Post-combustion CO_2 capture from flue gases emitted by fossil fuel-fired powered plants

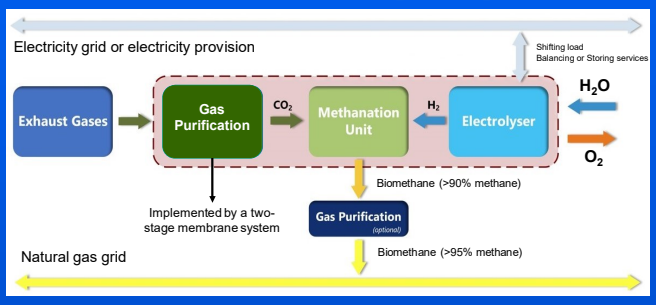
P. Gkotsis, E. Peleka and A. Zouboulis

Department of Chemistry, Aristotle University of Thessaloniki, Thessaloniki, 54124, Greece
Laboratory of Chemical and Environmental Technology
(E-mails: petgk@chem.auth.gr; peleka@chem.auth.gr; zoubouli@chem.auth.gr)

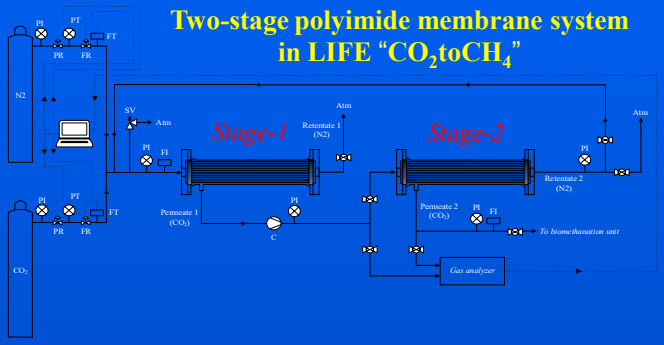
Abstract

The present study is part of a circular economy programme (LIFE "CO_2toCH_4"), which aims to develop and demonstrate an innovative, integrated and sustainable industrial process for the simultaneous energy storage and CO_2 Capture and Utilization (CCU). The principal idea of LIFE CO_2toCH_4 involves the construction, operation and demonstration of an autonomous mobile unit for hybrid energy storage, which uses the exhaust gases from a thermo-electric power plant (burning lignite), as well as hydrogen (H_2) produced from water electrolysis (by using renewable energy sources) and subsequently, converts them into (bio)methane (CH_4), i.e., into an alternative energy source. The mobile unit consists of three fundamental sub-units: (i) the electrolyzer (for the production of H_2), (ii) the exhaust waste gases cleaning/purification system, and (iii) the bio-methanation unit. Before the main implementation actions, which include the operation, optimization and demonstration of the prototype mobile unit, a detailed technical preparation design of the integrated process elements (i.e., electrolyzer, cleaning system, bio-methane reactor) was conducted. The present work describes the general operation of the mobile prototype unit and primarily focuses on the separation of CO_2 with a two-stage polyimide membrane system, providing also an overview of the most significant post-combustion CO_2 capture processes.

LIFE "CO_2toCH_4" mobile prototype unit



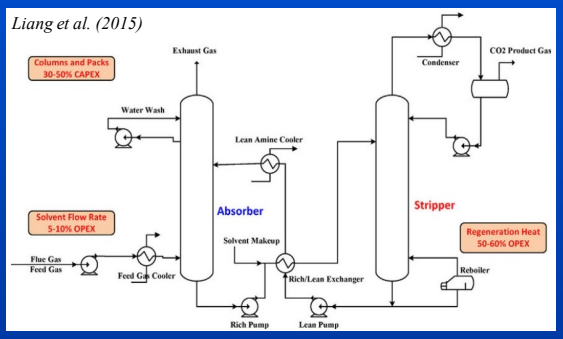
Two-stage polyimide membrane system in LIFE "CO_2toCH_4"



Post-combustion CO_2 capture technologies

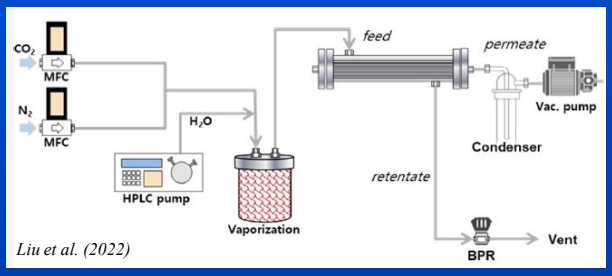
Absorption (with amines)

Liang et al. (2015)



- The separation is based on the counter-current contact of CO_2 with a descending lean solvent (amine)
- It is a commercially mature technology
- It presents very high efficiency (80-95%)

Separation with membranes

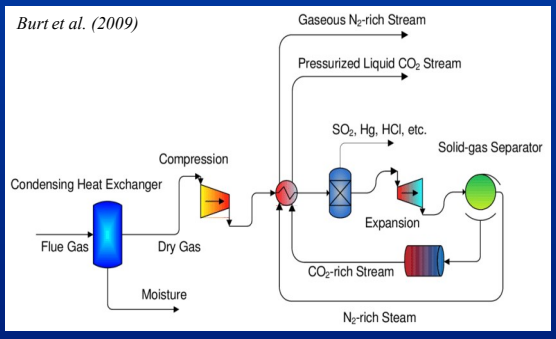


Liu et al. (2022)

- ✓ The separation is based on the selective permeation of gas components through a semi-permeable membrane
- ✓ It is environmentally friendly, and presents simple operation and low energy demand

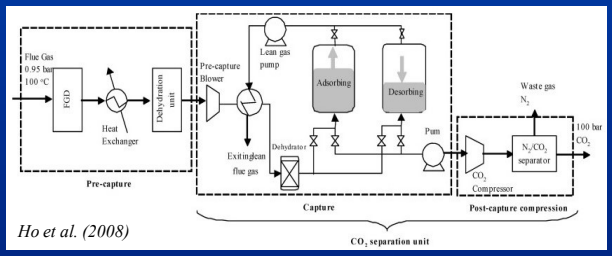
Cryogenic separation

Burt et al. (2009)



- The separation is based on the fact that the gases can be liquefied under the application of different pressure and temperature conditions
- Operation at very low temperature (-170° C) and high pressure (80 bars)
- Application of a step-by-step process to gradually reduce temperature

Adsorption



Ho et al. (2008)

- ✓ The separation is based on the capability of a porous adsorbent material to adsorb the target molecules (CO_2) from a gas mixture under the application of high pressure
- ✓ Typical adsorbent materials include zeolites and activate carbon

Anticipated outcome

- Construction of a complete prototype mobile system for hybrid energy storage and demonstration of the concept for the first time in Greece.
- The two-stage membrane system is expected to effectively separate CO_2 from the flue gases and produce a CO_2-stream of high purity.
- Production capacity of the mobile system ~ 600L bio-methane/day, which is equal to a thermal energy of ~21MJ/day (considering the average heating value of CH_4).
- The total conversion efficiency of CO_2 and H_2 to CH_4 is expected to exceed 90%.
- CO_2 capture and utilization efficiency from the mobile demo system of ~1kg CO_2/day.

Acknowledgements

The "Demonstration of a mobile unit for hybrid energy storage based on CO_2 capture and renewable energy sources(LIFE CO_2toCH_4)" project has received funding from the LIFE Programme of the European Union