Pure culture bio-capturing dissolved CO$_2$ at different potentials in microbial electrosynthesis cell (MES)

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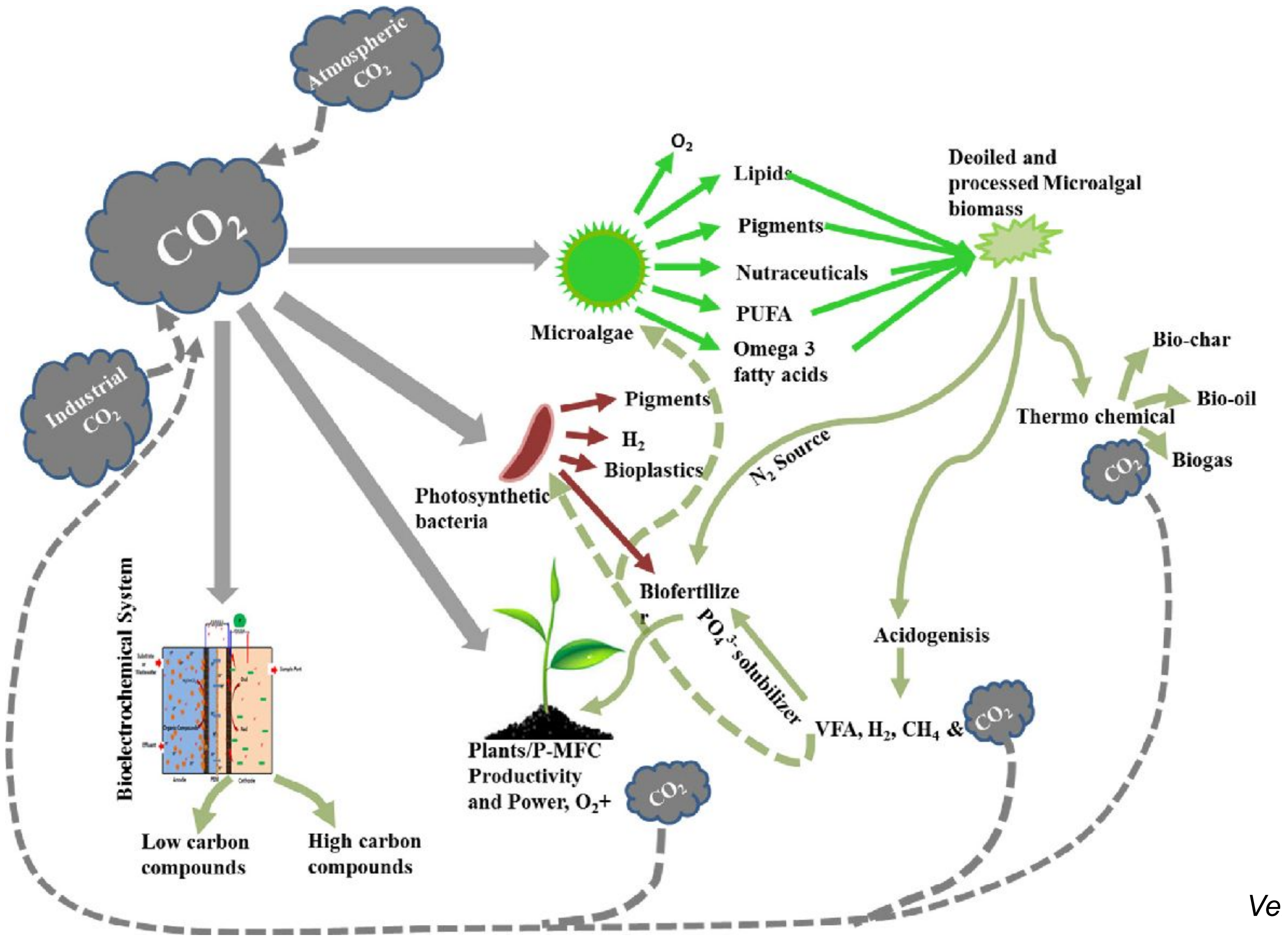
Biotechnologies helping mitigating CO_2 emission

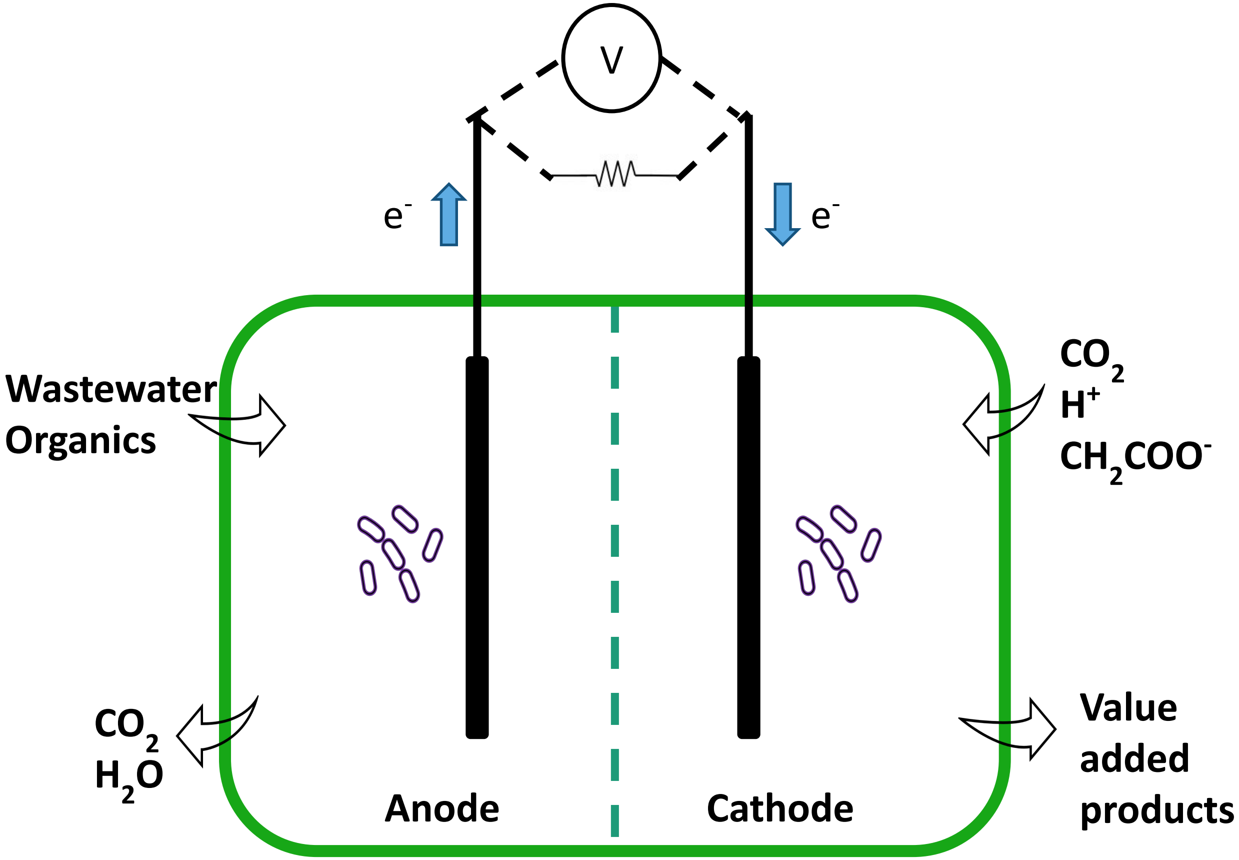


Main interest:

- Microalgae;
- Photosinthetic bacteria;
- Plants;
- BES.

Venkata Mohan et al., 2016

Bioelectrochemical systems (BESs)



Bioelectrochemical systems (BES) □ microorganisms use polarized electrodes to enable unfavourable reaction.

Several types of **substrates** □ **energy** or **bio-based** products

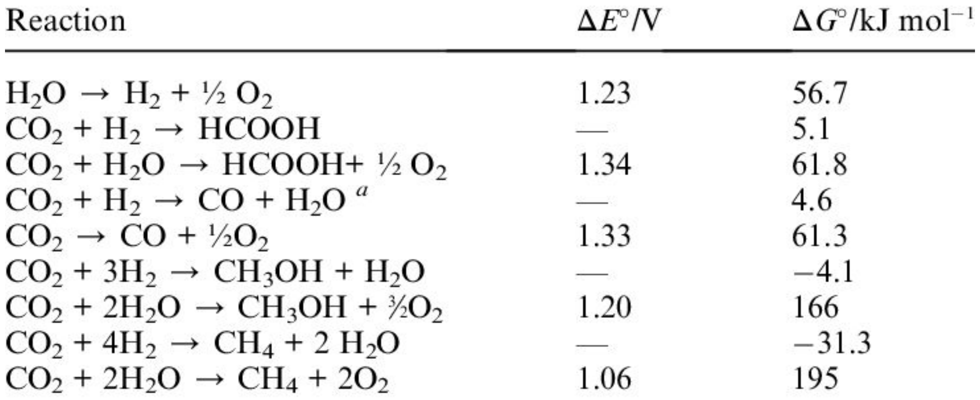
MES & CO_2

Provide electrical energy to produce **compounds of interest** from CO_2

There must be the availability of a reductant species

Required parameters:

- Presence of **electrons** or reducing equivalents;
- **Oxidizing** reaction at the anode;
- **External circuit** to drive electrons from the anode to the cathode.



Reaction	ΔE°/V	ΔG°/kJ mol^{-1}
$H_2O \rightarrow H_2 + \frac{1}{2} O_2$	1.23	56.7
$CO_2 + H_2 \rightarrow HCOOH$	—	5.1
$CO_2 + H_2O \rightarrow HCOOH + \frac{1}{2} O_2$	1.34	61.8
$CO_2 + H_2 \rightarrow CO + H_2O$ [a]	—	4.6
$CO_2 \rightarrow CO + \frac{1}{2}O_2$	1.33	61.3
$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$	—	−4.1
$CO_2 + 2H_2O \rightarrow CH_3OH + \frac{3}{2}O_2$	1.20	166
$CO_2 + 4H_2 \rightarrow CH_4 + 2 H_2O$	—	−31.3
$CO_2 + 2H_2O \rightarrow CH_4 + 2O_2$	1.06	195

Purple photothrophic bacteria

In particular *Rhodopseudomonas palustris*, a purple non-sulfur bacterium (PNB), α-proteobacteria

Chemoautotroph metabolism:
- ✔ CO_2 + inorg. reductants
- ✔ Light
- ✔ N

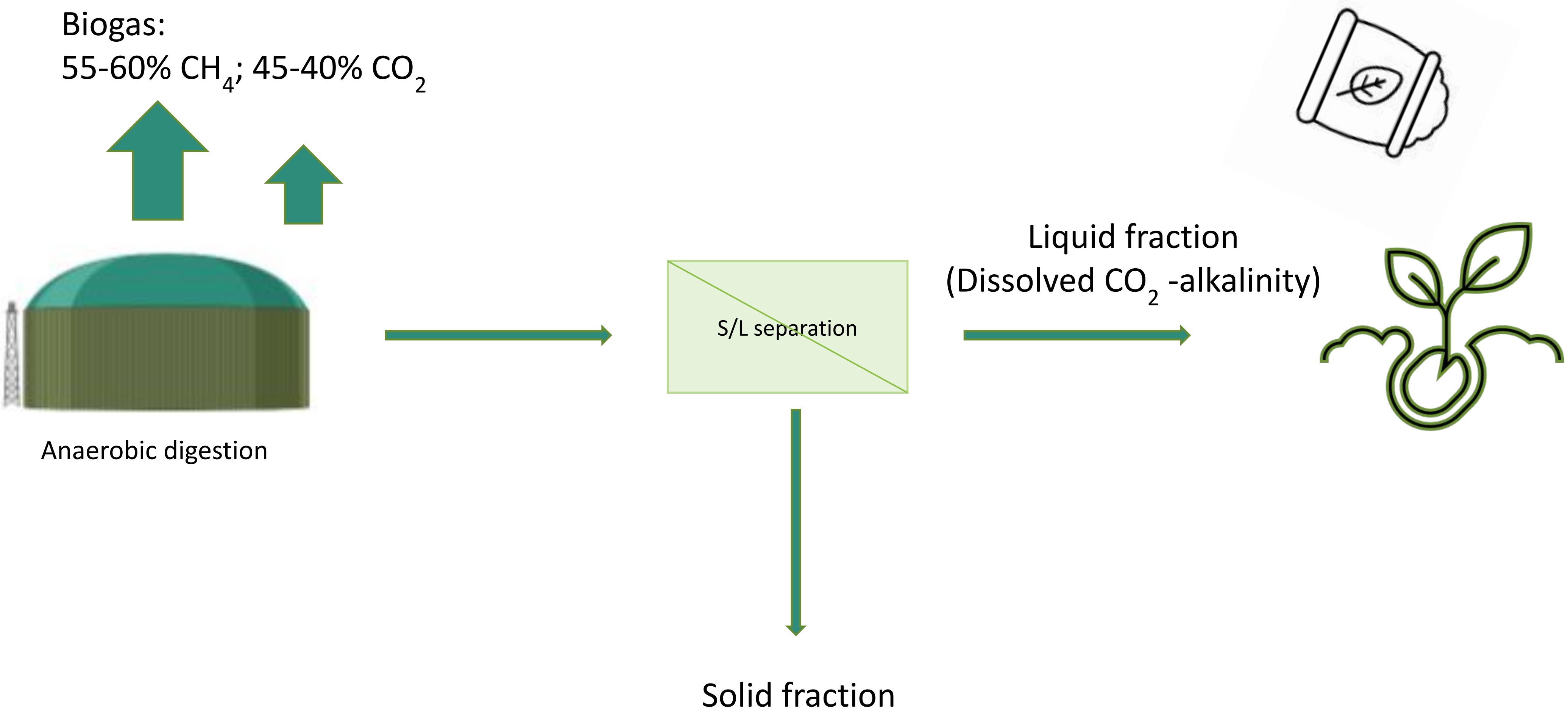
Chemoheterotroph metabolism:
- ✔ Org. C
- ✔ Anaerobiosis
- ✔ N

Produce bacteriochlorophyll(BChl)-a and bacteriopheophytin(BPhe)-a,

PHA and volatile fatty acids (VFAs)

CO_2 conversion and **N_2** fixation during growth

Different use for liquid digestate



Biogas:
55-60% CH_4; 45-40% CO_2

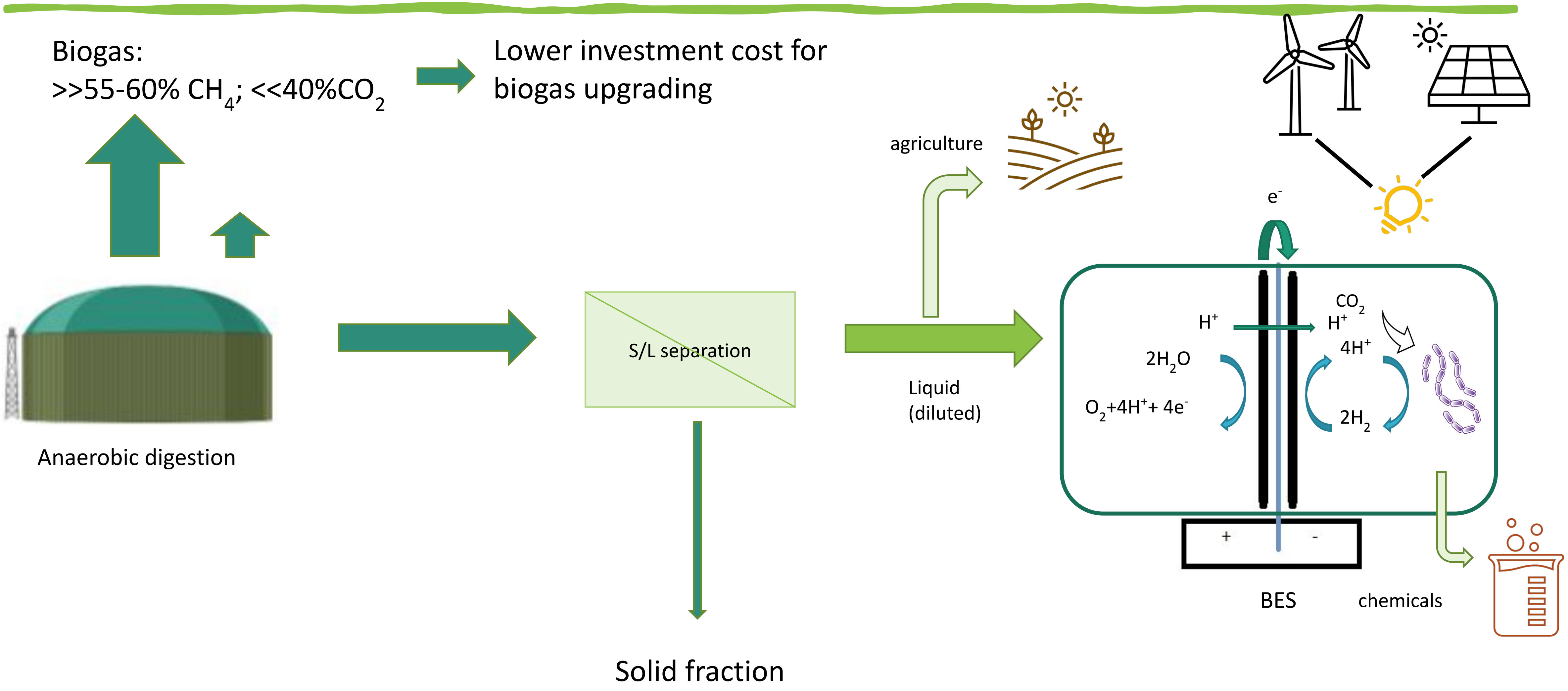
Anaerobic digestion

S/L separation

Liquid fraction
(Dissolved CO_2 -alkalinity)

Solid fraction

Different use for liquid digestate



Biogas:
>>55-60% CH_4; <<40%CO_2

Lower investment cost for biogas upgrading

Anaerobic digestion

S/L separation

Solid fraction

agriculture

Liquid (diluted)

BES

chemicals

Study Aim

To study the effect of

- the **applied voltage**

- **alkalinity concentration**

on the biomass growth (*R. palustris*) under anoxygenic phototrophic conditions using

dissolved inorganic carbon

Experimental set-up

Reactor:
H-cell (WE, RE and CE)
1 L each chamber separated by a Nafion® 117membrane (PEM)
Working chamber: Cathode

Electrodes:
2 graphite rods + reference Ag/AgCl

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Experimental period

Applied Voltage: @-1,1V vs Ag/AgCl;

@-1,2V vs Ag/AgCl;

@-1,4V vs Ag/AgCl.

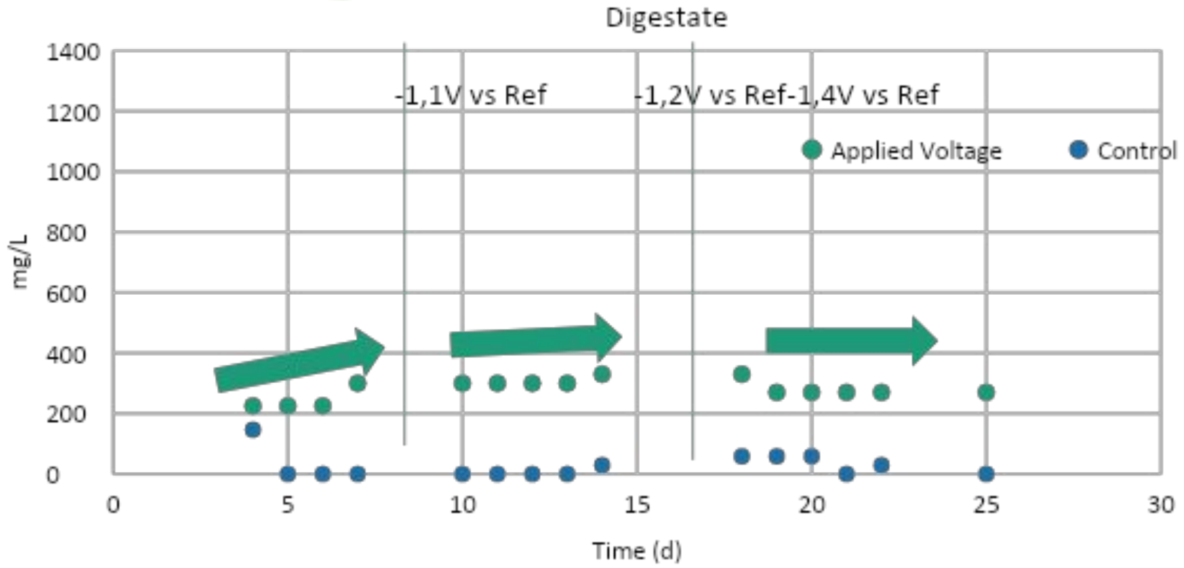
under <u>different alkalinity</u> (expressed as $CaCO_3$) concentration

- 2 $gCaCO_3/L$ (raw liquid fraction of anaerobic digestate)
- 4 $gCaCO_3/L$ (concentration increased by Na_2CO_3)

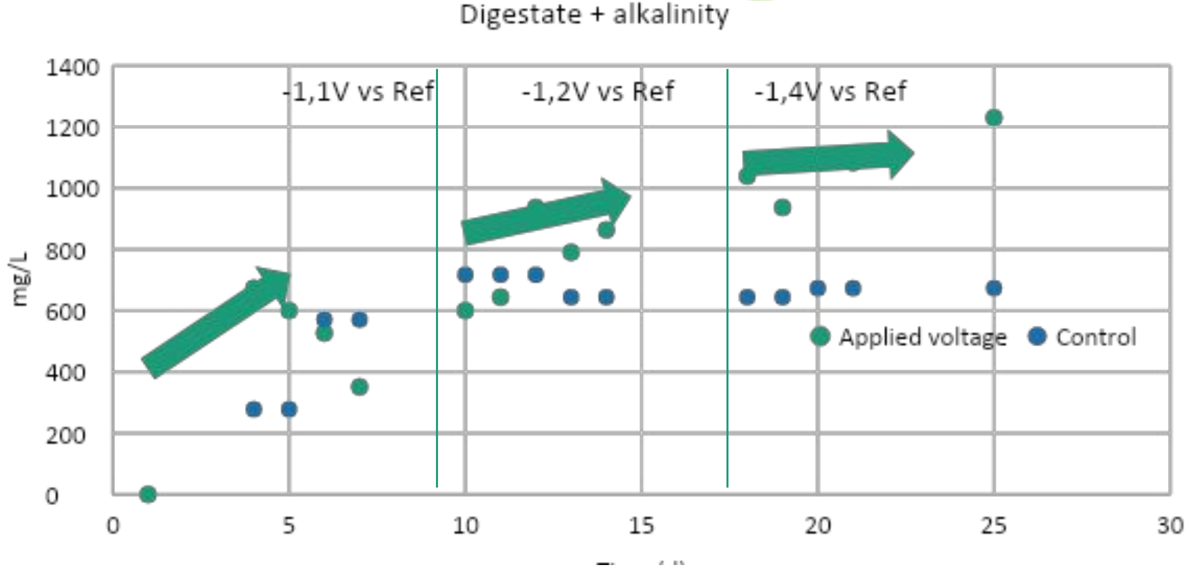
Parameters of interest

- COD □ valuation of the presence of bio-based products and biomass itself;
- Alkalinity □ CO_2 consumption;
- Solids □ planktonic growth of biomass;
- Current intensity □ energy required to perform the reaction.

Consumption of alkalinity



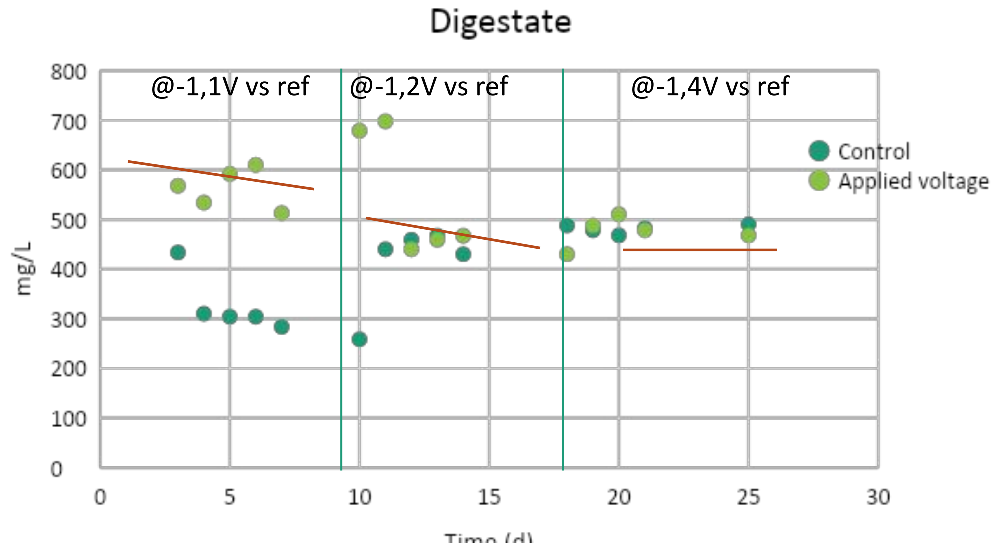
-1,1V vs Ref -1,2V vs Ref -1,4V vs Ref



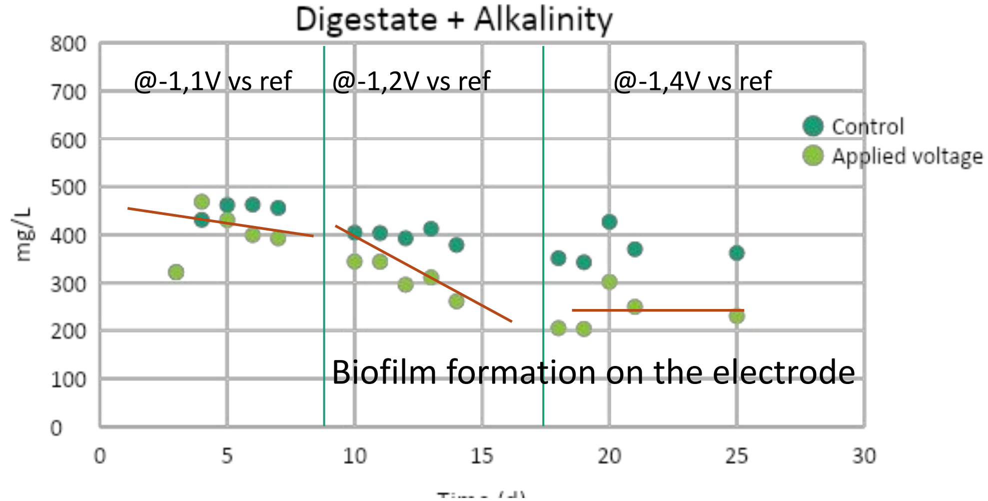
Applied voltage: at first there was a partial decrease in alkalinity, after the potential change the alkalinity increase at same level as at the beginning;

Applied voltage: slow uptake of CO_2 after changing the potential;

Profile of biomass concentration



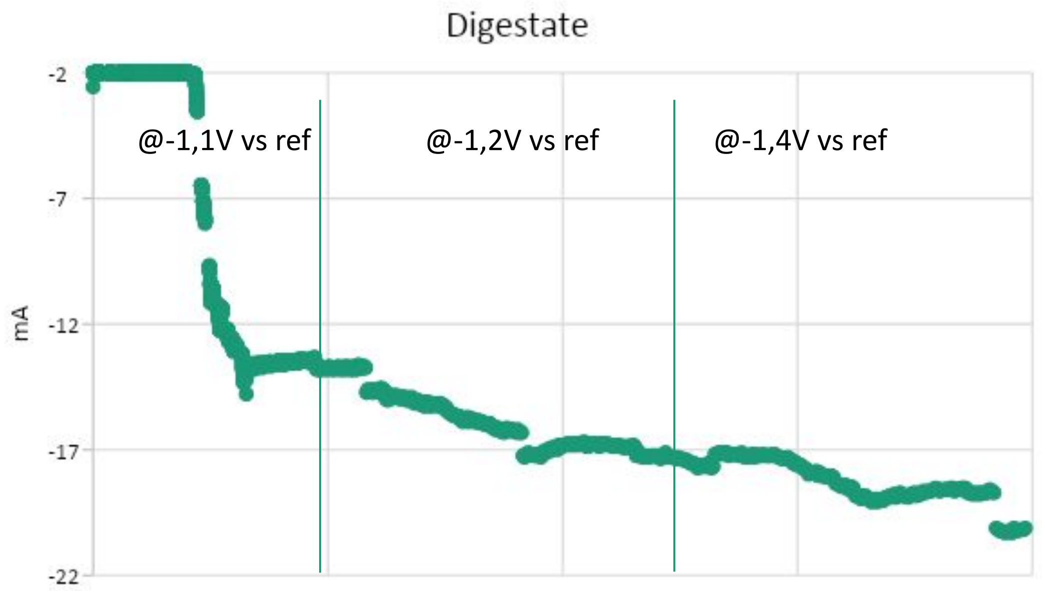
<u>Applied voltage</u>: initial increase, changing potential led to a decrease in biomass and then to a stabilization;
<u>Open circuit</u>: initial decrease but change the trends during the experimental period.

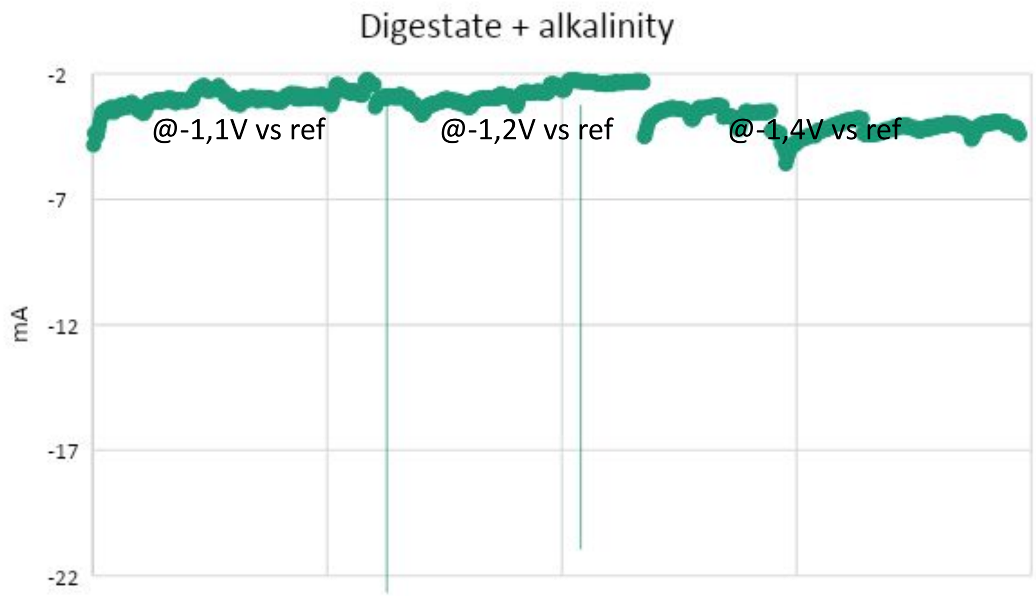


Biofilm formation on the electrode

<u>Applied voltage</u>: decreasing in biomass till @-1,4V vs ref that is stable;
<u>Open circuit</u>: the biomass remain stable during the experimental period

Results: current





The addition of alkalinity to the digestate improved the stability of the current flow in the test

V=R x I

Conclusions

- There is the necessity to add an external CO_2 source to optimize the biocapture of alkalinity in the digestate;
- @-1,1V vs Ag/AgCl is the best applied potential in the alkalinity bioconversion;
- An applied potential improve the ability of the microorganisms to bioconversion the dissolved CO_2

Future perspective

1. Choose the best voltage;
2. Fed-batch reactor with the chosen voltage;
3. Adjust the process in order to produce the compound of interest.

Thank you for your attention!

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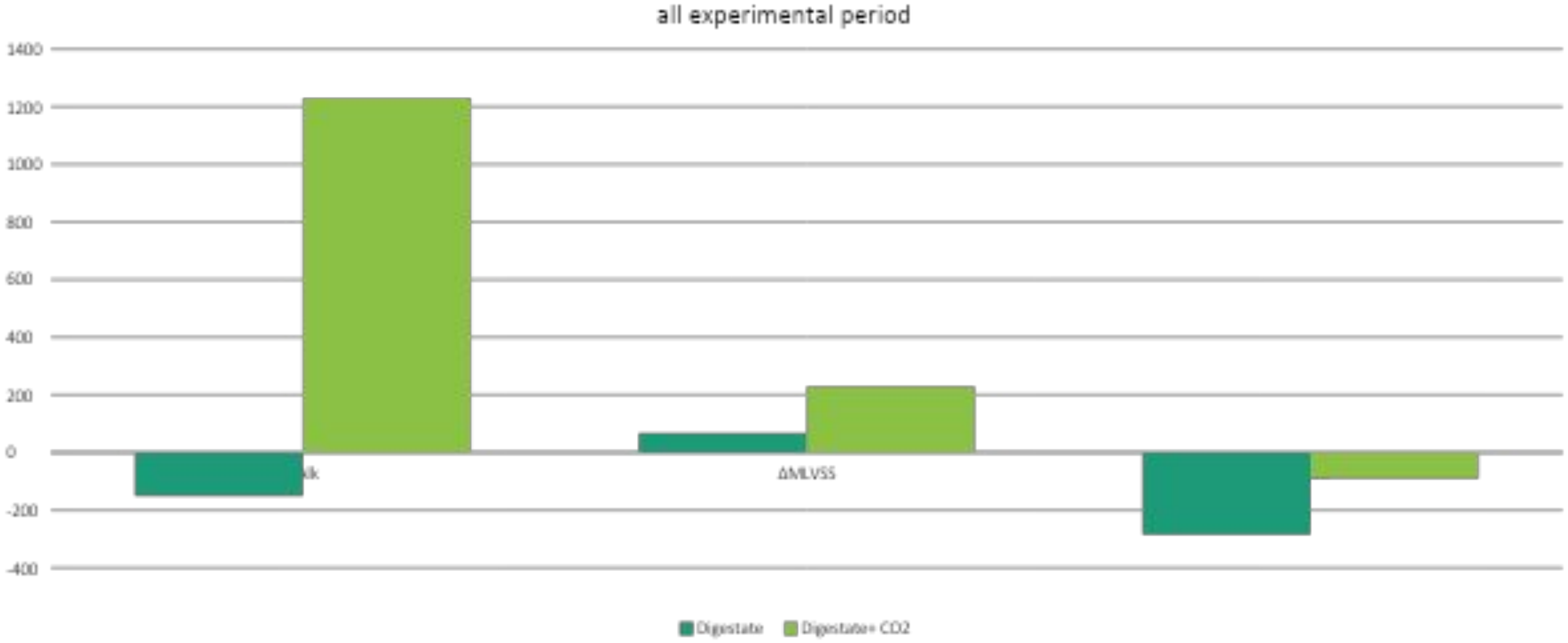
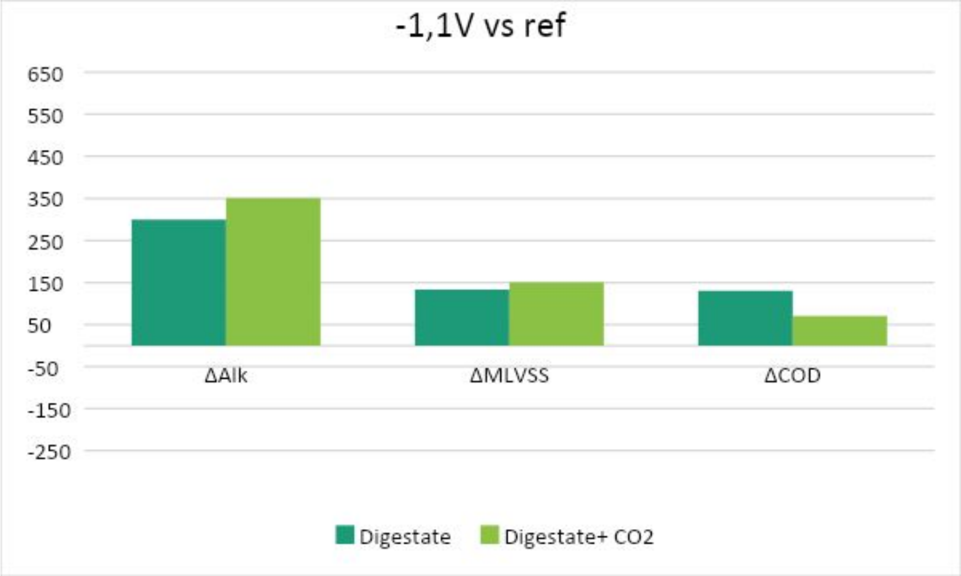
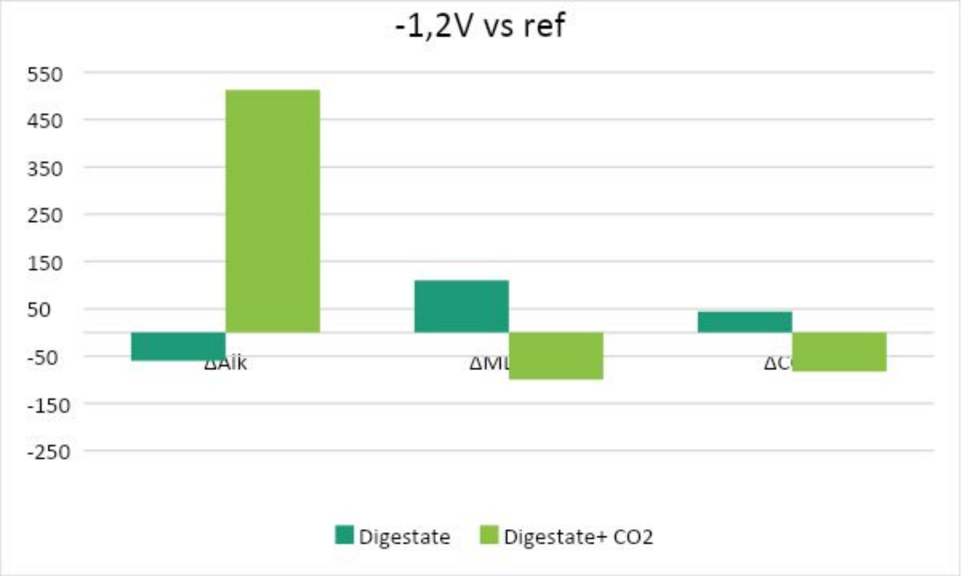
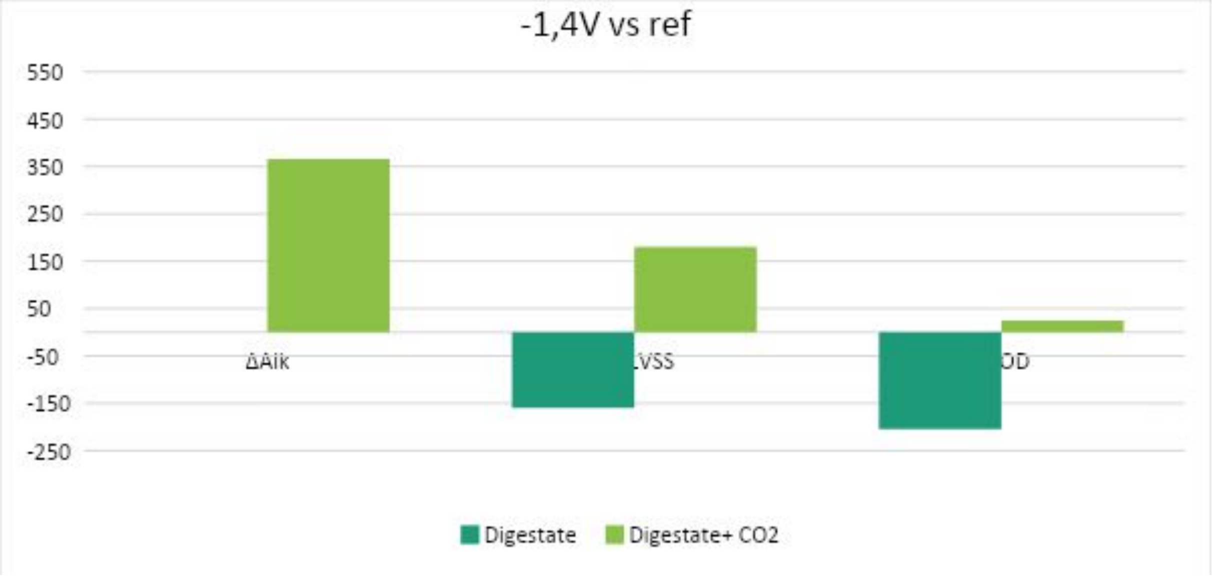
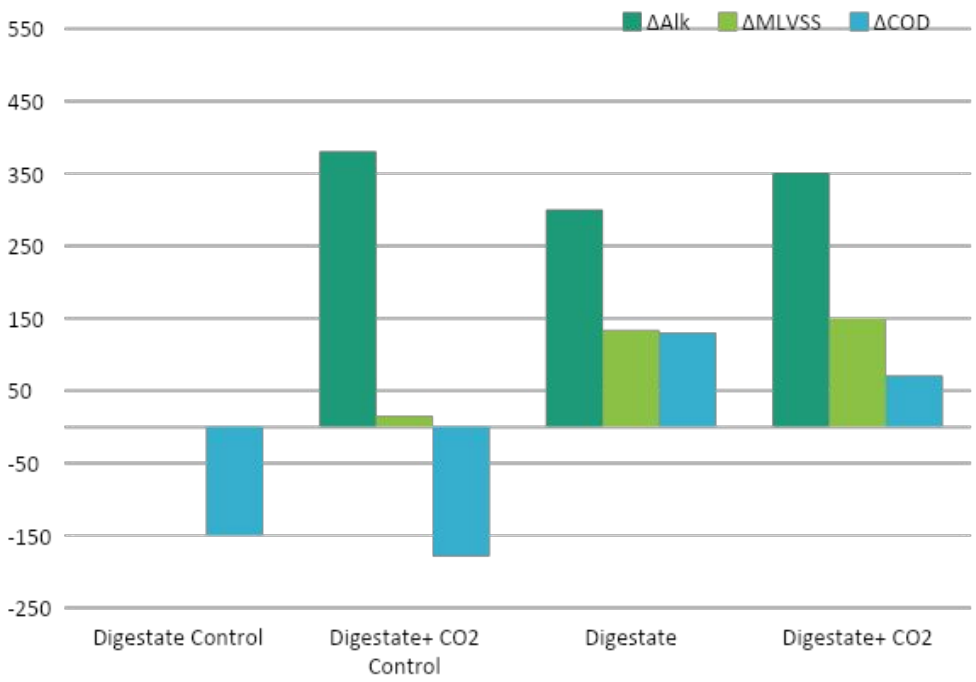

all experimental period
1400
1200
1000
800
600
400
200
0
-200
-400
lk
ΔMLVSS
Digestate
Digestate+ CO2

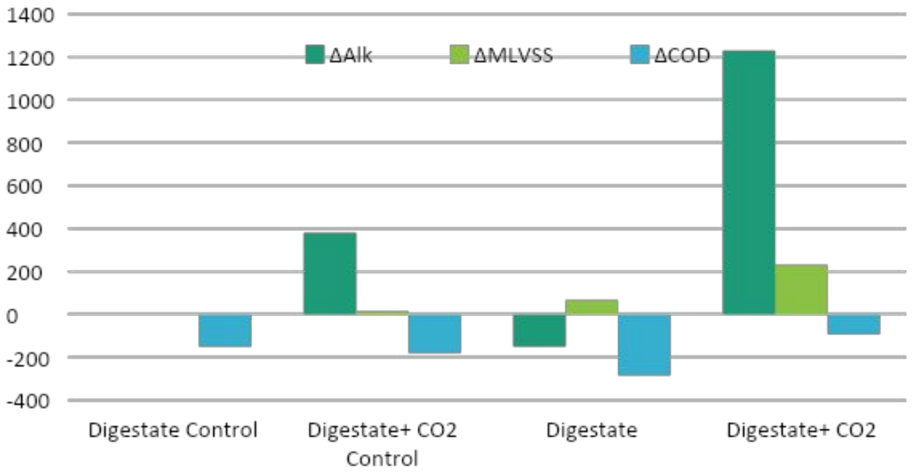

-1,1V vs ref
650
550
450
350
250
150
50
-50
-150
-250
ΔAlk
ΔMLVSS
ΔCOD
Digestate
Digestate+ CO2


-1,2V vs ref
550
450
350
250
150
50
-50
-150
-250
ΔAlk
ΔML
ΔC
Digestate
Digestate+ CO2


-1,4V vs ref
550
450
350
250
150
50
-50
-150
-250
ΔAlk
LVSS
OD
Digestate
Digestate+ CO2



Overview with -1,1V vs ref



Sperimental period overview

Re-thank you!