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# WalBioPower: Valorizing organic waste into energy


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## Aim of the project

WalBioPower aims at valorizing organic waste, such as food waste, urine and the liquid fraction of effluents.

The solid fraction of **food waste** is transformed into gaseous **biomethane** and a solid/liquid waste called **digestate.** The aim is to reduce the carbon/environmental footprint of the process by improving its yield, allowing its decentralization and increase the valorization of its by-product, digestate.

The **urea** contained in urine can be valorized to produce **hydrogen**, either by using it in a reaction of electrocatalysis or by producing ammonium in a controlled fashion which will be valorized energetically at later stages of the project.

## 1. Psychrophilic anaerobic digestion

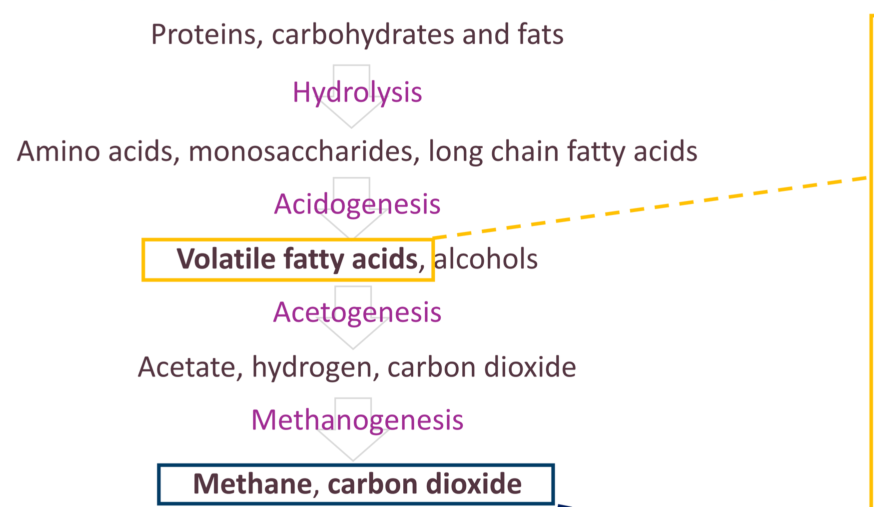



Figure 1.1. : Anaerobic digestion process

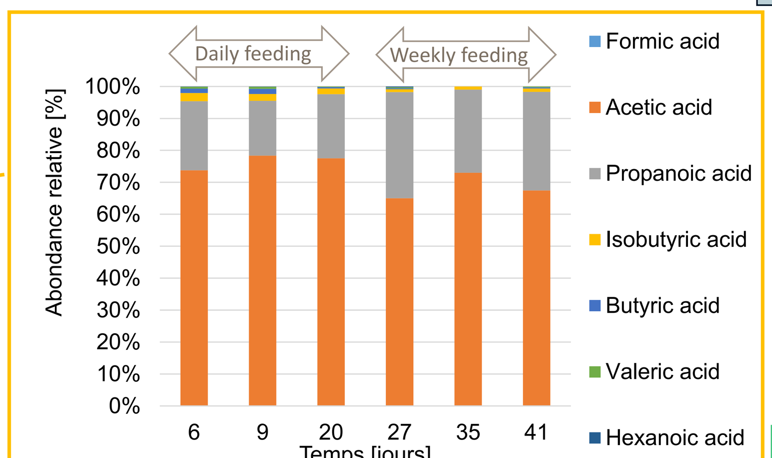



Figure 1.4. Evolution of volatile fatty acids composition in the digestate

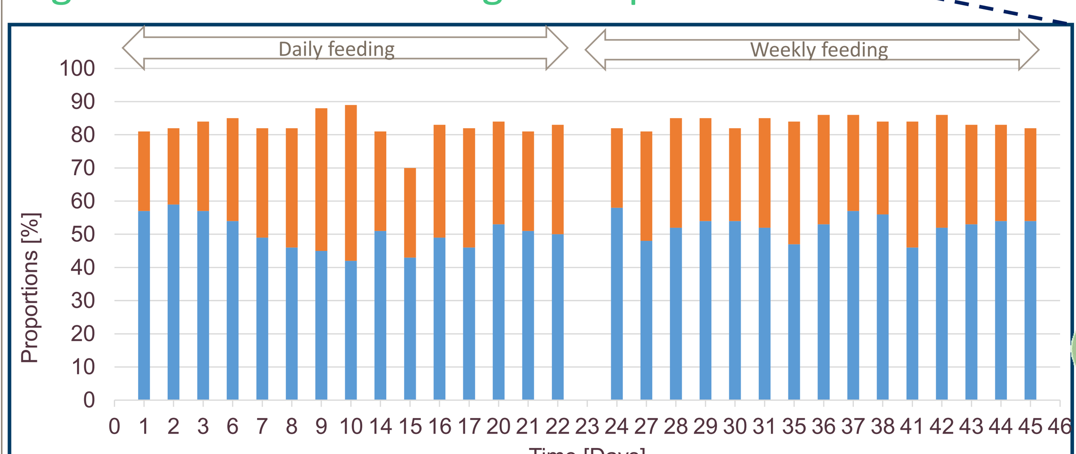



Figure 1.3. : Evolution of $CH_4$ and $CO_2$ proportions in the biogas produced during the methanogenesis stage ( $CH_4$ and $CO_2$)

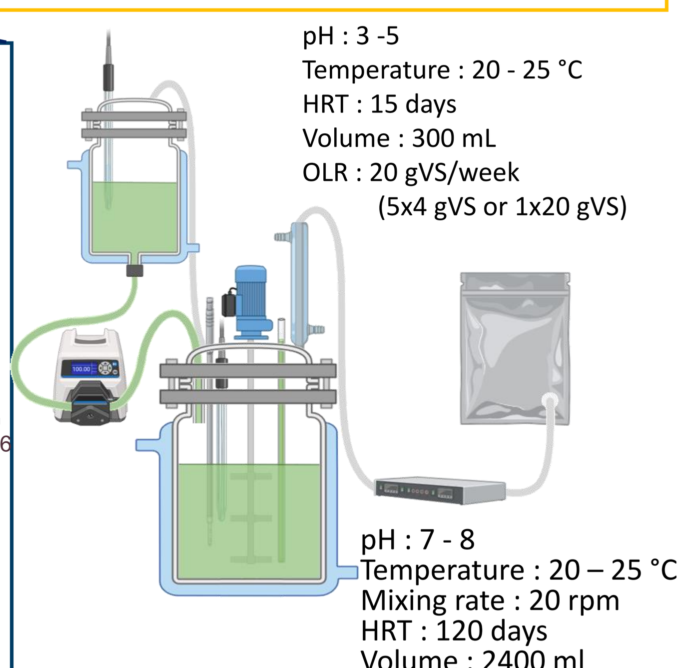



Figure 1.2. : Two-stages bioreactor configuration

| | Daily feeding | Weekly feeding |
|---|---|---|
| Specific biogas production [Nml/gVS] | 496 ± 28 | 329 ± 31 |
| Biogas production rate [Nml/h] | 59 ± 2 | 39 ± 5 |

Table 1 : Performance characteristics of the reactor expressed as 95% confidence intervals

Anaerobic digestion is a process where microorganisms break down organic matter, in the absence of oxygen, into valuable biogas composed of methane (50-75%) and $CO_2$ (25-50%).

## 2. Valorization of digestate by *Rhodospirillum rubrum*

Digestate contains volatile fatty acids which can be assimilated by purple non-sulphur bacteria (PNSB), such as *Rs. rubrum.*

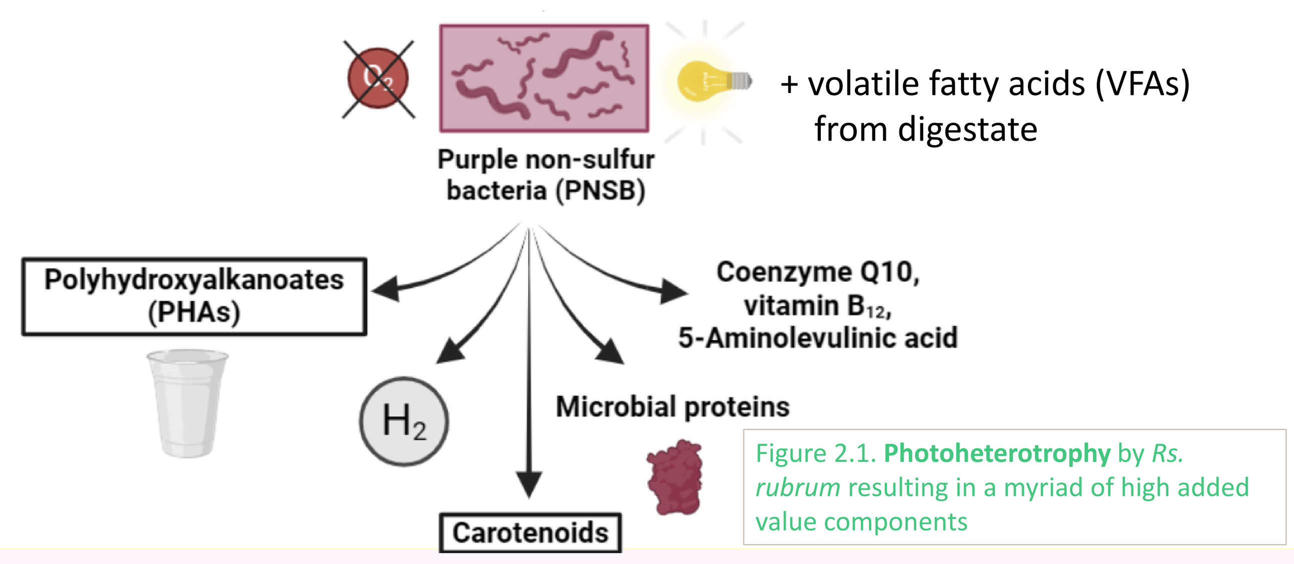



Figure 2.1. **Photoheterotrophy** by *Rs. rubrum* resulting in a myriad of high added value components

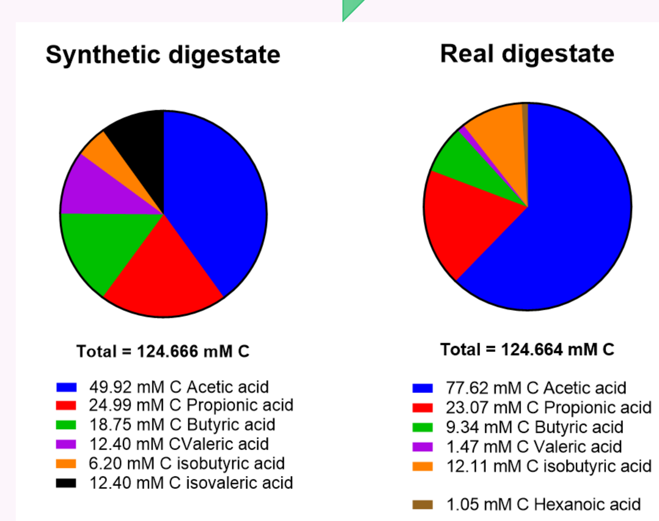



Figure 2.2. **Characterization of digestate VFAs composition.** Culture medium is composed of diluted digestate with nutrients added. It was adjusted to reach 124 mM C and 123 mM $NH_4$ in all tested cases.

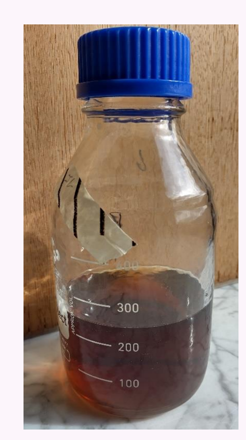
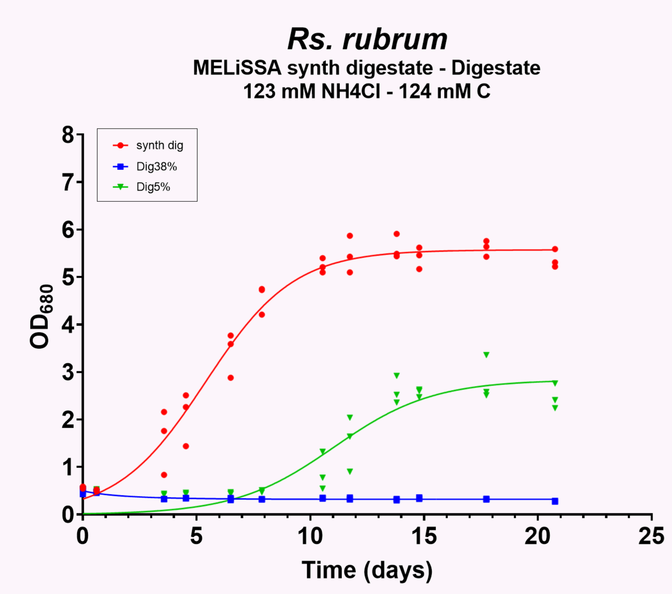


Figure 2.3. **Sample of culture medium with 10% digestate.** The culture medium color might inhibit photosynthetic growth.

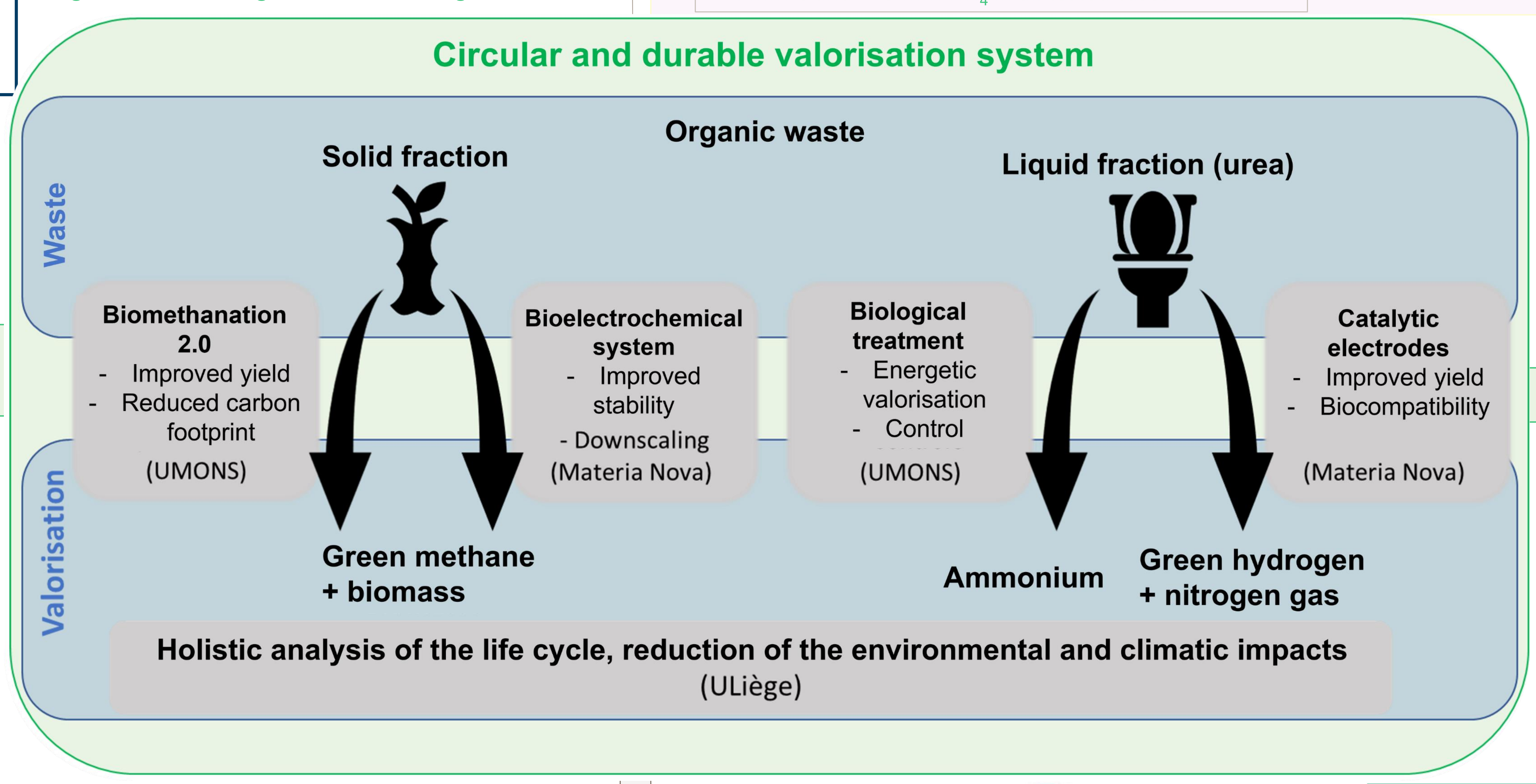
Figure 2.4. **Growth of *Rs. Rubrum* in 3 different culture mediums.** Reduced growth rate and maximal concentration was observed for culture medium with 5% digestate. No growth observed for culture medium with 38% digestate (no synthetic VFAs added).




**Ongoing work:**

- Test with 10% digestate using *Rs. rubrum* grown in 5% digestate culture medium: (growth observed)
- Comparison with wild (non adapted) strain
- Modelling of *Rs. rubrum* growth in transparent / absorbent medium

## Circular and durable valorisation system




## 3. Modelling and optimizing control of anaerobic digestion

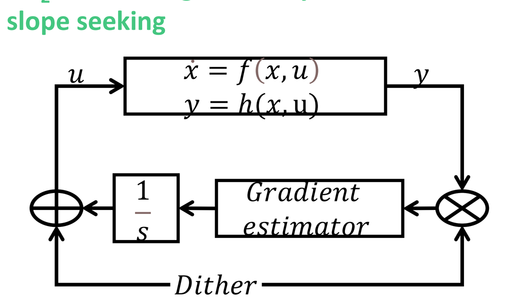
**Two-stage model** (Henrotin *et al.* 2023)

$$\begin{bmatrix} \dot{S}_1 \\ \dot{S}_2 \\ \dot{X}_1 \\ \dot{X}_2 \end{bmatrix} = \begin{bmatrix} -k_1 & 0 \\ k_2 & -k_3 \\ 1 & 0 \\ 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \mu_1 X_1 \\ \mu_2 X_2 \end{bmatrix}$$

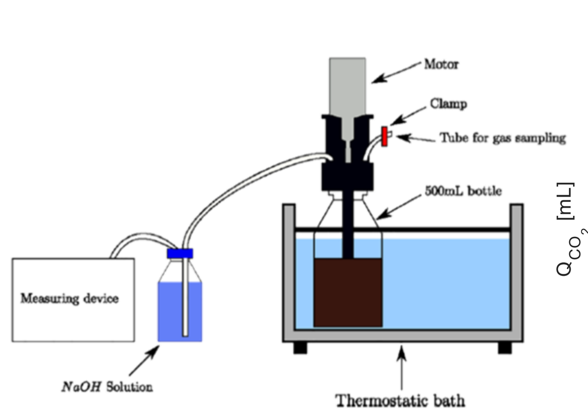
$$Q_{CO2} = k_4 \mu_1 X_1 + k_5 \mu_2 X_2$$

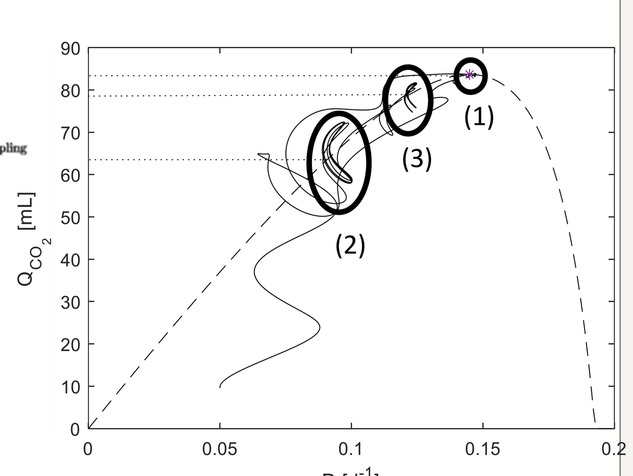
$$Q_{CH4} = k_6 \mu_2 X_2$$

$CO_2$ outflow regulation by model-free slope seeking



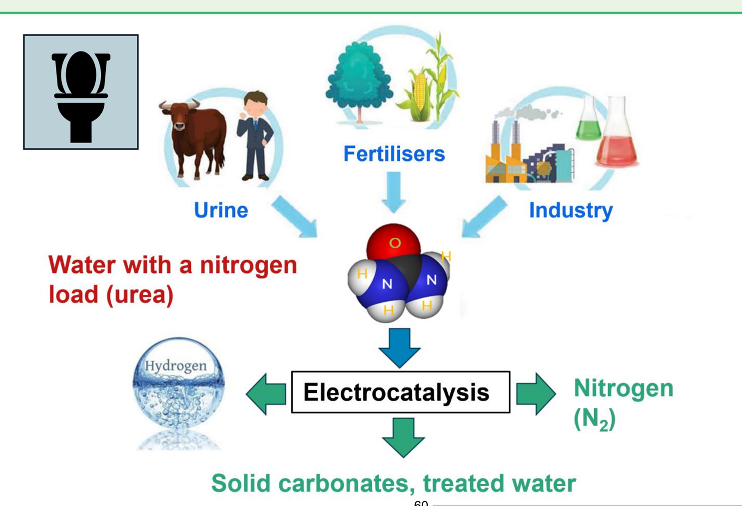

(1) $Q_{CO2}$ = 83,5 mL (Extremum seeking)
(2) $Q_{CO2}$ = 63 mL
(3) $Q_{CO2}$ = 79 mL

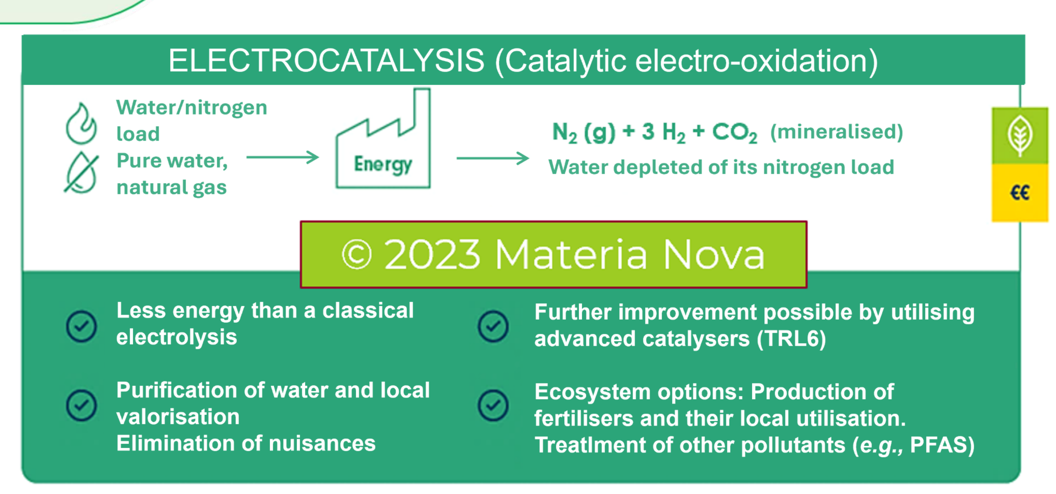



## 4. Electrocatalysis of urea

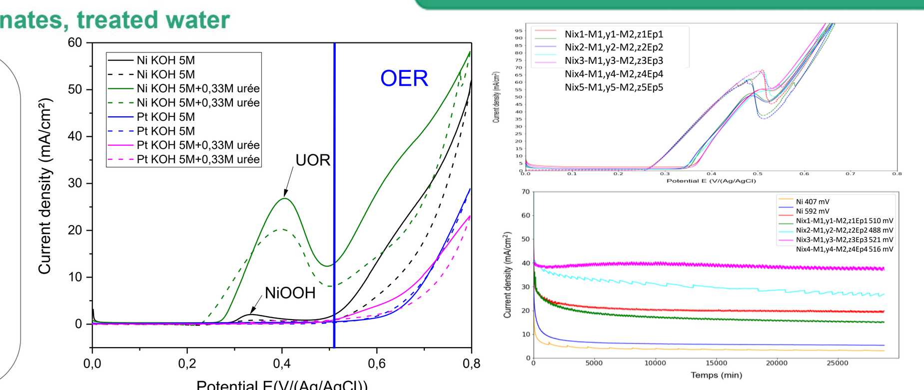
-30% of the electrical energy(vs. electrolysis)
No $CO_2$ emitted (10 t of $CO_2$ avoided per t $H_2$)




**OBJECTIVE**

Development of ternary/ quaternary alloys based on Ni




**Quaternary Ni alloy**

→Increased current density of the UOR (urea oxidation reaction) (x2/Ni)
→Low activation overpotential
→Stability of the catalytic activity over time (/Ni)
→Excellent corrosion resistance

## Conclusions and future work

- Anaerobic digestion in the reactor, the growth of *Rs. rubrum* and the model have been set up and optimized. Further optimizations will be carried out by feeding the model experimental data and with regards to the bacterial cultures.
- Life cycle assessments (LCA) will be used to evaluate the feasibility of the decentralization process.
- The quaternary Ni alloy increased the current density of the urea oxidation reaction and had a higher catalytic stability compared to Ni alone.
- The production of ammonium and its subsequent energetic valorization will be carried out in the coming months.