

Universitat Autònoma de Barcelona

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TECHNICAL NOTE 87.1.3

MPP integration strategy : 2009 roadmap

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Reference/Réference	MELiSSA Pilot Plant Frame Contract 19445/05/NL/CP
Issue/Edition	0
Revision/Révision	0
Date of issue/Date d'édition	01/12/11
Status/Statut	final

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APPROVAL

Title Titre	MPP integration strategy : 2009 roadmap	Issue 0 Revision Edition Révision			
Prepared by Auteur	Peiro, E. and Fossen, A.	Date Date	01/12/11		
Checked by Verifié par	Fossen, A. and Peiro, E. Anjue Peiro	Date Date	01/12/11		
Approved by	Gòdia, F.	Date Date	01/12/11		

CHANGE LOG

Issue/	Revision/	Status/	Date/	Reason of the change	Modified paragraphs
Edition	Révision	Statut	Date		
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
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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





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3. WP1 - Closure gas phase CIVa - CV

WP number	1.			Closure G phase CIVa - CV				
duration	4 months		wr uue					
	Hardware	CIVa	refurbished an	d validated	Х			
		CV d	elivered and va	lidated	Х			
		Ar. P	latensis harvest	ing system	TBD			
		Interf	ace G phase C	V-CIVa(CV G phase purification?)	TBD			
	Software	Contr	Control laws implemented in MPP PLCs					
inputs		Cpts	Cpts connected to the MPP supervision system, level 2					
		contro	control preliminary architecture					
	Knowledge	Contr	ol law CIVa (C		Х			
		Kla C	CIVa		TBD			
		Contr	rol law O ₂ /CO ₂		Х			
		Sizing	g validation		Х			
	Constraint		animal					
	Manipulable	inputs	CIVa light, C	IVa dilution rate, pH CIVa				
	Set-point		concentrations in O_2 and CO_2 in CV gas phase					
	Culture condi	tions	Ar Distancia a	ultura on nitrata				
content	Culture colla	tions	Ar.Platensis c	unture on intrate				
	Follow-up		O_2, CO_2, CV	gas phase composition, CIVa liquid p	hase			
	0 1:	1	composition (<u>SO4, PO4, C, N)</u>				
	Quality contr	01	axeny CIVa a	nd CV				
	Duration		1 month prep	ration + 1 month continuous operati	on ± 2			
	Durution		month additio	nal study	011 2			
	1-Demonstrat	ion of	Biorat O_2/CO_2	control law (with pH control and no				
Objectives /	equilibrium o	f respir	atory coefficie	nt)				
outputs	2-Validation	of AP ł	arvesting syste	m				
•	3- manageme	nt of co	ontaminants of	CV gas phase				
	Demonstratio	n of the	e O2/CO2 contr	ol law on new hardware				
Rationale	Communicati	on imp	act					
	Good training	g for the	e new MPP tear	n				
Remarks	Purification of	of CV C	phase to be fo	reseen, thermal control as well				





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4. WP2 – Connection liquid phase CII-CIII

WP number	2.		WD title	Connection L phase CII-CIII				
duration	7 months		wr uue					
inputs	Hardware	CIII v CII v Rubru Addit CII o Contr Cpts contr	Il validated , operational steady state I validated ibrum harvesting system Iditional interface to remove potential residual VFA in <u>I output</u> ontrol laws implemented in MPP PLCs ots connected to the MPP supervision system, level 2 ntrol preliminary architecture rt au control laws CIII (N) Kla CIII					
	Knowledge	Part a Part b N)	a: control law CIII (N), Kla CIII b: Control law CIII(N), Kla CIII, control law CII (C, T					
	Constraint		CII dilution ra	ate and CII light				
	Manipulable	inputs	puts CIII dilution rate (hydraulic residence time CII), O2 input (TBC)					
Content	Set-point		NO2 and NO3 concentrations CIII					
Part a	Culture condi	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							
	Duration		1 month prepa	aration + 3 months continuous operation	on			
	Constraint		C sources (VI input	FA composition and concentration) CI	I liquid			
	Manipulable	inputs	CII light, CII residence time	dilution rate, CIII dilution rate (hydrate in CII), O2 input (TBC)	ulic			
Content	Set-point		NH4 and VFA concentration	A concentrations CII, NO2 and NO3 s CIII				
Part b	Culture condi	tions	Segers&Verst	traete modified (various VFA sources)) CII			
	Follow-up	CII: VFA, NH4+ , SO4, PO4 CIII: pH, pO2 , NH4+, NO2, NO3, SO4, PO4						
	Quality control	ol axeny						
	Duration		3 months con	tinuous operation				
Objectives/ outputs	Control law v	alidate	d: CIII(N) , CII	I (C, N)				
Rationale	After CIVa, C closure of the	CIII is t liquid	he most advanc phase.	ed (know-how, knowledge). 1 st step in	n the			
Remarks			-					

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

WP number	3.			Connection L phase CIII-CIVa					
duration	3 months		wP title	Connection G phase CIVa-CIII					
	Hardware	CIII v	alidated, opera	tional steady state	Х				
		CIVa	refurbished, va	lidated	Х				
		Interf	ace L phase CI	II-CIVa	Х				
		Interf	ace G phase CI	Va – CIII	TBD				
		Spiru	piru harvest. system						
	Software	Contr	Control laws implemented in MPP PLCs						
inputs		Cpts	connected to th	e MPP supervision system, level 2					
		contro	ol preliminary a	architecture					
	Knowledge	Prefe	rably performed	d after WP 2.a, however feasible if	TBD				
		contro	ol law CIII, Kla	a CIII, control law CIVa (including					
		O2/C	O2 dynamic eq	uilibrium in the produced gas phase					
		jointl	ntly with pH control) and Kla CIVa known and						
	~ .	valida	/alidated						
	Constraint	CIII dilution rate							
	NC 111	• •							
	Manipulable inputs		CIVa light, CO2 addition CIVa						
	Set-point		CIVa O2 proc	luction CIII [NO3 or NO2_dependin	nding on				
	bet point		control law de	esign] output	5 011				
content	Culture condi	tions	Winogradsky	CIII					
	Follow-up		CIII: pH, pO2, NH4+, NO2, NO3, SO4, PO4, O2 CO2 gas						
			phase						
			CIVa: pO2, N	103, SO4, PO4					
	Quality control	ol	axeny						
	Duration		1 month prep	ration + 2 months continuous operation	<u></u>				
		1.1.			511.				
Objectives /	es/ Control laws validated: CIII-N+ dynamic gas phase C,O and CIVa-C,N								
outputs	+gas/iiquiu u	1 dynamic							
Detionals	Continuation	of the s	study of the liqu	uid phase closure					
Kationale	Opportunity t	o initia	te additional st	udy of gas phase closure					
Remarks	Equilibrium (G-L pha	uses CIII – CIV	a to be studied					
ixtilial KS	Validation of O2 toxicity in case of excess from CIVa to CIII								





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

WP number	4.			Closure G phase CIVa-CV				
duration	13 months		wP title	Connection L phase CII-CIII-CIVa				
inputs	Hardware	CII v CIII v CIVa CIVa CV v Interf Interf Spiru Rubri	validated validated, operational steady state a refurbished, validated validated rface L phase CIII-CIVa rface G phase CV-CIVa u Harvest. System rum harvest. system					
	Software	Contr Cpts contr	Control laws implemented in MPP PLCs Cpts connected to the MPP supervision system, level 2 control preliminary architecture					
	Knowledge	Outpu	utput of WP1+WP2+WP3					
	Constraint		animal					
	Manipulable	inputs	dilution rate, residence time	light, CII, dilution rate CIII (hydraulic e CII), CIVa light				
	Set-point	Set-point		02/CO2 CV				
	Culture condi	Culture conditions		raete CII				
content	Follow-up	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	ol	axeny (CIII,CIVa), CV					
Duration2 month preparation + 12 months continuous operation/study. (Validation of two control 1 loops (CIII –N an $C+N$) on CIII synthetic media \rightarrow 6 months Determination of limit behaviors \rightarrow 6 months)					∕a-			
Objectives/ outputs	Control loops	valida	ted: CIII(N) an	d CIVa (C+N)				
Rationale	Logic step aft the dynamic b Validation of	er WP prought the res	1, 2 and 3, prog by the animals ults obtained in	ressive closure of the liquid loop, incl on the gas phase the past, on new generation hardware	uding			
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							

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7. Wp 5 – closure gas phase CIVb-CV

WP number	5.		WP	Closure G phase CIVb-CV	
duration	5 months		title	_	
	Hardware	CIV	'b valida	ted, operational steady state	Х
		CV	validated	1	Х
		Inte	rface G I	phase CIVb-CV	TBD
innuts	Software	Con	trol laws	s implemented in MPP PLCs	Х
mputs		Cpt	s connec	ted to the MPP supervision system, level 2	
		con	trol preli	minary architecture	
	Knowledge	Con	trol law	CIVb	TBD
		Prel	iminary	sizing validation (O2 production)	
	Constraint		animal		
	ght, composition and residence time of CIVb liquid	1 phase .			
	inputs		CIVb lig	ght	1
	Set-point		concent	rations in O ₂ and CO ₂ in CV gas phase	
	Culture		Hoaglar	nd for CIVb	
content	conditions				
	Follow-up		CIVb ga	as phase composition (including hormones if possi	ble), O ₂ ,
			CO_2, CV	/ gas phase composition, CIVb liquid phase comp	osition
			(TBD)		
	Quality cont	rol	CV		
			microbi	ological control CIVb (HPC surfaces, liquid phase	, roots),
	Duration		1 month	preparation $+ 4$ month study	
Objectives/	Validated co	ntrol	law CIV	b (light, gas phase, NH4+/NO3 ratio)	
outputs					
Rationale	Need to prog	gress (on CIVb	knowledge and know-how	
Bomarks	Necessity of	preli	minary c	alculations for gas phase management between the	;
ACIIIAI NS	compartments				





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8. WP6 – connection liquid phase CIII-CIVa, gas pahse CIVa-CIII, closure gas phase CIVa-CV

WP number	6.			Connection L phase CIII-CIVa			
duration	10 months		WP title	Connections G phase CIVa-CIII			
duration				Closure G phase CIVa-CV			
	Hardware	CIII v	alidated, opera	tional steady state	Х		
		CIVa	refurbished, va	lidated			
		CIVb	validated, open	cational steady state			
		CV v	alidated				
		Interf	ace G phase CI	Vb-CV			
		Interf	ace G phase CI	Va-CV			
innuts		Interf	Interface L phase CIII-CIVa				
mputs		Interf	nterface G phase CIVa – CIII				
		Spiru	harvest. system	1			
	Software	Contr	Control laws implemented in MPP PLCs				
		Cpts	connected to th	e MPP supervision system, level 2			
		contro	ol preliminary a	architecture			
	Knowledge	Outpu	utput of WP1+WP3+WP5				
		Prelir	Preliminary sizing validation (O2, CO2)				
	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 CIV	/b			
	Follow-up		CIII: pH, pO2	2, NH4+, NO2, NO3, SO4, PO4,O2 (CO2 gas		
			phase CIII				
content			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, O_2, O_2, O_2, O_2, O_2, O_2, O_2, $	Cv gas phase	1		
			O_2, CO_2, CV	gas phase composition, CIVD inquid p	onase		
	Ovelity contr	-1	A very CIL C	IDD)			
	Quanty conu	51	CV				
			microbiologic	al control CIVb (HPC surfaces, liquid	d phase,		
			roots),		• ·		
	Duration		1 month prepa	aration and then			
			1- 6 mor	nths			
			2- 3 months				

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







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9. WP 7

WP number	7.		WD title	Connection S phase CIVb-CI			
duration	7 months		wr uue				
	Hardware	CI ful	lly characterize	d	Х		
		CIVb	validated, open	cational steady state	Х		
		Interf	ace S phase CI	Vb-CI			
					TBD		
inputs	Software	Contr	Control laws implemented in MPP PLCs				
		Cpts of	2pts connected to the MPP supervision system, level				
		contro	ol preliminary a	architecture			
	Knowledge	Contr	ol 1 loop CI (C	(+N)	TBD		
		Contr	ol law CIVb or	output WP5			
	Constraint		Plants metabo	lism/composition			
	Manipulable inputs		CI residence time				
			CIVb light				
			CIVb liquid solution composition and residence time				
	Set-point		CI [VFA] L output				
content	Culture conditions		Hoagland CIVb				
	Follow-up		CI: L input composition, L output composition, G				
			composition				
			CIVb: composition of plants, G phase composition				
	Quality control	ol	microbiological control CIVb (HPC surfaces, liquid phase,				
	D:		roots),				
	Duration		1 month + 6 n	nonths study			
Objectives /	Knowledge of	n CI ou	tputs				
outputs	Further valida	ation of	CI control 1 lo	оор			
Rationale	Initiate study of solid phase in MELiSSA with MELiSSA crops cultivated in						
Nationale	controlled conditions						
Remarks	Depending or different	the av	ailability of HF	PCs (1, 2 or 3), the amount of plants m	ight be		
	1						





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10. WP8

WP number	8.			Connection S phase CIVb-CI			
duration	7 months		wP title	Connection G phase CI-CIVb			
	Hardware	CI ful	lly characterize	d	Х		
		CIVb	validated, open	ational steady state	Х		
		Interf	Interface S phase CIVb-CI				
		Interf	nterface G phase CIVb-CI				
			•		TBD		
inputs	Software	Contr	ol laws implen	ented in MPP PLCs	TBD		
		Cpts of	connected to th	e MPP supervision system, level 2			
		contro	ol preliminary a	urchitecture			
	Knowledge	Outpu	ut WP 7		TBD		
	_	Prelin	ninary sizing va	alidation on gas phase and solid			
		phase	;				
	Constraint		Plants metabo				
	Manipulable inputs		CI residence time				
-			CIVb light				
			CIVb liquid s	CIVb liquid solution composition and residence time			
	Set-point	Set-point CI [utput			
content	Culture conditions		Hoagland CIVb				
	Follow-up		CI: L input composition, L output composition, G				
			composition				
			CIVb: composition of plants, G phase composition				
	Quality control	ol	microbiological control CIVb (HPC surfaces, liquid phase,				
			roots),				
	Duration		1 month + 6 m	nonths study			
Objectives/	Knowledge on CI outputs						
outputs	Further validation	ation of	CI control 1 lo	oop			
outputs	New step in t	he stud	y of gas phase a	and solid phase			
Rationale	Logic continuation of WP 7 to gain knowledge and know-how on gas phase						
management							
	Depending or	the av	ailability of HI	PCs (1, 2 or 3), the amount of plants m	ight be		
Remarks	different						
	SECOND Milestone for G loop closure demonstration						





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11. WP 9 -

WP number	9.			Connection S phase CIVb-CI and CI	Va –			
duration	4 months		WP title	CI				
uuration				Connection G phase CI-CIVb				
	Hardware	CI ful	lly characterize	ed	Х			
		CIVb	validated, ope	rational steady state	Х			
		CIVa	<i>Va</i> in operational steady state					
		Interf	face S phase CI	Vb-CI	TBD			
		Interf	face G phase C	IVb-CI	TBD			
inputs		Spiru	. Harvesting sy	stem				
	Software	Contr	ol laws implen	nented in MPP PLCs	TBD			
		Cpts	connected to th	e MPP supervision system, level 2				
		contro	ol preliminary a	architecture				
	Knowledge	Outpu	ut WP 8		TBD			
		Prelir	ninary sizing v	alidation on Solid phase				
	Constraint		Plants and algae metabolism/composition					
		•						
	Manipulable	inputs	CI residence					
			CIVa light and dilution rate, pH					
	<u> </u>		CIVb light					
	Set-point		CI [VFA] L c	output				
	Culture conditions		Zarrouk for CIVa					
content			Hoagland CIVb					
	Follow-up		CI: L input composition, L output composition, G					
			composition					
			CIVa :liquid phase composition, biomass composition					
		1	CIVb: compo	IV D: composition of plants, G phase composition				
	Quality contro	01	microbiological control CIVb (HPC surfaces, liquid phase,					
	Duration		1 month ± 2					
	Duration		$1 \operatorname{monun} + 5 \operatorname{I}$	nontris study				
	Knowledge o	n CI ou	itputs					
Objectives/	Further valida	ation of	CI control 1 lo	pop				
outputs	New step in the	he stud	y of gas phase	and solid phase (composition of the ga	as phase			
	versus waste	compos	sition)					
Rationale	Logic continu	ation c	of WP 8 to gain	knowledge and know-how on Cl	• • •			
	Depending or	the av	allability of HI	PCs $(1, 2 \text{ or } 3)$, the amount of plants m	nght be			
Remarks	aifferent		-1					
	It is mandator	y to ma	ake some preli	minary sizing validation to define the				
	quantities of plants/ algae to be used							





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12. WP10 –

WP number	10.			Connection S phase CIVb-CI, CIVa	– CI			
duration	6 months		WP title	and CII-CI				
uuration				Connection G phase CI-CIVb	-			
	Hardware	CI fu	lly characterize	d	Х			
		CII in	operational ste	eady state	Х			
		CIVb	validated, open	rational steady state				
		CIVa	in operational	steady state	TBD			
		Interf	ace S phase CI	Vb-CI	TBD			
		Interf	ace G phase CI	Vb-CI				
inputs		Spiru	. Harvesting sy	stem				
		R. Ru	brum harvestin	ig system				
	Software	Contr	ol laws implen	nented in MPP PLCs	TBD			
		Cpts	connected to th	e MPP supervision system, level 2				
		contro	ol preliminary a	architecture				
	Knowledge	Outpu	it WP 9	TBD				
		Prelir	ninary sizing v	alidation on Solid phase				
	Constraint		Plants and alg	ae metabolism/composition				
			~~	-				
	Manipulable	inputs	CI residence time					
				CII dilution rate and light				
CIVa ligh				light and dilution rate, pH				
		CIVb light, composition and residence time of liquid						
	Cat maint		SOLUTION					
	Set-point			utput				
	Culture condi	tions	Segers and Ve	erstraete CII				
content			Zarrouk for C	IVa				
			Hoagland CIV	/b				
	Follow-up		CI: L input co	omposition, L output composition, G				
			composition,	S composition				
			CII: liquid pr	ase composition, biomass compositio	n			
			CIVa: liquid p	sition of plants. C phase composition	on			
	Quality contra	-1	CIVD: compo	sition of plants, G phase composition	mbaga			
	Quality contro	51	roots) avery	CII and CIVa	i pilase,			
	Duration		100(s), axelly	ch and ch v a	in			
	Duration		WPQ	nonthis study (TDC, why 5 here and 5	111			
	Knowledge o	n CL ou						
Objectives/	Further valids	n Cr Ou	CI control 1 le	non				
outputs	New sten in t	he stud	v of gas phase a	and solid phase (composition of the or	is phase			
outputo	versus waste	composition)						
Rationale	Logic continu	ation c	of WP 9 to gain	knowledge and know-how on CI				
	Depending or	the av	ailability of HI	PCs (1, 2 or 3), the amount of plants m	ight be			
Remarks	different			(, = = = ;, uno uno er pranto in	8 0.2			
	It is mandator	y to m	ake some prelir	ninary sizing validation to define the				

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







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13. WP11 -

WP number	11.			Connection L phase CI-CII			
duration	9 months		WP title	Connection S phase CIVb-CI			
duration				Connection G phase CI-CIVb			
	Hardware	CI ful	lly characterize	d	Х		
		CII o	perational stead	ly state	Х		
		CIVb	validated, open	ational steady state			
		Interf	ace L phase CI	-CII (if any)			
		Interf	ace S phase CI	Vb-CI	TBD		
		Interf	ace G phase CI	Vb-CI			
		R.Ru	brum harvestin	g system	TBD		
inputs	Software	Contr	ol laws implem	nented in MPP PLCs	TBD		
		Cpts	connected to th	e MPP supervision system, level 2			
		contro	ol preliminary a	architecture			
	Knowledge	Outpu	ut WP 8		TBD		
		Contr	Control law CII				
		Full c	haracterization	of CI and CI L output			
		Prelir	ninary sizing va	alidation on gas phase and solid			
		phase					
	Constraint		Plants metabo	lism/composition			
			CII liquid inp	ut composition			
	Manipulable	lable inputs CI residence time (as a consequence CII dilutio CII light (and agitation?)					
		CIVb liquid solution composition and residence tim					
	G / · · ·		CIVb light	· · · · · · · /1 · · ·	·C' 1		
	Set-point		CI: total VFA	Cultication L output (however dif	ficult to		
		<i>.</i> .	have on-line)	or CII biomass production?			
content	Culture condi	tions	Hoagland CIV	76			
	Follow-up		CI: L input co	mposition, L output composition, G			
			composition				
			CII: L output	composition (including VFA), biomas	SS		
			composition				
		1	CIVb: compo	sition of plants, G phase composition	1 1		
	Quality contro	ol	microbiologic	al control CIVb (HPC surfaces, liquic	l phase,		
	Descrition		roots), CII axe	eny			
	Duration		1 to 2 months	+ / months study			
	1- Add. valid	ation of	f Control 1 loop	$O CII(C+N) \rightarrow 1 month$			
Objectives/	2- Determinat	tion of	CII limit behav	iors \rightarrow 6 month			
outputs	New step in the	he stud	y of L phase co	onnection			
	Further valida	ation of	CII control lav	V	1		
Rationale	Necessity to p	brogres	s on study of th	e liquid loop closure (the last step is t	he		
	connection fro	$\frac{\text{om CL}}{4}$	L phase to the r	est of the Cpts)	. 1 . 1		
D 1	Depending or	the av	allability of HI	Cs (1, 2 or 3), the amount of plants m	nght be		
Kemarks	afferent	1	141	Decharger have at			
	Can be performed with or without R. Rubrum harvesting system						

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







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14. WP12

WP number	12.			Connection L phase CI-CII-CIII				
duration	4 months		WP title	Connection S phase CIVb-CI				
uuration				Connection G phase CI-CIVb				
	Hardware	CI fu	lly characterize	d	Х			
		CII oj	perational stead	ly state	Х			
		CIII	operational stea	dy state				
		CIVb	validated, oper	rational steady state				
		Interf	ace L phase CI	-CII (if any)				
		Interf	ace S phase CI	Vb-Cl	TBD			
inputs		Interf	ace G phase CI	Vb-Cl	TDD			
	C - ft	R.Ru	brum narvestin	g system	TBD			
	Software	a MDD supervision system layel 2	IBD					
		Cpts	connected to th	e MPP supervision system, level 2				
	Vnowladaa	Outer	of preliminary a					
	Knowledge	Full c	ul WP II allu v	of CL and CLL output				
	Constraint	Func	Plants motobe	lism/composition				
	Constraint	CII liquid input composition						
Manipulable input			CI residence t	ime (as a consequence CII and CIII d	ilution			
	Wampulable	mputs	rate)	rate)				
			CII light (and agitation?)					
			CIII : O2 input (TBC)					
		CIVb liquid solution composition and residence time,						
			CIVb light					
	Set-point		CIII [NO3] or	ıtput				
content	Culture condi	tions	Hoagland CIV	/b				
	Follow-up		CI: L input co	omposition, L output composition, G				
	-		composition					
			CII: L output	composition (including VFA, NH4+,	, SO4,			
			PO4), biomas	s composition				
			CIII: pH, pO2	2 , NH4+, NO2, NO3, SO4, PO4				
			CIVb: compo	sition of plants, G phase composition				
	Quality contr	ol	microbiologic	cal control CIVb (HPC surfaces, liquid	d phase,			
	D /		roots), CII and	d CIII axeny				
	Duration		1 month + 3 r	nonths study				
011	1- Add. valid	ation of	f Control 1 loop	$O CII(C+N) \rightarrow 1 month$				
Objectives/	2- Determina	tion of	CII limit behav	$\gamma_{10rs} \rightarrow 6 \text{ month}$				
outputs	New step in t	ne stud	ie study of L phase connection					
	Further valida	ation of	CII and CIII C	ontrol law	ha			
Rationale	inecessity to j	or ogres	s on study of th	ie inquid loop closure (the last step is t	ine			
	Connection from CI L phase to the rest of the Cpts)							
	different	i ule av	anability of HI	(1, 2 or 5), the amount of plants if	ngni be			
Remarks	Can be perfor	med w	ith or without I	Rubrum harvesting system				
	Can be perfor	in be performed after WP8, or 9 depending if opportunity is taken to have						
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CIVa biomass sent to CI as well.







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15. WP13-

WP number	13.			Connection L phase CI-CII-CIII-CIV	/a			
duration	4 months		WP title Connection S phase CIVb-CI					
uuration				Connection G phase CI-CIVb	_			
	Hardware	CI ful	lly characterize	d	Х			
		CII oj	perational stead	ly state	Х			
		CIII c	perational stea	dy state				
		CIVa	operational ste	ady state				
		CIVb	validated, oper	cational steady state				
		Interf	ace L phase CI	-CII (if any), CII-CIII (if any), CIII-	TBD			
• ·		CIVa						
inputs		Interface C phase CIVb-CI						
		Interf	ace G phase CI	VD-CI	TDD			
		K.Ku	Unit narvesting	g system	IBD			
	Softwara	Contr	. Harvesting sy	Stelli Nontad in MDD DL Ca	TDD			
	Software	Conte	or laws inipien	a MPP supervision system level 2				
		contro	ol preliminary a	architecture				
	Knowledge	Outpu	itroit WP 12 and WP4					
	Constraint	Outp	Plants metabo	tabolism/composition				
	Constraint		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 s	olution composition and residence tim	ie,			
			CIVb light					
	Set-point		CIVa O2 proc	luction				
content	Culture condi	tions	Hoagland CIV	/b				
	Follow-up		CI: L input co	mposition, L output composition, G				
			composition		~~ (
			CII: L output	composition (including VFA, NH4+,	SO4,			
			PO4), biomas	s composition				
			CIII: pH, pO2	t composition biomass composition				
			CIVE: compo	sition of plants. G phase composition				
	Quality contro	1	microbiologic	al control CIVb (HPC surfaces liquid	nhase			
	Quality contro	roots) CIL CIII and CIVa aveny						
	Duration		1 month + 3 months study					
Objectives/	Demonstratio	n of L	phase connection	on over 4 cpts				
outputs			_	-				
Rationale	Necessity to p	orogres	s on study of th	e liquid loop closure (the last step is the	he			
	connection fro	$\frac{\text{om CL}}{4}$	\perp phase to the r	est of the Cpts), logic step after WP 1	2			
Remarks	Depending or	the av	allability of HI	$r_{\rm CS}$ (1, 2 or 3), the amount of plants m	aght be			
	airierent							

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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







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16. WP14 -

WP number	14.			Connection L phase CI-CII-CIII-CIV	/a			
	6 months],	WD title	Connection S phase CIVb-CI				
duration			wr uue	Connection G phase CI-CIVb and CIVa -				
				CIII				
	Hardware	CI ful	lly characterize	d	Х			
		CII oj	perational stead	ly state	Х			
		CIII c	operational stea	dy state				
		CIVa	a operational steady state					
		CIVb	b validated, operational steady state					
		Interf	ace L phase CI	-CII (if any), CII-CIII (if any), CIII-	TBD			
		CIVa	(if any)					
inputs		Interf	ace S phase CI	Vb-Cl				
		Interf	terface G phase CIVb-CI and CIVa-CIII Rubrum harvesting system piru. Harvesting system					
		R.Ru						
	C - ft	Spiru	. Harvesting sy	stem	TDD			
	Software	Contr	into laws implemented in MFF FLCs					
		Cpts of	control preliminary architecture					
	Knowledge	Outpu	itout WP 13 and WP3					
	Kilowieuge	Prelir	liminary sizing validation on Gas phase management					
	Constraint	1 Iem	Plants metabo	etabolism/composition				
	Constraint		CII liquid inp	uid input composition				
	Manipulable	inputs	CI residence time (as a consequence CII and CIII dilution					
	1	1	rate)					
			CII light (and	agitation?)				
			CIII : O2 inpu	at (TBC)				
			CIVa : light					
			CIVb liquid s	olution composition and residence tim	ne,			
			CIVb light					
	Set-point		CIVa O2 proc	luction, CIVb biomass production				
content	Culture condi	tions	Hoagland CIV	/b				
	Follow-up		CI: L input co	omposition, L output composition, G				
			composition					
			CII: L output composition (including VFA, NH4+, SO4,					
			PU4), biomass composition					
			CIII: pH, pU2, NH4+, NU2, NU3, SU4, PU4 CIVe: L output composition biomass composition					
			CIVa: L output composition, biomass composition					
	Ouality contro	ol	microbiologic	cal control CIVb (HPC surfaces, liquid	l phase.			
	roots), CII, CIII and CIVa axeny							
	Duration		1 month + 5 r	nonths study				
Objectives/	Further valida	ation of	CIII control la	W				
outputs	Progressive demonstration of the loop robustness							

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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?







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17. WP15

WP number	15.	Connection L phase CI-CII-CIII-CIVa					
	6 months			Connection S phase CIVb-CI			
		,	WD title	Connection G phase CI-CIVb and CIVa –			
duration		WI thic		CIII			
				Closure G phase CV-CIVb			
		~ ~ ~ ~		Closure G phase CV-CIVa			
	Hardware	CI fu	lly characterize				
		CII oj	perational stead	ly state			
			operational stea	dy state			
		CIVa	validated oper	ady state			
			alidated operat	ional steady state			
		Interf	ace L phase CI	-CII (if any) CII-CIII (if any) CIII-			
		CIVa	(if any)				
•		Interf	ace S phase CI	Vb-CI			
inputs		Interf	ace G phase CI	Vb-CI, CIVa-CIII, CV-CIVa, CV-			
		CIVb	-				
		R.Ru	brum harvestin	g system			
		Spiru	. Harvesting sy	stem			
	Software	Contr	ol laws implem	nented in MPP PLCs	TBD		
		Cpts of	control preliminary architecture				
	Vaculadas	contro	Output WP 14 and WP6				
	Knowledge	Duipi Prelir	liminary sizing validation on Gas phase management				
	Constraint	1 ICIII	Animal	andation on Gas phase management			
	Constraint		7 Millingi				
	Manipulable	nputs	CI residence t	ime (as a consequence CII and CIII di	lution		
	_		rate)				
			CII light (and	agitation?)			
			CIII : O2 inpu	it (TBC)			
			CIVa : light	avid solution composition and residen	aa timaa		
	Set_point		CIVE light, lie	uction CIVb O2 production	ce time		
	Culture condi	4.000	Usesland CI				
	Culture conditions						
content	Follow-up		CI: L input composition, L output composition, G				
			CII: L output composition (including VEA_NH4 - SO4				
			CII: L output composition (including VFA, $NH4+$, SO4, PO4) biomass composition				
			PO(4), diomass composition CIII: pH pO2 NH4+ NO2 NO3 SO4 PO4				
			CIII. p11, p02, NII4+, NO2, NO5, S04, P04 CIVa: L output composition biomass composition				
			CIVb: composition of plants, G phase composition				
	Quality control	ol	microbiologic	al control CIVb (HPC surfaces, liquid	phase,		
			roots), CII, C	III and CIVa axeny			
			CV				
	Duration		1 month + 5 m	nonths study			

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







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18. WP 16

WP number	16.	Connection L phase CI-CII-CIII-CIVa						
	15 months			Connection L phase CIVb-CV				
duration		,	WP title	Connection S phase CIVb-CI, CIVa-	CI,			
uuration				CII-CI				
		~ ~ ~ ~	<u></u>	Connection G phase CIVa – CIII	1			
	Hardware	CI fu	lly characterize	d				
			perational stead	ly state				
			operational stea	dy state				
		CIVa	validated oper	rational steady state				
		Interf	Interface L phase CI-CII (if any), CII-CIII (if any), CII- CIVa (if any), CIVa-CI (if any), CIII-CIVb(if any) Interface S phase CIVb-CI					
		CIVa						
		Interf						
inputs		Interf	ace G phase Cl	Va-CIII				
		R.Rul	brum harvestin	g system				
	9.6	Spiru	piru. Harvesting system					
	Software	Contr	Control laws implemented in MPP PLCs Costs connected to the MPP supervision system level 2					
		Cpis o	_pts connected to the MPP supervision system, level 2					
	Knowledge	Outpu	Output WP 16					
	Kilowiedge	Prelir	Preliminary sizing validation on Liquid phase					
		management						
	Constraint		CI liquid outp	put	•			
	Manipulable inputs		CI residence time (as a consequence CII and CIII dilution					
			rate)					
			CII light (and agitation?)					
			CIII: 02 input (IBC) CIVe : light					
			CIVb light					
	Set-point		CIVa O2 proc	luction, CIVb L output				
	Culture conditions		Hoagland CIVb					
contont	Follow-up		CI: L input composition, L output composition, G					
content			composition, S composition					
			CII: L output composition (including VFA, NH4+, SO4,					
			PO4), biomass composition					
			CIII: pH, pO2, NH4+, NO2, NO3, SO4, PO4 CIVe: L output composition biomass composition					
			CIVa: L output composition, biomass composition					
			output compo	sition	-			
	Quality control	ol	microbiologic	al control CIVb (HPC surfaces, liquid	l phase,			
	-		roots), CII, CIII and CIVa axeny					
			CV					
	Duration		1 month + 14	months study				

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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







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19. WP 17

WP number	17.	Connection L phase CI-CII-CIII-CIVa-						
	10 months			CIVb				
				Connection S phase CIVb-CI, CIVa-CI,				
Junetian			WP title	CII-CI				
duration				Connection G phase CIVa – CIII				
				Closure G phase CV-CIVb				
				Closure G phase CV-CIVa				
	Hardware	CI ful	lly characterize	d				
		CII oj	CII operational steady state					
		CIII	operational stea	perational steady state				
		CIVa	operational ste	operational steady state				
		CIVb	validated, open	rational steady state				
		Interf	ace L phase CI	-CII (if any), CII-CIII (if any), CIII-				
		Civa	(if any), CIII-C	CIVb (if any)				
		Interf	ace S phase CIVb-CI					
inputs		CIVI	ace G phase CIVb-CI, CIVa-CIII, CV-CIVa, CV-					
			mum homissing system					
		K.Ku Spiru	ru Harvesting system					
	Software	Contr	ol laws implem	pented in MPP PL Cs	TBD			
	Software	Conts	is connected to the MPP supervision system, level 2					
		contro	rol preliminary architecture					
	Knowledge	Outpu	wit WP 15 and WP10					
	6	Prelir	minary sizing validation on Liquid phase					
		mana	gement					
	Constraint	•	TBC					
	Manipulable	inputs	CI residence t	time (as a consequence CII and CIII di	lution			
			rate)					
			CII light (and agitation?)					
			CIII: O2 input (TBC)					
			CIVa : light					
	Sat point		CIVE O2 prov	J2 Input				
content	Set-point	tions	CIVA OZ proc	fuction, CTV b biomass production				
		uons						
	Follow-up		CI: L input composition, L output composition, G					
			composition,	S composition	504			
			PO4) biomag	composition (including VFA, NH4+,	504,			
			$\Gamma U4$, biomas	NHA \downarrow NO2 NO2 SOA DOA				
			CIVa: Louto	2, 11114+, 1102, 1103, 504, F04	G			
			phase compos	sition	J			
CIVb: composition of plants, G phase comp					L			

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		output composition				
	Quality control	microbiological control CIVb (HPC surfaces, liquid phase, roots), CII, CIII and CIVa axeny				
	Duration	ration 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 ph	ase 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?					







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20. WP 18 – MELiSSA loop demonstration

WP number	18.	WD 4:41		MELiSSA loop demonstration				
duration	34 months		wP tute	_				
	Hardware	All co stead	All compartments and interfaces operational and in steady-state					
	Software	Contr	ol laws implem	nented in MPP PLCs	TBD			
inputs		Cpts	connected to th	e MPP supervision system, level 2				
•		contro	ol preliminary a	architecture				
	Knowledge	Outpu	ut of all WPs					
	_	Prelir	ninary sizing validation on all phases management					
	Constraint		animal					
	Manipulable	inputs	CI residence t	ime (as a consequence CII and CIII di	lution			
			rate)					
			CII light (and	agitation?)				
			CIII : O2 inpu	ut (TBC)				
			CIVa : light					
			CIVb light					
	Set-point	Set-point						
-	Culture conditions							
	Follow-up		CI: L input co	mposition, L output composition, G				
content			composition, S composition					
			CII: L output composition (including VFA, NH4+, SO4,					
			PO4), biomas	s composition				
			CIVa: L output composition biomass composition G					
			nhase composition					
			CIVb: compo	sition of plants. G phase composition	T			
			output compo	sition	L			
			$CV \cdot G$ phase					
	Quality control	ol	microbiological control CIVb (HPC surfaces liquid phase					
	Quality conta		roots). CII. CIII and CIVa axenv CV					
	Duration		1 month + 9 months to reach steady-state + 24 months					
			continuous op	peration				
Objectives/	Full demonstr	tration						
outputs								
Rationale	Combination	of L pł	nase, G phase a	nd S phase loop closure				
Remarks	Should be per	formed	d with the three	HPCs				
Neillai KS	Any interest ending CIVb L output back to CI?							

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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,....)