# Macroalgae waste from the Agar-Agar industry: Bioenergy through pyrolysis processes (biofuels) and biogas upgrading

*E. Ciurcina[1], E. Fuente[1], S. Paniagua[2,3], L. Taboada-Ruiz[1], L.F. Calvo[4], F. Suárez-García[1], M. Díaz Somoano[1], B. Ruiz[1]*

[1]Instituto de Ciencia y Tecnología del Carbono (INCAR), CSIC. C/ Francisco Pintado Fe, 26. 33011, Oviedo, Spain
[2]Department of Applied Physics, University of Valladolid. 47011, Valladolid, Spain
[3]Department of Chemical Engineering and Environmental Technology, Institute of sustainable processes, Univ. Valladolid, Spain
[4]Department of Chemistry and Applied Physics, Chemical Engineering Area, IMARENABIO, University of Leon. León, Spain

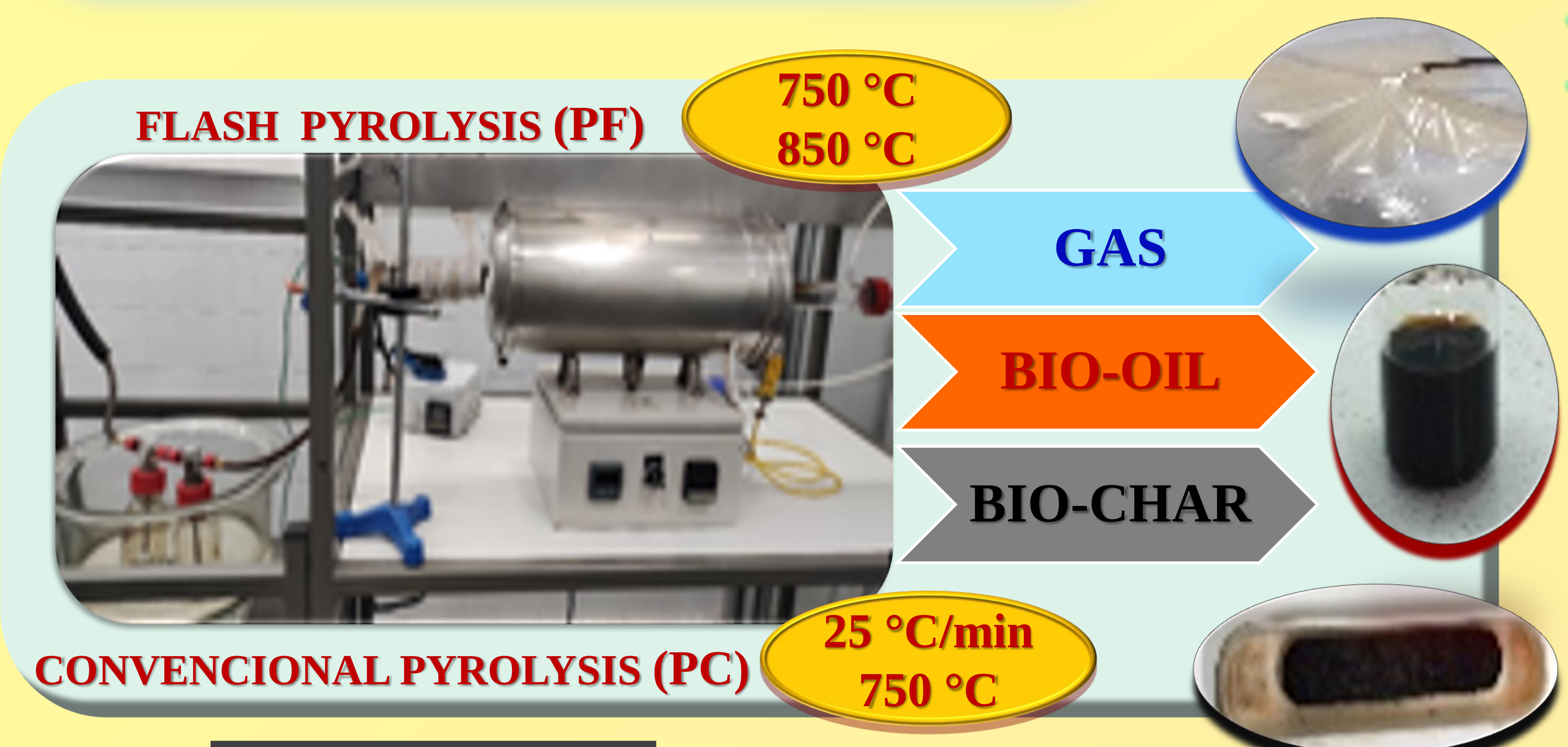
## Agar-Agar Industry



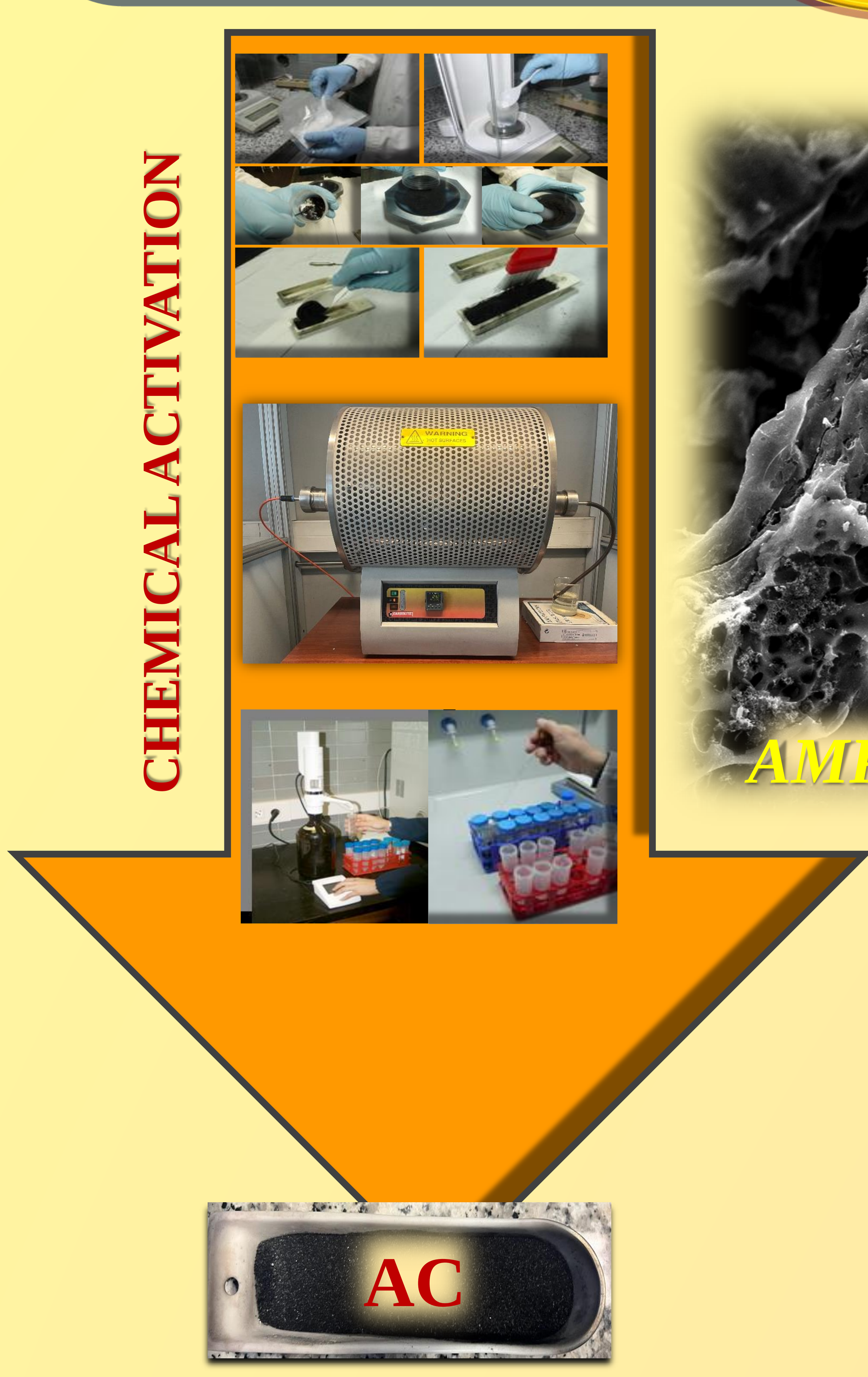
## Objective

BIO-FUEL ? BIOGAS UPGRADING ?

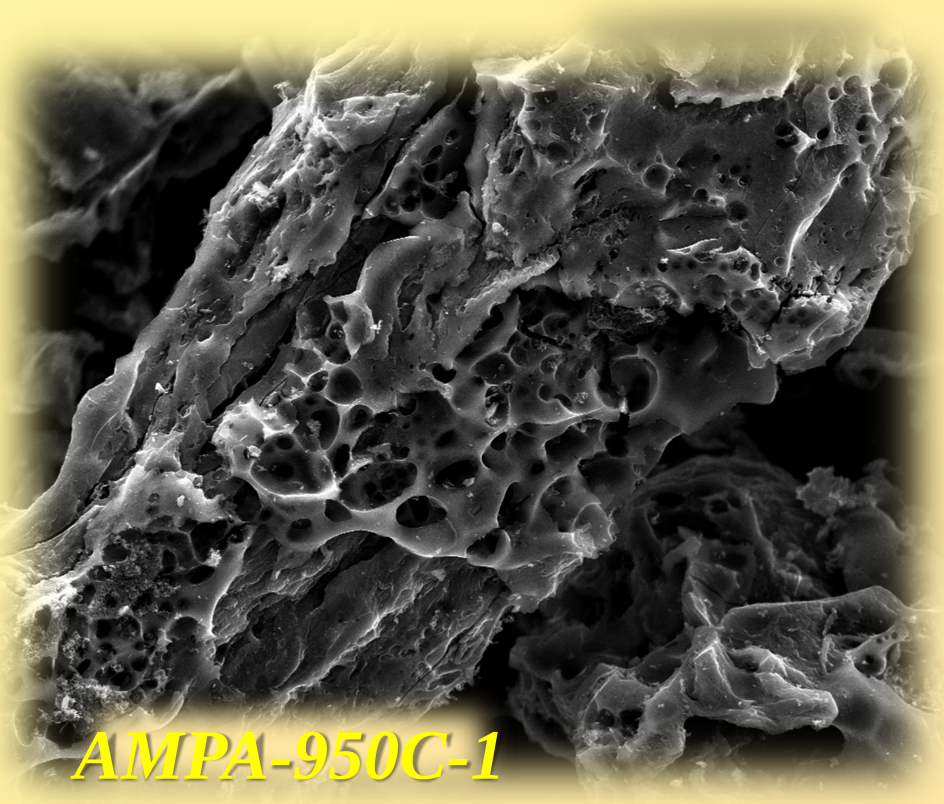
- ❖ Conventional and flash pyrolysis of AM to obtain Bio-char, Bio-oil and Gas as energy source. Evaluate their potential as bio-fuels in the bioenergy sector.
- ❖ Obtain activated carbons (ACs) from pyrolyzed macroalgae waste (bio-char) by alkaline chemical activation (KOH and $K_2CO_3$).
- ❖ ACs for purification/separation of gas mixture ($CO_2/CH_4$ or $CO_2/H_2$) with the biogas upgrading purposes for the renewable energy production.







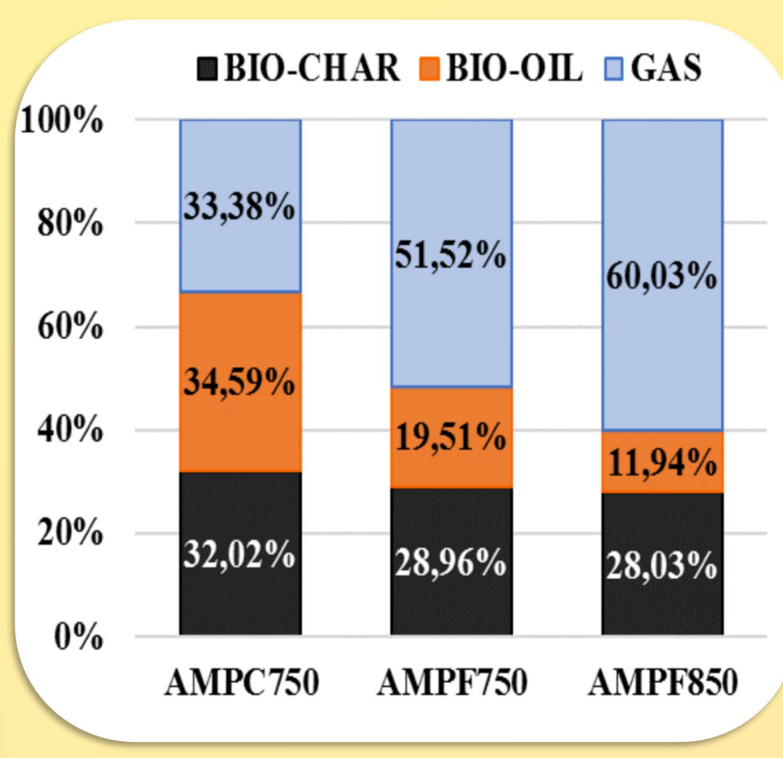




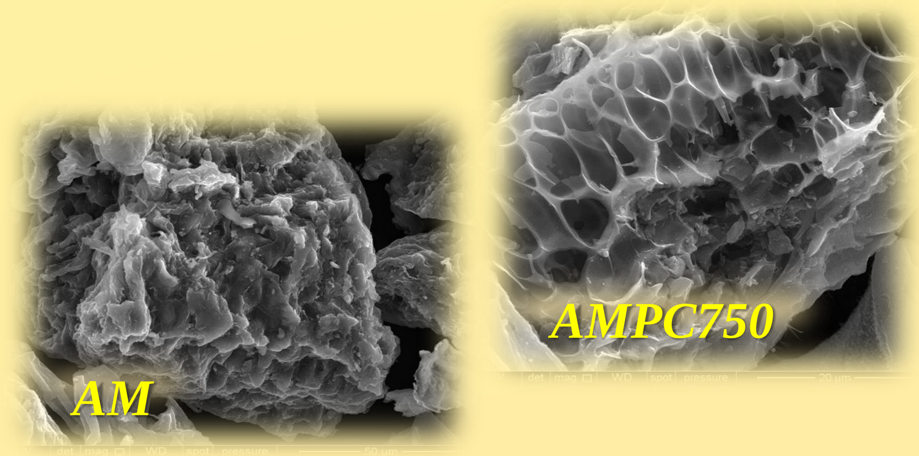


## Results & Discussion

*Yield of pyrolysis fractions*





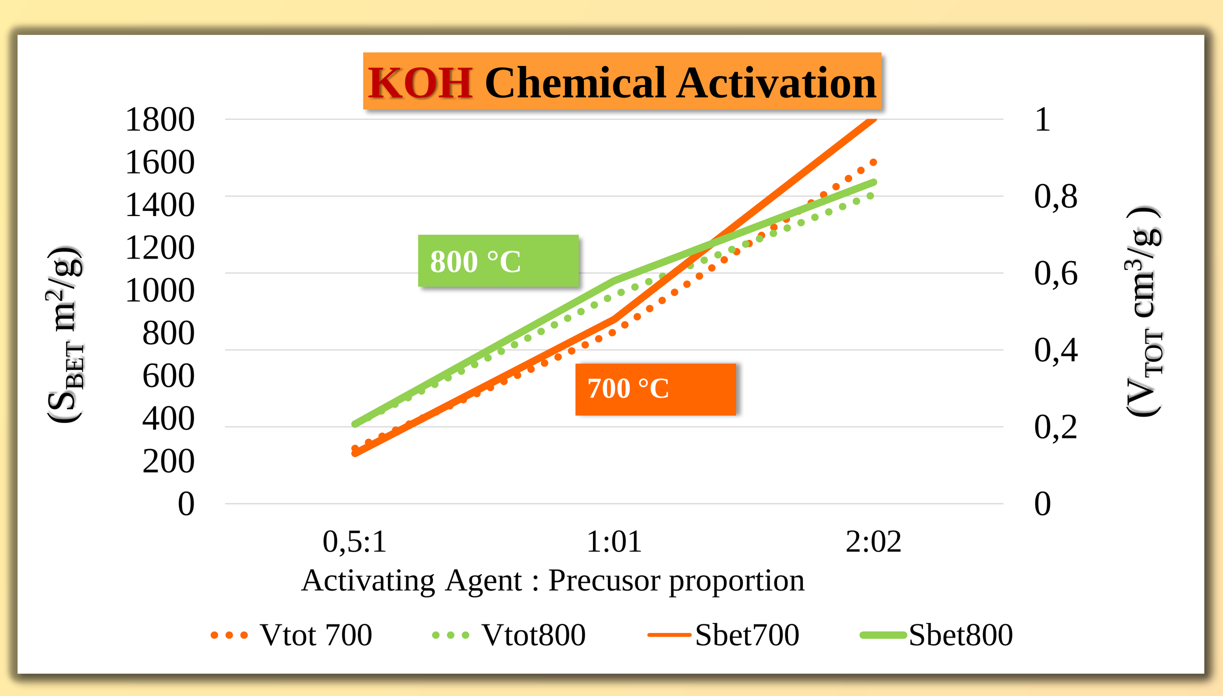




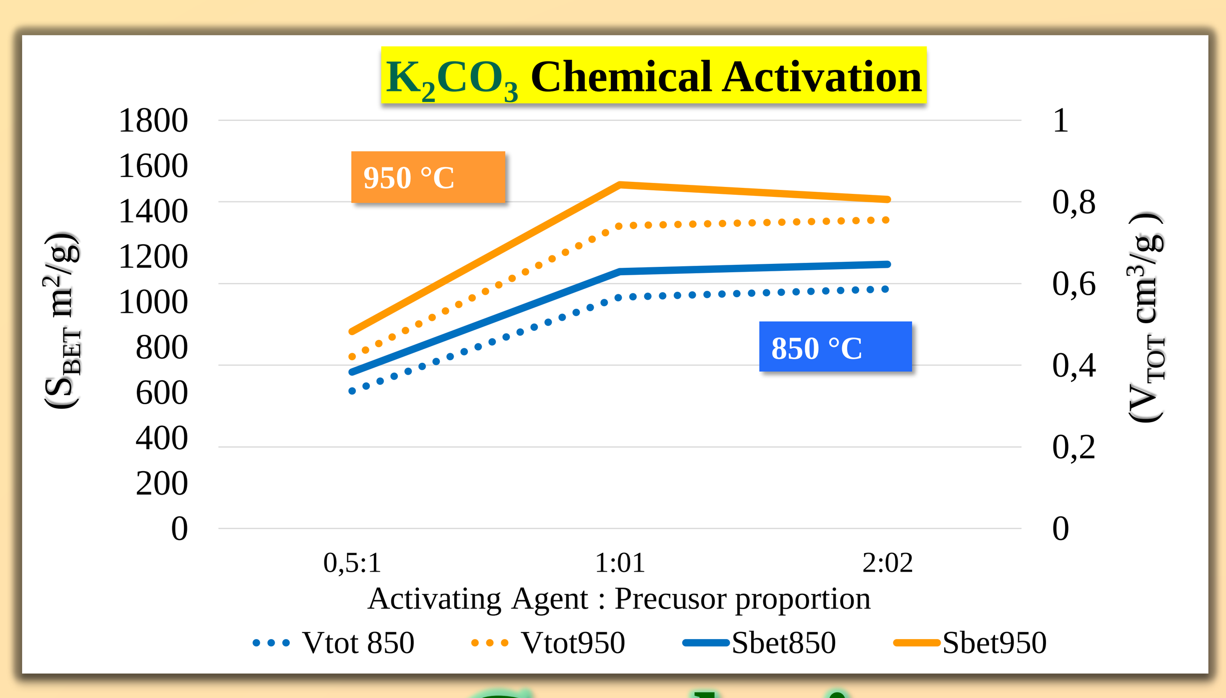
*Chemical characterization of AM and bio-chars*

| Sample | Ash (%) | C (%) | H (%) | N (%) | S (%) | O (%) |
|---|---|---|---|---|---|---|
| AM | 10.58 | 43.15 | 5.43 | 4.27 | 1.06 | 35.51 |
| AMPC750 | 26.32 | 62.66 | 1.00 | 4.30 | 1.70 | 4.02 |
| AMPF750 | 30.44 | 62.18 | 1.09 | 4.28 | 1.89 | 0.12 |
| AMPF850 | 30.13 | 62.66 | 0.85 | 4.14 | 1.99 | 0.23 |

| Sample | Activating Agent | Activating agent: Precursor Weight ratio | C (%) | N (%) |
|---|---|---|---|---|
| AMPA-700K-1 | KOH | 1:1 | 85.49 | 2.45 |
| AMPA-800K-1 | KOH | 1:1 | 86.95 | 1.57 |
| AMPA-850C-1 | $K_2CO_3$ | 1:1 | 85.3 | 1.69 |
| AMPA-950C-1 | $K_2CO_3$ | 1:1 | 87.50 | 1.29 |
| AMPA-700K-2 | KOH | 2:1 | 87.29 | 0.55 |
| AMPA-800K-2 | KOH | 2:1 | 88.56 | 0.66 |
| AMPA-850C-2 | $K_2CO_3$ | 2:1 | 88.19 | 0.72 |
| AMPA-950C-2 | $K_2CO_3$ | 2:1 | 88.23 | 0.57 |

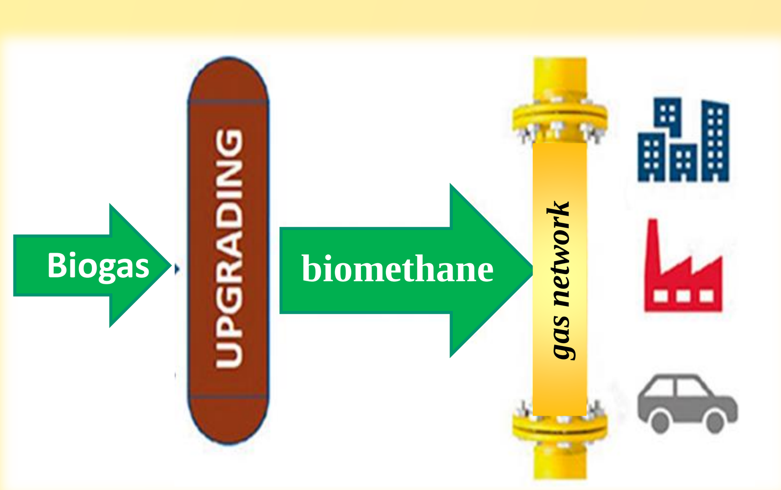




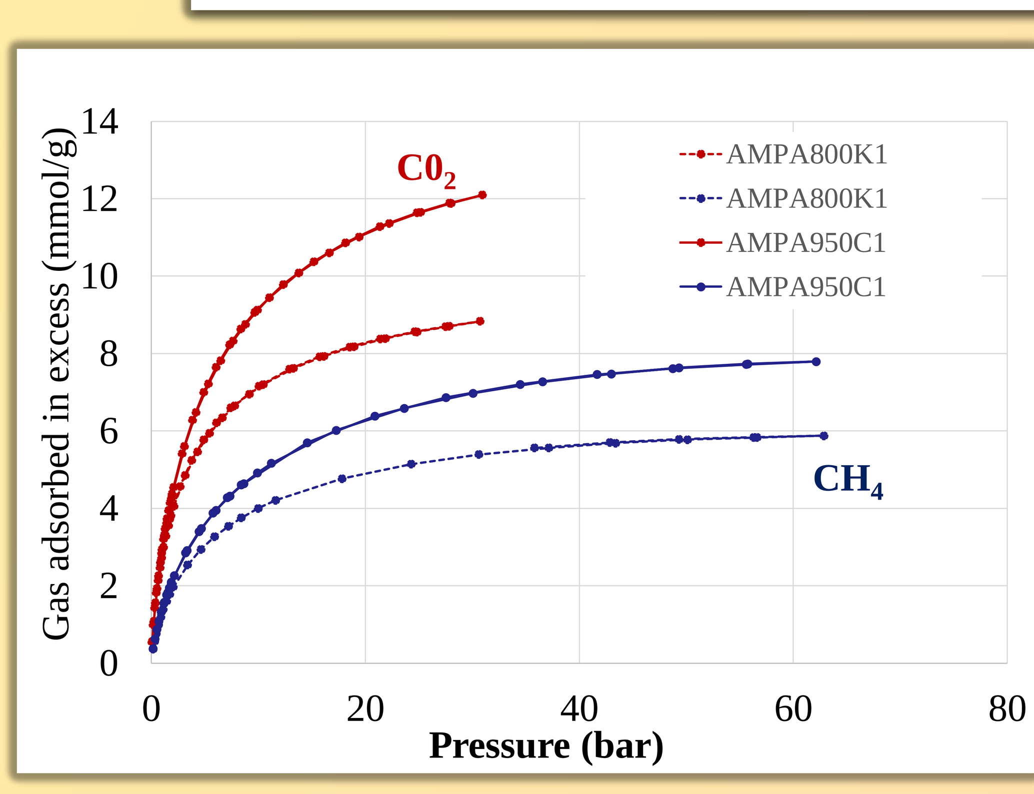




## BIOGAS UPGRADING









## Conclusions

- ❖ Gas yield in PF at 850 °C was the highest (60%).
- ❖ HHV of PF gases is very higher than those from PC (16 *vs* 6 MJ/kg).
- ❖ Bio-char can be used as sustainable activated carbon precursor (ACs).
- ❖ ACs are microporous materials with BET surface area up to 1800 $m^2/g$.
- ❖ ACs developed at 800ºC-950ºC presented lower ultramicropore volume and higher wide micropore and mesopore volume.
- ❖ Chemical and textural properties of the ACs obtained make them an excellent candidate for biogas upgrading.

**Acknowledgements:** Eleonora Ciurcina thanks to Spanish Research Council (CSIC) the JAE INTRO ICU SCHOLARSHIP 2021 [Ref: JAEICU21-INCAR-9], Recovery and Resilience Mechanism, Principado of Asturias, Investigo Programe. (Ref: 032022004265).
The authors thank for economic support to Principado de Asturias (FICYT, grants for research groups, AYUD/2021/51379) and to Ministry of Science and Innovation of Spain ("Proyectos Transición Ecológica y Transición Digital, 2021", TED2021-131713B-I00).
The authors thank the company ROKO-AGAR, Asturias-Spain, for providing the industrial residue, algae meal, for this work.