Universitat Autònoma de Barcelona

TECHNICAL NOTE 87.1.3

MPP integration strategy : 2009 roadmap

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CHANGE LOG

Issue/ *Edition*	Revision/ *Révision*	Status/ *Statut*	Date/ *Date*	Reason of the change	Modified paragraphs
0	0	final	01/12/11	Formalization of the integration strategy as per the feedback provided by experts in TN87.1.2	

Distribution List

Name/Nom	Company/Société	Quantity/Quantité
Brigitte LAMAZE	ESA	2 hardcopies + electronic version
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Table of Content

1. Scope

The present technical note is summarizing the roadmap of the integration steps between the compartments already installed or to be installed in the near future.

The work packages are described in the same format, providing information on
The necessary inputs for the considered step (hardware, software, knowledge)
The expected outputs (hardware, software, knowledge)

For each work package a schematic is explaining the configuration of interconnection proposed between the various compartments of the MELiSSA loop, with gas phase connections in red and with a G letter, liquid phase connections in blue with a L letter and solid phase connections in green and with a S letter. The symbol of a star represents an interface element needed for the connection.

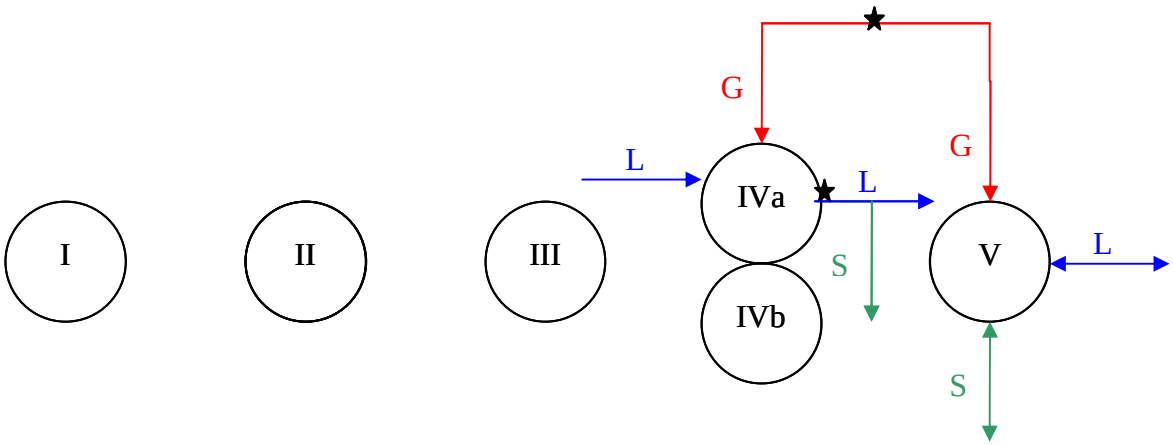
2. Rationale for the definition of the sequence of work packages

The logic followed for the integration approach was to respect the following guidelines:

- start where we have the max knowledge on control issues
- use as much as possible CIVb biomass to feed CI
- progressively enhance our control knowledge
- deal with the availability of hardware

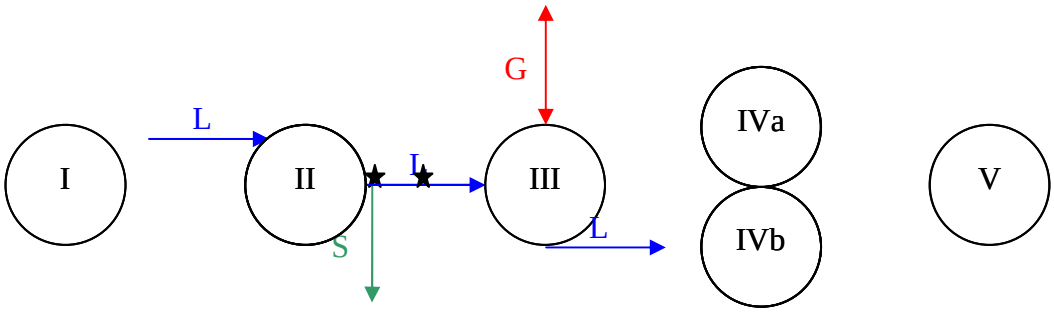
3. WP1 - Closure gas phase CIVa - CV

WP number	1.	**WP title**	Closure G phase CIVa - CV
duration	4 months		
inputs	Hardware	CIVa refurbished and validated	X
		CV delivered and validated	X
		Ar. Platensis harvesting system	TBD
		Interface G phase CV-CIVa(CV G phase purification?)	TBD
	Software	Control laws implemented in MPP PLCs	TBD
		Cpts connected to the MPP supervision system, level 2 control preliminary architecture	TBD
	Knowledge	Control law CIVa (C)	X
		Kla CIVa	TBD
		Control law O_2/CO_2	X
		Sizing validation	X
content	Constraint	animal	
	Manipulable inputs	CIVa light, CIVa dilution rate, pH CIVa	
	Set-point	concentrations in O_2 and CO_2 in CV gas phase	
	Culture conditions	Ar.Platensis culture on nitrate	
	Follow-up	O_2, CO_2, CV gas phase composition, CIVa liquid phase composition (SO4, PO4, C, N)	
	Quality control	axeny CIVa and CV	
	Duration	1 month preparation + 1 month continuous operation +2 month additional study	
Objectives/ outputs	1-Demonstration of Biorat O_2/CO_2 control law (with pH control and no equilibrium of respiratory coefficient) 2-Validation of AP harvesting system 3- management of contaminants of CV gas phase		
Rationale	Demonstration of the O2/CO2 control law on new hardware Communication impact Good training for the new MPP team		
Remarks	Purification of CV G phase to be foreseen, thermal control as well		



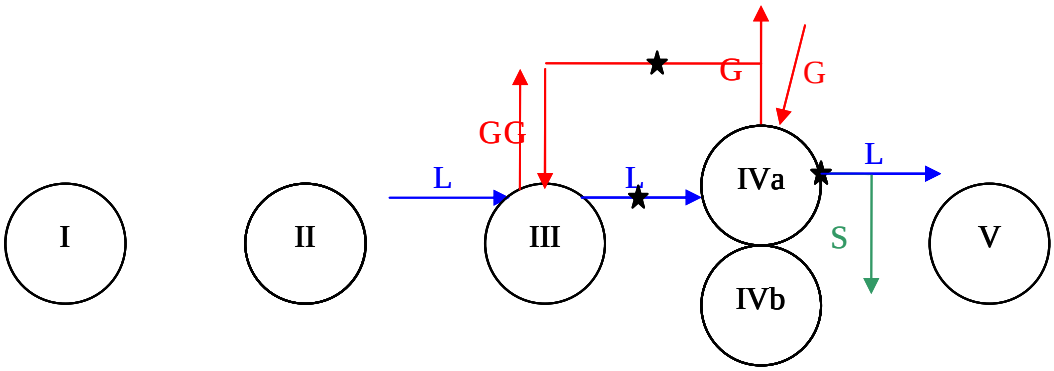
4. WP2 – Connection liquid phase CII-CIII

WP number	2.	**WP title**	Connection L phase CII-CIII	
duration	7 months			
inputs	Hardware	CIII validated , operational steady state CII validated Rubrum harvesting system Additional interface to remove potential residual VFA in CII output		X X X TBD
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture		TBD TBD
	Knowledge	Part a: control law CIII (N), Kla CIII Part b: Control law CIII(N), Kla CIII, control law CII (C, N)		TBD TBD
Content Part a	Constraint	CII dilution rate and CII light		
	Manipulable inputs	CIII dilution rate (hydraulic residence time CII), O2 input (TBC)		
	Set-point	NO2 and NO3 concentrations CIII		
	Culture conditions	Segers&Verstraete CII		
	Follow-up	pH CIII, pO2 CIII, NH4+, NO2, NO3 CIII, VFA, NH4+ CII liquid phase, SO4, PO4 CII and CIII		
	Quality control	axeny		
	Duration	1 month preparation + 3 months continuous operation		
Content Part b	Constraint	C sources (VFA composition and concentration) CII liquid input		
	Manipulable inputs	CII light, CII dilution rate, CIII dilution rate (hydraulic residence time in CII), O2 input (TBC)		
	Set-point	NH4 and VFA concentrations CII, NO2 and NO3 concentrations CIII		
	Culture conditions	Segers&Verstraete modified (various VFA sources) CII		
	Follow-up	CII: VFA, NH4+ , SO4, PO4 CIII: pH, pO2 , NH4+, NO2, NO3, SO4, PO4		
	Quality control	axeny		
	Duration	3 months continuous operation		
Objectives/ outputs	Control law validated: CIII(N) , CII (C, N)			
Rationale	After CIVa, CIII is the most advanced (know-how, knowledge). 1st step in the closure of the liquid phase.			
Remarks				



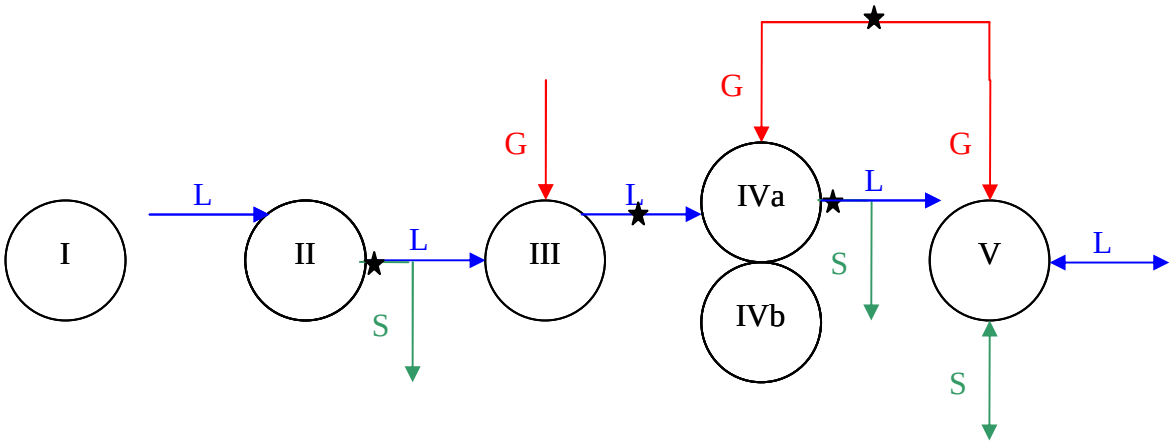
5. WP3 - Connection liquid phase CIII-CIVa and gas phase CIVa-CIII

WP number	3.	**WP title**	Connection L phase CIII-CIVa Connection G phase CIVa-CIII
duration	3 months		
inputs	Hardware	CIII validated, operational steady state CIVa refurbished, validated Interface L phase CIII-CIVa Interface G phase CIVa – CIII Spiru harvest. system	X X X TBD TBD
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture	TBD
	Knowledge	Preferably performed after WP 2.a, however feasible if control law CIII, Kla CIII, control law CIVa (including O2/CO2 dynamic equilibrium in the produced gas phase jointly with pH control) and Kla CIVa known and validated	TBD
content	Constraint	CIII dilution rate	
	Manipulable inputs	CIVa light, CO2 addition CIVa	
	Set-point	CIVa O2 production, CIII [NO3 or NO2 , depending on control law design] output	
	Culture conditions	Winogradsky CIII	
	Follow-up	CIII: pH, pO2, NH4+, NO2, NO3, SO4, PO4, O2 CO2 gas phase CIVa: pO2, NO3, SO4, PO4	
	Quality control	axeny	
	Duration	1 month preparation + 2 months continuous operation.	
Objectives/ outputs	Control laws validated: CIII-N+ dynamic gas phase C,O and CIVa-C,N +gas/liquid dynamic		
Rationale	Continuation of the study of the liquid phase closure Opportunity to initiate additional study of gas phase closure		
Remarks	Equilibrium G-L phases CIII – CIVa to be studied Validation of O2 toxicity in case of excess from CIVa to CIII		



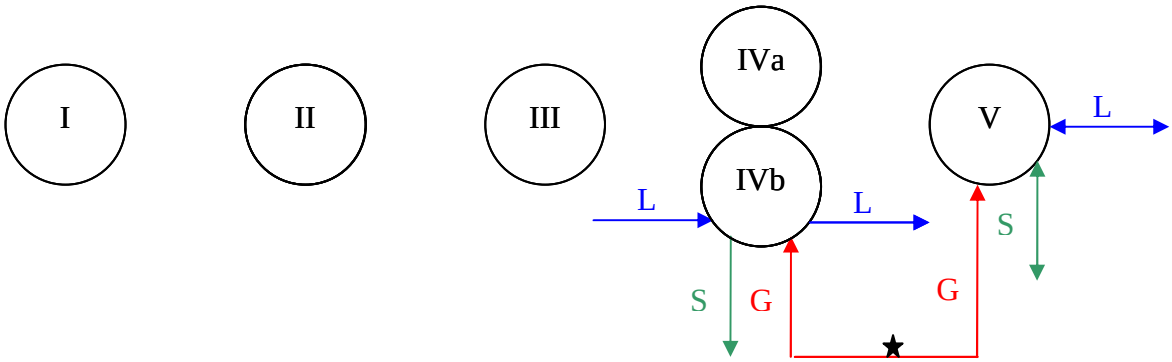
6. WP 4 - Closure gas phase CIVa-CV and Connection liquid phase CII-CIII-CIVa

WP number	4.	**WP title**	Closure G phase CIVa-CV Connection L phase CII-CIII-CIVa	
duration	13 months			
inputs	Hardware	CII validated CIII validated, operational steady state CIVa refurbished, validated CV validated Interface L phase CIII-CIVa Interface G phase CV-CIVa Spiru Harvest. System Rubrum harvest. system		X X X X TBD TBD X
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture		TBD
	Knowledge	Output of WP1+WP2+WP3		
content	Constraint	animal		
	Manipulable inputs	dilution rate, light, CII, dilution rate CIII (hydraulic residence time CII), CIVa light		
	Set-point	O2/CO2 CV		
	Culture conditions	Segers&Verstraete CII		
	Follow-up	CII: NH4+, VFA, SO4, PO4 CIII: pH , pO2 , NH4+, NO2, NO3 , SO4, PO4 CIVa: pO2, NO3, SO4, PO4 , O2, CO2 CV: O2, CO2, contaminants gas phase		
	Quality control	axeny (CIII,CIVa), CV		
	Duration	2 month preparation + 12 months continuous operation/study. (Validation of two control 1 loops (CIII –N and CIVa-C+N) on CIII synthetic media→ 6 months Determination of limit behaviors → 6 months)		
Objectives/ outputs	Control loops validated: CIII(N) and CIVa (C+N)			
Rationale	Logic step after WP1, 2 and 3, progressive closure of the liquid loop, including the dynamic brought by the animals on the gas phase Validation of the results obtained in the past, on new generation hardware			
Remarks	Performance with or without Spiru harvesting This scenario for L phase connection has been performed in the past however with “manually “connected compartments FIRST MILESTONE for L phase connection demonstration			



7. Wp 5 – closure gas phase CIVb-CV

WP number	5.	**WP title**	Closure G phase CIVb-CV	
duration	5 months			
inputs	Hardware	CIVb validated, operational steady state CV validated Interface G phase CIVb-CV		X X TBD
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture		X
	Knowledge	Control law CIVb Preliminary sizing validation (O2 production)		TBD
content	Constraint	animal		
	Manipulable inputs	CIVb light, composition and residence time of CIVb liquid phase , CIVb light		
	Set-point	concentrations in O_2 and CO_2 in CV gas phase		
	Culture conditions	Hoagland for CIVb		
	Follow-up	CIVb gas phase composition (including hormones if possible) , O_2, CO_2, CV gas phase composition, CIVb liquid phase composition (TBD)		
	Quality control	CV microbiological control CIVb (HPC surfaces, liquid phase, roots),		
	Duration	1 month preparation + 4 month study		
Objectives/ outputs	Validated control law CIVb (light, gas phase, NH4+/NO3 ratio)			
Rationale	Need to progress on CIVb knowledge and know-how			
Remarks	Necessity of preliminary calculations for gas phase management between the compartments			


I
II
III
IVa
IVb
V
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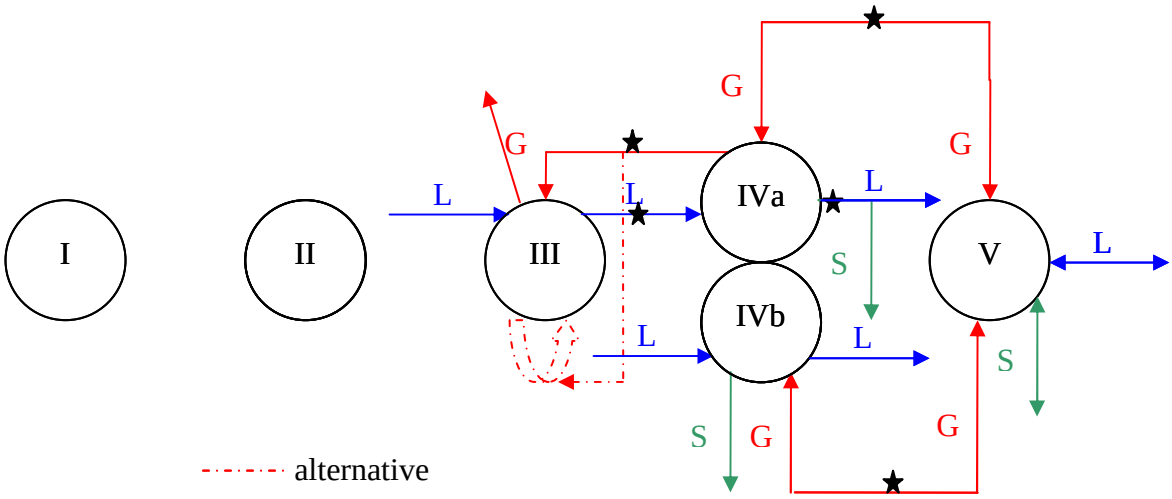
8. WP6 – connection liquid phase CIII-CIVa, gas pahse CIVa-CIII, closure gas phase CIVa-CV

WP number	6.	**WP title**	Connection L phase CIII-CIVa Connections G phase CIVa-CIII Closure G phase CIVa-CV	
duration	10 months			
inputs	Hardware	CIII validated, operational steady state CIVa refurbished, validated CIVb validated, operational steady state CV validated Interface G phase CIVb-CV Interface G phase CIVa-CV Interface L phase CIII-CIVa Interface G phase CIVa – CIII Spiru harvest. system		X
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture		X
	Knowledge	Output of WP1+WP3+WP5 Preliminary sizing validation (O2, CO2)		
content	Constraint	animal		
	Manipulable inputs	CIII dilution rate, O2 in CIII CIVb liquid phase composition and residence time CIVa light, CIVb light pH CIVa		
	Set-point	concentrations in O_2 and CO_2 in CV gas phase		
	Culture conditions	Winogradsky CIII Hoagland CIVb		
	Follow-up	CIII: pH, pO2 , NH4+, NO2, NO3, SO4, PO4,O2 CO2 gas phase CIII CIVa: liquid phase composition (SO4, PO4, C, N), pO2, NO3, SO4, PO4 CIVb: CIVb gas phase composition (including hormones if possible) CV: O_2, CO_2, CV gas phase O_2, CO_2, CV gas phase composition, CIVb liquid phase composition (TBD)		
	Quality control	Axeny: CII, CIII, CIVa CV microbiological control CIVb (HPC surfaces, liquid phase, roots),		
	Duration	1 month preparation and then 1- 6 months 2- 3 months		

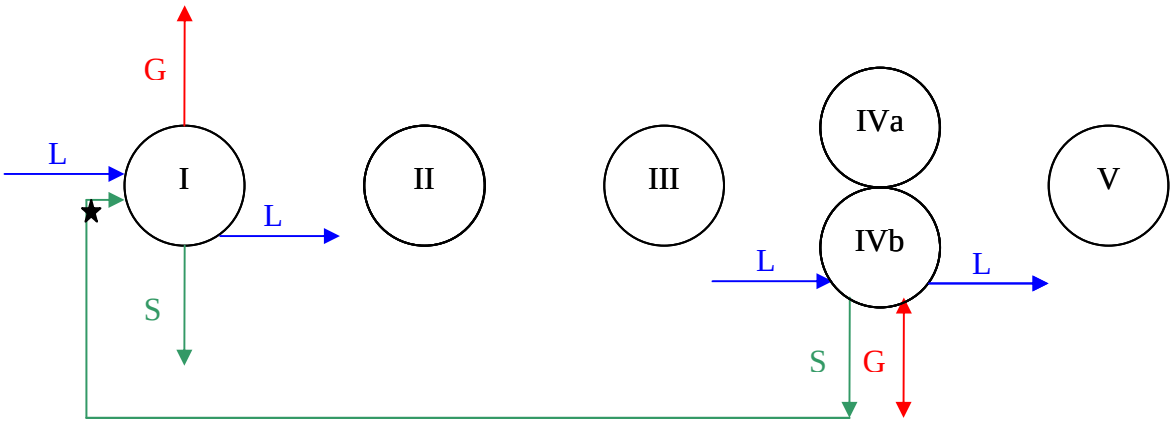
Objectives/ outputs	1-Validation of two control 1 loops (CIII –N and CIVa- C+N) on CIII synthetic media 2- Determination of limit behaviors Gaining expertise on process operation, especially on gas phase management
Rationale	Continuation of the study on gas loop closure
Remarks	To avoid loosing O2 in CIII output gas phase, recirculation of CIII gas phase could be foreseen Necessity of preliminary calculations for gas phase management between the compartments FIRST MILESTONE For gas loop closure demonstration



9. WP 7

WP number	7.	**WP title**	Connection S phase CIVb-CI
duration	7 months		
inputs	Hardware	CI fully characterized CIVb validated, operational steady state Interface S phase CIVb-CI	X X TBD
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture	TBD
	Knowledge	Control 1 loop CI (C+N) Control law CIVb or output WP5	TBD

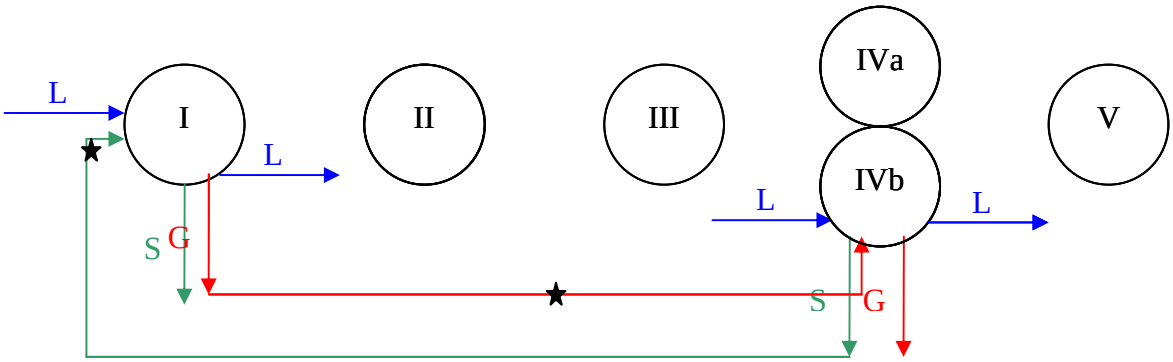
content	Constraint	Plants metabolism/composition
	Manipulable inputs	CI residence time CIVb light CIVb liquid solution composition and residence time
	Set-point	CI [VFA] L output
	Culture conditions	Hoagland CIVb
	Follow-up	CI: L input composition, L output composition, G composition CIVb: composition of plants, G phase composition
	Quality control	microbiological control CIVb (HPC surfaces, liquid phase, roots),
	Duration	1 month + 6 months study
Objectives/ outputs	Knowledge on CI outputs Further validation of CI control 1 loop	
Rationale	Initiate study of solid phase in MELiSSA with MELiSSA crops cultivated in controlled conditions	
Remarks	Depending on the availability of HPCs (1, 2 or 3), the amount of plants might be different	



10. WP8

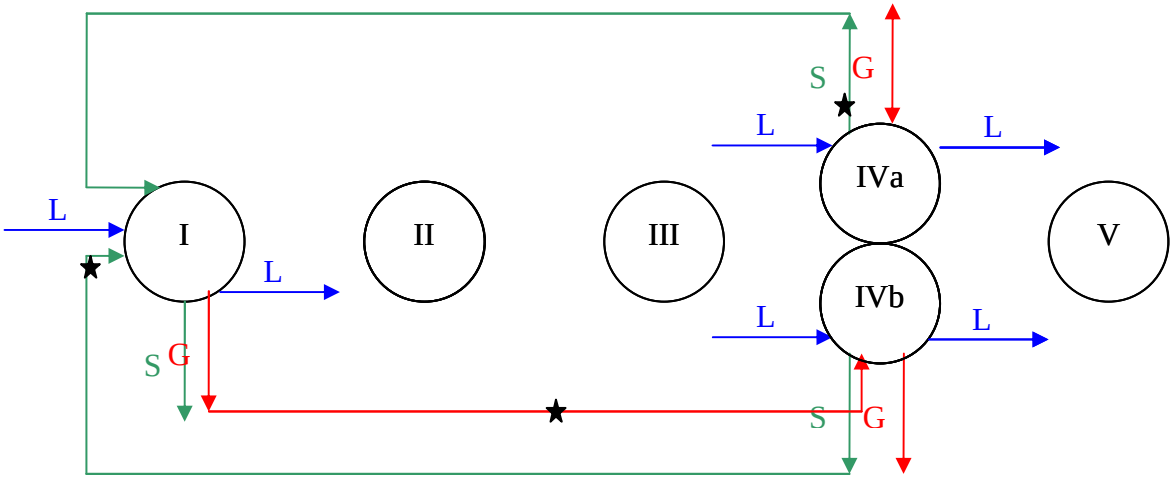
WP number	8.	**WP title**	Connection S phase CIVb-CI Connection G phase CI-CIVb
duration	7 months		
inputs	Hardware	CI fully characterized CIVb validated, operational steady state Interface S phase CIVb-CI Interface G phase CIVb-CI	X X TBD TBD
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture	TBD
	Knowledge	Output WP 7 Preliminary sizing validation on gas phase and solid phase	TBD

content	Constraint	Plants metabolism/composition
	Manipulable inputs	CI residence time CIVb light CIVb liquid solution composition and residence time
	Set-point	CI [VFA] L output
	Culture conditions	Hoagland CIVb
	Follow-up	CI: L input composition, L output composition, G composition CIVb: composition of plants, G phase composition
	Quality control	microbiological control CIVb (HPC surfaces, liquid phase, roots),
	Duration	1 month + 6 months study
Objectives/ outputs	Knowledge on CI outputs Further validation of CI control 1 loop New step in the study of gas phase and solid phase	
Rationale	Logic continuation of WP 7 to gain knowledge and know-how on gas phase management	
Remarks	Depending on the availability of HPCs (1, 2 or 3), the amount of plants might be different SECOND Milestone for G loop closure demonstration	



11. WP 9 -

WP number	9.	**WP title**	Connection S phase CIVb-CI and CIVa – CI Connection G phase CI-CIVb	
duration	4 months			
inputs	Hardware	CI fully characterized CIVb validated, operational steady state CIVa in operational steady state Interface S phase CIVb-CI Interface G phase CIVb-CI Spiru. Harvesting system		X X TBD TBD
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture		TBD
	Knowledge	Output WP 8 Preliminary sizing validation on Solid phase		TBD
content	Constraint	Plants and algae metabolism/composition		
	Manipulable inputs	CI residence time CIVa light and dilution rate, pH CIVb light		
	Set-point	CI [VFA] L output		
	Culture conditions	Zarrouk for CIVa Hoagland CIVb		
	Follow-up	CI: L input composition, L output composition, G composition CIVa :liquid phase composition, biomass composition CIVb: composition of plants, G phase composition		
	Quality control	microbiological control CIVb (HPC surfaces, liquid phase, roots), axeny CIVa		
	Duration	1 month + 3 months study		
Objectives/ outputs	Knowledge on CI outputs Further validation of CI control 1 loop New step in the study of gas phase and solid phase (composition of the gas phase versus waste composition)			
Rationale	Logic continuation of WP 8 to gain knowledge and know-how on CI			
Remarks	Depending on the availability of HPCs (1, 2 or 3), the amount of plants might be different It is mandatory to make some preliminary sizing validation to define the quantities of plants/ algae to be used			

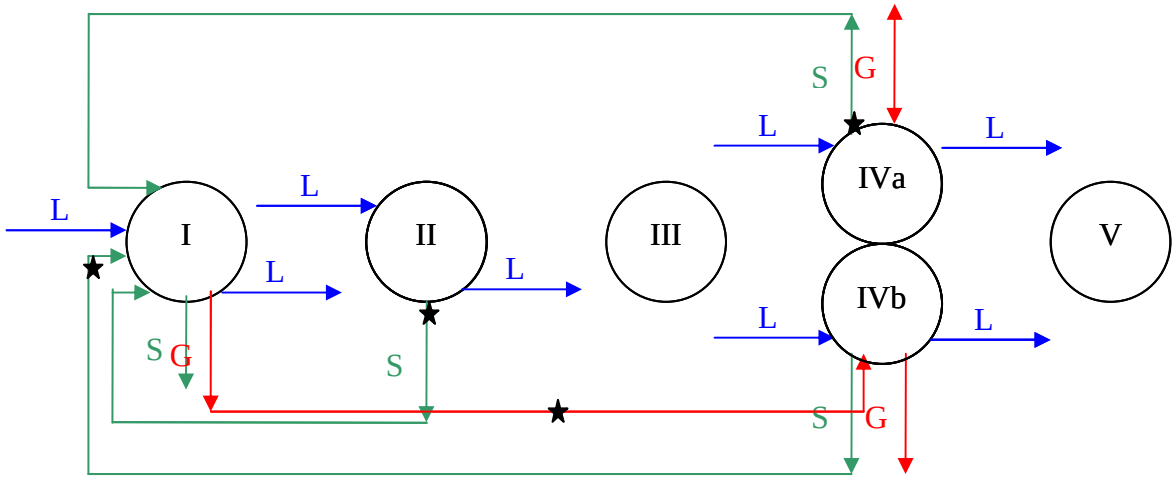


12. WP10 –

WP number	10.	**WP title**	Connection S phase CIVb-CI, CIVa – CI and CII-CI Connection G phase CI-CIVb
duration	6 months		
inputs	Hardware	CI fully characterized CII in operational steady state CIVb validated, operational steady state CIVa in operational steady state Interface S phase CIVb-CI Interface G phase CIVb-CI Spiru. Harvesting system R. Rubrum harvesting system	X X TBD TBD
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture	TBD
	Knowledge	Output WP 9 Preliminary sizing validation on Solid phase	TBD

content	Constraint	Plants and algae metabolism/composition
	Manipulable inputs	CI residence time CII dilution rate and light CIVa light and dilution rate, pH CIVb light, composition and residence time of liquid solution
	Set-point	CI [VFA] L output
	Culture conditions	Segers and Verstraete CII Zarrouk for CIVa Hoagland CIVb
	Follow-up	CI: L input composition, L output composition, G composition, S composition CII : liquid phase composition, biomass composition CIVa: liquid phase composition, biomass composition CIVb: composition of plants, G phase composition
	Quality control	microbiological control CIVb (HPC surfaces, liquid phase, roots), axeny CII and CIVa
	Duration	1 month + 5 months study (TBC, why 5 here and 3 in WP9)
Objectives/ outputs	Knowledge on CI outputs Further validation of CI control 1 loop New step in the study of gas phase and solid phase (composition of the gas phase versus waste composition)	
Rationale	Logic continuation of WP 9 to gain knowledge and know-how on CI	
Remarks	Depending on the availability of HPCs (1, 2 or 3), the amount of plants might be different It is mandatory to make some preliminary sizing validation to define the	

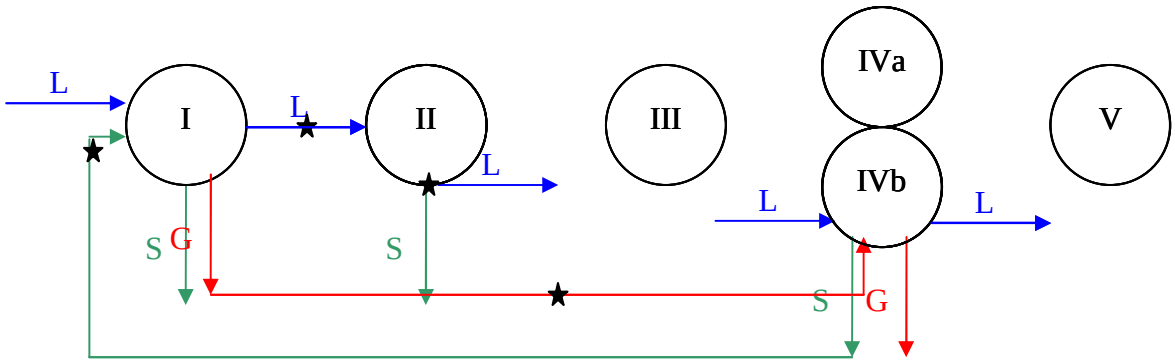
	quantities of plants/ algae to be used and to validate that CI can reach a steady state MILESTONE on Solid loop closure demonstration



13. WP11 -

WP number	11.	**WP title**	Connection L phase CI-CII Connection S phase CIVb-CI Connection G phase CI-CIVb
duration	9 months		
inputs	Hardware	CI fully characterized CII operational steady state CIVb validated, operational steady state Interface L phase CI-CII (if any) Interface S phase CIVb-CI Interface G phase CIVb-CI R.Rubrum harvesting system	X X TBD TBD
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture	TBD
	Knowledge	Output WP 8 Control law CII Full characterization of CI and CI L output Preliminary sizing validation on gas phase and solid phase	TBD
content	Constraint	Plants metabolism/composition CII liquid input composition	
	Manipulable inputs	CI residence time (as a consequence CII dilution rate) CII light (and agitation?) CIVb liquid solution composition and residence time, CIVb light	
	Set-point	CI : total VFA concentration L output (however difficult to have on-line)or CII biomass production?	
	Culture conditions	Hoagland CIVb	
	Follow-up	CI: L input composition, L output composition, G composition CII: L output composition (including VFA), biomass composition CIVb: composition of plants, G phase composition	
	Quality control	microbiological control CIVb (HPC surfaces, liquid phase, roots), CII axeny	
	Duration	1 to 2 months + 7 months study	
Objectives/ outputs	1- Add. validation of Control 1 loop CII(C+N)→ 1 month 2- Determination of CII limit behaviors→ 6 month New step in the study of L phase connection Further validation of CII control law		
Rationale	Necessity to progress on study of the liquid loop closure (the last step is the connection from CI L phase to the rest of the Cpts)		
Remarks	Depending on the availability of HPCs (1, 2 or 3), the amount of plants might be different Can be performed with or without R. Rubrum harvesting system		

	Can be performed after WP8, or 9 depending if opportunity is taken to have CIVa biomass sent to CI as well.

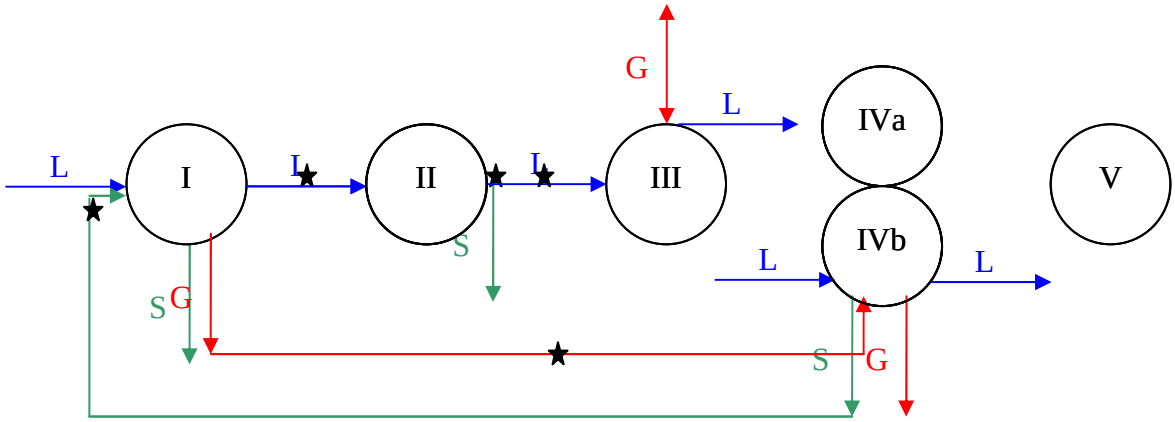


14. WP12

WP number	12.	**WP title**	Connection L phase CI-CII-CIII Connection S phase CIVb-CI Connection G phase CI-CIVb
duration	4 months		
inputs	Hardware	CI fully characterized CII operational steady state CIII operational steady state CIVb validated, operational steady state Interface L phase CI-CII (if any) Interface S phase CIVb-CI Interface G phase CIVb-CI R.Rubrum harvesting system	X X TBD TBD
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture	TBD
	Knowledge	Output WP 11 and WP2 Full characterization of CI and CI L output	

content	Constraint	Plants metabolism/composition CII liquid input composition
	Manipulable inputs	CI residence time (as a consequence CII and CIII dilution rate) CII light (and agitation?) CIII : O2 input (TBC) CIVb liquid solution composition and residence time, CIVb light
	Set-point	CIII [NO3] output
	Culture conditions	Hoagland CIVb
	Follow-up	CI: L input composition, L output composition, G composition CII: L output composition (including VFA, NH4+ , SO4, PO4), biomass composition CIII: pH, pO2 , NH4+, NO2, NO3, SO4, PO4 CIVb: composition of plants, G phase composition
	Quality control	microbiological control CIVb (HPC surfaces, liquid phase, roots), CII and CIII axeny
	Duration	1 month + 3 months study
Objectives/ outputs	1- Add. validation of Control 1 loop CII(C+N)→ 1 month 2- Determination of CII limit behaviors→ 6 month New step in the study of L phase connection Further validation of CII and CIII control law	
Rationale	Necessity to progress on study of the liquid loop closure (the last step is the connection from CI L phase to the rest of the Cpts)	
Remarks	Depending on the availability of HPCs (1, 2 or 3), the amount of plants might be different Can be performed with or without R. Rubrum harvesting system Can be performed after WP8, or 9 depending if opportunity is taken to have	

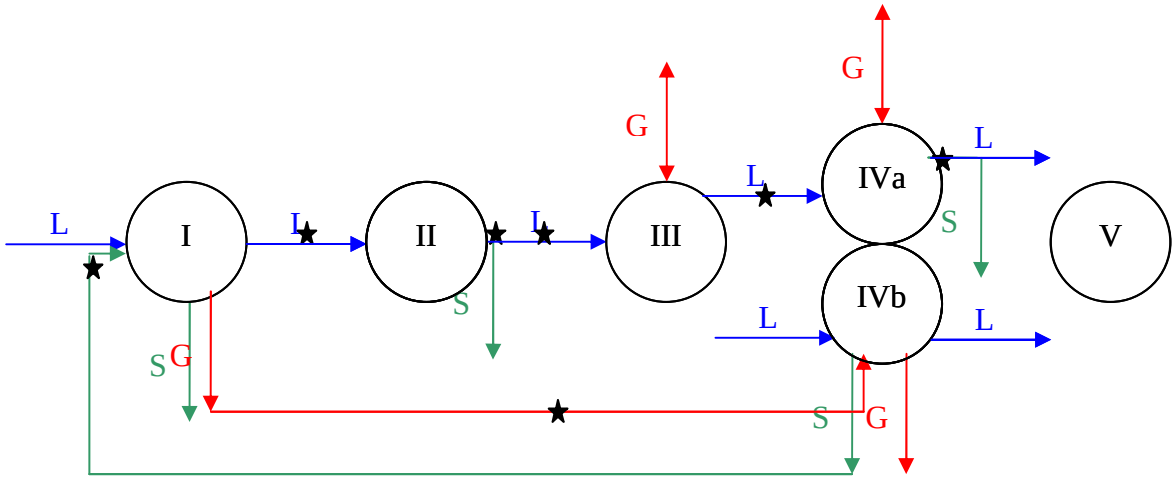
	CIVa biomass sent to CI as well.



15. WP13-

WP number	13.	**WP title**	Connection L phase CI-CII-CIII-CIVa Connection S phase CIVb-CI Connection G phase CI-CIVb
duration	4 months		
inputs	Hardware	CI fully characterized CII operational steady state CIII operational steady state CIVa operational steady state CIVb validated, operational steady state Interface L phase CI-CII (if any), CII-CIII (if any), CIII-CIVa (if any) Interface S phase CIVb-CI Interface G phase CIVb-CI R.Rubrum harvesting system Spiru. Harvesting system	X X TBD TBD
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture	TBD
	Knowledge	Output WP 12 and WP4	
content	Constraint	Plants metabolism/composition CII liquid input composition	
	Manipulable inputs	CI residence time (as a consequence CII and CIII dilution rate) CII light (and agitation?) CIII : O2 input (TBC) CIVa : light CIVb liquid solution composition and residence time, CIVb light	
	Set-point	CIVa O2 production	
	Culture conditions	Hoagland CIVb	
	Follow-up	CI: L input composition, L output composition, G composition CII: L output composition (including VFA, NH4+ , SO4, PO4), biomass composition CIII: pH, pO2 , NH4+, NO2, NO3, SO4, PO4 CIVa: L output composition, biomass composition CIVb: composition of plants, G phase composition	
	Quality control	microbiological control CIVb (HPC surfaces, liquid phase, roots), CII, CIII and CIVa axeny	
	Duration	1 month + 3 months study	
Objectives/ outputs	Demonstration of L phase connection over 4 cpts		
Rationale	Necessity to progress on study of the liquid loop closure (the last step is the connection from CI L phase to the rest of the Cpts), logic step after WP 12		
Remarks	Depending on the availability of HPCs (1, 2 or 3), the amount of plants might be different		

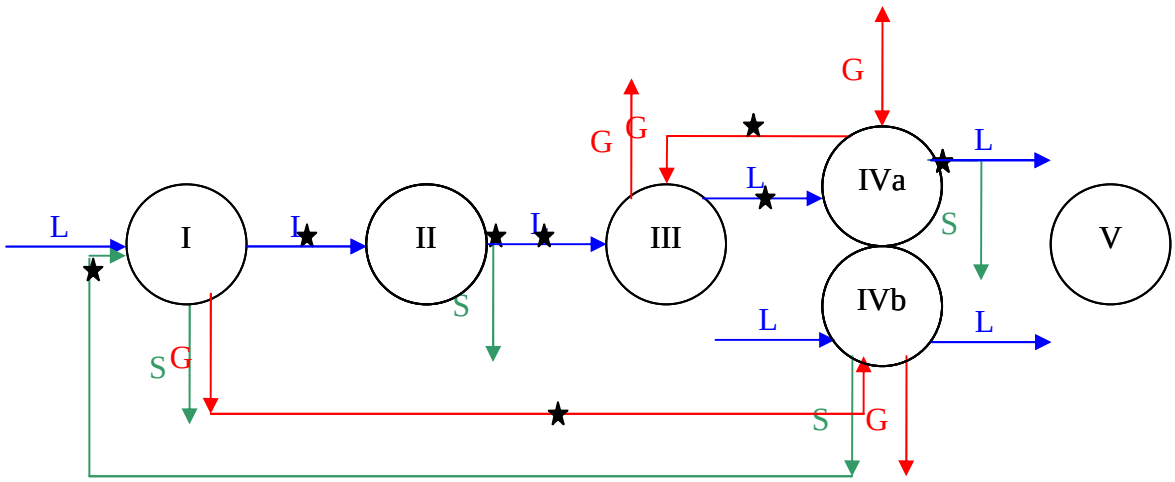
	Can be performed with or without R. Rubrum and Spiru.harvesting system Any interest in: having CIVa biomass sent to CI as well? Connecting CIVb on L phase? SECOND MILESTONE for L phase connection demonstration



16. WP14 –

WP number	14.	**WP title**	Connection L phase CI-CII-CIII-CIVa Connection S phase CIVb-CI Connection G phase CI-CIVb and CIVa - CIII
duration	6 months		
inputs	Hardware	CI fully characterized CII operational steady state CIII operational steady state CIVa operational steady state CIVb validated, operational steady state Interface L phase CI-CII (if any), CII-CIII (if any), CIII-CIVa (if any) Interface S phase CIVb-CI Interface G phase CIVb-CI and CIVa-CIII R.Rubrum harvesting system Spiru. Harvesting system	X X TBD TBD
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture	TBD
	Knowledge	Output WP 13 and WP3 Preliminary sizing validation on Gas phase management	
content	Constraint	Plants metabolism/composition CII liquid input composition	
	Manipulable inputs	CI residence time (as a consequence CII and CIII dilution rate) CII light (and agitation?) CIII : O2 input (TBC) CIVa : light CIVb liquid solution composition and residence time, CIVb light	
	Set-point	CIVa O2 production, CIVb biomass production	
	Culture conditions	Hoagland CIVb	
	Follow-up	CI: L input composition, L output composition, G composition CII: L output composition (including VFA, NH4+ , SO4, PO4), biomass composition CIII: pH, pO2 , NH4+, NO2, NO3, SO4, PO4 CIVa: L output composition, biomass composition CIVb: composition of plants, G phase composition	
	Quality control	microbiological control CIVb (HPC surfaces, liquid phase, roots), CII, CIII and CIVa axeny	
	Duration	1 month + 5 months study	
Objectives/ outputs	Further validation of CIII control law Progressive demonstration of the loop robustness		

Rationale	Several scenarii have been performed to reach key knowledge on L phase connection, closure of solid loop and gas phase management/loop closure. The scenarii studied previously need to be combined progressively up to maximal closure as foreseen in the MELiSSA Pilot Plant. This WP is the first one in this logic.
Remarks	Depending on the availability of HPCs (1, 2 or 3), the amount of plants might be different Can be performed with or without R. Rubrum and Spiru.harvesting system Any interest in: having CIVa biomass sent to CI as well? Connecting CIVb on L phase?

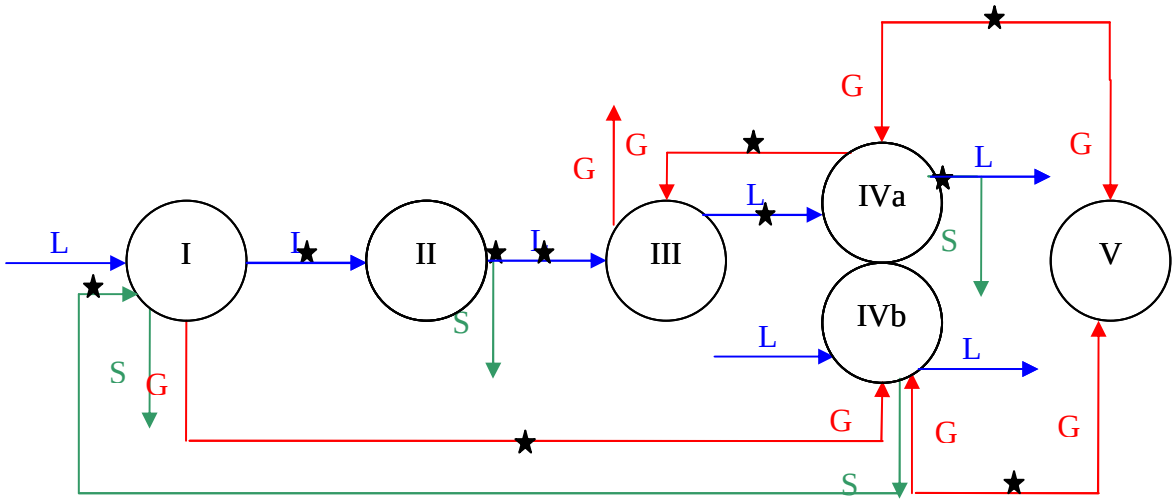


17. WP15

WP number	15.	**WP title**	Connection L phase CI-CII-CIII-CIVa Connection S phase CIVb-CI Connection G phase CI-CIVb and CIVa – CIII Closure G phase CV-CIVb Closure G phase CV-CIVa
duration	6 months		
inputs	Hardware	CI fully characterized CII operational steady state CIII operational steady state CIVa operational steady state CIVb validated, operational steady state CV validated, operational steady state Interface L phase CI-CII (if any), CII-CIII (if any), CIII-CIVa (if any) Interface S phase CIVb-CI Interface G phase CIVb-CI, CIVa-CIII, CV-CIVa, CV-CIVb R.Rubrum harvesting system Spiru. Harvesting system	
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture	TBD
	Knowledge	Output WP 14 and WP6 Preliminary sizing validation on Gas phase management	

content	Constraint	Animal
	Manipulable inputs	CI residence time (as a consequence CII and CIII dilution rate) CII light (and agitation?) CIII : O2 input (TBC) CIVa : light CIVb light, liquid solution composition and residence time
	Set-point	CIVa O2 production, CIVb O2 production
	Culture conditions	Hoagland CIVb
	Follow-up	CI: L input composition, L output composition, G composition CII: L output composition (including VFA, NH4+ , SO4, PO4), biomass composition CIII: pH, pO2 , NH4+, NO2, NO3, SO4, PO4 CIVa: L output composition, biomass composition CIVb: composition of plants, G phase composition
	Quality control	microbiological control CIVb (HPC surfaces, liquid phase, roots), CII, CIII and CIVa axeny CV
	Duration	1 month + 5 months study

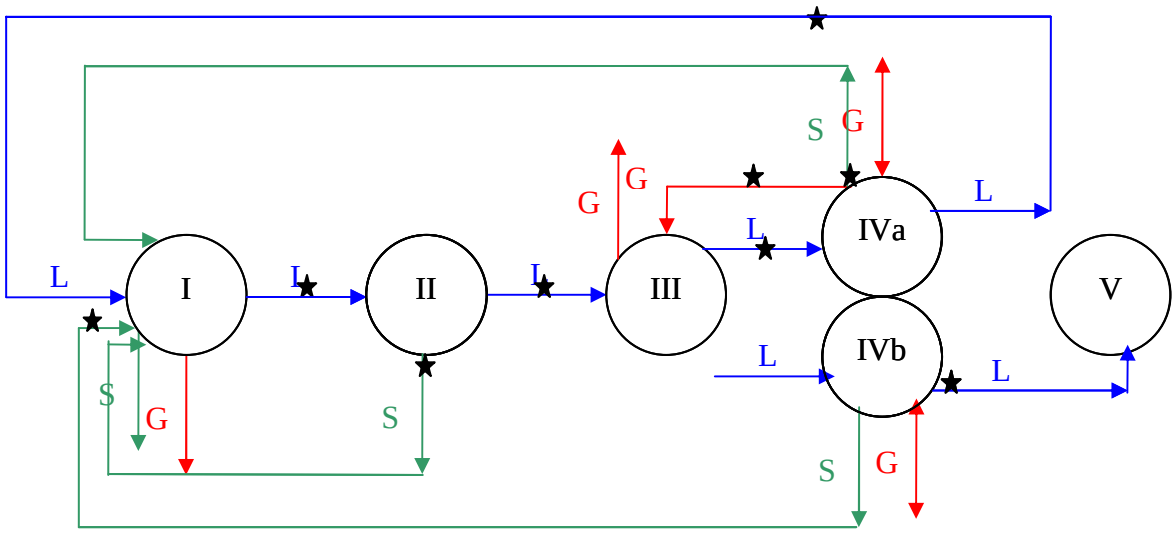
Objectives/ outputs	Further validation of CIII control law Progressive demonstration of the loop robustness
Rationale	See WP 14 Combination of L phase and G phase loop closure
Remarks	Depending on the availability of HPCs (1, 2 or 3), the amount of plants might be different Can be performed with or without R. Rubrum and Spiru.harvesting system Any interest in: having CIVa biomass sent to CI as well? Connecting CIVb on L phase? THIRD MILESTONE for G loop closure demonstration



18. WP 16

WP number	16.	**WP title**	Connection L phase CI-CII-CIII-CIVa Connection L phase CIVb-CV Connection S phase CIVb-CI, CIVa-CI, CII-CI Connection G phase CIVa – CIII	
duration	15 months			
inputs	Hardware	CI fully characterized CII operational steady state CIII operational steady state CIVa operational steady state CIVb validated, operational steady state Interface L phase CI-CII (if any), CII-CIII (if any), CIII-CIVa (if any), CIVa-CI (if any), CIII-CIVb(if any) Interface S phase CIVb-CI Interface G phase CIVa-CIII R.Rubrum harvesting system Spiru. Harvesting system		
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture		TBD
	Knowledge	Output WP 16 Preliminary sizing validation on Liquid phase management		
content	Constraint	CI liquid output		
	Manipulable inputs	CI residence time (as a consequence CII and CIII dilution rate) CII light (and agitation?) CIII : O2 input (TBC) CIVa : light CIVb light		
	Set-point	CIVa O2 production, CIVb L output		
	Culture conditions	Hoagland CIVb		
	Follow-up	CI: L input composition, L output composition, G composition, S composition CII: L output composition (including VFA, NH4+ , SO4, PO4), biomass composition CIII: pH, pO2 , NH4+, NO2, NO3, SO4, PO4 CIVa: L output composition, biomass composition CIVb: composition of plants, G phase composition, L output composition		
	Quality control	microbiological control CIVb (HPC surfaces, liquid phase, roots), CII, CIII and CIVa axeny CV		
	Duration	1 month + 14 months study		

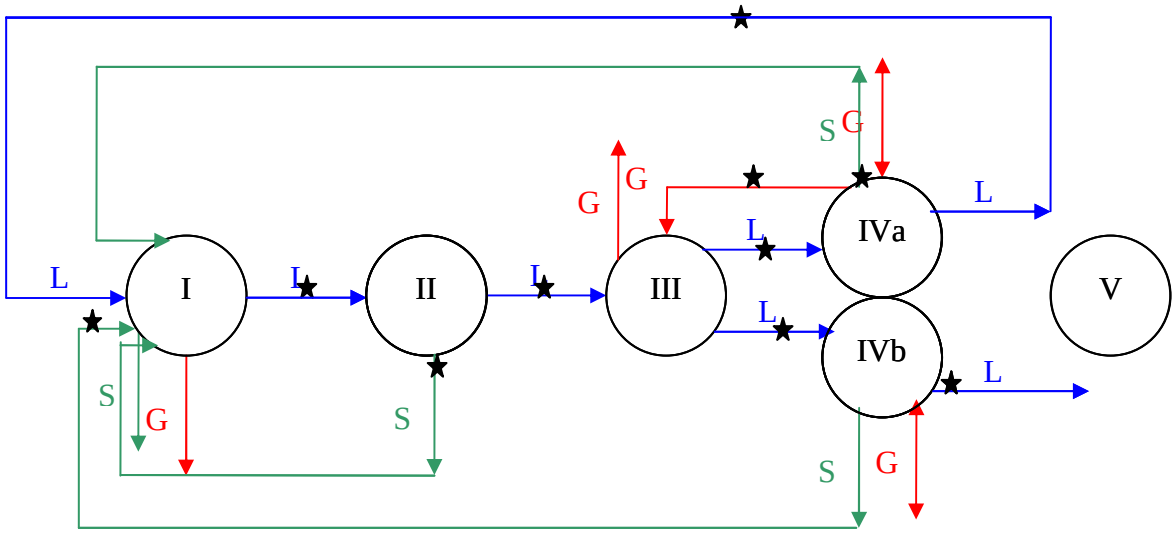
Objectives/ outputs	Further validation of CI control law/performances when increasing L loop closure Progressive demonstration of the loop robustness
Rationale	New step in liquid loop closure
Remarks	Depending on the availability of HPCs (1, 2 or 3), the amount of plants might be different



19. WP 17

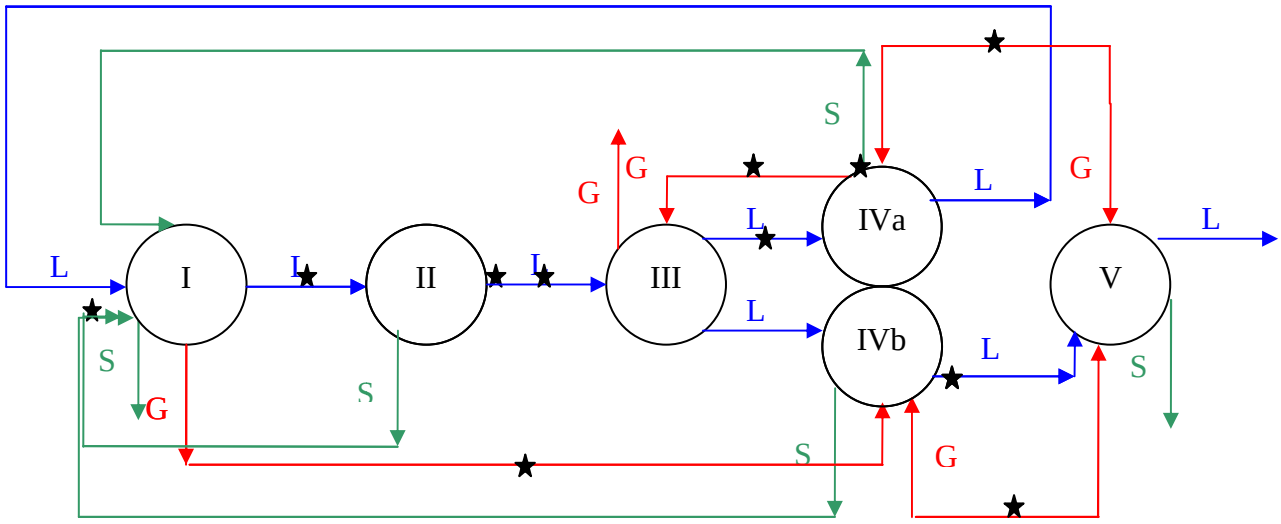
WP number	17.	**WP title**	Connection L phase CI-CII-CIII-CIVa-CIVb Connection S phase CIVb-CI, CIVa-CI, CII-CI Connection G phase CIVa – CIII Closure G phase CV-CIVb Closure G phase CV-CIVa
duration	10 months		
inputs	Hardware	CI fully characterized CII operational steady state CIII operational steady state CIVa operational steady state CIVb validated, operational steady state Interface L phase CI-CII (if any), CII-CIII (if any), CIII-CIVa (if any), CIII-CIVb (if any) Interface S phase CIVb-CI Interface G phase CIVb-CI, CIVa-CIII, CV-CIVa, CV-CIVb R.Rubrum harvesting system Spiru. Harvesting system	
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture	TBD
	Knowledge	Output WP 15 and WP10 Preliminary sizing validation on Liquid phase management	
content	Constraint	TBC	
	Manipulable inputs	CI residence time (as a consequence CII and CIII dilution rate) CII light (and agitation?) CIII : O2 input (TBC) CIVa : light CIVb light CO2 input	
	Set-point	CIVa O2 production, CIVb biomass production	
	Culture conditions		
	Follow-up	CI: L input composition, L output composition, G composition, S composition CII: L output composition (including VFA, NH4+ , SO4, PO4), biomass composition CIII: pH, pO2 , NH4+, NO2, NO3, SO4, PO4 CIVa: L output composition, biomass composition, G phase composition CIVb: composition of plants, G phase composition, L	

		output composition
	Quality control	microbiological control CIVb (HPC surfaces, liquid phase, roots), CII, CIII and CIVa axeny
	Duration	1 month + 9 months study
Objectives/ outputs	Further validation of CI control law/performances when increasing L loop closure Further validation of CIVb control law	
Rationale	See WP 14 Combination of L phase and S phase loop closure	
Remarks	Depending on the availability of HPCs (1, 2 or 3), the amount of plants might be different Any interest ending CIVb L output back to CI?	



20. WP 18 – MELiSSA loop demonstration

WP number	18.	**WP title**	MELiSSA loop demonstration
duration	34 months		
inputs	Hardware	All compartments and interfaces operational and in steady-state	
	Software	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture	TBD
	Knowledge	Output of all WPs Preliminary sizing validation on all phases management	
content	Constraint	animal	
	Manipulable inputs	CI residence time (as a consequence CII and CIII dilution rate) CII light (and agitation?) CIII : O2 input (TBC) CIVa : light CIVb light	
	Set-point	CV O2 input	
	Culture conditions		
	Follow-up	CI: L input composition, L output composition, G composition, S composition CII: L output composition (including VFA, NH4+ , SO4, PO4), biomass composition CIII: pH, pO2 , NH4+, NO2, NO3, SO4, PO4 CIVa: L output composition, biomass composition, G phase composition CIVb: composition of plants, G phase composition, L output composition CV: G phase	
	Quality control	microbiological control CIVb (HPC surfaces, liquid phase, roots), CII, CIII and CIVa axeny, CV	
	Duration	1 month + 9 months to reach steady-state + 24 months continuous operation	
Objectives/ outputs	Full demonstration		
Rationale	Combination of L phase, G phase and S phase loop closure		
Remarks	Should be performed with the three HPCs Any interest ending CIVb L output back to CI?		



21. Conclusion and perspectives

A few remarks can be made on the hereabove presented work packages :

1. additional knowledge on CI may introduce some changes in the WP (depending on the composition of the gas phase….)
2. additional investigation in sizing simulation may introduce drastic changes
3. For CIVb liquid output, we have considered only one liquid stream; however, maybe we could separate the liquid nutrient solution from the evapotranspirated water (foreseen to be used (partly or totally)for preparation of animal “potable”water; then should we envisage to feed-back CI with the rest of the available water?
4. From the preliminary information we have on sizing (e.g. calculations performed within BELISSIMA), we know that most probably, CI liquid output will have to be diluted before being further processed by CII . This may introduce some changes in the WPs scenario
5. The potential integration of complementary technologies (e.g. Fiber degradation unit) can introduce major changes as well.
6. Sizing for gas phase management is clearly an issue as today we still miss basic information, like buffer capacities, strategy of storage (e.g do we reach a given composition for each gas stream, so that they can be mixed and used for buffer capacity,….)