Coupling microbial electrosynthesis of platform molecules to organic waste oxidation

French Investissement d'Avenir

BIORARE project

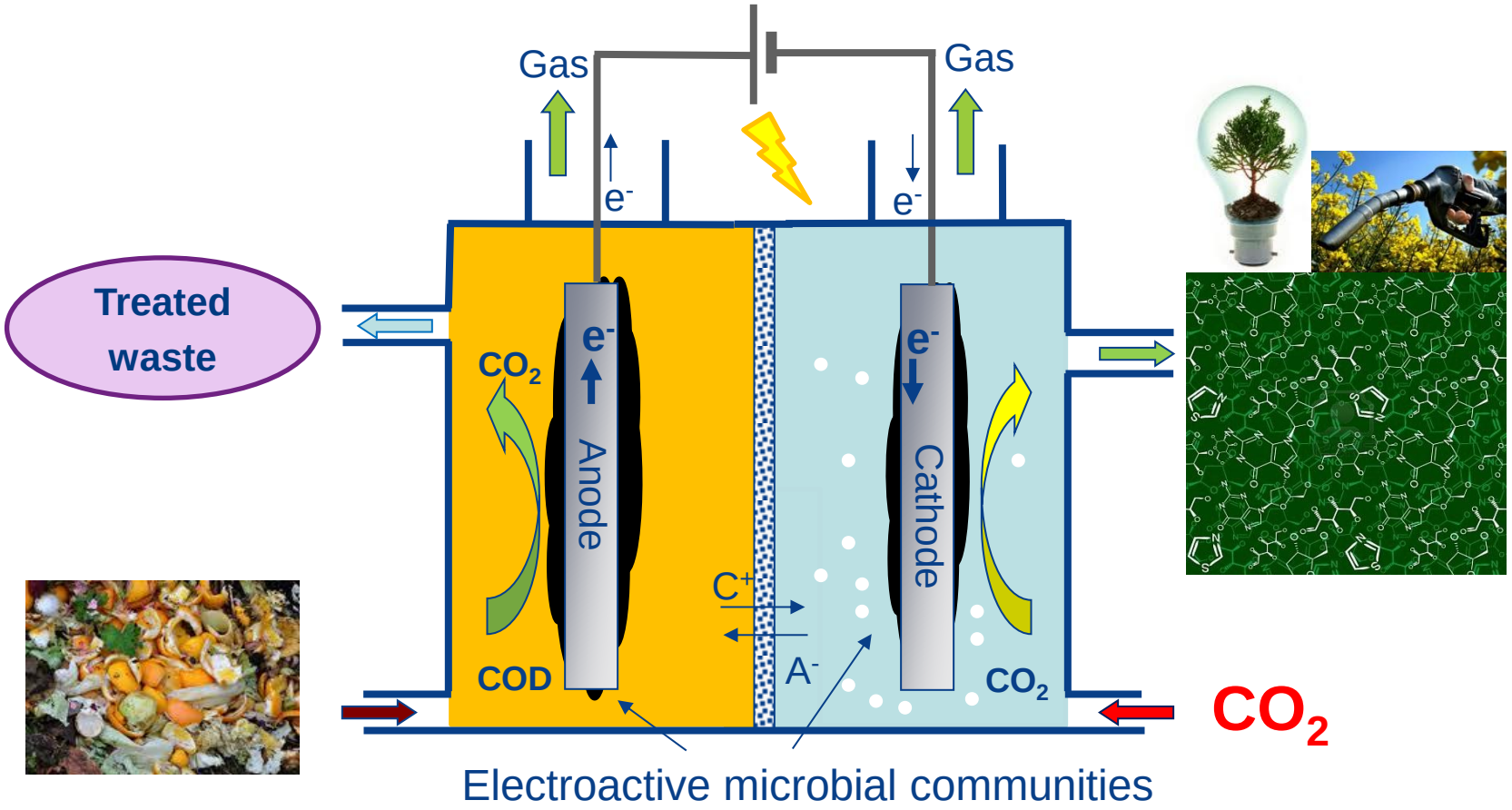
ANR-10-BTBR-02

MELiSSA WORKSHOP

8-9 June 2016, Lausanne Switzerland

www.irstea.fr

BIORARE technological rationale



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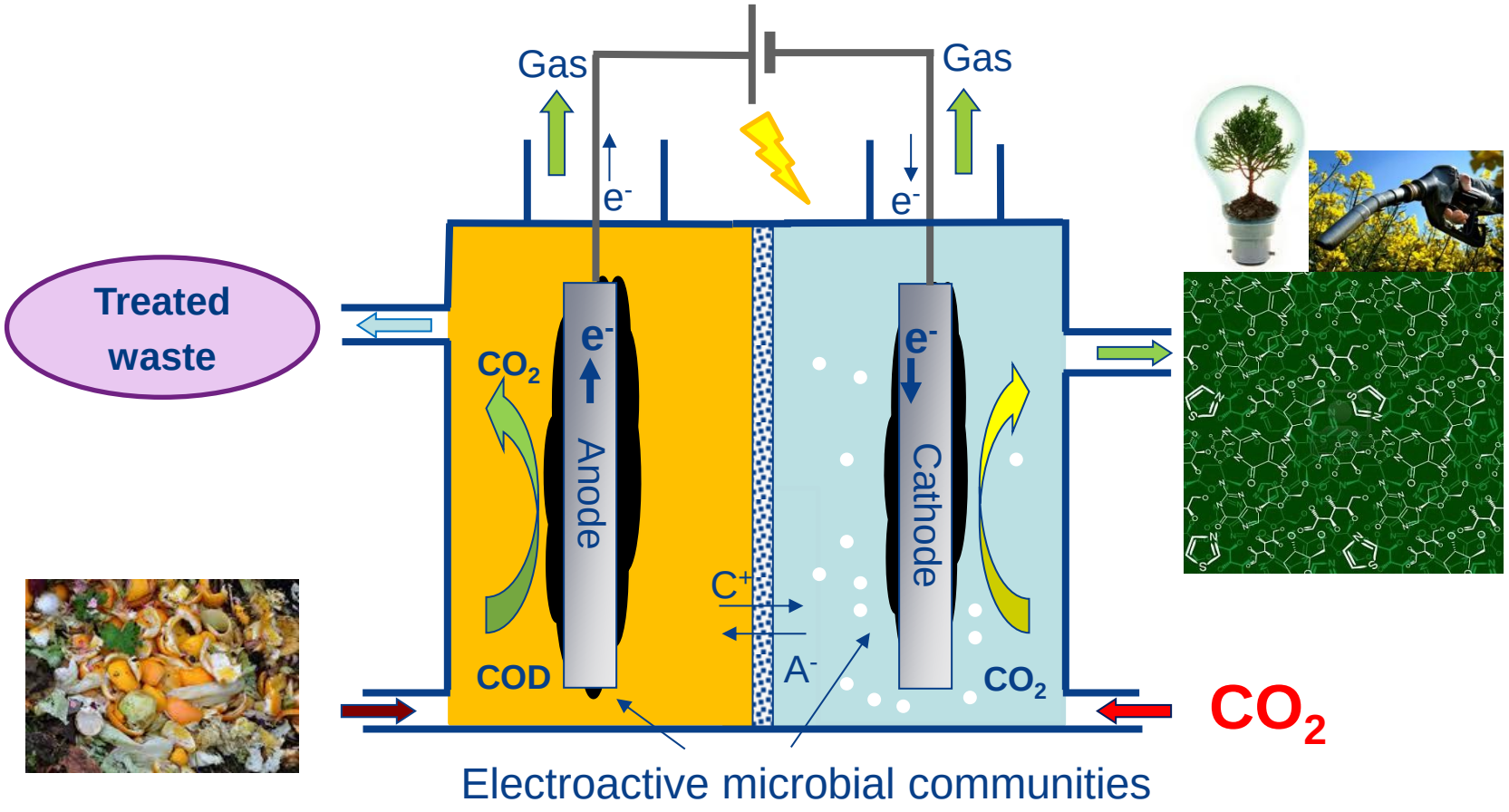
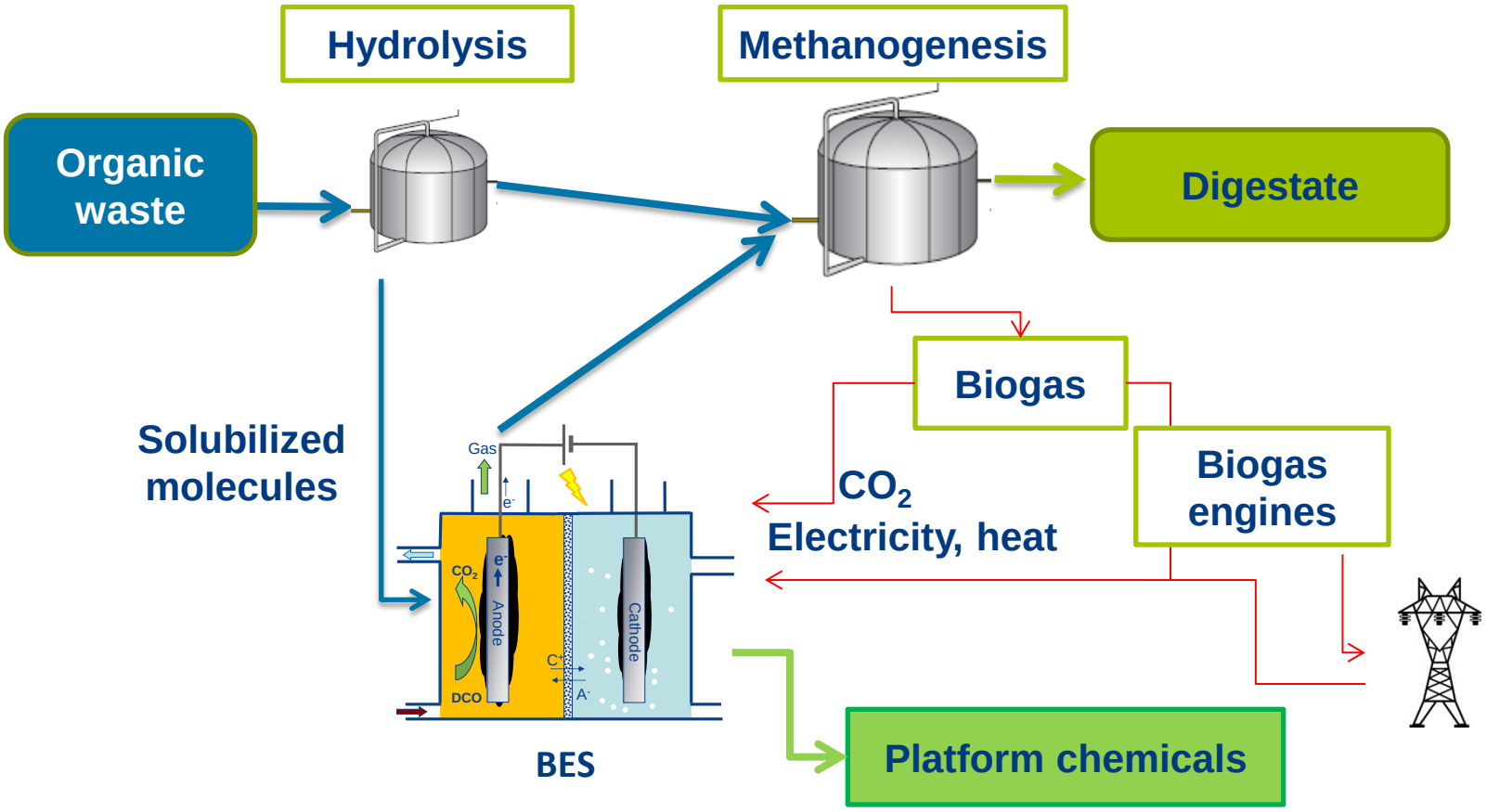
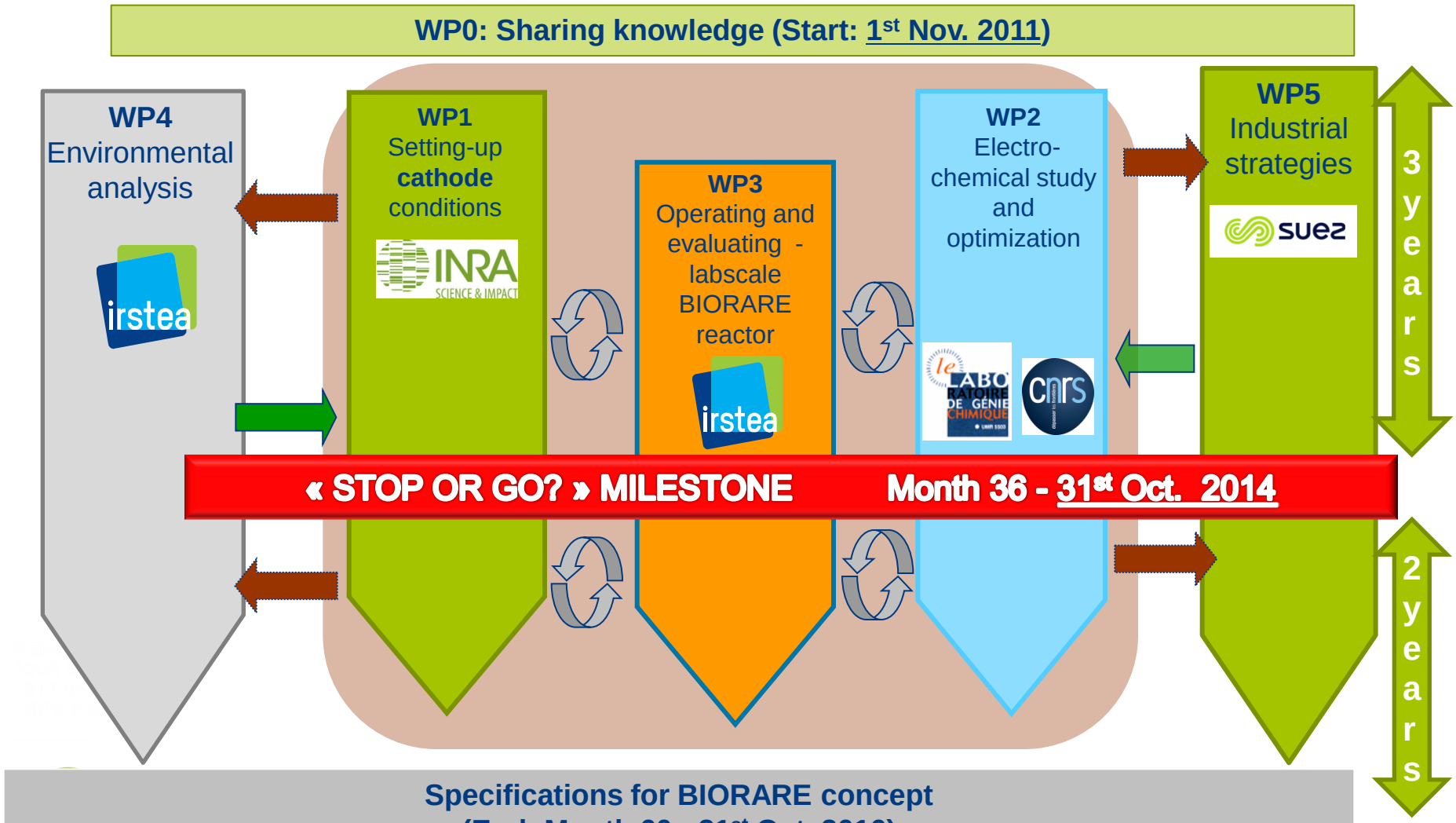


- Production of fuel and chemicals from waste material
- Separation of synthetized products from contaminated waste streams
- Interfacing microbial community metabolic activities with eletrical circuits

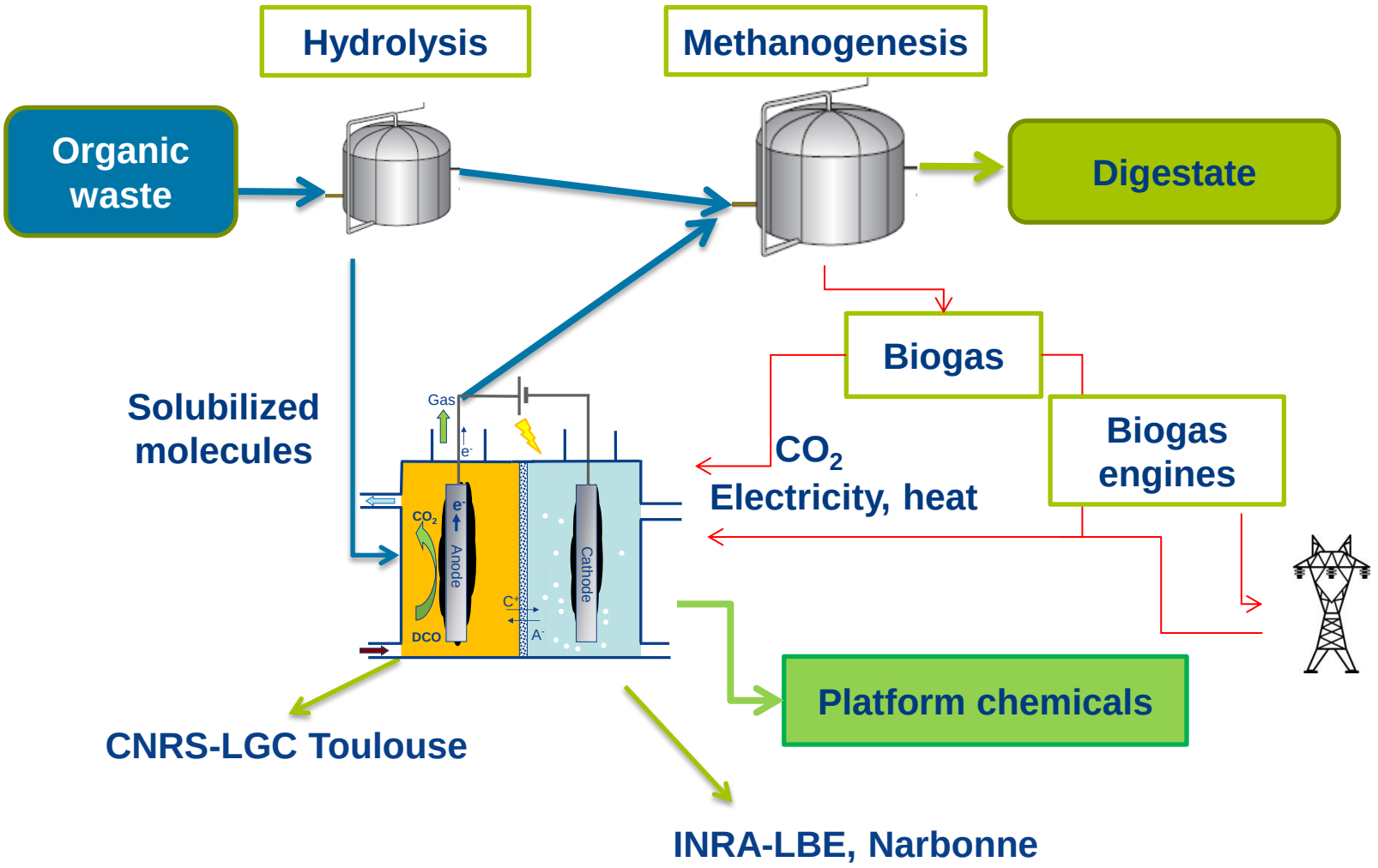
BIORARE working scheme



BIORARE PROJECT STRUCTURE



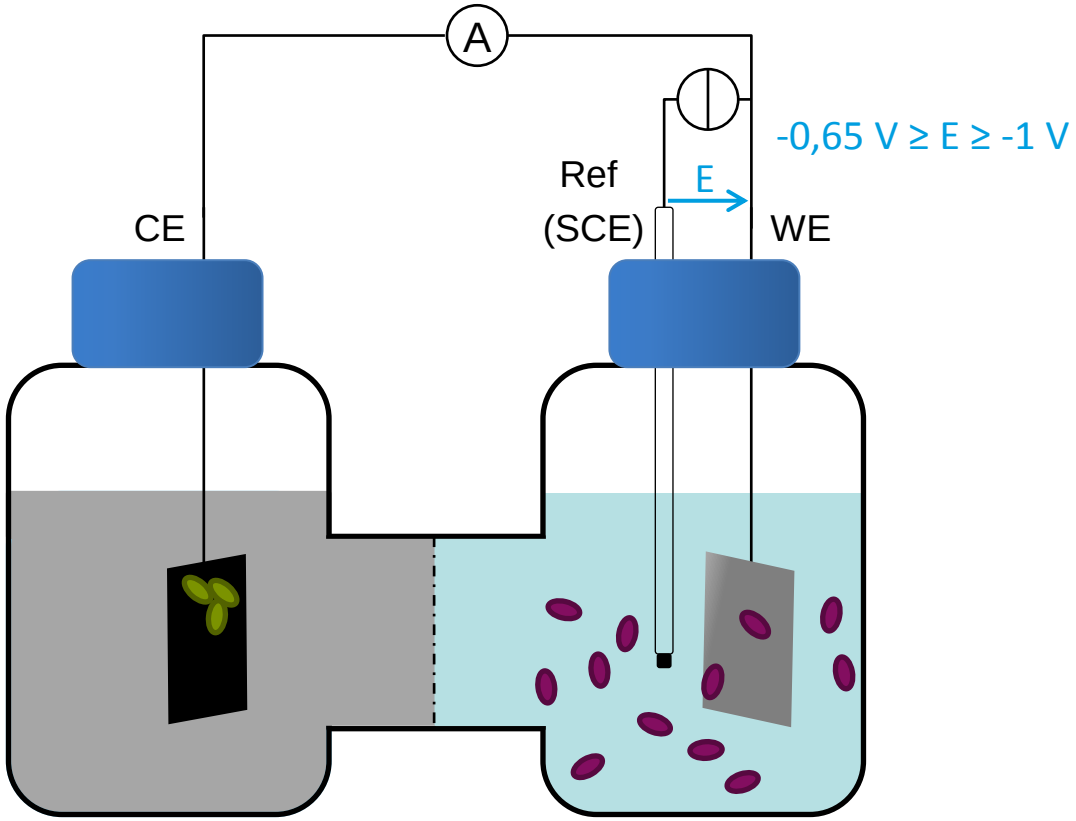
About bioanodes, biocathodes…and coupling!



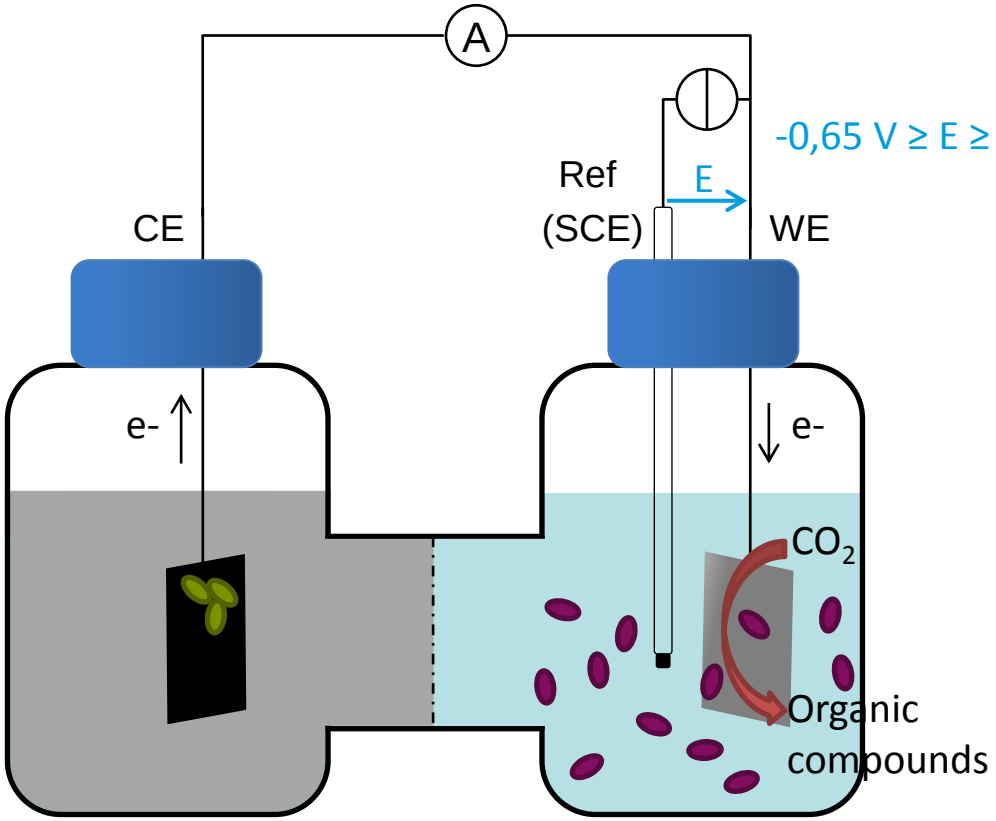
BIORARE = how to couple bioanodes to biocathodes?

Irstea-HBAN, Antony

Let's try to couple by polarizing the cathode…

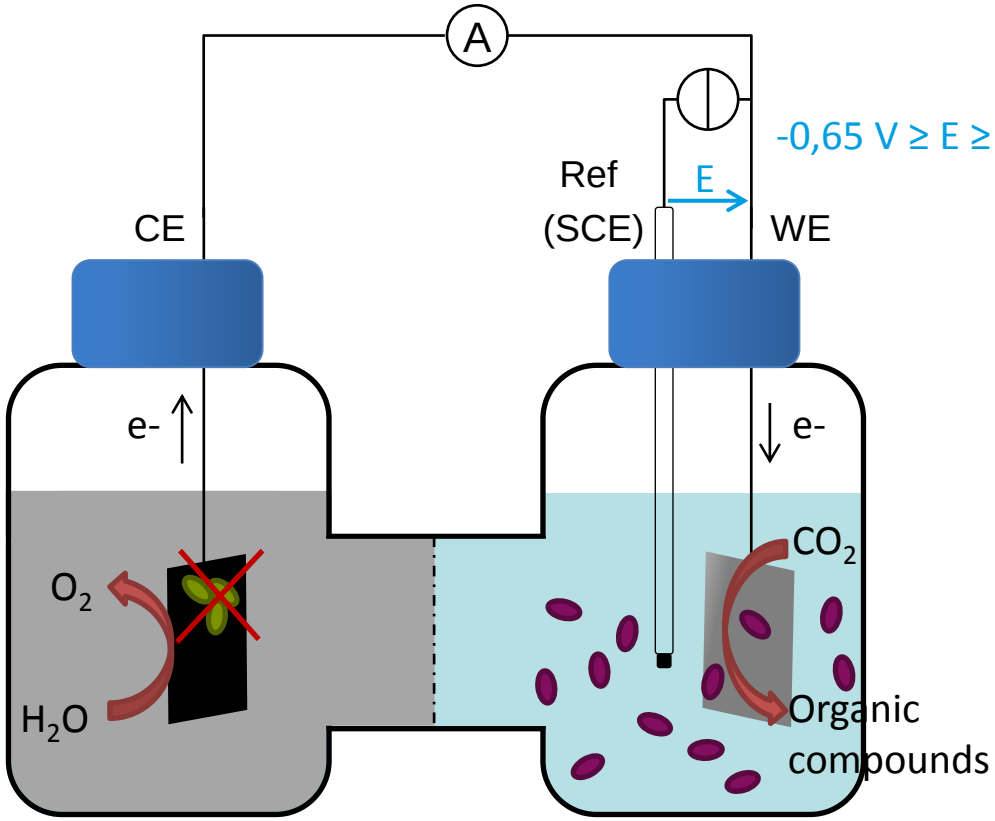


Let's try to couple by polarizing the cathode…



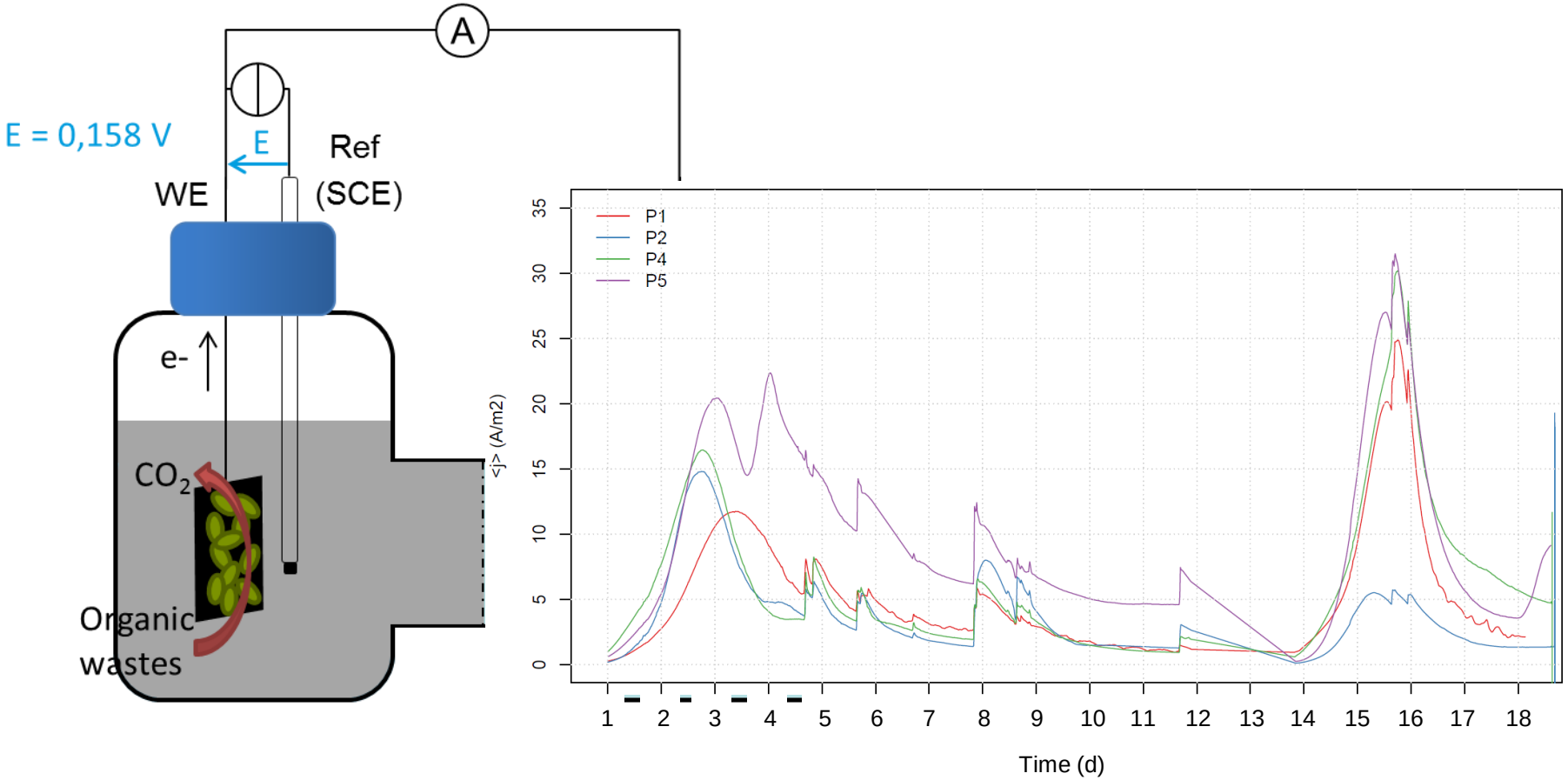
Let's try to couple by polarizing the cathode…

E_{anode} > 1 V !!



…Failure due to anodic biofilm oxidation !!

What about polarizing the anode?



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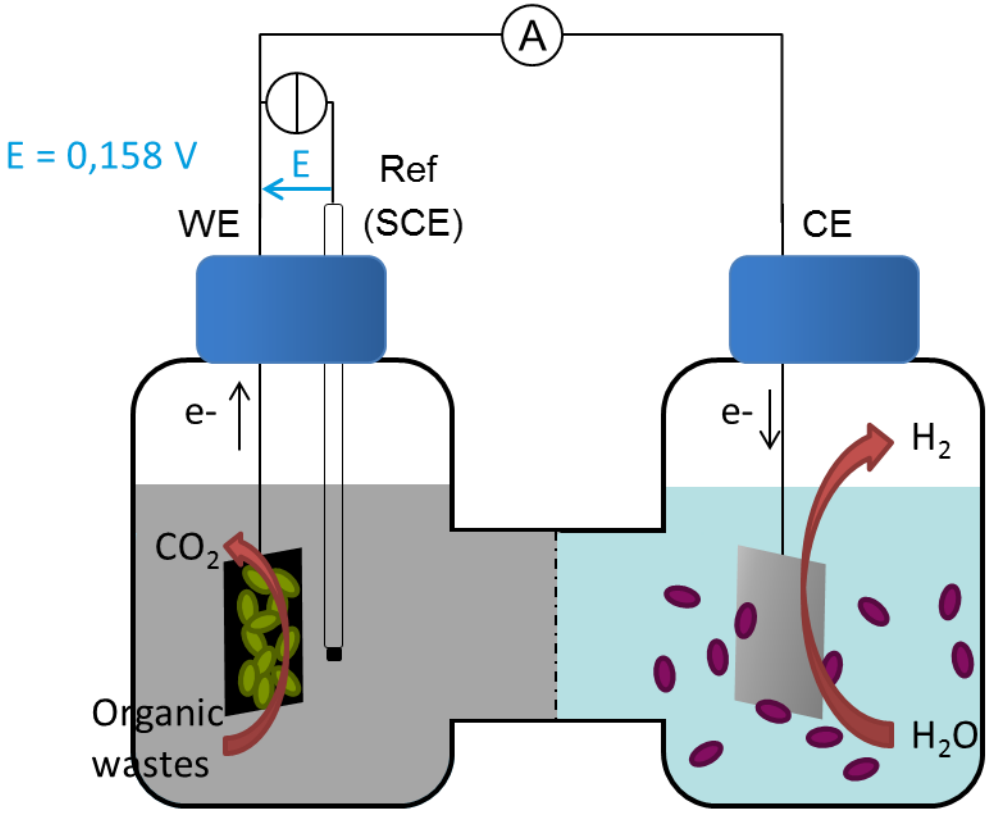
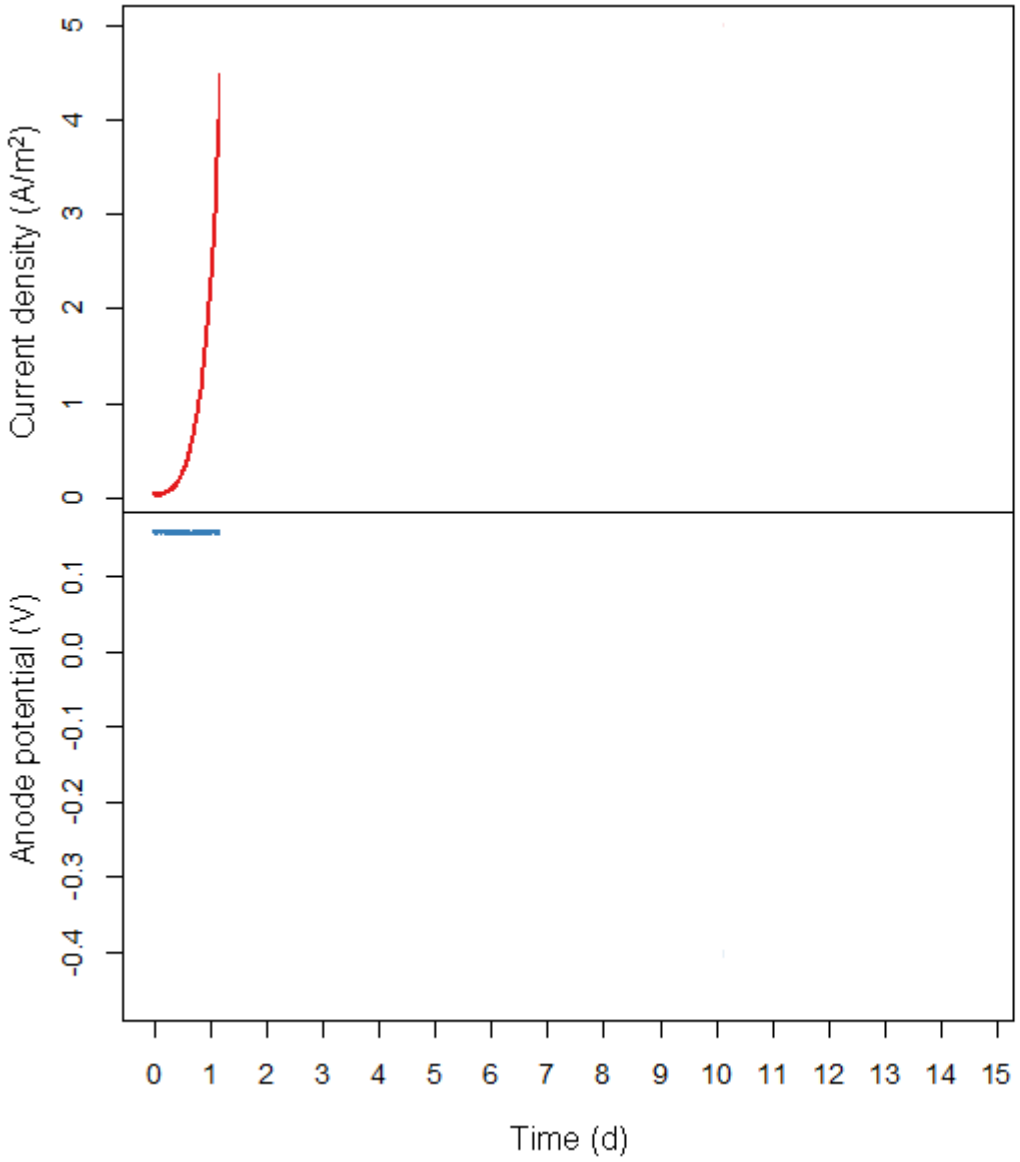
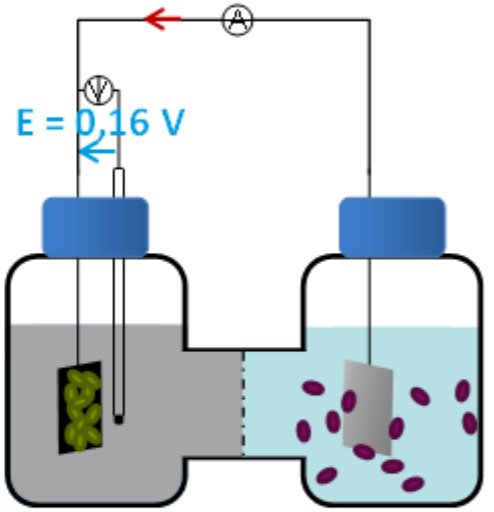


- Unsteady current densities with high maxima
- Hydrogen production resulting in sub-optimal coulombic efficiency at the cathode

Double regulation: anode polarization ↔ fixed current density





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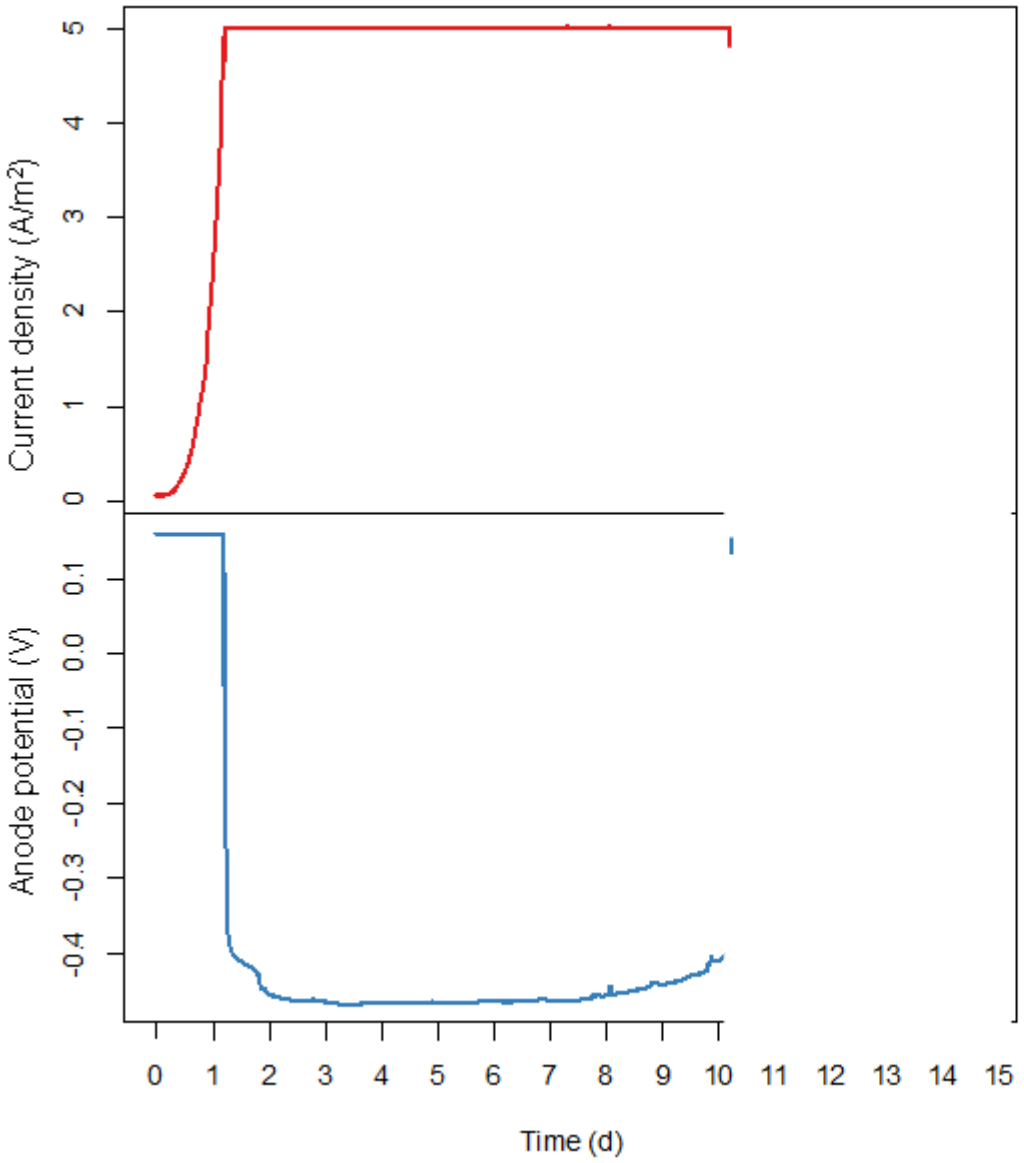

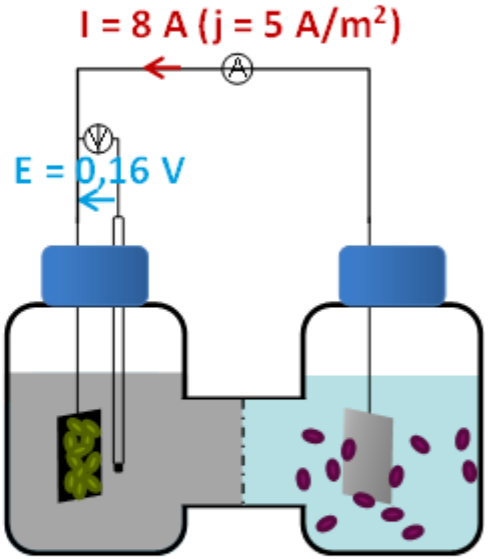

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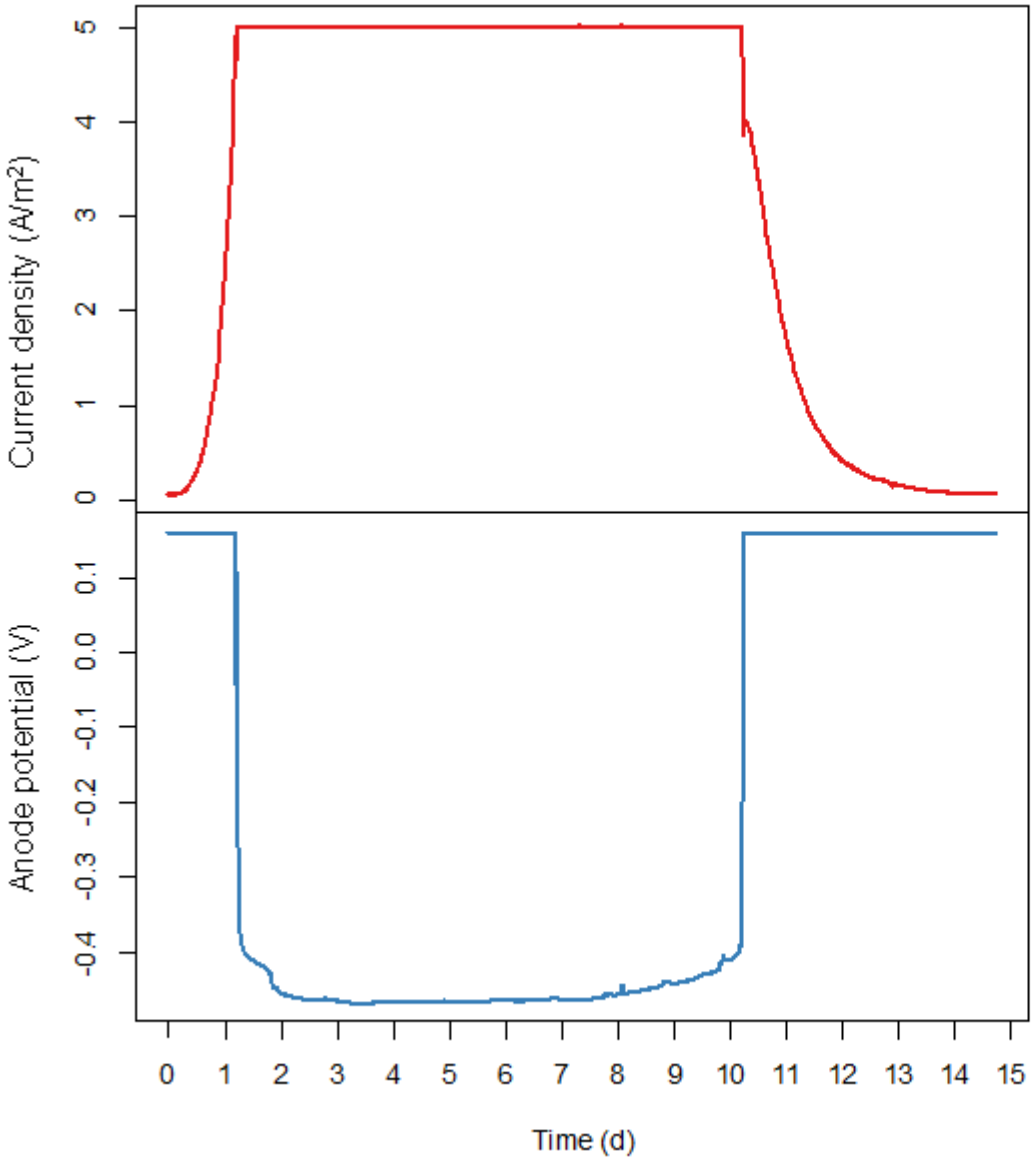
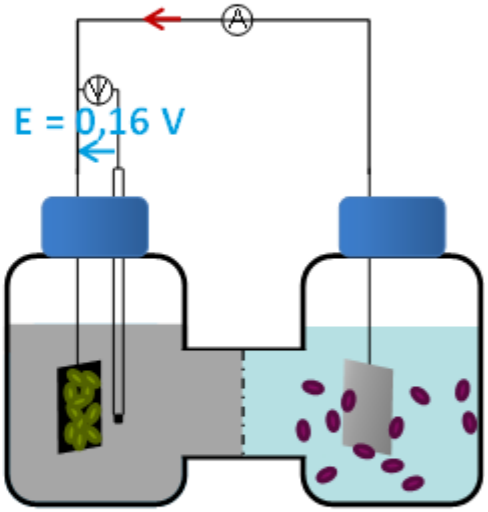
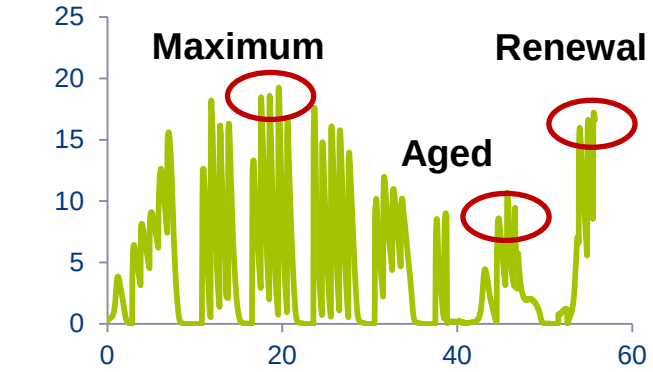




Long term operation of bioanodes fed with biowaste

Bridier et al, 2015, Bioelectrochemistry
Bridier et al., In prep



Chronoamperometry

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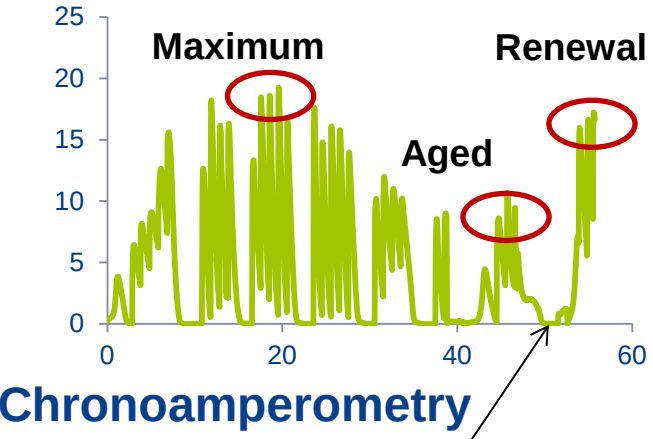
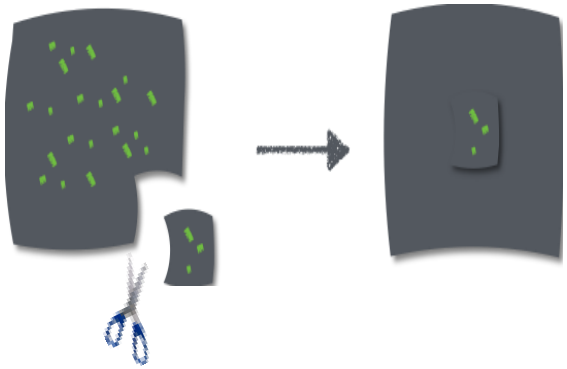


Chronoamperometry



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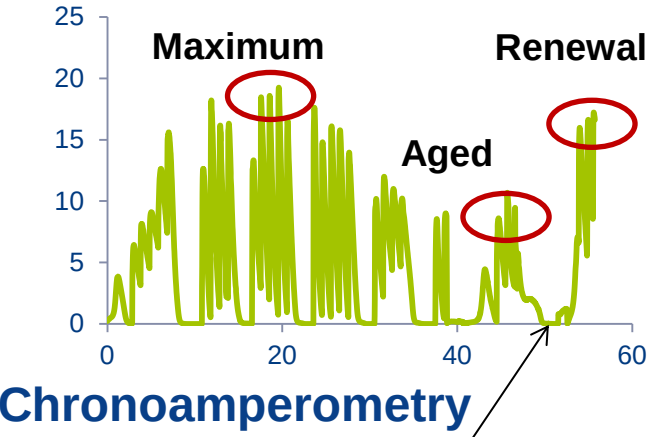

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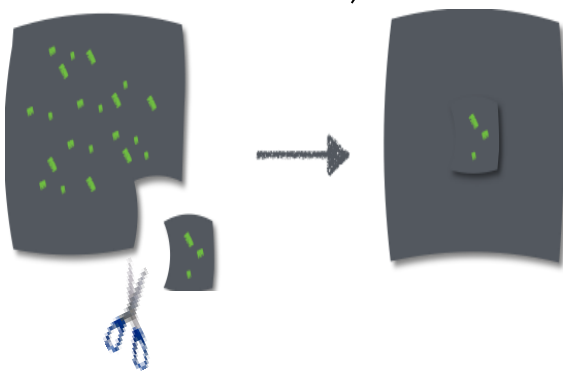
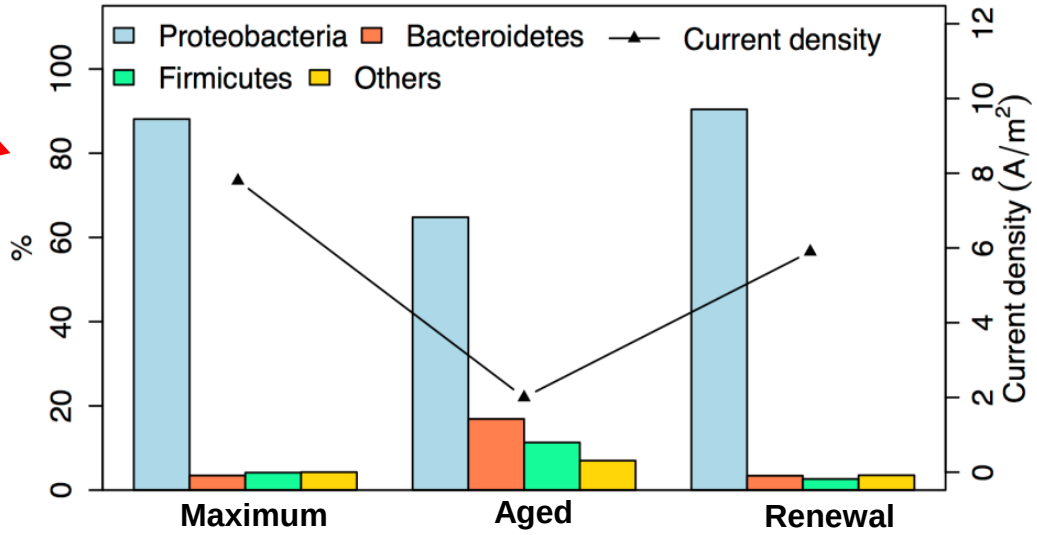


16s rDNA sequencing



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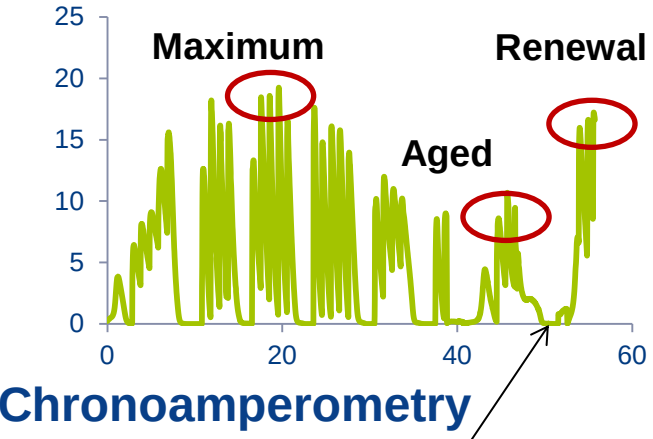

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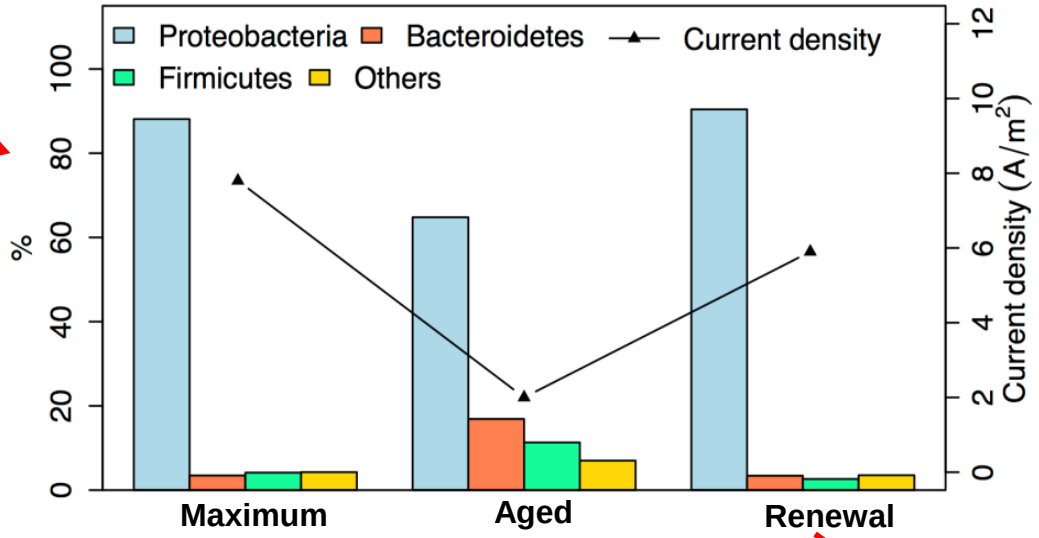
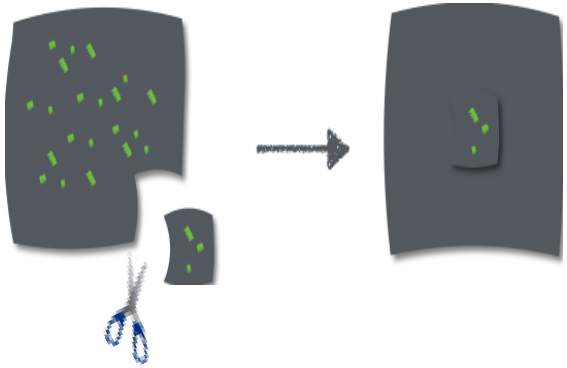
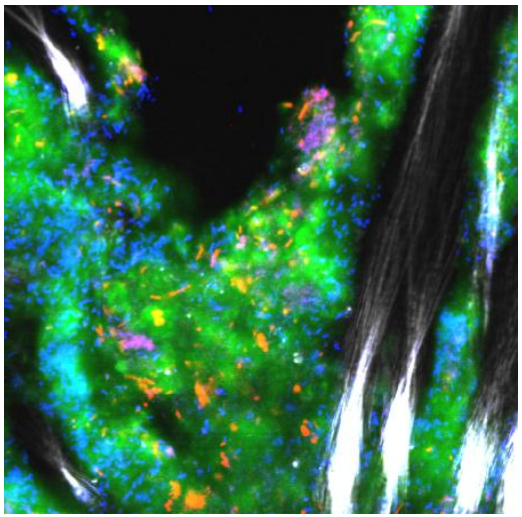
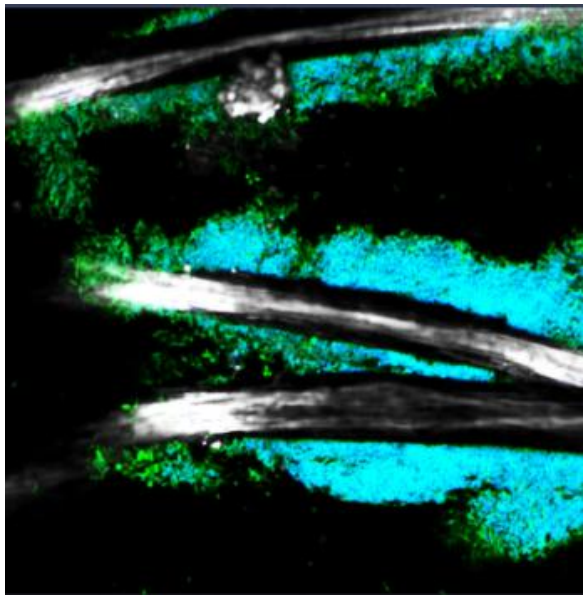


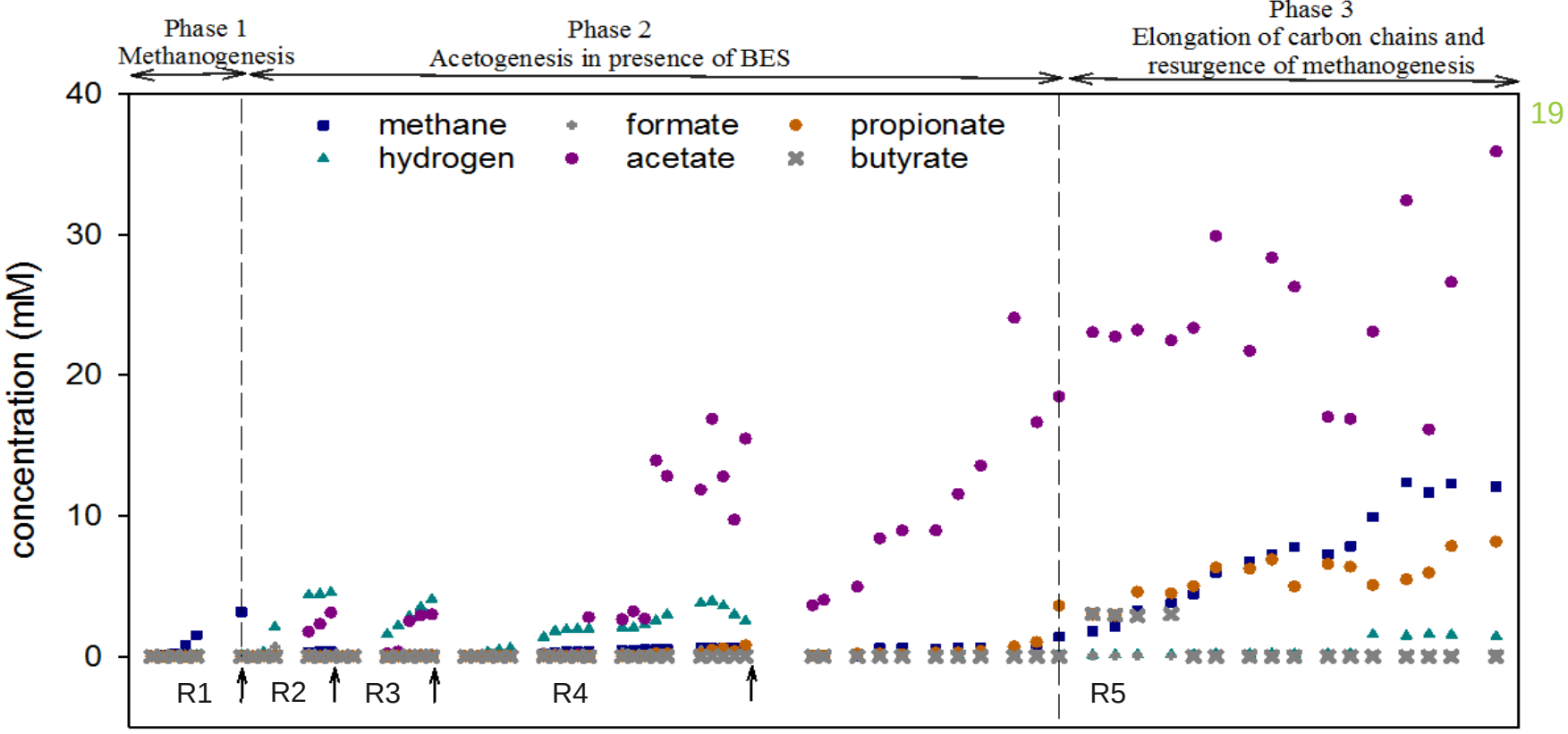


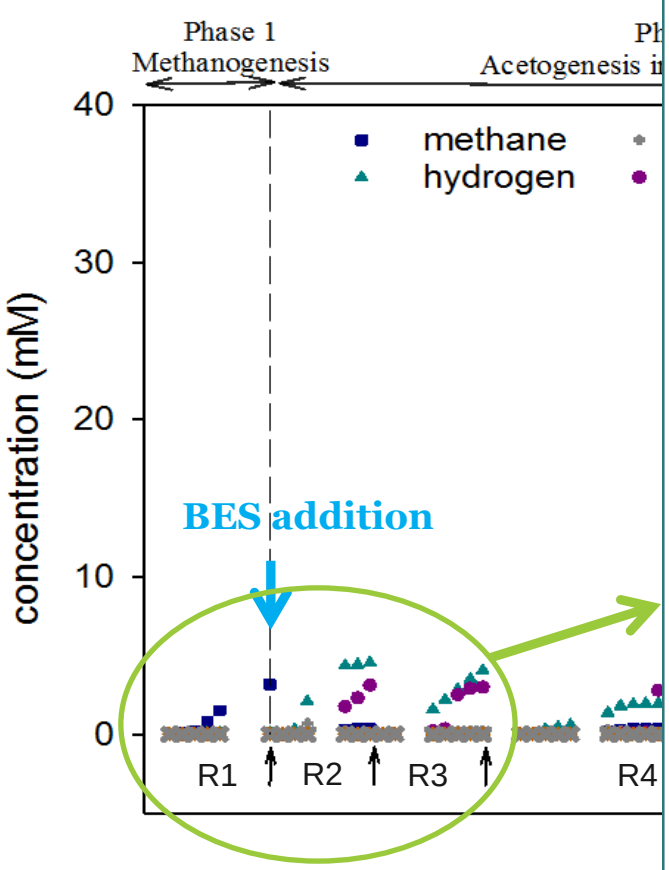
FISH

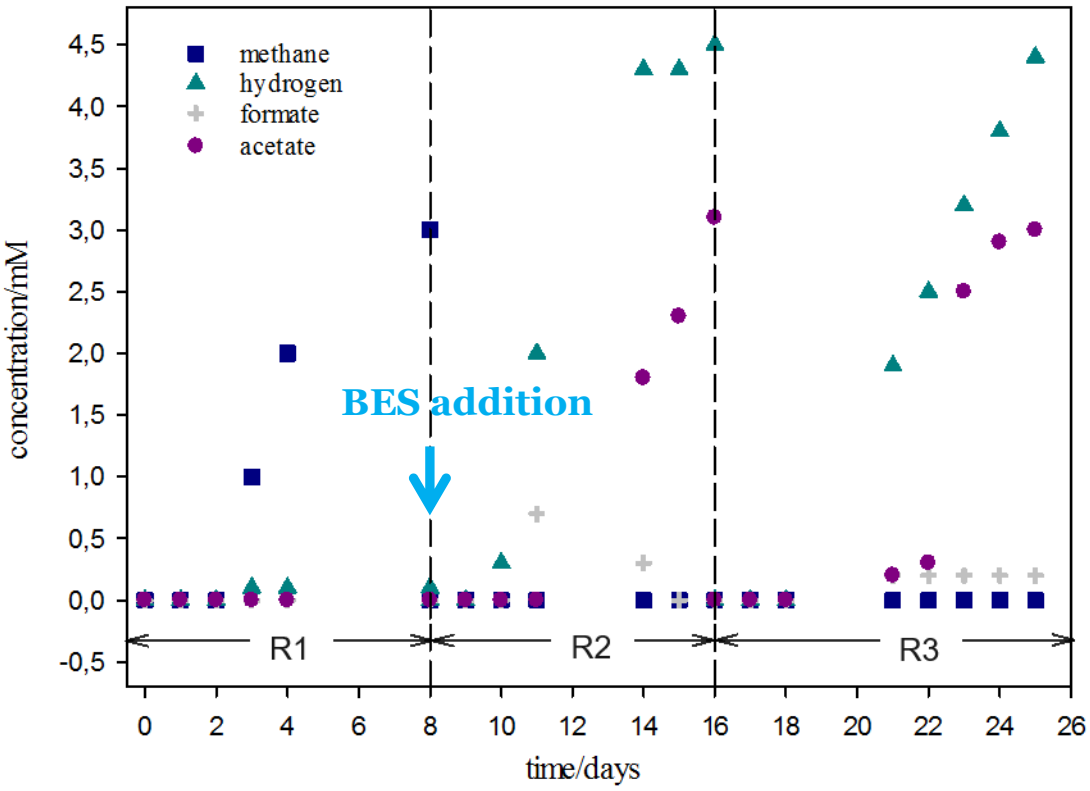


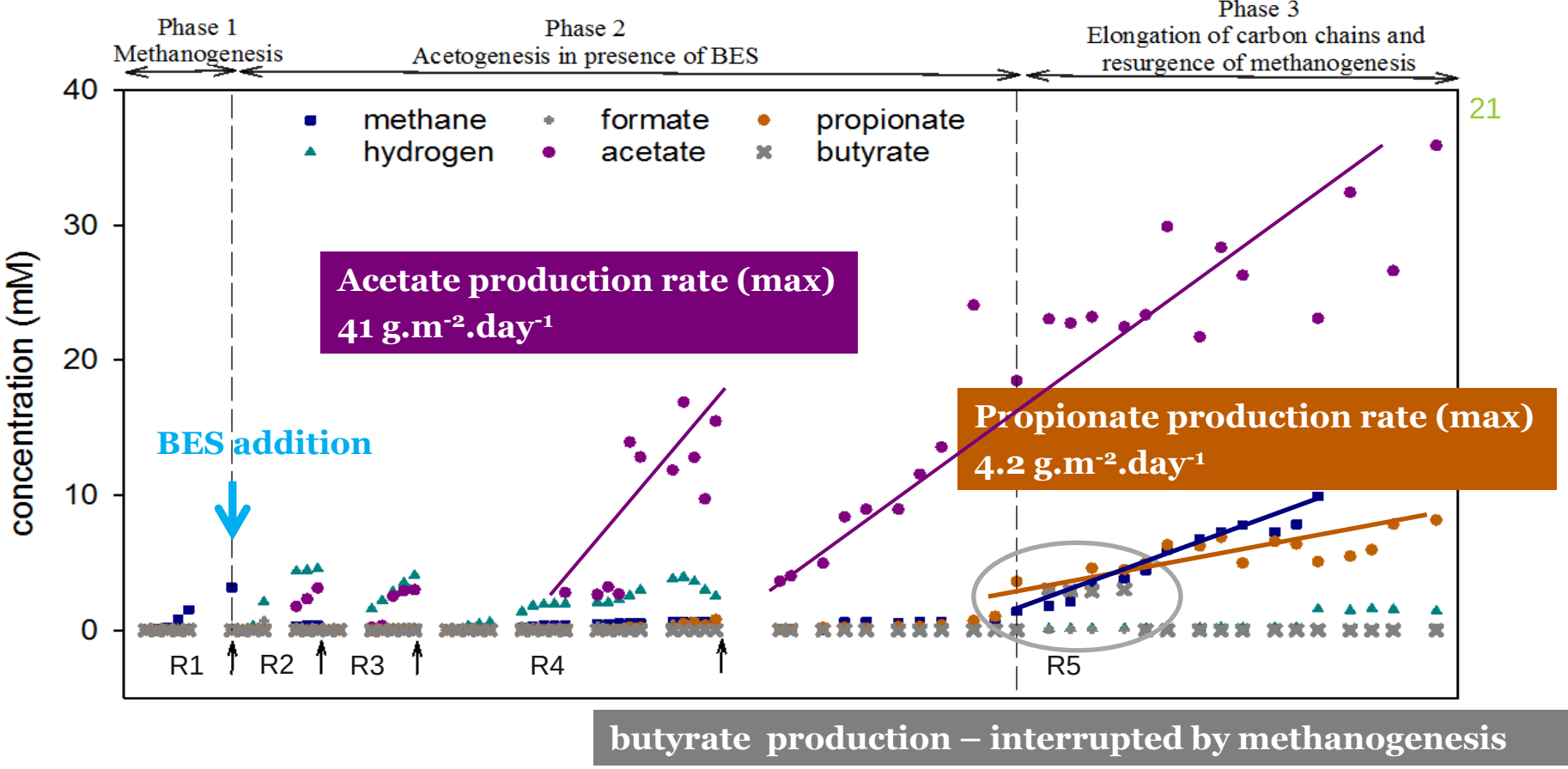


Total bacteria (EUB338) - Geobacter sp. (Geo1A) - Firmicutes (LGC354)

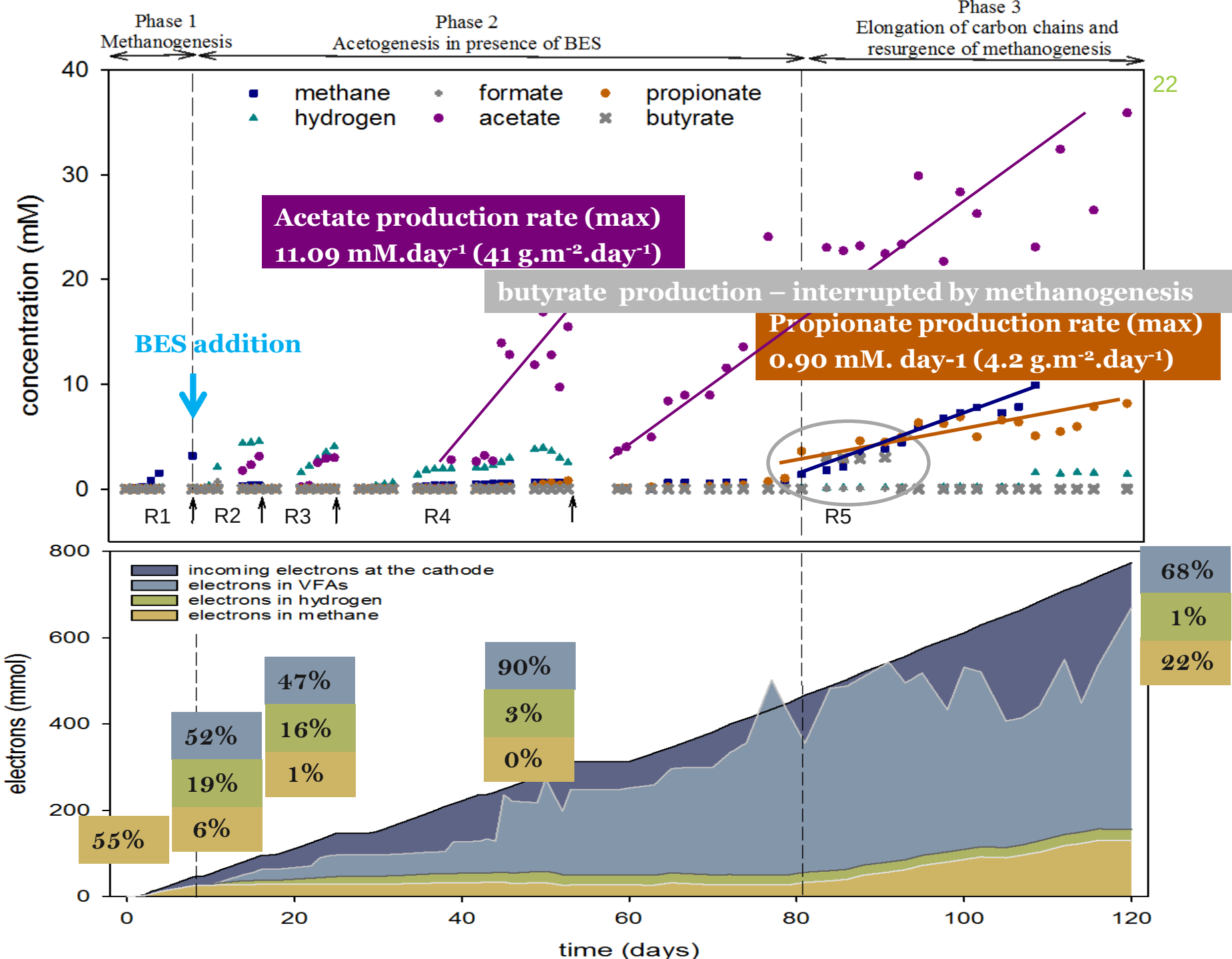

Phase 1
Methanogenesis
Phase 2
Acetogenesis in presence of BES
Phase 3
Elongation of carbon chains and
resurgence of methanogenesis
methane
hydrogen
formate
acetate
propionate
butyrate
concentration (mM)
40
30
20
10
0
R1
R2
R3
R4
R5


Phase 1
Methanogenesis
Ph
Acetogenesis i
methane
hydrogen
concentration (mM)
40
30
20
10
0
BES addition
R1
R2
R3
R4

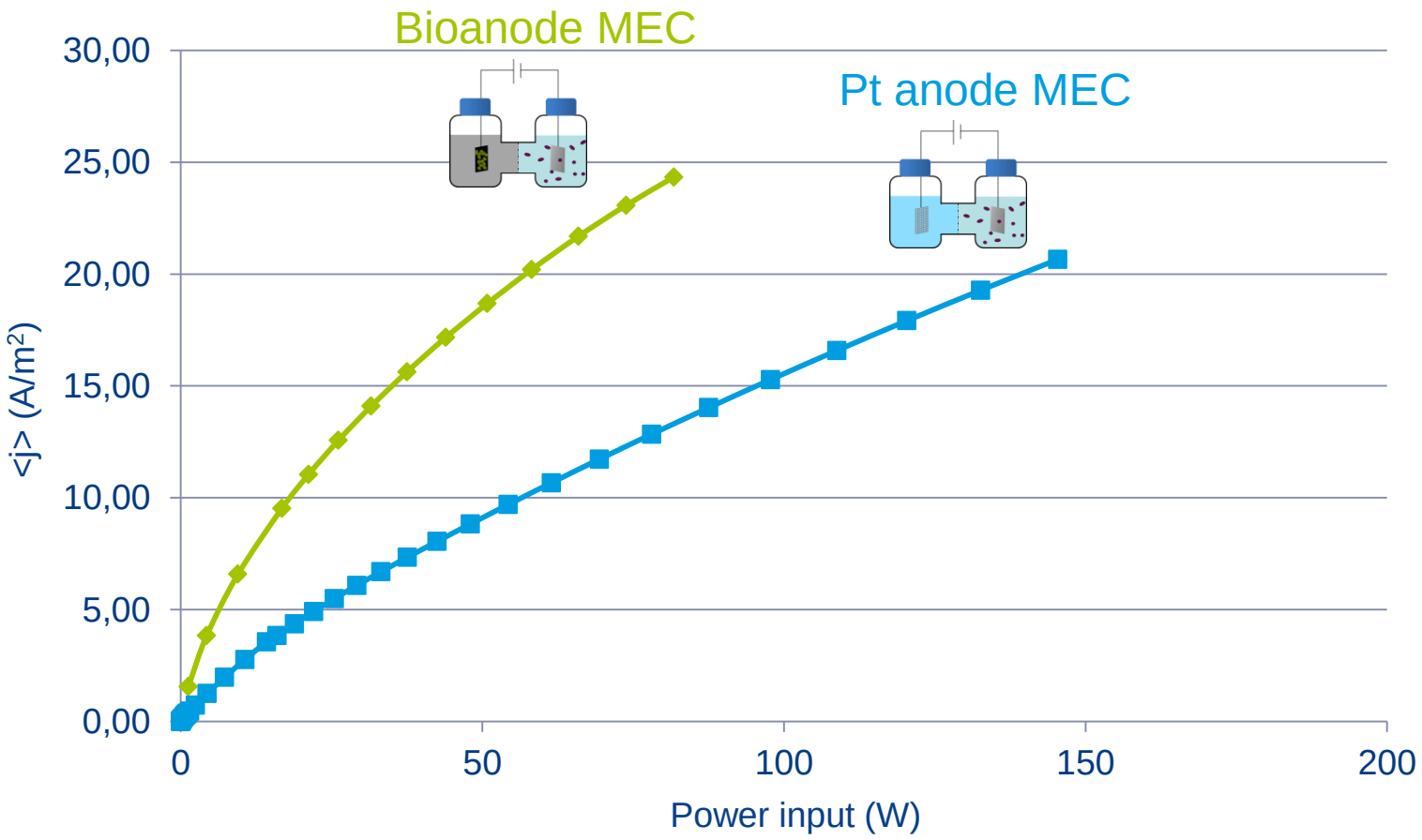

methane
hydrogen
formate
acetate
concentration/mM
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
-0,5
BES addition
R1
R2
R3
0
2
4
6
8
10
12
14
16
18
20
22
24
26
time/days



butyrate production – interrupted by methanogenesis


Phase 1
Methanogenesis
Phase 2
Acetogenesis in presence of BES
Phase 3
Elongation of carbon chains and resurgence of methanogenesis
methane
hydrogen
formate
acetate
propionate
butyrate
concentration (mM)
Acetate production rate (max)
11.09 mM.day-1 (41 g.m-2.day-1)
butyrate production – interrupted by methanogenesis
Propionate production rate (max)
0.90 mM. day-1 (4.2 g.m-2.day-1)
BES addition
R1
R2
R3
R4
R5
incoming electrons at the cathode
electrons in VFAs
electrons in hydrogen
electrons in methane
electrons (mmol)
55%
52%
19%
6%
47%
16%
1%
90%
3%
0%
68%
1%
22%
time (days)

What about energy efficiency?



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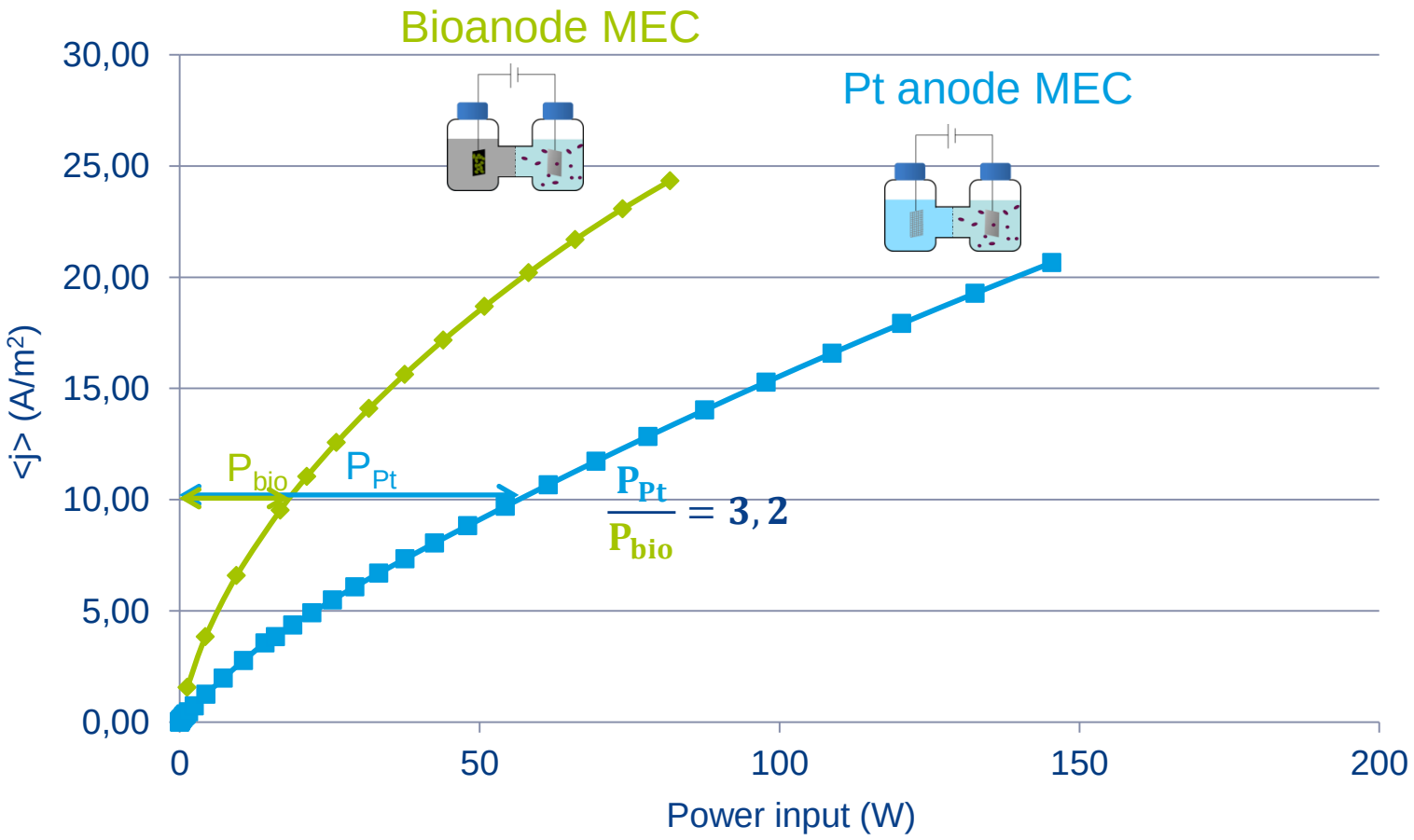

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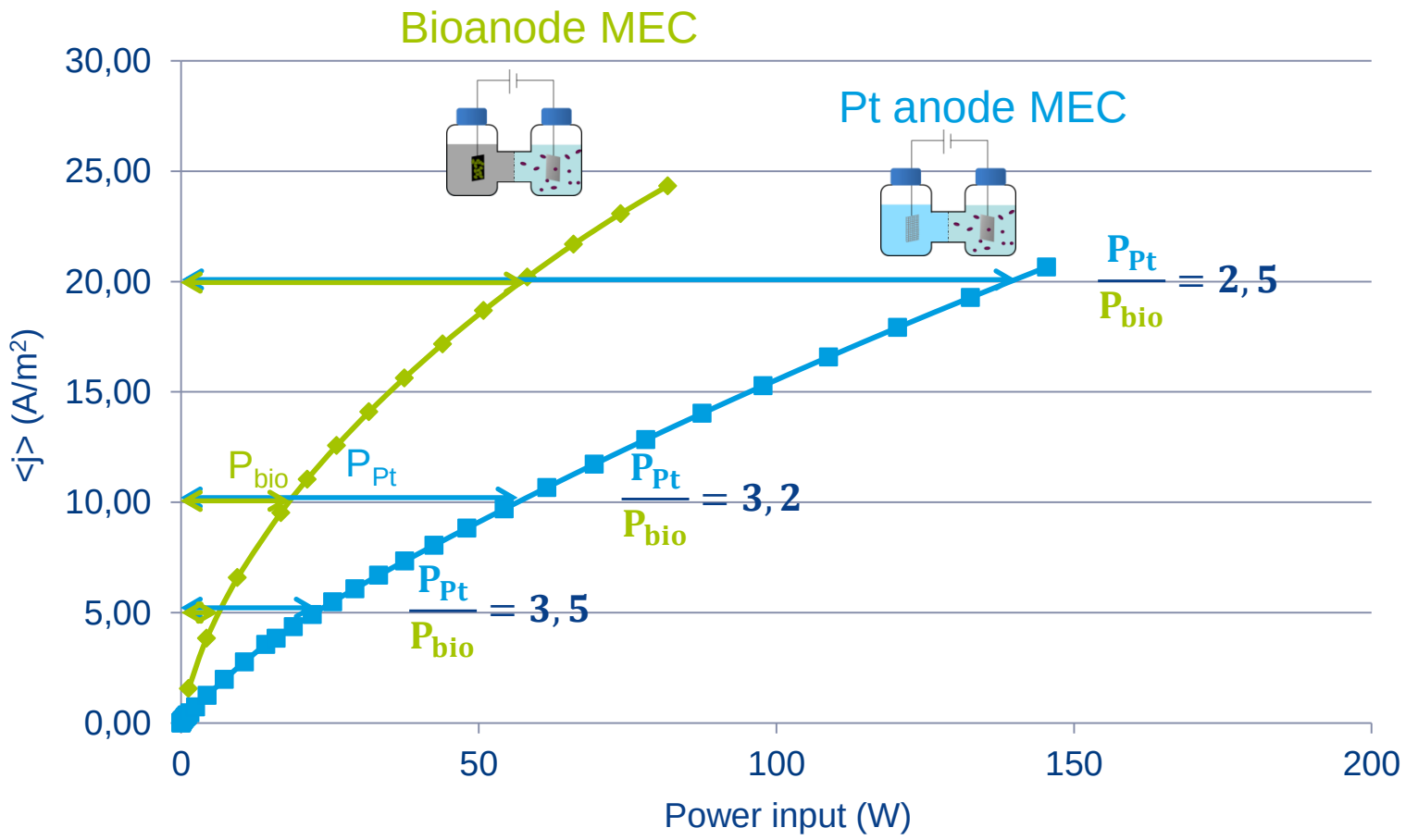

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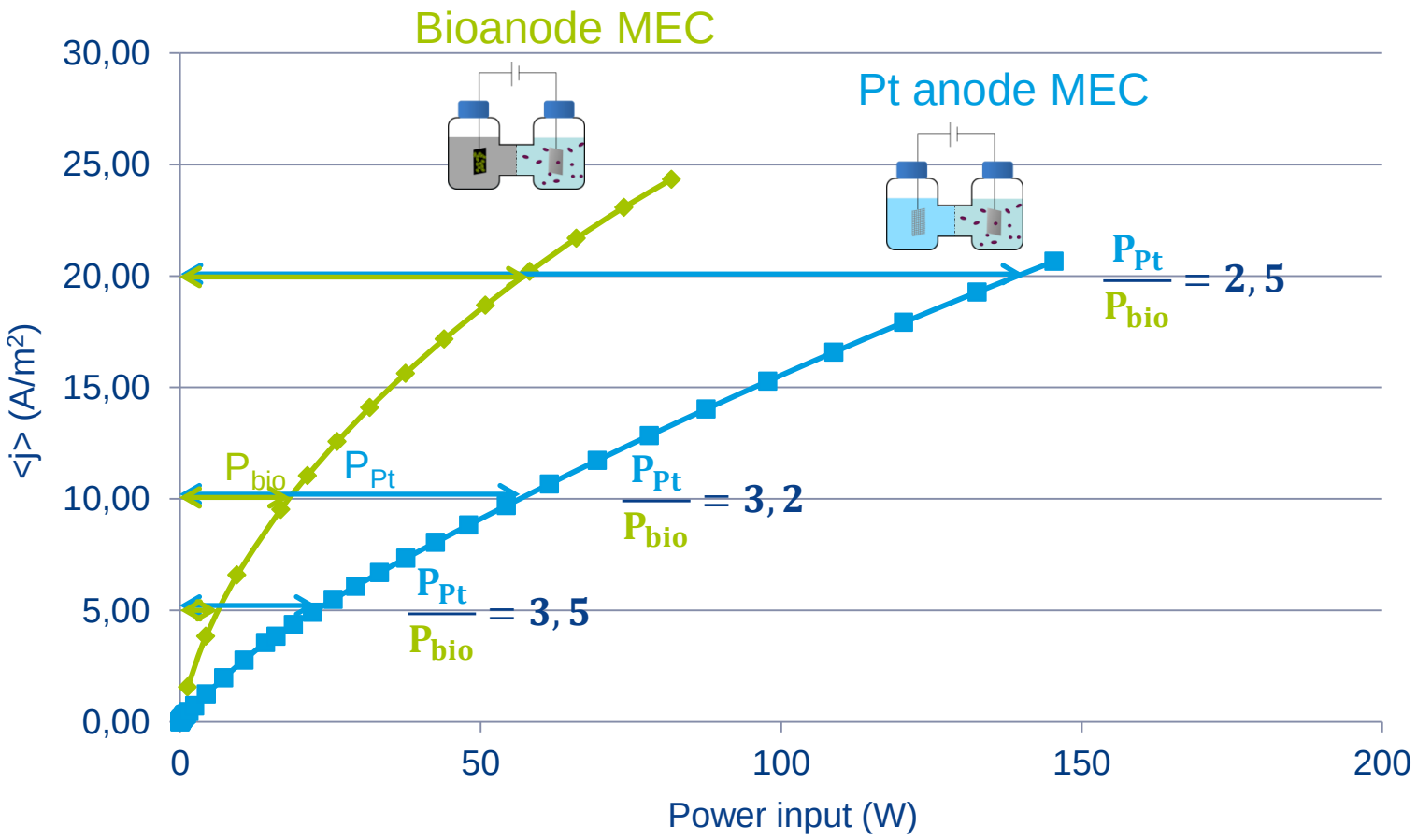
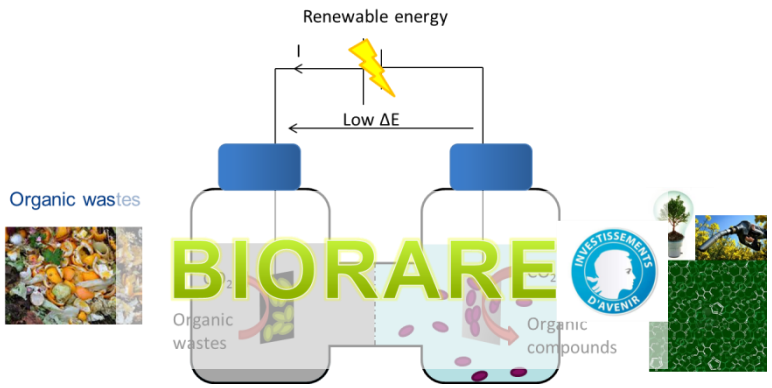


➢ **Power input** required is **2,5 to 3,5 times lower** with a bioanode compared to Pt anode oxidizing water

Conclusion

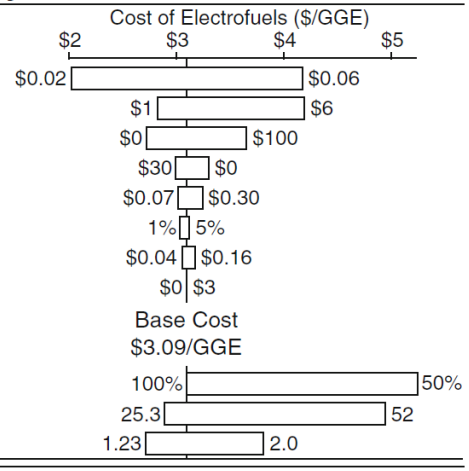


- System coupling a bioanode and a biocathode with good performances
- Energetic efficiency increase by 2,5 to 3,5 !
- Costs divided by 1,7 to 2 ?

Table 3 Major cost components of electrofuels process

Item	Base Cost	Cost ($/GGE)
Electricity Feedstock	$0.04/kWh	$2.15
Capital Cost	$2/yearly GGE	$0.45
CO_2 Feedstock	$40/ton CO_2	$0.37
O_2 Co-product	$20/ton O_2	-$0.20
Labor and Overhead	$0.15/GGE	$0.15
Maintenance and Taxes	4% of TPI	$0.09
Materials and Waste	$0.08/GGE	$0.08
Water Feedstock	$2/1000 gallons	$0.01
Total Cost	**Supp Calc 8**	**$3.09**

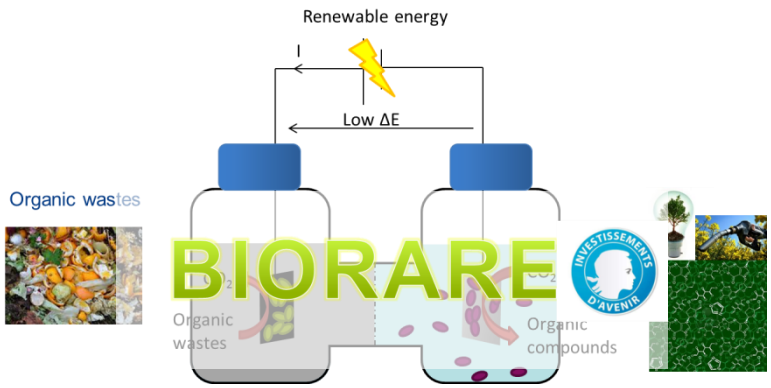
Item	Base Value
Cellular Energy Efficiency	100%
e- Consumed per Butanol Produced	28 e-
Delivered Voltage	1.5 V



Cost components and base values are tabulated to determine the individual cost of specific components as well as the overall cost of fuel production through electrofuels. With each cost item, a sensitivity analysis is provided in the Tornado chart on the *right* to illustrate how the variation in a single parameter influences the overall cost. The *top* of the table/chart itemizes standard engineering parameters, whereas the *bottom* of the table/chart itemizes biological constraints, the latter which each of the Electrofuels projects address

Conrado *et al.*, 2012, Electrofuels: A New Paradigm for Renewable Fuels

Conclusion



- System coupling a bioanode and a biocathode with good performances
- Energetic efficiency increase by 2,5 to 3,5 !
- Costs divided by 1,7 to 2 ?

- Patent **FR 14 59281** (in total 14 papers ISI-WoS, 3 patents up to now for the project)
- BIORARE technology from TRL0 to TRL3
- TRL4 coming soon (optimized pilot under test)
- LCA analysis: identification of environmentaly sensitive components and first environmental impact evaluations based on virtual scenarii (WP4)
- Market Study and industrial strategies under progress (WP5)

Many thanks to…

INRA-LBE : Nicolas Bernet, Eric Trably, Gunda Mohanakrishna, Alessandro Carmona, Roman Moscoviz

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Suez-Cirsee : Laure Renvoisé, Alain Huyard

ANR-10-BTBR-02

Irstea-OPAALE : Lynda Aissani, Lucas Giard, Amandine Foulet

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