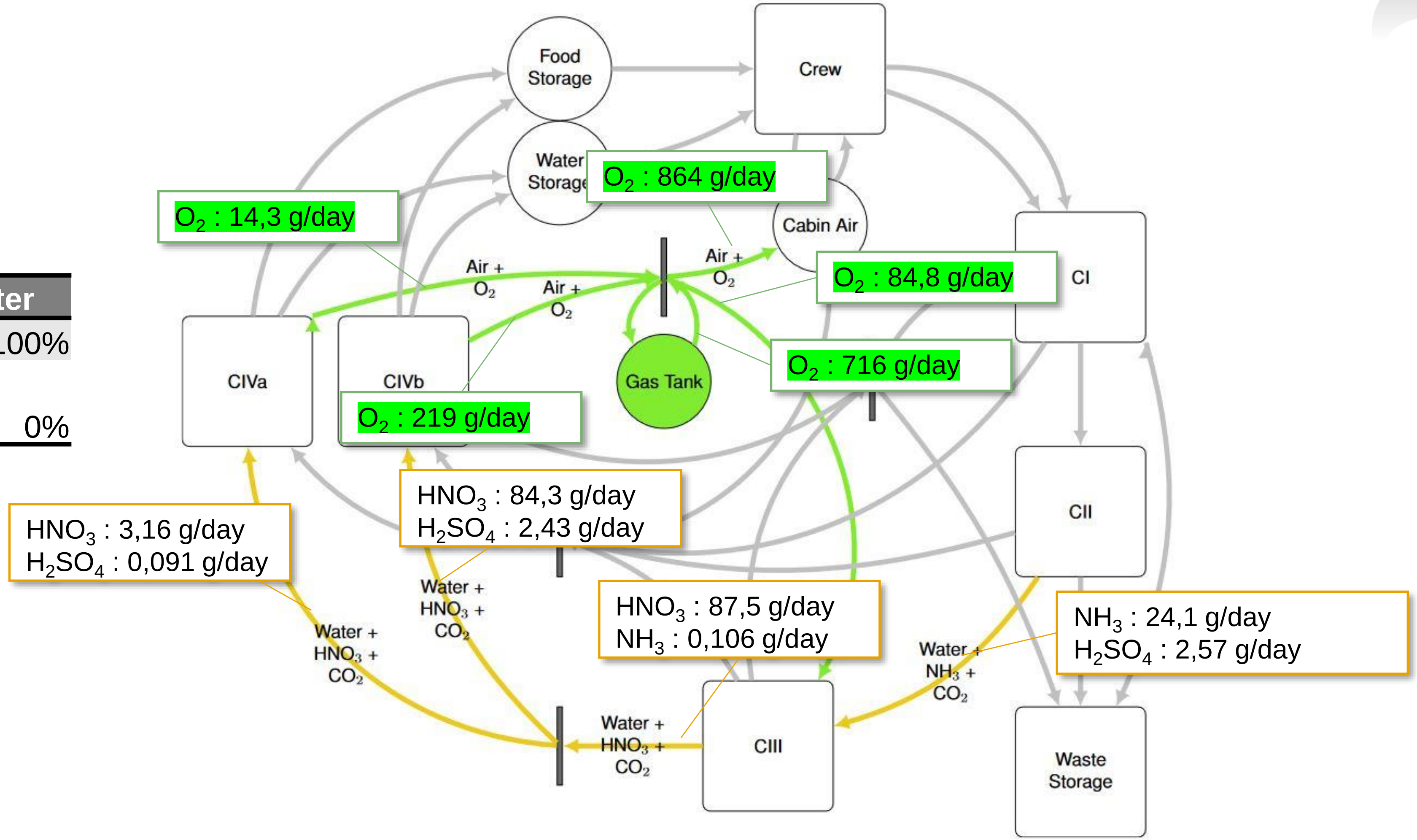
NH_3 & H_2SO_4

Example : results for basic configuration

Results :

Basic configuration

	O2	Food	Water
From loop	25%	13%	100%
From storage	75%	87%	0%



Example : results for C4 enrichment

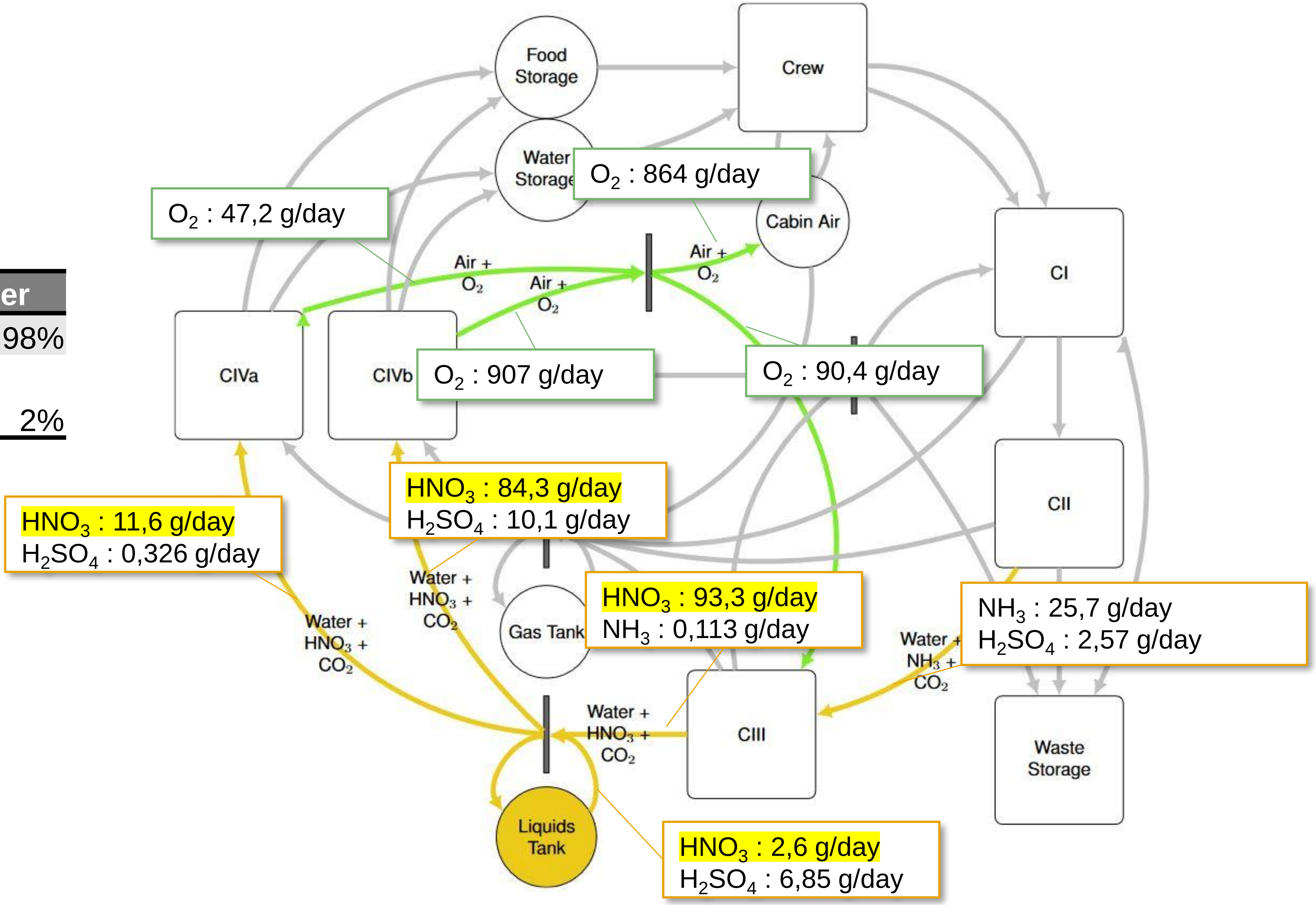
Results :

Configuration 1 – C4 enrichment

	O2	Food	Water
From loop	100%	52%	98%
From storage	0%	48%	2%

Nitrates :

- 2,7 % from the liquid tank
- 97,3 % from CIII



Example : results for C3 enrichment

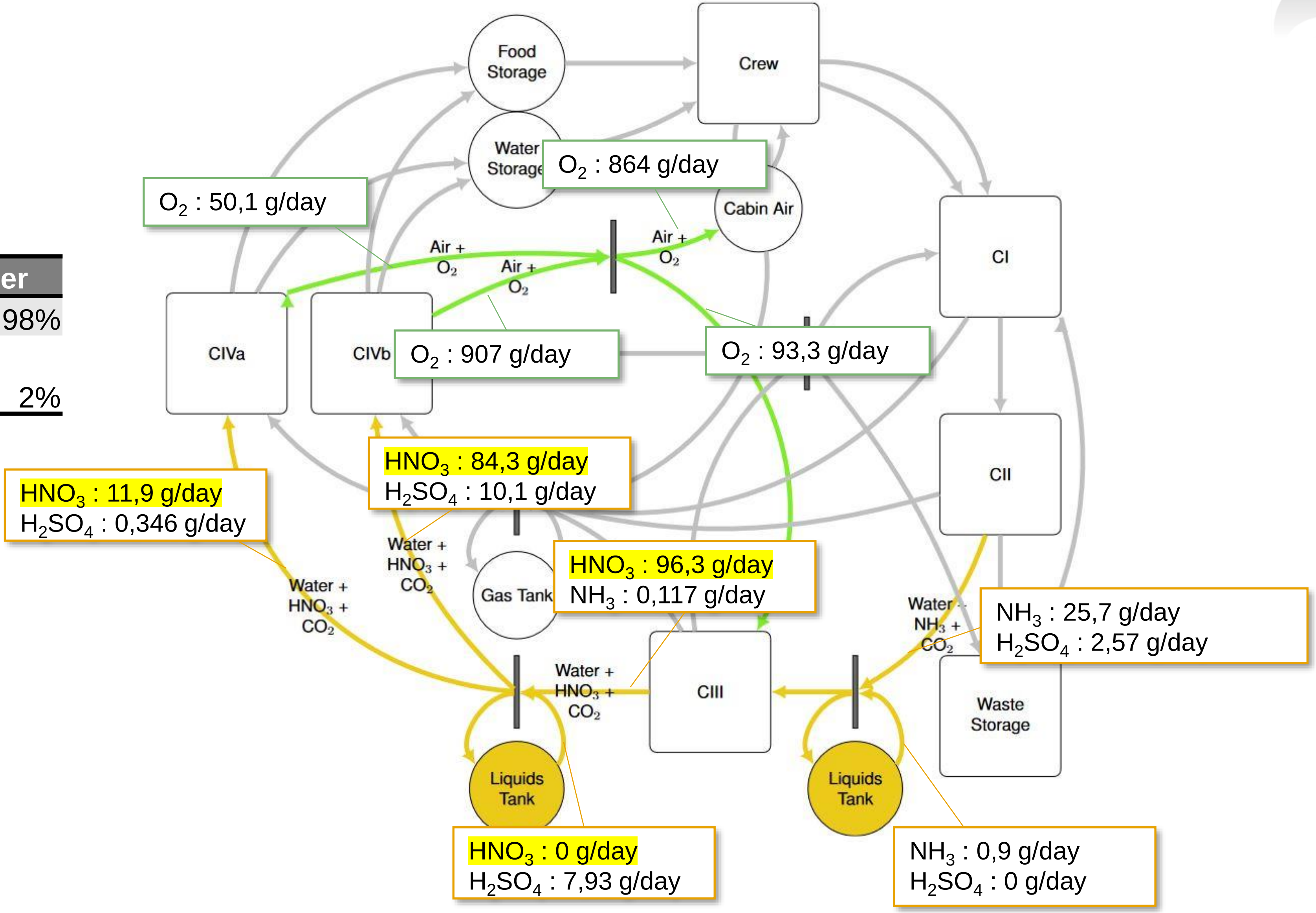
Results :

Configuration 2 – C3 enrichment

	O2	Food	Water
From loop	100%	52%	98%
From storage	0%	48%	2%

Nitrates :

- 0 % from the liquid tank
- 100 % from CIII

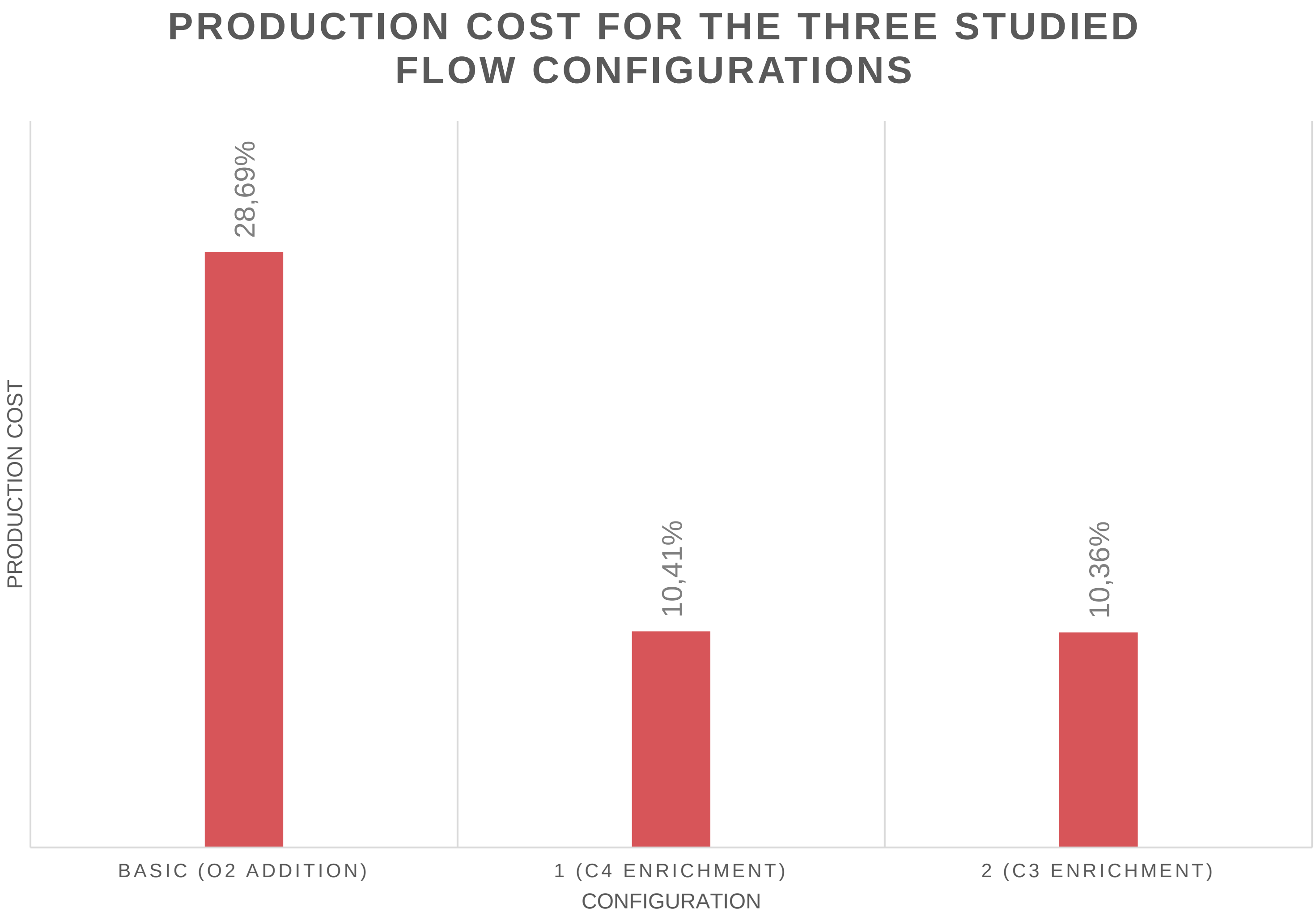


Example : ALiSSE criteria results

Results :

Comparison of production cost

→ Chemical product addition more efficient ! (in term of production cost)



Next steps

Tasks	
Scenario and requirements definition	✓
Methodology definition	✓
Study of the differents parameters and configurations	
Validation with complex models	

VARSITY Project

esa

ENGINSOFT

GHENT UNIVERSITY

ODYS – Advanced Controls & Optimization

SHERPA engineering

ThalesAlenia Space – a Thales / Leonardo company

UCA – Université Clermont Auvergne

SHERPA engineering

MELiSSA

Thank you

SHERPA Engineering